社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY

DEPARTMENT OF IRRIGATION
MINISTRY OF WATER RESOURCES
THE KINGDOM OF NEPAL

THE STUDY
ON
FLOOD MITIGATION PLAN
FOR
SELECTED RIVERS IN THE TERAI PLAIN
IN
THE KINGDOM OF NEPAL

FINAL REPORT

VOLUME I

EXECUTIVE SUMMARY

MAY 1999

NIKKEN Consultants, Inc.
NIPPON KOEI CO., LTD.

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VOLUME I : EXECUTIVE SUMMARY

VOLUME II : MAIN REPORT

VOLUME III : SUPPORTING REPORT

- A1: FLOOD MITIGATION PLAN/RATUWA RIVER
- A2: FLOOD MITIGATION PLAN/LOHANDRA RIVER
- A3: FLOOD MITIGATION PLAN/LAKHANDEI RIVER
- A4: FLOOD MITIGATION PLAN/NARAYANI RIVER
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- A6: FLOOD MITIGATION PLAN/WEST RAPTI RIVER
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The costs are estimated based on the price and average exchange rate in October 1998.

The average exchange rate is as follows:

US$ 1.00=NRs.67.93

¥ 1.00 =NRs.0.59

PREFACE

In response to a request from His Majesty's Government of Nepal, the Government of Japan decided to conduct the Study on Flood Mitigation Plan for Selected Rivers in the Terai Plain in the Kingdom of Nepal and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched the study team headed by Mr. Noboru Jitsuhiro of NIKKEN Consultants, Inc. and composed of NIPPON KOEI Co., Ltd. to Nepal, three (3) times between December 1997 and May 1999. In addition, JICA set up an advisory committee headed by Mr. Hidetomi Oi, Development Specialist of JICA, between December 1997 and May 1999, which examined the study from specialist and technical points of view.

The Team held discussions with the officials concerned of His Majesty's Government of Nepal and conducted field surveys at the study area. Upon returning to Japan, the Team conducted further studies and prepared this final report.

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

Finally, I wish to express my sincere appreciation to the officials concerned of His Majesty's Government of Nepal for their close cooperation extended to the Study.

May, 1999

Kimio Fujita
President
Japan International Cooperation Agency

May 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita

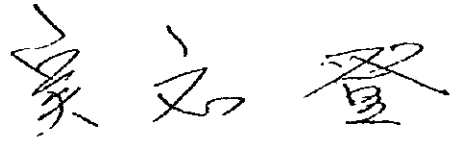
Letter of Transmittal

We are pleased to submit to you the Final Report on "the Study on Flood Mitigation Plan for Selected Rivers in the Terai Plain in the Kingdom of Nepal". We carried out the Study for a period of 18 months from December 1997 to May 1999.

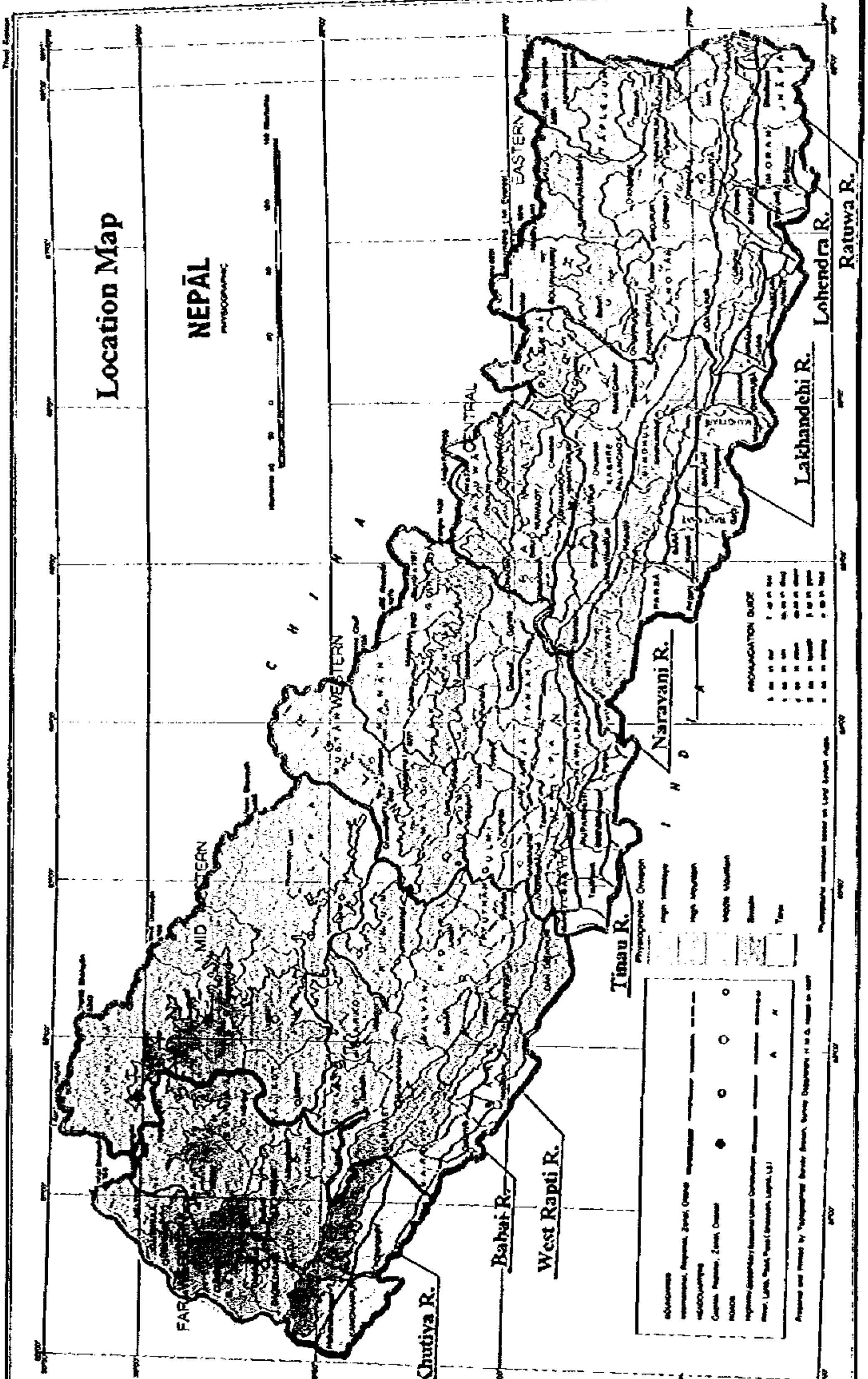
The Final Report presents a flood mitigation master plan for eight (8) river basins and a result of feasibility study for the priority projects (the Lakhandei and Babai river basins). The Final Report proposes a series of low-cost and sustainable flood mitigation activities consisting of watershed management, river control and community development components. The priority projects are proved technically viable, economically feasible, and socially and environmentally acceptable, and are recommended for immediate implementation as pilot project for flood mitigation in the Terai plain.

We wish to take this opportunity to express our sincere gratitude to your Agency and the Advisory Committee for the Study. We also wish to express our deep gratitude to His Majesty's Government of Nepal, the Embassy of Japan in Nepal, the JICA Nepal Office and JICA experts for close cooperation and assistance extended to us during our investigation and study.

Very truly yours,



Noboru Jitsuhiro
Team Leader,
The Study on Flood Mitigation Plan
For Selected Rivers in the Terai Plain
In the Kingdom of Nepal



His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

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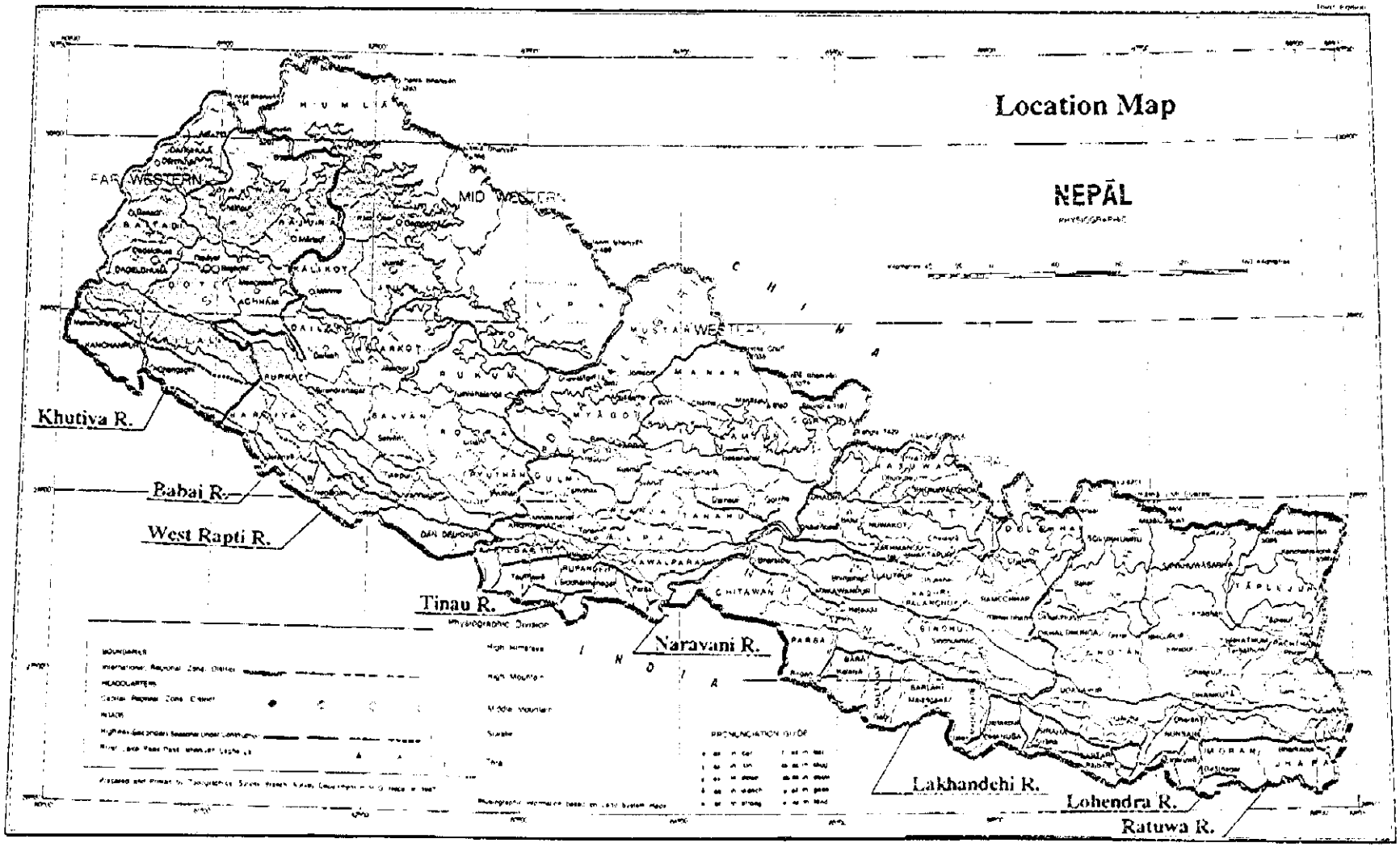

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THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
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SUMMARY

1. INTRODUCTION

Objective of Study: The Study aims (1) to formulate a Master Plan for flood mitigation for eight (8) rivers in the Terai plain, (2) to conduct a Feasibility Study for the priority (urgent) project(s) identified in the Master Plan, and (3) to carry out technology transfer to the counterpart personnel of HMG/N in the course of the Study.

Study Area: The Study Area of the Master Plan shall cover the selected eight (8) rivers in the Terai plain. The selected rivers are the Ratuwa, Lohandra, Lakhandei, Narayani, Tinau, West Rapti, Babai and Khutiya rivers. The feasibility study shall be carried out for the priority project(s) selected as a result of the Master Plan study.

2. SOCIO-ECONOMIC FRAME

Socio-Economic Situation: Nepal is a predominantly agrarian economy. The share of the agriculture sector in Nepal's GDP has been between 40 and 50 %. In addition, more than 80 % of the labor force is dependent upon agriculture. Almost a half of the country's cultivated land is in the Terai plain. Moreover, farmers in the Terai produce nearly 60 % of the country's food grain.

Population Flow: The major pattern of the population flow in Nepal is from the mountain/hill areas to the Terai. Because of in-migration into the area, the population of the Terai is anticipated to double in 20 years.

Flood Mitigation in Basic Frame: The Ninth Plan (1997-2002) focuses on poverty alleviation as the main objective of the plan. The development of agriculture is a key to enhance employment opportunities and GDP. Agricultural productivity has to be enhanced by increasing unit area production. In this regard, the flood mitigation in the Terai plain plays an important role, mitigating damages of flood and sediment, and providing people with safe lands of high productivity.

3. EXISTING CONDITION OF STUDY AREA

River Basin: Basin areas of eight rivers are summarized below with their mountain and plain basin areas.

River	River class	Mountain		Plain		Total
		(km^2)	(%)	(km^2)	(%)	(km^2)
Ratuwa R.	III	133	35	250	65	383
Lohandra R.	III	140(31)	33	279	67	419(310)
Lakhandei R.	III	106	35	194	65	300
Narayani R.	I	35,075	98	705	2	35,780
Tinau R.	II	669	62	412	38	1,081
West Rapti R.	II	5,800	90	618	10	6,418
Babai R.	II	3,054	89	371	11	3,425
Khutiya R.	III	175	54	150	46	325

(Remarks) Areas in ( ) of the Lohandra indicate those excluding mountainous basin of the Chisan river.

Channel Characteristics: The basic features of the existing river channels are summarized below for the plain reaches from the top of plain to Indian border.

River	River class	Length(km)	Slope	Width(m)
Ratuwa R.	III	43.7 (33.4)	1/170~1180	200~690
Lohandra R.	III	67.5 (51.9)	1/80~2000	50~520
Lakhandei R.	III	51.4 (40.9)	1/240~1240	50~900
Narayani R.	I	83.0 (80.6)	1/720~1/1560	400~2500
Tinau R.	II	59.5 (57.7)	1/110~3180	100~940
W. Rapti R.	II	53.0 (163.5)	1/540~1920	200~1700
Babai R.	II	48.0 (48.0)	1/320~3000	200~1300
Khutiya R.	III	35.0 (28.6)	1/70~2130	50~650

(Remarks) River length in ( ) indicates that downstream from E-W Highway

Flood and Sediment Disasters: All the eight rivers experienced big flood in recent three years. River bank erosion, sedimentation and flooding and inundation are the major types of disasters. Many of the residents in the flood prone areas have experience of evacuation and participation in flood mitigation activities. Moreover, majority of them expressed their willingness to participate in flood mitigation activities.

Existing River Facilities: Spur (groin) works shares the majority of river facilities of the rivers in the Terai plain. Almost all the spur and revetment works are made of gabions with boulders put in galvanized iron (G.I.) wire net.

Basin and Water Resources Development Projects: The major national level irrigation systems are located in the Lohandra, Lakhandei, Tinau, West Rapti and Babai river basins. There exist nine major hydro-power plants in Nepal. Out of these, 6 plants are located in the Narayani river, while others are in the Sunkosi and Bagmati rivers. Study on Bheri-Babai Diversion Scheme is underway by JICA.

4. FLOOD MITIGATION MEASURES

Flood Mitigation Measures and Project Components: In order to undertake the project in a practical and sustainable manner, the flood mitigation in the Terai plain is composed of three components, i.e., watershed management, river control, and community development components.

Watershed Management Component: For the conservation of watershed, construction of erosion control facilities, encouragement of afforestation and land use regulation are recommended as primary measures. In order to mobilize local communities and related organizations, publicity activities are also essential to materialize the measures.

River Control Component: As a datum line for river course stabilization, river boundary line (RBL) should be first designated and authorized for the flood mitigation activities. Continuous dikes was not proposed for the flood mitigation Master Plan. The river control component includes bioengineering measures such as forest and grass belts as dike works, and preventive bank protection by vegetation in addition to the conventional river control measures.

Community Development Component: This component consists of three sets of activities, i.e., community mobilization to build up organizational bases for implementation of the Plan, local coping measures to enable the communities to live with flooding, and community-based sustainable flood mitigation measures to motivate the local people to maintain and sustain the flood control structures.

5. MASTER PLAN

Concept of Master Plan: The Master Plan aims to direct or guide the flood mitigation activities that will be conducted by various agencies and organizations concerned. In conformity with terms of the national development plan, target year was set at the end of 12th Plan in 2017.

Preliminary Project Cost :

Name of River	Ratuwa river	Lohandra river	Lakhandei river	Narayani river	Tinau river	W.Rapti river	Babai river	Khutiya river
Cost(Rs.mill.)	551.8	651.3	597.4	574.8	802.7	232.0	428.0	115.5

(Remarks) Price contingency and value added tax are not included.

Preliminary Economic Evaluation for Master Plan Projects: Flood damage reduction benefit, bank protection benefit, and indirect benefit were considered. According to the evaluation, the Babai river shows relatively high economic viability. However, these results should be handled only as a rule of thumb, since the evaluation was made under the conditions without basic data like channel sections.

Selection of Priority Project for Feasibility Study: River basins for the Feasibility Study shall be selected from different classes of rivers and different development regions of the country. The following two river basins, ranked 1st and 2nd according to evaluation, were selected finally:

1) Babai river basin : Class-II river in Mid-Western Region
2) Lakhandei river basin : Class-III river in Central Region

River Basin for Comprehensive Flood Mitigation Plan: Out of two river basins for the Feasibility Study, the Lakhandei river was selected for comprehensive flood mitigation plan including measures for watershed, since the Lakhandei river originates in the Siwalik hills which yields much sediment.

6. FEASIBILITY STUDY

Channel Characteristics: Based on the new river survey results.

1) **Lakhandei River:**

River stretch	Bed slope	River width (m)	Mean depth (m)	Flow area (m^2)	Bank-full capacity (m^3/s)
Segment 2-2:					
No.0-No.21	1/1,531～862	62	0.59	36	26
Segment 2-1:					
No.21-No.32	1/569	411	0.81	324	354
No.32-No.40	1/376	598	0.89	533	745
Segment 1:					
No.40-No.52	1/253～150	498	1.97	848	2,793

2) **Babai River:**

Segment 2-2:					
No.0-No.13	1/3,716	407	3.21	1,264	1,511
No.13-No.30	1/1,820	471	2.42	1,094	1,600
Segment 2-1:					
No.30-No.37	1/1,000	623	2.53	1,534	2,610
Segment 1:					
No.37-No.46	1/436～383	804	2.38	1,796	3,932

Implementation: Although the target year for the Master Plan has been set in the year 2017, the implementation of the priority project for the Lakhandei and Babai rivers should be completed in advance by the year 2007 as a pilot project. The flood mitigation program will be managed by the DOI Project Management Office (PMO) to be set up at the district level. The PMO will Upper Catchment, Flood Control, and Community Development Divisions.

Fund Required: Considering the price contingency during the implementation period, fund required for the project implementation was estimated at Rs.689.3 million for the Lakhandei river and Rs.744.7 million for the Babai river.

Required External Input: Considering the financial constrains of the MHG/N and necessity of intensive implementation of the work as pilot project, financial assistance especially for the river control component and technical assistance for watershed management, river control and community development components are deemed necessary.

Economic Evaluation: According to the cost-benefit analysis, the economic internal rate of return (EIRR) of the proposed project is 20.8% and 15.2% respectively for the Lakhandei and Babai rivers under future basin conditions. The proposed flood mitigation measures can be implemented at any place and at any size. Though the EIRR-value is low under the existing basin, the project can be made economically viable, since the project works would be implemented from those of higher cost-performance keeping pace with basin's development.

Environmental Screening: The flood mitigation interventions on the river basins in the Terai are overwhelmingly environmentally positive. For each of the eight rivers, the environmental screening gives very positive results. Discrete environmental impact assessment (EIA) is necessary for designated wetlands along the rivers. Otherwise, this environmental screening should be sufficient to satisfy the environmental obligations of the project, provided the local people are fully involved in the decision making process.

Technical Evaluation: The flood mitigation activities should be performed in sustainable manner and, therefore, the plan must fit well with the local situation, technical capability and financial solvency. In planning flood mitigation plan of the rivers in the Terai plain, various attempts were made so that the plan should meet the actual situation of the country and the project sites. Therefore, the project is considered to be sustainable.

7. RECOMMENDATION

Master Plan: Considering the crucial importance of the flood mitigation in the Terai plain, the proposed Master Plan for the Ratuwa, Lohandra, Narayani, Tinau, West Rapti and Khutiya rivers should be promoted to the Feasibility Study.

Proposed Projects for Lakhandei and Babai Rivers: The Feasibility Study verified that the proposed projects are economically and technically feasible and exert little adverse effect to the environment. The projects are recommended for immediate implementation in order to support people's livelihood and sound development of the basin.

SUMMARY

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LIST OF ABBREVIATIONS AND ACRONYMS.

APP	Agricultural Perspective Plan
CIDA	Canadian International Development Agency
CDRC	Central Disaster Relief Committee
CO	Community Organization
DDC	District Development Committee
DDRC	District Disaster Relief Committee
DHM	Department of Hydrology and Meteorology
DOA	Department of Agriculture
DOE	Department of Environment in MOPE
DOF	Department of Forest
DOI	Department of Irrigation in MOWR
DONP	Department of National Park
DOR	Department of Roads
DOSC, DOSCWM	Department of Soil Conservation and Watershed Management in MOFSC
DPNET	Disaster Preparedness Network
DPTC	Water-induced Disaster Prevention Technical Center
DSCO	District Soil Conservation Office
EAS	Environmental Assessment Study
ECR	Environmental Conservation Rules
EIA	Environmental Impact Assessment
ENTMP	Eastern Nepal Topographic Mapping Project
EPA	Environmental Protection Act
ES	Environmental Study
ET	Environmental Test
FAO	Food and Agricultural Organization of the UN
FEMD	Flood Control, Environmental & Mechanical Division
FS	Forest Survey
GAD	Gender and Development
GDP	Gross Domestic Product
GNP	Gross National Product
GTZ	German Aid Agency
HMG/N	His Majesty's Government of Nepal
IBRD	International Bank for Reconstruction and Development (WB)
ICIMOD	International Center for Integrated Mountain Development
IDNDR	International Decade for Natural Disaster Reduction
IUCN	International Union for the Conservation of Nature
JICA	Japan International Cooperation Agency
LGI	Local Governing Institutions

LRMP	Land Resource Mapping Project
LWS	Lutheran World Services
LZMP	Lumbini Zone Mapping Project
MC	Municipal Council
MLD	Ministry of Local Development
MOFSC	Ministry of Forest and Soil Conservation
MOH	Ministry of Home
MOPE	Ministry of Population and Environment
MOWR	Ministry of Water Resources
NEA	Nepal Electricity Authority
NGO	Non-Governmental Organization
NP	National Park
NPC	National Planning Commission
NRCS	Nepal Red Cross Society
RCIW	Rural Community Infrastructure Works Program
RIO	Regional Irrigation Offices in DOI
SCWM	Soil Conservation and Watershed Management
SOW	Scope of Work
SP	Sub-Project
UN-DMS	UN Disaster Management Secretariat
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
VDC	Village Development Committee
WB	The World Bank
WECS	Water and Energy Commission Secretariat
WFP	World Food Program
WMP	Watershed Management Plan
WNTMP	Western Nepal Topographic Mapping Project
WR	Wildlife Reserve.
WRES	Water Resources and Energy sector of the ECR

ha	hectare, (10,000 square meters)
km	kilometer (1000 meters)
Ma	Mega d'annees (million years)
NRs, Rs	Nepali Rupee
s, sec	second
t, ton	Metric ton
US$	US dollar
¥	Japanese yen
%	percent

CHAPTER 1. INTRODUCTION

101. Background: The Terai Plain, which occupies southern part of the territory of the Kingdom of Nepal, shares about 14% of total land area and about 50% of total population of the country. The plain is a prominent granary area of the country and recently the population in the plain is increasing rapidly.

The rivers in the plain cause damages every rainy season and His Majesty's Government of Nepal (HMG/N) has been taking measures in these disaster-stricken areas. Disaster prevention is an important task to alleviate the poverty of the country as stated in the Ninth Plan. It is required to draw up a master plan for flood mitigation and to implement the measures effectively based on the master plan.

Under these circumstances, HMG/N requested technical cooperation of Japanese Government on the flood mitigation. In response to the request, the Government of Japan has decided to conduct the Study on Flood Mitigation Plan for Selected Rivers in the Terai Plain in the Kingdom of Nepal (the Study) through the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan.

102. Objective of Study: The Study aims (1) to formulate a Master Plan for flood mitigation for eight (8) rivers in the Terai plain, (2) to conduct a Feasibility Study for the priority (urgent) project(s) identified in the Master Plan, and (3) to carry out technology transfer to the counterpart personnel of HMG/N in the course of the Study.

103. Study Area: The Study Area of the Master Plan shall cover the selected eight (8) rivers in the Terai plain (Fig. 1.1). The selected are the Ratuwa, Lohandra, Lakhandei, Narayani, Tinau, West Rapti, Babai and Khutiya rivers. The feasibility study shall be carried out for the priority project(s) selected as a result of the Master Plan study.

104. The Study: The Study is implemented in two phases, i.e., Phase-I for formulation of Master Plan and selection of priority projects, and Phase-II for the Feasibility Study (Fig. 1.2). Each phase comprises work in Nepal and work in Japan. The Phase-I study started with the work in Nepal from 6 December 1997 to 26 March 1998. After the work in Nepal, the Study Team worked out a flood mitigation Master Plan for the eight rivers. Results of study on the flood mitigation Master Plan were compiled in the Interim Report.

The Phase-II study for the Feasibility Study started from the river survey/topographic-mapping in May 1998. Full-scale Study Team was presented in Nepal from July 2 to November 26, 1998, to conduct Feasibility Study for the Lakhandei and Babai rivers. Following the second work in Nepal, the Feasibility Study was finalized in Japan. In the middle of February 1999, the Study Team visited Nepal to present and discuss on the Draft Final Report and to hold the Technical Transfer Seminar. Final Report for the Study were prepared after receiving comments from HMG/N on the Draft Final Report.

105. Final Report: This Final Report presents all the study results on Flood Mitigation Plan for Selected Rivers in the Terai Plain in the Kingdom of Nepal. The Report consists of Executive Summary, Main Report, Supporting Report and Data Book.

CHAPTER 2. EXISTING CONDITIONS

2.1 Topography and Geology

211. Topographical and Geological Zone: Nepal is located from 26°30'N to 30°30'N in latitude, from 80°00'E to 88°30'E in longitude, and from about 50 to 8,848 m above mean sea level (m,MSL) in altitude. The topography and geology of the Nepal can be divided into Inner Himalayan Valleys, Higher Himalayan zone, Lesser Himalayan zone (Midland and Mahabharat ranges), Siwalik (Churia) hills, Dun Valleys, and the Terai plain. As far as the sediment yield is concerned, the Midland ranges, Mahabharat ranges and Siwalik hills are important.

212. Midland, Mahabharat and Siwalik: Since the Midland ranges are composed of soft rocks (phyllite, slate and dolomite) covered with thick soil, the land is densely populated. The Mahabharat ranges consist of comparatively harder rocks than those of the Midland ranges. The topography is steeper on the southern slope compared to the northern one. Siwalik hills are low hill ranges bordering the Terai plain in the south. They mostly consist of alternating beds of clay, sandstone, sand and pebble.

213. Terai Plain: The Terai plain has an elevation ranging from 50 to 300 m,MSL. The plain slopes towards south with steeper slopes at the foot hill region and becomes nearly level at the southern end. The Terai plain is further divided into three parts; Bhabhar zone (foot of hills), marshy area (middle area), and southern Terai (proximity of Indian border).

2.2 Meteorology and Hydrology

221. Climate of Nepal: The variation of altitude causes a variety of climatic conditions in Nepal from Tropical to Tundra. In addition, dry and rainy seasons due to the monsoon cause extreme climatic contrasts. The coldest month is January and the hottest in June or July. Below 600 m,MSL in altitude, the climate is tropical with a hot and moist atmosphere.

222. Rainfall: Nepal is influenced by the southeast monsoon from June to September. The monsoon air-stream is forced to rise as it meets the Himalayas, resulting in a heavy rainfall on the slopes facing southwards. The climate of the Terai belongs to monsoon sub-tropical zone. The rainy season lasts from June to September and the dry season from October to May. Heavy rainfall is recorded along the Siwalik hills and

Mahabharat ranges on the southern margins of the mountain zone. In the lee of these zones, the rainfall is small. The monsoons have little effects in the areas above 3,000 m,MSL.

2.3 Environment

231. Environmental Overview: The Terai is the main grain producing area in the country. In order to meet the growing demand for food, while at the same time protecting the indigenous flora and fauna, agricultural productivity has to increase. This should be done by increasing unit production, rather than converting more forest land to agriculture. The Study Area contains two large national parks and listed wetlands. From an environmental viewpoint, protecting these areas is of high priority.

232. Chitwan National Park and Bardiya Wildlife Reserve: The Narayani river runs along the western border of Chitwan national park, and the Babai river runs through Bardiya wildlife reserve. The national park in Chitwan (93,200 ha) and the wildlife reserve in Bardiya (96,800 ha) are fully protected from encroachment.

233. Wetlands: Of far more importance, are the potential effects of flood mitigation measures on the listed wetlands in six of the eight rivers, excluding the Lohandra and Lakhandei rivers. There are three large and three small wetlands. Two of the large ones are associated with the Chitwan national park and Bardiya wildlife reserve on the Narayani and Babai rivers. Some flood mitigation interventions may affect these floodplains, but 25% of the Narayani and 10% of the Babai flood plains are already farmed and have settlements on them. However, bearing in mind the needs of the human and domestic animal populations, the wetlands will be given high priority if measures are suggested in their vicinity, and environmental impact assessments (EIA) will be undertaken.

234. Environmental Organizations and Institutions: The Environmental Division of the Ministry of Population and Environment(MOPE) has overall responsibility for environmental matters in Nepal. In June of 1997, Environmental Conservation Rules (ECR) were issued under the 1997-Environmental Conservation Act. The ECR lay down procedure to be followed when new projects are proposed or existing projects extended.

2.4 Socio-Economy

241. Socio-Economic Situation of Nepal: Nepal is a landlocked country with a total area of 147,181 sq. km. The estimated population is 21 million (as of 1995), with an annual growth of about 2.5 %. Per capita income is around US$ 200 per annum. The GDP growth rate has been between 4 to 5% per annum during the past 10 years. Nepal is a predominantly agrarian economy. The share of the agriculture sector in Nepal's GDP has been between 40 and 50 %. In addition, more than 80 % of the labor force is dependent upon agriculture.

242. Socio-Economic Situation of Terai: The Terai plain is called the "granary of Nepal". Almost a half of the country's cultivated land is in the Terai and farmers in the Terai produce nearly 60 % of the country's food grain. A wide range of crops are produced, with major crops of paddy, maize, wheat, pulses, and oilseeds. All these major crops but wheat and oilseeds are grown during monsoon.

243. Population Flow: The major pattern of the population flow in Nepal is from the mountain/hill regions to the Terai plain. As a result, the Terai saw a population growth rate nearly three times the rate of the hills and mountain areas. The percentage of the Terai's population increased from 37% of the whole country in 1971 to 46 % in 1991. The population of the Terai is anticipated to double in 20 years. Thus by 2020, the Terai may contain 67% of Nepal's population.

2.5 River and Basin Conditions

251. River Systems and River Classes in Nepal: About 71 % of the total area of Nepal is drained by four major rivers, i.e., the Kosi, Narayani (Gandaki), Karnali, and Mahakali rivers which originate in the Himalayas and Tibet (Class-I rivers). Other individual rivers originating in the Midland or Mahabharat ranges (Class-II rivers) are the Kankai, Kamala, Bagmati, Tinau, West Rapti, and Babai rivers. Aside from the above, there are numerous rivers of small scale originating in the Siwalik hills (Class-III rivers). The Ratuwa, Lohandra, Lakhandei and Khutiya rivers selected for this present study fall under this class.

252. River Basin: Basin area of each river is and summarized below.

River	Mountain (km^2)	Plain (km^2)	Total (km^2)
Ratuwa R.	133	250	383
Lohandra R.	140(31)	279	419(310)
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(Remark) Areas in ( ) of the Lohandra river indicate those excluding mountainous basin of the Chisan river.

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Tinau R.	II	59.5 (57.7)	1/110～3180	100～940
W. Rapti R.	II	53.0 (163.5)	1/540～1920	200～1700
Babai R.	II	48.0 (48.0)	1/320～3000	200～1300
Khutiya R.	III	35.0 (28.6)	1/70～2130	50～650

(Remark) River length in ( ) indicates that downstream from East-West Highway

254. River Course Shifting: In the upper reaches, rivers are rather straight as a whole with wide riverbed on which braided river channels run. The river becomes narrow and starts meandering in the lower reaches. Actual changes of river course in the past were examined superimposing the old topographic map (1/50,000 prepared in 1960s) on the latest map (1/25,000 prepared in 1990s). During the time intervals of 38 or 42 years, the bank erosions occur within a limited river area along the existing river course, and significant river-course shifting was not found except for the lower reaches of the West Rapti and the Babai rivers.

255. Riverbed Materials: Riverbed materials of the plain reaches were investigated by the Study Team at 121 sites for eight rivers. Generally, the riverbed material has wide range of grain size distributions in the upper reaches, and gradually it becomes more uniform toward downstream sorted by river flows. It is noteworthy that the grain size distribution changes in a short distance in the West Rapti and Babai rivers.

256. **Existing River Facilities:** The conditions of existing river facilities were also investigated covering a total of 484 facilities for the eight rivers. Spur (groin) works shared, by far, the majority of river facilities, followed by revetment works. Almost all the spur and revetment works are made of gabions with boulders put in galvanized iron (G.I.) wire net. A variety of works should be introduced considering the river conditions and the availability of materials.

257. **Past Flood and Sediment Disasters:** The conditions of past flood and sediment disasters were investigated for all the eight rivers. A total of 78 village development committee(VDC) and 3 municipality offices were visited during the investigation, and a total of 1,124 residents in the flood-prone areas were interviewed. According to the investigation, all the eight rivers suffered from severe flood disasters in previous three years. Bank erosion, flooding over farm land, and sedimentation are the major types of disasters. It is noteworthy that, in the Lakhandei and Tinau river basins, more than half of the residents have experience of evacuation and participation in flood mitigation activities as well. And that most of the interviewees of the eight rivers expressed their willingness to participate in flood mitigation activities.

2.6 Basin Development Projects and Plans

261. **Irrigation Projects:** In the Study Area there are various irrigation projects at the national and local levels. The major national level projects are listed below.

1) Sunsari Morang Irrigation Project in the Lohandra river basin
2) Bagmati Irrigation Project in the Lakhandei river basin
3) Bhairahawa Lumbini Groundwater Project in the Tinau river basin
4) Sikta Irrigation Project in the West Rapti river basin
5) Babai Irrigation Project in the Babai river basin

262. **Hydropower plants:** There exist nine major hydro-power plants in Nepal. Out of these, 6 plants (136.5 MW in total) are located in the Narayani river, while others are in the Sunkosi and Bagmati rivers. Nepal Electricity Authority (NEA) has selected 7 priority sites for the medium hydropower project (ranging from 10 to 300 MW) in the basins of the Sunkosi, Kamala, Narayani and Karnali rivers. Study on Bheri-Babai Diversion Scheme is underway by JICA. The scheme aims at power generation and irrigation, taking a part of water from the Bheri river into the Babai river.

2.7 Institutional Setting

271. Policy Framework: The Government of Nepal has just formulated an overall "Approach to the Ninth Plan (1997-2002)", and is currently in the process of finalizing the detailed Ninth Five-Year Development Plan. The Approach Paper emphasizes the need for a more comprehensive approach to river training. In addition to the Ninth Plan, the policy framework for flood mitigation activities includes the "National Action Plan on Disaster Management", "Draft River Training Policy", "Watershed Development Policy" and "Natural Calamity (Relief) Act", etc.

272. Organizations Involved in Flood Mitigation: The Department of Irrigation (DOI) is responsible for flood mitigation. The Water-Induced Disaster Prevention Technical Center (DPTC) is developing technologies and methodologies for flood mitigation. The Department of Soil Conservation and Watershed Management (DOSCWM) also contributes to flood mitigation through soil conservation in watershed areas. The Local Governing Institutions (LGIs) can play a significant role in facilitating community mobilization and also in coordinating different organizations operating in their own jurisdictions. There exists an NGO-led Disaster Preparedness Network (DPNET), an association of organizations concerned with community-based disaster management.

CHAPTER 3. BASIC INVESTIGATION AND STUDY

301. Basic Investigation: The following investigations were carried out to collect basic data and information necessary for planning flood mitigation:

1) Investigation of river facilities
2) Investigation of flood and sediment disasters
3) Investigation of riverbed materials

3.1 Hydrological Study

311. Meteo-hydrological Observatory: Responsibilities for meteo-hydrological data collection and analysis in Nepal have been born mainly by the Department of Hydrology and Meteorology (DHM) in the Ministry of Science and Technology. Meteo-hydrological observations conducted by other authorities are sent to the DHM in principle. The DHM publishes these data as a yearbook after basic checking has been completed.

312. Rainfall Analysis: The following analyses were made based on the records at 29 stations over the country:

1) Probable daily rainfall
2) Relationship between 24-hour and daily rainfalls
3) Rainfall depth for short duration

313. Runoff Analysis: The following analyses were made on the daily discharge collected from the DHM at 62 stations in 7 basins of the Mahakali, Karnali, West Rapti, Narayani, Bagmati, Sapta Koshi and Kankai rivers:

1) Peak discharge and daily discharge
2) Relationship between discharge and basin area
3) Ratio of probable discharges
4) Estimation of probable discharge

3.2 Sediment Yield

321. Forest Vegetation: Watershed was covered widely by Sal forests But recently, the forest decreased rapidly, by land clearing and settlement of farmers from the mountain/hill areas. Although large forest areas are still left in the western part of the country, the forest has been cleared in the eastern and central parts where the population is large. The forest is important to farmers for production of fodder, litter, compost,

firewood and timber, and they are collected from nearby forests. The selective and over-grazing by livestock may also influence the natural vegetation adversely. Because of these, trees in the forest are being depleted and waste lands are increasing, which results in severe soil erosion.

322. Annual Sediment Yield: Five watersheds were selected for the sediment yield study. They are the Ratuwa, Lohandra, Lakhandei, Tinau and Khutiya rivers, of which sediment yield may influence directly to the sediment problems in the Terai plain. The sediment yield in the watershed area was estimated assuming annual soil erosion rates by land use types. The estimated overall soil erosion rate ranges from 2.70 mm/year in the Lohandra watershed to 1.66 mm/year in the Lakhandei watershed. According to an estimate, sediment yield during the 1993-flood reached seven to eight times of that of ordinary (average) year.

CHAPTER 4. FLOOD MITIGATION MASTER PLAN

4.1 Principles for Formulation of Master Plan

411. Basic Frame of Flood Mitigation: Nepal is a predominantly agrarian economy. The share of the agriculture sector in Nepal's GDP has been between 40 and 50 %. In addition, more than 80 % of the labor force is dependent upon agriculture. Almost a half of the country's cultivated land is in the Terai. Moreover, farmers in the Terai produce nearly 60 % of the country's food grain. On the other hand, major pattern of the population flow in Nepal is from the mountain/hill regions to the Terai. Because of in-migration into the area, the population of the Terai is anticipated to double in 20 years time.

412. Flood Mitigation in Basic Frame: The Ninth Plan (1997-2002) focuses on poverty alleviation as the main objective of the plan. The development of agriculture is a key to enhance employment opportunities and GDP, and accordingly to alleviate poverty. In order to meet the growing population in the Terai and demand for food, while at the same time protecting indigenous flora and fauna, the Agricultural productivity has to be enhanced by increasing unit area production, not by converting more forest land to agriculture. In this regards, the flood mitigation in the Terai plain plays an important role, mitigating damages of flood and sediment, and providing people with flood-free lands of high productivity.

413. Concept of Master Plan: The Master Plan aims to direct or guide the flood mitigation activities that will be conducted by various agencies and organizations concerned. Flood mitigation measures generally needs long and continuous periods of efforts to accomplish. Therefore, all of these efforts must be directed in an orderly manner toward flood mitigation targets described in the Master Plan. In the present study, flood mitigation always means the mitigation of damages due to flood and sediment induced disasters.

414. Target Year and Objects to be Protected: In conformity with terms of the national development plan, target year was set at the end of 12th Plan in 2017. The flood mitigation will be discussed mainly for the Terai plain. As to the watershed, recommendation will be made from watershed conservation viewpoint. Major causes of damages in the Terai plain are (1) bank erosion, (2) sedimentation in the riverine areas, and (3) flooding and inundation. Owing to these, human being and properties in

the flood-prone area, such as settlements, public facilities, highway and rural roads, farm lands and livestock, have suffered from damages. These objects and lands located in flood-prone areas along the river shall be protected from flood and sediment disasters.

415. Approach to Flood Mitigation: Considering the natural and social conditions of the Study Area and the financial situation of HMG/N, the following approach is taken in planning the flood mitigation of the rivers in Terai plain:

1) Maximum use of local materials and human resources.
2) Provision of safe and productive lands for the expanding rural towns and increasing population.
3) Comprehensive flood mitigation measures adopting structural and non-structural measures.
4) Technical model for other river basins of similar nature.

4.2 Strategy for Flood Mitigation

421. Flood Mitigation Measures: In order to mitigate flood damage in the Terai plain, it is necessary to employ all the possible measures. The flood mitigation measures are broadly classified into four according to their functions as follows (Fig. 4.1):

1) Erosion and sediment control by watershed management
2) Storage or detention of flood water
3) Smooth transport of flood water and sediment
4) Damage mitigation by flood plain management

422. Continuous Dike: Continuous dike constructed along the river course is an effective measure to protect flood prone areas from floodwater and sediment, confining them in the river area. However, the continuous dike also induces various problems. After due consideration and discussions, the continuous dike was not proposed for the flood mitigation Master Plan, mainly for the following reasons:

1) **Concentration of sediment and floodwater in lower reaches:** This problem is more serious in the river basin with much sediment yield like the Siwalik. The concentration of sediment would bring about riverbed raising unless the river channel is improved in India to meet with that of Nepal. Furthermore the concentration of floodwater will increase potential damages in the lower reaches due to both concentrating floodwater and increased houses and other properties near the dike.

2) **Necessity of Plan Coordination with India:** Plan coordination with India is necessary so as not to cause flooding and sediment problems around the border. The continuous dike will not be realized unless the plan is agreed with India.

3) **Budgeting for Maintenance:** The damaged dike should be repaired immediately for coming floods. A breach of dike brings about more serious damages than ever. Therefore, the appropriate and timely maintenance are the basic requirement of the continuous dike. However, considering the present financial constrain of the government, such a timely response is deemed difficult.

423. Project Components: In order to undertake the project in a practical and sustainable manner, it is important to implement the measures in combination with community development activities. Therefore, the flood mitigation efforts are divided into three components, i.e., watershed management, river control and community development components.

4.3 Watershed Management Component

431. Watershed Management: For the conservation of watershed, construction of erosion control facilities, encouragement of afforestation and land use control are recommended as primary measures. In order to mobilize local community, and governmental and non-governmental organizations, publicity activities are also essential to materialize the measures.

4.4 River Control Component

441. Design Discharge: According to the runoff data recorded in the rivers in Nepal, probable flood discharge has been estimated at the major points of rivers in the Terai plain. Probable discharges at the lower end (Indian border) of respective river basins are shown below.

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
1.Ratuwa	383	500	810	1,010	1,200	1,450
2.Lohandra	310	450	720	900	1,070	1,300
3.Lakhandei	300	440	710	880	1,050	1,280
4.Narayani	31,645	12,400	16,600	19,400	22,100	25,600
5.Tinau	1,081	830	1,340	1,670	1,990	2,420
6.West Rapti	6,418	2,320	3,680	4,590	5,420	6,530
7.Babai	3,425	2,500	4,300	5,500	6,660	8,160
8.Khutiya	325	460	740	920	1,100	1,330

(Note) Qn denotes probable discharge of n-year return period.

442. River Segments and Channel Characteristics: The river is generally divided into four segments with similar characteristics mainly based on river slope and bed materials, i.e., Segment M for the mountain reaches, Segment 1 for the alluvial fan, Segment 2 for the natural levee zone, and Segment 3 for the delta. Segment-3 does not exist in the Terai plain rivers. River control measures should be discussed based on the channel characteristics of the respective segments.

443. River Boundary Line (RBL): The stabilization of a river course is a fundamental task in order to achieve river control. As a datum for the river course stabilization, river boundary line (RBL) should be first designated and authorized for the flood mitigation activities. The RBL must be fixed and marked clearly in the field by permanent objects such as stakes, planted trees, dike roads and local dikes. The RBL should be set identifying the lands and objects to be protected and providing enough channel capacity. The RBL itself should also be protected from the erosion. All the river facilities for flood mitigation and water use should be planned and designed in consideration of the authorized RBL. By so doing, the efforts of flood mitigation carried out continuously would be accumulated and the safety level of the river would be enhanced gradually.

444. Channel Treatment: The works include tributary work to fix the river system and catchment boundary, and branch/anabranch work to prevent river course shifting and flood water spilling.

445. Bank Protection: Bank protection aims to protect the bank from erosion and accordingly to stabilize the river course. Spur (or groin) works, revetment works and preventive bank protection works are the major types of works. In order to identify the sites in critical conditions and prioritize the work sites for protection, riverbanks should be classified depending on the conditions of bank erosion and situation of the RBL.

Riverbank conditions shall be monitored every year after the flood season and the types of river bank shall be classified. Necessity of protection works shall be examined based on the above criteria.

446. Proposed Dike Works: Dike works aim to prevent floodwater and sediment from spilling over the land. The continuous dike is not proposed for the rivers in the Terai plain. Instead, the following works were proposed:

1) **Forest and grass belts:** Trees and grass planted along the river course will alleviate flood damages in the flood prone areas, retarding the flood flows and promoting the formation of a natural levee along the belt (Fig. 4.2). Owing to these, it is expected that a river channel of about 2-year return period will be formed.
2) **Dike road:** Road embankment constructed along the river as rural road and flood dike as well. The road embankment protects nearby lands from flooding and sedimentation.
3) **Local dike:** A local dike is applicable to protect a specific area from flooding.
4) **Ring dike:** A ring dike is applicable to protect sporadic important objects like settlements in flood prone areas.

447. Other Channel Works: Channel excavation works primarily aims to increase channel capacity and to normalize the river courses. Collection of riverbed material also contributes to the increase of channel capacity, as far as the amount and places of collection are carried out appropriately from a river control viewpoint. Cut-off channel (COC) will ensure smooth flood and sediment flows by shortening the channel in meandering sections, and keep away the river course from the site to be protected. As to the diversion channel, appropriate sites are not found in the Study Area.

448. Storage or Detention of Flood Water: Because of geological and economical reasons, dam reservoir to control flood and sediment flows is not incorporated in the Master Plan. In order to reduce flood peaks in the downstream reaches, a retarding basin can be considered at the confluence of tributaries and inherent low-laying land by conserving existing flood storage function.

4.5 Community Development Component

451. Community Development: The component of "community development" consists of three sets of activities. The "community mobilization" intends to build up

organizational bases for implementation of the Plan. The "local coping measures" will enable the communities to live with flooding. The "community-based sustainable flood mitigation measures" will motivate the local people to maintain and sustain the flood control structures (Fig. 4.3).

452. Community Mobilization: The community development will start with the community mobilization, to strengthen the organizational bases for local flood mitigation initiatives. Unlike the past practices, more focus will be placed on awareness-raising and capacity-building of the communities themselves.

1) Workshops for Local Government Institutions (LGIs): In order to upgrade the LGIs' capacities to perform the full-fledged community mobilization tasks, a series of training workshop will be undertaken at the inception of the community development activities.
2) Creation of Organizational Bases at the Community: Formation of community organizations (COs), promotion of public awareness, knowledge and skills, and generation of financial resources by COs.

453. Local Coping Measures: Since it is not possible to contain all flooding through river control facilities alone, it is important for people also to take coping measures on their own. The local coping measures will be undertaken on a community-by-community basis. The following are a menu of support, to enhance their local coping measures:

1) Flood proofing: agricultural adjustments, housing structures, etc
2) Forecasting, warning, and evacuation
3) Flood fighting:

454. Community-based Sustainable Measures: The community-based sustainable measures are to derive additional benefits from the physical facilities, and to motivate the beneficiaries to sustain the structures. For example, (1) forest and grass belts and (2) preventive bank protection works will derive tree and grass products out of the flood control measures, while (3) access improvements and (4) bed material collection will produce other additional benefits. These additional values will motivate the COs to sustain the physical structures, through (5) operation and maintenance (O&M) of flood control structures, and (6) land use management.

4.6 Proposed Flood Mitigation Plan

461. Layout Plan: Based on the facility plan discussed above, Master Plan for the flood mitigation were worked out for each river. Layout of the Master Plan of each river basin is shown in Fig. 4.4. The Master Plan still remains at the conceptual plan level, since the plan was prepared on the topographic map basis (scale 1/25,000 and partly 1/50,000) without river section data.

462. Project Cost : Preliminary project cost estimated under the price prevailing in October 1998 are summarized below.

Name of River	Cost (million NRs)
1. Ratuwa river	551.8
2. Lohandra river	651.3
3. Lakhandei river	597.4
4. Narayani river	574.8
5. Tinau river	802.7
6. West Rapti river	232.0
7. Babai river	428.0
8. Khutiya river	115.5

(Remarks) Price contingency and value added tax are not included.

4.7 Action Plan toward Target Year

471. Actions to be Taken: The Master Plan is proposed for implementation by the year of 2017. The project works must be carried out effectively in an orderly manner toward the target. It is also important to realize the flood mitigation effects even in the course of implementation corresponding to the progress of work. The works are broadly divided into three, i.e., preparatory works, coordination for flood mitigation, and river works.

472. Action Plan: Implementation of the Master Plan project is programmed in conformity with the phases of the national development plans from the ninth through twelfth plans as follows:

1) 1st Phase (Ninth plan: 1997-2002)
2) 2nd Phase (Tenth plan: 2002-2007)
3) 3rd Phase (Eleventh and twelfth plan: 2007-2017)

473. Implementation Arrangements: The Department of Irrigation (DOI) is the overall coordinating agency for the entire flood mitigation plan (watershed management, river control, and community development activities). DOI is expected to see to it so

that the whole plan is undertaken in a coordinated manner. For this purpose, DOI will work through its District Irrigation Offices (DIOs) which head the district-level implementation committee.

474. District-level Implementation Committee: In implementing the plan, a district-level implementation committee (DIC) will be formed in each district. The Committee will be headed by the District Irrigation Office (DIO) representative, and will draw members from the concerned LGIs, i.e., the representatives of the District/Village Development Committees (DDC/VDCs) and Municipality. In addition, the DIC members will include the district-level representatives of the Departments of Soil Conservation and Watershed Management (DOSCWM), Forest (DOF), and Agriculture (DOA). Other line agencies, and concerned NGOs may be considered for inclusion in the Committee, if deemed appropriate. The Chief District Officer will also be a member, who is chief administrator of the district.

4.8 Economic Evaluation

481. Potential benefits and effects: Implementation of the flood mitigation Master Plan will primarily safeguard the land and properties in the flood prone areas and also bring about other favorable effects to the Study Area. The potential benefits and effects accruing from the Master Plan are (1) Reduction of damage due to flood and sediment, (2) protection of riverbank from erosion, (3) indirect effects, (4) Land enhancement, (5) Land reclamation, (6) flood-free embankment, (7) income generation, (8) stabilization of residents' livelihood, and (9) Community development.

482. Economic Evaluation for Master Plan Projects: Economic viability of the flood mitigation Master Plan was examined preliminarily. Out of the various effects listed above, (1) flood damage reduction benefit, (2) bank protection benefit, and (3) indirect benefit were considered as tangible benefit for the evaluation. According to the preliminary cost-benefit analysis, the Babai river yields high EIRR-value, while the value is low for the Lohandra and Khutiya rivers. The EIRR-values of the remaining 5 rivers are almost the same ranging around 10. However, these results should be handled only as a rule-of-thumb and reviewed through feasibility study based on the river survey data.

CHAPTER 5. SELECTION OF PRIORITY PROJECT

501. Priority Ranking: Priority orders of the eight river basins for the Study were evaluated from the aspects of (1) higher economic viability, (2) urgency of flood mitigation, (3) more favorable social impacts, (4) less adverse social and environment impacts, (5) sustainability of flood mitigation activities, and (6) availability of basic data. According to the evaluation on the above items, the top five priority rivers are ranked as follows:

(Rank)	(River)	(River class)	(Development region)
1.	Babai river	II	Mid Western
2.	Lakhandei river	III	Central
3.	Tinau river	II	Western
4.	Ratuwa river	III	Eastern
4.	Narayani river	I	Central/Western

502. River Basins for Feasibility Study: River basins should be selected from different classes of rivers and different development regions of the country, since the result of study made on the selected basin would be a technical guideline for planning flood mitigation measures of other river basins of a similar nature. The following two river basins, ranked 1st and 2nd, are selected for further study:

1) **Babai river basin** : Class-II river in Mid-Western Region
2) **Lakhandei river basin** : Class-III river in Central Region

503. River Basin for Comprehensive Flood Mitigation Plan: Out of two river basins selected for the Feasibility Study, one river is to be selected for the study on comprehensive flood mitigation plan including watershed. The Lakhandei river was selected for the study, since the Lakhandei river originates in the Siwalik hills which yield much sediment. The study includes the sabo (erosion control) and soil conservation in the mountainous watershed as well,

CHAPTER 6. ADDITIONAL INVESTIGATIONS AND STUDIES

6.1 Investigations

611. Additional Investigation: Supplemental and detailed data necessary for the Feasibility Study were collected for two rivers selected for the Feasibility Study, i.e., the Lakhandei and Babai river basins. The additional investigations and studies covered the following:

1) **Topographic Mapping and River Survey:** Preparation of topographic maps of scale 1/10,000 with the contour intervals at 2.5 m and river survey for longitudinal and cross sectional surveying with flood mark surveying.
2) **Flood Flow Investigation:** The investigation aims to collect information and field data on flood flow conditions, and to prepare flood and sediment hazard map based on the above.
3) **Environmental Study:** The study consists of (1) general environmental inventory in a belt up to 500-m wide on either side of the Lakhandei and Babai rivers, (2) environmental study at the specific sites on the Babai river, and (3) environmental study in two sub-watershed areas of the Lakhandei.

6.2 Additional Studies

621. Study on Watershed of Lakhandei River: Studies are made for the Lakhandei watershed on the geological and topographic characteristics related to the watershed management measures. As a result, it is found that there are two major sources of sediment brought into the Terai plain. One is due to hill-side erosion in the southern slope of Siwalik hills facing to the Terai plain, and the other is due to side erosion of the main Lakhandei river in the middle watershed. The clearing of natural forests also aggravate the sediment problems coupled with inherent poor geological situation.

622. River Course Shifting of Lakhandei River: River course actively shifts in the lower reaches of the Lakhandei river. Near the Padariya village, the Lakhandei river took a new route toward west since the 1997-flood. At about 400 m downstream of Phulparasi bridge of Hulaki Sadak road, flood water often flowed toward Inaruwa village. At about 1.5 km downstream from the bridge, a new flood route was formed on the left bank in July, 1998. In spite of these active instantaneous river course shifting, the river course seems to remain within the meandering belt over the past 38 years, according to the old topographic maps prepared in 1953/54 (scale: 1/50,000).

623. Channel Characteristics: Based on the results of river survey conducted by the Study Team, the principal characteristics of the Lakhandei and Babai rivers such as overall channel profile, hydraulic mean depth, channel width, flow area, bank-full capacity and profile of the riverbed materials were studied (Figs. 6.1 and 6.2). From the channel characteristics, the river was divided into several stretches. Average channel sizes of respective river stretches are summarized below.

River stretch	Bed slope (I)	River Width (m)	Mean depth (m)	Flow area (m^2)	Bank-full capacity (m^3/s)
(LAKAHNDEI R.)					
Segment 2-2:					
No.0-No.21	1/1,531～862	62	0.59	36	26
Segment 2-1:					
No.21-No.32	1/569	411	0.81	324	354
No.32-No.40	1/376	598	0.89	533	745
Segment 1:					
No.40-No.52	1/253～150	498	1.97	848	2,793
(BABAI R.)					
Segment 2-2:					
No.0-No.13	1/3,716	407	3.21	1,264	1,511
No.13-No.30	1/1,820	471	2.42	1,094	1,600
Segment 2-1:					
No.30-No.37	1/1,000	623	2.53	1,534	2,610
Segment 1:					
No.37-No.46	1/436～383	804	2.38	1,796	3,932

624. Runoff Analysis: The Lakhandei river has a total area of 300 km^2 of which the main Lakhandei river shares 107 km^2 (36 % of the total basin area) before the confluence of the Chapani river. On the other hand the basin area of the Babai river is 3,425 km^2 in total. The watershed area upstream from the Babai barrage covers 3,002 km^2 (88% of the total basin area). Runoff hydrograph for flood flow analysis was estimated with assumed triangular discharge hydrograph, since the actual runoff hydrograph was not available:

625. Flood Flow Analysis: Flood flow analysis was made using an unsteady flow simulation model. The model consists of channel and flood plain models. The model was first adjusted for each basin condition using the latest flood data, i.e., 1997-flood for the Lakhandei river and 1995-flood for the Babai river. Then the model was run under the various probable floods. The results of flood flow analysis are used to evaluate hydraulic effects of proposed project works and to estimate the flood flow conditions required for estimation of probable flood damages.

CHAPTER 7. PROJECT PLANNING FOR FEASIBILITY STUDY

7.1 Principles for Planning:

711. General: Within the frame of the Master Plan set forth in Chapter 4, the priority project selected for the Feasibility Study shall be planned here further in detail, based on the results of additional surveys and investigations. The principles established for the Master Plan shall also be observed in this phase.

1) **Objective of Project:** The flood mitigation project aims to support people's livelihood and the development of agriculture in the Terai plain, reducing damages due to flood and sediment, reclaiming some of the sterile land, and enabling intensified cropping.
2) **Project Area:** The project covers plain and watershed areas of the Lakhandei river and plain area of the Babai river.
3) **Safety Level:** It is intended to form a river channel of about 2-year return period by bioengineering measures. In addition, every efforts will be made to mitigate substantial damages.

712. Target Year and Implementation of Pilot Project: Although the target year for the Master Plan has been set in the year 2017, the implementation schedule of the priority project for the Lakhandei and Babai rivers should be rearranged, so that the project could be completed by the year 2007 (by the end of 10th national plan). These two rivers bear an important role as a model and/or pilot project of the flood mitigation in the Terai plain. The experience and technical know-how obtained through the priority project could be applied to more than sixty rivers in the Terai plain as well.

713. Flood Mitigation Budget and Project Size: Budgetary situation of HMG/N is summarized below on the expenditure basis. The existing river training budget is too small to implement basin-wide flood mitigation project and should be considered as a part of maintenance cost.

Descriptions	1996/97 (Rs. mill)	1997/98 (Rs. mill)
National total expenditure	50,724	69,693
DOI total expenditure	2,577.9	3,040.8
Local-level river training program	44.9	120.0
District-wise river training budget		
- Sarlahi District	0.8	1.4
- Bardiya District	0.8	4.4

An idea on the project size can be drawn from the ongoing national-level river training

works. As of March 1998, DOI operates six national-level undertakings for river training. Cost of these projects ranges from 28.5 to 370 million Rupees.

7.2 Watershed Management Component

721. Source of sediment and Coping Measures: The major sources of sediment in the Lakhandei watershed and proposed coping measures are as follows:

1) **Hill-side erosion** on the southern slope of Siwalik hills: Gully erosion control and hill-side works.
2) **River-side erosion** of the main Lakhandei river and main tributaries: Consolidation of riverbed, protection of riverbank from scoring, and planting permanent crops along the riverbanks.
3) **Devastated forest** in the whole watershed: Afforestation and land use regulation, and publicity activities.

722. Erosion Control Facilities: The effects of erosion control facilities depend on the geology and mechanism of erosion. These are not investigated yet intensively in any part of the Siwalik hills. It is, therefore, proposed to conduct following two sets of experimental works in the Lakhandei watershed:

1) **Experimental work on hill-side erosion** in the Siwalik hills
2) **Experimental work for river-side erosion** in the Lakhandei river

723. Afforestation and Land Use Regulations:

1) Management of natural and community forests should be encouraged.
2) Designation of steep slopes for planting permanent crops.
3) Encouragement of planting commercial and multi-year crop vegetation such as fruit trees, medicinal herbs, aromatic plant and dye plants.
4) Restriction of grazing within a permissible limit for the sustainable use of pasture and forest.
5) Training of local people in the appropriate management of community forest, pasture and farm land in watershed areas.

724. Publicity Activities: In order for communities, NGOs, and local/central governments to benefit from the efforts made in other watershed, and to be familiar with watershed management, any possible activities for publicity should be undertaken.

7.3 River Control Component

731. Design Criteria and Standards: The following criteria were applied to the structural design:

1) Design Manual for River Training Works in Nepal, prepared by Ministry of Water Resources, Nepal.
2) Technical Standard for River and Sabo Facilities, prepared by the Ministry of Construction, Japan.

732. Preliminary Facility Design: River control facilities such as forest and grass belts, spurs (groins), revetments, ring dikes, dike roads and closing dikes were designed preliminarily, considering river segments classified based on the mainly topographic conditions and riverbed materials of the river.

733. Studies on Alternative Schemes: In order to seek for the optimal scheme, the following problems were studied comparing the alternative schemes from technical, financial, economic, social and environmental aspects.

1) Route of Lakhandei river between Laksmipur and Belhi villages.
2) Route of Lakhandei river downstream from Phulparasi bridge.
3) Severe meandering of Babai river at Indrapur bridge.
4) Sharp bend of Babai river near Kusumba Bazar.

734. Construction Plan:

1) **Construction Method:** On-land excavation works by a combination of manpower and hauling machines, embankment works by a combination of man-power and suitable compaction machines, and other construction works such as gabion work, concrete work, masonry work, afforestation work, etc. by conventional methods.
2) **Construction Materials:** According to the result of riverbed material investigation, the earth materials along the length of the Lakhandei and Babai rivers are mostly usable as embankment materials, boulders for gabion and masonry works, and coarse and fine aggregate for concrete works. As to the Babai river, quarry site in the Karnali river is also applied to the work.
3) **Construction Schedule:** The target year of completion of the priority project is set for 2007. After completing the preparatory work, construction phase will start in 2002.

7.4 Community Development Component

741. General: The overall framework of the community development discussed for the Master Plan will be taken over for the Feasibility Study (Table 7.1). At this stage, it was discussed further how the basic framework of the community development component will be tailored to the location-specific situations along the Lakhandei and Babai rivers, based on the latest and in-depth data and information collected specifically for these river basins.

742. Location-Specific Strategies: In order to materialize the community development for flood mitigation, studies were focused on what community development strategies will be taken in the sites, where additional flood control measures are planned (i.e., mainly dike and spur works), within the overall framework. The location-specific strategies for the Lakhandei river were studied for the respective VDCs of Patharkot, Gurkauli, Haripur, Pidari, Janaki Nagar, Shripur, Padariya, Belhi, Sundarpur, Laksmipur and Sakraul. Likewise, the location-specific strategies for the Babai river were studied for the respective VDCs of Bagnaha, Baniyabhar, Sano Shri, Padnaha, Dhadhawar, Mahamadpur, and Gulariya Wards 2, 5, 6, 8 and 10.

7.5 Proposed Project Works

751. Layout Plan: As a summary of project planning, general location map and general plans of the project works are shown in Figs. 7.1 through 7.3 for the Lakhandei river and in Figs. 7.4 through 7.6 for the Babai river.

7.6 Project Implementation Program and Maintenance Plan

761. Preparatory Works: Upon completion of the Feasibility Study, the following activities should be taken immediately:

1) **Fund arrangement**
2) **Definite plan/detail design:** A definite plan of the flood mitigation works, including establishment of river boundary line (RBL) will be drawn up after getting consent of the agencies and communities concerned. A detailed design will be prepared of the project facilities.
3) **Environmental study:** In parallel with the definite plan and detail design, environmental study will be conducted in accordance with the procedures stipulated in the Environmental Conservation Rules (ECR) to get approval of Ministry of Population and Environment (MOPE) for project implementation.

4) **Preservation of Lands:** Population in the Terai is growing rapidly and more and more people live in flood prone areas. Therefore, it is essential to preserve the lands for flood mitigation facilities. This should start immediately after the preparation of definite flood mitigation plan. Appropriate land use should also be encouraged as outlined in the definite plan and detail design.
5) **Coordination among Agencies and Communities:** Coordination should be started as soon as possible after completion of the Feasibility Study, in order to mobilize agencies and communities concerned toward project implementation.

762. Community Development: Community development activities should precede the implementation of the river control works. Community mobilization and local coping measures should go first in parallel with the definite plan study. Community mobilization is a key for the successful project implementation. Community-based sustainable flood mitigation measures will be executed in line with the definite plan.

763. Watershed Management: Afforestation and land use regulation and publicity activities can be started immediately. The erosion control experimental works in the Lakhandei river will be commenced upon completion of the detailed design.

764. River Control: Flood hazard map will be prepared during the definite plan stage refining those prepared in this stage. The river control works will be started upon completion of the detailed design. Sequence of implementation among the component works is not important. Any work can be started basically at any places where the inceptive procedures are ready.

765. Associate Activities: The following associate activities are required to be started soon. These activities will support the effective project implementation.

1) **Research and Investigation:** Flood and sediment runoff, bank erosion mechanism, bank protection works, bioengineering technology, construction materials, etc.
2) **Technical Guidance:** Publicity of existing technical know-how, consultation on technical problems, training of local leaders, etc.

766. Time Schedule: Time schedules for the Babai and Lakhandei rivers are shown in Figs. 7.7 and 7.8. Implementation of the works for the Lakhandei and Babai rivers are scheduled in advance to the other river basins for M/P study as priority project. Period

of definite plan/detailed design for the Lakhandei river was scheduled one year longer than that of the Babai river. The Lakhandei river includes route alternatives and it is anticipated that longer time period would be necessary to reach to a consent among the VDCs and peoples concerned.

767. Required External Input: Considering the financial constrains of the MHG/N and necessity of intensive implementation of the work as pilot project, the following external inputs are required for the project implementation:

1) **Financial assistance**, especially for the river control component.
2) **Technical assistance** for watershed management, river control and community development components. Especially for the community development, it is proposed that a expert group stations in the community and promote the activities collaborating with the community peoples. The expert group should include various field of expert such as community development, forestry, agriculture, and flood mitigation.

768. Organization for Project Implementation: The flood mitigation program will be managed by the DOI Project Management Office (PMO) to be set up at the district level. The PMO will comprise three divisions, i.e., an Upper Catchment Division, Flood Control Division, and Community Development Division. It is expected that DOSCWM will depute its staff to work as the chief of the Upper Catchment Division, while all the other key posts will be filled by DOI staff.

7.7 Project Cost

771. Conditions of Cost Estimate: All unit costs are expressed at the constant price as of October 1998. Currency exchange rates are assumed as follows:

US$1.00 = NRs.67.93 = ¥115.14 (NRs.1.00 = ¥1.69)

Project costs are composed of the following costs:

1) Construction base cost: Unit cost basis
2) Compensation cost: Unit cost basis
3) Administration cost: 5% of [(1) + (2)]
4) Engineering service cost: Lump sum basis
5) Physical Contingency = 10% of [(1) + (2) + (3) + (4)]
6) Price contingency (Financial cost only): At annual escalation rate of 3 % for the foreign currency, and 10 % for the local currency portions

772. Estimate of Project Cost: Quantities of project works and estimates of project costs are shown in Tables 7.2 and 7.3 respectively for the Lakhandei and Babai rivers.

Item	Lakhandei R. (million NRs)	Babai R. (million NRs)
1. Construction Base Cost	280.5	338.7
2. Compensation Cost	45.4	26.6
3. Administration Cost	16.3	18.3
4. Engineering Cost	56.1	67.7
5. Physical Contingency	39.8	45.3
6. Value added tax	43.8	49.6
6. Total	481.9	546.1

(Note) Price contingency is not included.

773. Annual Disbursement Schedule and Fund Required: Annual disbursement of the project costs were prepared on the basis of the implementation schedule. Considering the price contingency, fund required for the project implementation of the was estimated at Rs.689.3 million for the Lakhandei river and Rs.744.7 million for the Babai river as summarized below.

Items	Lakhandei R. (million NRs)			Babai R. (million NRs)		
	F.C.	L.C.	Total	F.C.	L.C.	Total
Project cost	155.9	326.0	481.9	197.4	348.6	546.1
Price contingency	23.2	184.3	207.5	25.6	173.0	198.6
Fund required	179.1	510.3	689.3	223.0	521.0	744.7

7.8 Evaluation

781. Economic Evaluation: Economic viability was examined for the flood mitigation projects proposed for the Feasibility Study for the Lakhandei and Babai river basins. Flood damage reduction benefit, bank protection benefit and indirect benefit were considered for the evaluation. Cash flows of the project cost, maintenance cost and benefit were prepared for the project life assumed to be 50 years including implementation period. The results of economic evaluation are summarized below.

River	Existing basin			Future basin		
	EIRR (%)	B/C	NPV (10^6Rs)	EIRR (%)	B/C	NPV (10^6Rs)
Lakhandei	9.5	0.95	-14.6	20.8	2.05	308.0
Babai	9.7	0.98	-8.7	15.2	1.54	188.7

(Note) B/C and NPV were calculated under the discount rate of 10%.

782. Environmental Screening: The flood mitigation interventions on the river basins in the Terai are overwhelmingly environmentally positive. For each of the eight rivers, the environmental screening gives very positive results. The initial environmental evaluation (IEE) only have to be undertaken on areas where large-scale mechanical(structural) river bank protection is required, (one kilometer or more) and perhaps where people are displaced. Discrete environmental impact assessment (EIA) are necessary for designated wetlands along the rivers but not where interventions in buffer zones are proposed. Otherwise, this environmental screening should be sufficient to satisfy the environmental obligations of the project, provided the local people are fully involved in the decision making process.

783. Technical Evaluation: The flood mitigation activities must be performed continuously and, therefore, the plan must fit well with the local situation, technical capability and financial solvency of the central and local government agencies, non-governmental organizations and local communities concerned. In planning the flood mitigation plan of the rivers in the Terai plain, various attempts were made so that the plan should meet the actual situation of the country and the project sites. Therefore, the project is considered to be sustainable.

CHAPTER 8. CONCLUSION AND RECOMMENDATION

801. Economic Viability of Master Plan: Implementation of the Master Plan is expected to bring about various tangible and intangible benefits to the communities in the Study Area. According to the preliminary cost-benefit analysis, the Babai river yields high EIRR-value, while the value is low for the Lohandra and Khytiya rivers. This result should be handled only as a rule-of-thumb and reviewed through feasibility study based on the river survey data.

802. Economic Viability of Priority Project: According to the cost-benefit analysis based on the river survey data, the priority projects (the Lakhandei and Babai rivers) yield high EIRR-values under the future basin condition, though the value is low under the existing basin. The proposed flood mitigation measures can be implemented at any place and at any size. The project can be economically viable, since the project works would be implemented from those of higher cost-performance, keeping pace with basin's development.

803. Environmental Impacts: From environmental conservation viewpoint, the proposed project overwhelmingly positive exerting favorable effects on social and natural environment and no pollution problems will accrue. Only problems found so far are conservation of wetlands most of which have already been developed as farm lands or reserved as national parks.

804. Technical Aspects: The technology proposed for the project are appropriate from the viewpoint of technical competence, since the plan took much consideration on fitness to the local situation, technical capability and financial solvency to make the project sustainable.

805. Recommendation: Considering the crucial importance of the flood mitigation in the Terai plain, the proposed Master Plan for the Ratuwa, Lohandra, Narayani, Tinau, West Rapti and Khutiya rivers should be promoted to the Feasibility Study. As to the proposed flood mitigation projects for the Lakhandei and Babai rivers, the Feasibility Study verified that the projects are economically and technically feasible and exert little adverse effect to the environment. The projects are recommended for implementation in order to support people's livelihood and sound development of the basin.

TABLES

OVERALL FRAMEWORK OF COMMUNITY DEVELOPMENT

Lakahndei River

Community Mobilization

1) Formation of Community Groups
- Learning from a limited # of outstanding cases of community mobilization

2) Creation of Awareness, Knowledge & Skills
- Education on technical measures for flood control (spurs, dikes etc.)
- Skills training on gabion netting and masonry
- Promotion of proper land use practices

3) Groups Savings for Disaster Management
- Resource mobilization for regular maintenance of river training facilities
- Local contributions for community-based actions
- More emphasis on women's participation

Local Coping Strategy

1) Flood Proofing
- Agricultural adjustments (esp. through flood-proof varieties, & storage of rice saplings)
- Housing structure through plantation of trees for durable construction materials

2) Forecasting, Warning, & Evacuation
- Warning utilizing existing facilities (e.g., PCO, & mosques)
- Accessibility enhancement for evacuation

3) Flood Fighting
- Supply of materials not available locally (e.g., boulders, gabion)
- Dissemination of flood fighting activities

Multi-purpose Facility

1) Collection of Bed Materials
- Clear-cut rules for sand/gravel extraction
- Enforcement of guidelines for proper extractions

2) Forest/Grass Belts
- Use of trees/grass for livelihood improvements (fuel, fruits etc.)
- Plantation of trees for evacuation & housing

3) Preventive Bank Protection
- Introduction of high-value grass /shrubs
- Simple protection works using local materials
- Dissemination of bio-engineering

4) Road Network Development
- Access improvement using river control facilities (esp. dikes)
- Road improvements for flood mitigation & to meet other local needs

Babai River

Community Mobilization

1) Formation of Community Groups
- Working through, or building upon, traditional irrigation groups

2) Creation of Awareness, Knowledge & Skills
- Education on technical measures for flood control (spurs, revetments etc.)
- Skills training on gabion netting and masonry
- Promotion of proper land use practices

3) Groups Savings for Disaster Management
- Resource mobilization for regular maintenance of river training facilities
- Local contributions to undertake community-based disaster management actions

Local Coping Strategy

1) Flood Proofing
- Agricultural adjustments (esp. through irrigation, & flood-proof varieties)
- Reforestation/aforestation
- Installation of drainage

2) Forecasting, Warning, & Evacuation
- Forecasting & warning utilizing existing facilities (e.g., irrigation barrage)
- Organized strategy for river watching

3) Flood Fighting
- Local production and procurement of flood fighting materials (e.g., bamboo, sandbags)
- Dissemination of flood fighting activities

Multi-purpose Facility

1) Collection of Bed Materials
- Exemption of prohibitive rules
- Enforcement of guidelines for proper extractions

2) Forest/Grass Belts
- Use of trees/grass for livelihood improvements (fuel, fodder, roofing, etc.)
- Plantation of trees for flood fighting

3) Preventive Bank Protection
- Introduction of high-value grass /shrubs
- Simple protection works using local materials
- Dissemination of bio-engineering

4) Road Network Development
- Access improvement using river control facilities (esp. bank protection)

SUMMARY OF PROJECT COST FOR LAKHANDEI RIVER (FINANCIAL) FEASIBILITY STUDY

(NRs1,000)

Item	Unit	Quantity	Amount		
			F.C.	L.C.	Total
I . Construction Base Cost			108,045	172,411	280,456
1. Preparatory Works	L.S.	1.00	9,822	15,674	25,496
2. Bank Protection			32,806	48,522	81,328
2-1 Pile Spur	km	4.10	10,497	13,165	23,662
2-2 Gabion Spur	km	11.46	22,309	35,357	57,666
2-3 Revetment	km	0.00	0	0	0
3. Dike Embankment			38,947	68,578	107,525
3-1 Forest and Grass Belt	ha	377.50	9,471	40,059	49,530
3-2 Dike Road	km	6.55	10,247	7,849	18,096
3-3 Ring Dike	km	5.30	10,623	9,980	20,603
3-4 Closing Dike	place	8.00	8,607	10,690	19,297
4. Channel Excavation	km	9.88	17,540	25,387	42,928
5. Miscellaneous Works	L.S.	1.00	8,929	14,249	23,178
II . Compensation Cost	L.S.	1.00	0	45,384	45,384
III. Addministration Cost	L.S.	1.00	0	16,292	16,292
IV. Engineering Cost	L.S.	1.00	33,655	22,436	56,091
V . Physical Contingency	L.S.	1.00	14,170	25,652	39,822
VI. Total			155,870	282,176	438,046
VII. Value Added Tax	L.S.	1.00	0	43,805	43,805
VIII. Grand Total			155,870	325,980	481,850

Note: 1: Price Level in October 1998
2: Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
3: Cost does not include price contingency
4: Figures may not add up to totals due to rounding
F.C:Foreign currency portion
L.C:Local currency portion

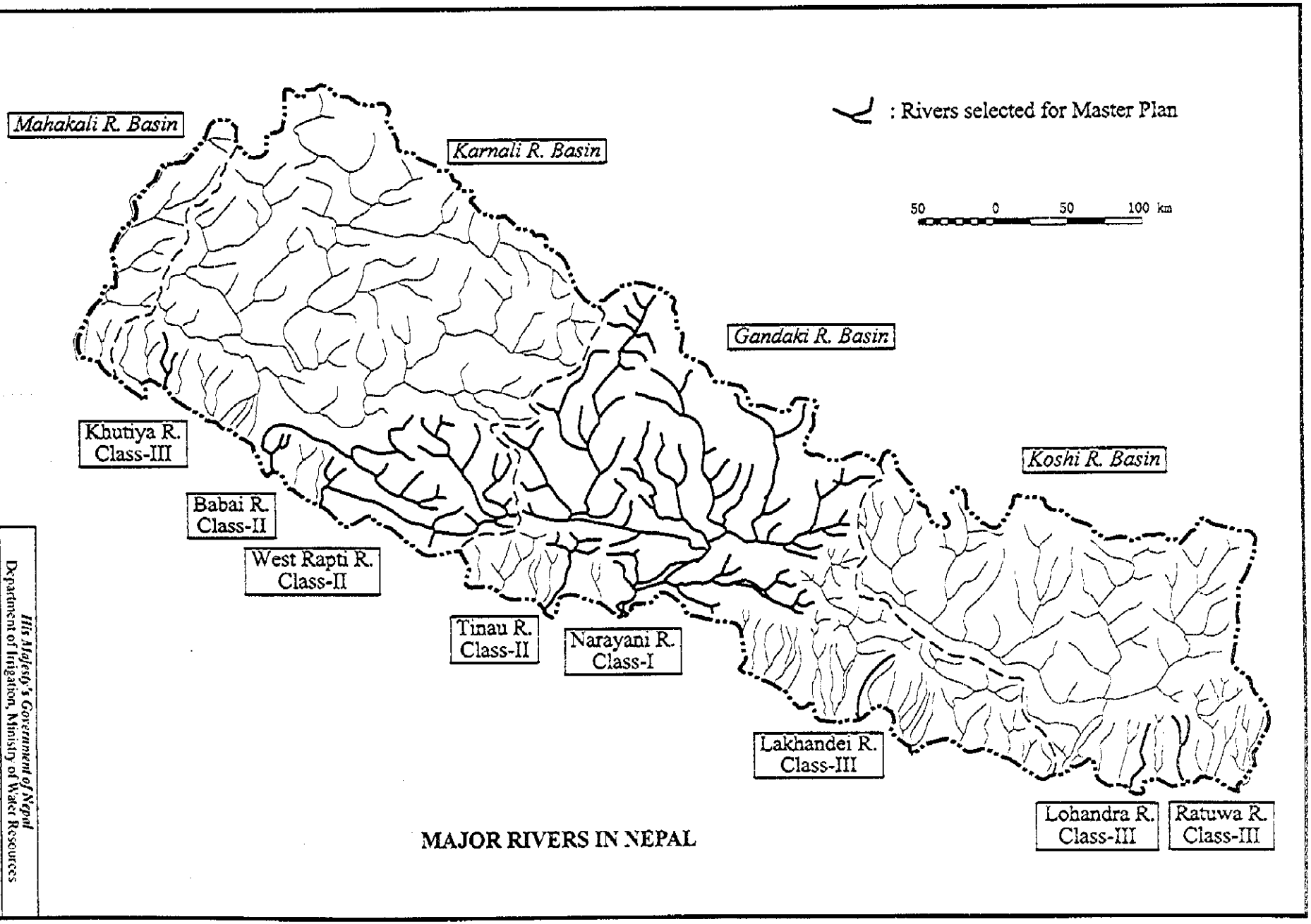
SUMMARY OF PROJECT COST FOR BABAI RIVER (FINANCIAL) FEASIBILITY STUDY

(NRs1,000)

Item	Unit	Quantity	Amount		
			F.C.	L.C.	Total
I . Construction Base Cost			138,837	199,821	338,658
1. Preparatory Works	L.S.	1.00	12,622	18,166	30,787
2. Bank Protection			87,178	120,310	207,488
2-1 Pile Spur	km	13.19	46,627	57,917	104,544
2-2 Gabion Spur	km	5.21	11,873	18,460	30,333
2-3 Revetment	km	3.30	28,678	43,934	72,611
3. Dike Embankment			12,743	23,381	36,125
3-1 Forest and Grass Belt	ha	284.00	2,509	10,612	13,120
3-2 Closing Dike	place	8.00	10,234	12,770	23,004
4. Cut-off Channel	km	1.40	14,820	21,450	36,270
5. Miscellaneous Works	L.S.	1.00	11,474	16,514	27,988
II . Compensation Cost	L.S.	1.00	0	26,640	26,640
III . Addministration Cost	L.S.	1.00	0	18,265	18,265
IV. Engineering Cost	L.S.	1.00	40,639	27,093	67,732
V . Physical Contingency	L.S.	1.00	17,948	27,182	45,130
VI. Total			197,424	299,001	496,425
VII. Value Added Tax	L.S.	1.00	0	49,642	49,642
VIII. Grand Total			197,424	348,643	546,067

Note: 1: Price Level in October 1998
2: Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
3: Cost does not include price contingency
4: Figures may not add up to totals due to rounding
F.C:Foreign currency portion
L.C:Local currency portion

FIGURES


Mahakali R. Basin
Karnali R. Basin
Gandaki R. Basin
Koshi R. Basin
: Rivers selected for Master Plan
50 0 50 100 km
Khutiya R.
Class-III
Babai R.
Class-II
West Rapti R.
Class-II
Tinau R.
Class-II
Narayani R.
Class-I
Lakhandei R.
Class-III
Lohandra R.
Class-III
Ratuwa R.
Class-III
MAJOR RIVERS IN NEPAL
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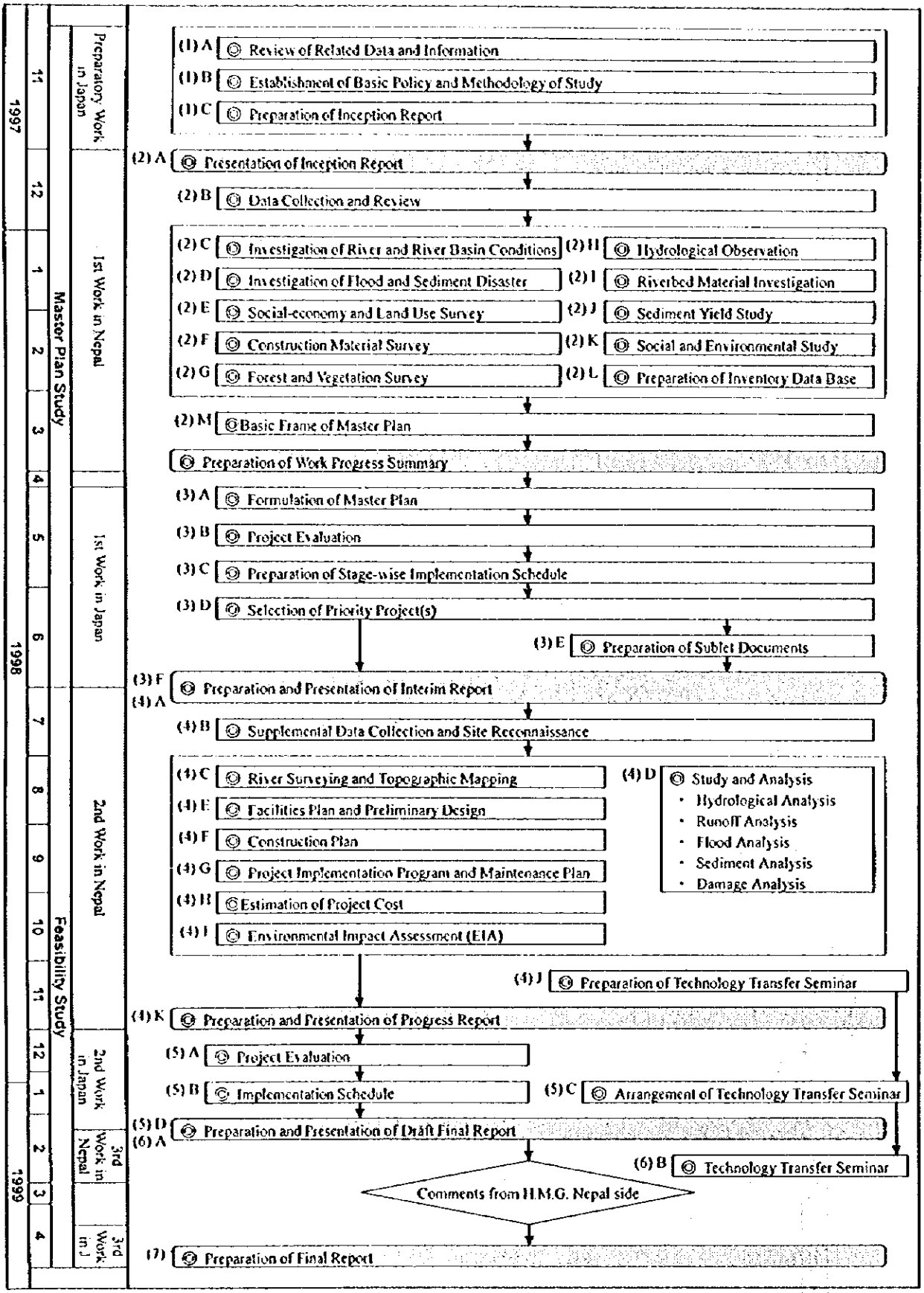
F-1

Fig. 1.1

Fig. 1.2



FLOW CHART OF THE STUDY

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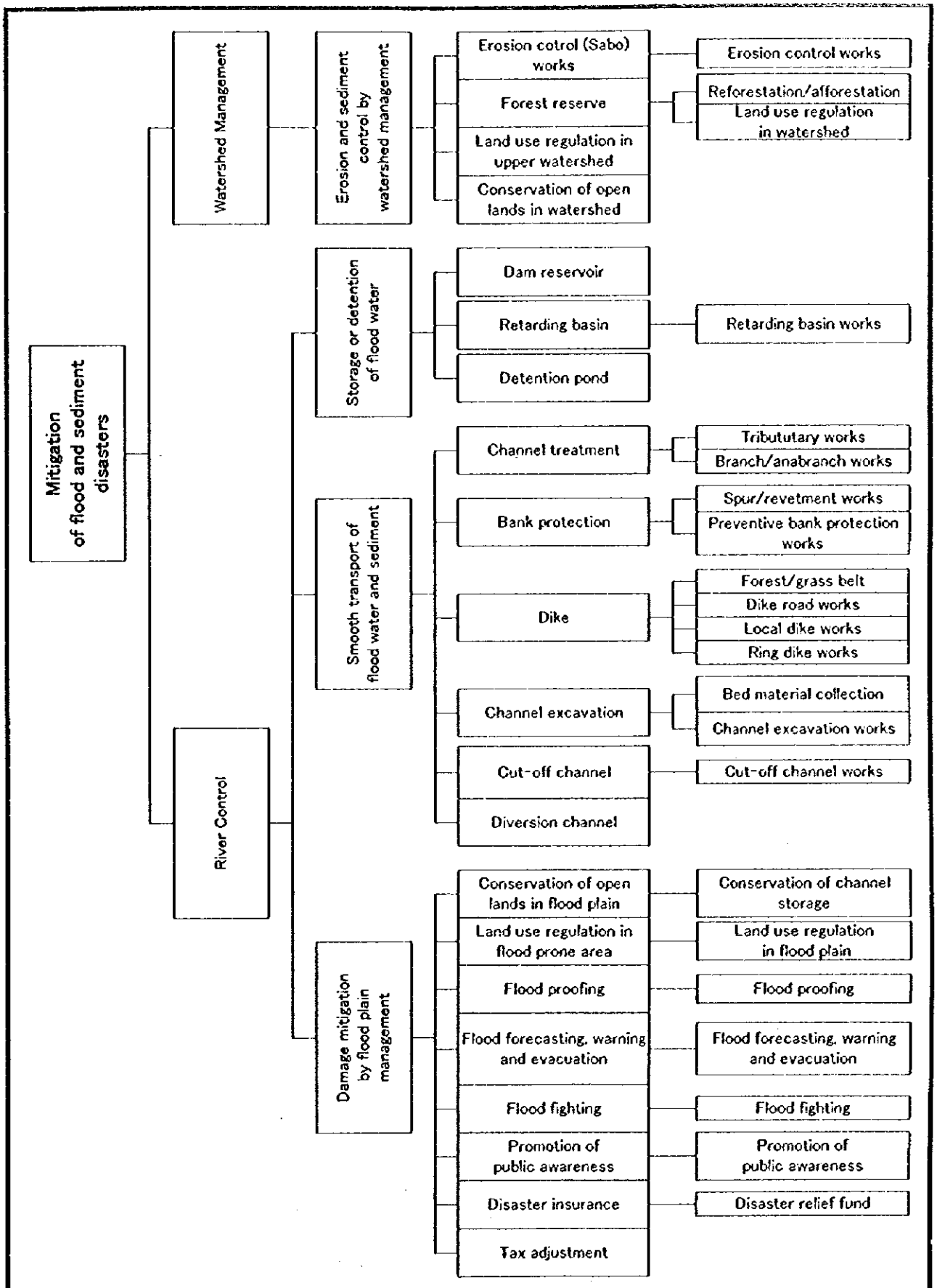

FLOOD MITIGATION MEASURES

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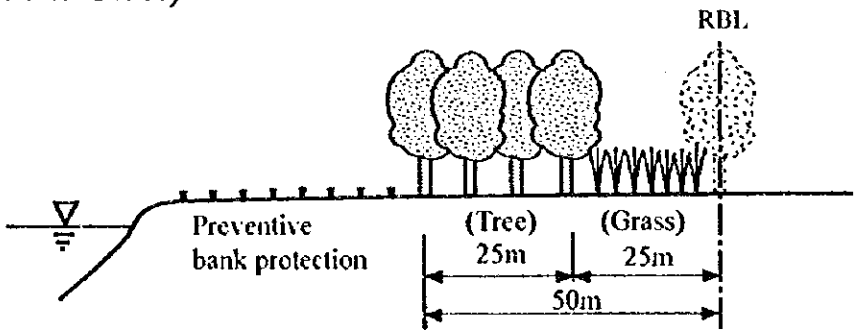
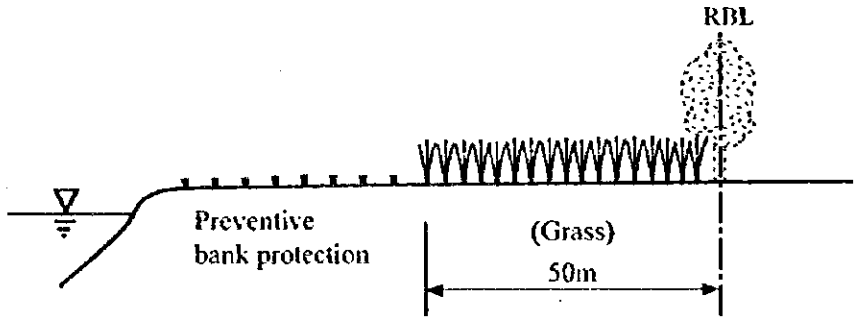
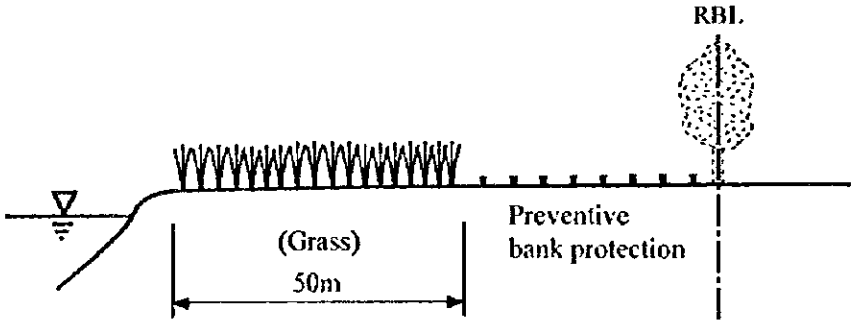
Forest Belt
(Tree and Grass)



Grass Belt



Grass Belt along Low Water Channel (Seg.2-2 of Lakhandei R.)



- RBL shall be marked clearly in field by tree-row or stacker.
- If there are forests more than 50m-wide on river side of RBL, tree/grass belt is not necessary.
- If the river side bank area of RBL is less than 50m in width, width of grass belt should be reduced.

FOREST/GRASS BELT AND RIVER BOUNDARY LINE

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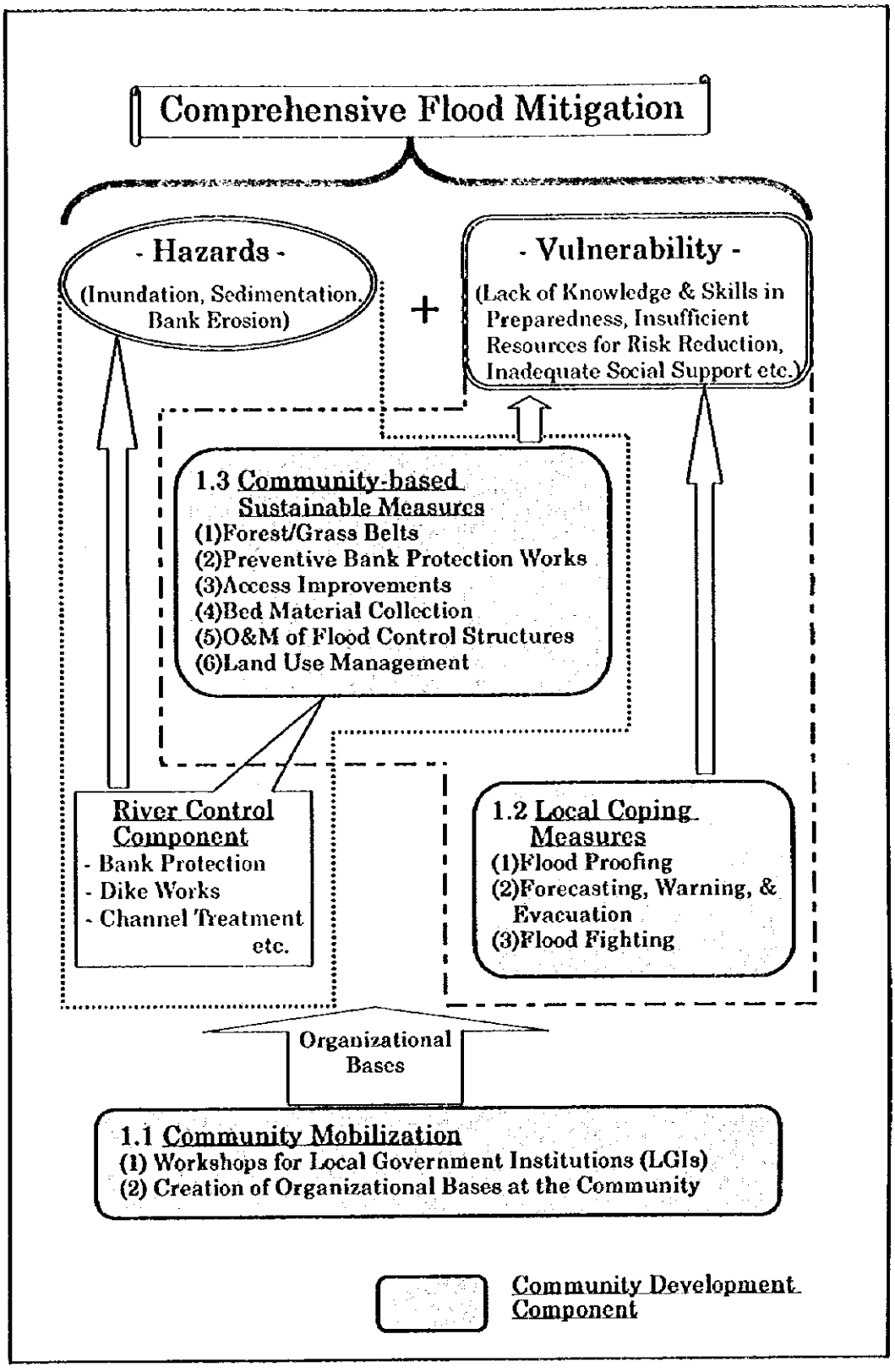

COMPREHENSIVE FLOOD MITIGATION

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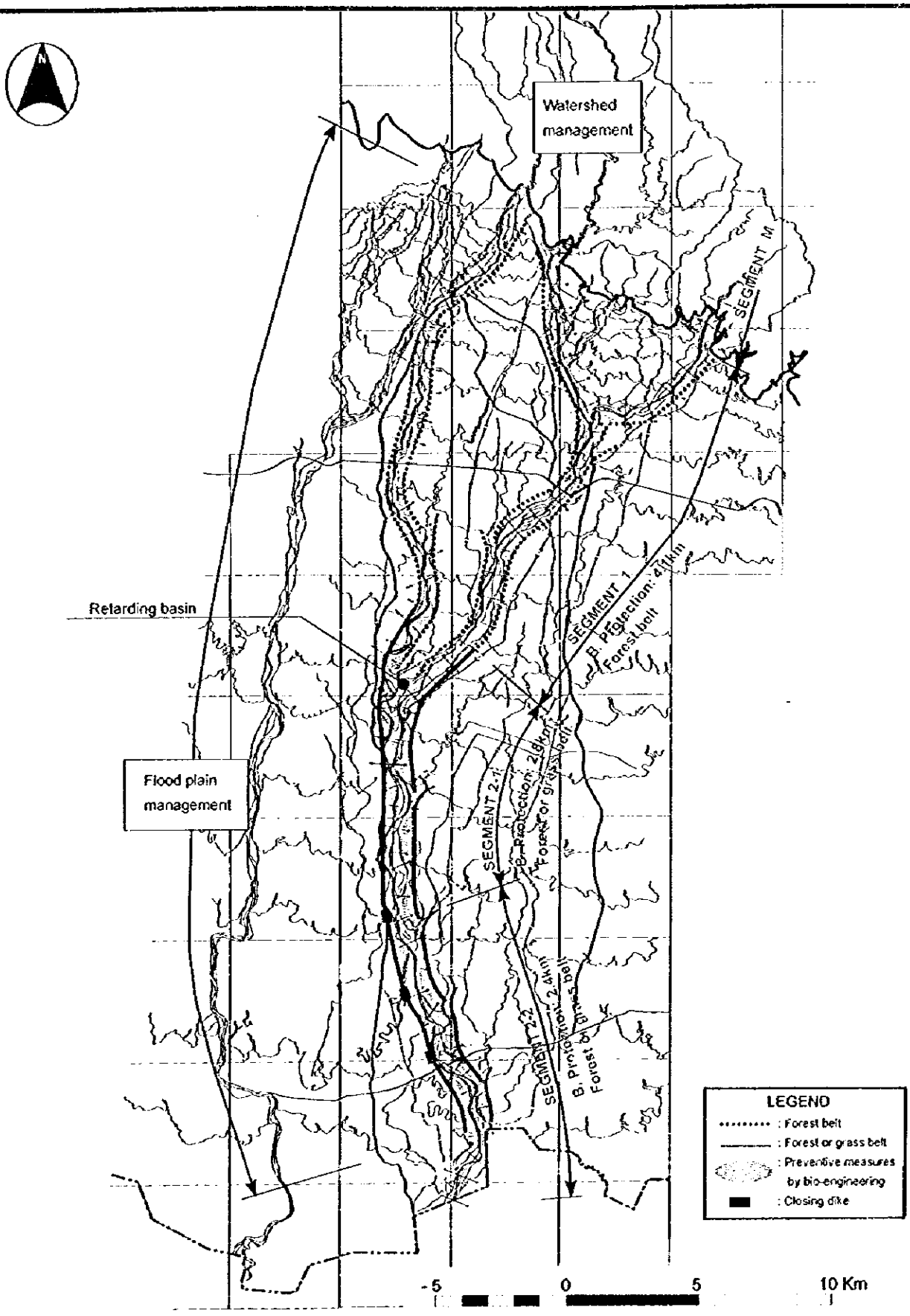

LAYOUT PLAN FOR FLOOD MITIGATION (RATUWA RIVER)

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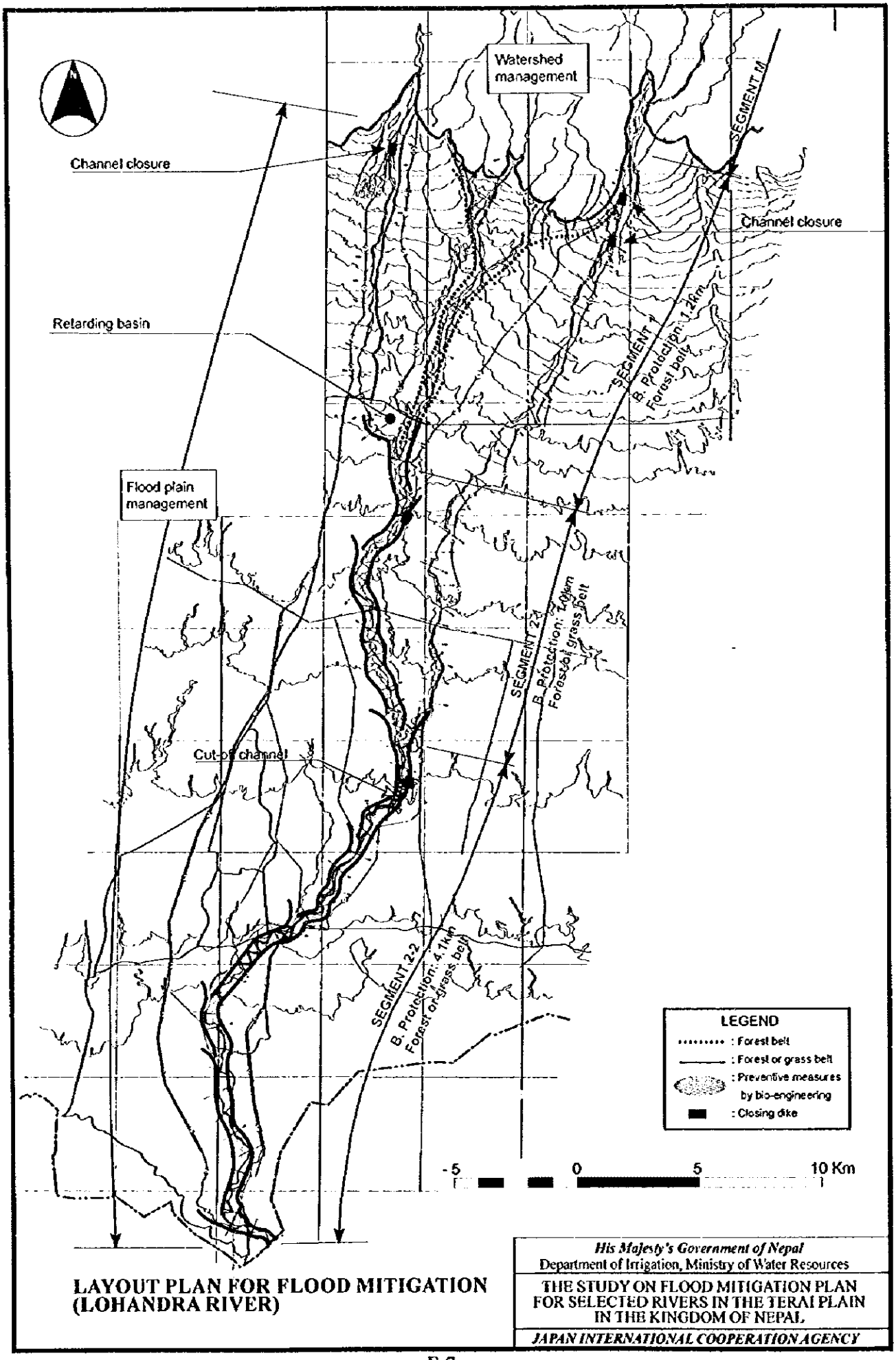

LAYOUT PLAN FOR FLOOD MITIGATION (LOHANDRA RIVER)

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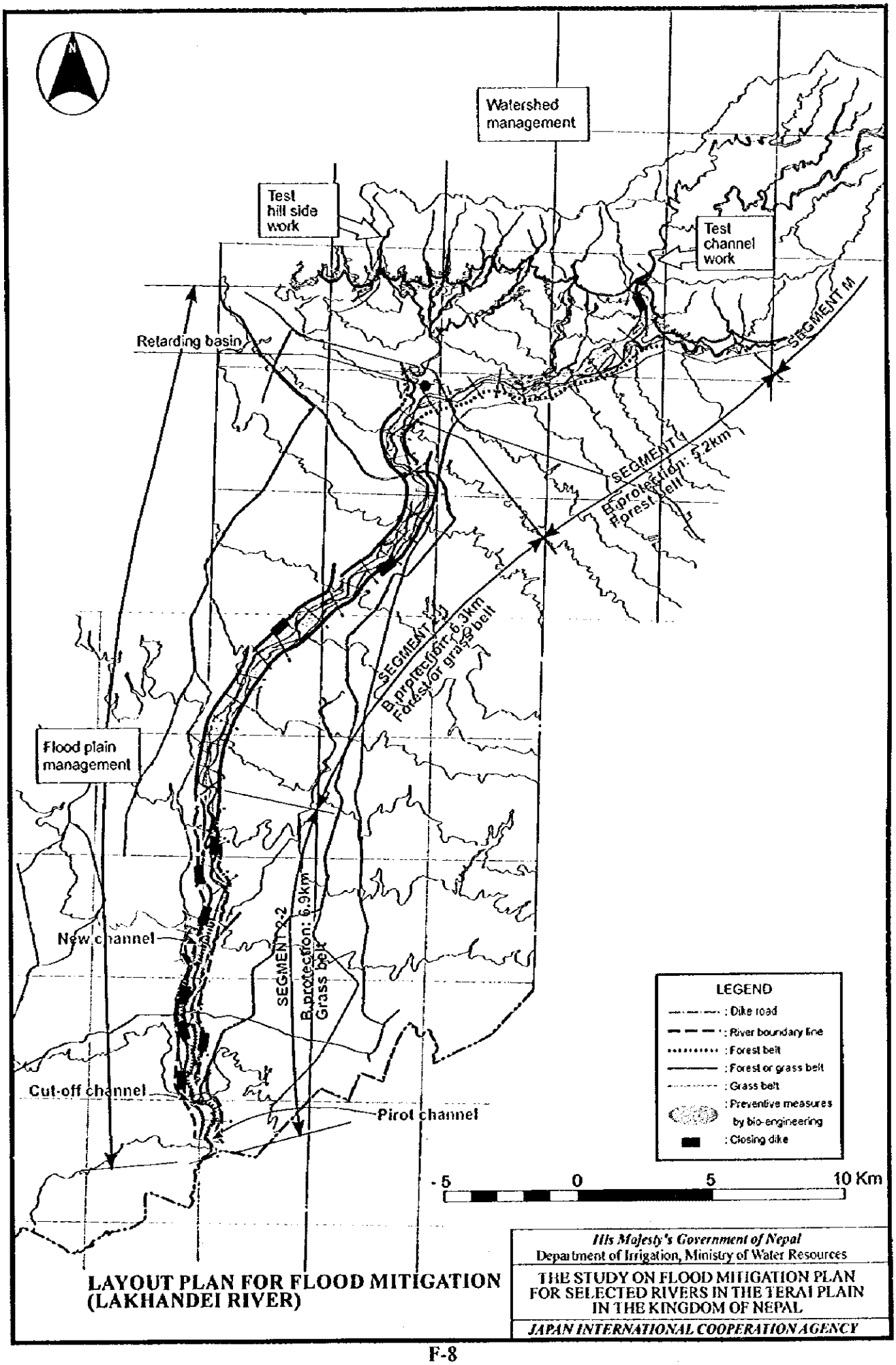

LAYOUT PLAN FOR FLOOD MITIGATION (LAKHANDEI RIVER)

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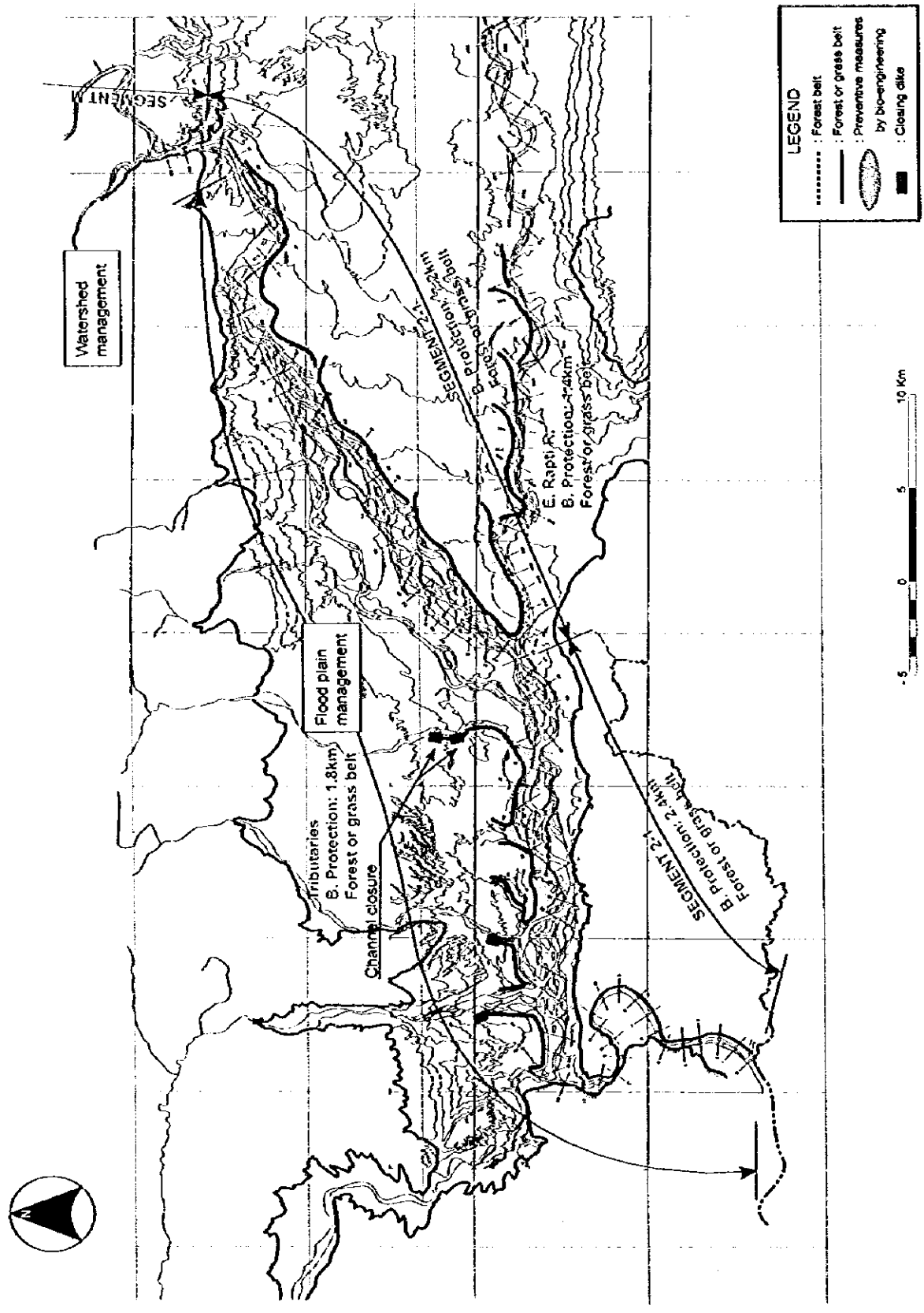

LAYOUT PLAN FOR FLOOD MITIGATION
(NARAYANI RIVER)

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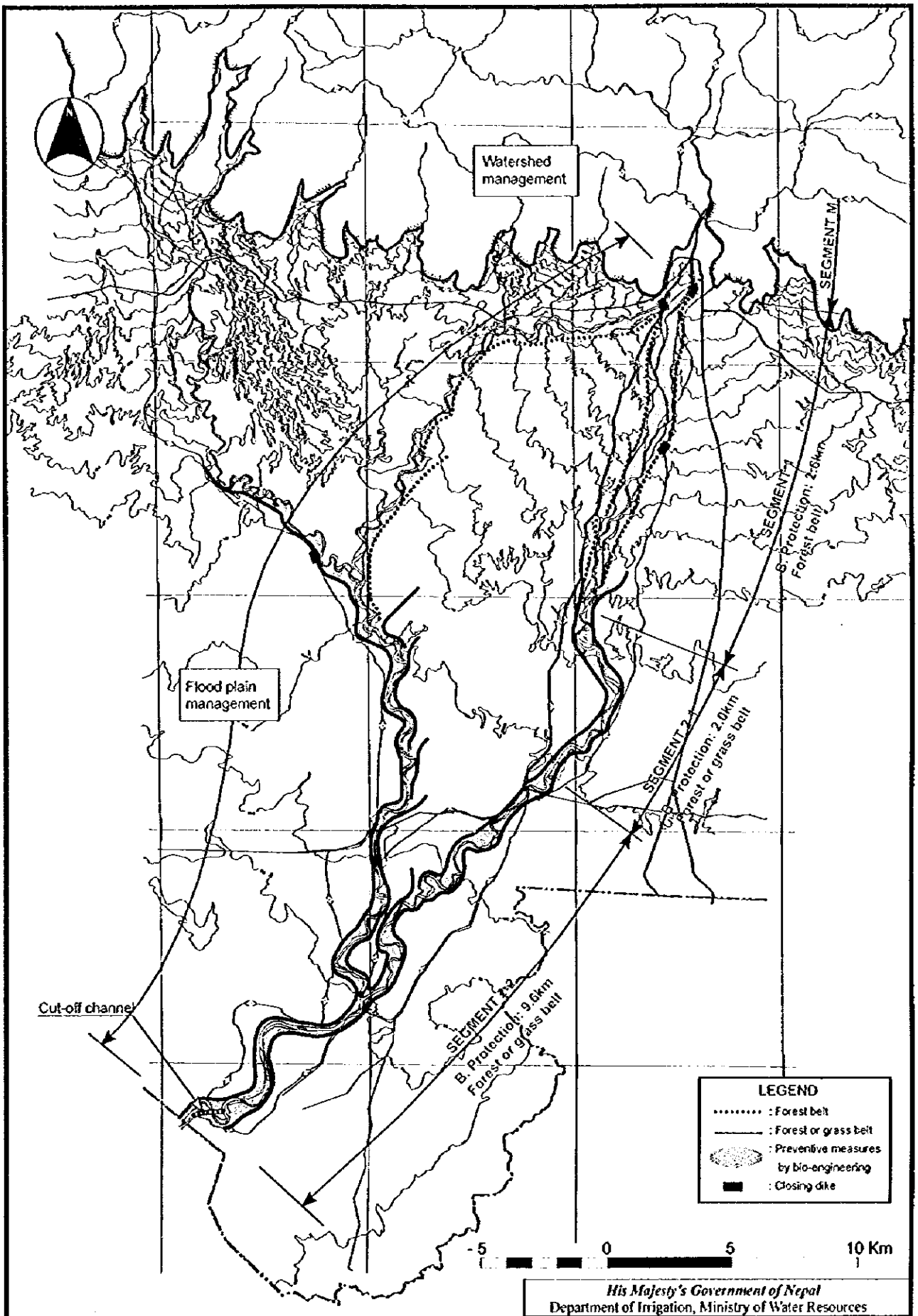

LAYOUT PLAN FOR FLOOD MITIGATION (TINAU RIVER)

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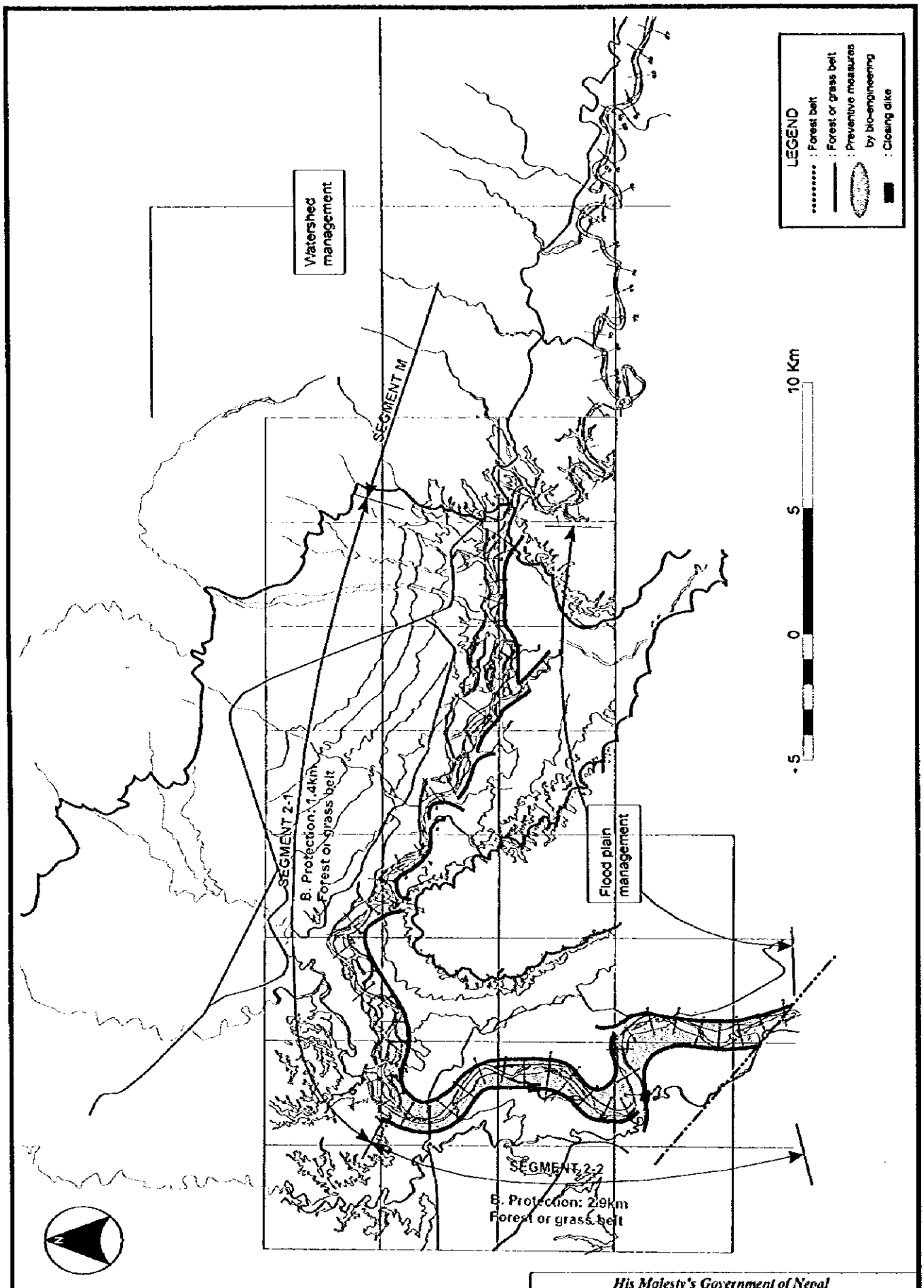
Fig. 4.4 (6/8)



LAYOUT PLAN FOR FLOOD MITIGATION (WEST RAPTI RIVER)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

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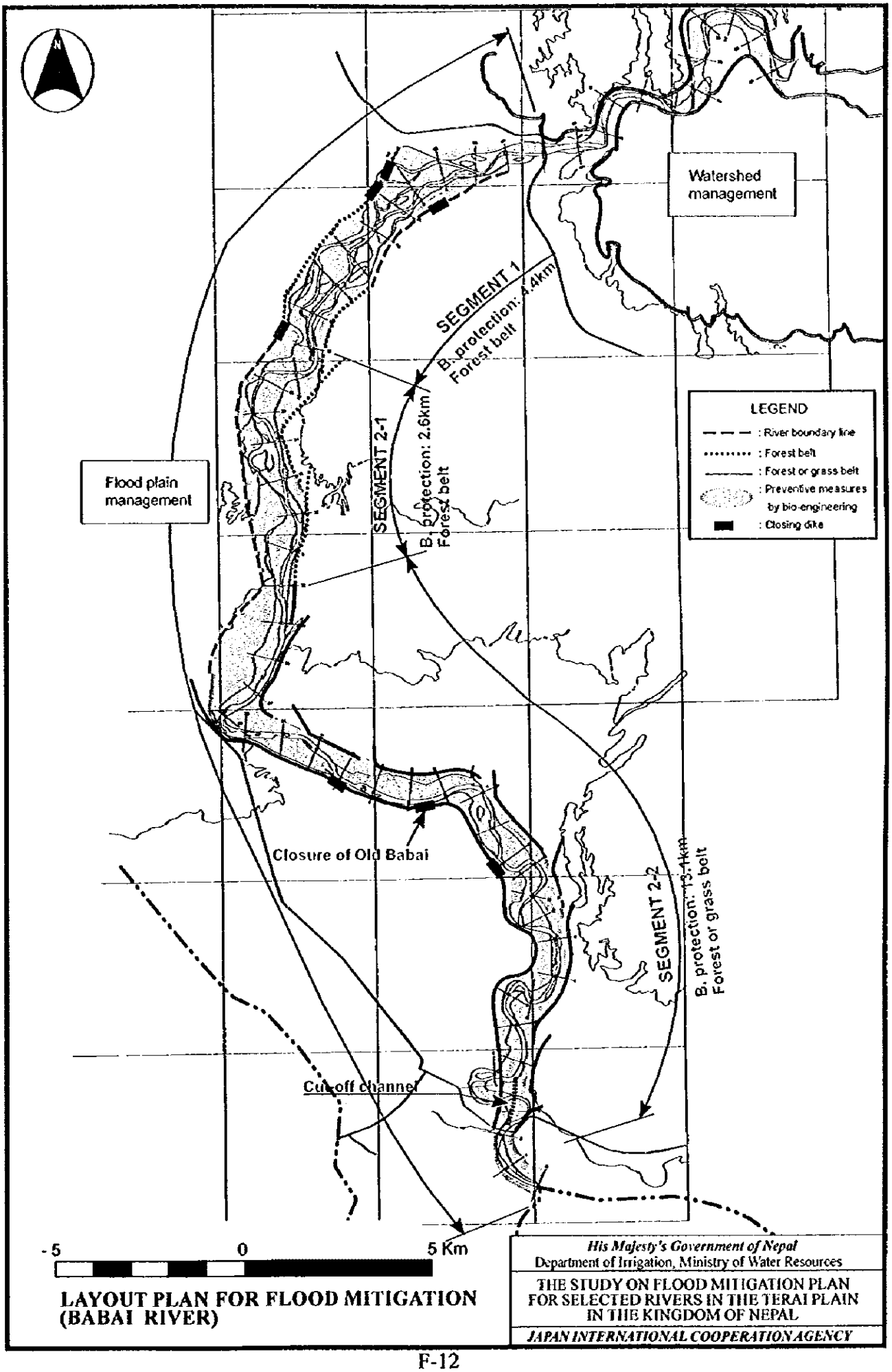

LAYOUT PLAN FOR FLOOD MITIGATION (BABAI RIVER)

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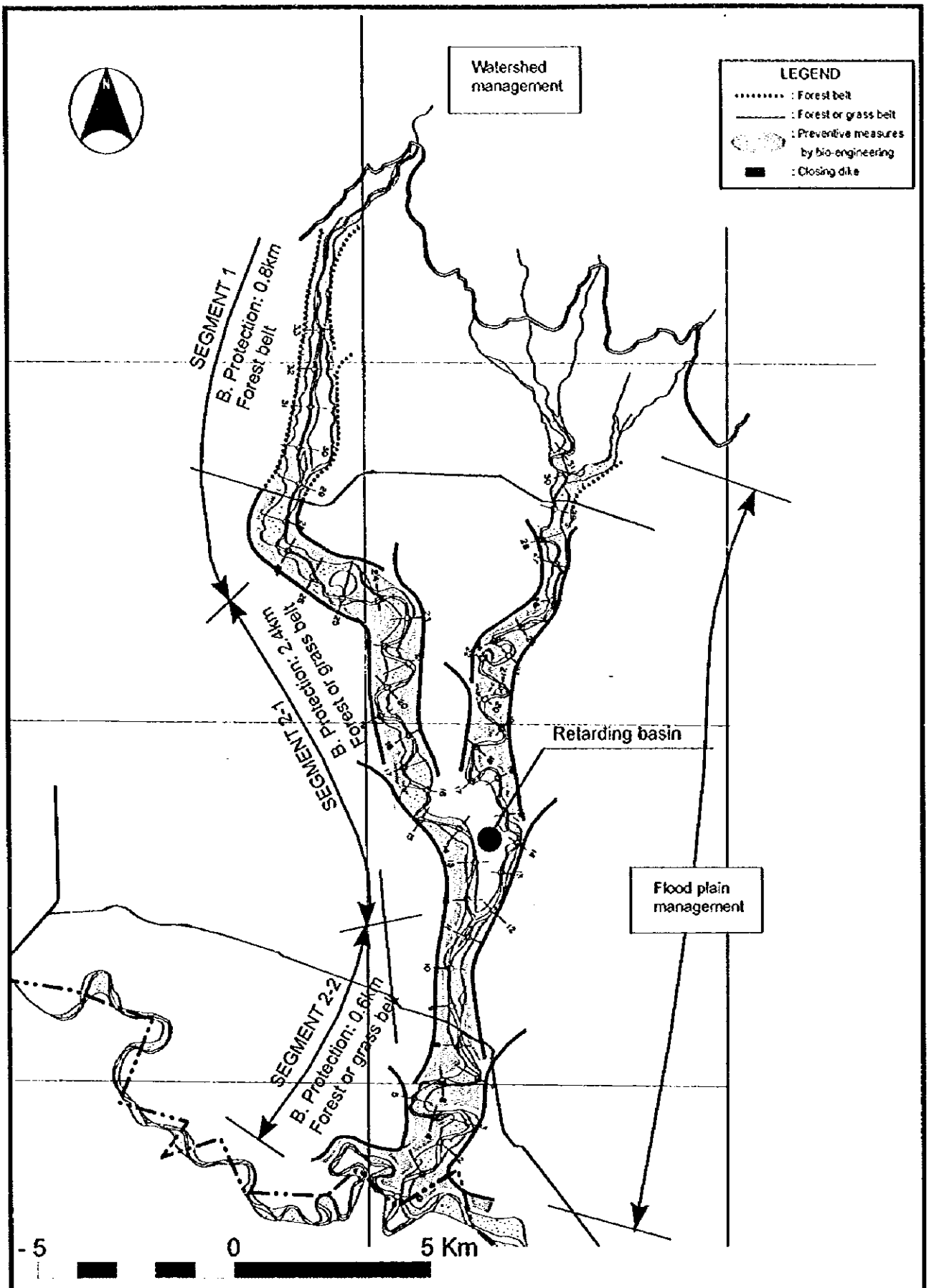
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

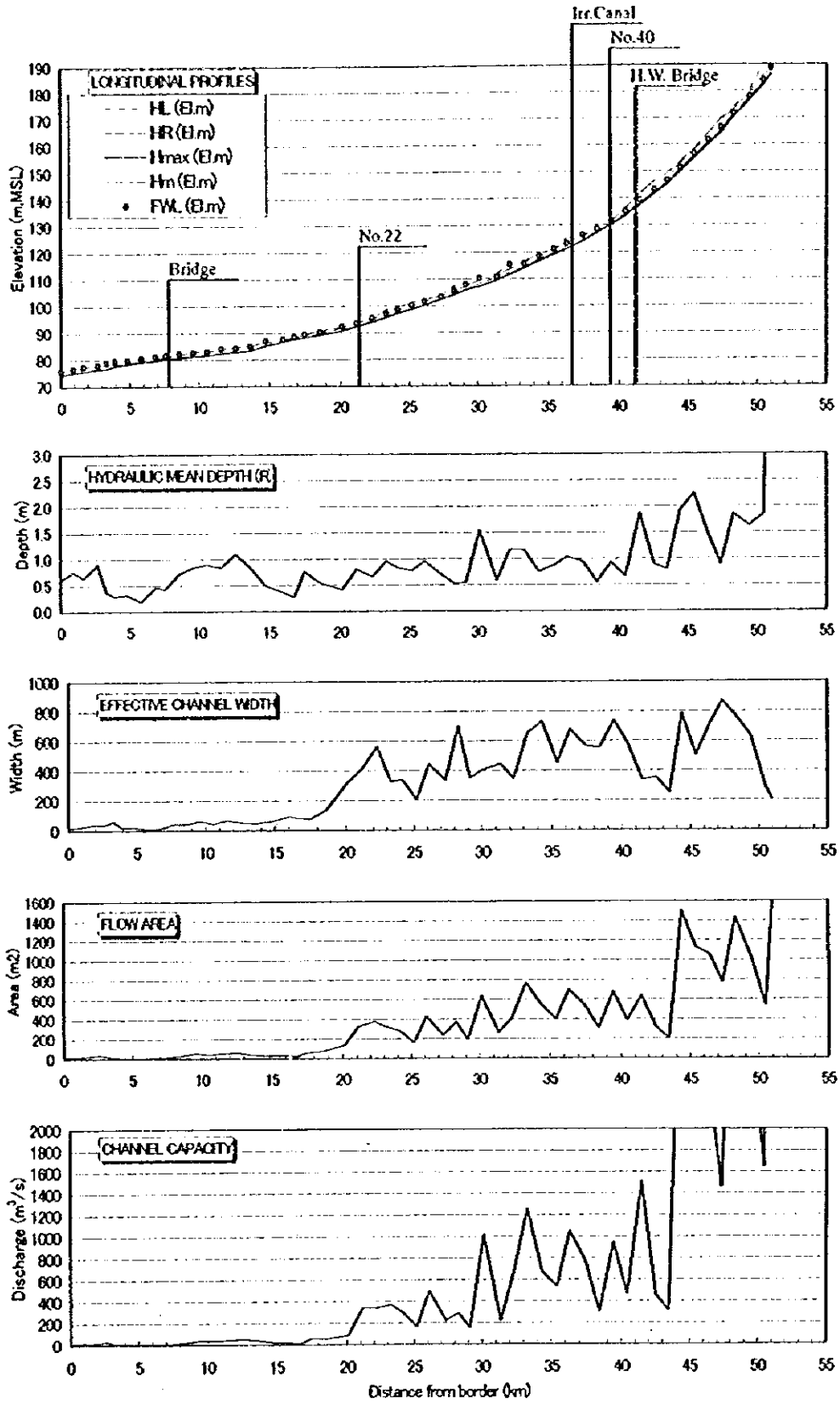


LAYOUT PLAN FOR FLOOD MITIGATION
(KHUTIYA RIVER)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



PRINCIPAL CHANNEL CHARACTERISTICS OF LAKHANDEI RIVER

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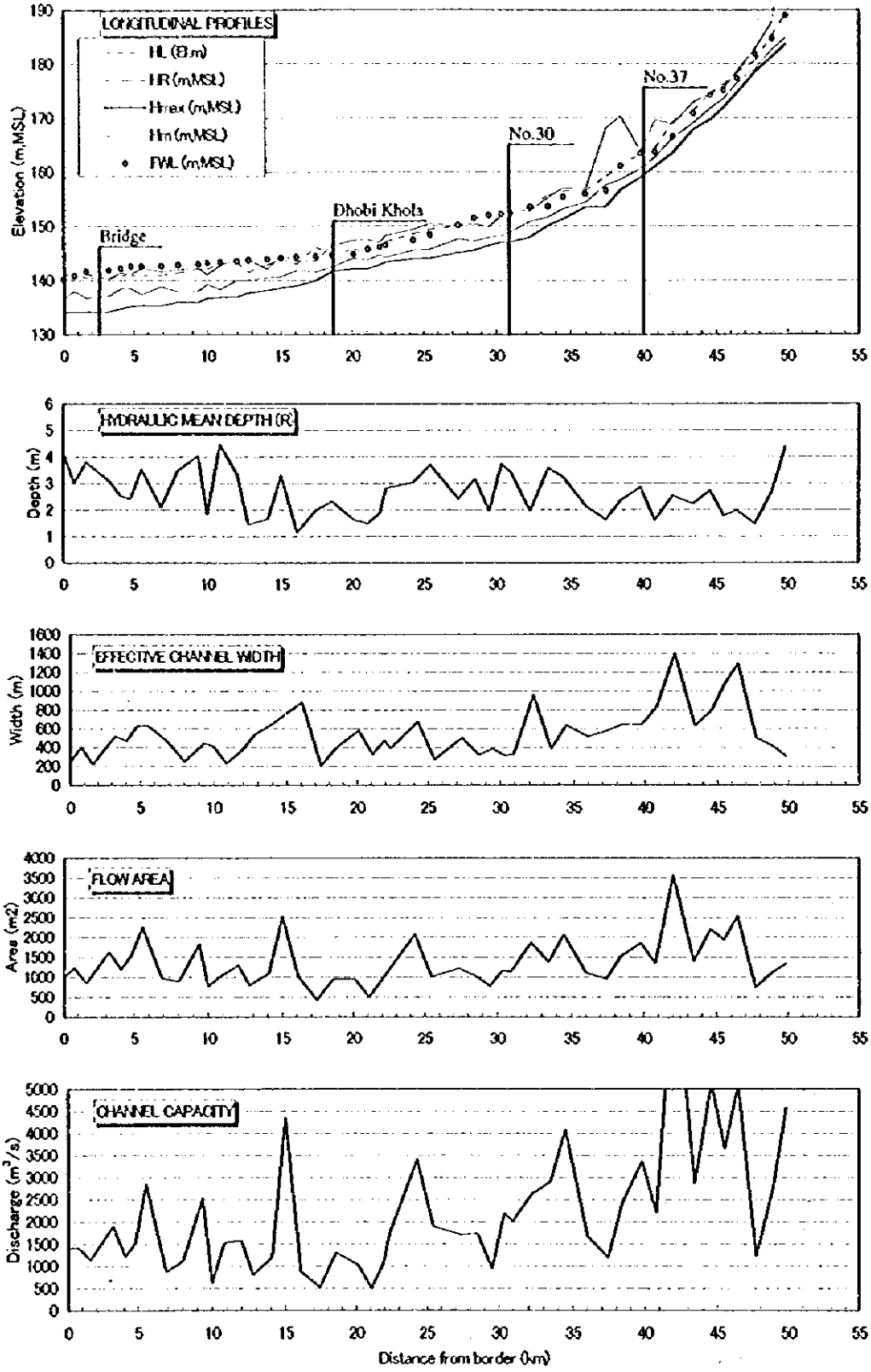

PRINCIPAL CHANNEL CHARACTERISTICS OF BABAI RIVER

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