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 III (3/9)

SUPPORTING REPORT

(A3: FMP/LAKHANDEI RIVER)

MAY 1999

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

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 III (3/9)

SUPPORTING REPORT

(A3: FMP/LAKHANDEI RIVER)

MAY 1999

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

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

FINAL REPORT

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
- A5: FLOOD MITIGATION PLAN/TINAU RIVER
- A6: FLOOD MITIGATION PLAN/WEST RAPTI RIVER
- A7: FLOOD MITIGATION PLAN/BABAI RIVER
- A8: FLOOD MITIGATION PLAN/KHUTIYA RIVER
- B : OVERALL DESCRIPTION OF STUDY AREA
- C : BASIC INVESTIGATIONS AND STUDIES
- D : OTHER DOCUMENTS

VOLUME IV : DATA BOOK

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

A3. FLOOD MITIGATION PLAN:

LAKHANDEI RIVER BASIN

SUPPORTING REPORT
A3. FLOOD MITIGATION PLAN: LAKHANDEI RIVER BASIN

TABLE OF CONTENTS

(page)

PART-I: MASTER PLAN STUDY

1. EXISTING CONDITIONS A-1.1

1.1 Topography and Geology A-1.1
1.2 Meteorology and Hydrology A-1.4
1.2.1 Meteo-Hydrological Observation A-1.4
1.2.2 Meteo-Hydrological Features of Basin A-1.5
1.3 Environment A-1.6
1.3.1 Environmental Organizations and Institutions A-1.6
1.3.2 Environmental Overview A-1.6
1.4 Socio Economy A-1.7
1.5 River and Basin Conditions A-1.10
1.5.1 Principal Basin Features A-1.10
1.5.2 Characteristics of River Channel A-1.11
1.5.3 River Course Shifting A-1.11
1.5.4 Riverbed Materials A-1.12
1.5.5 Land Use A-1.13
1.5.6 Existing Basin Development Projects and Plans A-1.13
1.6 Vegetation and Sediment Yield in Watershed Area A-1.15
1.7 Past Flood and Sediment Disasters A-1.17
1.8 Flood Mitigation Activities A-1.18
1.8.1 Existing River Facilities A-1.18
1.8.2 Policy Framework A-1.19
1.8.3 Organizations Involved in Flood Mitigation A-1.19

2. FLOOD MITIGATION MASTER PLAN A-2.1

2.1 Principles for Formulation of Master Plan A-2.1
2.2 Flood Mitigation Measures and Project Components A-2.3
2.3 Watershed Management Component A-2.4
2.4 River Control Component A-2.6
2.4.1 Design Discharge A-2.6
2.4.2 River Segments and Channel Characteristics A-2.7
2.4.3 River Boundary Line (RBL) A-2.8

2.4.4 Facility Plan A-2.9
2.5 Community Development Component A-2.13
2.5.1 Community Mobilization A-2.14
2.5.2 Local Coping Measures A-2.16
2.5.3 Community-based Sustainable Measures A-2.18
2.6 Flood Mitigation Plan A-2.22

3. ACTION PROGRAM TOWARD TARGET YEAR A-3.1
3.1 Sequence of Works A-3.1
3.2 Action Plan A-3.3

4. ECONOMIC EVALUATION FOR MASTER PLAN PROJECT A-4.1
4.1 Basin Overview A-4.1
4.2 Effects of Flood Mitigation A-4.1
4.3 Preliminary Economic Evaluation A-4.3

PART-II: FEASIBILITY STUDY

5. ADDITIONAL INVESTIGATIONS AND STUDIES A-5.1
5.1 General A-5.1
5.2 Topographic Mapping and River Survey A-5.1
5.3 Flood Flow Investigation A-5.2
5.4 Environmental Study A-5.3
5.5 Watershed of Lakhandei River A-5.4
5.6 Additional Findings on Channel Characteristics A-5.9
5.7 Runoff and Flood Flow Analyses A-5.11
5.7.1 Runoff Analysis A-5.11
5.7.2 Flood Flow Analysis A-5.12

6. PROJECT PLANNING A-6.1
6.1 Principles for Planning A-6.1
6.2 Watershed Management Component A-6.4
6.3 River Control Component A-6.8
6.3.1 General A-6.8
6.3.2 Preliminary Facility Design A-6.9
6.3.3 Studies on Alternative Schemes A-6.13
6.3.4 Construction Plan A-6.15
6.4 Community Development Component A-6.17
6.4.1 Community Mobilization A-6.18
6.4.2 Local Coping Measures A-6.20

6.4.3 Community-based Sustainable River Control Measures A-6.23
6.4.4 Location-specific Strategies A-6.26
6.4.5 Examples of Community-based Actions for Flood Mitigation A-6.33
6.5 Proposed Project Works A-6.35
6.6 Project Implementation Program and Maintenance Plan A-6.35
6.6.1 Project Implementation Plan A-6.35
6.6.2 Organization for Project Implementation A-6.39
6.7 Project Cost A-6.42
6.7.1 Basic Conditions for Cost Estimates A-6.42
6.7.2 Estimation of Project Cost A-6.44
6.7.3 Annual Disbursement Schedule and Fund Required A-6.45
6.8 Evaluation A-6.45
6.8.1 Economic Evaluation A-6.45
6.8.2 Environmental Screening A-6.46
6.8.3 Technical Evaluation A-6.52
6.8.4 Summary and Conclusion A-6.53

LIST OF TABLES

(page)

Table A1.1	List of Meteorological Stations	A-1.20
Table A1.2	Results of Riverbed Material Tests	A-1.22
Table A1.3	Summary of Questionnaires	A-1.23
Table A1.4	Loss of Life and Damage to Properties	A-1.25
Table A2.1	Candidate Species for Bioengineering Works in Terai	A-2.24
Table A2.2	Income Generation Opportunities through Bioengineering	A-2.25
Table A2.3	Project Cost for Master Plan	A-2.26
Table A2.4	Annual Disbursement Schedule for Master Plan	A-2.27
Table A4.1	Cost Benefit Flow for Master Plan	A-4.4
Table A5.1	Preliminary Environmental Study	A-5.15
Table A5.2	Principal Channel Characteristics of Lakhandei River	A-5.17
Table A5.3	Basin Area and Runoff Hydrographs: Lakhandei River	A-5.18
Table A5.4	Result of Flood Flow Analysis (Lakhandei River)	A-5.19
Table A6.1	Profile of DOI's National-Level River Training Projects	A-6.55
Table A6.2	Route of Lakhandei between Laksmipur and Belhi Villages	A-6.56
Table A6.3	Costs Estimated for Alternative Schemes	A-6.57
Table A6.4	National Holidays	A-6.58
Table A6.5	Monthly Rainy Day in Lakandei River	A-6.59
Table A6.6	Monthly Workable Day for Concrete Works	A-6.60
Table A6.7	Monthly Workable Day for Earthworks	A-6.61
Table A6.8	Community Development Component	A-6.62
Table A6.9	List of Local Organizations in Flood-Affected VDCs along Lakhandei River	A-6.63
Table A6.10	Results of Community Interviews on Causes of Floods & Proposed Measures	A-6.64
Table A6.11	Availability of Skilled Labourers	A-6.66
Table A6.12	Possible Catch Crops at Flood Affected Area (Lakhandei R.)	A-6.67
Table A6.13	Existing Facilities and Offices along Lakhandei River	A-6.68
Table A6.14	Trees/Shrubs/Grass along Lakhandei River	A-6.69
Table A6.15	Trees/Shrubs/Grass Availabi /Needs in Various Localities (Lakhandei)	A-6.70
Table A6.16	Overall Framework of Community Development	A-6.71
Table A6.17	Labor Wage & Construction Equipment Cost	A-6.72
Table A6.18	Material Price and Work Cost for Feasibility Study	A-6.73
Table A6.19	Summary of Project Cost for Lakhandei River (Feasibility Study)	A-6.74
Table A6.20	Summary of Project Cost for Erosion Control Test Works	A-6.75
Table A6.21	Annual Disbursement Schedule of Lakhandei River Project	A-6.76
Table A6.22	Cost-Benefit Flow	A-6.77

Table A6.23 Social Environment Assessment.....A-6.79
Table A6.24 Natural Environment Assessment.....A-6.80
Table A6.25 Pollution Assessment.....A-6.81

LIST OF FIGURES

(page)

Fig. A1.1 Topographical and Geological Classification (N-S Profile)....A-1.26
Fig. A1.2 Overall Longitudinal Profiles of Rivers Originated in Siwalik Hills....A-1.27
Fig. A1.3 Geological Map....A-1.28
Fig. A1.4 Location of Meteorological Stations....A-1.29
Fig. A1.5 Meteorological Conditions....A-1.30
Fig. A1.6 Annual Rainfall Distribution of Nepal....A-1.31
Fig. A1.7 Lakhandei River Basin....A-1.32
Fig. A1.8 Characteristics of Existing Channel....A-1.33
Fig. A1.9 Change of Lakhandei River Course....A-1.34
Fig. A1.10 Sampling Sites of Riverbed Materials....A-1.35
Fig. A1.11 Grading Curves of Riverbed Materials....A-1.36
Fig. A1.12 Existing Land Use of Lakhandei River Basin....A-1.37
Fig. A1.13 Bagmati Irrigation Project....A-1.38
Fig. A1.14 Drainage System of Lakhandei Watershed....A-1.39
Fig. A1.15 Locations of Steep Slope in Lakhandei Watershed....A-1.40
Fig. A1.16 Flood Suffering Area....A-1.41
Fig. A1.17 Locations of River Facilities....A-1.42
Fig. A1.18 Typical River Facilities....A-1.43
Fig. A2.1 Flood Mitigation Measures....A-2.28
Fig. A2.2 Classification of Types of River Bank....A-2.29
Fig. A2.3 Dike Works....A-2.30
Fig. A2.4 Relationship between Bed Material Size and Friction Velocity....A-2.31
Fig. A2.5 Comprehensive Flood Mitigation....A-2.32
Fig. A2.6 Community Mobilization....A-2.33
Fig. A2.7 Local Coping Measures....A-2.34
Fig. A2.8 Community-Based Sustainable Measures....A-2.35
Fig. A2.9 Layout Plan for Flood Mitigation....A-2.36
Fig. A3.1 Action Program Toward Target Year....A-3.5
Fig. A5.1 Hazard Map Lakhandei River 1997 Flood....A-5.21
Fig. A5.2 Geological Map of Lakhandei River....A-5.27
Fig. A5.3 Schematic Geologic Profile of Lakhandei Watershed....A-5.28
Fig. A5.4 River Terraces in Siwalik Hill along the Main Lakhandei River, Sarlahi District....A-5.29
Fig. A5.5 Topography of Lakhandei Watershed....A-5.30
Fig. A5.6 Relief and Slope of Lakhandei Watershed....A-5.31
Fig. A5.7 River Course near Belhi Village after 1998-Flood....A-5.32

Fig. A5.8 River Course near Sakaraul Village after 1998-Flood A-5.33
Fig. A5.9 Longitudinal Profile of Lakhandei River A-5.34
Fig. A5.10 Principal Channel Characteristics of Lakhandei River A-5.35
Fig. A5.11 Result of Flood Flow Analysis (Lakhandei River) A-5.36
Fig. A6.1 Erosion Control Measures in Watershed Area A-6.82
Fig. A6.2 Typical Design of Pile Spur (Type-Pa) A-6.85
Fig. A6.3 Typical Design of Gabion Spur A-6.86
Fig. A6.4 Typical Section of Revetment A-6.87
Fig. A6.5 Forest/Grass Belt and River Boundary Line A-6.88
Fig. A6.6 Typical Earth Dike Sections A-6.92
Fig. A6.7 Typical Design of Sluice A-6.93
Fig. A6.8 Route of Lakhandei River between Laksmipur and Belhi Villages A-6.94
Fig. A6.9 Construction Schedule for Lakhandei River in Feasibility Study A-6.95
Fig. A6.10 Flood-Affected VDCs: Lakhandei River A-6.96
Fig. A6.11 General Location Map: Lakhandei River A-6.97
Fig. A6.12 Layout Plan for Flood Mitigation: Lakhandei River A-6.98
Fig. A6.13 Community Development Component: Lakhandei River A-6.104
Fig. A6.14 Implementation Schedule: Lakhandei River A-6.107
Fig. A6.15 Implementation Agencies and Organizations A-6.108
Fig. A6.16 Implementation Arrangement for Flood Mitigation in Terai A-6.109

PART-I: MASTER PLAN STUDY

1. EXISTING CONDITIONS

1.1 Topography and Geology

The topography and geology of Nepal can be divided into the following zones (Fig. A1.1):

1) Inner Himalayan valleys
2) Higher Himalayan zone
3) Lesser Himalayan zone
   - Midland range
   - Mahabharat range
4) Siwalik (Churia) hills
5) Dun valleys
6) Terai plain

The Lakhandei river basin falls under the topographical and geological zones of Siwalik hills and Terai plain. Principal features of these zones are presented below.

(1) Siwalik (Churia) Hills

The Siwalik (Churia) hills are the lowest hills bordering the Indo-Gangetic plain in the north. Mostly it consists of rocks of alternating beds of clay, sandstone, sand and pebble. The rocks generally dip northwards. Alternately loose and hard rock beds have produced the escarpment feature. In many places rugged land with numerous gullies and mound of talus are found. The topographic slope varies from 200 to 400 m/km on the average. The Siwalik hills are divided into three layers, i.e., upper, middle and lower Siwaliks.

Upper Siwalik

The upper Siwalik is mainly conglomerate with pebbles and boulders of pale schistose quartzite, purple and white quartzite; dark phyllites; purple and dark pebbly quartzite and silt brown sandstone. The depth of upper Siwalik is about 2000 to 3000 meters.

Middle Siwalik

The layer of middle Siwalik is found in the form of thick deposits of sandstone. These

are characterized by their feldspar and mica content. Apparently the sandstone has been derived from granite rocks. Calcareous concretions and seams of coal are found in the basal part. In many sections, the sandstone forms vertical cliffs. The depth of middle Siwalik is about 2000 to 2500 meters.

Lower Siwalik

The lower Siwalik is alteration of brown, weathered sandstone and chocolate colored clays. The alternation of beds is not thick as the sandstone. Beds of impure limestone also occur within the lower Siwalik. The depth of lower Siwalik is about 1200 to 1500 meters. All pebbles except those found in the brown sandstone are derived from rocks of Pre-tertiary age.

(2) Terai Plain

The Terai plain is the continuation of Indo-Gangetic plain having an elevation from 50 to 300 m,MSL. Its width varies between 10 to 30 km with one exception at Koilabash narrow, and extends from east to west Nepal for about 900 km.

The Terai slopes toward south with steeper slope at the foot hill region and nearly flat at the southern end.

In the Terai plain the changes of river stream are often seen in places by the lateral erosion incorporated by much sediment from the mountainous area. On such rivers, artificial structure works such as bridge, roads and irrigation facilities have to be given careful consideration.

The Terai plain is divided into three zones, i.e., (1) Bhabhar zone (foot of hill), (2) Marshy area (spring line), and (3) Southern Terai (Indian border).

Bhabhar Zone

The Bhabhar zone lies at the foot of Siwalik hills and is about 12 km wide (Charkose Jhadi). It is composed of boulder, pebble, cobble and sand of Siwalik hills or Mahabharat range deposited by the present rivers. In most cases the rocks are sandstone, quartz or charty dolomite. The foot of hills is covered with evergreen forest.

Soils are mainly alluvium consisting of sand, silt, clay looms and silty clay. In the dry

season almost all rivers in this zone have no flow on the surface and water flow underground only.

Marshy Area

The marshy area is found in the south of Bhabhar zone where two lithological units having different porosity and permeability meet or inter finger along with the change of elevation mainly resulting in spring lines, ponds, lakes, etc. The lithology is mostly composed of pebbles and sandy bed with a few clay partings. The lithology of the pebbles is similar to the boulder zone and sand beds are loose, brownish to greenish with black and red shale fragments. The clay is mostly blackish gray where a thick sequence is found, but yellow one is also observed at some places where there was a temporary hiatus in its deposition or because of a flood at that time. This is particularly true in Lumbini zone.

Southern Terai

This nearly flat and not well-drained area is found between middle Terai and the Indo-Nepal border. The area is composed of sand, clay and silt with less pebble.

(3) Lakhandei River Basin

The Lakhandei river basin is located in the eastern part of Nepal. The river originates in the eastern Siwalik hills. These hills are composed of loose stratums, especially clastic sediments such as sand, gravel and clay. During the monsoon period, heavy rainfall drops on the soft rocks or clay, sand and loose pebble layers, causing serious erosion and landslide.

During rainy season, the Siwalik hills yield much sediment and discharge them to the Terai plain. Rainfall in the eastern part of Nepal is heavier than the western part. Large flood carries and deposits these sediment in the hill valleys or Bhabhar zone in the Terai plain. Marshy areas of the Terai are composed of sand and clay, and southern zones of the Terai are of fine sand, silt and clay. In the marsh and southern zones, the river sometime shifts to new route.

Overall longitudinal profile of the Lakhandei river is shown in Fig. A1.2 in comparison with those of other rivers originating in the Siwalik hills. Geological map of the Lakhandei river area is shown in Fig. A1.3.

1.2 Meteorology and Hydrology

1.2.1 Meteo-Hydrological Observation

Responsibilities for meteo-hydrological data collection and analysis in Nepal have been born mainly by the Department of Hydrology and Meteorology (DHM), the Ministry of Science and Technology. Other authorities such as the Department of Irrigation (DOI), Nepal Electricity Authority (NEA), and International Center for Integrated Mountain Development (ICIMOD) also conduct meteo-hydrological observations. In principle, all of these data observed by other authorities are also sent to the DHM. The DHM publishes data in yearbooks after basic checking has been completed.

The Meteorology Section of DHM is responsible for compilation and analysis of meteorological observation records such as precipitation, temperature, humidity, vapor pressure, sunshine, wind, evaporation and soil temperature. And the Hydrology Section of DHM is responsible for compilation and analysis of hydrological observation records such as water level and sediment.

Based on the DHM's data, a list of meteorological stations in the Central Development Region is shown in Tables A1.1 and their locations in Fig. A1.4. No hydrometric station exists in the Lakhandei river system. In order to supplement the existing observatory, the Study Team installed new gauges at the following sites:

1) Recording rain gauge: At Bagmati Irrigation Project Office (1 site) for the Lakhandei river basin: This office is under the direct control of DOI. An ordinary rain gauge (sta. code: 1121 under DHM) is installed here.

River basin	Caretaker	Serial Number
Lakhandei	Bagmati Irrigation Project Office (Karmaiya, Sarlahi)	Gauge: 232734 Recorder: 244190

2) Water level gauges (staff gauge): Hulaki road near Malangawa for the Lakhandei river (2 sites).

River	Caretaker	Remarks
Lakhandei	Sarlahi District Irrigation Office (Malangawa)	Left bank bridge abutment: 4 m Left bank bridge pier: 3 m

1.2.2 Meteo-Hydrological Features of Basin

Climate of the Lakhandei river basin falls under monsoon subtropical zone, and the dry season (from October to May) and rainy season (from June to September) are clear. The dry and rainy seasons due to monsoon are the major cause of climatic contrasts in the Lakhandei river basin. Figure A1.5 shows the meteo-hydrological features of the basin based on the monthly average data at Manusmara (sta. code: 1118).

(1) Temperature

Altitude affects much the temperature. The annual average temperature is 25.0℃, ranging from 8.9℃ in the coldest month to 30.8℃ in the hottest month. The coldest month is in January and the hottest falls in between June and July. The temperature rises from March to June-July while it decreases from October to January.

(2) Relative Humidity

According to Fig. A1.5, annual average relative humidity is 83.8%, ranging from 67.4% in April to 90.5 % in January.

(3) Rainfall

The study area receives the southeast monsoon during the months from June to September. The monsoon air-stream is forced to rise as it meets the Himalayas and causes heavy rainfall on the south facing slopes (Fig. A1.6).

According to Fig. A1.5, annual rainfall at Manusmara is 1,369mm on average ranging from 1,005 to 2,486mm depending on the year. The maximum rainfall is 2,486mm in 1987. The 81% of annual rainfall is concentrated in rainy season from June to September.

(4) Runoff

Although the hydrometric records such as water level and discharge are not available for the class-III river basins originating at the Siwalik hills, the following runoff characteristics are presumed from the rainfall and geological features of the basin:

1) Runoff concentrates in monsoon season and that in driest months is very low because of small basin size and porous geological condition.

2) Flood hydrograph would be very sharp with high peak discharge and short runoff duration less than 1 day.
3) The flood runoff is accompanied with heavy sediment from the Siwalik hills.

1.3 Environment

1.3.1 Environmental Organizations and Institutions

The Environmental Division of the Ministry of Population and Environment has overall responsibility for environmental matters in Nepal. In June of 1997, Environmental Conservation Rules were issued under section 24 of the 1997 Environmental Conservation Act. These rules lay down procedure to be followed when new projects are proposed or existing projects extended.

1.3.2 Environmental Overview

The Lakhandei river is a class-III river rising in the Siwalik hills with a length of about 68 km. and a basin area of some 300 km^2 (30,000 hectares). The distance from the base of Siwalik hills to the Indian border is about 30 km, but it meanders considerably and its length is 52 km. controlling an area of 194 km^2 (19,400 ha). During the monsoons, riverbank erosion occurs. Additionally, many areas are inundated with coarse sand and/or floodwater. Three tributaries join the Lakhandei when it meets the plain. These are the Chanan, Atrauli and Baune rivers. About 35 tributaries feed these rivers. The existing land use and population of this Terai basin is shown below.

(Land Area, Land Use and Population: 1998)

Items	Agri-culture	Forest	Barren/ Sand	Other	Total	Population
Area (ha)	16,660	1,410	850	480	19,400	(101,600)*
Ratio (%)	85.9	7.2	4.4	2.5	100	(5.2)**

(Note)*: Population (persons), **: Population density (per/ha)

There is very little natural vegetation remaining along the Lakhandei river, but some natural sal (*Shorea robusta*) forests occur along the boundary between the hills and the plain. However, over 80% of the Lakhandei basin area in the Terai is now farmed with less than 10% of the area under trees. The population density is high and as population increases, there is a movement away from this area towards the less densely populated areas in the west and also into the Siwalik hills.

According to the Inventory of Wetlands in the Terai, (IUCN 1996), there are no registered wetlands in the vicinity of the Lakhandei river, but of course, the river itself is a wetland. Thus, from an environmental viewpoint, protecting the river is important, but with such a high population density, the protection of the farmland and property is critical. Every year, sand, silt and/or floodwater covers on average over 2,900 hectares of which more than 700 ha are covered with sand and soil. Some of this inundation is a result of human activity, especially in the Siwalik hills. In addition, an estimated 4% of the land is barren or covered with sand, principally due to flooding and inundation.

This is why flood mitigation measures, including watershed activities are essential to protect the environment. With appropriate flood mitigation measures, some land could be reclaimed and soil/sand inundation reduced. Also, farmers knowing their land are safe from flooding and inundation could invest in irrigation and increase their productivity. This may relieve the pressure on the remaining wetlands, curtail deforestation and boost grain production.

1.4 Socio Economy

(1) Economic Activities

Land Use: The Lakhandei river flows in Sarlahi district. According to the district data, agricultural and forestland makes up 94.5% of the total plain area.

unit: hectare

District	Agriculture	Forest	Sand/Gravel /Boulder	Others	Total
SARLAHI	84,944 78.1%	17,866 16.4%	5,586 5.1%	372 0.3%	108,768 90%
10 Districts (where M/P rivers flow)	800,591 64.1%	352,508 28.2%	43095 3.5%	52,449 4.2%	1,248,643 90%

Source: Land Resources Mapping Project 1986, Department of Survey
Forest Survey 1993, Department of Forest

Economically Active Population (10 Years of Age and Over) by Major Occupation: A ratio of 78.3% of the labor force is engaged in agriculture, as opposed to 3.5% in manufacturing and 12.3% in service sectors.

District	Agriculture Worker	Service Worker	Production Worker	Sales Worker and Others
SARLAHI	120,059 78.3%	18,829 12.3%	5,381 3.5%	9086 5.9%
10 Districts (where M/P rivers flow)	1,123,328 73.9%	215,393 14.2%	73,937 4.9%	107522 7%

Source: Population Census 1991, Central Bureau of Statistics

Crop Area and Productively of Agriculture Crop: Sarlahi district produces a wide range of crops, with major crops of paddy, wheat, pulses, sugarcane, and maize. These major crops but wheat are grown during the monsoon. Although there are also winter paddy and maize, most of the paddy and maize are grown in summer.

unit: hectare. (metric ton/ha.)

District	Paddy	Maize	Wheat	Pulses	Oilseeds	Sugarcane	Vegetables
SARLAHI	27,151 (2.35)	9,350 (1.65)	27,000 (1.4)	26,820 (0.60)	5,620 (1.54)	5,500 (33.56)	4,125 (7.09)
10 Districts (where M/P rivers flow)	537671 (27.79)	145489 (18.14)	174589 (19)	98536 (4.9)	102720 (7.92)	17331 (233.06)	11930 (52.58)

Source: Annual Agricultural Development Program 1995/96, District

(2) Land Holding

Land Ownership & Holding: In Sarlahi district, the average land holding size has not declined in recent years unlike other districts in the Terai plain. The average size is far below the 16.4 hectare ceiling imposed by the 1964 Lands Act. More than 90 % of the agricultural land is under owner-cultivation. With regard to the agricultural land under "formal" tenancy, the most dominant form is sharecropping.

District	Owner-Cultivated (%)		Average Holding Size (ha.)	
	1981/82	1991/92	1981/82	1991/92
SARLAHI	86.8	90.6	1.06	1.14
Terai	91.8	87.6	1.47	1.22

Tenure Arrangements: However, that since informal arrangements of land tenancy are not recorded in the official census, the above figure of owner-cultivation should be treated with caution. Underlying the sharecropping category is a commonly known phenomenon of "dual ownership". To undertake flood mitigation works for land under "dual ownership", it will be imperative to involve both land owners and tenants, both of whom are entitled to certain shares of the proceeds of the land.

District	Tenure Arrangement – 1991/92 (%)		
	Fixed Rent	Share Crop	Others
SARLAHI	29.4	52.1	18.5
Terai	30.6	62.7	6.7

Source: Nepal Sample Census of Agriculture 1991/92, Department of Agriculture

(3) Population

From nation-wide viewpoint, in-migration in the east is approaching to zero, as new lands available for cultivation are being closed. On the other hand, the western districts continue to exhibit high population growth, since the land frontiers are relatively open. In a similar vein, the original inhabitants of the Terai constitute nearly or more than half the population towards the west, while the proportion of indigenous groups makes up less than half in most of the eastern districts.

Population of Sarlahi district is 493,000 as of 1991 with population growth rate of 2.1% (1981-1991). The population growth ratio was markedly high during 1970s and, since then, it has gradually been declining.

Demographic Records of Flood-Prone VDCs: The following table shows the population trends of the VDCs affected by Lakhandei floods. The 1981-91 population growth rate of the affected VDCs is 5.7%. This indicates that the population pressure is higher in the flood-risk VDCs, than other localities in Sarlahi district.

District	VDC	1971	1981	1991	1996
Sarlahi	Haripur	3,366	5,918	7,822	8,687
	Pidari	1,623	-	2,978	3,307
	Pipariya	3,141	6,513	4,560	5,064
	Shripur	-	-	2,927	3,251
	Netragunj	2,342	-	6,149	6,829
	Patharkot	2,600	6,361	4,714	5,235
	Bhadsar	2,177	-	2957	3,284
	Sakraul	2,253	-	2,778	3,085
	Sundarpur	4,260	4,414	4,583	5,090
	Belhi	2,043	-	3,693	4,101
	Janki Nagar	-	-	4,897	5,439
	Laksmipur	3,002	5,190	5,384	5,979
	Ghurkauli	-	6,095	7,542	8,376
	Simara	3,847	5,181	5,995	6,658
	Padariya	3,189	-	-	-
	Phul Parasi	1,739	-	2,357	2,618
Total		35,582	39,672	69,336	77,003

Source: Population Census 1991, Central Bureau of Statistics
Nepal District Profile 1997, National search Associates

(4) Human Development Index (HDI)

In terms of the Human Development Index (which is a development indicator based on life expectancy, adult literacy, and GDP), the districts in eastern areas of the country receive, in general, higher performance, and become lower toward the west. However, the HDI of Sarlahi district (located towards the east of the Central Development Region) is low (35th among all 75 districts) comparing with other M/P districts in the east (such as Morang and Jhapa).

1.5 River and Basin Conditions

1.5.1 Principal Basin Features

The Lakhandei river basin extends from 26°48′N to 27°12′N and from 85°30′E to 85°46′E. The Lakhandei river originates in Siwalik hills and is classified as a class III river. Administratively it is located in Sarlahi district of Central Development Region.

Basin area of the Lakhandei river is 300 km^2 in total, consisting of 106 km^2 of mountainous area and 194 km^2 of plain area. Boundaries of the river basin and sub-basins were drawn on the basin map. Basin boundary in the Terai plain was delineated in consideration of existing drainage channels, irrigation canals, road networks and other ground objects. General basin maps of the Lakhandei river is shown in Fig. A1.7. The basin map was prepared based on the topographic maps of scale 1/25,000.

Significant features of the Lakhandei river basin are as follows:

1) River channel is wide and braided in the upper reaches and becomes narrow gradually toward lower reaches.
2) Major tributaries are the Baune and Chapani rivers.
3) Middle and lower portions of the flood prone areas are service areas of the Bagmati Irrigation Project.

1.5.2 Characteristics of River Channel

Channel slope and width of the existing river are shown in Fig. A1.8 for the plain reaches. These were prepared based on the topographic map of scale 1/25,000, since river survey results were not available. In order to obtain the river profile, spot elevation data on the topographic map were used and the river width was measured on

the map at the intervals of 1 km along the river. The river width includes perennial river sections and sandbars of the meandering and braided river section.

According to the figure, principal features of the existing river in the Terai plain are summarized below.

River	Class	Length (km)	Slope	Width(m)
Lakhandei R.	III	51.4(40.9)	1/240~1240	50~900

Note: River length in ( ) indicates that downstream from E-W highway

1.5.3 River Course Shifting

It is generally said that rivers in the Terai plain have tendency to shift westwards. If it is true the existing talweg might take closer to west or right side bank as a whole. To confirm this hypothesis, the location of talweg in the river section was measured at every 1 km and shown in the Fig. A1.8. The clear tendency of westward shifting was not seen.

In order to look into the actual shifting of river course in the past, topographic maps prepared in 1953/54 (scale: 1/50,000) and those in 1992 (scale: 1/25,000) were superimposed and shown in Fig. A1.9.

According to the figure showing river course change during the past 38 years, meander of the both river channels is not severe, and the shifting of river course seems to remain within the meandering belt.

1.5.4 Riverbed Materials

The Study Team investigated riverbed materials along the plain reaches of the river. The investigation includes the following outdoor and indoor works:

1) Sampling of river bed materials at site
2) Grain size analysis at site field and in laboratory
3) Specific gravity test in laboratory

Bed materials of the Lakhandei river were sampled at 13 sites (Fig. A1.10) among which outdoor analyses were carried out at 8 sites.

Results of riverbed material tests are shown in Table A1.2 and the grading curves in Fig. A1.11.

Principal features of the riverbed materials are summarized below. In the descriptions below, UI denotes uniformity index defined as a ratio of d_{84} to d_{16}, SG stands for specific gravity, and classification of grain size is principally based on classification by AGU.

1) Samples: All samples are from the main course of the Lakhandei river except for La-11 from Chapani river.
2) Grain size: Sand for downstream reaches from La-10 and very coarse sand and gravel for the upstream reaches.
   - d_{60} = 0.17 to 0.37 (fine to medium sand): downstream from La-10 site and La-11 site
   - d_{60} = 1.63 to 7.01 (very coarse sand to fine gravel): Upstream from La-12 site
3) Uniformity index: Riverbed materials are well sorted and uniform in the downstream reaches from La-7 site:
   - UI = 2.2 to 3.6: downstream from La-7
   - UI = 5.1 to 6.2: downstream from La-10 except La-9
   - UI = 15 to 78: upstream from La-10 and La-11
4) Specific gravity:
   - SG = 2.64 g/cc on average ranging from 2.60 to 2.698 g/cc
5) Longitudinal distribution: Significant change in grain size is seen at two sections between (1) La-4 and La-5 sites, and La-10 and La-12 sites

Based on the investigation result, grain size distribution along the river is shown in the Fig. A1.8.

1.5.5 Land Use

Land utilization map and land capability map (scale: 1/50,000) are available. These maps have been prepared by Topographic Survey Section of Survey Department under the Canadian assistance program.

Mapping details are based on aerial photos taken in 1978 and 1979 and extensive field truthing and sampling during the year 1980 and 1981. The maps were published in 1982.

Existing land use of the plain area is shown in Fig. A1.12 based on the land utilization map. These maps were prepared rearranging the classifications into five categories, i.e., (1) rice field, (2) diversified cropland, (3) grazing land, (4) forest, and (5) settlement.

Land capability map is also available, which shows the land capability for agricultural development mainly based on the land system such as topography, land slope, soil and drainage conditions. Future land use would be prospected from the land capability.

1.5.6 Existing Basin Development Projects and Plans

Bagmati Irrigation Project

Project Area: Bagmati Irrigation Project is a run-of-the river irrigation scheme drawing water from the barrage situated in Karmaiya, Sarlahi. The barrage is situated about 500 m upstream of the east-west highway bridge crossing Bagmati river. The project area and lies administratively in the two Terai districts namely Sarlahi and Rautahat in the Central Development Region.

The Bagmati river, which is the source of water for the project, has the watershed area of 2,720 km^2 at the diversion site. The average annual rainfall in the river basin is about 2313 mm. The 100-year flood of the river at the diversion site is estimated to be 10,700 cumecs.

Historical Background: The project was first formulated as a priority project in the Sunkoshi Terai Project for which the master plan study was carried out by UNDP/FAO from 1967 to 1972. The project was later reformulated in 1979/80 under a technical assistance financed by the German Agency for the Technical Cooperation (GTZ).

Nippon Koei Co. Ltd., Japan carried out a detailed feasibility study on the command area development in 1992. This study identified the possible command area of the project to be 37,000 ha utilizing the natural flow available at the barrage site and the existing main canal systems.

The construction works of the project was initiated in 1979 utilizing HMG/N's own resources. At later stages, some amount of grants/loans has been received from UNDP, Saudi Fund foe Development (SFD) and Debt Relief Fund.

Efforts have been concentrated at present to make use of the available natural flow in the shortest possible time to provide irrigation to 37,000 ha. The project has suffered from substantial delays in works due to the unprecedented flood of July 1993.

Project Description (Fig. A1.13)

1) Bagmati Barrage: A diversion barrage of 403.5 m length having a discharge capacity of 8,000 cumecs has been constructed across the Bagmati river. A Control building has been constructed on the eastern bank to regulate the electric power supply and to remotely control the gates.
2) East Canal System: The East Canal System (ECS) offtaking from the East Head Regulator is 21.5 km long. At present, it has a discharging capacity of 15.0 cumecs and thus can command a total of 14,000 ha in the Sarlahi District.
3) West Canal System: The West Canal System (WCS) offtakes from the West Head Regulator and is 28 km long. At present, it has a discharging capacity of 48.2 cumecs. It has a command area of 23,000 ha in the Rauthahat district.

Works Completed: The headwork together with installation of the gates and flood rehabilitation works has been completed. Similarly, the ECS and WCS main canal systems, 4 branch canals and 8 distributaries have also been completed.

Rehabilitation of Bagmati Barrage and Irrigation System: The July 1993 flood had damaged the barrage gates, control building, flood protection works and some parts of east and west main canals. This work was initiated with the previous Loan No 3/258 and was completed in July 1996. The final payment for the rehabilitation of the barrage is yet to be made which would be done only after the expiration of the maintenance period.
(Source: Status Report, Bagmati Irrigation Project, Sep. 1997)

1.6 Vegetation and Sediment Yield in Watershed Area

(1) Climate and Vegetation Division

Watershed of the Lakhandei river is classified as the Terai and Outer Himalaya division from the climate and vegetation viewpoint.

The Terai plain is composed of an alluvial fan and an alluvial plain of elevation ranging from 50 m to 300 m,MSL extending from the foot of Siwalik hills to the Indian border. The climate of this area belongs to the monsoon subtropical zone, and the dry season is

from October to May with the rainy season from June to September. The Terai plain was covered widely by Sal forests (*Shorea robusta*). But, recently farmers from Middle Mountains cleared the forests rapidly for agricultural land and villages.

The Siwalik hills were formed by upheaval of sediment bed carried from Himalaya. Forests are left in the Siwalik hills, because of too steep inclination for settlement and farming. But, clearing forest takes place recently even in the Siwalik hills.

(2) Land Use in Watershed Area

The land use of the watershed area of the Lakhandei river are worked out using the aerial photos taken in 1992 and topographic maps of 1/25,000 as follows:

(Land Use of Watersheds)

Land use	Area (ha)	Ratio (%)
Forest	7,855	73.4
Bush	75	0.7
Cultivation	2,236	20.9
Cliff	22	0.2
River	508	4.7
Urban	0	0
Total	10,696	100.0

(Remarks) 1) Bush: Scrub, Bush, Grass & Bamboo

2) Cliff: Soil cliff, Rock cliff & Out crop of rock

Watershed of the Lakhandei river is located in the west of eastern Siwalik hills. Three main tributaries flow through the Siwalik hills.

The 73.4% of the watershed area is covered with forest. The main watersheds are covered with Dun Sal forest. Branches in the lower part of the watershed are located on the steep slope of the Siwalik hills facing to the south. Vegetation on the south slope of the hills is Hill Sal forest. Cultivated land is about 20%, located widely along the three main tributaries. Bush land shares only 0.7%. About 0.2% of cliffs scatter over the main watersheds. Some sites of small-scale landslides are found in the branch watershed of the Siwalik hills facing to the south.

(3) Erosive Landform of Watershed Area

The drainage system and slope of watershed of the Lakhandei river are shown in Figs.

A1.14 and A1.15. The drainage system and slope maps allow the interpretation of erosive landform characteristics of the watershed area.

The drainage density is lower in the Lakhandei river watersheds as a whole, especially the density of steep slope more than 40° is lower. The drainage density is the highest in the northern area and it gradually decreases toward the south. The cultivated lands are distributed on the slopes in a zonal pattern along the stream.

(4) Estimation of Sediment Yield

The sediment yield of the Lakhandei river is estimated by the soil erosion rate depending on the land use. The soil erosion rate was assumed mainly referring to the data of soil erosion rates of the Ratu river.

(Estimation of Sediment Yield: Lakhandei River)

Land use	Area (ha)	Erosion rate(mm/yr)	Yield(m^3/yr)
Forest	7,855	2	157,000
Bush	75	10	8,000
Cultivation	2,236	0.4	9,000
Cliff	22	20	4,000
River	508	0	0
Urban	0	0	0
Total/average	10,696	1.66	178,000

According to an investigation for the soil erosion rate, sediment yield in the disaster of 1993 has been estimated at about seven (7) times of that in an ordinary year. From this, it is anticipated that the sediment yield in disastrous year may amount to some ten times of the above value estimated for the ordinary year.

1.7 Past Flood and Sediment Disasters

The Study Team investigated conditions of past flood and sediment disasters in January 1998. On the basis of the information obtained from the District Irrigation offices and District Development Committee offices, a total of 13 VDC/Municipality offices were selected for the investigation. Furthermore, a total of 192 residents in the flood prone areas were selected for the interview using questionnaire form.

Questionnaires to the residents are summarized in Table A1.3. The Lakhandei river floods over the riverbanks almost every year. In recent 10 years, the biggest flood took

place in 1997, and floods in 1993 and 1995 follow it. The flood and sediment disasters are caused not only by the runoff from its own basin, but by the floodwater from the Bagmati river as well.

The 1997-August flood inundated the land to a depth of 1.5 m for 3 to 7 days. This caused extensive damage due to sedimentation and inundation to the farmland. The 1997-flood also brought about epidemic diseases such as malaria, dysentery and typhoid resulting in loss of 91 human lives in the whole Sarlahi district.

Sedimentation, bank erosion and flooding over the farmland are the major types of disasters. According to the data and information obtained from DDC and DIO of Sarlahi district, areas suffering bank erosion and flooding are summarized as shown below:

(Areas Suffering from Bank Erosion and Flooding)

VDC	Village/Ward
Janaki Nagar	Nakaha Tol, Khaira Tol, Mushari, Gangapur,
Ghurkauli	Chheda Tol, Koira Tol, Chhyana
Haripur	Jagatpur, Sakhuwa Mouja, Pulchouk, Hattisal, Haripur
Pidari	Pidari (No.1 - No.9)
Pipariya	Pipariya (No.1 - No.9)
Shreepur	Shreepur (No.1 - No.9)
Padariya	Padariya (No.1 - No.5), Shiv (No.6, 7, 8 and No.9)
Belhi	Belhi (No.1 – No.9)
Sundarpur	Sundarpur (No.1 - No.9)
Laxmipur	Sukhchaina (No.5, 6, 7,8 and No.9)
Phool Parasi	Phool Parasi, Inarwa (No.1 - No.9)
Simara	Simara (No.1 - No.5), Fendhara (No.6, No.7), Pakari (No.8)
Bhadsar	Bhadsar, Mallah (No.1 - No.9)

Loss of life and damage to properties are shown in Table A1.4, based on data during 1997-flood. According to the field investigation and interviews of residents, flood-suffering areas during the 1997-flood are shown in Fig. A1.16.

1.8 Flood Mitigation Activities

1.8.1 Existing River Facilities

According to the result of investigation conducted by the Study Team in January 1998, major river facilities of the Lakhandei river are as follows:

1) Embankment: 2 sites
2) Spur : 48 sites
3) Revetment : none
4) Head work : none
5) Bridge : 2 sites

Location of these facilities is shown in Fig. A1.17. As seen in the above, spur (groin) works share by far the majority of the facilities followed by revetment works. Almost all the spur and revetment works are made of gabion by boulder and galvanized iron (G.I.) wire net.

The existing facilities are located sporadically along the river course. Some of these spur and revetment works are damaged already probably due to inappropriate foot protection. In some sites single spur was seen, though the spur works can function effectively, in general, when they are installed as a series. The types of existing spur or bank protection works are monotonous. Variety of works should be introduced taking account the river condition and availability of materials. Photos of typical river facilities are shown in Fig. A1.18.

1.8.2 Policy Framework

There are various laws and policies governing and orientating the flood mitigation activities. The followings are the major ones, among others:

1) Approach to the Ninth Plan (1997-2002)
2) National Action Plan on Disaster Management
3) Draft Flood Mitigation Policy
4) Watershed Development Policy

1.8.3 Organizations Involved in Flood Mitigation

The Department of Irrigation (DOI) is responsible for flood mitigation in the downstream areas. At the same time, there are other agencies that can make significant contributions to the implementation of flood mitigation project, both within and outside the central Government.

The Water-induced Disaster Prevention Technical Center (DPTC) has developed

technologies and methodologies which can be applied to the project.

The Department of Soil Conservation and Watershed Management (DOSCWM), with an increasing number of branch offices in the Terai plain, also contributes to the project implementation through soil conservation which is also a crucial factor in promoting flood mitigation in the target areas.

As indicated by the experience of the efforts for small-scale infrastructure development by the Ministry of Local Development (MLD), 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 can participate in implementing community development components of the flood mitigation project.

Table A1.1 (1/2)

LIST OF METEOROLOGICAL STATIONS

Station No.	Station Name	Type of Station	Reg.	Latitude			Longitude			Elevation (m)	Start of Record	Remarks
				°	'	"	°	'	"			
0902	Rampur	Agrometeology	C	27	37	00	84	25	00	256	01-1967	Narayani
0903	Jhawani	Precipitation	C	27	35	00	84	32	00	270	02-1957	Narayani
0904	Chisapani Gadhi	Precipitation	C	27	33	00	85	08	00	1,706	05-1956	Narayani
0905	Daman	Climatology	C	27	36	00	85	05	00	2,314	09-1965	Narayani
0906	Hetaunda N F.I	Climatology	C	27	25	00	85	03	00	474	08-1966	Narayani
0907	Amlekhganj	Precipitation	C	27	17	00	85	00	00	396	06-1955	
0909	Simara Airport	Agrometeology	C	27	10	00	84	59	00	130	09-1965	
0910	Nijgadh	Precipitation	C	27	17	00	85	10	00	244	06-1955	
0911	Parwanipur	Agrometeology	C	27	04	00	84	58	00	115	01-1967	
0912	Ramoli Bairiya	Precipitation	C	27	01	00	85	23	00	152	01-1956	
0915	Karkhu Gaun	Precipitation	C	27	37	00	85	09	00	1,530	12-1971	
0917	Hetaunda (Ind Dis)	Precipitation	C	27	26	00	85	02	00	466	01-1974	Narayani
0918	Birgunj	Precipitation	C	27	00	00	84	52	00	91	02-1974	
0919	Makwanpur Gadhi	Precipitation	C	27	25	00	85	10	00	1,030	12-1974	Narayani
0920	Betuwa	Precipitation	C	27	30	00	84	45	00	274	12-1974	Narayani
0921	Kalaiya	Precipitation	C	27	02	00	85	00	00	140	02-1976	
0922	Gaur	Climatology	C	26	46	00	85	18	00	90	03-1983	
1001	Timure	Precipitation	C	28	17	00	85	26	00	1,900	06-1957	Narayani
1002	Aru Ghat D.Bazar	Precipitation	C	28	03	00	84	49	00	518	06-1957	Narayani
1003	Trishuli	Precipitation	C	27	55	00	85	09	00	595	12-1955	Narayani
1004	Nuwakot	Climatology	C	27	55	00	85	10	00	1,003	05-1956	
1005	Dhading	Precipitation	C	27	52	00	84	56	00	1,420	05-1956	Narayani
1006	Gumthang	Precipitation	C	27	52	00	85	52	00	2,000	07-1947	
1007	Kakani	Agrometeology	C	27	48	00	85	15	00	2,064	01-1962	Narayani
1008	Nawalpur	Precipitation	C	27	48	00	85	37	00	1,592	06-1959	
1009	Chautara	Precipitation	C	27	47	00	85	43	00	1,660	07-1947	
1011	Kathmandu (US AID)	Precipitation	C	27	42	00	85	20	00	1,335	01-1954	
1012	Sundarijal (Pwr House)	Precipitation	C	27	45	00	85	25	00	1,364	05-1940	
1013	Sundarijal (Water Res.)	Precipitation	C	27	47	00	85	26	00	1,576	05-1940	
1014	Kathmandu (I.E.)	Precipitation	C	27	44	00	85	20	00	1,324	01-1921	
1015	Thanket	Precipitation	C	27	41	00	85	12	00	1,630	09-1966	
1016	Sarmathang	Climatology	C	27	57	00	85	36	00	2,625	11-1970	
1017	Dubachaur	Precipitation	C	27	52	00	85	34	00	1,550	11-1970	
1018	Baunepati	Precipitation	C	27	47	00	85	34	00	845	11-1970	
1020	Mandan	Precipitation	C	27	42	00	85	39	00	1,365	07-1947	
1022	Godavari	Climatology	C	27	35	00	85	24	00	1,400	05-1952	
1023	Dolal Ghat	Precipitation	C	27	38	00	85	43	00	710	07-1947	
1024	Dhulikhel	Climatology	C	27	37	00	85	33	00	1,552	06-1947	
1025	Dhap	Precipitation	C	27	55	00	85	38	00	1,240	12-1976	
1027	Bahrabise	Precipitation	C	27	47	00	85	54	00	1,220	12-1965	
1028	Pachuwar Ghat	Precipitation	C	27	34	00	85	45	00	633	01-1966	
1029	Khumaltar	Agrometeology	C	27	40	00	85	20	00	1,350	05-1967	
1030	Kathmandu Airport	Agrometeology	C	27	42	00	85	22	00	1,336	06-1949	
1035	Sankhu	Precipitation	C	27	45	00	85	29	00	1,449	09-1970	
1036	Panchkhal	Agrometeology	C	27	41	00	85	38	00	865	11-1970	
1038	Dhunibesi	Climatology	C	27	43	00	85	11	00	1,085	04-1971	Narayani
1039	Panipokari (Kathmandu)	Climatology	C	27	44	00	85	21	00	1,335	04-1971	
1043	Nagarkot	Climatology	C	27	42	00	85	31	00	2,163	05-1971	
1047	Pharping	Precipitation	C	27	37	00	85	18	00	1,500	05-1971	
1049	Khopasi (Panauti)	Precipitation	C	27	35	00	85	31	00	1,517	06-1971	
1052	Bhaktapur	Precipitation	C	27	41	00	85	25	00	1,330	05-1971	
1054	Thamachit	Precipitation	C	28	10	00	85	19	00	1,847	11-1971	Narayani
1055	Dhunche	Climatology	C	28	06	00	85	18	00	1,982	11-1971	Narayani
1056	Tokha	Precipitation	C	27	48	00	85	26	00	1,790	12-1972	
1057	Pansayakhola	Climatology	C	28	01	00	85	07	00	1,240	01-1973	
1058	Tarka Ghyang	Precipitation	C	28	00	00	85	33	00	2,480	01-1974	
1059	Changu Narayan	Precipitation	C	27	45	00	85	25	00	1,543	05-1974	
1060	Chapa Gaun	Precipitation	C	27	36	00	85	20	00	1,448	10-1975	
1061	Lubhu	Precipitation	C	27	39	00	85	23	00	1,341	11-1975	
1062	Sangachok	Climatology	C	27	42	00	85	43	00	1,327	05-1979	
1063	Thokarpa	Precipitation	C	27	42	00	85	47	00	1,750	07-1979	
1071	Buddhanilakantha	Climatology	C			00			00	1,360	*	
1072	Paigutang	Climatology	C	28	13	00	85	11	00	4,091	*	
1101	Nagdaha	Precipitation	C	27	41	00	86	06	00	850	01-1977	
1102	Charikot	Precipitation	C	27	40	00	86	03	00	1,940	06-1959	
1103	Jiri	Agrometeology	C	27	38	00	86	14	00	2,003	08-1961	

LIST OF METEOROLOGICAL STATIONS

Station No.	Station Name	Type of Station	Reg	Latitude			Longitude			Elevation (m)	Start of Record	Remarks
				°	'	"	°	'	"			
1104	Melung	Precipitation	C	27	31	00	86	03	00	1,536	06-1959	
1106	Ramechhap	Precipitation	C	27	19	00	86	05	00	1,395	04-1948	
1107	Sindhuli Gadhi	Climatology	C	27	17	00	85	58	00	1,463	06-1955	
1108	Bahun Tilpung	Precipitation	C	27	11	00	86	10	00	1,417	05-1958	
1109	Patharkot (East)	Precipitation	C	27	05	00	85	40	00	275	01-1956	Lakhandehi
1110	Tulsi	Precipitation	C	27	02	00	85	55	00	457	12-1955	
1111	Janakpur Airport	Climatology	C	26	43	00	85	58	00	90	06-1968	
1112	Chisapani Bazar	Precipitation	C	26	55	00	86	10	00	165	07-1955	
1114	Hardinath	Precipitation	C	26	48	00	85	59	00	93	11-1968	
1115	Nepal Thok	Precipitation	C	27	27	00	85	49	00	1,098	04-1948	
1116	Hariharpur Gadhi	Precipitation	C	27	20	00	85	30	00	880	06-1955	
1117	Hariharpur Gadhi Valley	Precipitation	C	27	20	00	85	30	00	250	03-1978	
1118	Manusmara	Climatology	C	26	53	00	85	25	00	100	02-1979	
1119	Gausala	Precipitation	C	26	53	00	85	47	00	200	02-1979	
1120	Malangwa	Precipitation	C	26	52	00	85	34	00	150	03-1983	Lakhandehi
1121	Karmaiya	Climatology	C	27	07	00	85	28	00	131	08-1983	
1122	Jalesore	Climatology	C	26	39	00	85	47	00		03-1989	

(Note) Reg. C: Central Region (All the stations of this region are listed)

GRAIDING OF RIVERBED MATERIALS

Sample code	Cumulative percentage of passing materials (%)														
	<0.075 (mm)	<0.106 (mm)	<0.25 (mm)	<0.425 (mm)	<0.85 (mm)	<2 (mm)	<4.75 (mm)	<9.5 (mm)	<19 (mm)	<26.5 (mm)	<37.5 (mm)	<53 (mm)	<100 (mm)	<200 (mm)	<400 (mm)
	0.075	0.106	0.250	0.425	0.850	2.00	4.75	9.50	19.0	26.5	37.5	53.0	100.0	200.0	400.0
Lakhandei River															
La-1	4.4	11.6	75.6	93.6	98.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
La-2	8.3	16.8	92.9	99.4	99.6	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
La-3	7.7	15.9	82.5	95.7	98.3	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
La-4	2.9	8.5	68.8	95.0	99.3	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
La-5	2.0	4.0	37.0	83.1	98.2	99.6	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
La-6	4.0	8.8	61.8	84.0	89.7	90.7	91.5	92.0	93.3	96.3	98.8	100.0	100.0	100.0	100.0
La-7	2.3	5.8	56.6	87.2	95.7	97.1	97.8	98.3	98.7	98.9	99.4	100.0	100.0	100.0	100.0
La-8	2.4	5.2	46.4	77.9	86.9	88.2	89.0	90.0	92.3	94.9	98.5	98.9	100.0	100.0	100.0
La-9	2.0	3.7	25.2	67.3	80.8	82.3	83.6	86.0	91.7	95.4	98.3	99.1	100.0	100.0	100.0
La-10	1.2	3.0	38.5	73.5	83.8	86.6	90.1	94.5	96.3	97.3	98.8	100.0	100.0	100.0	100.0
La-11	1.7	2.6	40.1	66.4	78.2	83.3	90.9	97.2	99.0	99.7	100.0	100.0	100.0	100.0	100.0
La-12	0.6	1.8	15.5	38.0	54.2	61.8	69.2	77.0	86.0	92.6	94.9	96.7	100.0	100.0	100.0
La-13	0.4	0.8	9.7	22.7	35.8	43.4	53.0	65.4	78.6	84.9	92.0	96.3	100.0	100.0	100.0

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size					Specific gravity (g/cc)		
	16 (%)	60 (%)	65 (%)	84 (%)	d84/d16	S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
Lakhandei River								
La-1	0.11	0.20	0.22	0.32	2.85	2.65	2.63	2.64
La-2	0.10	0.17	0.18	0.23	2.20	2.63	2.66	2.65
La-3	0.11	0.19	0.20	0.27	2.50	2.63	2.67	2.65
La-4	0.12	0.22	0.24	0.34	2.89	2.67	2.63	2.65
La-5	0.14	0.33	0.35	0.44	3.06	2.69	2.65	2.67
La-6	0.12	0.24	0.27	0.43	3.58	2.61	2.58	2.60
La-7	0.13	0.27	0.29	0.40	3.19	2.59	2.63	2.61
La-8	0.13	0.31	0.34	0.68	5.13	2.63	2.60	2.62
La-9	0.17	0.39	0.41	5.31	30.66	2.68	2.70	2.69
La-10	0.15	0.35	0.37	0.91	6.24	2.63	2.68	2.66
La-11	0.14	0.37	0.41	2.17	15.05	2.63	2.65	2.64
La-12	0.25	1.63	2.90	16.26	64.27	2.66	2.69	2.68
La-13	0.32	7.01	9.27	25.32	78.32	2.59	2.63	2.61
							Average	2.64

SUMMARY OF QUESTIONNAIRES

Name of river: **LAKHANDEI RIVER(1/2)**

No.	Questions/items	Summary of answers
1. FLOOD EVENTS		
1.1	Year of most severe flood in past 10 years (nop)	1997(161), 1993(29)
1.2	Floods in a year (times)	Average(10) ranging(10 to 20)
1.3	Severe floods in past 10 years (times)	Average(6) ranging(3 to 5)
1.4	(Cancelled)	(Cancelled)
1.5	Cause of flood (nop)	• Too much rain(179) • Sediment flow(146) • Bank erosion(191) • Others(3)
2. EFFECT DUE TO SEVERE FLOOD IN PAST		
2.1	Loss of human life (nop)	0 (excluding those due to epidemic disease)
2.2	Loss of livestock/husbandry (nos)	• Cow(20) • Buffalo(22) • Sheep/Goat(214) • Poultry(2)
2.3	Damage to farm land (ha)	• Irrigated land: Average(0.8) ranging(0.7 to 1.7) • Non-irrigated land: Average(1.4) ranging(0.6 to 3.1)
2.4	Extent of damage to farm land	• Simple inundation (nop): 1 • Loss of crops (nop): Paddy(98), Sugarcane(52), Maize(28), Others(23) • Total washout (ha): Average(1.0) ranging(0 to 1.0)
2.5	Extent of damage to dwelling and asset	• Flooding duration (days): Average(7.0) ranging(3 to 28) • Flooding depth in (m): Average(1.6) ranging(0.3 to 3.0) • Damage to house (nop): Severe(88), Moderate(22), Ordinary(47) • Loss of cash (Rs): Average(6,500) ranging(0 to 50,000) • Loss of food grains (kg): Paddy: Average(3,200) ranging(0 to 26,500) • Clothing (nos): Average(5) ranging(1 to 10) • Other valuables: Average(1) ranging(0 to 1)
2.6	Problems during flood (nop)	• Erosion of river bank(177) • Sediment in the river(170) • Sediment in irrigation canal(145) • Drinking water problem(186) • Sanitary problem(166) • Salinity(36) • Flooding over farm land(51) • Others(2)
2.7	Epidemic disease after flood? (nop)	• Yes(169) • No(16)
2.8	If yes, kind of epidemic disease (nop)	• Cholera(5) • Dysentery(160) • Typhoid(151) • Others(13)
2.9	Fatal causality? (nop)	• Yes(8) • No(34)
2.10	Reason of flood(nop)	• Too much rain(171) • Lack of flood protection works(190) • Weak river training works(153) • Sediment load in the flood water(144) • Flood from adjoining rivers(30)
2.11	Total amount of damage (Rs)	Average(164,000) ranging(0 to 245,000)

(Remarks) nop: Number of persons who answer to the item.

SUMMARY OF QUESTIONNAIRES

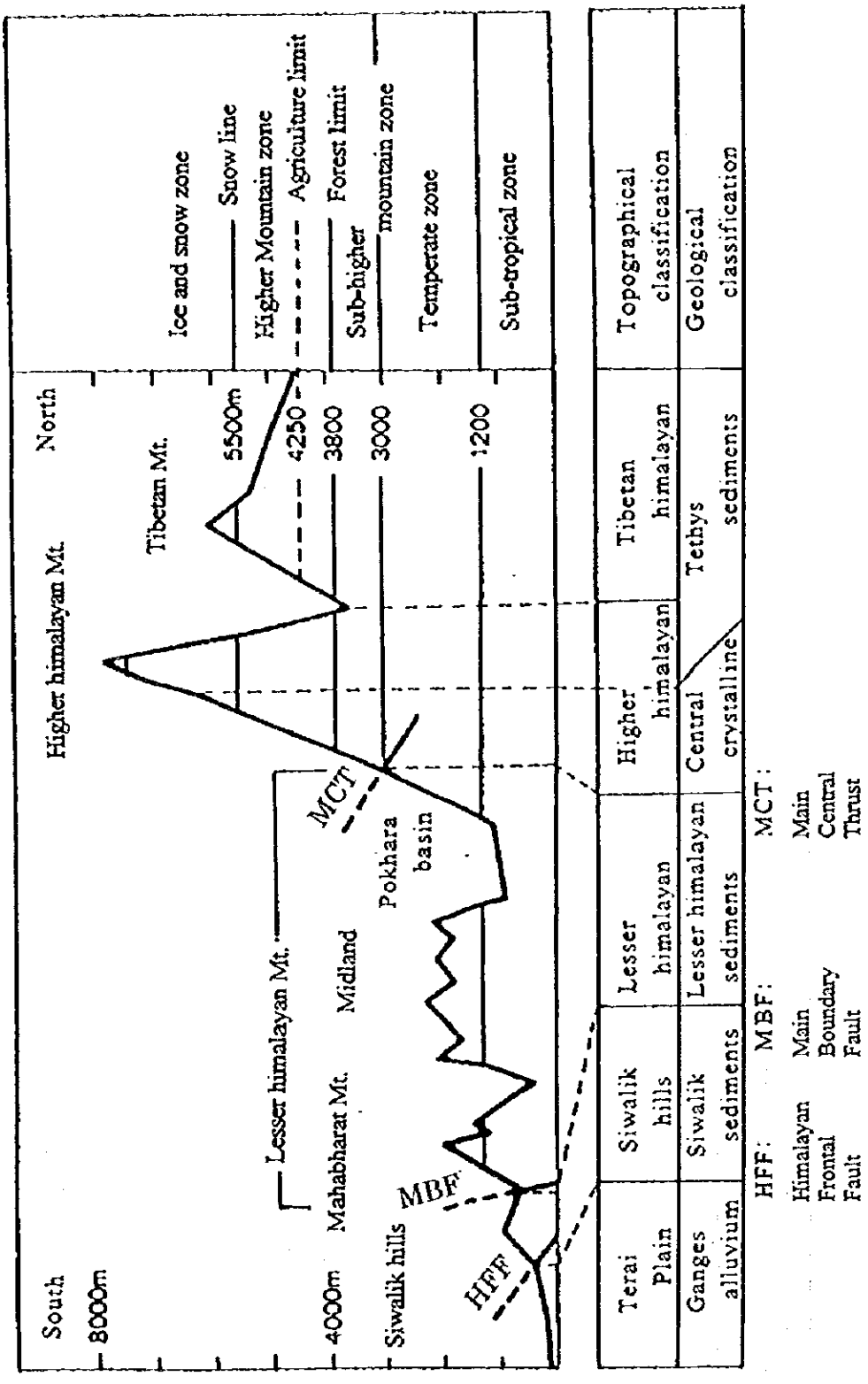
Name of river: **LAKHANDEI RIVER(2/2)**

No.	Questions/items	Summary of answers
3. FLOOD WARNING SYSTEM		
3.1	(Cancelled)	(Cancelled)
3.2	Self warning (nop)	• Heavy rain/High flood level(1) • Bank erosion(1) • Smelled mud(0) • Unusual sound(0) • Others(0)
3.3	Warning by others (nop)	• Neighbors(0) • Institutions(0) • Others(0)
4. FLOOD RELIEF MEASURES		
4.1	Evacuation experience? (nop)	• Yes(120) • No(72)
4.2	If yes, place of evacuation (nop)	• High ground(52) • Public building(37) • Others houses(58) • Other sites(4)
4.3	Being relieved? (nop)	• Yes(45) • No(136)
4.4	If yes, how?(nop)	• In cash(16) • Kind(10)
4.5	Organization/individual giving relief (nop)	• Central government(17) • DDC(1) • VDC(1) • Other institutions(5) • NGO(2) • Individuals(0)
4.6	(Cancelled)	(Cancelled)
5. PREVENTIVE MEASURES AGAINST FLOOD		
5.1a	Current preparedness/ measures (nop)	• Warning(18) • Evacuation(68) • Settlement(2)
5.1b	Proposed preparedness/ measures (nop)	• Warning(155) • Evacuation(5) • Settlement(72)
5.2a	Current non-structural measures (nop)	• Seed storage(3) • Cash pools(0) • Informal insurance(1) • Others(0)
5.2b	Proposed non-structural measures (nop)	• Seed storage(10) • Cash pools(4) • Informal insurance(24) • Others(1)
5.3a	Current structural measures (nop)	• Embankment(92) • Spur(18) • Simple gabion(82) • Plantation(6) • Others(3)
5.3b	Proposed structural measures(nop)	• Embankment(185) • Spur(144) • Simple gabion(170) • Plantation(171) • Others(0)
6. PARTICIPATION ACTIVITIES		
6.1	Experience of Participation in activities? (nop)	• Yes(180) • No(12)
6.2	If yes, type (nop)	• Cash(5) • Labor(172) • Kind(3) • Care taker(17) • Others(0)
6.3	If no, reason (nop)	• Being affected badly(1) • Financially weak(88) • Being out of the area(0) • No willingness(1) • Others(7)
6.4	Willing to participate in future? (nop)	• Yes(182) • No(3)
6.5	If yes, type (nop)	• Cash(32) • Labor(182) • Kind(2) • Care taker(16) • Others(0)
6.6	If no, reasons (nop)	• No time(0) • No benefit(1) • No Willingness(0) • Not known how to participate(0) • Others(1)

(Remarks) nop: Number of persons who answer to the item.

LOSS OF LIFE AND DAMAGE TO PROPERTIES (LAKHANDEI RIVER)
(1997-FLOOD)

VDC/Municipality	Loss of					Damage of							Remarks
									Public Facilities				
	Life (nos.)	Cattle (nos.)	Crops (ton)	Land (hac)	Houses (nos.)	Cross (ton)	Land (hac)	Houses (nos.)	Road (m)	Culvert (nos.)	School (nos.)	Irrigation Channel	
Bhadsar	-	50	222	-	-	3	166	50	50	1	-	v	
Simara	-	-	250	-	-	1	103	125	10	2	1	v	
Phool Parasi	1	50	500	-	-	1	200	150	80	-	-	v	
Laxmipur	-	-	67	-	17	-	32	-	5	-	-	v	
Sundarpur	-	-	500	7	-	-	160	20	15	1	1	v	
Padariya	5	7	250	-	-	-	83	101	10	-	1	v	
Belhi	-	95	250	-	-	15	90	150	50	1	-	v	
Shreepur	2	100	1,000	20	200	30	333	10	12	1	1	v	
Pipariya (1993)	-	20	2,460	60	-	2	-	-	13	-	1	v	
Pidari (1993)	3	50	2,000	1	-	3,000	60	60	10	1	1	v	
Haripur	-	7	470	43	-	-	-	-	1	-	-	v	
Janaki Nagar	-	-	250	100	-	-	-	25	10	-	-	v	
Ghurkali (1993)	3	19	456	3	19	-	36	-	9	-	-		
Total	14	398	8,675	234	236	3,052	1,263	691	275	7	6		

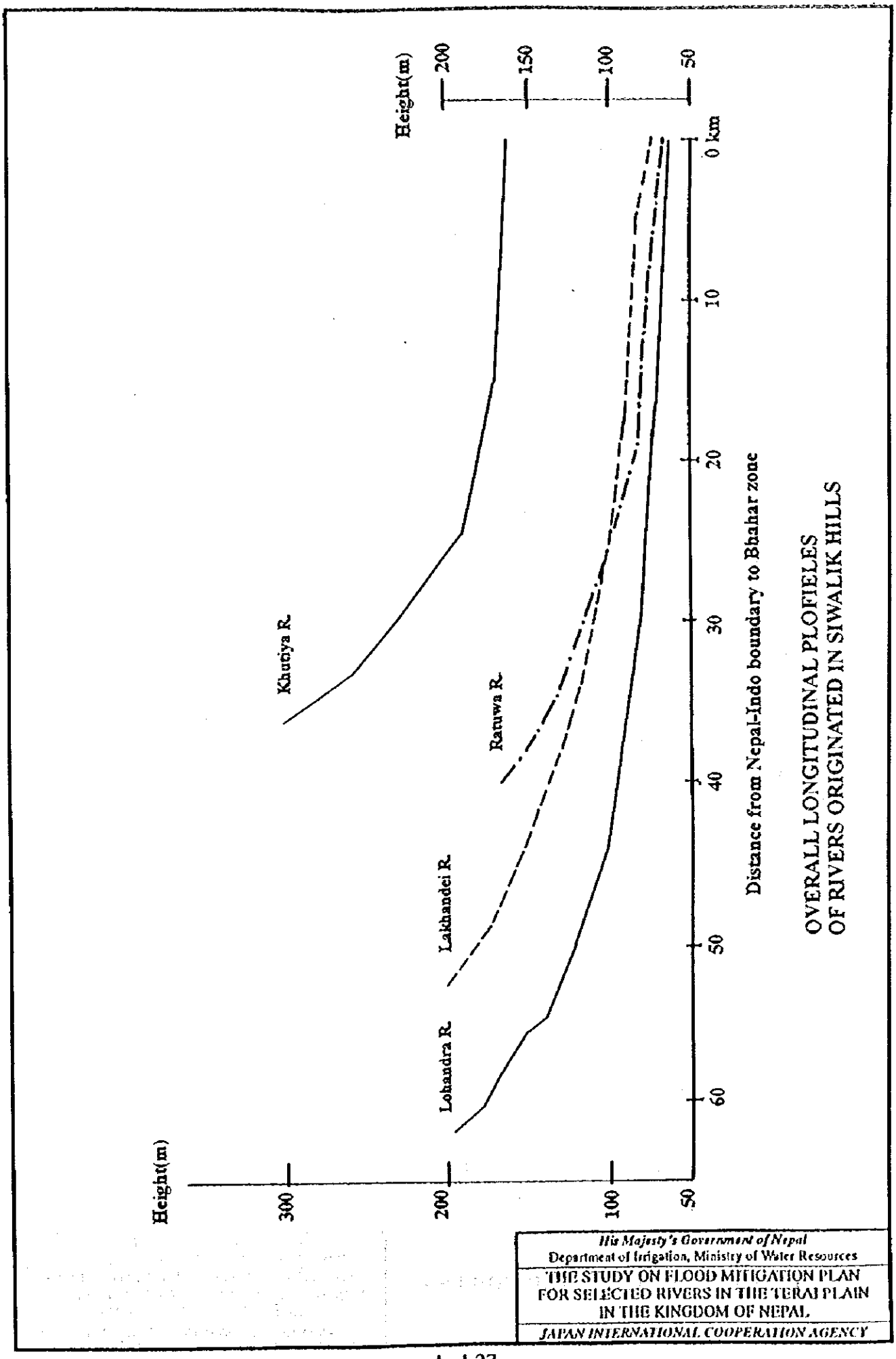


TOPOGRAPHICAL AND GEOLOGICAL CLASSIFICATION(N-S PROFILE)

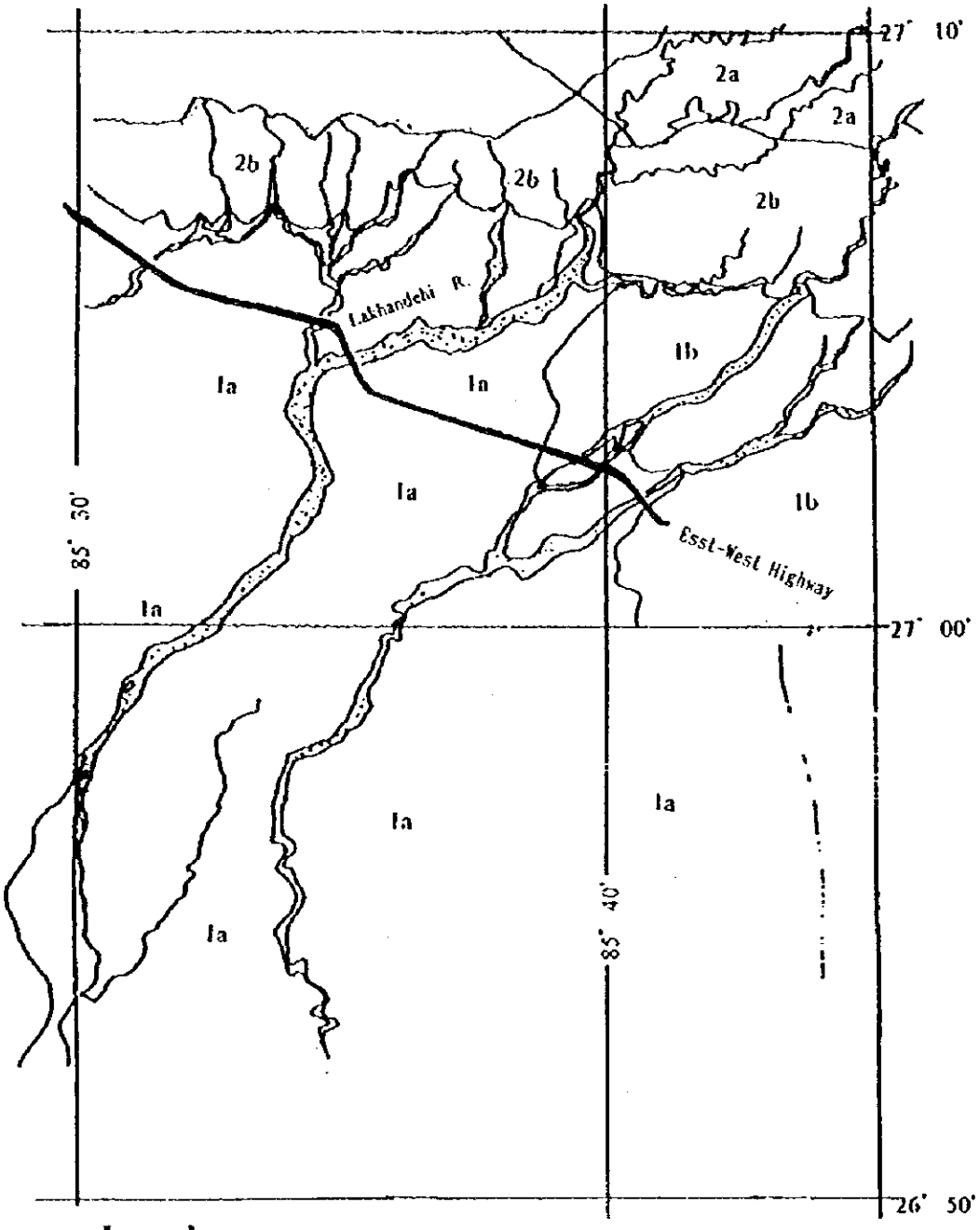
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

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

JAPAN INTERNATIONAL COOPERATION AGENCY


Height(m)
200
150
100
50
0 km
10
20
30
40
50
60
Khutiya R.
Ratuwa R.
Lakhandei R.
Lohandra R.
Distance from Nepal-Indo boundary to Bhabar zone
OVERALL LONGITUDINAL PLOFIELES
OF RIVERS ORIGINATED IN SIWALIK HILLS
Height(m)
300
200
100
50
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

Lakhandei R.

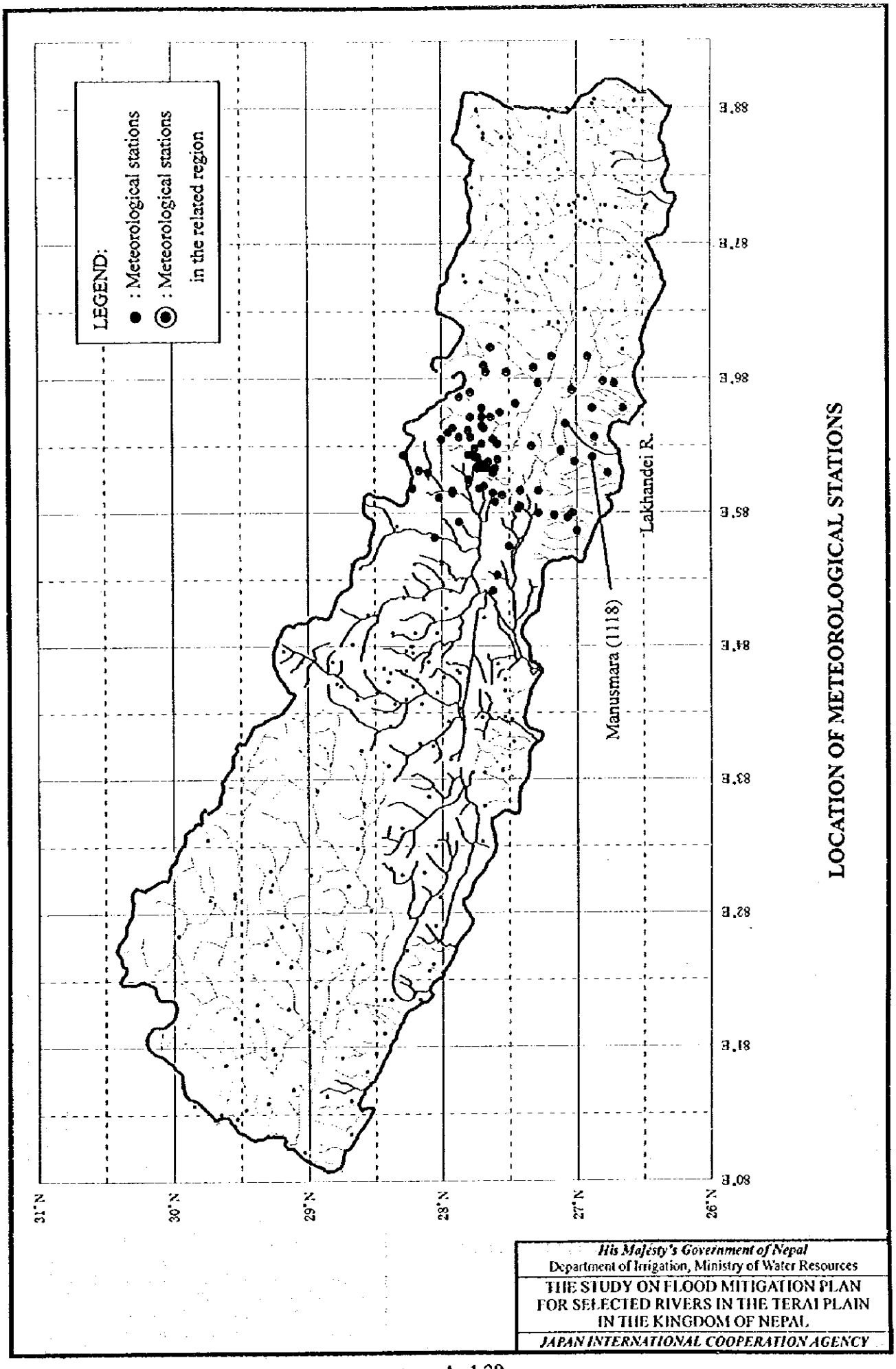


Legend

1. Unconsolidated sediments, chiefly in the Terai plain
   - 1a. alluvium, deposited or reworked by water
   - 1b. alluvial fans, talus, colluvium
2. Siwalik sedimentary system
   - 2a Upper formation-generally coarser clastics
   - 2b. Lower formation-generally finer clastics

GEOLOGICAL MAP (LAKHANDEI R.)

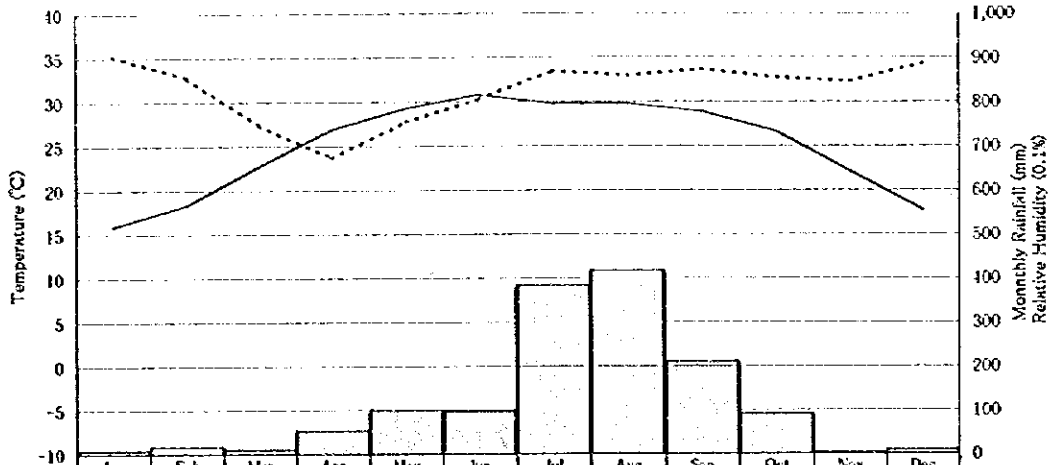
His Majesty's Government of Nepal Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY


LEGEND:
● : Meteorological stations
◉ : Meteorological stations in the related region
Manusmara (1118)
Lakhandei R.
31°N
30°N
29°N
28°N
27°N
26°N
LOCATION OF METEOROLOGICAL STATIONS
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

Code: 1118
Station: Manusmara

Latitude: 26°53'
Longitude: 85°25'
Elevation: 100 m

Manusmara (1118)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation, Total	8.9	17.1	10.8	53.4	99.8	97.2	384.7	416.9	210.9	91.1	2.3	9.1
Air Temperature, Mean	15.9	18.4	22.8	26.9	29.3	30.8	29.8	29.8	29.0	26.7	22.2	17.8
Relative Humidity, 08:45	905	857	748	674	756	807	870	859	874	855	847	888

Air Temperature, Mean (Unit: °C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	-	-	-	-	-	-	-	-	-	-	-	-	-
1986	-	18.0	23.1	26.9	27.8	31.1	29.2	29.8	28.2	25.4	22.3	17.7	-
1987	16.1	19.7	23.1	26.9	29.2	31.6	29.1	29.2	29.1	26.8	22.5	18.8	25.2
1988	16.9	19.5	23.1	27.0	29.8	30.1	30.0	29.3	-	-	22.8	19.0	-
1989	15.0	17.1	22.3	26.7	29.3	30.5	29.0	29.6	28.9	27.6	21.5	16.7	24.5
1990	16.4	18.5	22.1	26.7	29.1	31.1	29.6	30.2	29.0	26.0	22.6	18.2	24.9
1991	15.3	18.9	23.8	27.1	30.4	30.5	30.3	30.0	29.3	26.9	20.7	17.1	25.0
1992	15.8	16.5	23.0	28.2	28.8	31.2	30.2	30.4	29.5	27.2	22.7	17.5	25.1
1993	14.8	19.5	21.1	26.0	29.3	30.2	30.3	29.4	28.8	27.4	23.0	18.7	24.8
1994	17.4	18.0	23.5	27.2	30.6	31.3	30.9	30.4	29.1	26.1	22.0	17.1	25.3
Ave.	15.9	18.4	22.8	26.9	29.3	30.8	29.8	29.8	29.0	26.7	22.2	17.8	25.0

Relative Humidity, 08:45 (Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	-	-	-	-	-	-	-	-	-	-	-	-	-
1986	-	88	70	60	63	69	82	80	80	82	83	91	-
1987	94	81	71	71	74	81	90	88	83	77	79	91	81.7
1988	93	86	67	66	71	77	85	85	-	-	76	87	-
1989	92	84	72	53	70	80	87	84	89	82	85	91	80.8
1990	94	86	75	68	78	81	87	82	86	83	84	85	82.4
1991	89	83	72	67	73	80	84	85	87	88	87	89	82.0
1992	87	85	75	57	78	79	87	87	89	90	88	88	82.5
1993	87	88	83	82	87	90	90	91	92	90	89	87	88.0
1994	88	90	88	83	86	89	91	91	93	92	91	90	89.3
Ave.	90.5	85.7	74.8	67.4	75.6	80.7	87.0	85.9	87.4	85.5	84.7	88.8	83.8

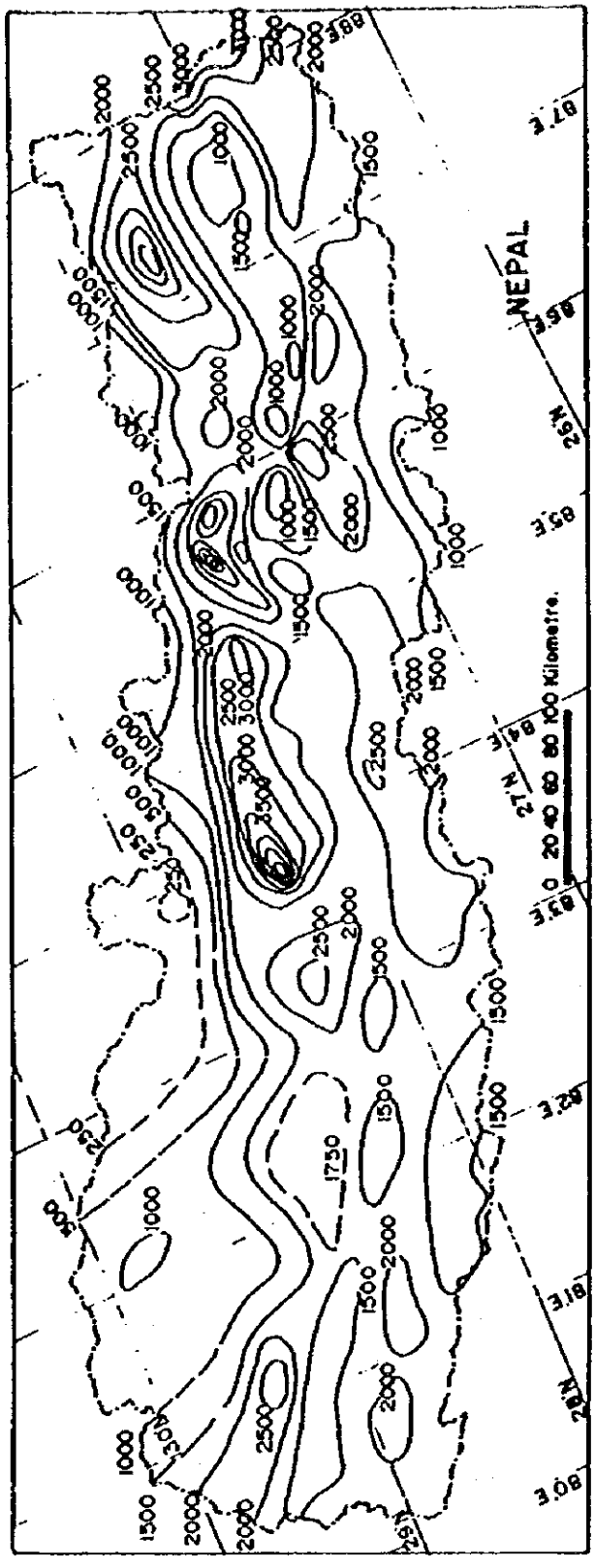
Precipitation, Total (Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	-	-	-	-	-	-	-	-	-	-	-	-	-
1986	-	33	1	62	99	115	429	335	138	167	16	60	-
1987	0	3	3	114	24	100	519	1,097	320	302	0	4	2,486
1988	0	39	35	133	89	165	379	439	-	-	0	11	-
1989	11	14	21	0	159	84	407	70	244	50	0	1	1,061
1990	0	32	5	32	171	85	450	333	258	14	0	0	1,380
1991	28	2	3	33	30	124	257	433	107	105	0	6	1,128
1992	1	11	0	39	158	31	278	222	178	82	5	0	1,005
1993	7	4	29	85	44	141	406	542	158	7	0	0	1,423
1994	24	16	0	3	124	30	337	281	284	2	0	0	1,101
Ave.	8.9	17.1	10.8	53.4	99.8	97.2	384.7	416.9	210.9	91.1	2.3	9.1	1,369

METEOROLOGICAL CONDITIONS

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

MEAN ANNUAL PRECIPITATION (mm) 1971-1985

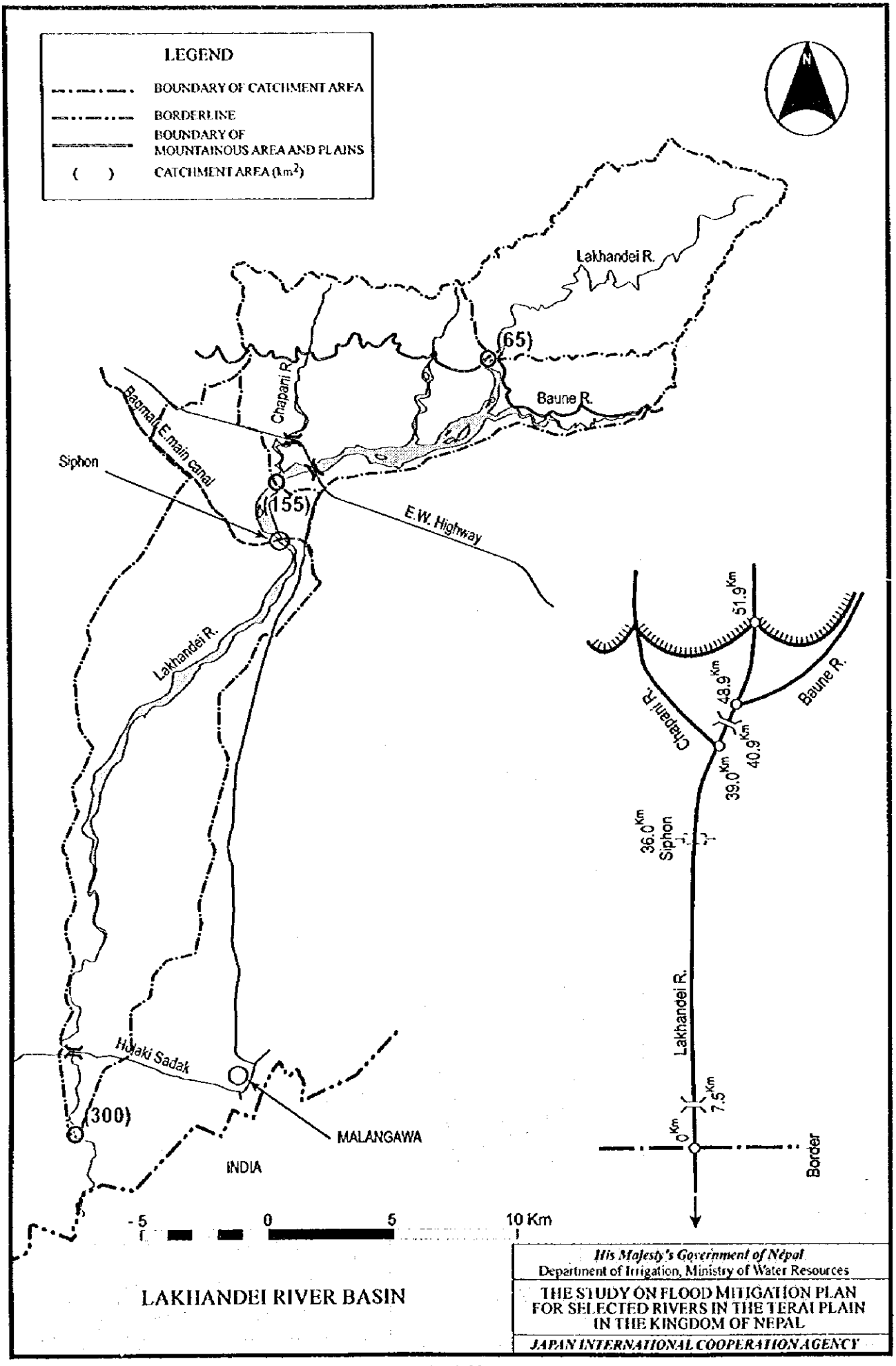


Source: Natural Hazards and Man Made Impacts in The Nepal Himalaya, C.K.Sharman, 1988

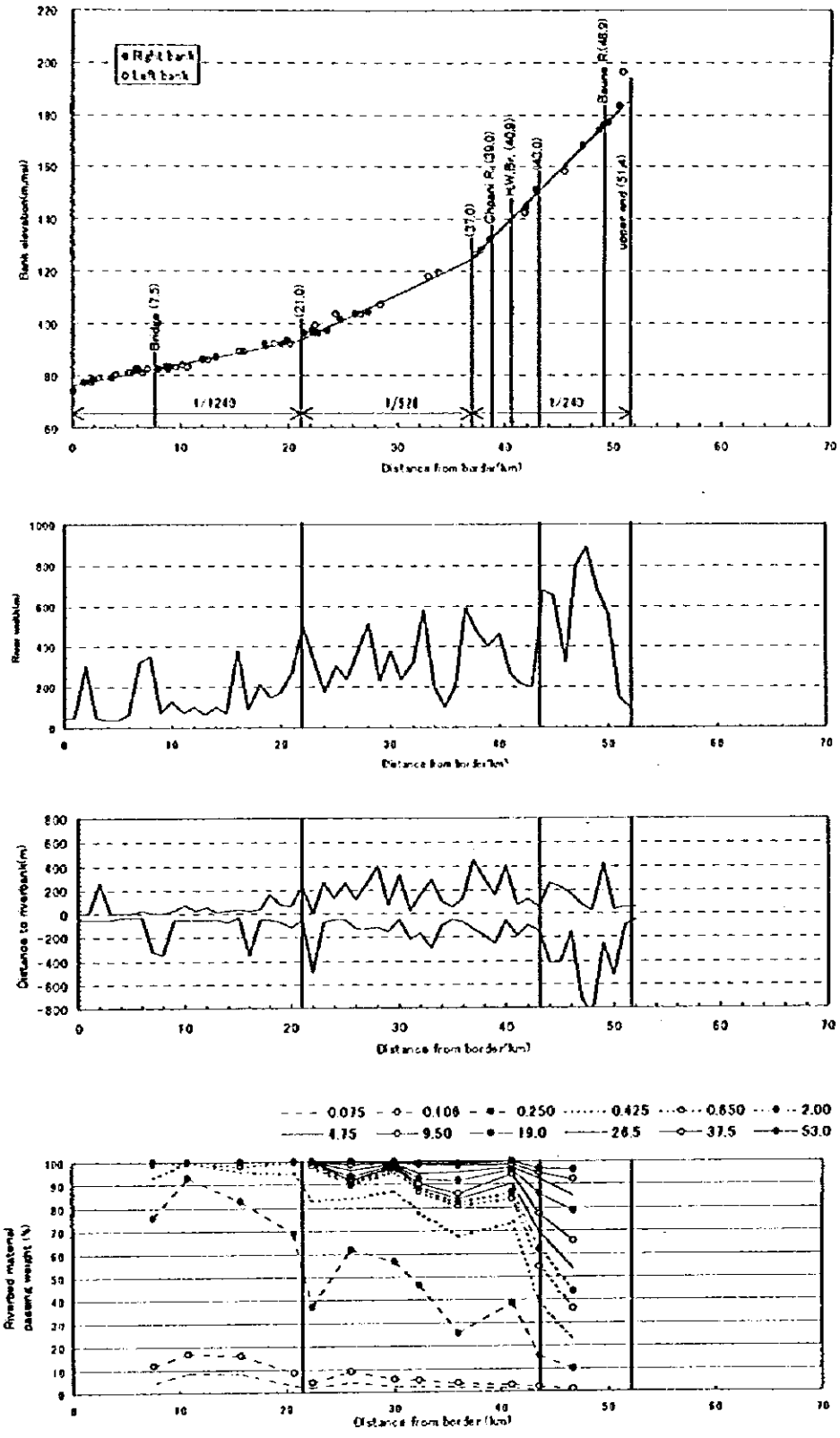
ANNUAL RAINFALL DISTRIBUTION OF NEPAL

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
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. A1.7

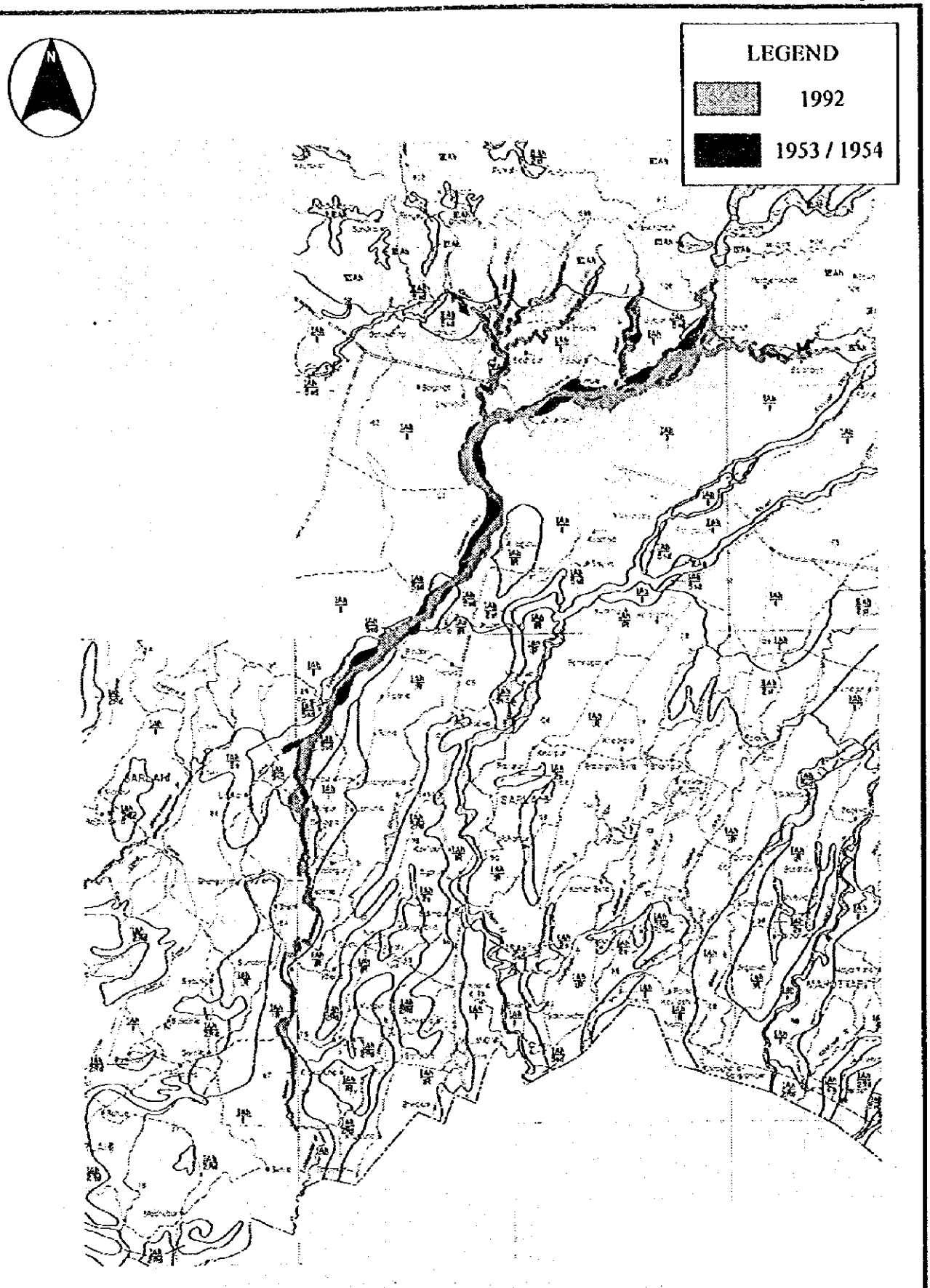

LEGEND
BOUNDARY OF CATCHMENT AREA
BORDERLINE
BOUNDARY OF MOUNTAINOUS AREA AND PLAINS
( ) CATCHMENT AREA (km²)
N
Lakhandei R.
(65)
Chapani R.
Baune R.
Ragmati E.main canal
Siphon
(155)
E.W. Highway
Lakhandei R.
Hulaki Sadak
(300)
MALANGAWA
INDIA
51.9Km
48.9Km
40.9Km
39.0Km
36.0Km
Siphon
Chapani R.
Baune R.
Lakhandei R.
7.5Km
0Km
Border
5 0 5 10 Km
LAKHANDEI RIVER BASIN
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

LAKHANDEI RIVER



CHARACTERISTICS OF EXISTING CHANNEL

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

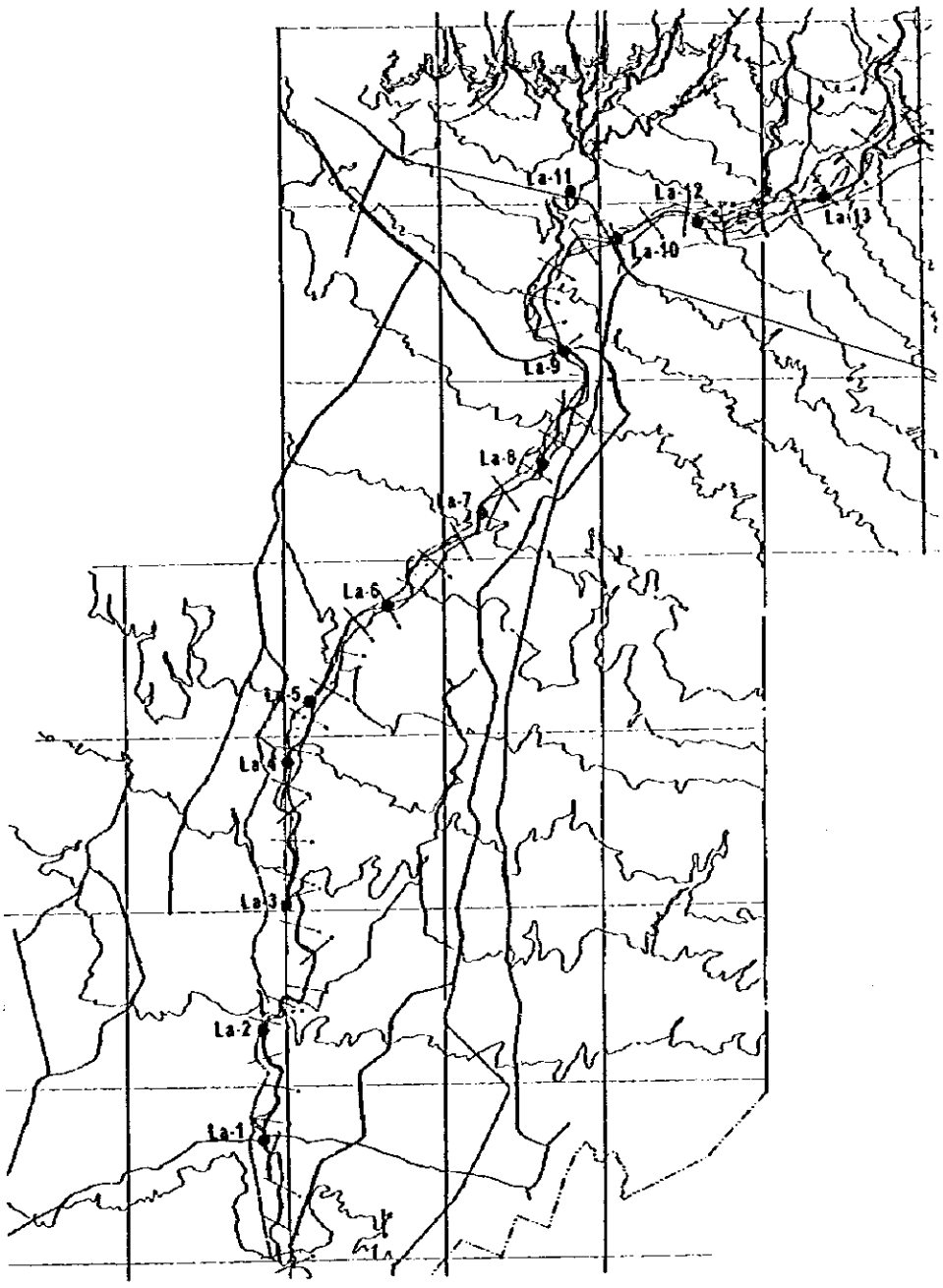


CHANGE OF LAKHANDEI RIVER COURSE

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

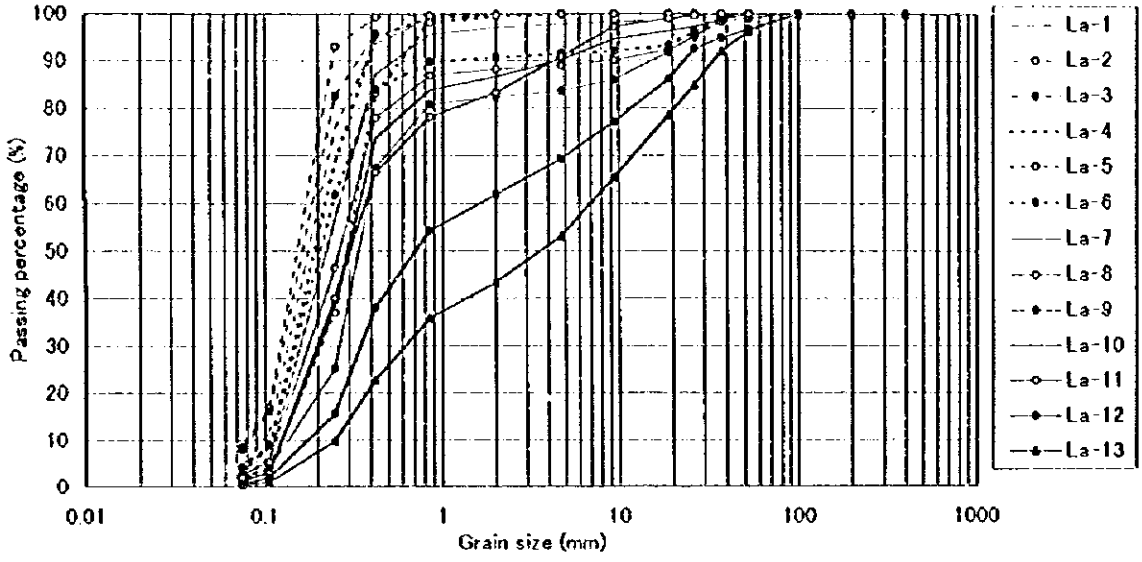
JAPAN INTERNATIONAL COOPERATION AGENCY

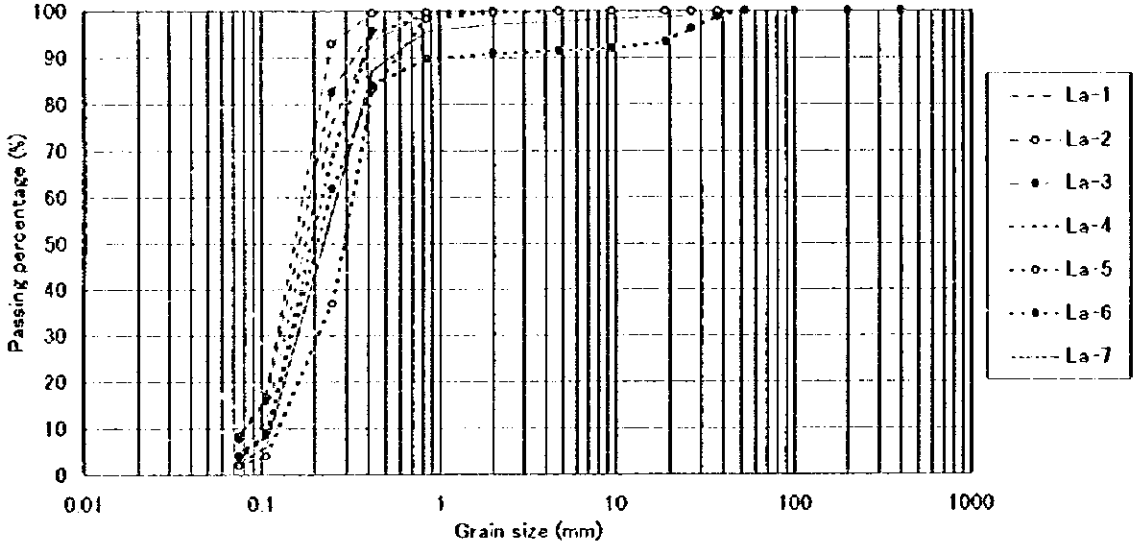


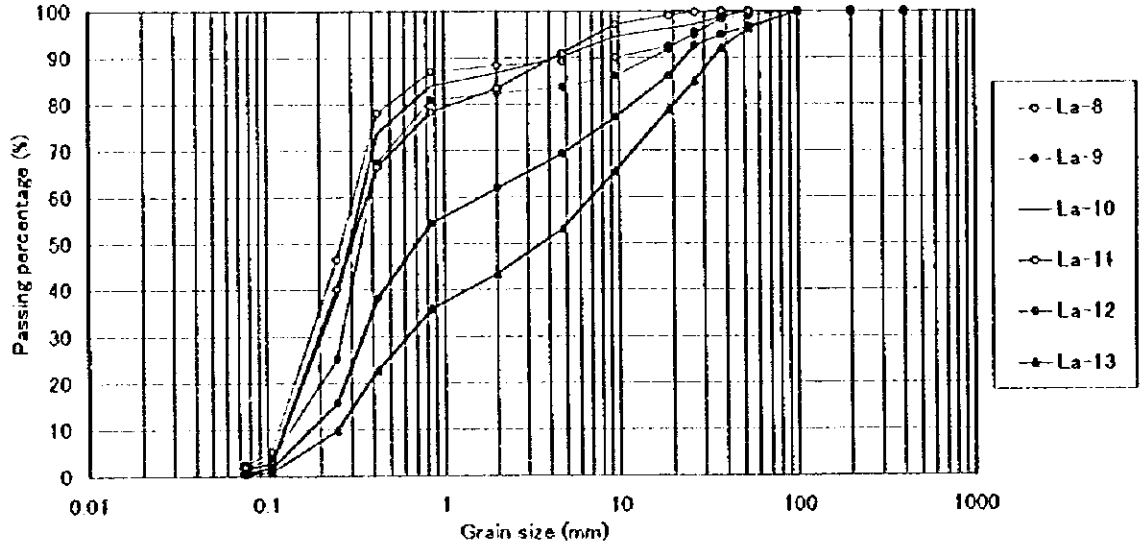
SN	Sample code	Soil classification by eye	Description of sampling place	GPS Reading N	GPS Reading E	FGA (Y/N)
1	La-1	Silty sand	Near bridge on Hulaki road	26°51.776′	85°29.636′	N
2	La-2	Silty sand	Sundarpur WN 9	26°53.259′	85°29.641′	N
3	La-3	Silty sand	Padari WN 5	26°55.009′	85°30.026′	N
4	La-4	Silty sand	Shreepur WN 1	26°57.020′	85°30.081′	N
5	La-5	Silty sand	Hempur WN 5	26°58.005′	85°30.454′	N
6	La-6	Gravel mixed sand	Pipariya WN 3	26°59.349′	85°31.589′	Y
7	La-7	Gravel mixed sand		27°00.644′	85°33.094′	Y
8	La-8	Gravel mixed sand	Haripur WN 8	27°01.377′	85°34.124′	Y
9	La-9	Boulder mixed sand	Netragunj WN 4	27°02.953′	85°34.472′	Y
10	La-10	Gravel mixed sand	Nawalpur WN 6	27°04.466′	85°34.240′	Y
11	La-11	Gravel mixed sand	Sashapur WN 1	27°05.203′	85°34.558′	Y
12	La-12	Boulder mixed sand	Nawalpur WN 9	27°04.683′	85°36.642′	Y
13	La-13	Boulder mixed sand	Patharkot WN 5	27°05.069′	85°38.406′	Y

SAMPLING SITES OF RIVERBED MATERIALS (LAKHANDEI 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

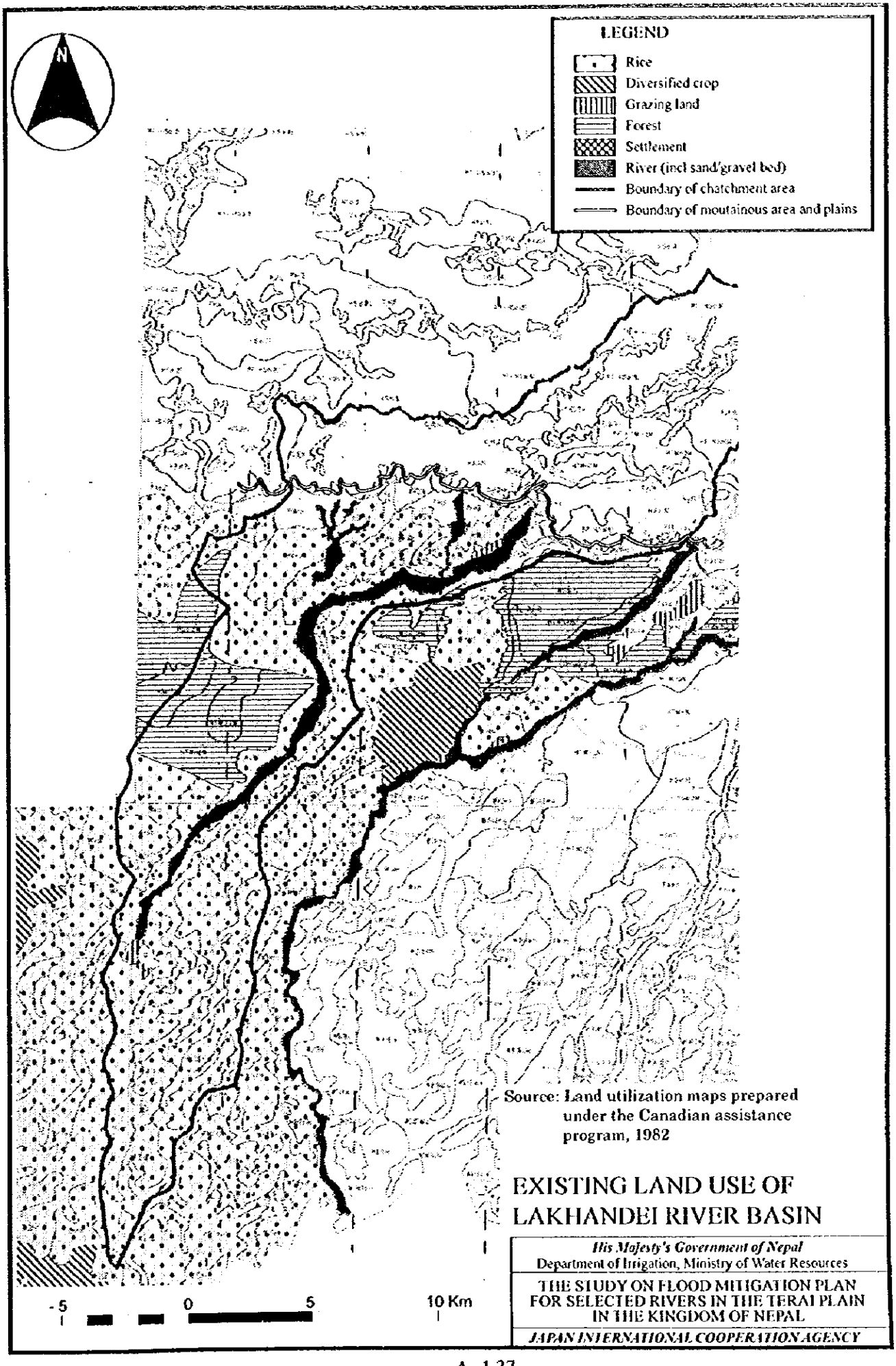






GRADING CURVES OF RIVERBED MATERIALS (LAKHANDEI R.)

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



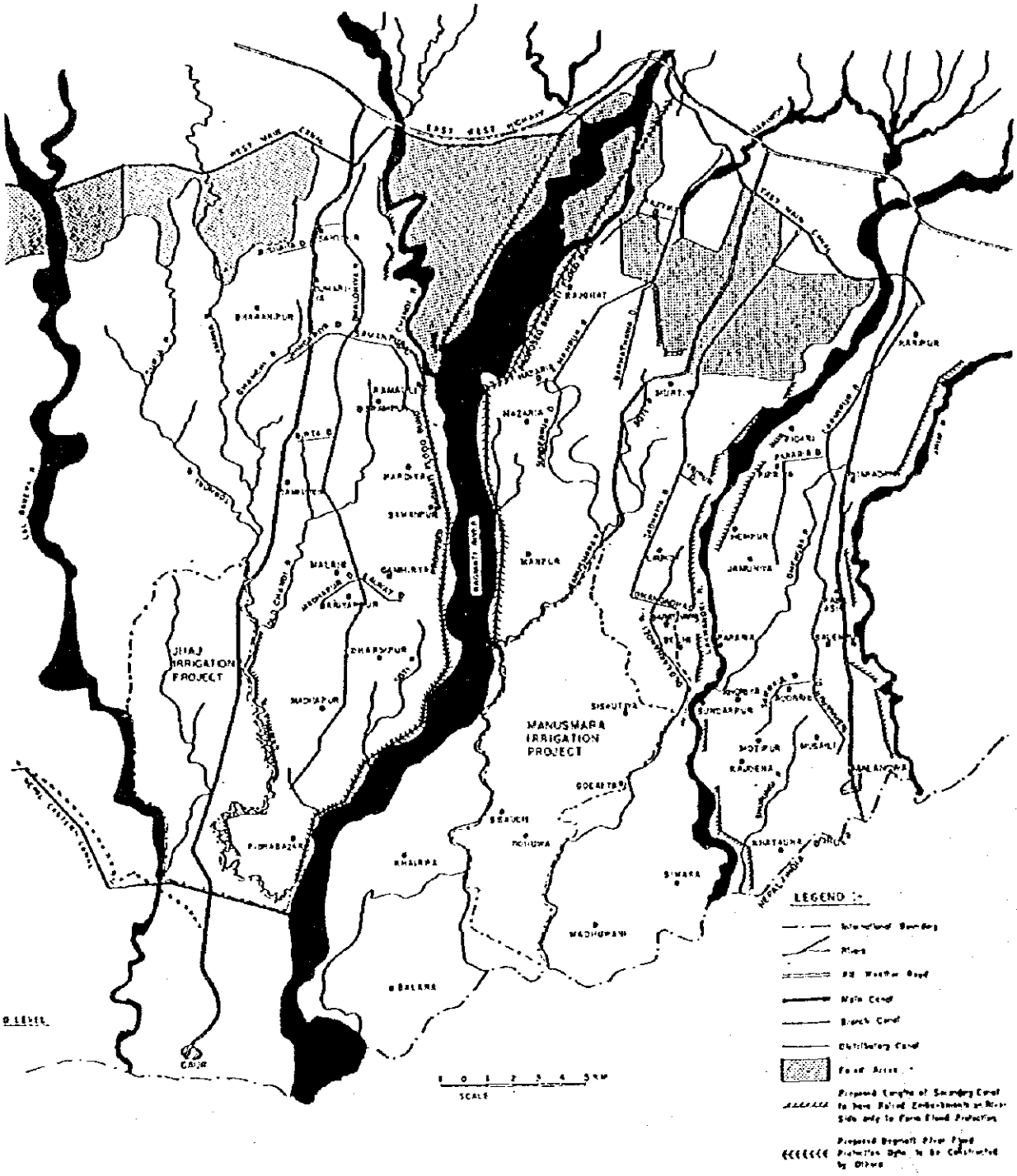
Source: Land utilization maps prepared under the Canadian assistance program, 1982

EXISTING LAND USE OF LAKHANDEI RIVER BASIN

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



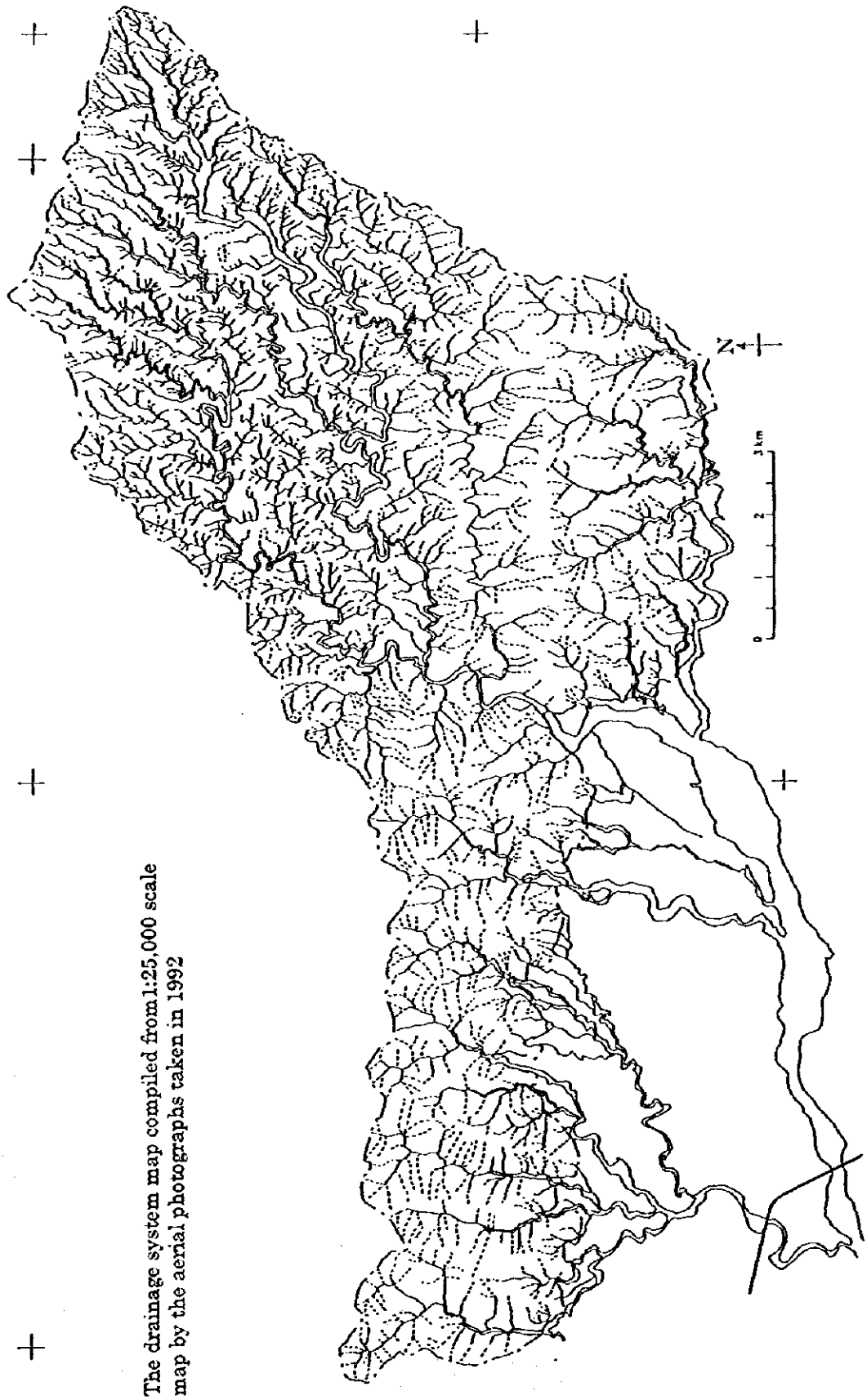
Source: Feasibility Study, Bagmati Command Area Development Project, ADB

BAGMATI IRRIGATION PROJECT

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



DRAINAGE SYSTEM OF THE LAKHANDEI WATERSHED

The drainage system map compiled from 1:25,000 scale map by the aerial photographs taken in 1992

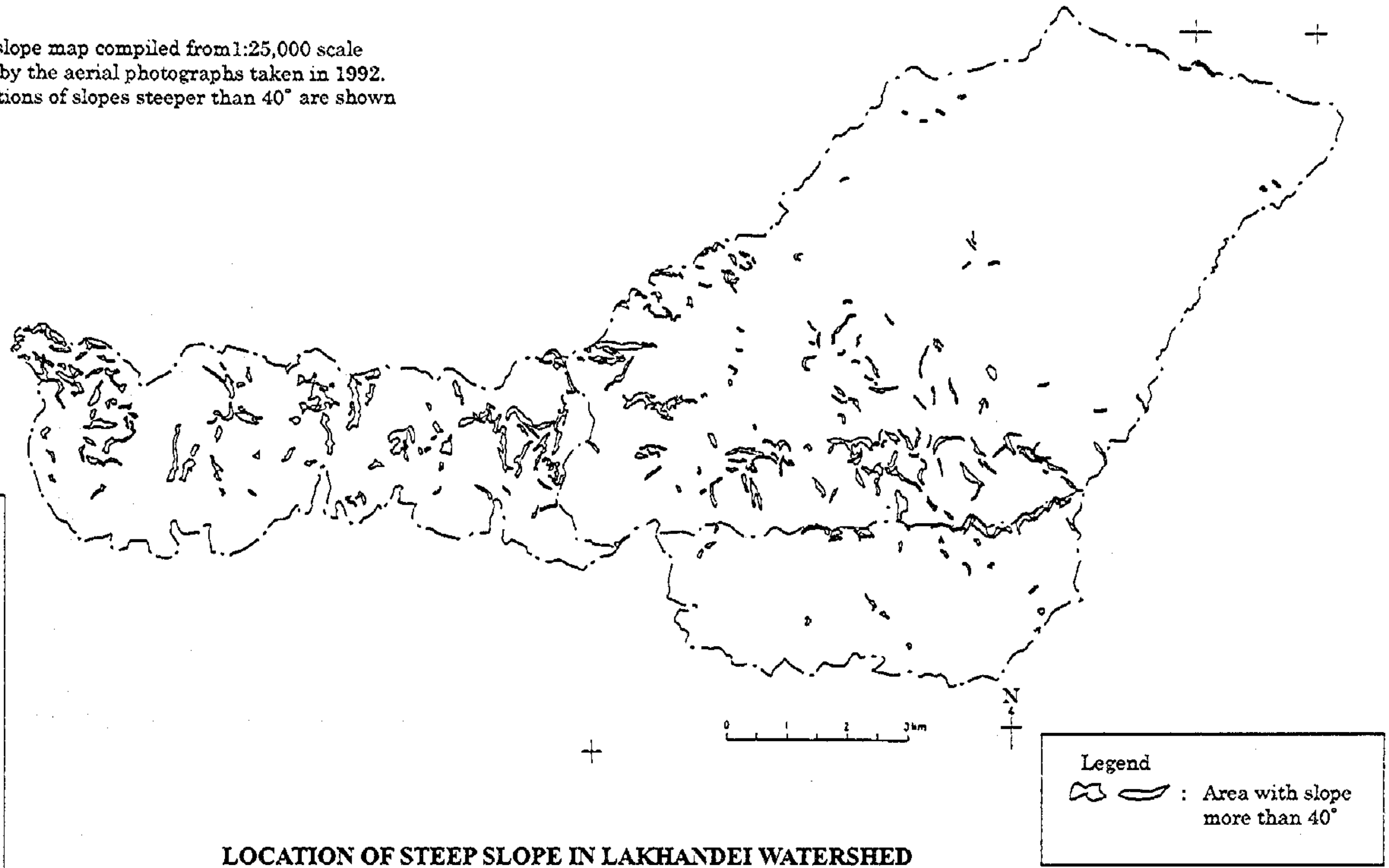
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

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

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. A1.15

The slope map compiled from1:25,000 scale
map by the aerial photographs taken in 1992.
Locations of slopes steeper than 40° are shown



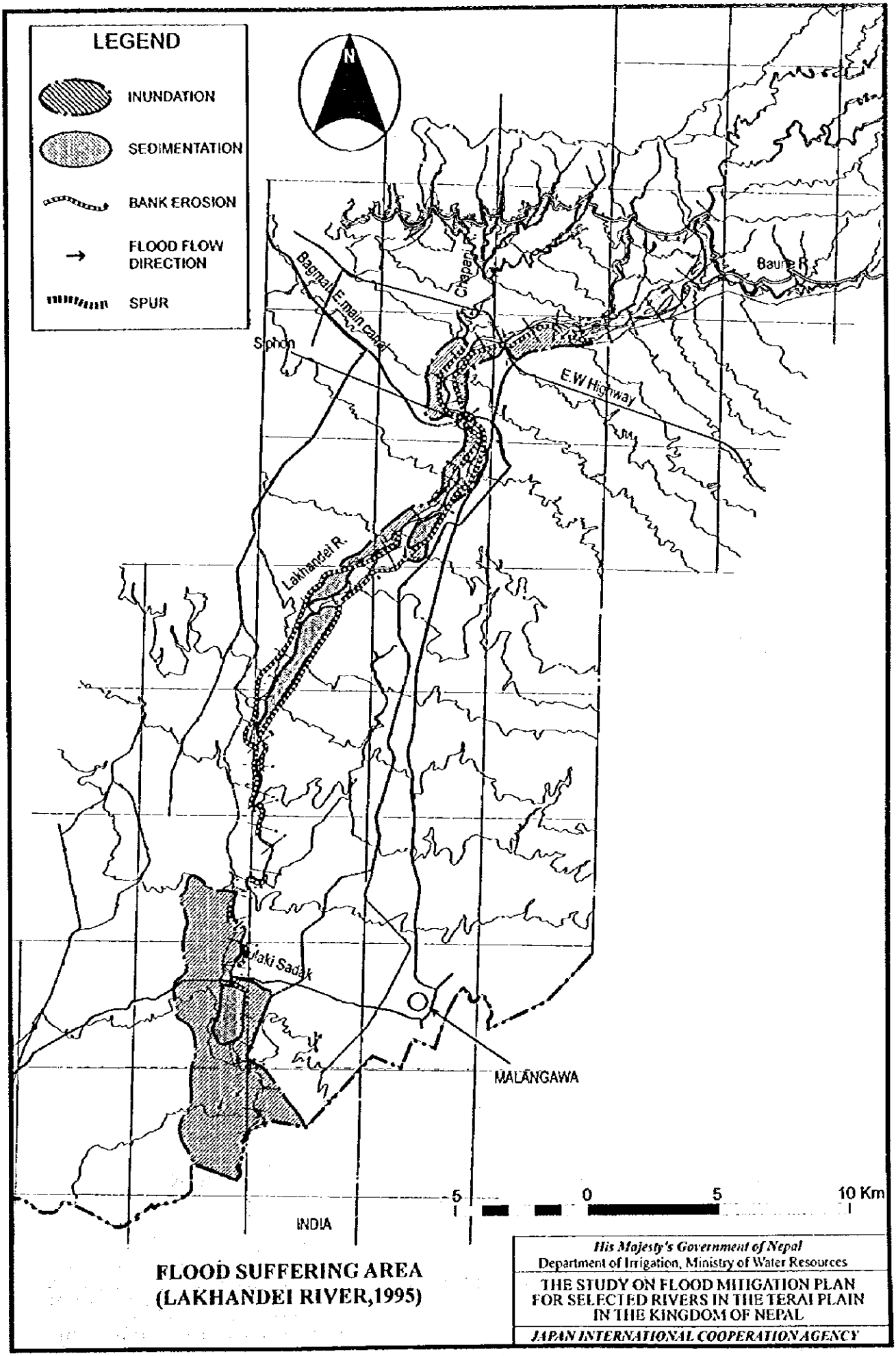
LOCATION OF STEEP SLOPE IN LAKHANDEI WATERSHED

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

Fig. A1.16

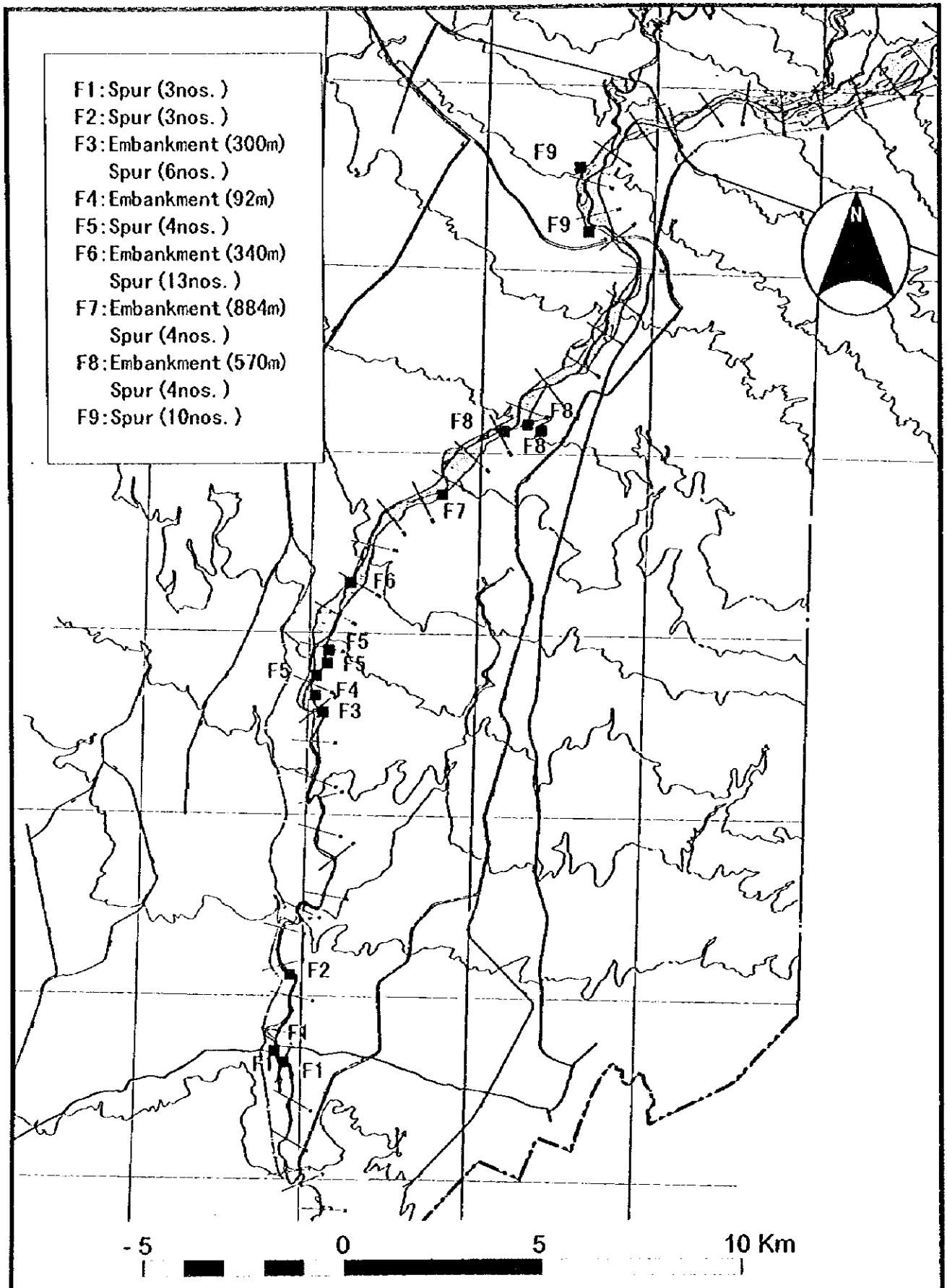


FLOOD SUFFERING AREA (LAKHANDEI RIVER,1995)

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



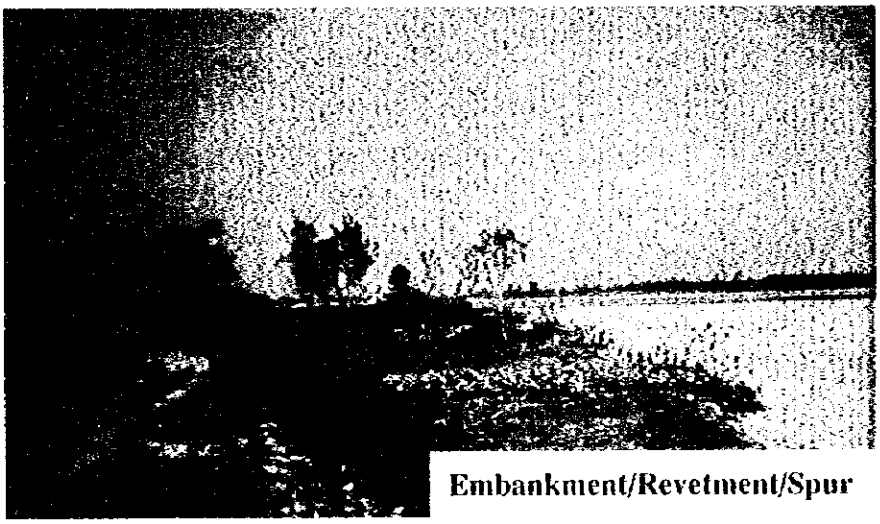
LOCATIONS OF RIVER FACILITIES

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

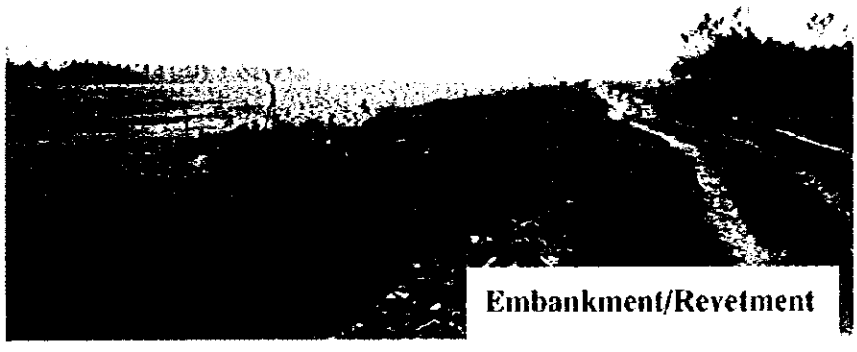
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

Spur



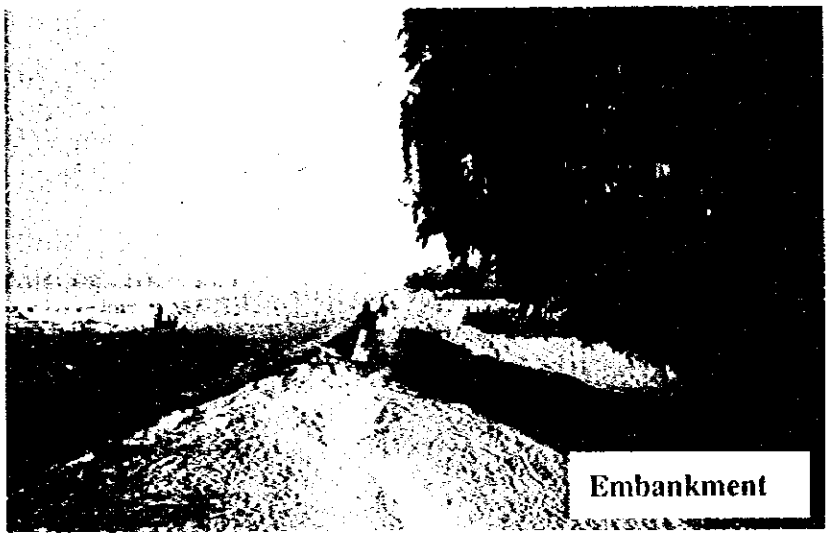
Embankment/Revetment/Spur

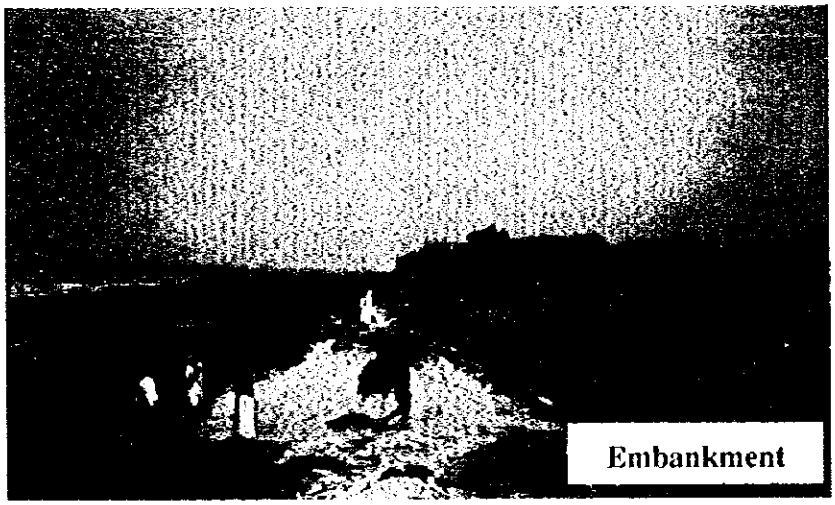


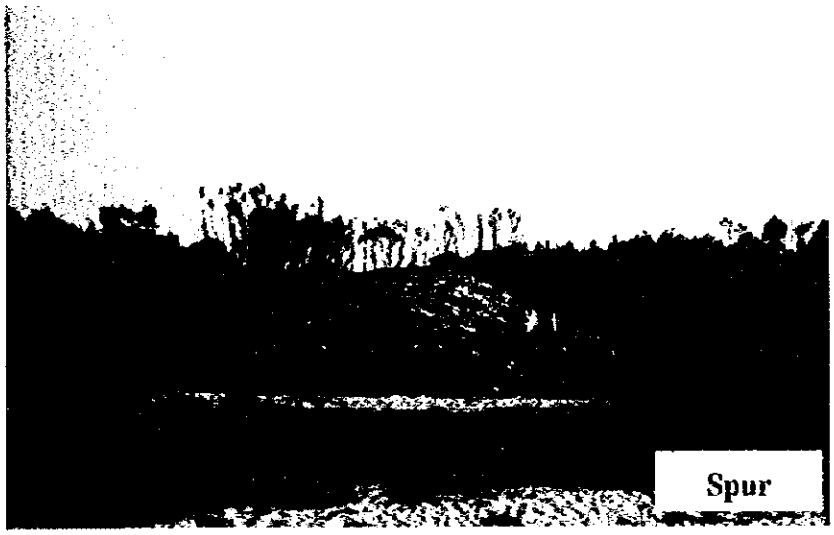
Embankment/Revetment

TYPICAL RIVER FACILITIES (1/2)

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







TYPICAL RIVER FACILITIES (2/2)

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

2. FLOOD MITIGATION MASTER PLAN

2.1 Principles for Formulation of Master Plan

(1) Objective of Master Plan

Objective: The Master Plan aims to direct or guide the flood mitigation activities that will be conducted by various agencies and organizations concerned. In the present study, flood mitigation always means the mitigation of damages due to flood and sediment induced disasters.

Master Plan: Flood mitigation measures generally needs long and continuos 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. The Master Plan includes the following contents:

1) Present conditions and problems
2) Flood mitigation measures: The measures consist of watershed management, river control and community development components.
3) Master Plan: A conceptual plan for flood mitigation is prepared to cope with basin's flood and sediment disasters. Discussions on the technical details are left for future studies.
4) Action program: Activities to be performed by the target year are clarified and actions toward the target year are detailed. Execution methods and procedures for the implementation are also discussed.

(2) Target Year

In line with the national development plan, target year was set at the end of Twelfth Plan in 2017.

(3) Objects to be Protected

According to the investigation of flood and sediment disasters, the major causes of damage in the Terai plain are:

1) Bank erosion,
2) Sedimentation in the riverine areas, and

3) Flooding and inundation.

Owing to these, the following objects in the flood prone area have been affected by damage:

1) Human being: Injury and loss of life
2) Settlements: Houses and household effects, public buildings such as school and hospital, etc.
3) Public facilities: Highway and roads, bridges, electric cables, irrigation canals, river training works, etc.
4) Farm lands and livestock: Paddy and other crops, livestock, etc.

Such people, land and facilities in flood prone areas located along the rivers shall be protected from flood and sediment disasters.

(4) Approach to Flood Mitigation

Considering the natural and social conditions of the Study Area and the financial situation of HMG/N, the following matters are taken into consideration in planning the flood mitigation of the rivers in Terai plain:

1) **Maximum use of local materials and human resources:** The proposed plan should fit in with the financial situation of the country. The proposed project must be practical and sustainable, low cost for both construction and in the maintenance. In this regard, consideration is given to the use of local materials in parallel with the participation of local residents as much as possible.
2) **Provision of safe lands:** Expansion of rural towns and isolated farmhouse is taking place due to migration and population increase in the Terai plain. Some of the new residents live on the land which are flood prone. Provision of safe and productive land is one of the important tasks of the flood mitigation projects in the Terai plain, and the prevention of loss of human life is a top priority.
3) **Comprehensive measures:** Flood mitigation measures should be inclusive adopting non-structural measures as well as structural measures.
4) **Technical Model:** The proposed flood mitigation plan should be a technical model for other river basins of similar nature.

2.2 Flood Mitigation Measures and Project Components

(1) Conceivable Flood Mitigation Measures

In order to mitigate damage due to flood and sediment disaster, it is necessary to employ all the possible measures. The flood mitigation measures are broadly classified into four, according to their functions, as follows:

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

These flood mitigation measures are shown in Fig. A2.1. Considering the characteristics of the river and the existing situation of the basin, measures applicable to the rivers in the Terai plain are also shown in the Figure.

(2) Project Components

In order to undertake the project in a practical and sustainable manner, it is important to implement the watershed management and river control measures in combination with community development activities. Therefore, the flood mitigation is composed of three components, i.e., watershed management, river control and community development components.

2.3 Watershed Management Component

Enhancement of the living standard of the resident is the premise for preventing soil erosion and the watershed management. Therefore, it is preferable to adopt countermeasures for promotion of watershed conservation together with community development activities.

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 materialize the measures, publicity activities mobilizing local community, and governmental and non-governmental organization are also essential. The Department of Soil Conservation and Watershed Management (DOSCWM) and Water-induced Disaster Prevention Technical Center (DPTC) are expected to take the

leading role in this regard.

(1) Erosion Control Facilities

As remedial measures, the following erosion control facilities, solely or in combination with bioengineering technology, could be applied considering topographical, geographical and social situation of the site:

1) Construction of check dam
2) Revetment works along river banks
3) Protection of hillside slope by revetment work and small terracing with vegetation
4) Protection of small-scale channel with gully plugging and surrounding slopes by planting shrubs and grasses.

(2) Afforestation/Reforestation and Land Use Regulation

Afforestation/reforestation and land use regulation aim to foster physical strength of the watershed area against land erosion. The followings are the recommended measures for the watersheds under study:

1) Afforestation and reforestation artificially and fostering natural regeneration of trees.
2) Promoting farm tree and shrub planting by growing commercial crops such as fruit trees, medicinal herbs, aromatic plants and natural dyes. Well-managed commercial crops preventsland erosion in watersheds and promotes sustainable watershed management activities through income generation. The cultivation of medicinal and aromatic plants has been one of the main programs of Nepalese forestry policy. Root crops should not be chosen.
3) Planting of fodder grasses on slopes, fodder trees on terraces, and restricting the number of livestock within permissible limits for sustaining the pasture and forest.
4) Conservation of wild medical herbs, by protecting from over-collect, thus allowing a sustained yield.
5) Reducing energy use through the promotion of improved stoves.
6) Training the local leaders in land use and woodland management, and exchanging know-how among other communities.

(3) Publicity Activities

Afforestation and reforestation have already been carried out in Nepal. However, public people have little knowledge on this matter. In order to promote watershed management, the understanding and cooperation of communities, local and central governments and other organizations are indispensable. In this regard, publicity activities should be extended employing all possible means as follows:

1) Establishing a specific date or dates for tree planting activities as a national and/or local level events and conducting tree planting campaign for afforestation, reforestation, form tree planting and forest conservation.
2) Commemorative tree planting for any ceremonies and memorial events by residents, and local and national leaders.
3) Environmental education, tree nursery and small arboretums in school.
4) Enactment of a system of commendation for excellent tree planting projects, including agro-forestry, riverside plantings and other community activities.
5) Combination of natural regeneration and/or afforestation project with tourism and local development project.
6) Campaign by mass media for planting trees.
7) Establishment of foundations and solicitation of funds to encourage tree planting.
8) Organizing tree-planting volunteer groups and facilitating volunteers from the overseas countries to participate as well.
9) Conducting of study tours to on-going projects to learn from past initiatives.

2.4 River Control Component

2.4.1 Design Discharge

The probable peak discharges at a specific section of the river were estimated by the following equation:

$$Q_n = (Q_n / Q_2) \cdot q_2 \cdot A$$

$$q_2 = C \cdot A^{(A^{-0.05}-1)}$$

where

Q_n : Probable discharge of n-year return period (m^3/s)

(Q_n/Q_2) : Ratio of n-year probable discharge to 2-year discharge

q_2 : Probable specific discharge on 2-year return period ($m^3/s/km^2$).

C_2 : Coefficient of Creager's formula for 2-year return period

The values of C_2 and Q_n/Q_2 for the Lakhandei river basin were estimated commonly for the river originating at Siwalik hills as shown in the following table, based on the probable discharges of the upper East Rapti (460), Manahari (465) and Lothar rivers:

(Q_n/Q_2-values for Lakhandei River)

C	Q_2/Q_2	Q_5/Q_2	Q_{10}/Q_2	Q_{20}/Q_2	Q_{50}/Q_2	Q_{100}/Q_2
6.0	1.00	1.62	2.02	2.41	2.92	3.30

Probable discharges of 2, 5, 10, 20 and 50-year return periods at the lower end (Indian border) of the basin are shown below:

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
Lakhandei	300	440	710	880	1,050	1,280

2.4.2 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 mountain reaches, Segment 1 for alluvial fan, Segment 2 for natural levee zone, and Segment 3 for delta.

Segment-3 does not exist in the Terai plain rivers. The Segment 2 is divided further into Segments 2-1 and 2-2. River control measures should be discussed based on the channel characteristics of respective segments.

River channel of the Lakhandei was divided into four stretches depending on the channel slope, grain size distribution, river width, surrounding topography, etc. as follows:

- LA-1: Reaches from Indian border to Sta. 21 km
- LA-2: Reaches from Sta. 21 km to Sta. 37.0 km
- LA-3: Reaches from Sta. 37.0 km to Sta. 43.0 km upstream of E-W highway bridge
- LA-4: Reaches from Sta. 43.0 km to upper end (Sta. 51.4 km)

Grain size and other channel factors are worked out for respective stretches as follows:

River stretch	River segment code	Ground elevation		Ground slope (1/I)	Grain size		River width Bm (min-max) (m)
		From (m)	To (m)		d_{60} (mm)	d_R (mm)	
Lakhandei R.							
LA-1	2-2	76	93	1,240	0.20	0.20	143(38-375)
LA-2	2-1	93	124	520	0.31	0.31	326(100-588)
LA-3	1	124	150	240	0.35	0.35	371(200-588)
LA-4	1	150	185	240	4.3	4.3	547(200-888)

2.4.3 River Boundary Line (RBL)

Necessity of River Boundary Line: Stabilization of river course is a fundamental task to achieve river control. As a reference datum for the river course stabilization, the river boundary line (RBL) should be first designated and authorized for the flood mitigation activities, identifying the lands and objects to be protected. The RBL must be fixed and protected from movements of the river courses.

Use of the RBL: All the river-related facilities for flood mitigation and water use should be planned and designed in consideration of the authorized RBL. By so doing the efforts for flood mitigation to be carried out when the occasion demands would be accumulated and the safety level of the river would be enhanced gradually in line with the plan.

Setting the RBL: The RBL should be set satisfying the following requirements:

1) Protection of properties: The RBL should be placed to protect important lands and objects from flood and sediment disasters.
2) Enough channel capacity: The river width between the right and left RBLs should be more than average width of the existing river and enough to transport of flood water and sediment.
3) Free from erosion: The RBL itself should be free from erosion keeping enough distance from river bank or providing appropriate bank protection measures.

Procedure of Setting RBL: Therefore, the RBL is designed and authorized through the following procedures:

1) To study river width necessary to transport design flood water and sediment

2) To investigate erosion width along the both river banks. The erosion width discussed here is total erosion width of riverbank throughout a flood season. Design erosion width (B_e) is determined as the maximum value for respective river reaches based on the investigated data.
3) To draw initial RBLs on both banks keeping distance more than B_e from river bank. The RBL should be set on a smooth alignment for flood water flow.
4) The initial RBLs are examined from the viewpoints of property protection and channel capacity. The RBL will be revised partially, if the result of examination demands.
5) The RBLs are fixed and authorized finally after getting consent of government authorities and local communities concerned.

The RBL should be clearly marked in the field by permanent objects such as stakes, planted trees, dike road or dike embankment.

The design erosion width (B_e) was assumed, tentatively for the present study, to be B_e = 50 m based on the information obtained in the field.

2.4.4 Facility Plan

(1) Channel Treatment

1) **Tributary works:** Treatment of tributaries by diversion structure, closing dike, and connecting channel works, to fix the river system and catchment boundary.
2) **Branch/anabranch works:** Treatment of branches and anabranches by closing dike works with diversion structure, if necessary, to prevent river course shifting and flood water spreading.

(2) Bank Protection

Bank protection aims to protect the banks from erosion and accordingly to stabilize the river course.

1) **Spur (or groin) works:** A series of spurs to prevents bank erosion, primarily by two functions, namely to retard flow velocity near the bank and to change the flow direction away from the bank. Spur and revetment works are the primary bank protection measures. These measures can be planed independently or jointly. Various types of bank protection works have been

developed empirically over the world, and the works should be selected considering the channel characteristics of the river.

2) **Revetment works:** Revetment works prevent bank erosion by covering bank slopes and protecting their foundations.
3) **Preventive bank protection works:** Grass and trees planted on the riverbanks to resist and retard erosion. These bioengineering technologies can be used as preventive measures against bank erosion, not as direct bank protection works.

Design of Spur: For the purpose of Master Plan study, spur works were tentatively selected for bank protection, since river section data were not available. The following assumptions were also introduced mostly based on the data in Japan:

1) Total length of a series of spurs (L):
   L = X/4.0 for Segment 1
   L = X/3.0 for Segment 2-1
   L = X/2.0 for Segment 2-2
   where X : Bank length to be protected
2) Crown height of spur (h_{sp}) from bank level:
   h_{sp} = 0.0 h_L for Segment 1
   h_{sp} = 0.3 h_L for Segment 2-1
   h_{sp} = 0.5 h_L for Segment 2-2
   where h_L: Mean depth of low water channel
3) Type of spur:
   Gabion spur for Segments 1 and 2-1
   Pile groin for Segment 2-2

Classification of riverbank: In order to identify the sites in critical conditions and prioritize the work sites for protection, riverbanks should be classified in the following types (Fig. A2.2) based on the relationship between the distance from river bank to the river boundary line (B_h) and design erosion width (B_e):

1) **Type-C bank:** $B_h \geqq B_e$ and bank erosion is not active due to topographical and geological reasons.
2) **Type-B bank:** Bh ≧ Be and bank erosion is active.
3) **Type-A bank:** Bh < Be and bank erosion is active.
4) **Type-As bank:** Bh < 0.5 Be and bank erosion is active.
5) **Type-Ass bank:** Bh < 3hH, 7hH and 10hH for Segment 1, Segment 2-1

and Segment 2-2, respectively, where hII : design water depth in high water channel.

Periodic monitoring: Conditions of riverbank shall be monitored every year after the flood season and the necessity of protection works shall be examined based on the following criteria depending on the types of river bank:

1) **Type-C bank:** No bank protection works are needed.
2) **Type-B bank:** Preventive measures for bank erosion are needed.
3) **Type-A bank:** Bank protection works are desirable as far as the fund is available. Preventive measures for bank erosion are needed immediately.
4) **Type-As bank:** Bank protection works are needed immediately.
5) **Type-Ass bank:** Protection works of dike slope are needed.

(3) Dike Works

Dike works aim to prevent floodwater and sediment from spreading over the land.

1) **Forest and grass belts:** Trees and grass planted along the river course are not strictly dikes. However, these grass and tree belts would alleviate flood damages in the flood prone areas, retarding the flood flows and promoting the formation of a natural levee along the belt (Fig. A2.3).
2) **Dike road:** Road embankment constructed along the river as rural road and flood dike as well. Even if the embankment height is lower than the design level, the road embankment would protect nearby lands from flooding and sedimentation most of the time.
3) **Local dike:** A local dike is applicable to protect a specific area from flooding in such places as the confluence of tributaries, the bifurcation site of an old river course and other local sites of low elevation.
4) **Ring dike:** A ring dike is applicable to protect sporadic important objects like settlements in flood prone areas. A facility for interior drainage is also required.
5) **Continuous dike:** A continuous dike along the river course is an effective measure for the prevention of flooding. However, a continuous dike was not proposed considering the present land use of the flood prone area, the anticipated difficulties in maintenance under the uncontrolled sediment yield in watershed area and the necessity of coordinating the plan with India.

These dikes are aligned, in principle except for the ring dike, on the river boundary line (RBL). The river zone between the RBLs on both banks is planed considering the water and sediment transport capacity and existing river width. Various types of dike works are conceivable. Selection of these works should be made considering the channel characteristics, land use in flood prone areas, etc.

For the purpose of the Master Plan study, following dike works are tentatively selected:

1) Forest belt for Segment 1
2) Grass belt for Segments 2-1 and 2-2
3) Local dike
4) Ring dike

(4) Excavation of Low Water Channel

Channel excavation works primarily aims to increase channel capacity and to normalize the river courses.

1) **Channel excavation:** Intensive channel excavation is not recommended for the rivers in the Terai plain, since the sediment in the upper watershed is not controlled yet. Therefore, channel excavation may be executed only for channel normalization in extremely narrow sections and for collecting materials for earth dikes.
2) **Collection of bed material:** Collection of riverbed material also contributes to the increase of the channel capacity, as far as the amount and places of collection are planned appropriately from a river control viewpoint. The collection can be undertaken on the coarse material bed such as in the alluvial fan.

Channel section: Wide channel has large capacity for floodwater transport but small capacity for sediment transport, which may result in silting up of channel sections. The designed width of the low water channel should be checked with the empirical relationship developed by Dr. Koichi Yamamoto (Fig. A2.4). Since this relationship was prepared based on the data of rivers in Japan, it is recommended to reproduce the relationship using data from Terai rivers in future.

(5) Realignment of Channel

1) **Cut-off Channel (COC):** This will ensure smooth flood and sediment flows by shortening and steepening the channel in meandering sections, and keep away the river course from the site to be protected. The COC may not be applicable to the channels in alluvial fan, since the river course is braided and unstable. The COC is planed considering the following:
   - Cut-off channel was planned for the severe by meandering channel.
   - Cut-off channel section was designed with the average width and depth of the existing river.
   - Closing dike shall close the head of the existing channel.
2) **Diversion Channel:** The primary functions of a diversion channel are to divert all or a part of the river water to alleviate flood discharge in the lower reaches, or to keep the river course away from the objects and areas to be protected. However, appropriate sites for diversion channels are difficult to locate for the rivers in the Terai plain, since these rivers take routes in parallel to each other, in a south-east direction, and the trans-basin of the flood water may cause another problem in the receiving river.

(6) Storage or Detention of Flood Water

1) **Dam Reservoir:** Dam reservoir to control flood and sediment flows is not applicable in class-III river basins, because of the poor geological conditions in the Siwalik hills. Single purpose dam for flood mitigation would not be economically feasible. As to multi-purpose dams, promising projects are not proposed at present for the river basins in the Study Area. Therefore, the dam schemes were not incorporated at present.
2) **Retarding Basin:** In order to reduce flood peaks in the downstream reaches, a retarding basin by conserving natural flood storage function can be considered. The retarding basin can be planned at the confluence of tributaries. It will (1) reduce runoff peak by spilling floodwater into the retarding basin; (2) collect flood water from the upper reaches; and (3) join tributaries without a drainage sluice, thereby as a back-water levee.

2.5 Community Development Component

The "Community Development Component" will consist of three sets of activities (Fig. A2.5). The "Community Mobilization" intends to build up organizational bases for the

Plan implementation. The "Local Coping Measures" will enable the communities to "live with flooding". The "Community-based Sustainable Measures" will motivate the local people to maintain and sustain the flood control structures.

This Master Plan will address both hazards (e.g., inundation, sedimentation, and bank erosion) and people's vulnerability (e.g., lack of awareness and motivation for flood mitigation, inadequate resources to adjust to flooding, lack of access to alternative sources of livelihoods) as shown in Fig. A2.5. The hazard control will be addressed by the "River Control" component (and partly by "Community-based Sustainable Measures" with some structural measures). The "Community Development" will promote vulnerability reduction in itself (by enhancing the people's capabilities to adjust to hazards, through "Local Coping Measures"), and also will bring the "River Control" component to impact on vulnerability (by linking the physical structures with community development, through "Community-based Sustainable Measures"). In this way, the "Community Development" component will contribute towards Comprehensive Flood Mitigation (tackling both hazards and vulnerability).

2.5.1 Community Mobilization

The "Community Development" will start with the "Community Mobilization" component, to strengthen the organizational bases for local flood mitigation initiatives (Fig. A2.6). Unlike the past practices in which the people are hastily "organized" primarily for the construction of physical facilities, more focus will be placed on awareness-raising and capacity-building of the communities themselves.

(1) Workshops for Local Government Institutions (LGIs)

There are specific set of "Community Development" activities that will be entrusted to the LGIs. Although the DIO even presently seeks the LGIs' cooperation in mobilizing the communities in flood control projects, the LGIs contribute only to labor hiring, with little regard to awareness-raising of the local people. 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. The subjects to be taken up in the workshops are as follows:

1) Technicalities of Flood Control Measures (functioning of various measures)
2) Local Initiatives for Flood Mitigation (actions expected of communities)
3) Community Mobilization Processes (procedures for community mobilization)

4) Facilitative Roles by LGIs (roles and responsibilities of LGIs)

(2) Creation of Organizational Bases at the Community

Formation of Community Organizations (COs)

1) **Step 1: Organize Settlement-wise Meetings:** An initial meeting will be held in each settlement, inviting all the households.
2) **Step 2: Dialogues with Communities:** This step is to enable the communities to understand the potential benefits of the Plan through a) Presentation of "Flood Control" Component, and b) Relating "Flood Control" with Other Local Needs
3) **Step 3: Establishment of COs for Forest/Grass Belts:** To develop and maintain the forest/grass belts, settlement-wise COs will be established, through a) Formalization of COs, b) Preparation of Forest/Grass Belt Operational Plan, and c) Registration of CO with the District Authority.
4) **Step 4: Strengthening of COs for Other Flood Control Works:** Where additional structures (other than forest/grass belts) are proposed, the CO will be strengthened, through a) Formation of Inter-CO Groups, where necessary, and b) Formulation of "Community Development" Action Plans.
5) **Step 5: Enter into Agreement with CO Groups:** Finally, a formal agreement is signed with COs, which stipulates project activities, time-frames and budgets, as well as responsibilities of both sides.

Promotion of Public Awareness, Knowledge & Skills

Once the COs are formalized, formal training will be conducted on the following topics:

1) **Technicalities of Flood Control Measures:** to understand how various measures are to function and are to be maintained, and also why continuous dikes are not opted.
2) **Skills in Masonry and Gabion-netting:** to gain employment during the construction stage, and also to obtain skill necessary for the maintenance activities.
3) **Community Participation in Flood Mitigation:** to understand modalities of "participation", e.g., labor/in-kind/cash contributions, as well as local practice.

Generation of Financial Resources by COs

The COs can generate financial resources through a) Forest/Grass Belt Products, b) Nursery Products (in case the communities run nurseries), and c) Group Savings. Savings will primarily be used as capital to for regular maintenance and minor repair of flood control structures, and/or for undertaking community-based flood mitigation activities. At the same time, it is important to assist COs in establishing a record keeping system, and in acquiring skills in running it in a transparent manner.

2.5.2 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, to complement the physical structures. The Plan component for "Local Coping Measures" will be undertaken on a community-by-community basis (Fig. A2.7). The following are a menu of support, in assisting local communities to enhance their local coping measures.

(1) Flood Proofing

The following are examples of flood proofing measures observed in the Terai plain:

1) **Agricultural Adjustments:**
   - Immediately after the summer crops are damaged, cultivate fast-growing crops (e.g., certain types of vegetables, Arun maize) which can even harvested in a few months' time - even in time for farmers to start winter crops;
   - Grow sweet potatoes if as a result of floods their farming lands are covered by thick sand, thus preventing them from cultivating other crops;
   - Where feasible, change from maize growing to rice cultivation which is less vulnerable to inundation, and in other words, more flood-resistant; and
   - Set aside rice seedlings, in order that they can re-plant paddies, even in case rice fields are destroyed due to flooding.

2) **Housing Structures:**
   - Construct houses on plinths, so that flood water flows underneath;
   - Raise grain stores on stilts, while build escape areas under roofs for family members and other valuables; and,

- Concentrate houses on higher grounds of the communities, to prevent residential shelters from being inundated during floods.

3) **Other Possible Flood Proofing Measures:**
   - Afforestation/reforestation on the riverbanks will serve to curtail the speed of overflow water in case of emergencies;
   - In low-lying areas, drainage will serve to reduce the level of inundation as well as to improve hygienic conditions during the monsoon; and,
   - Small-scale reservoirs (e.g., creation/expansion of new/existing ponds) on community-owned barren land.

One modality of possible support is to introduce the above-mentioned practices to localities where they are feasible but sill unknown. Some communities may be facing the resource constraints, which can be supported with the supply of those lacking materials. Moreover, support will also be provided even to existing flood proofing efforts, when there is scope for further improvements.

(2) Forecasting, Warning, & Evacuation

The following are some of such examples of local measures:

1) **Forecasting and Warning:** Some people anticipate floods when they observe;
   - Changes in the water flow (e.g., rising levels of water, river water mixed with mud, leaves floating on the water, increasing number of fish);
   - Unusual sound/smell of rivers (e.g. rumbling sounds coming from the river, muddy smells of the stream); and,
   - Continued rainfall in surrounding areas, or in the upper watersheds.

2) **Evacuation:**
   - Stay in under-roof areas/ on rooftops, until floodwater subsides;
   - Stay on trees (e.g., bananas, and mangoes) planted around houses;
   - Evacuate to neighbors' second-story houses, or to others' houses in surrounding areas on higher grounds; and,
   - Shift valuables (e.g., money, grain, and livestock) to safer areas, before the monsoon season starts.

For both "forecasting/warning" and "evacuation", a possible strategy is to improve upon

local measures (e.g., it is fairly common that warning and evacuation are undertaken individually, which can be organized as joint efforts). More systematic approaches to forecasting/warning simply by utilizing existing facilities, such as P.C.O. (Public Call Office). In localities that find it difficult to secure suitable evacuation sites, support will be provided, e.g., in developing accessible roads to safer areas.

(3) Flood Fighting

The following are examples of local flood fighting measures:

1) Install bamboo piles as bank protection works;
2) Grow indigenous shrubs on the land-cutting sites;
3) Plant bamboo on river banks as protective works;
4) Construct temporary spurs made of logs;
5) Use sandbags with bamboo piles; and
6) Place boulders and tree trunks, where embankments are being breached.

However, such village-level measures often lack technical soundness. In such cases, the faults will be corrected with the provision of technical advice. Where certain materials are not available locally, support will be extended for the local communities themselves to procure or produce those materials locally. Only for those materials beyond the reach of the local populations will be donated to the local communities.

2.5.3 Community-based Sustainable Measures

The "Community-based Sustainable Measures" component is to derive additional benefits from the physical facilities, and to motivate the beneficiaries to sustain the structures (Fig. A2.8). (1) forest/grass belts, (2) preventive bank protection works will derive tree/grass products out of the flood control measures, while (3) access improvements, (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.

(1) Forest/Grass Belts as Dike Works

The flood mitigation plan envisages the development of forest/grass belts. Table A2.1 shows a list of potential candidate trees/shrubs/grass that can be used as part of the Belts. The belts will also serve various necessities of the local residents. As illustrated in

Table A2.2, there are various local trees, shrubs, and grass that are of multi-purpose (e.g., fuel, timber, roofing, etc). The COs can sell surpluses of forest products in the market. Moreover, in case the local communities choose those species that require nurseries, the COs can sell extra seeds/seedlings that are produced in their nurseries.

In addition to these direct opportunities, there are also multitude of indirect benefits that farmers can tap into. Certain trees/grasses can be used to promote livestock farming, i.e., as fodder for domestic animals (e.g., buffaloes, goats, and cows). In places where bioengineering strategies include forestry development, bee keeping, ginger/turmeric farming, and coffee growing could also be initiated near/in the forests.

(2) Preventive Bank Protection Works

There are broadly two types of bank protection works that the local communities can undertake using their own resources. One is the construction of flood control works entirely relying upon local materials (e.g., bamboo and sandbags). In some cases, the communities attempt to contain bank erosion and/or flooding by installing revetments/spurs using local materials such as bamboo and sandbags. These will be disseminated where the velocities are not high. Local communities will also be assisted to generate their own resources, e.g., the plantation of bamboo, group savings to purchase sandbags themselves. The government agencies will also be encouraged to refrain from handing out those materials, to the extent possible.

Another modality of local bank protection works is the plantation of trees/shrubs/grass, usually to supplement engineering structures. Bioengineering will help derive at long-term stability of the river control measures, by stabilizing the land that adjacent to the engineering structures. It will be used to derive tree/grass products. As Table A2.2 shows, there exist two categories of income-earning opportunities, i.e., one emanates from sales of extra seeds and seedlings produced in nurseries, and the other from the supply of tree products, e.g., fuel wood, fodder, and timber. In addition to extension activities, support will also be extended to those localities that already practice bioengineering, but still have room for improvements (e.g., introduction of higher-value species).

(3) Access Improvements using Flood Control Structures

Flood mitigation projects, when dikes are constructed, provide opportunities to simultaneously develop rural road networks. In some places, the dikes alone will be

designed as access roads. In other areas, short-distance unpaved roads (gravel, or earthen) will be constructed, to link embankments with outside road networks. Where revetments will be constructed, it is expected that the riverbanks are also stabilized. Therefore in places where access improvements are required, gravel and/or earthen roads will be developed along those banks.

In doing so, it is important to take into consideration a variety of expectation people may have concerning accessibility improvements, e.g., to transport agricultural products, to send children to school, to go to health clinics, or to attend village meetings. One critical issue, in the context of flood mitigation, is the damages to roads during flooding which prevent the people for evacuating to safer sites. In such places, support will be extended to link road development with the evacuation requirements.

Community-based approaches have been extensively tested for rural road construction at various locations in Nepal. Such approaches can encourage people to contribute their own resources to the rural road projects (e.g., land, labor, construction materials, and cash). This way, local road projects contain unit costs of road construction, usually ranging from 50,000 to 80,000 Rs/km for gravelling earthen roads.

(4) Bed Material Collection as Channel Excavation Works

Many rivers in the Terai are being mined for sand, gravel and boulder, which serves as one important source of revenues for many District Development Committees (DDCs). More importantly, sand/gravel/boulder collection from a riverbed can be part of a river training scheme, which serves to increase the transport capacity of a river. It can also provide employment opportunities for rural people in the Terai plain.

It is to be noted bed material collection is not feasible in all the areas along the rivers. Certain localities face the constraints of (a) unavailability of sand/gravel, (b) low quality of sand /gravel, (c) lack of roadways roads from outside to excavation sites, (d) distance to transport to markets, (e) lack of flexible/clear-cut rules and regulations, and (f) objections from community members. However, efforts can be made to redress the above-mentioned constraints except (a) and (b).

Despite the high demands for sand/gravel/boulder, riverbed extraction should not be promoted *laissez-faire*. On the contrary, tighter control should be exercised over contractors, to minimize the extraction of sand/gravel/boulder in accessible locations

(near riverbanks or bridges). Generally speaking, it is necessary to dig in the middle part of the river where the sediments are deposited and which generally causes the diversion of river flow towards the banks.

(5) Operation and Maintenance of Flood Control Structures

The local communities will be responsible to constantly monitor the sites, and when necessary, seek external support for rehabilitation. For revetment works made of galvanized iron (G.I.) wire boxes, community will be instructed to monitor the river bed, and when it is scoured, to place stones and rubbles on the river bed. When the gabion wire is cut, the local residents will request the DIO, through the DDC/VDC, for additional nets. It is also necessary, on a regular basis, to remove objects which may be hooked to the G.I. wire boxes.

Gabion spurs and permeable types of pile spurs, similarly, require monitoring of the riverbeds. When the surface of the riverbeds are washed off, it is crucial to stabilize the foundation of the spurs by placing stones and rubbles on the riverbeds. Moreover, the local residents need to ensure that any objects hooked to the piles or the gabion should be removed. In case of gabion spurs, it is also desirable to plant grass or shrubs on the sand-deposit areas, to stabilize the land adjacent to the structures.

Dike works are subject to scouring of their slopes, given its objective to counteract the flood forces. It is therefore critical to ensure that the local communities undertake timely repairs of slope failures. Moreover, it is expected that the dikes are also used as rural roads throughout the year. In this respect, another maintenance task required is to watch the conditions, and whenever necessary to flatten the bumps of the dike roads.

(6) Land Use Management

The purpose of land use management is to ensure flood risks are not worsened by ill-conceived land uses, by conserving the land adjacent to the rivers. Along the target rivers, the following types of poor land use are observed.

1) **Over cultivation:** Farmers with land adjacent to the rivers cultivate right on the riverside. This exacerbates soil compaction, thus accelerating bank erosion.
2) **Over grazing:** Pasture land along the target rivers is usually used freely by herdsmen, which cause overgrazing problems. This leads to the reduction of vegetation cover, which also stability of the riverbank.

3) **Deforestation:** Not all the forests along the rivers are properly managed. Some are being deforested, while others are maintained but not in a manner conducive to soil conservation.

Against this background, it is crucial for the local communities to agree on local rules and practices that will stop the above-mentioned poor land use management. Those with landholdings on the riverside will be encouraged to stop over cultivation. This can be promoted, through the introduction of high yield crops, or other income-generating activities, e.g., livestock raising. It is important for the farmers to gain alternative sources of income to compensate for the loss of cultivated land. To curb over grazing, more organized systems of pasture land management will be initiated, e.g., rotational grazing, and fodder plantation. Planting of trees near the rivers will be also promoted, both on community land as well as on private farmlands.

2.6 Flood Mitigation Plan

Based on the discussions and analyses made so far, Master Plan for flood mitigation activities by the target year 2017 was worked. The Master Plan still remains at the concept level, since the planning was made on the topographic map basis (scale 1/25,000 and partly 1/50,000) and the river survey data were not available. In future the Master Plan should be upgraded based on a river survey to be conducted, in line with the concept of flood mitigation described here.

(1) Present Conditions and Problems

1) River basin:
   - Class-III river in Central Development Region
   - Basin area: 300 km^2 in total consisting of mountainous basin 106 km^2 and plain area 194 km^2.
   - Middle and lower portions of the flood prone areas are the service areas of the Bagmati Irrigation Project.
2) River system: Major tributaries are the Baune and Chapani rivers.
3) River channel: River is wide and braided in the upper reaches and becomes narrower gradually toward lower reaches. Riverbed materials ranges from fine sand in the lower reaches to very coarse gravel in the upper reaches.
4) River segments:
   - Segment 2-2: From 0.0 km (Indian border) to 21.0 km
   - Segment 2-1: From 21.0 km to 37.0 km

- Segment 1 : From 37.0 km to 51.4 km (upper end)

5) Flood and sediment disasters:
   - Recent major floods: 1997,1993 and 1995 floods in order of severity
   - Kinds of damages: Sedimentation, bank erosion and flooding over farm lands
   - Suffering areas: 27 villages in 11 VDCs in Sarlahi district
   - Conditions and mechanism of flooding: The Lakhandei river floods over the riverine area almost every year. The flood and sediment disasters are caused not only by the runoff from its own basin, but flood water from the Bagmati river as well. The 1997-August flood inundated the lands as deep as 1.5 m for 3 to 7 days, causing extensive damages due to sedimentation and inundation over the farm lands. The 1997-flood also brought about diseases such as malaria, dysentery and typhoid, resulting in loss of 91 human lives in the whole Sarlahi district.

(2) Principal Measures to be Taken

1) A branch and anabranches at 26.1 km, 16.3 km and 31.9 km will be closed securely with diversion facilities if necessary.
2) Forest belt will be provided along the river boundary line (RBL) for Segment 1 and grass belt for Segments 2-2 and 2-1.
3) Cut-off channel will be constructed at severe bends.
4) An area at the confluence of the Lakhandei and Chapani rivers will be preserved for retarding basin.
5) Bank protection works by a series of spurs will be implemented based on the monitoring result of riverbanks. Preventive measures for bank erosion will also be taken by adopting bioengineering approach.
6) Watershed management will be carried out for erosion and runoff control.
7) Flood plain management will be carried out for mitigation of damage due to flood and sediment disasters.

(3) Layout Plan

Layout of the flood mitigation Master Plan is shown in Fig. A2.9.

(4) Project Works and Cost

Quantities of works for the Master Plan were estimated based on the standards and

assumptions discussed in the previous sections, and preliminary cost required for the project implementation was estimated under the following conditions:

1) Price Level: The project cost and other related unit costs are expressed under the economic conditions prevailing in October 1998.

2) Exchange Rate of Currencies: Exchange rate of currencies are assumed as follows:

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

3) Constitution of Project Cost: Project cost is the sum of construction base cost, land and compensation cost, administration cost, engineering, physical contingency and value added tax. Calculation is carried out based on the following:
   (1) Construction base cost = (Work volume) x (Unit work cost)
   (2) Land and compensation cost = (Area of land to be acquired and number of houses to be relocated) x (Unit cost)
   (3) Administration cost = 5% of (1)
   (4) Engineering service cost = 10% of (1)
   (5) Sub-total = (1) + (2) + (3) + (4)
   (6) Physical contingency = 10% of (5)
   (7) Price contingency =Assumed annual escalation rate at 3% for foreign currency portion, and 10% for local currency portion
   (8) Value added tax = 10% of (5) + (6) + (7)

Quantity of work, unit work cost and amount of project cost are shown in Table A2.3. Annual disbursement of investment cost was estimated on the basis of the implementation schedule. The annual disbursement schedule of financial and economic costs for Lakhandei river are shown in Table A2.4.

CANDIDATE SPECIES FOR BIOENGINEERING WORKS IN TERAI

	Naturally Grown Species	Nursery Species
Grasses	- Arundo clonax (Narkato) - Cymbopogon microtheca (Khar) - Cymbopogon pendulus (Dangre Khar) - Cynodon dactylon (Dhubo) - Eulaliopsis ninanta (Babiyo, Sabai Grass) - Neyraudia arundinacea (Sito) - Neyraudia reynaudiana (Dhonde) - Pennisetum clandestinum (Kikuyu, Thulo Dhubo) - Pogonatherum paniceum (Musekharuki) - Saccharum spontaneus (Kans)	- Desmodium intortum - Pennisetum purpureum (Napier) - Setaria anceps - Thysanolaena maxima (Amliso) - also in forests - - Stylo - Molasess grass
Shrubs & Non-Plantation Trees	- Adhatoda vasica (Assuro) - Butea minor (Bhujetro) - Calatorpha giganteum (Aak) - Colebrookea oppositifolia (Chusun) - Ipomoea fistulata (Saruwa --- Beheu) - Lantana camara (Phul Kanda) - Phoenix humilis (Thakal) - Trema orientalis (Kunyelo) - Vitex negundo (Simali) - Wedlandia species (Tilka) - Woodfordia fruticosa (Dhanyero)	
Trees	- Acacia catechu (Khayer) --- also in nursery - Acacia auriculiformis - Albizia julibrissin - Ficus semicordata (Khasre Khayu, Khanayo) - Shorea robusta (Sal) -- also in nursery	- Bauhinia purpurea (Tanki) - Delonix regia (Gulmohar) - Leucaena species (Ipil Ipil) - Bamboo species

source: "Vegetation Structures for Stabilizing Highway Slopes", Dept. of Roads, 1991

INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

From:	Species Used	Income-generating Products
Nursery	<u>Trees</u>	
	- Acacia catechu (Khayer)	- saplings
	- Shorea robusta (Sal)	- saplings
	- Bauhinia purpurea (Tanki)	- saplings
	- Delonix regia (Gulmohar)	- seeds/saplings
	- Leucaena species (Ipil Ipil)	- seeds/saplings
	- Bamboo species	- roots
	<u>Grasses</u>	
	- Desmodium intortu	
	- Pennisetum purpureum (Napier)	- seeds
	- Thysanolaena maxima (Amliso)	- cutting
	- Stylo	- seeds/cutting
	- Molasess grass	- seeds
		- seeds
Bio-Engineering Facility	<u>Grasses</u>	
	- Desmodium intortum	- fuel wood
	- Pennisetum purpureum (Napier)	- fodder/mulching
	- Thysanolaena maxima (Amliso)	- fodder/broom
	- Stylo	- fodder/seed
	- Molasess grass	- fodder/seed
	- Arundo clonax (Narkato)	- fencing
	- Cymbopogon microtheca (Khar)	- roof thatch
	- Cymbopogon pendulus (Dangre Khar)	- roof thatch
	- Cynodon dactylon (Dhubo)	- fodder
	- Eulaliopsis ninanta (Babiyo)	- rope
	- Saccharum spontaneus (Kans)	- roof thatch/rope
	<u>Shrubs</u>	
	- Adhatoda vasica (Assuro)	- green manure/medicine
	<u>Trees</u>	
	- Bamboo species	- furniture/timber
	- Bauhinia purpurea (Tanki)	- fodder/fuel wood
	- Delonix regia (Gulmohar)	- fuel wood
	- Leucaena species (Ipil Ipil)	- fodder/fuel wood
	- Acacia catechu (Khayer)	- timber/fuel wood/medicine
	- Shorea robusta (Sal)	- leaf plate

source: "Vegetation Structures for Stabilizing Highway Slopes", Dept. of Roads, 1991

PROJECT COST FOR MASTER PLAN

LAKHANDEI RIVER (unit: NRs1000)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				348,680
1. Preparatory Works	L.S.	1.00		31,698
2. Bank Protection Works				131,417
2-1 Pile Spur (Type-A)	km	6.90	5,301	36,577
2-2 Gabion Spur (Type-A)	km	11.50	8,247	94,841
3. Cannel Works				108,416
3-1 River Boundary Line	km	75.50	27	2,039
3-2 Tree Belt	ha	27.50	68	1,870
3-3 Grass Belt	ha	350.00	126	44,100
3-4 Channel Excavation	$1000m^3$	461.59	93	42,928
3-5 Closing Dike/structure	place	8.00	2,185	17,480
4. Ring Dike Works				24,699
4-1 Dike Embankment	km	5.30	2,596	13,759
4-2 Drainage Sluice	place	4.00	1,275	5,100
4-3 Gravel Metaling	km	5.30	1,102	5,841
5. Dike Road Works				23,632
5-1 Dike Embankment	km	6.55	2,506	16,414
5-2 Gravel Metaling	km	6.55	1,102	7,218
6. Miscellaneous Works	L.S.	1.00		28,817
II . Compensation Cost	L.S.	1.00		120,771
III. Administration Cost	L.S.	1.00		23,473
IV. Engineering Service	L.S.	1.00		52,302
V . Physical Contingency	L.S.	1.00		52,175
Poject Cost				597,401

Note: *1 Price Level in October 1998
*2 Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
*3 Cost do not include Price Contingency and Value Added Tax
*4 Figures may not add up to totals due to rounding

ANNUAL DISBURSEMENT SCHEDULE OF LAKHANDEI RIVER PROJECT FOR MASTER PLAN

(Financial Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	348,680	0	0	0	30,377	30,377	30,377	19,811	19,811	19,811	19,811	19,811	19,811	19,811	19,811	19,811	19,811	19,811	19,811	19,811
1. Preparatory Works	31,698	0	0	0	10,566	10,566	10,566	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	131,417	0	0	0	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214	8,214
3. Channel Woks	108,416	0	0	0	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776	6,776
4. Ring Dike Works	24,699	0	0	0	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544	1,544
5. Dike Road Woks	23,632	0	0	0	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477	1,477
6. Miscellaneous Works	28,817	0	0	0	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801	1,801
II . Compensation Cost	120,771	0	0	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	7,548	0
III. Addministration Cost	23,473	0	0	377	1,896	1,896	1,896	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368	991
IV. Engineering Cost	52,302	8,717	8,717	8,717	2,278	2,278	2,278	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486
1. F/S, D/D etc.	26,151	8,717	8,717	8,717	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	26,151	0	0	0	2,278	2,278	2,278	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486	1,486
V. Physical Contingency (10% of Items I , II &IV)	52,175	872	872	1,627	4,020	4,020	4,020	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,130
VI. Total	597,401	9,589	9,589	18,269	46,121	46,121	46,121	33,098	33,098	33,098	33,098	33,098	33,098	33,098	33,098	33,098	33,098	33,098	33,098	24,418

Note: *1 Price Level in October 1998
*2 Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
*3 Cost do not include Price Contingency and Value Added Tax
*4 Figures may not add up to totals due to rounding

(Economic Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	313,812	0	0	0	27,340	27,340	27,340	17,830	17,830	17,830	17,830	17,830	17,830	17,830	17,830	17,830	17,830	17,830	17,830	17,830
1. Preparatory Works	28,528	0	0	0	9,509	9,509	9,509	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	118,276	0	0	0	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392	7,392
3. Channel Woks	97,575	0	0	0	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098	6,098
4. Ring Dike Works	22,229	0	0	0	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389	1,389
5. Dike Road Woks	21,269	0	0	0	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329	1,329
6. Miscellaneous Works	25,935	0	0	0	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621	1,621
II . Compensation Cost	108,694	0	0	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	6,793	0
III. Addministration Cost	21,125	0	0	340	1,707	1,707	1,707	1,231	1,231	1,231	1,231	1,231	1,231	1,231	1,231	1,231	1,231	1,231	1,231	892
IV. Engineering Cost	47,072	7,845	7,845	7,845	2,050	2,050	2,050	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337
1. F/S, D/D etc.	23,536	7,845	7,845	7,845	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	23,536	0	0	0	2,050	2,050	2,050	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337
V. Physical Contingency (10% of Items I , II &IV)	46,958	785	785	1,464	3,618	3,618	3,618	2,596	2,596	2,596	2,596	2,596	2,596	2,596	2,596	2,596	2,596	2,596	2,596	1,917
VI. Total	537,661	8,630	8,630	16,442	41,509	41,509	41,509	29,788	29,788	29,788	29,788	29,788	29,788	29,788	29,788	29,788	29,788	29,788	29,788	21,976