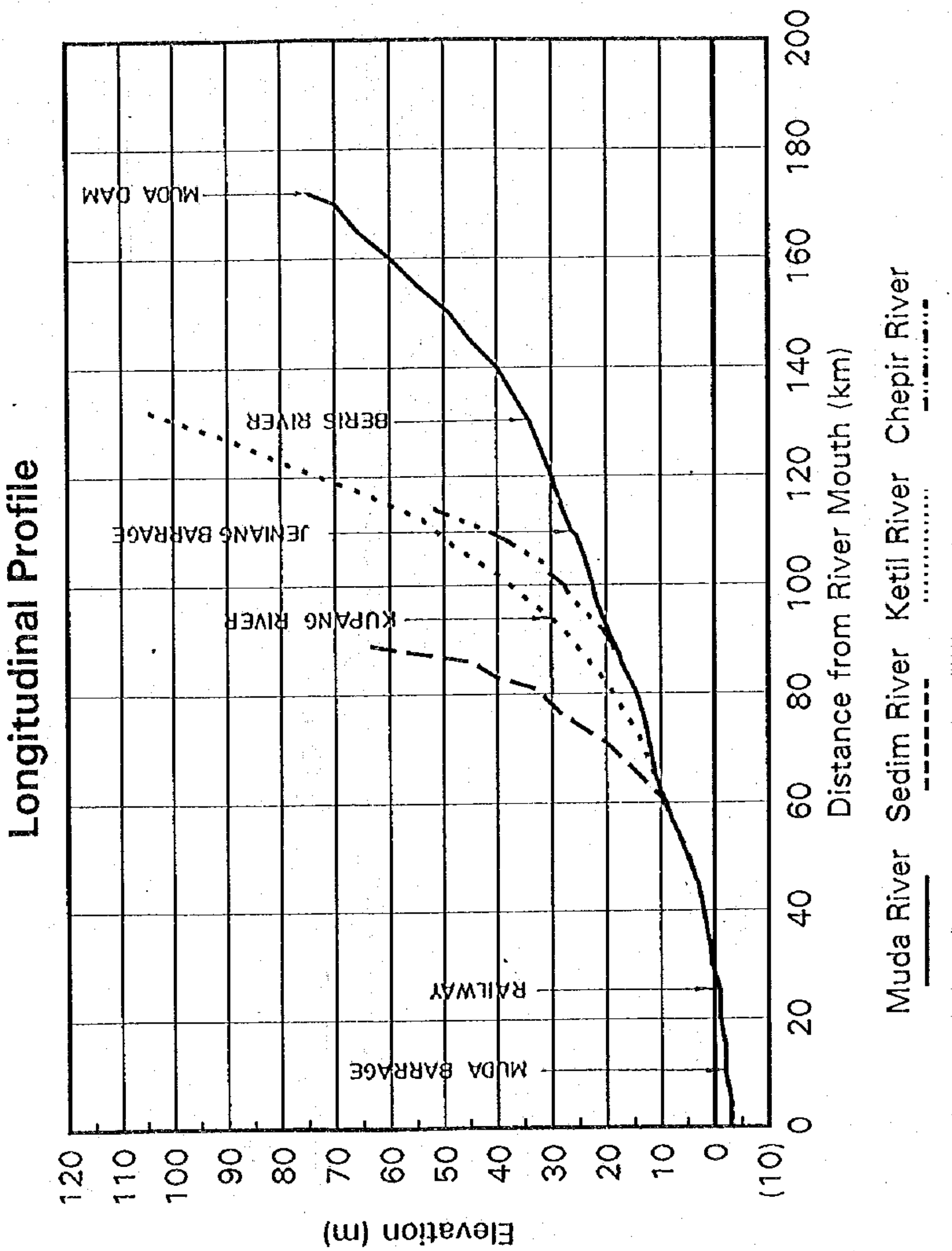
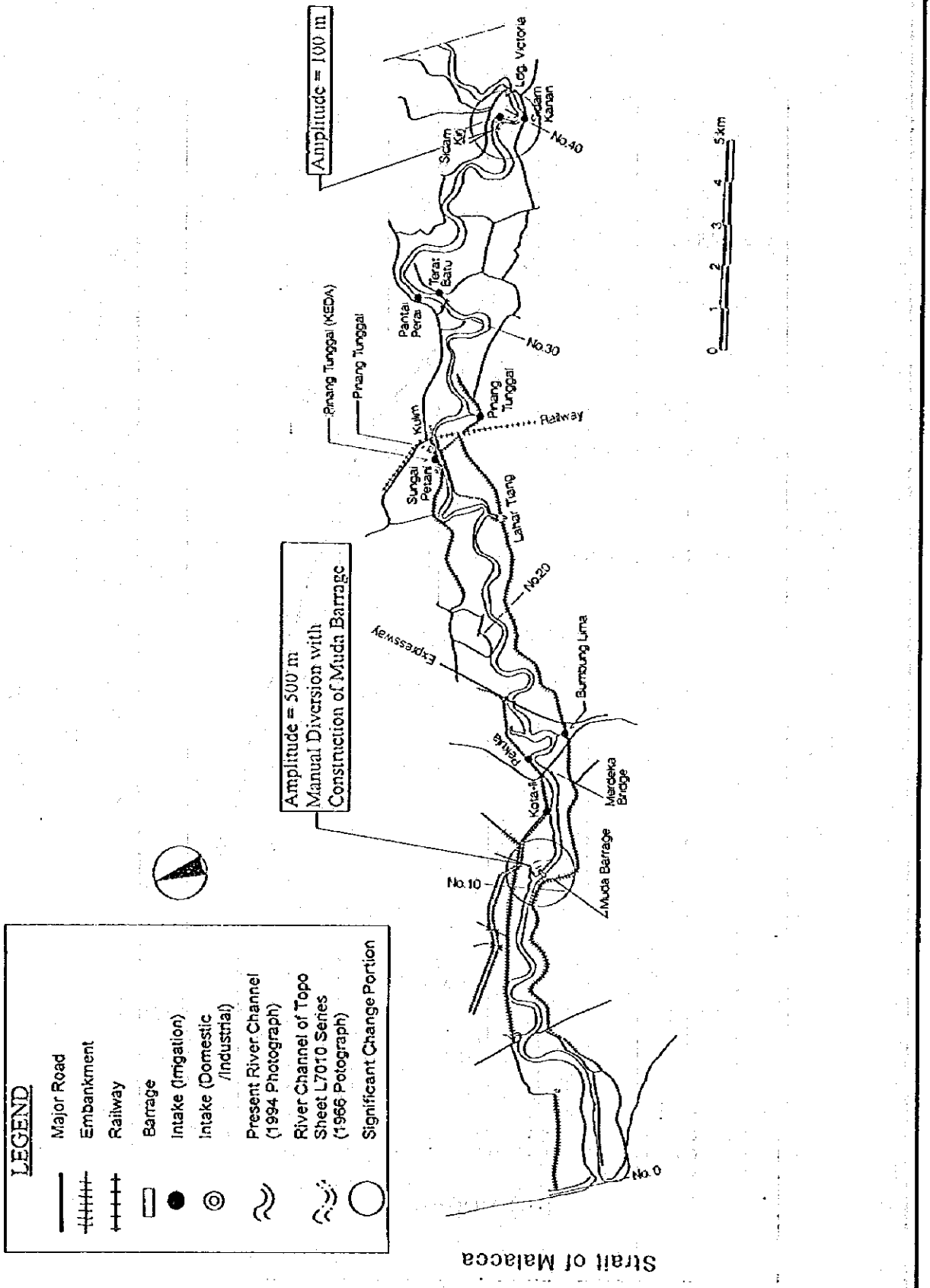
FIGURES

SECTOR II

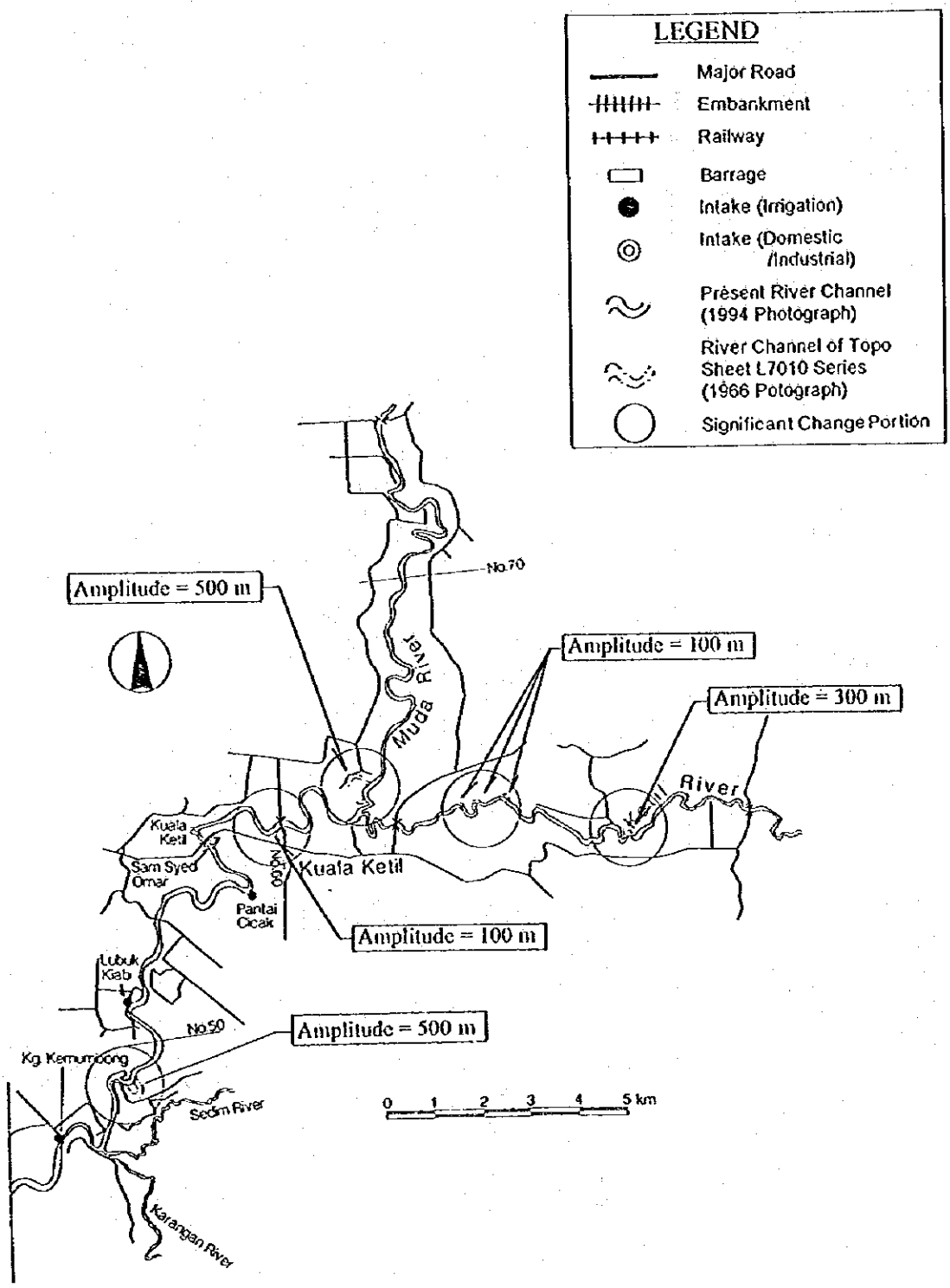
FLOOD MITIGATION PLAN



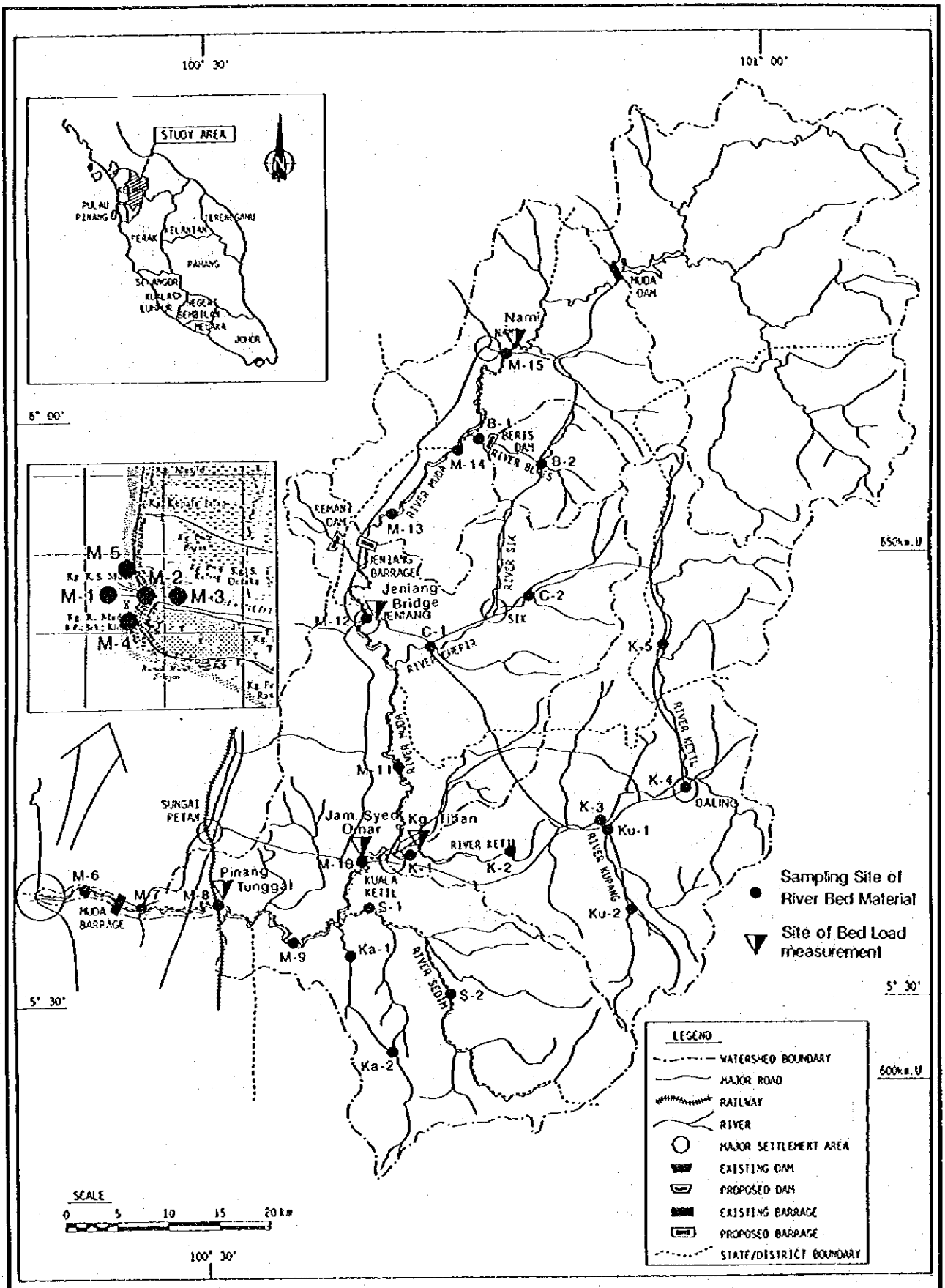
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.1.1.1
JAPAN INTERNATIONAL COOPERATION AGENCY	LONGITUDINAL PROFILES OF MUDA RIVER AND TRIBUTARIES



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.1.1.2 (1/2) LOCATION OF RIVER COURSE CHANGE
JAPAN INTERNATIONAL COOPERATION AGENCY	



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.1.1.2 (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF RIVER COURSE CHANGE

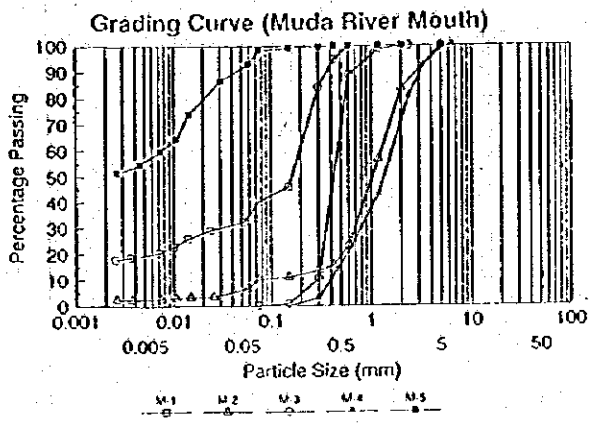


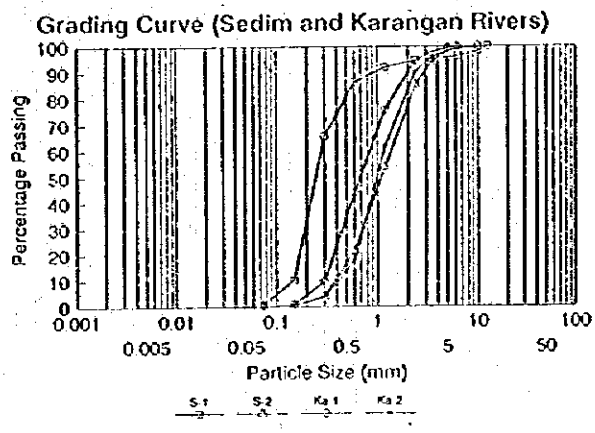
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

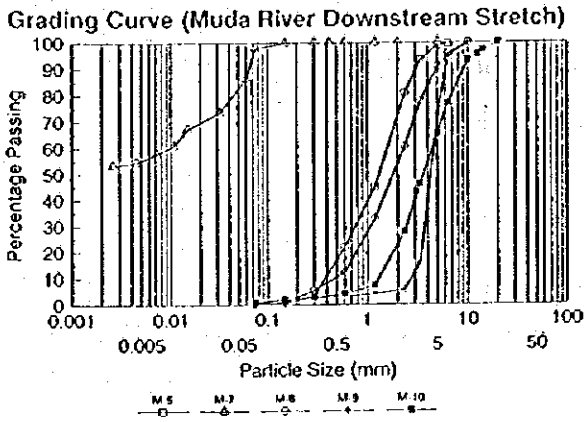
JAPAN INTERNATIONAL COOPERATION AGENCY

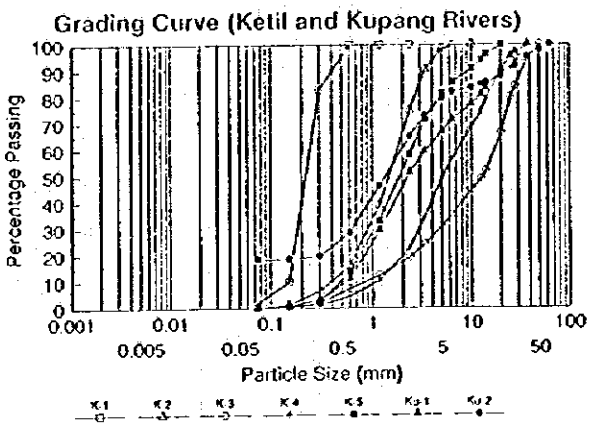
FIG. II.1.2.1

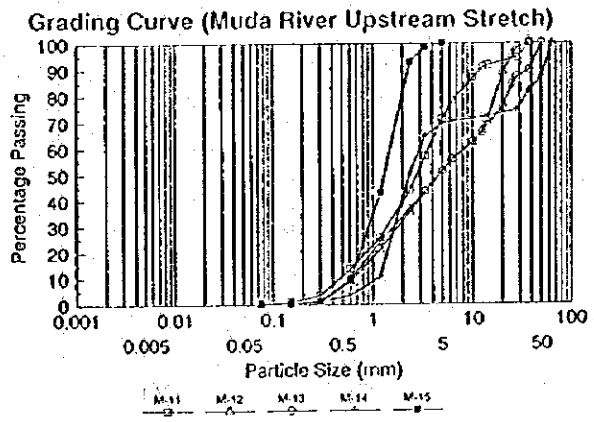
LOCATION OF RIVER SEDIMENT SURVEY

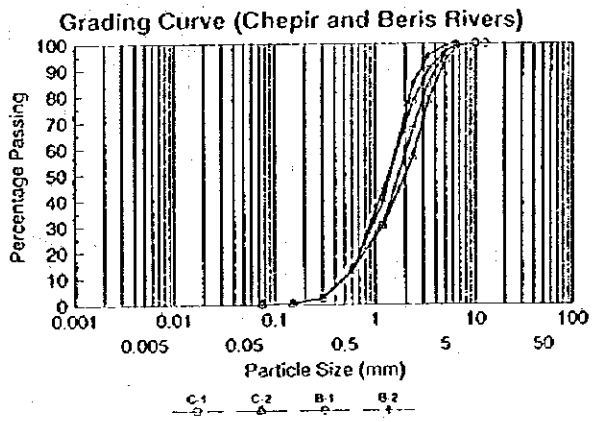




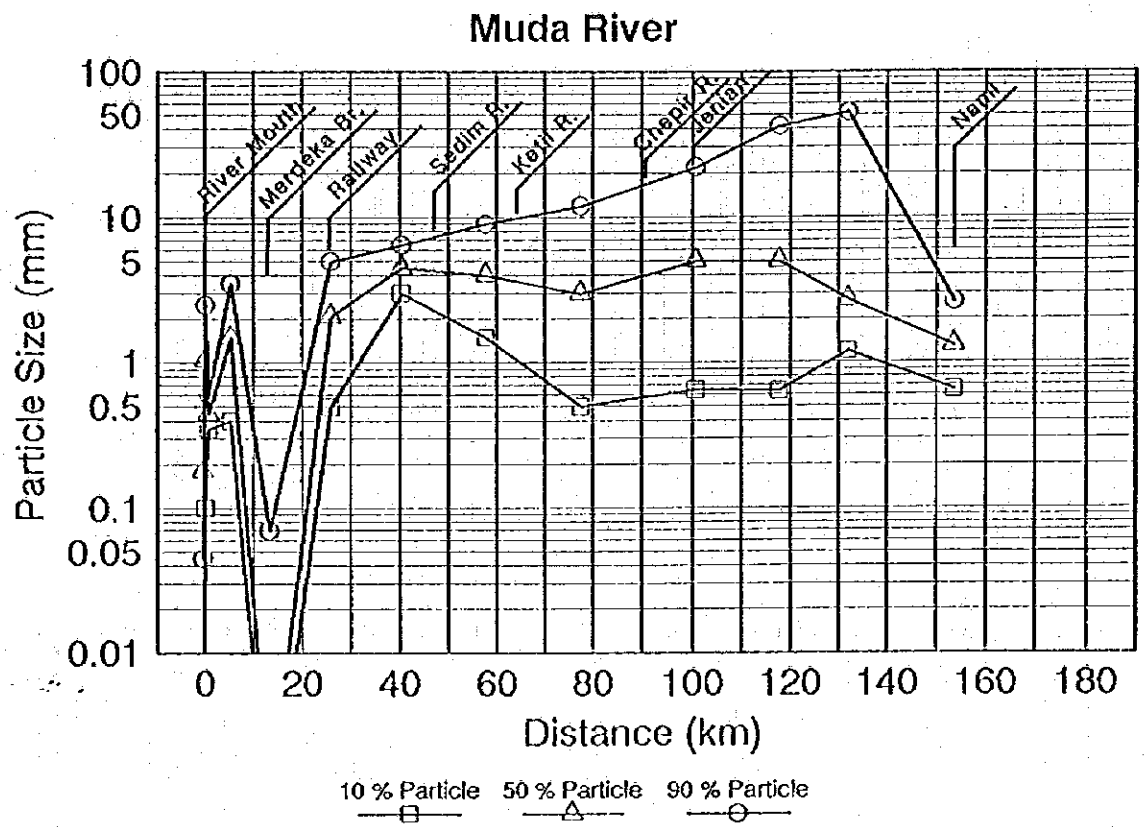


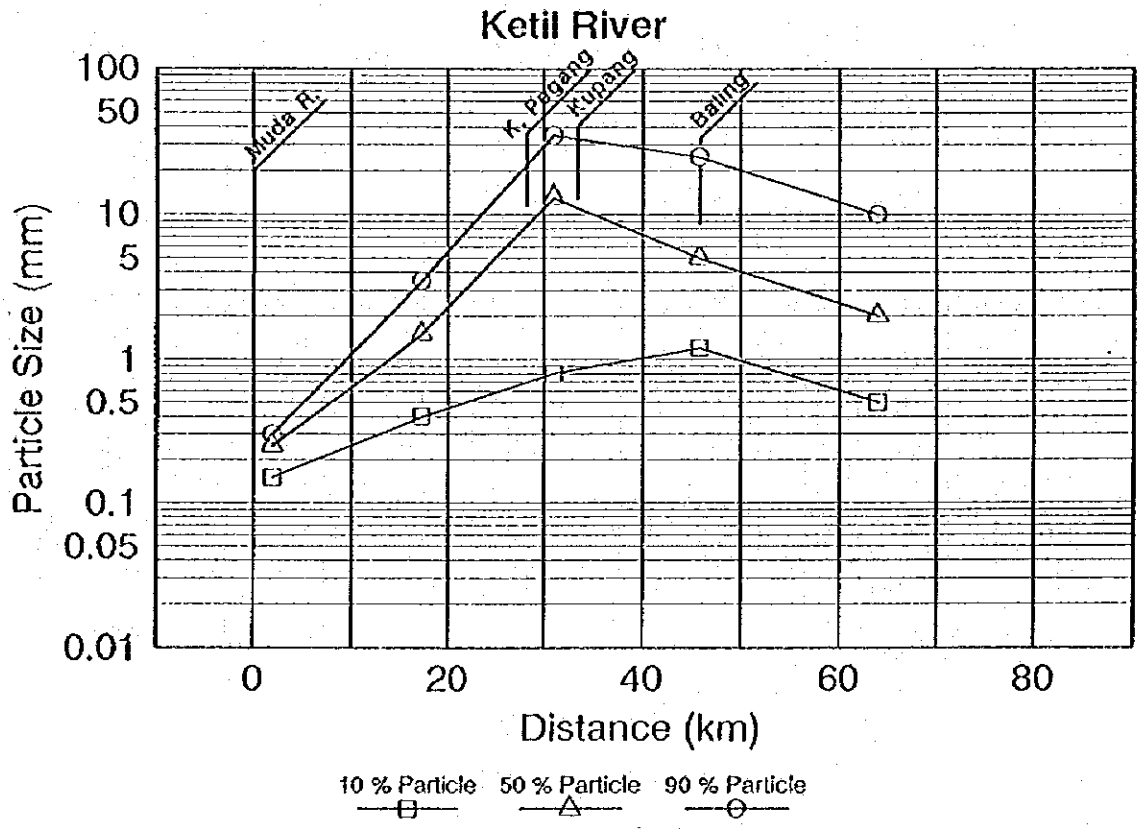




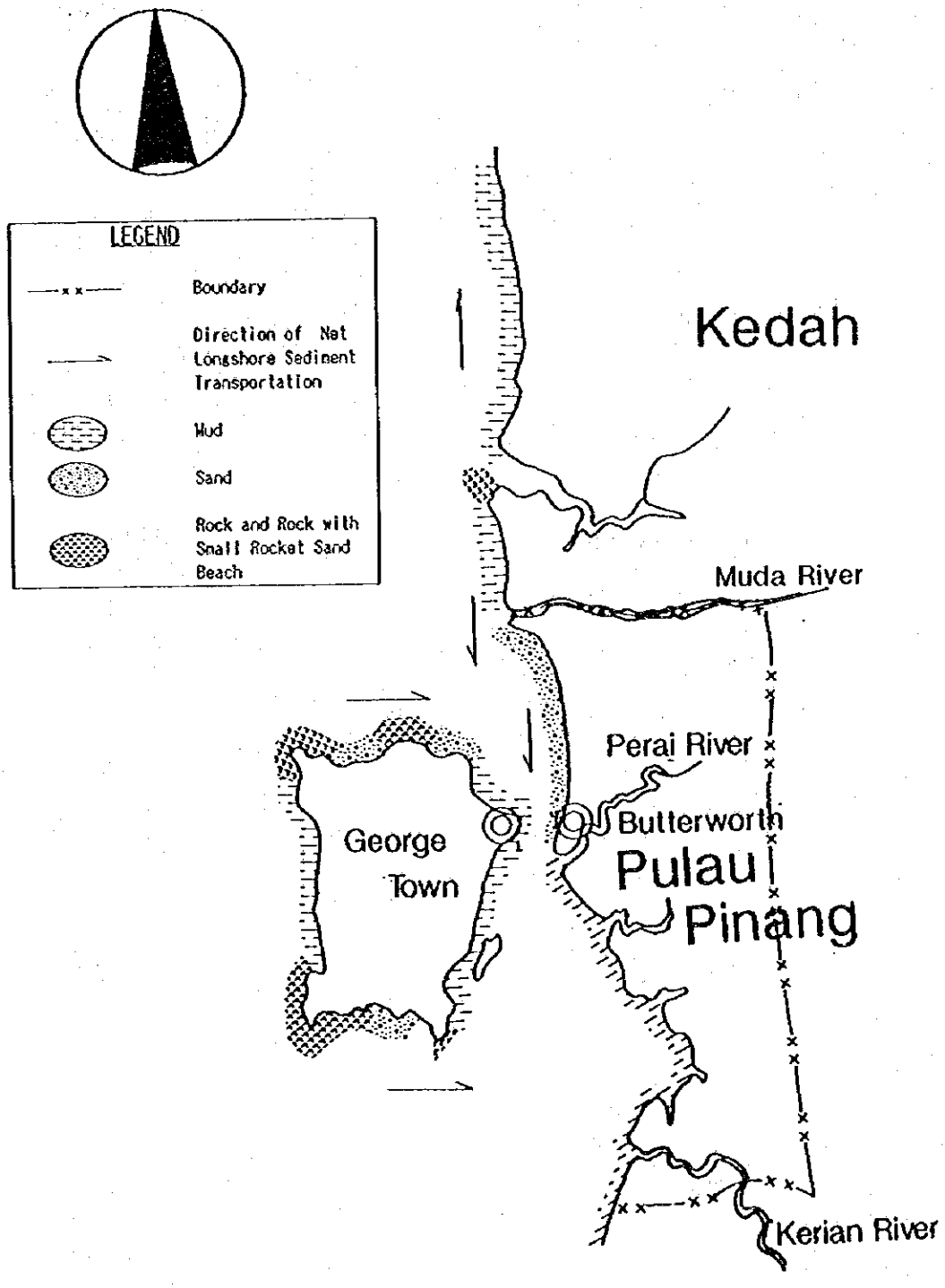


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.1.2.2
JAPAN INTERNATIONAL COOPERATION AGENCY	GRADING CURVES OF RIVER BED MATERIAL IN MUDA RIVER SYSTEM



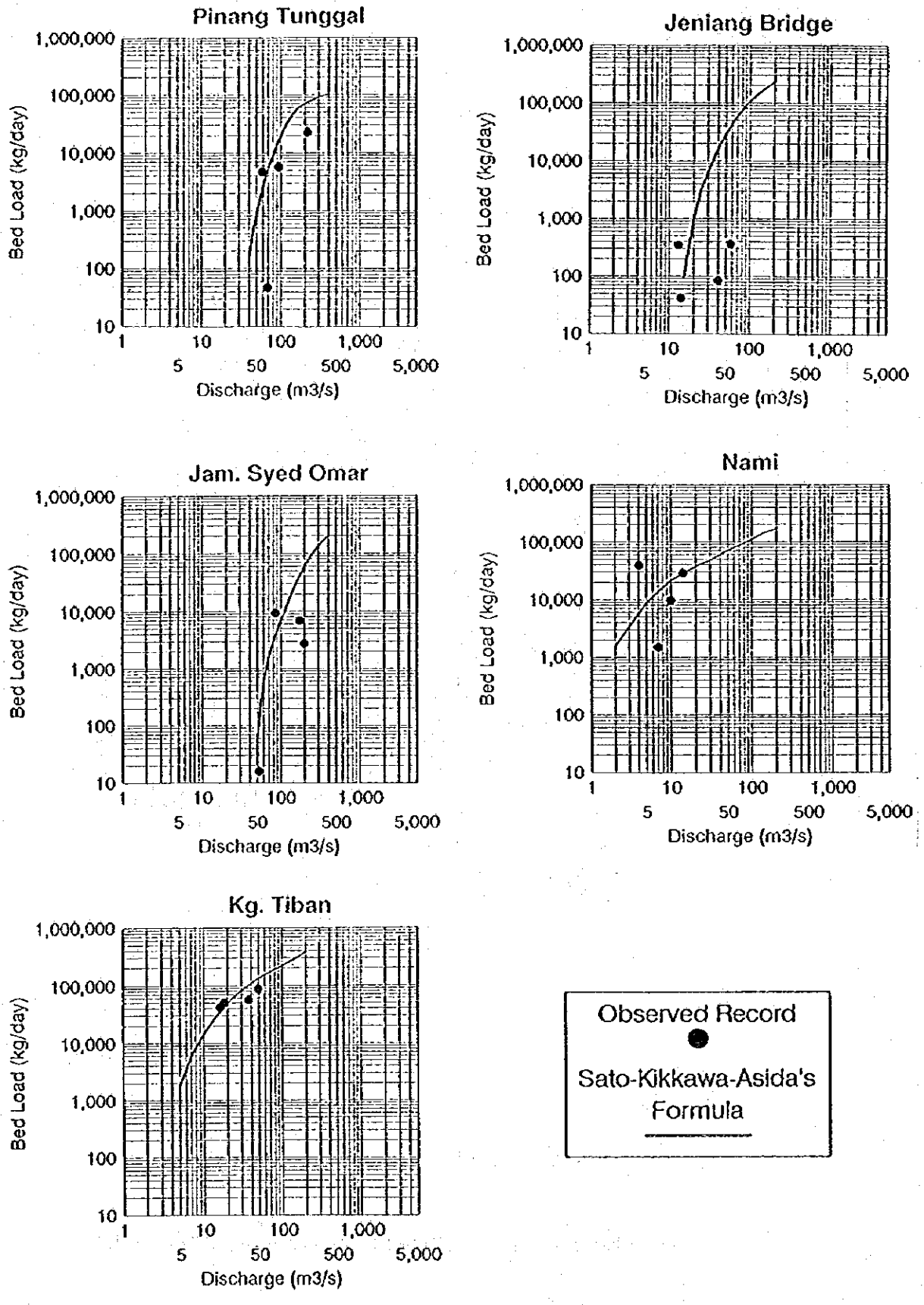


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.1.2.3 LONGITUDINAL DISTRIBUTION OF PARTICLE SIZE ALONG MUDA AND KETIL RIVERS



Data Source: National River Months Study, 1994. JICA

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.1.2.4 BEACH MATERIAL DISTRIBUTION AND DIRECTION OF LONGSHORE SEDIMENT TRANSPORTATION
JAPAN INTERNATIONAL COOPERATION AGENCY	

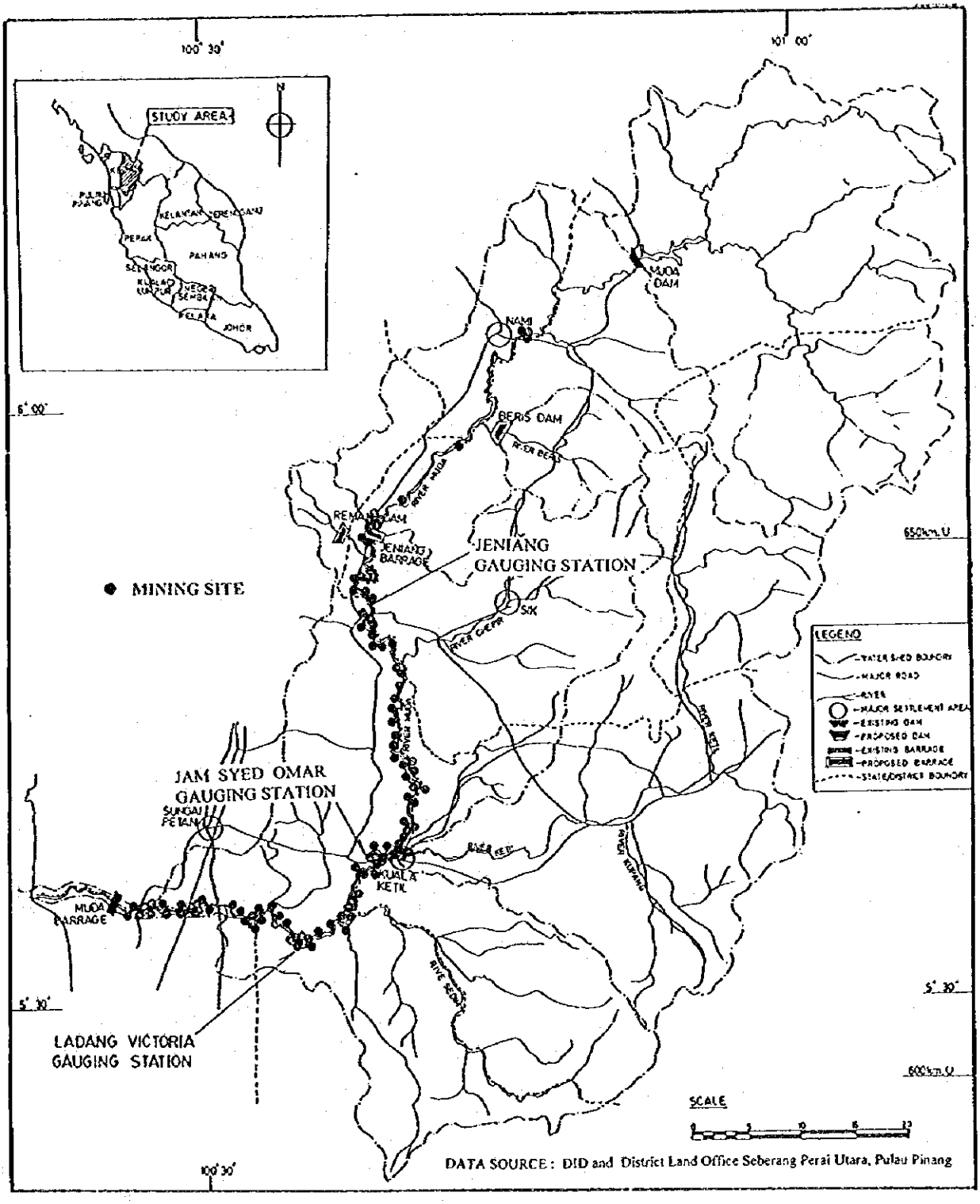


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

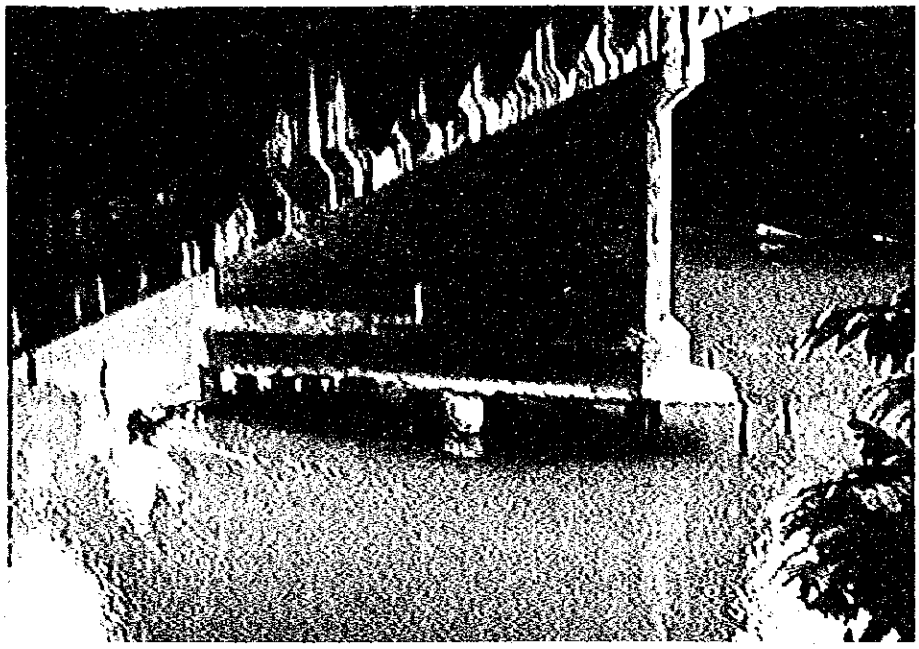
JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.1.3.1

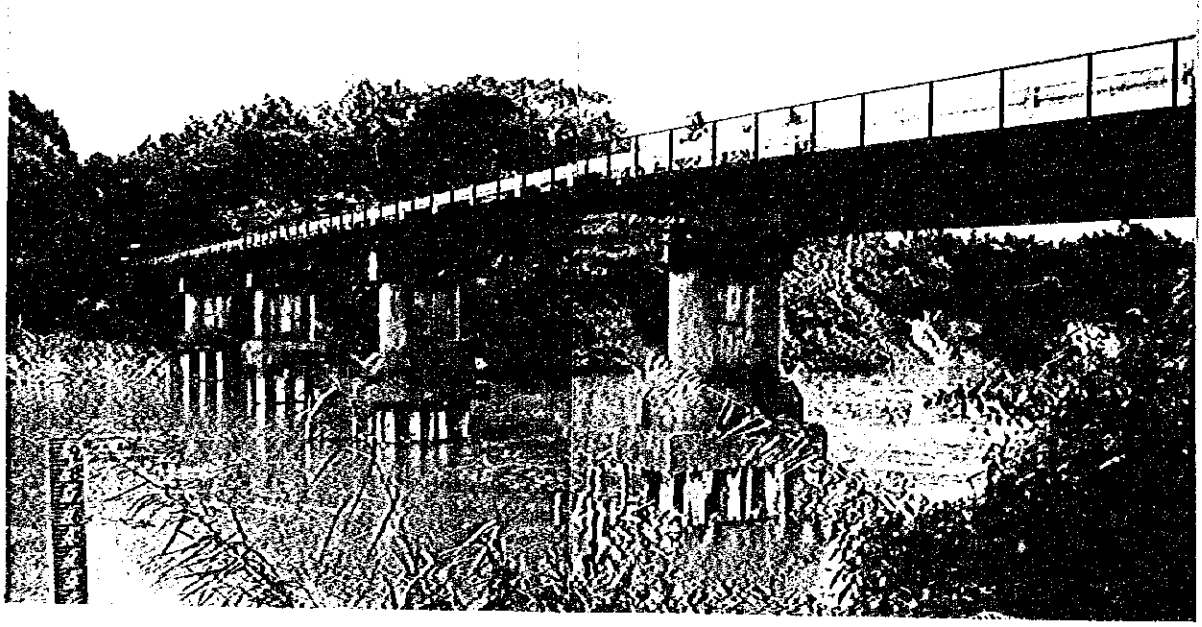
RESULT OF BED LOAD SURVEY AND ESTIMATED RATING CURVE



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.1.4.1
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF SAND MINING SITES

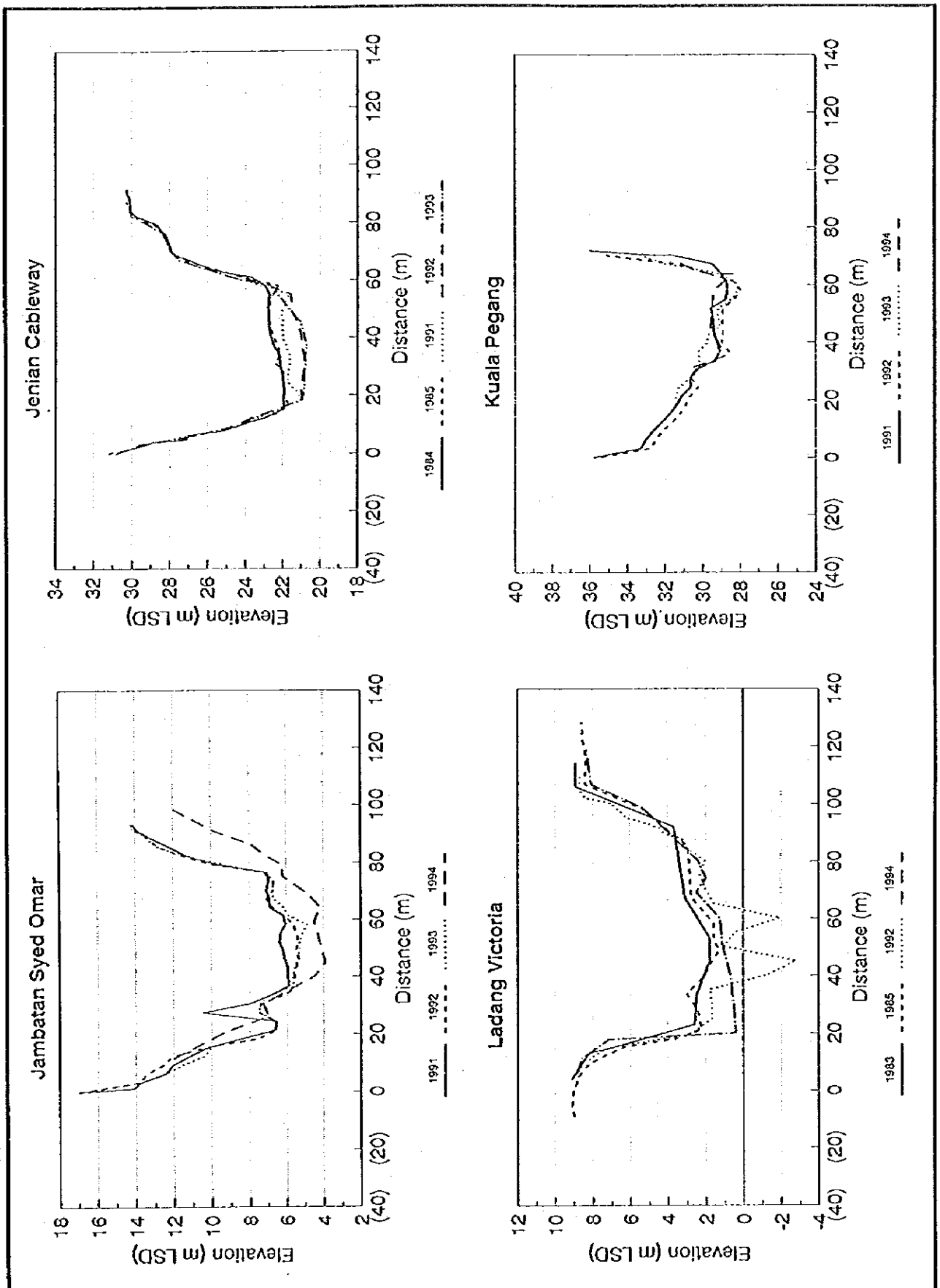


(1) Bridge Crossing Ketil River 1km Upstream of Muda River

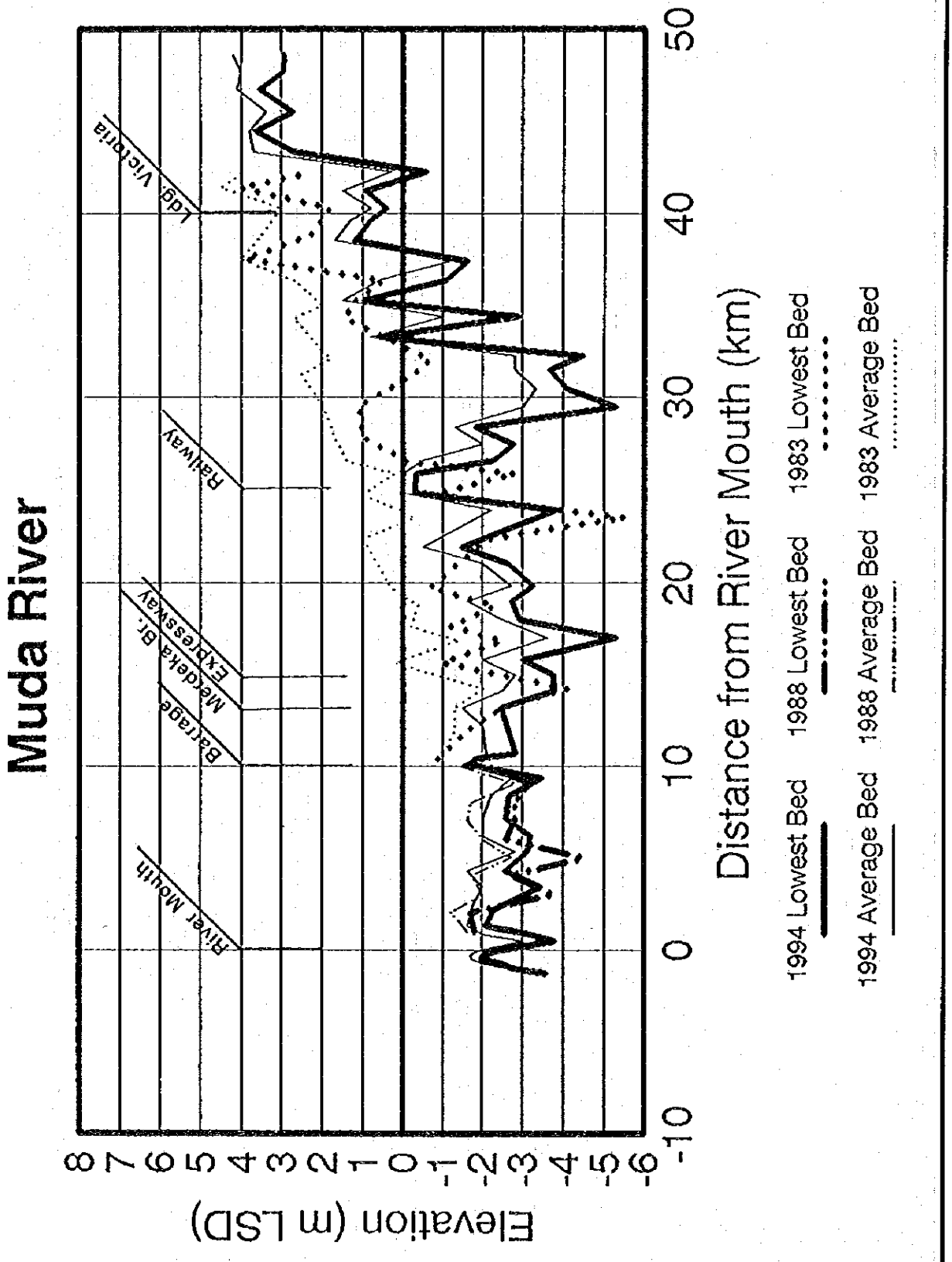


(2) Bridge Crossing Muda River at Ldg. Victoria

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.1.4.2 PHOTOGRAPH OF BRIDGE AFFECTED BY RIVER BED SUBSIDENCE

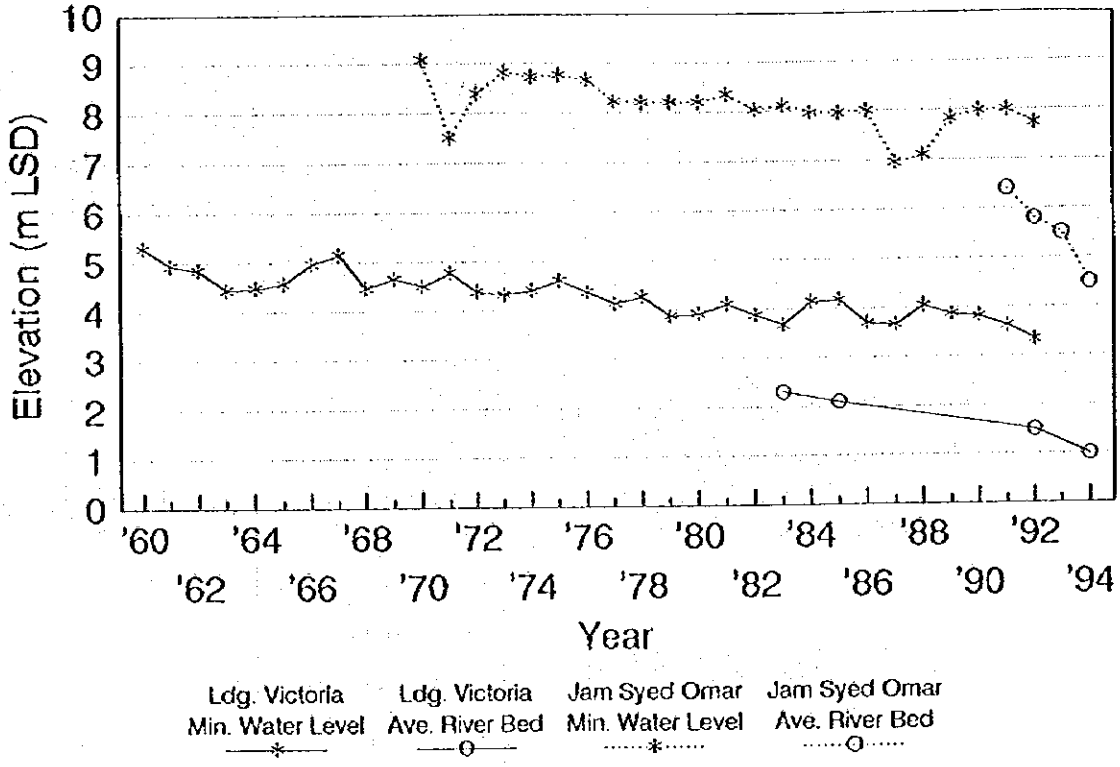


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.1.4.3 CHANGE OF CROSS SECTION AT RIVER DISCHARGE STATION

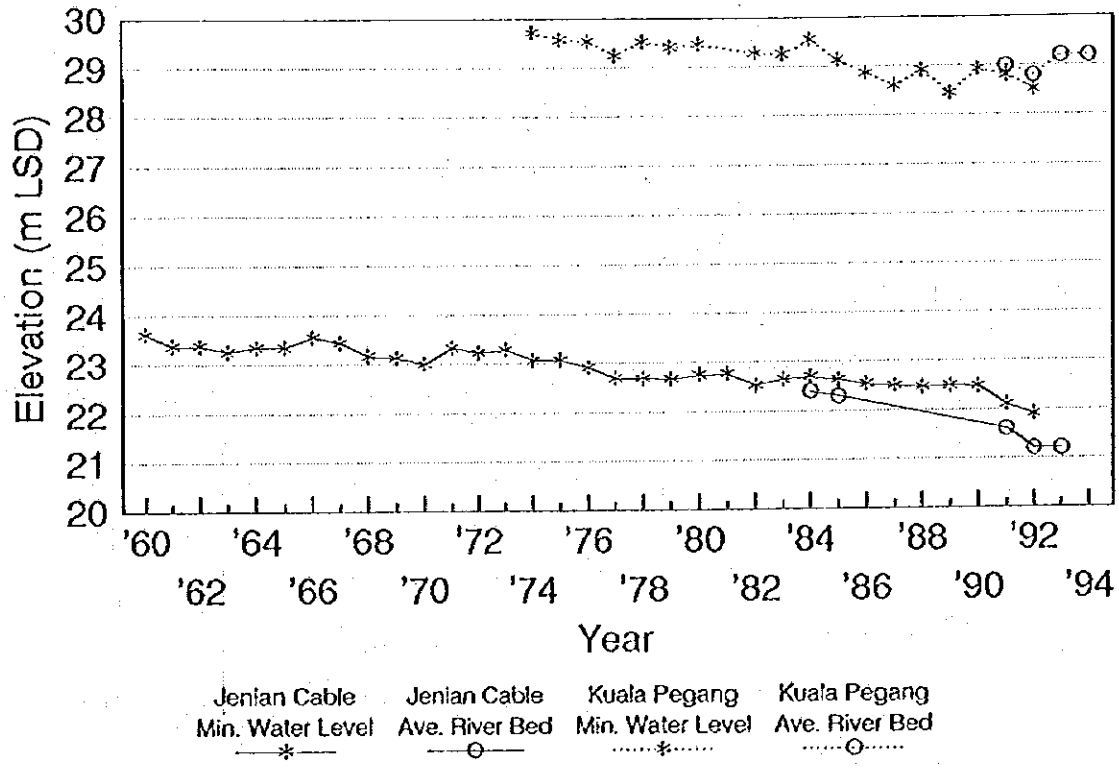


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.1.4.4 CHANGE OF LONGITUDINAL PROFILE OF MUDA RIVER

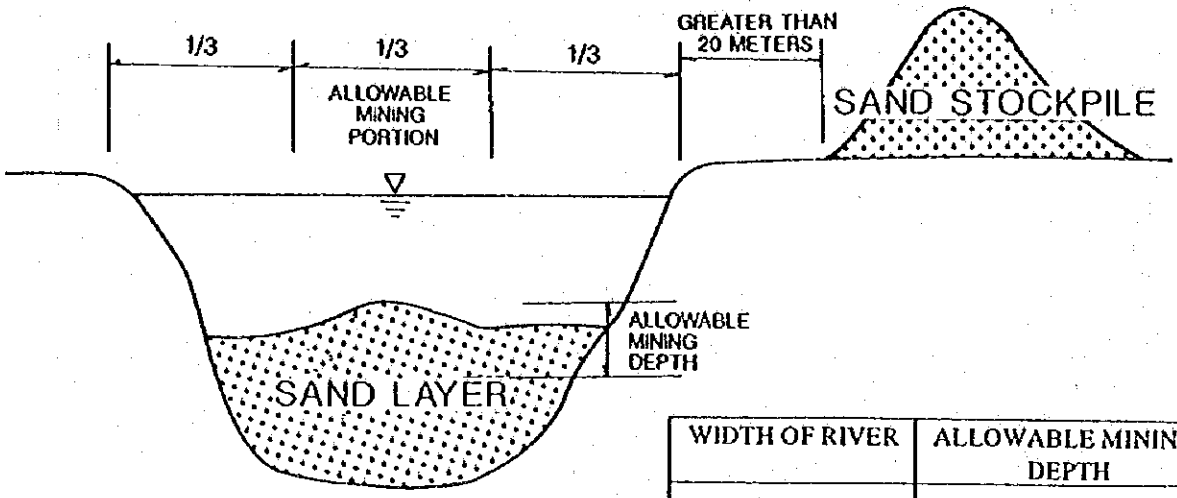
Ldg. Victoria and Jam. Syed Omar



Jenian Cable and Kuala Pegang



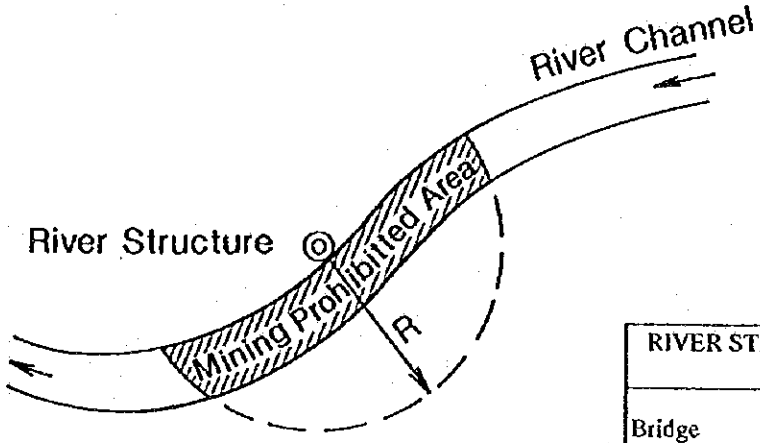
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.1.4.5 CHANGE OF ANNUAL MINIMUM WATER LEVEL AT RIVER DISCHARGE STATION



(1) CROSS SECTION

WIDTH OF RIVER	ALLOWABLE MINING DEPTH
Less than 10m	-
Between 10 to 20m	0.5m
Between 20 to 30m	1.0m
More than 50m	1.5m

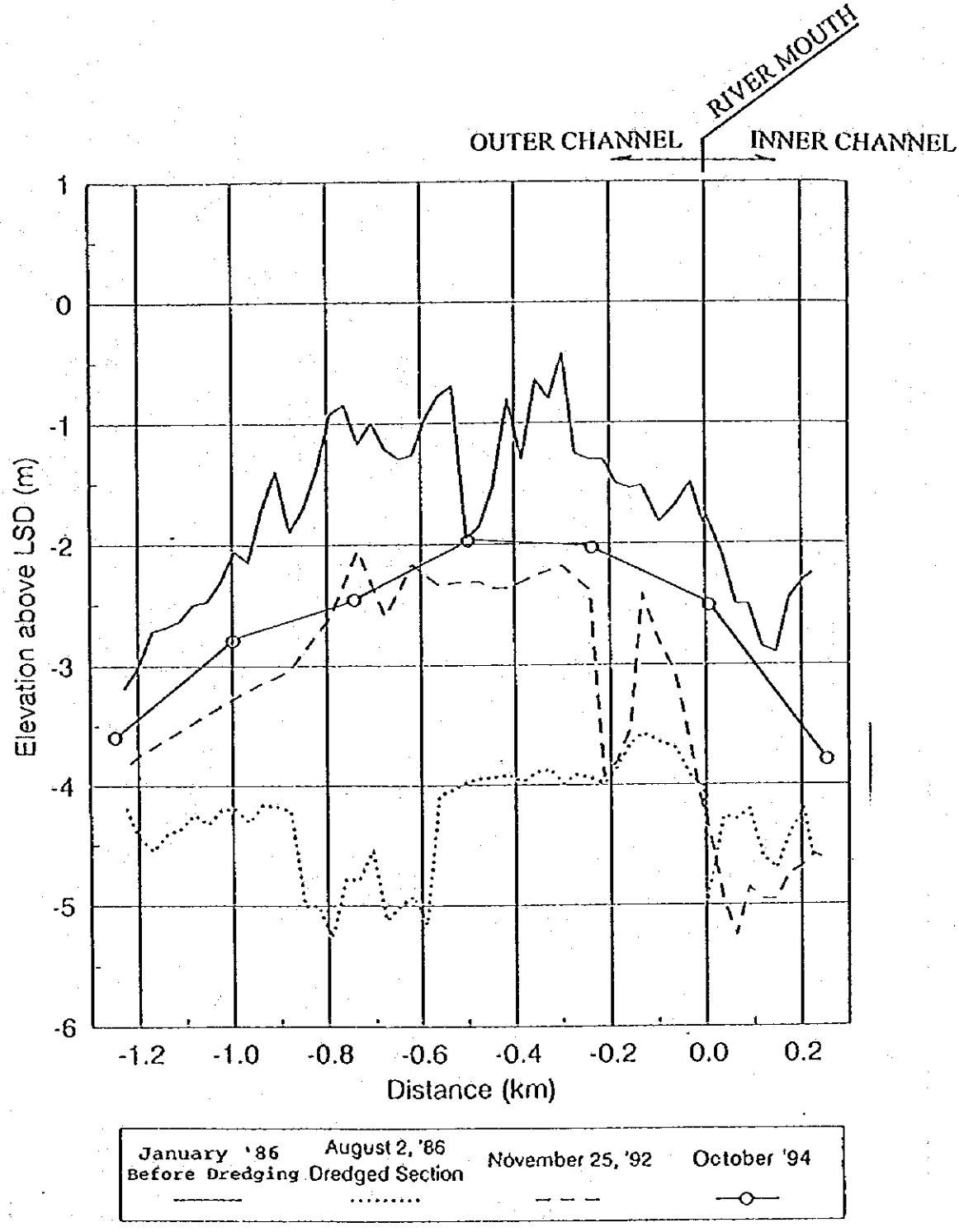
DATA SOURCE : DID



(2) PLAN

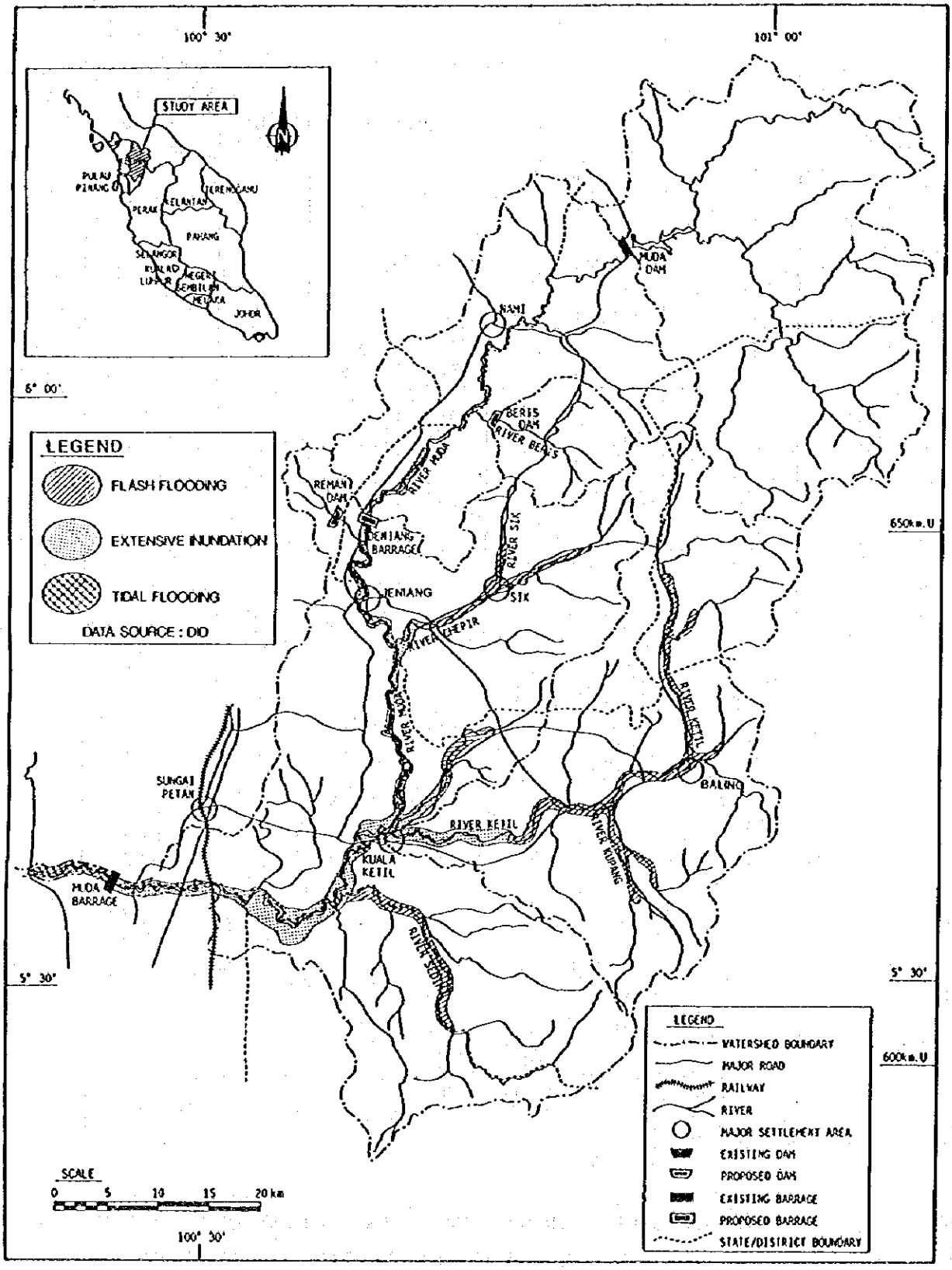
RIVER STRUCTURE	MINIMUM RADIUS R
Bridge Building Others	200m
Pump House Intake Structure Others	500m

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.1.4.6 SAND MINING LOCATION REGULATED BY DID

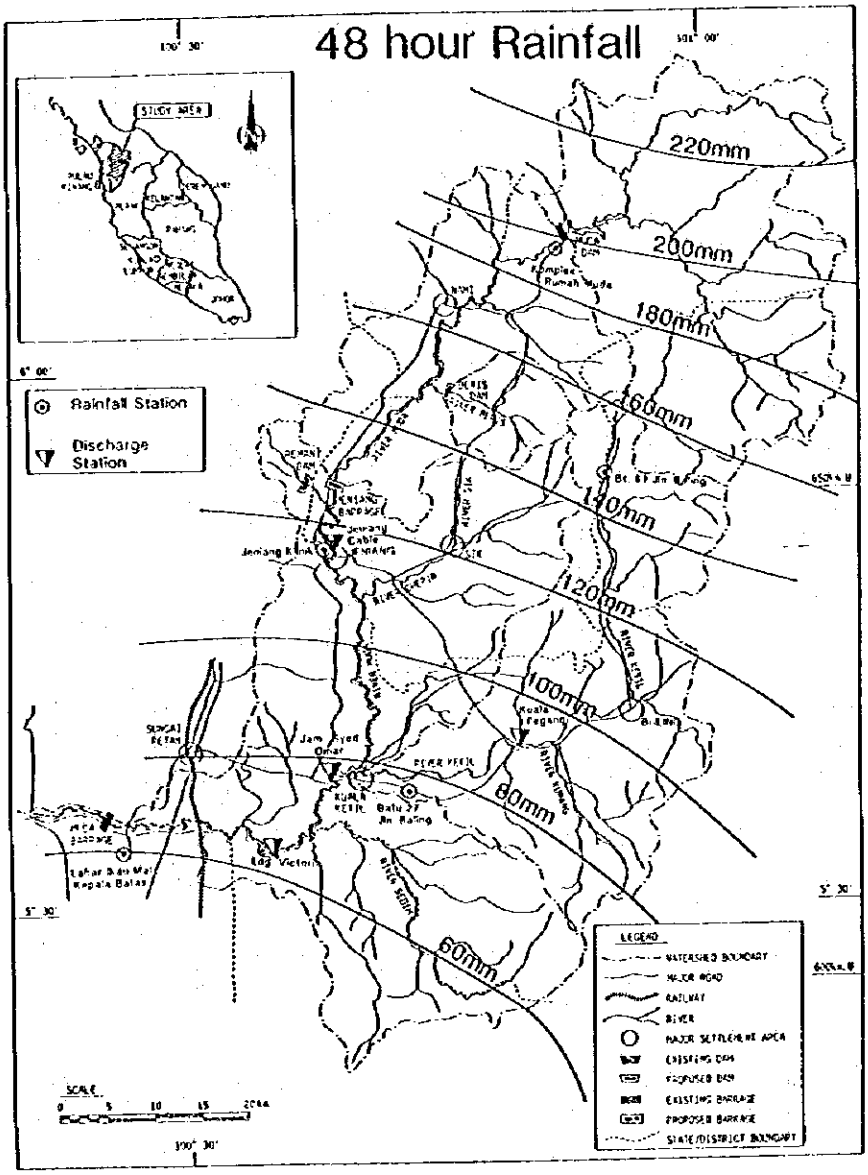


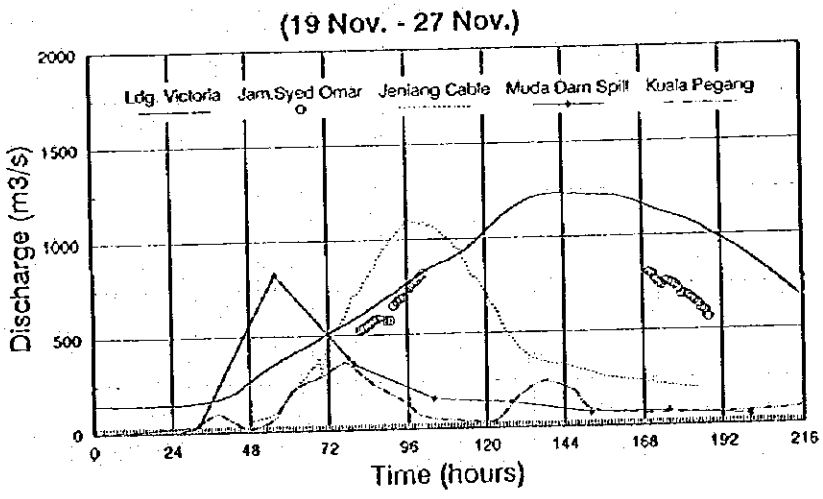
DATA SOURCE : " THE NATIONAL RIVER MOUTH STUDY " DRAFT FINAL REPORT
VOL. 3 SUPPORTING REPORT, JICA, MARCH 1994

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.1.5.1 LONGITUDINAL PROFILE AT MUDA RIVER MOUTH

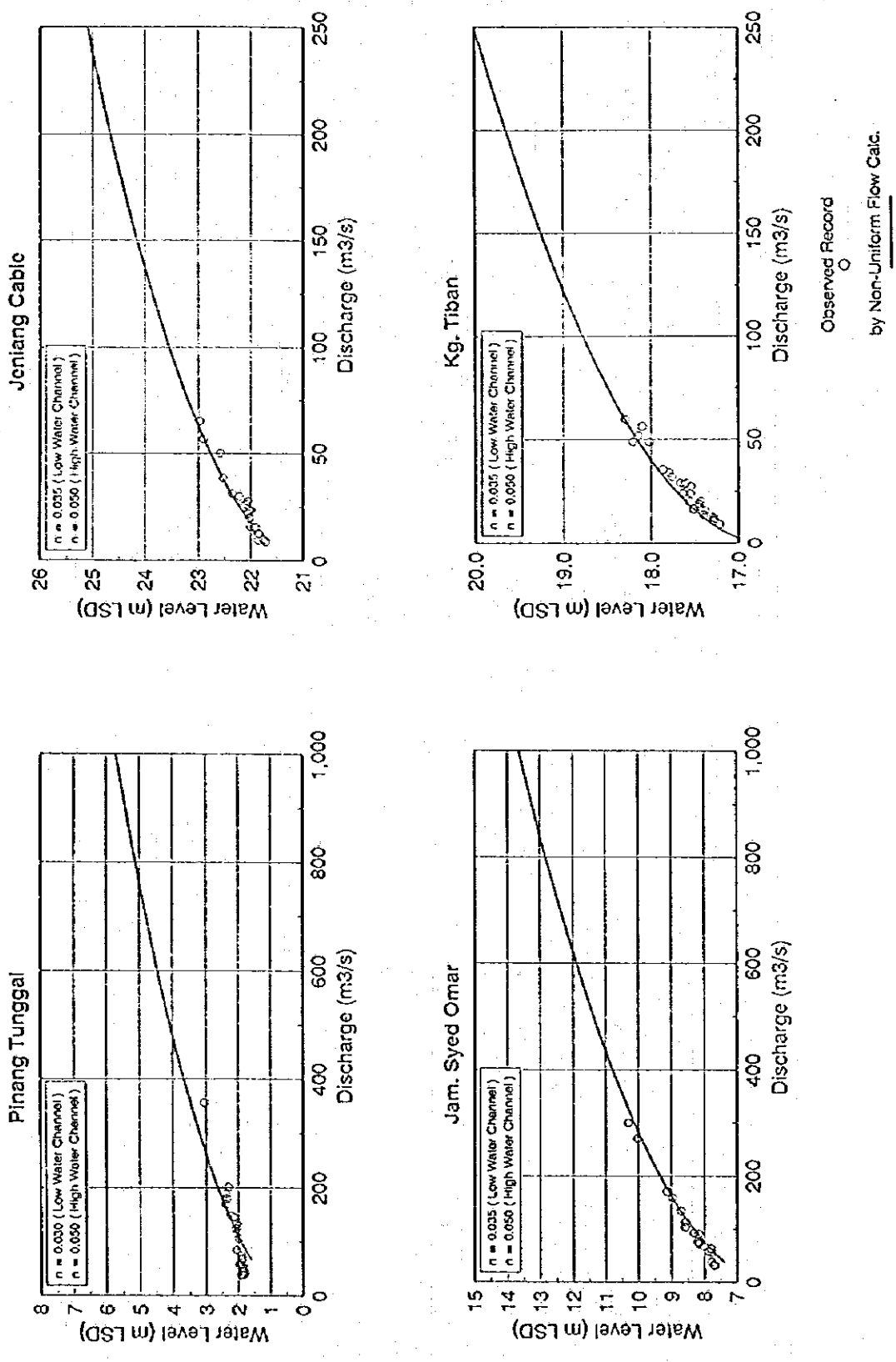


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.2.1.1 FLOOD PRONE AREA IN MUDA RIVER BASIN





COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.2.2.1
JAPAN INTERNATIONAL COOPERATION AGENCY	ISOHYETAL MAP OF 48-HOUR RAINFALL AND FLOOD HYDROGRAPH DURING 1988 FLOOD

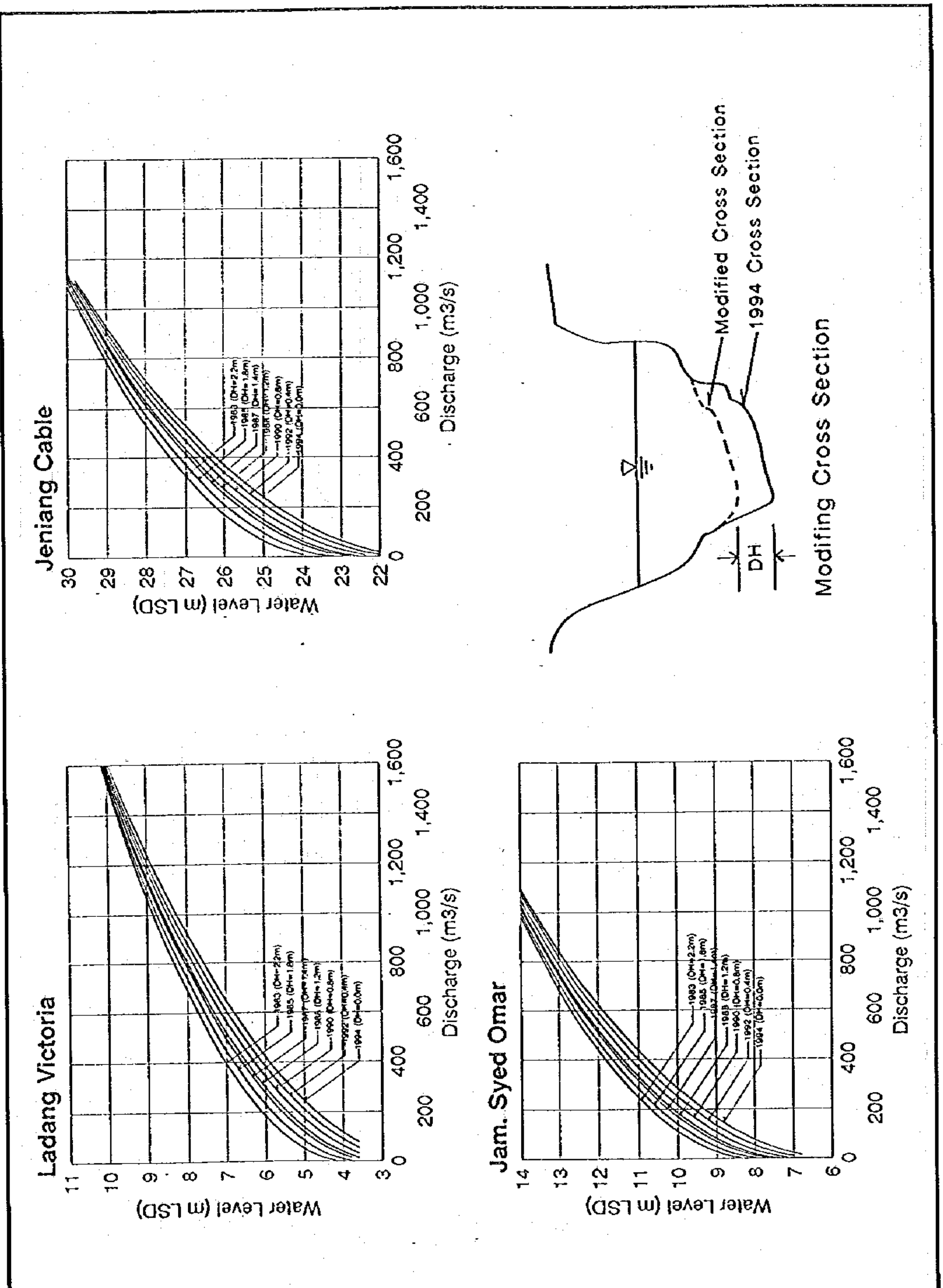


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

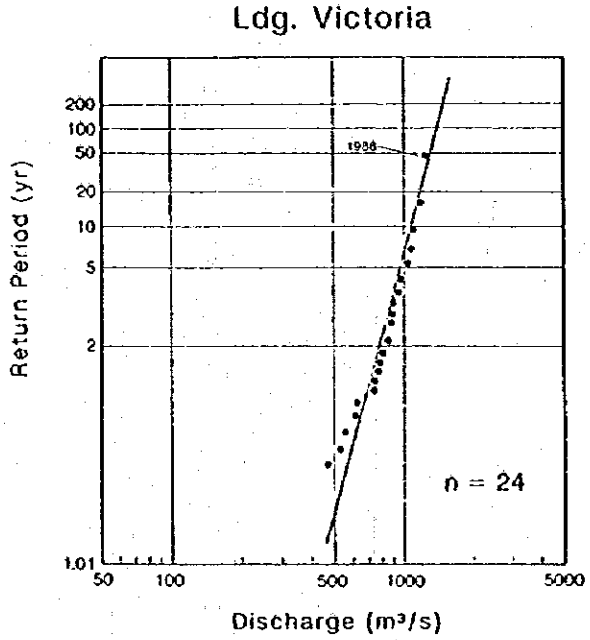
JAPAN INTERNATIONAL COOPERATION AGENCY

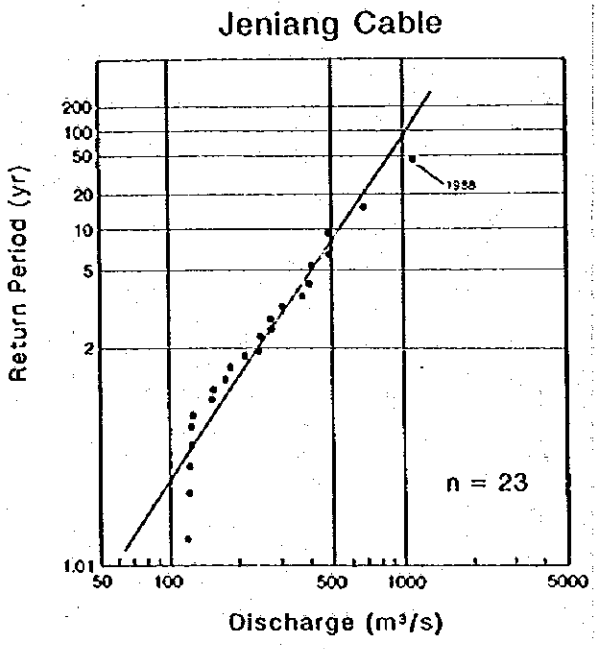
FIG. II.2.2.2

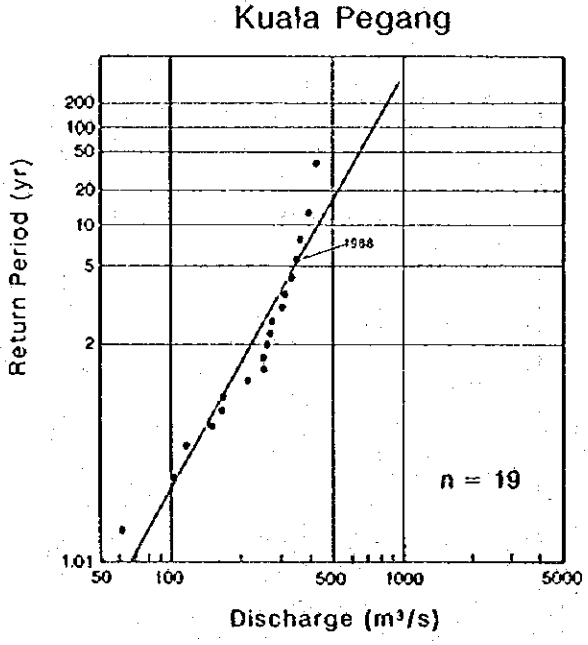
CALIBRATION OF MANNING'S ROUGHNESS COEFFICIENT BY NON-UNIFORM FLOW CALCULATION



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.2.2.3
JAPAN INTERNATIONAL COOPERATION AGENCY	ESTIMATED RATING CURVE BASED ON MODIFIED CROSS SECTION





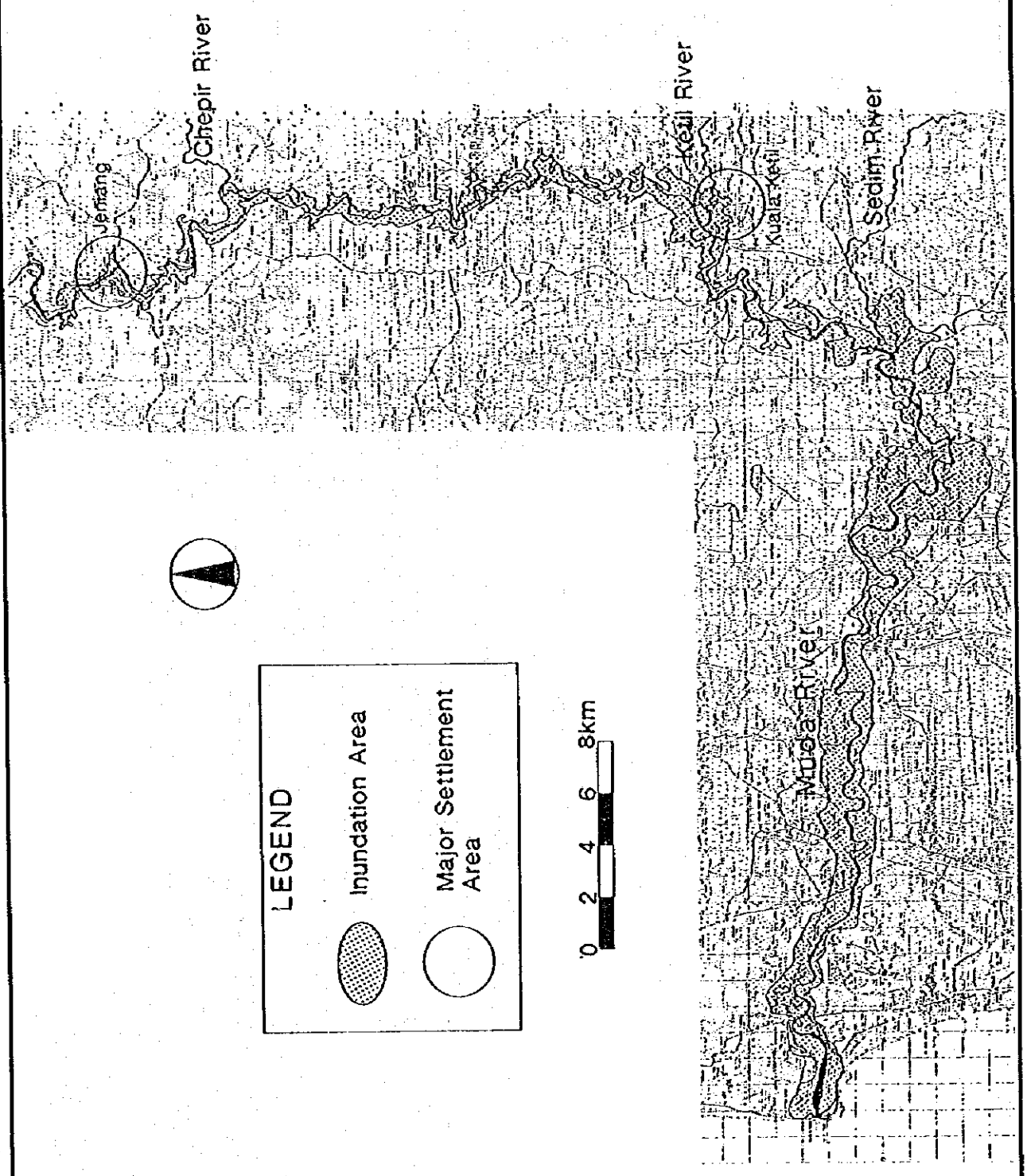


Estimated Return Period of 1988 Flood

Location	Return Period
Ldg. Victoria	45 years
Jeniang Cable	140 years
Kuala Pegang	5.5 years

Note : For Ldg. Victoria and Jeniang Cable, data before completion of Muda dam in 1969 were excluded from the statistical analysis (refer to TABLE 4.2.1).

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.2.2.4
JAPAN INTERNATIONAL COOPERATION AGENCY	STATISTICAL ANALYSIS OF FLOOD DISCHARGE

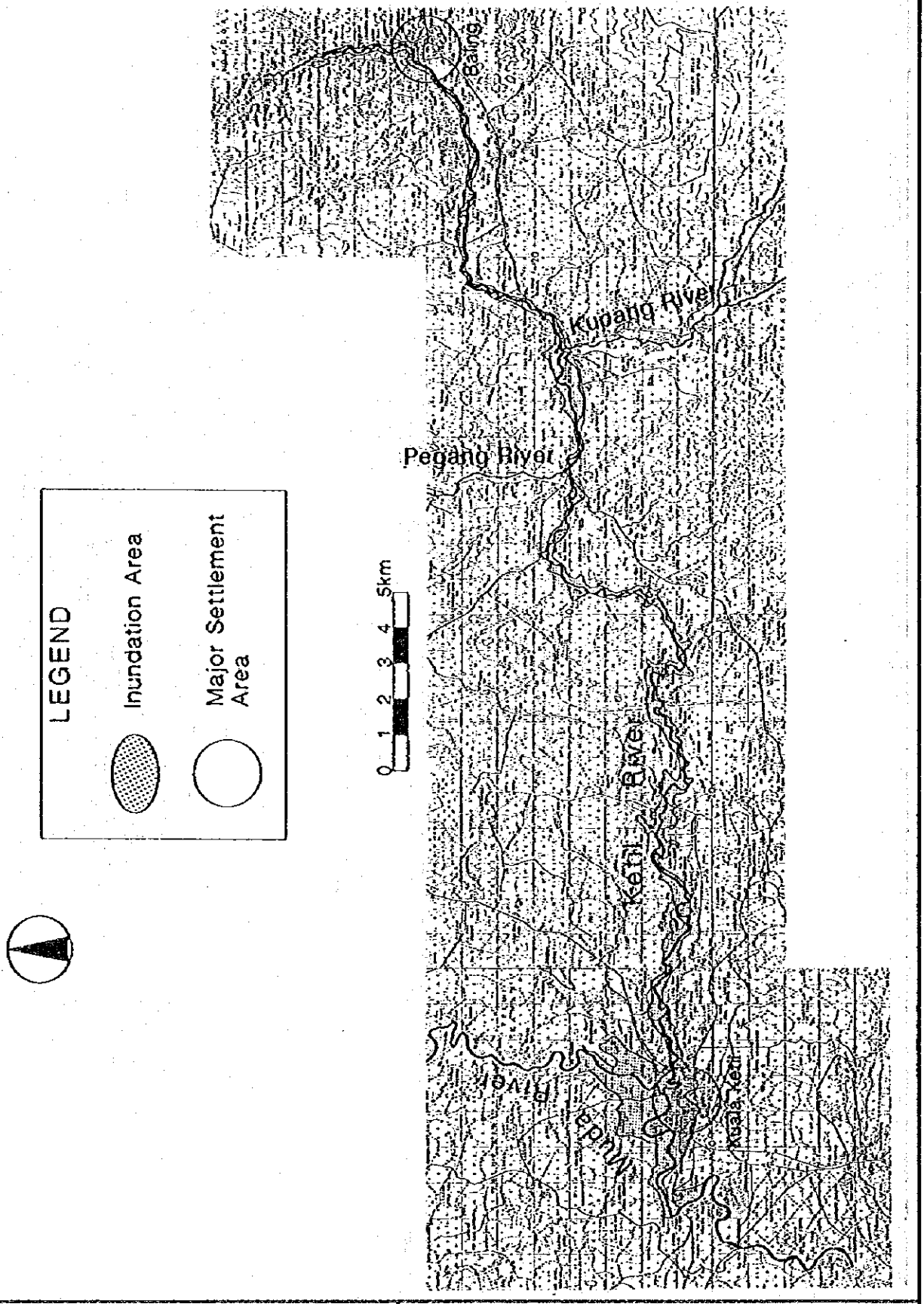


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

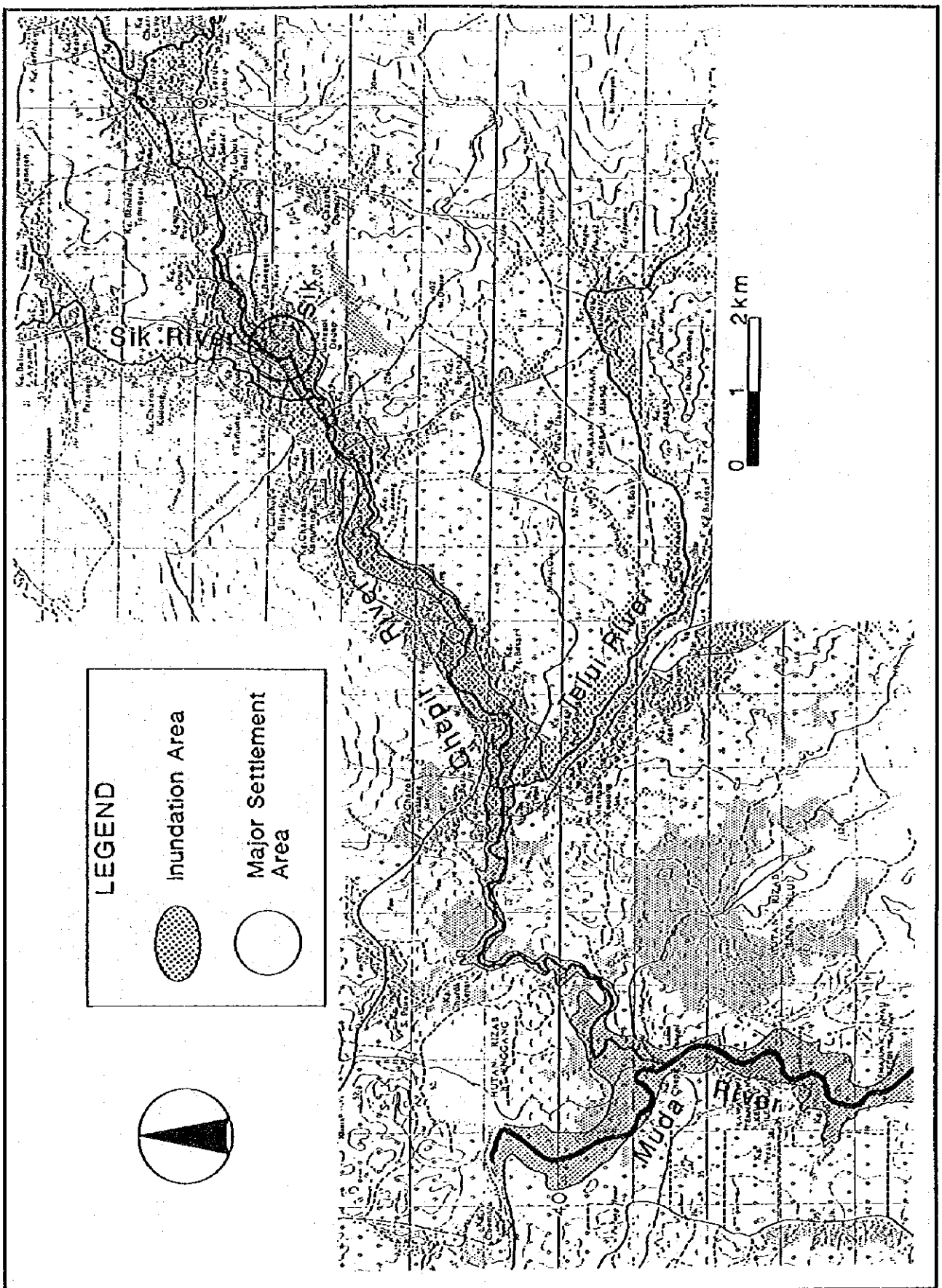
JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.2.2.5

FLOOD INUNDATION AREA ALONG MUDA RIVER DURING 1988 FLOOD



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.2.2.6
JAPAN INTERNATIONAL COOPERATION AGENCY	FLOOD INUNDATION AREA ALONG KETIL RIVER DURING 1988 FLOOD

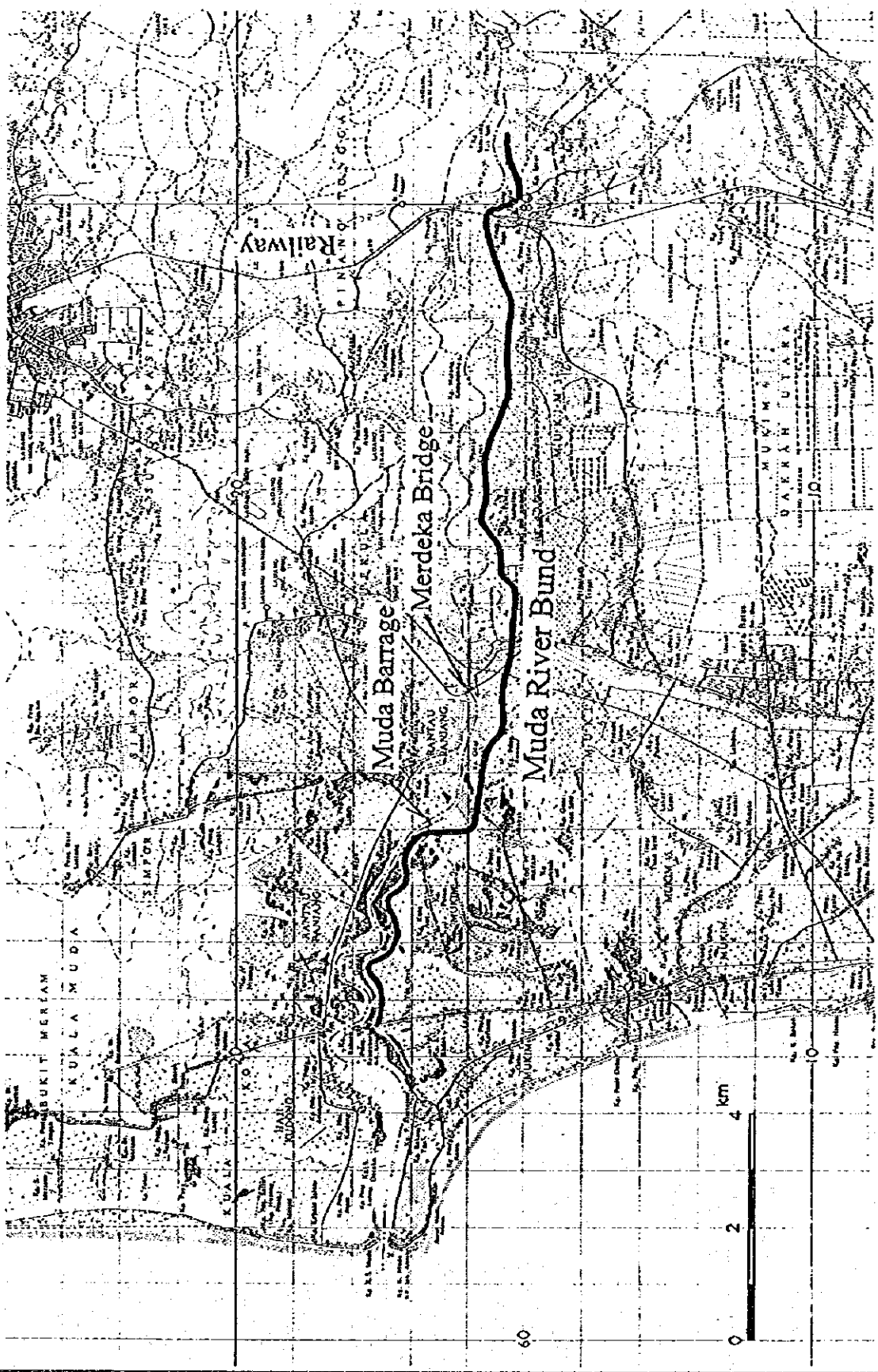


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

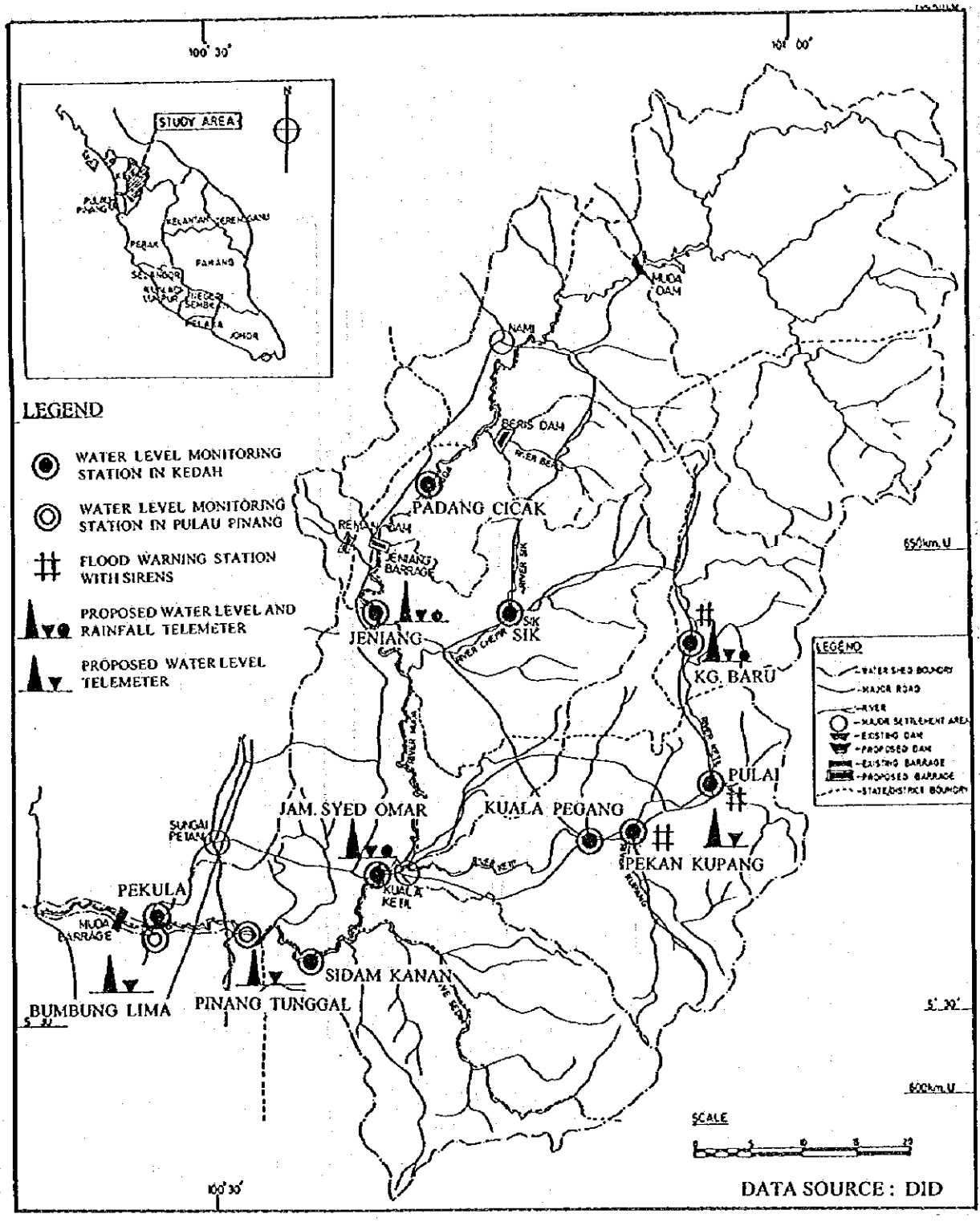
JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.2.2.7

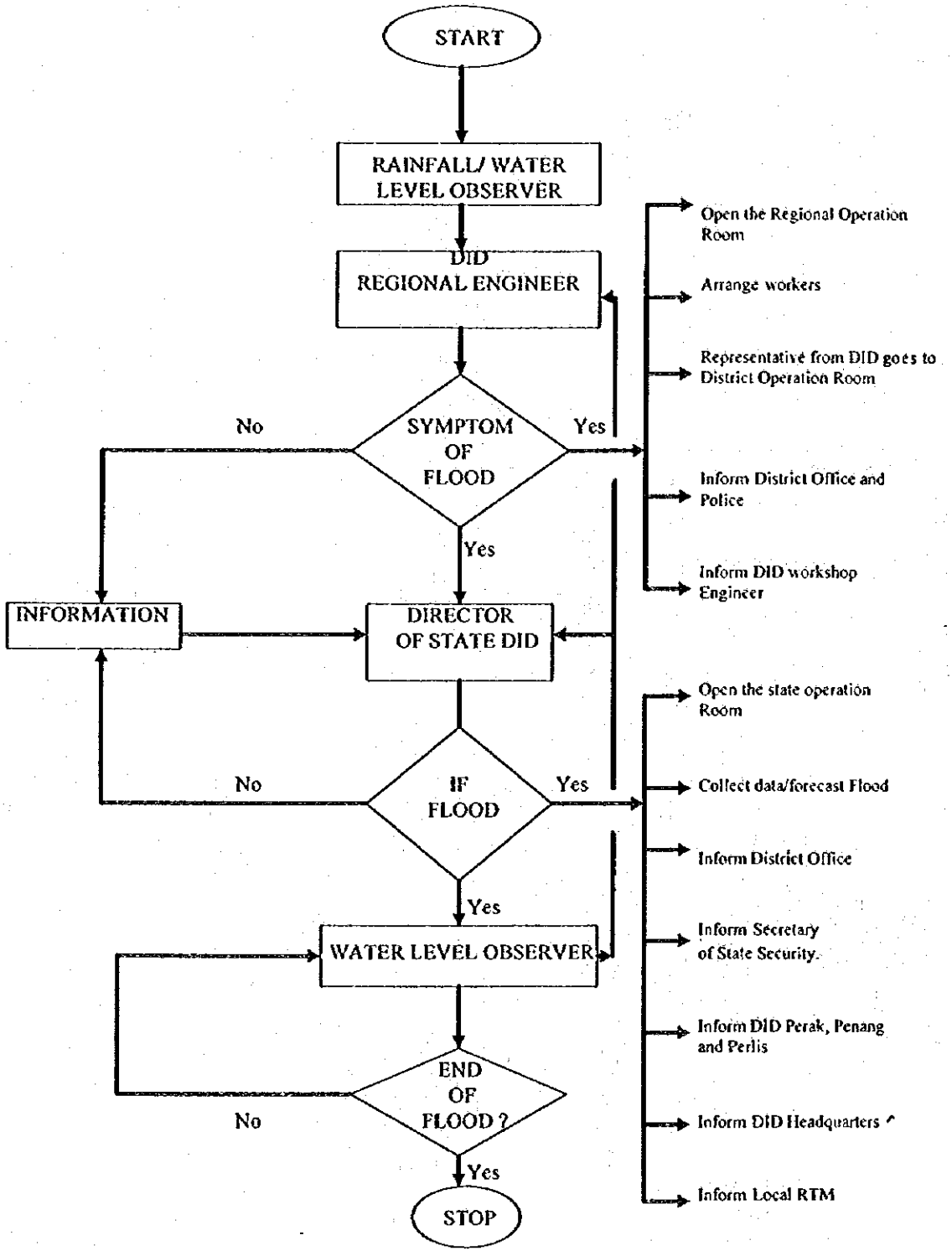
FLOOD INUNDATION AREA ALONG CHEPIR RIVER DURING 1988 FLOOD



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.3.1.1
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF MUDA RIVER BUND



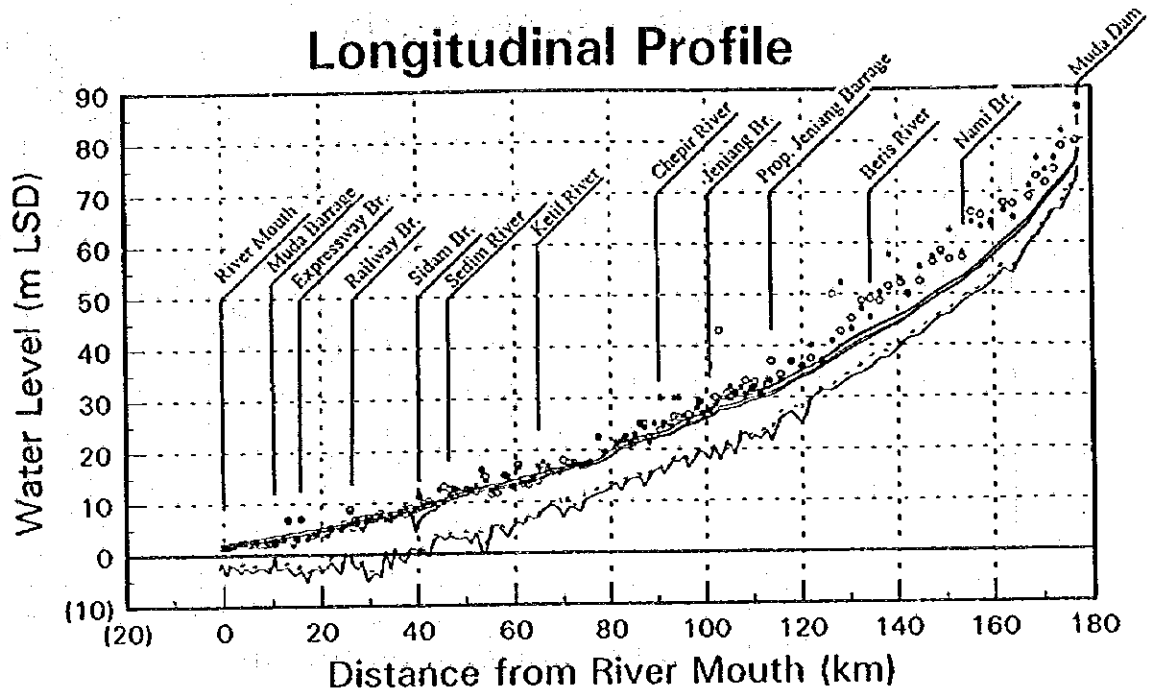
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.3.2.1 LOCATION OF WATER LEVEL MONITORING STATIONS IN MUDA RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY	



DATA SOURCE : DID

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.3.2.2 FLOW CHART OF FLOOD FORECASTING AND WARNING SYSTEM IN STATE OF KEDAH

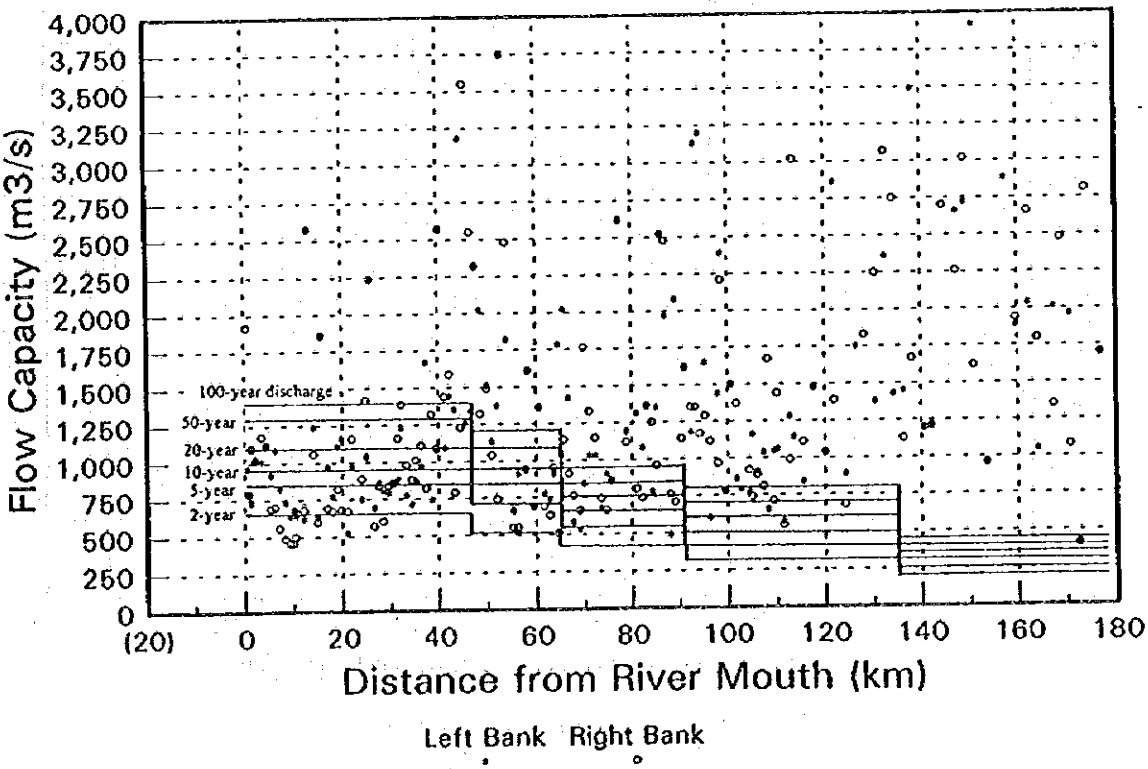
Longitudinal Profile



Lowest Bed — Average Bed — Left Bank — Right Bank

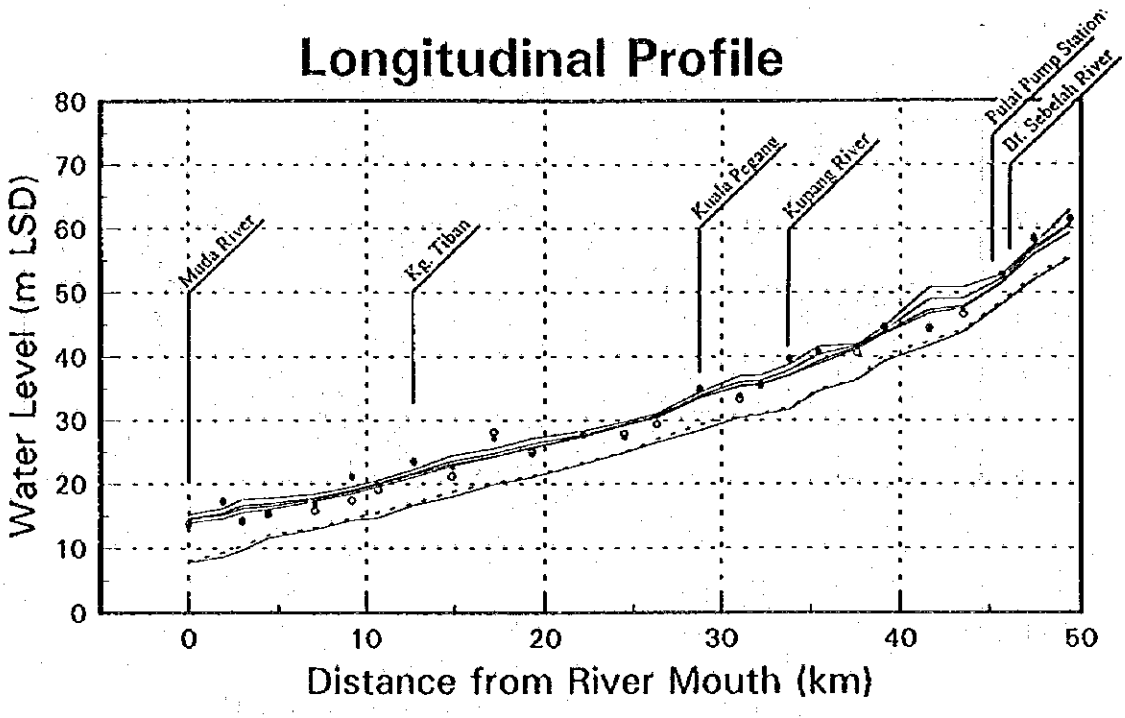
Water Level (1/5) — Water Level (1/10) — Water Level (1/50) — Water Level (1/100)

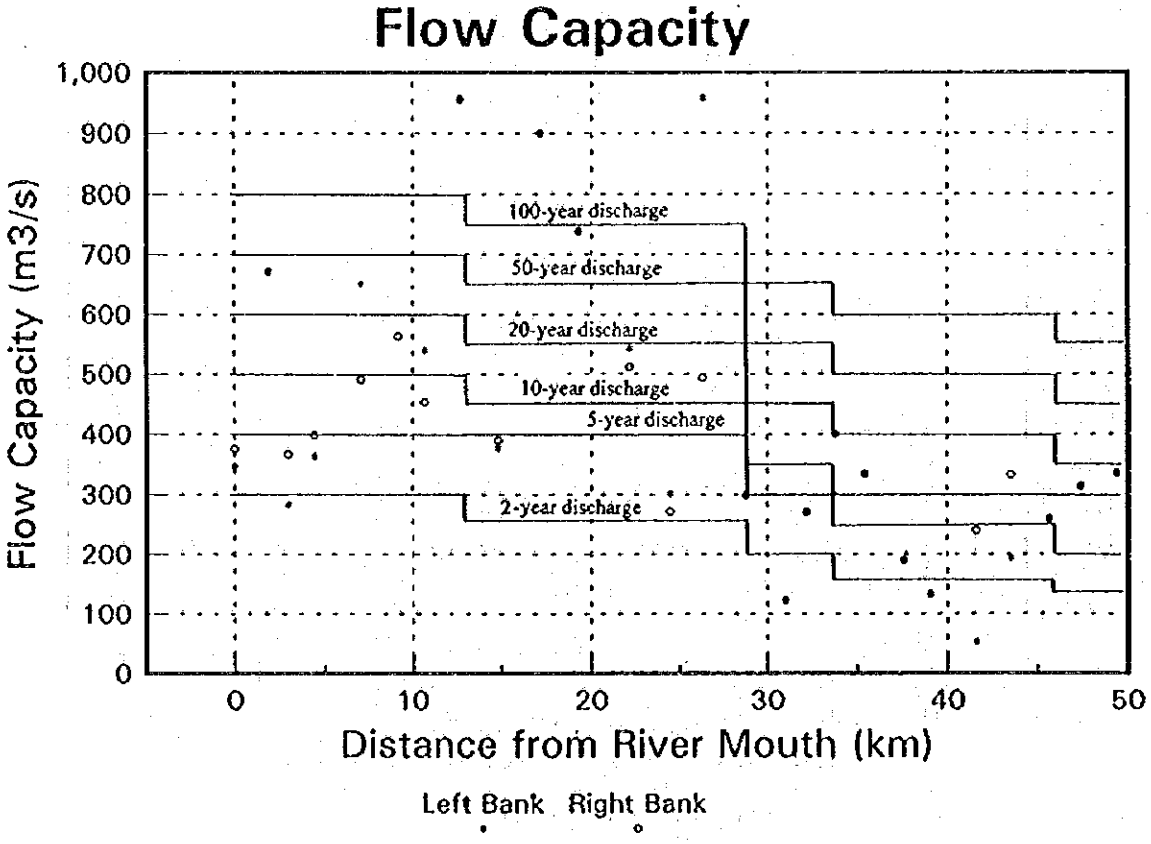
Flow Capacity



Left Bank — Right Bank

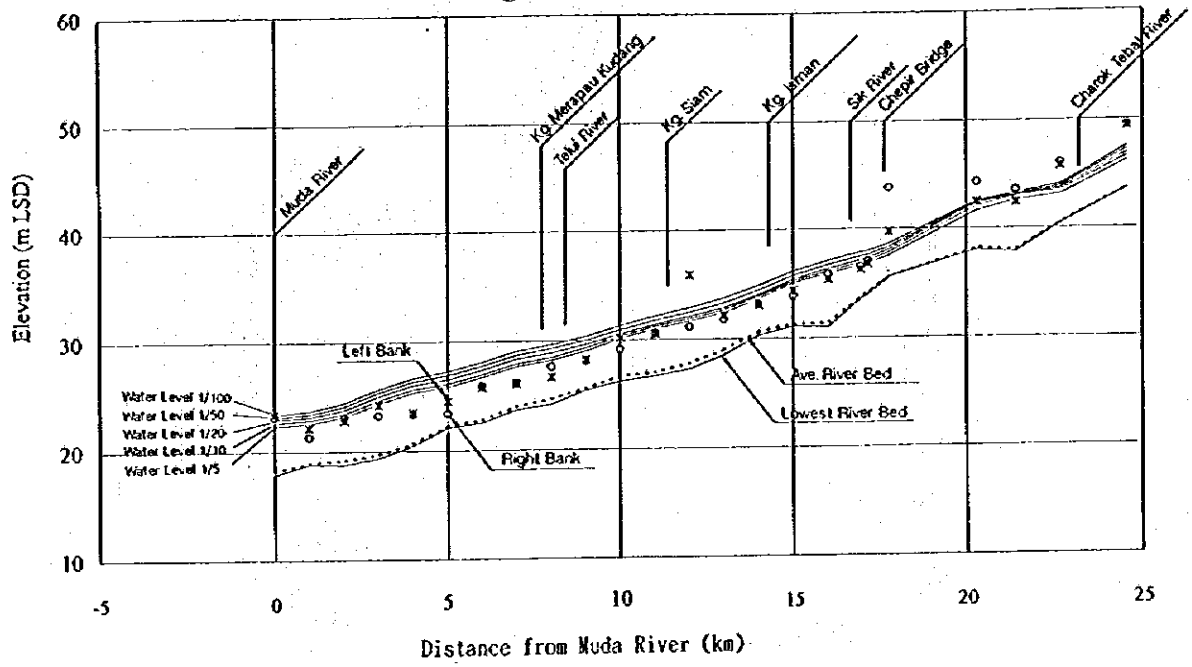
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.4.1.1 (1/3) FLOOD WATER PROFILE AND FLOW CAPACITY (MUDA RIVER)



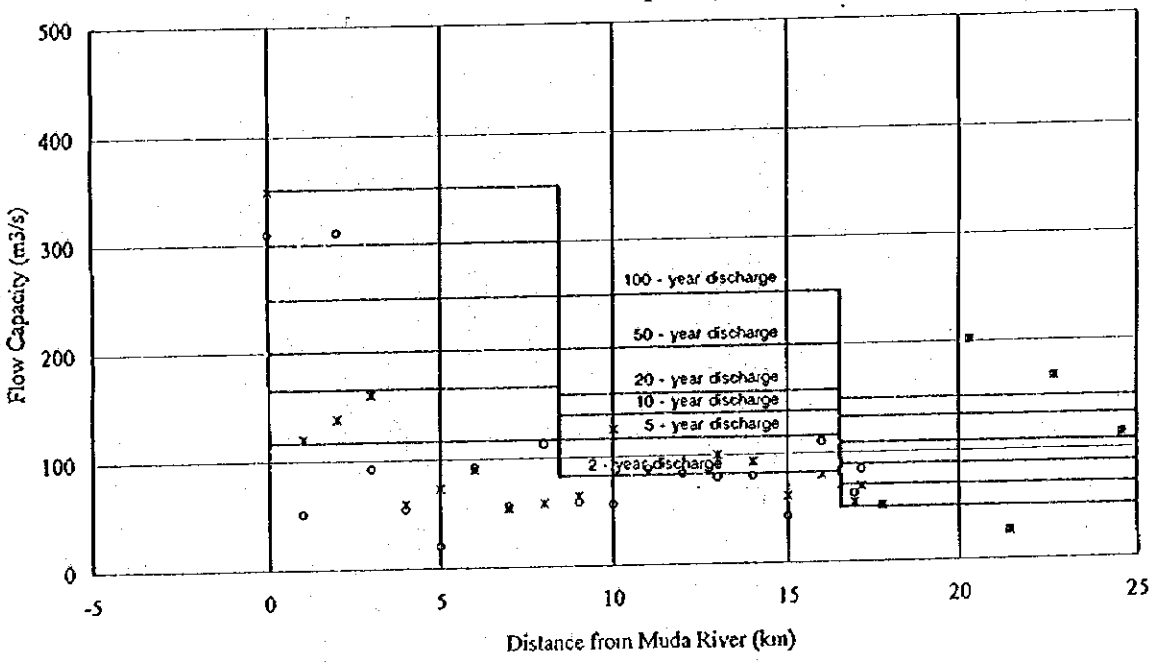


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.4.1.1 (2/3) FLOOD WATER PROFILE AND FLOW CAPACITY (KETIL RIVER)

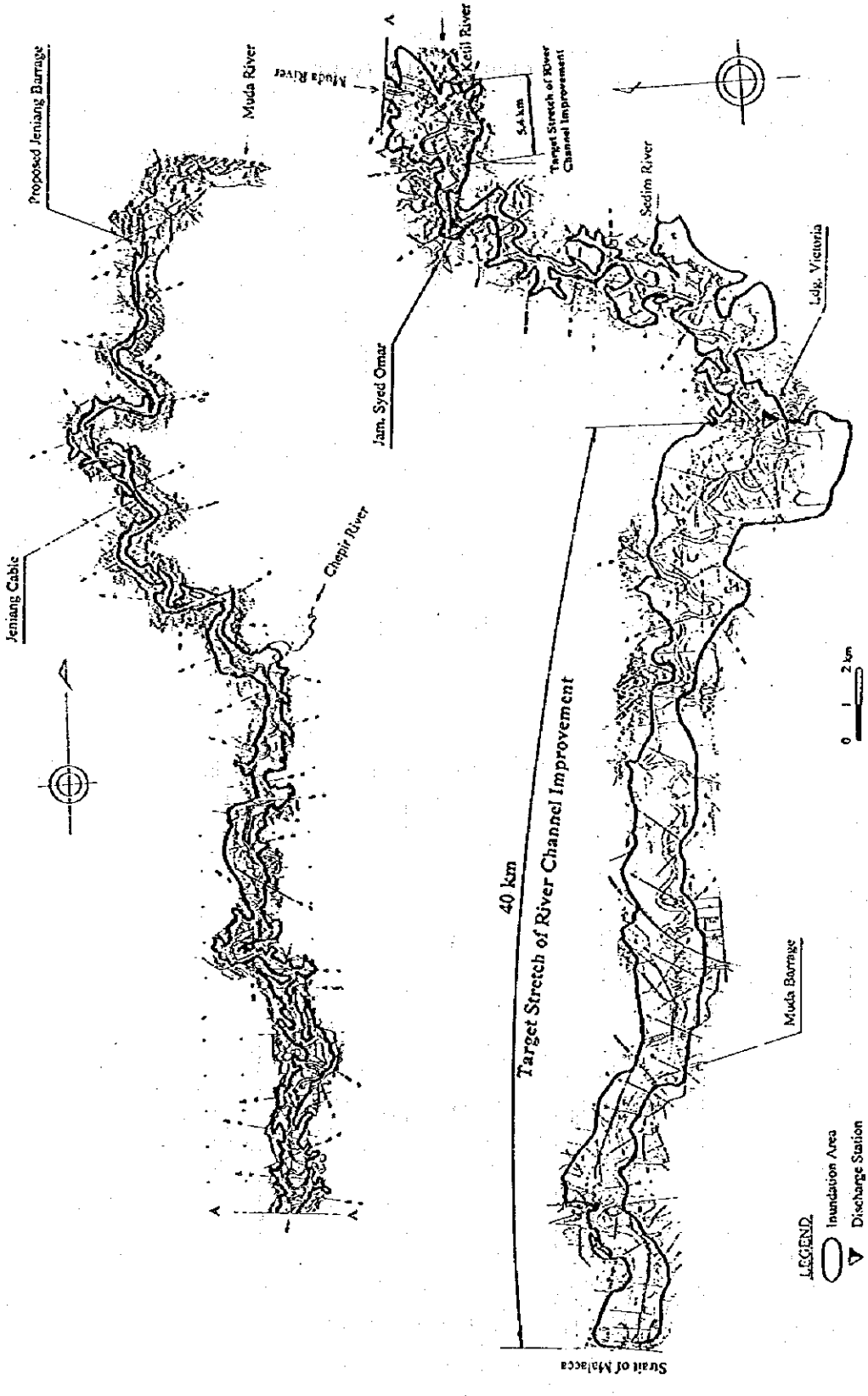
Longitudinal Profile



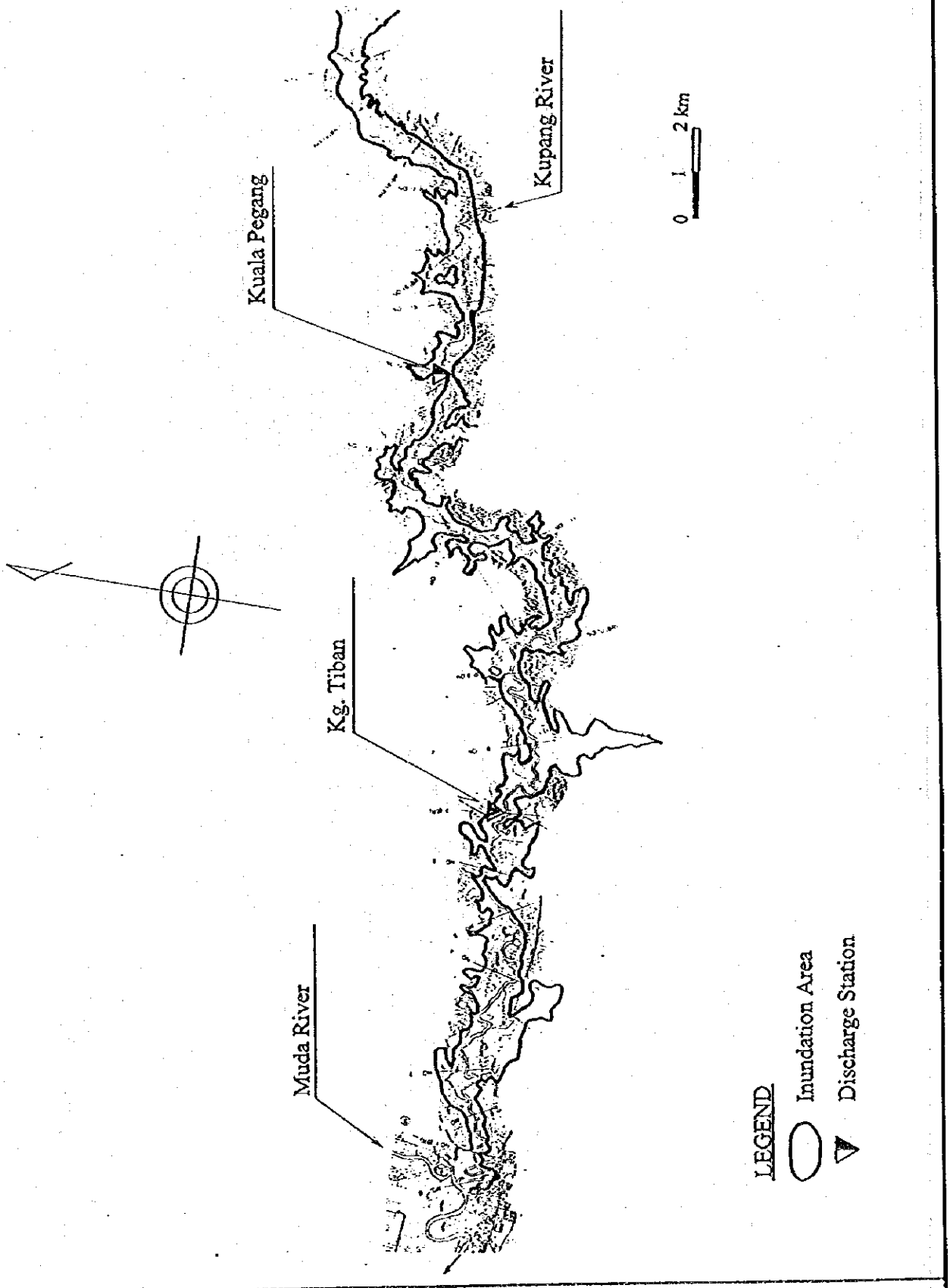
Flow Capacity



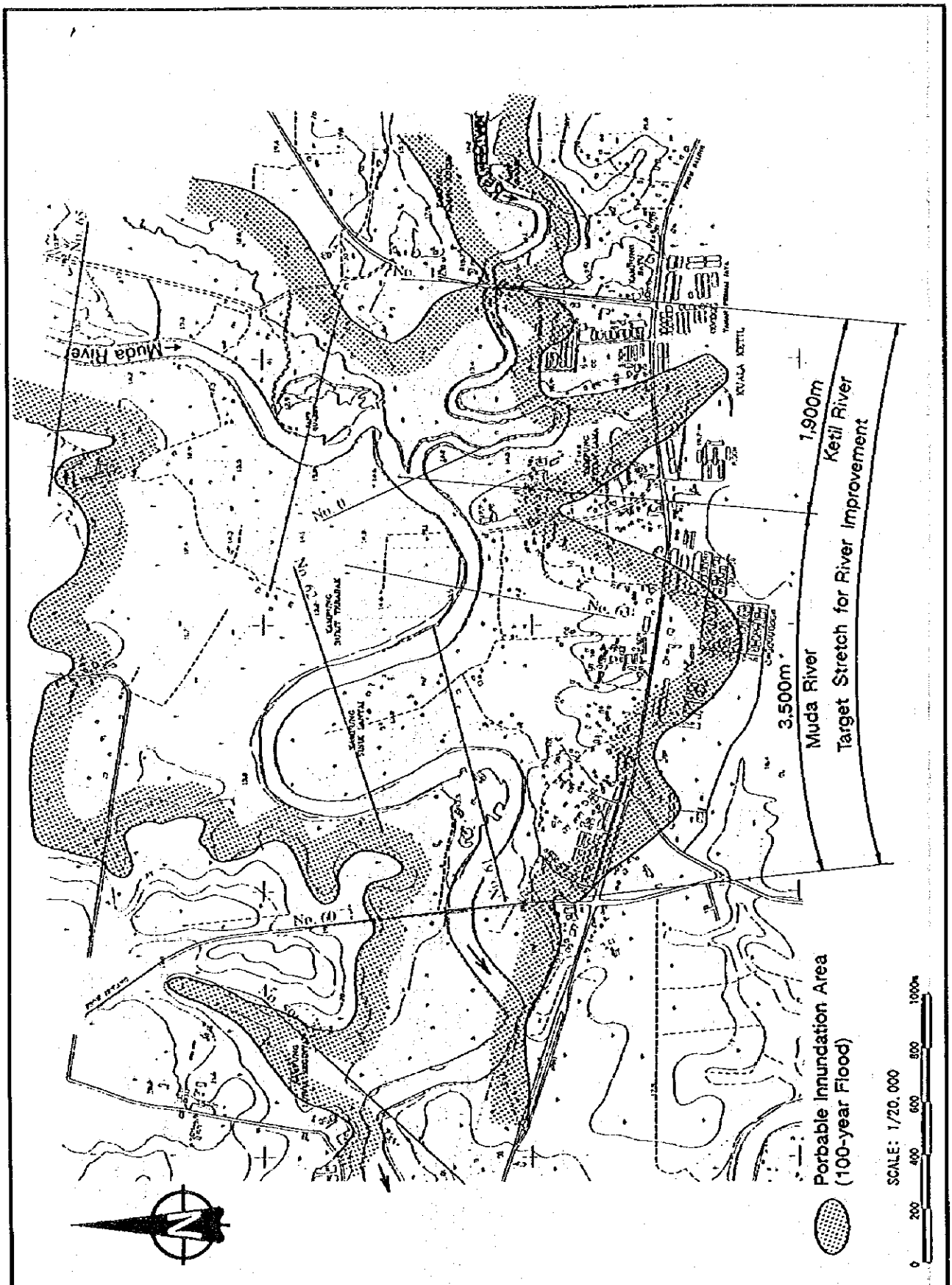
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.4.1.1 (3/3)
JAPAN INTERNATIONAL COOPERATION AGENCY	FLOOD WATER PROFILE AND FLOW CAPACITY (CHEPIR RIVER)



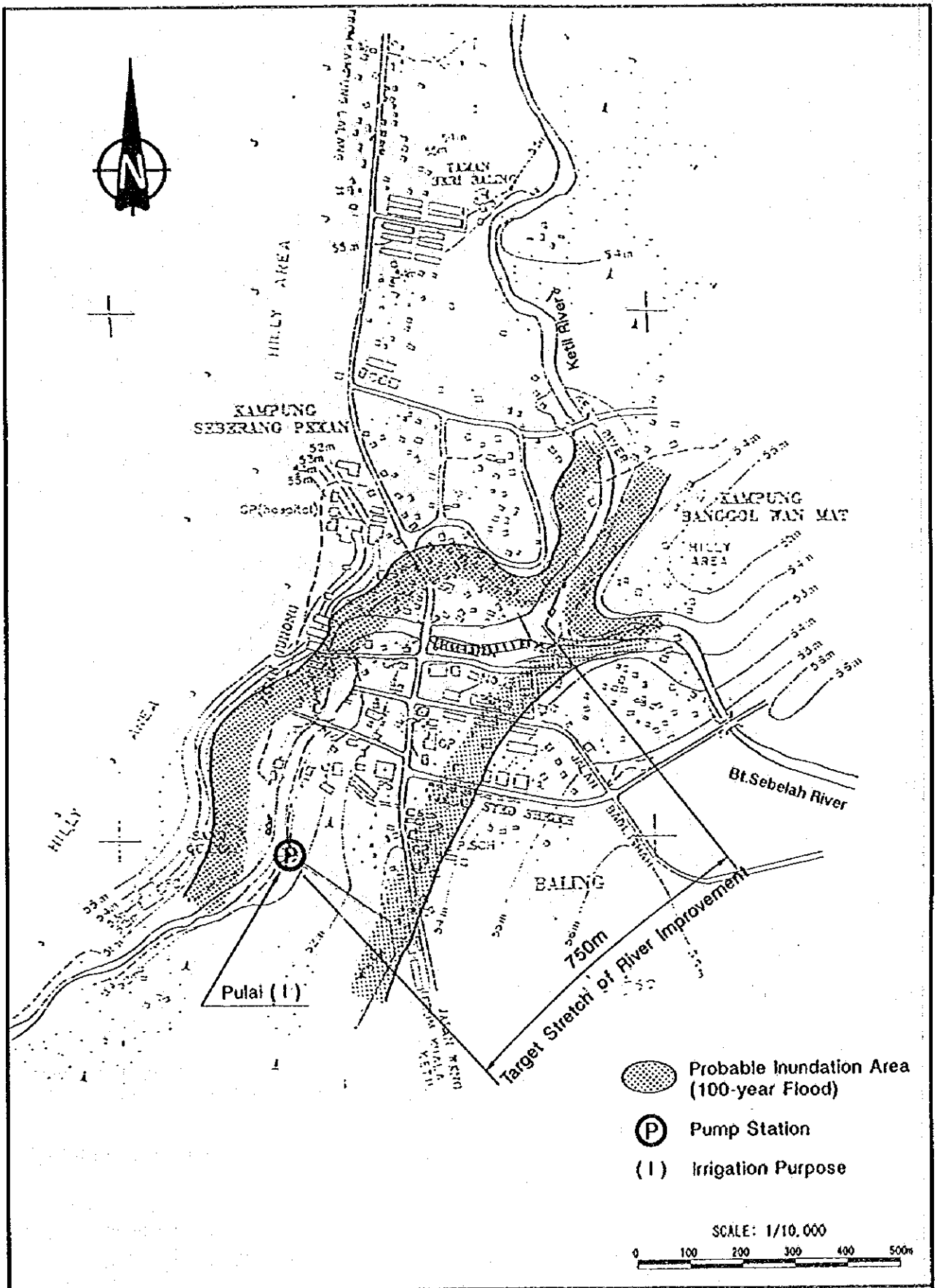
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.4.1.2 (1/2) PROBABLE INUNDATION AREA BY 100-YEAR FLOOD (MUDA RIVER)



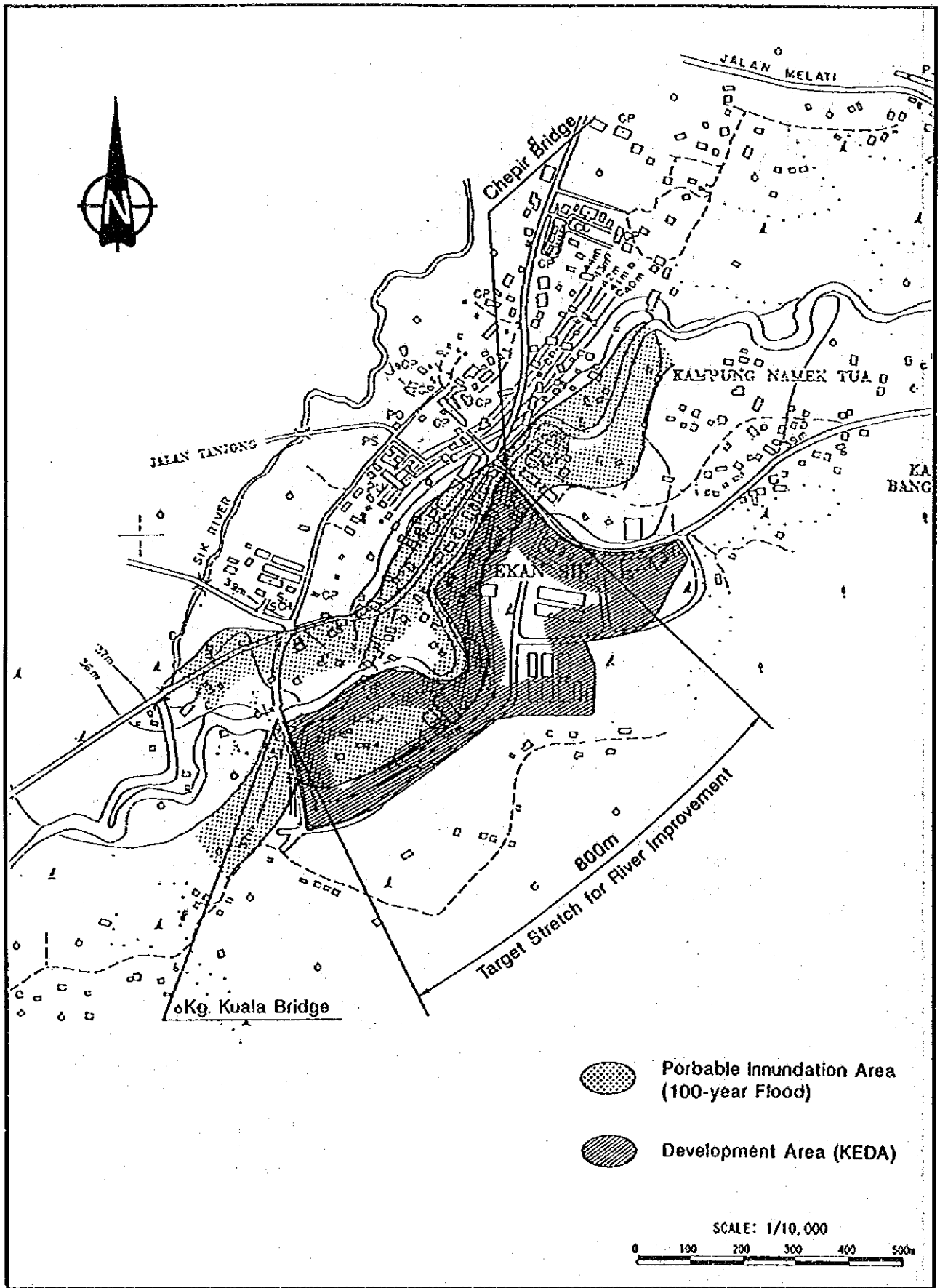
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.4.1.2 (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	PROBABLE INUNDATION AREA BY 100-YEAR FLOOD (KETIL RIVER)



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.4.1.3 (1/3)
JAPAN INTERNATIONAL COOPERATION AGENCY	PROBABLE INUNDATION AREA BY 100-YEAR FLOOD ALONG SHORT TARGET STRETCH (KUALA KETIL TOWN)

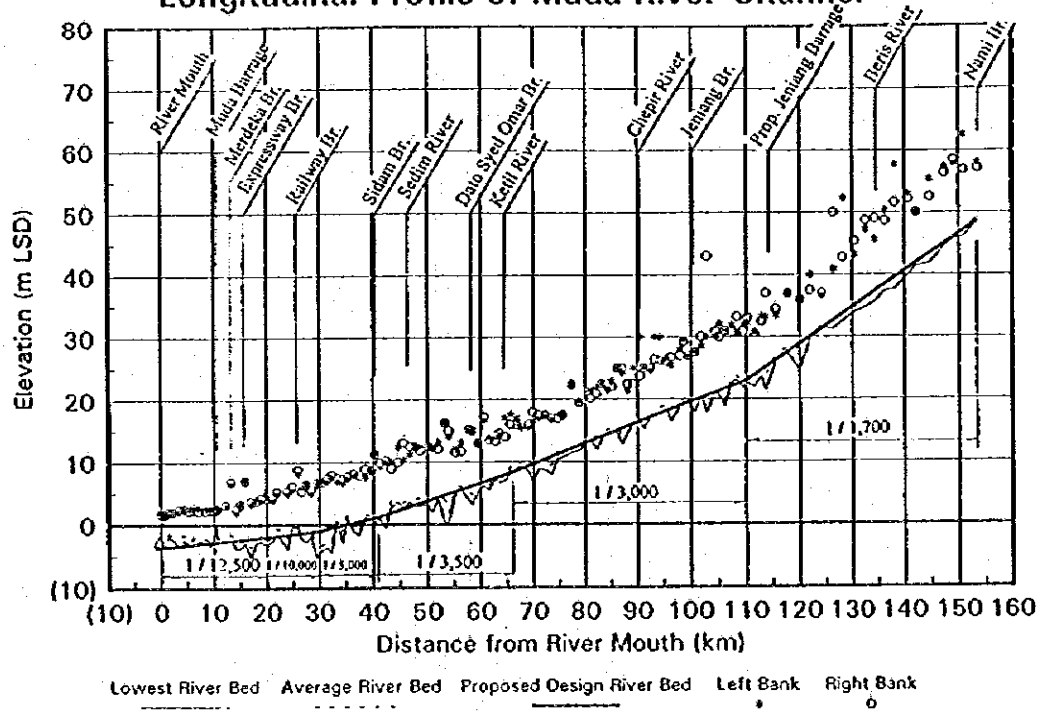


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.4.1.3 (2/3)
JAPAN INTERNATIONAL COOPERATION AGENCY	PROBABLE INUNDATION AREA BY 100-YEAR FLOOD ALONG SHORT TARGET STRETCH (BALING TOWN)

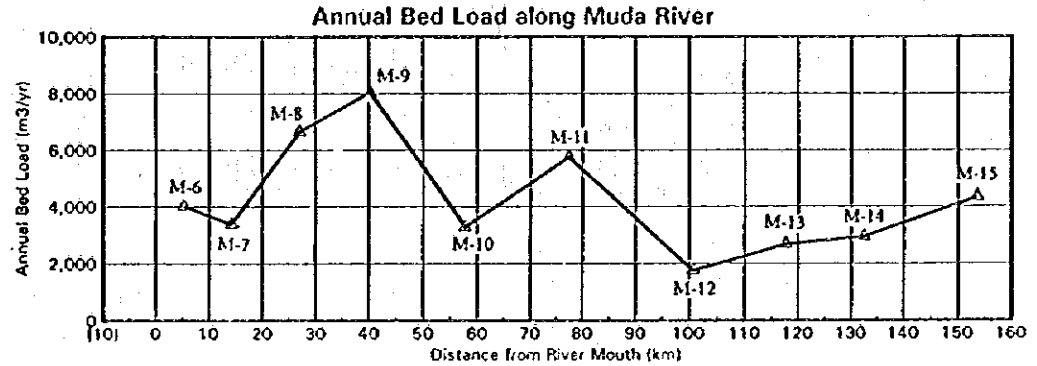


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.4.1.3 (3/3) PROBABLE INUNDATION AREA BY 100-YEAR FLOOD ALONG SHORT TARGET STRETCH (SIK TOWN)

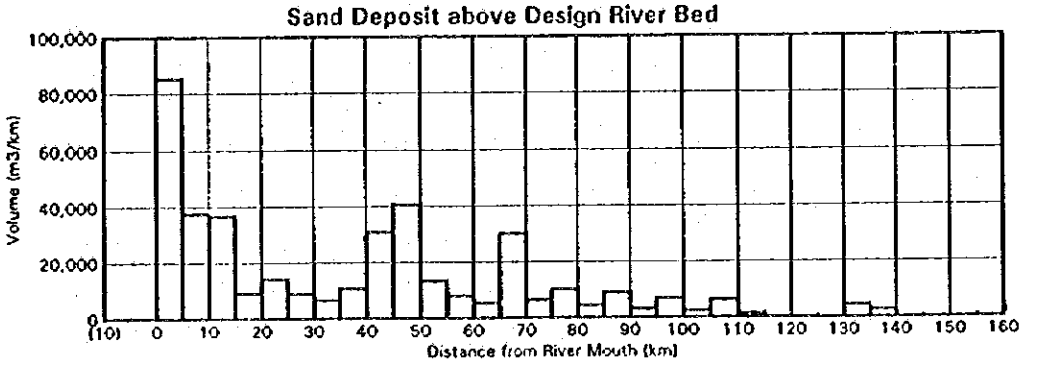
Longitudinal Profile of Muda River Channel



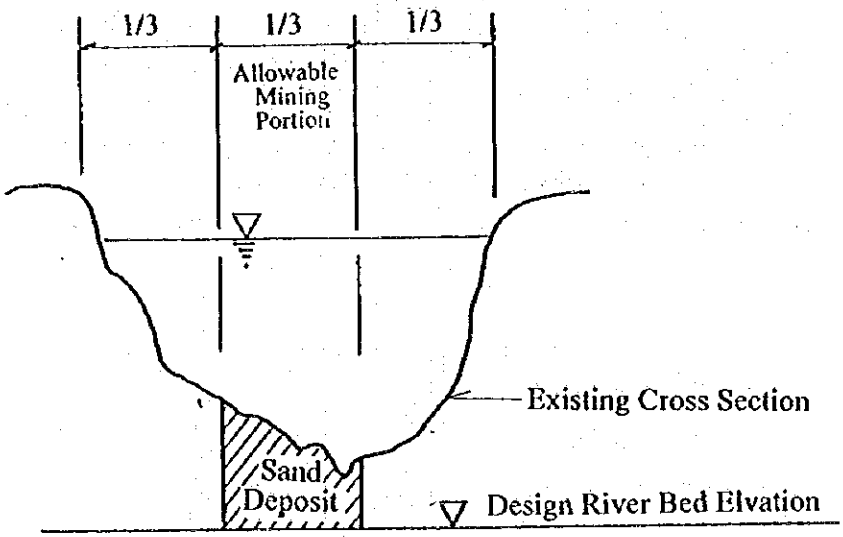
Annual Bed Load along Muda River



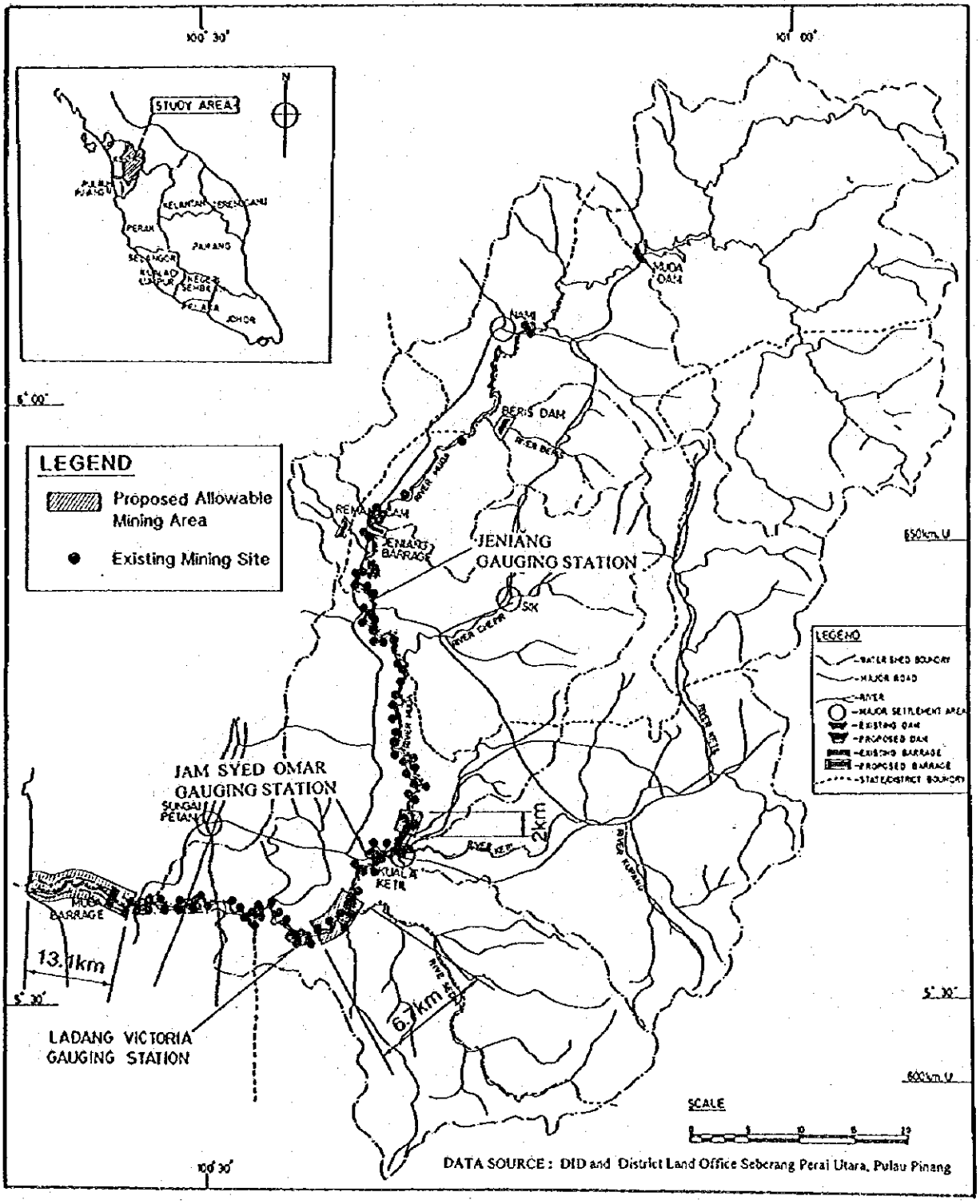
Sand Deposit above Design River Bed



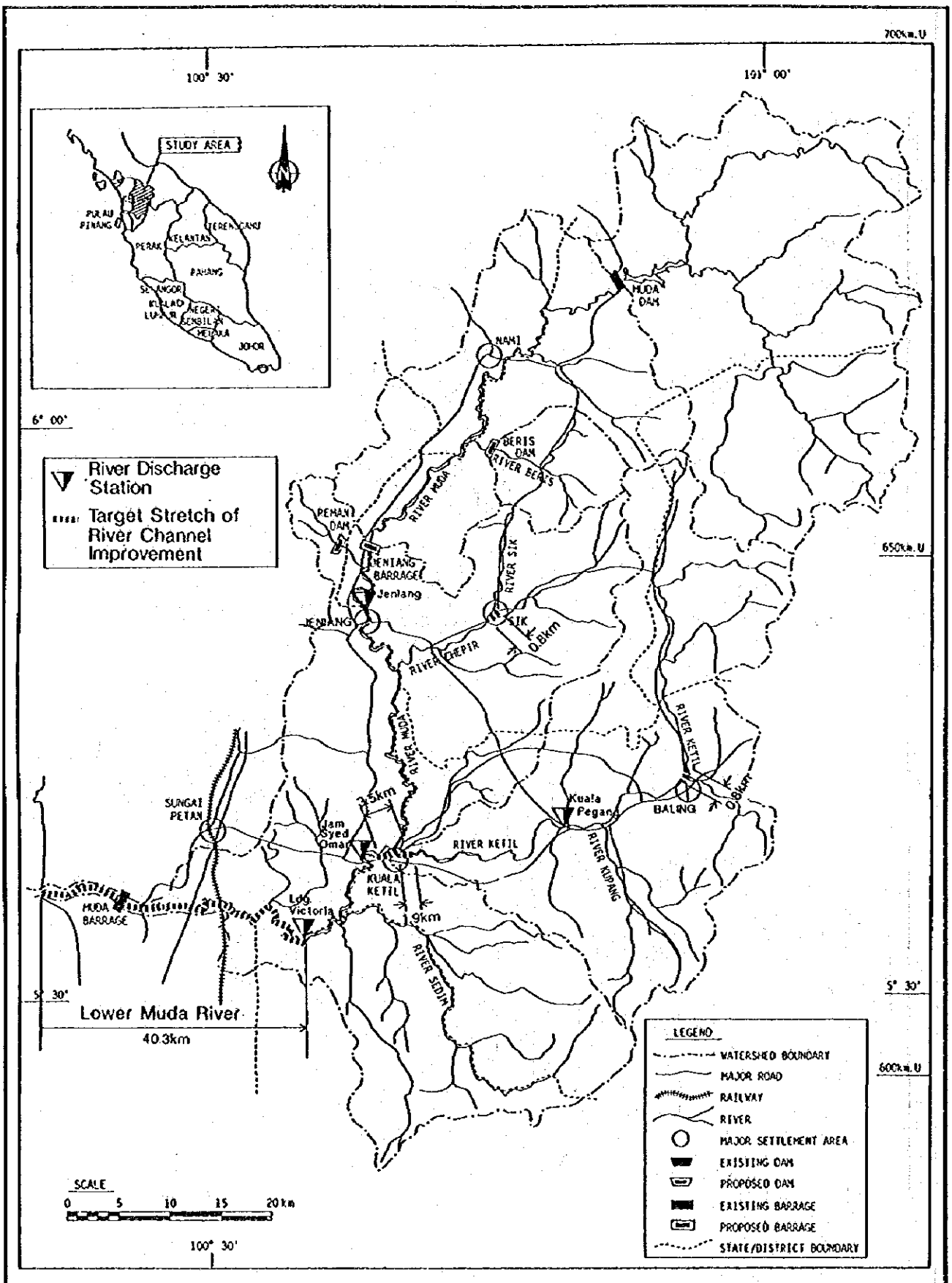
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.4.2.1 PROPOSED DESIGN RIVER BED PROFILE OF MUDA RIVER



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.4.2.2 SAND DEPOSIT ABOVE DESIGN RIVER BED ELEVATION



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.4.2.3
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF PROPOSED ALLOWABLE SAND MINING AREA

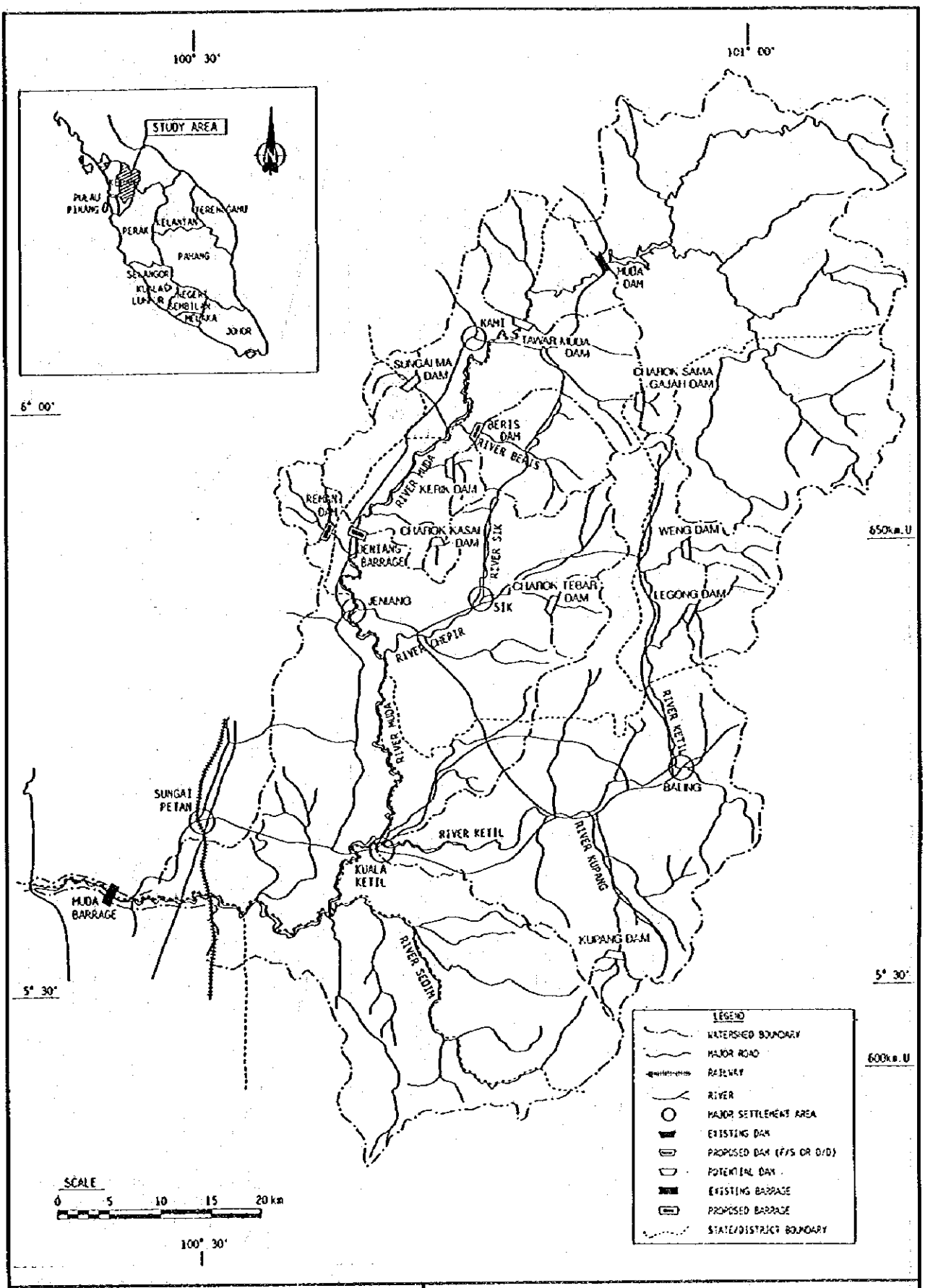


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

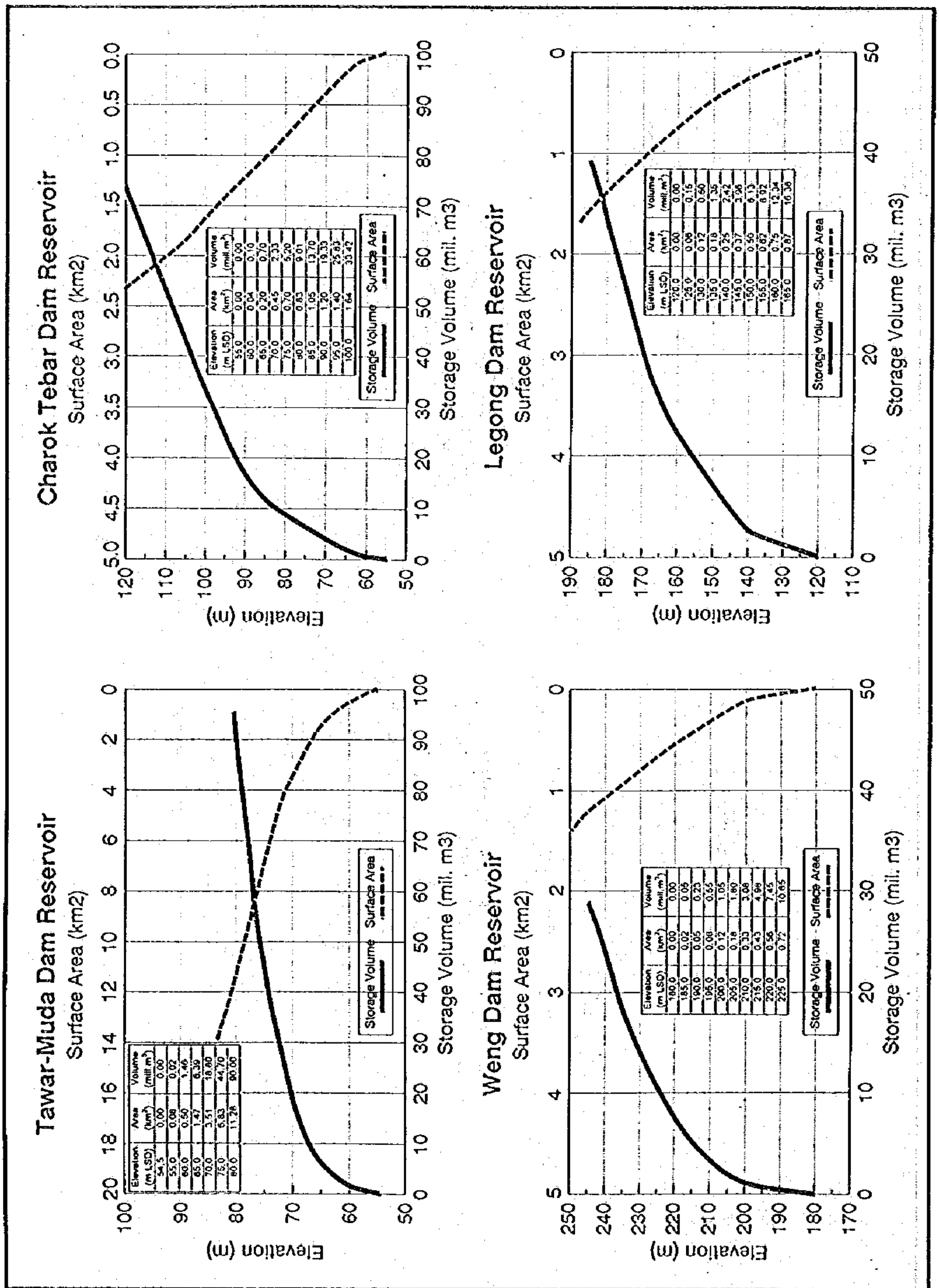
JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.5.1.1

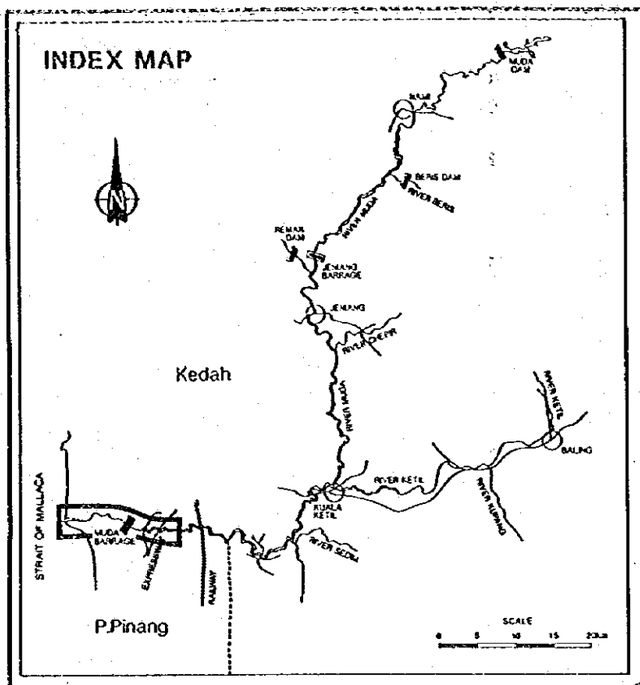
TARGET STRETCH FOR STRUCTURAL FLOOD MITIGATION PLAN



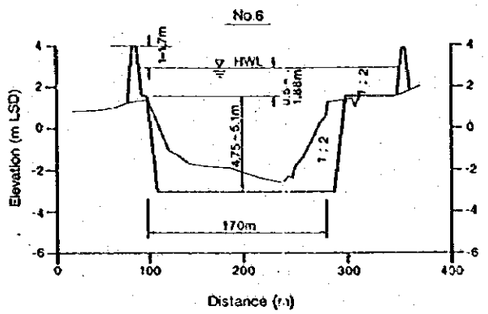
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.1.2
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF DAM RESERVOIR IN MUDA RIVER BASIN



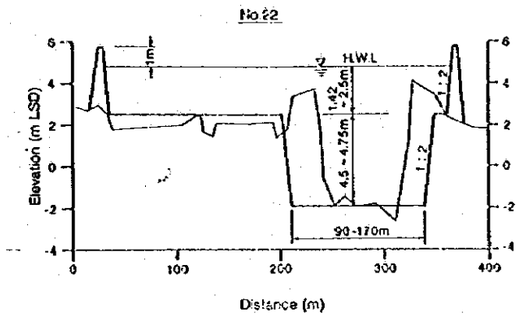
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.5.1.3 WATER LEVEL - STORAGE CAPACITY - SURFACE AREA CURVE OF POTENTIAL DAM RESERVOIR

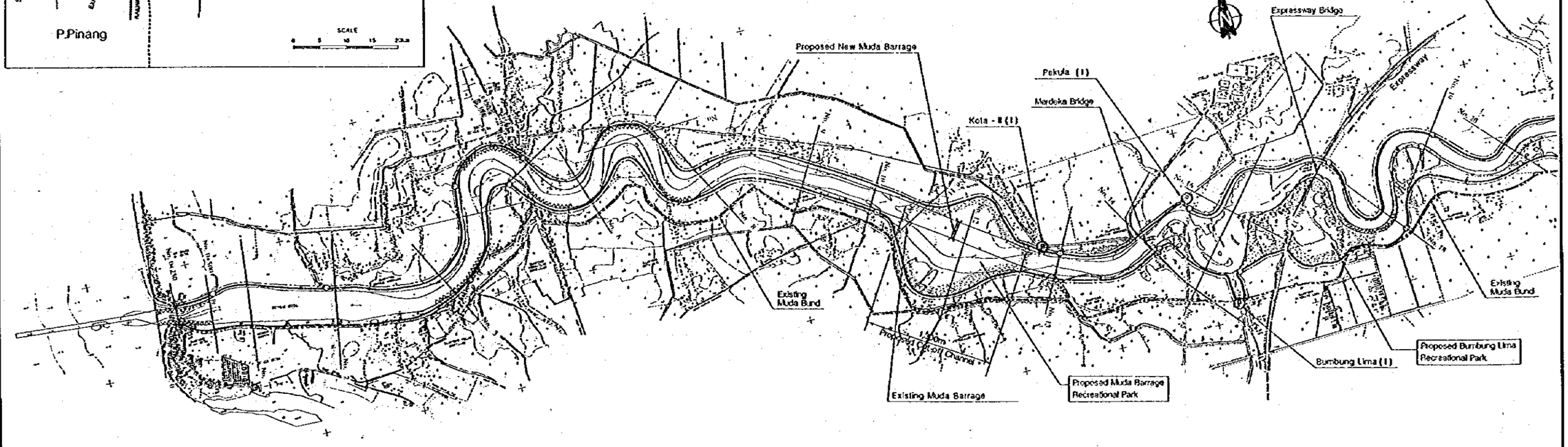


Typical Cross Section
(No.0 ~ No.11+300)



Typical Cross Section
(No.11+300 ~ No.30+55)

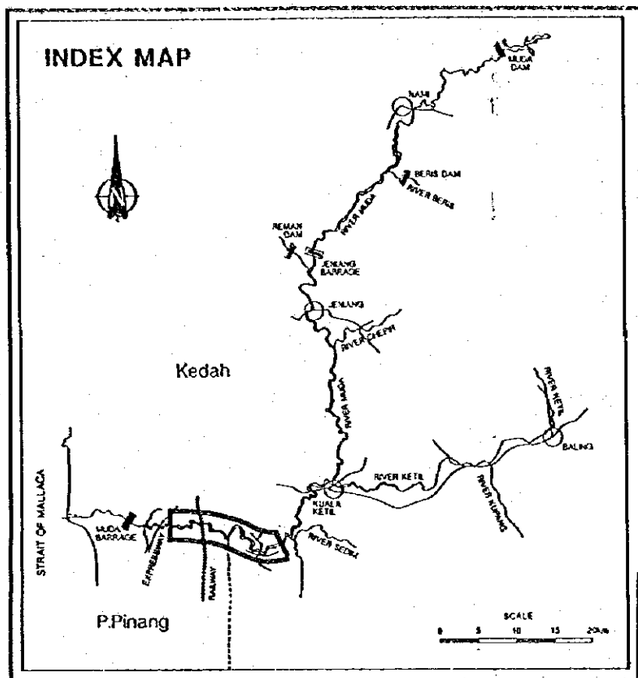




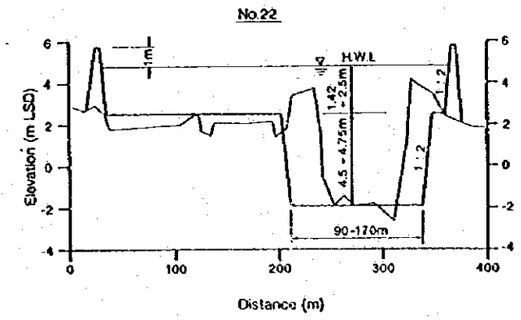
LEGEND

Proposed Dike		Proposed Drop	
Proposed Low Water Channel		Discharge Station	
Proposed Pavement		Proposed Sluice	
Existing Sea Dike	(P)	Pump Station	
Boundary of Proposed River Reserve Area	(I)	Irigation Purpose	
Proposed Barrage	(D)	Domestic / Industrial Purpose	

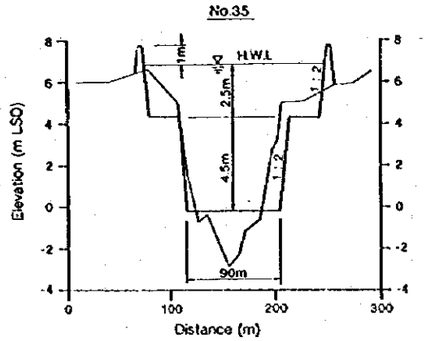
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.2.1 (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	PLAN AND TYPICAL CROSS SECTION OF PROPOSED LOWER MUDA RIVER IMPROVEMENT

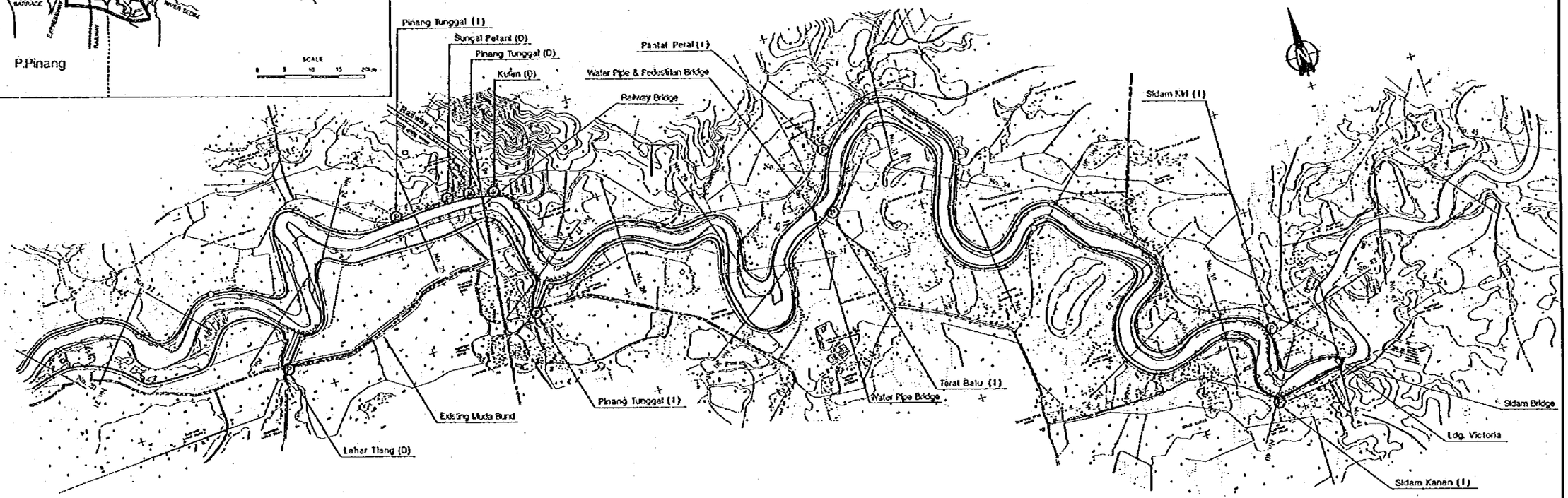


Typical Cross Section
(No.11+300 - No.30+55)



Typical Cross Section
(No.30+55 - No.41)

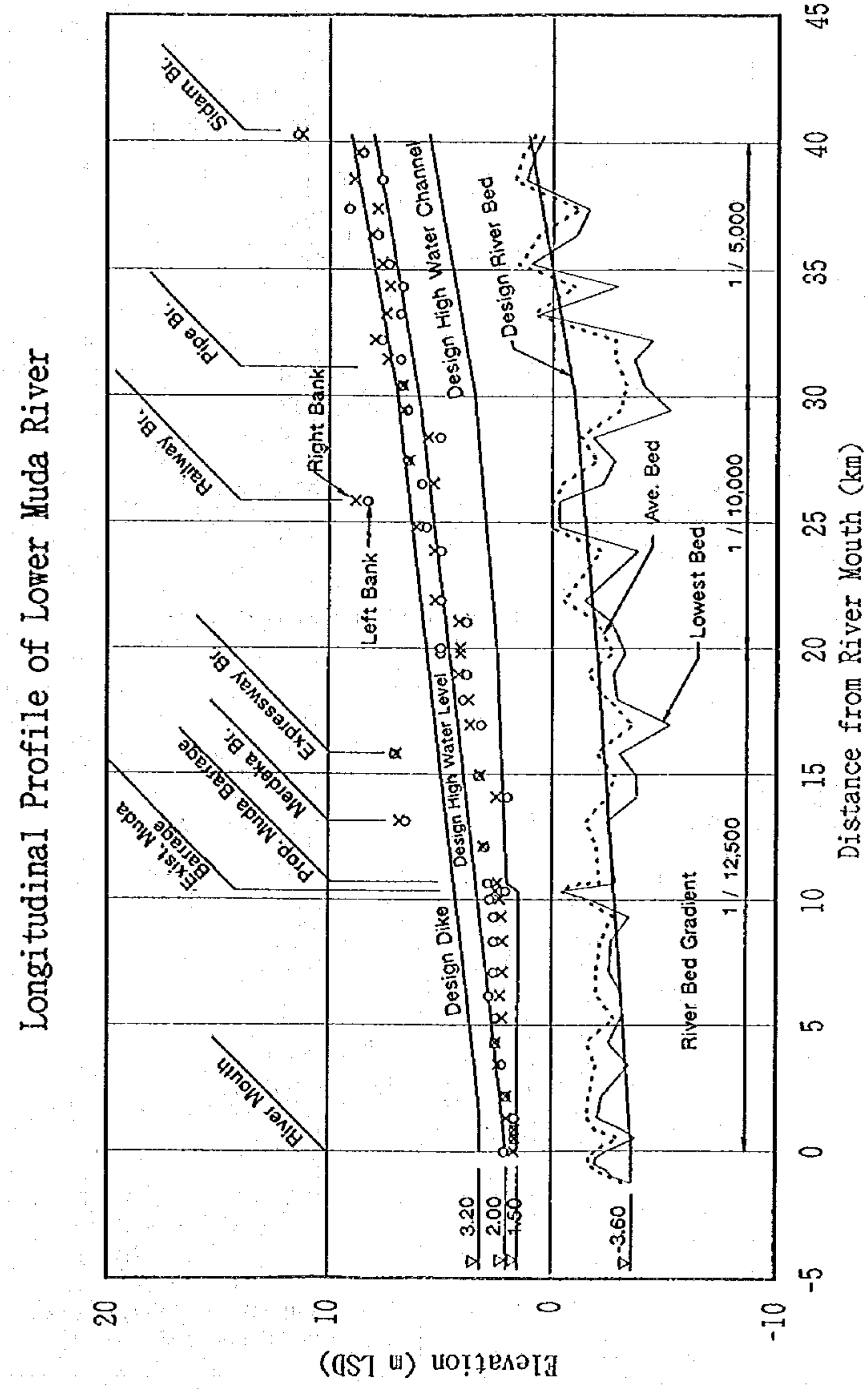




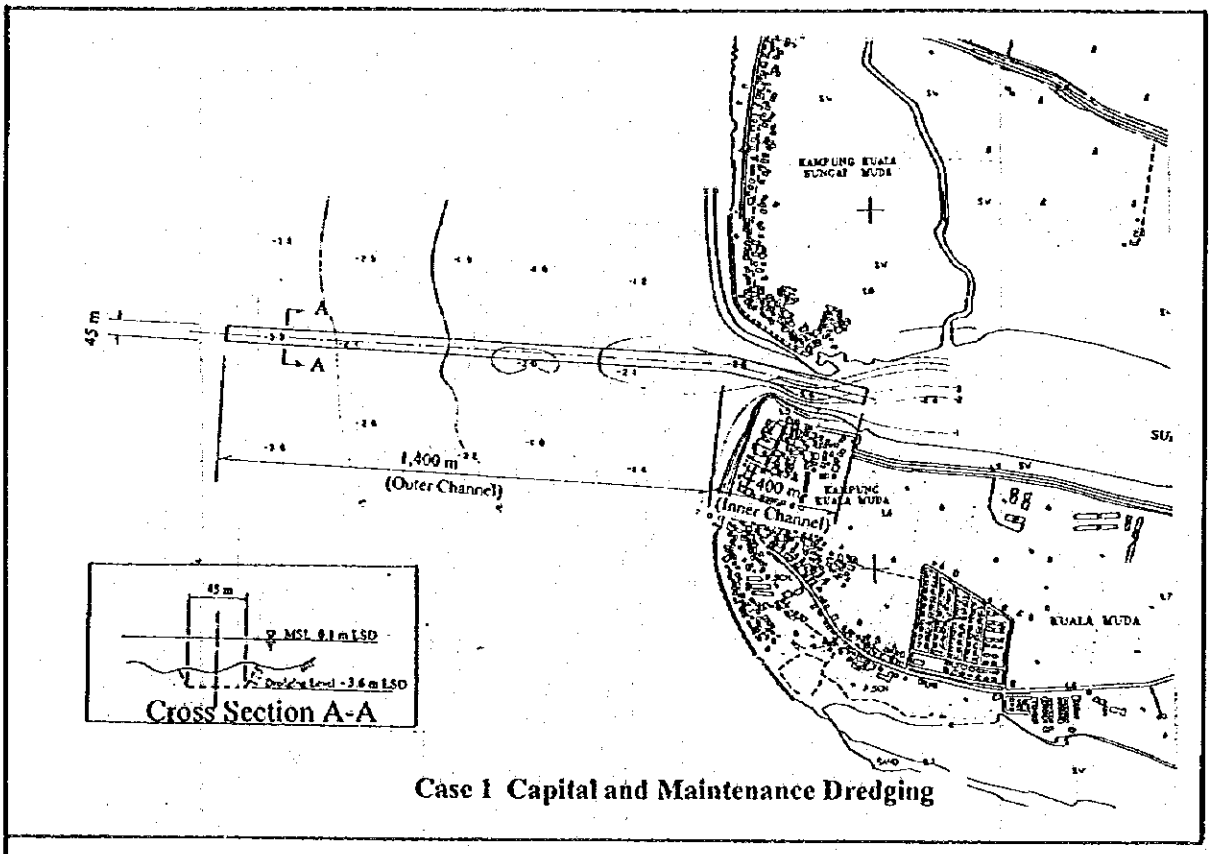
LEGEND

Proposed Dike		Proposed Drop	
Proposed Low Water Channel		Discharge Station	
Proposed Revetment		Proposed Sluice	
Existing Sea Dike		Pump Station	
Boundary of Proposed River Reserve Area		(I)	Irrigation Purpose
Proposed Barrage		(D)	Domestic / Industrial Purpose

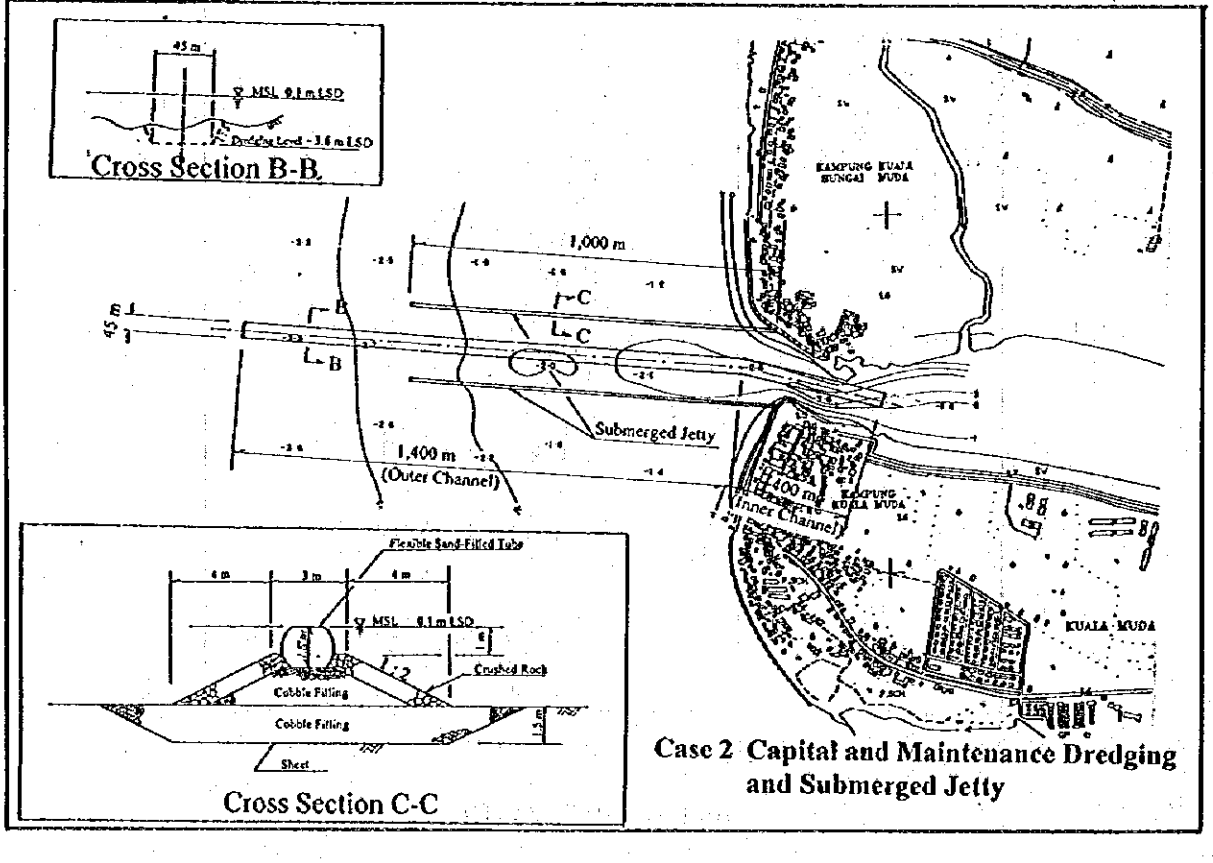
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.2.1 (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	PLAN AND TYPICAL CROSS SECTION OF PROPOSED LOWER MUDA RIVER IMPROVEMENT



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.2.2
JAPAN INTERNATIONAL COOPERATION AGENCY	LONGITUDINAL PROFILE OF PROPOSED LOWER MUDA RIVER IMPROVEMENT

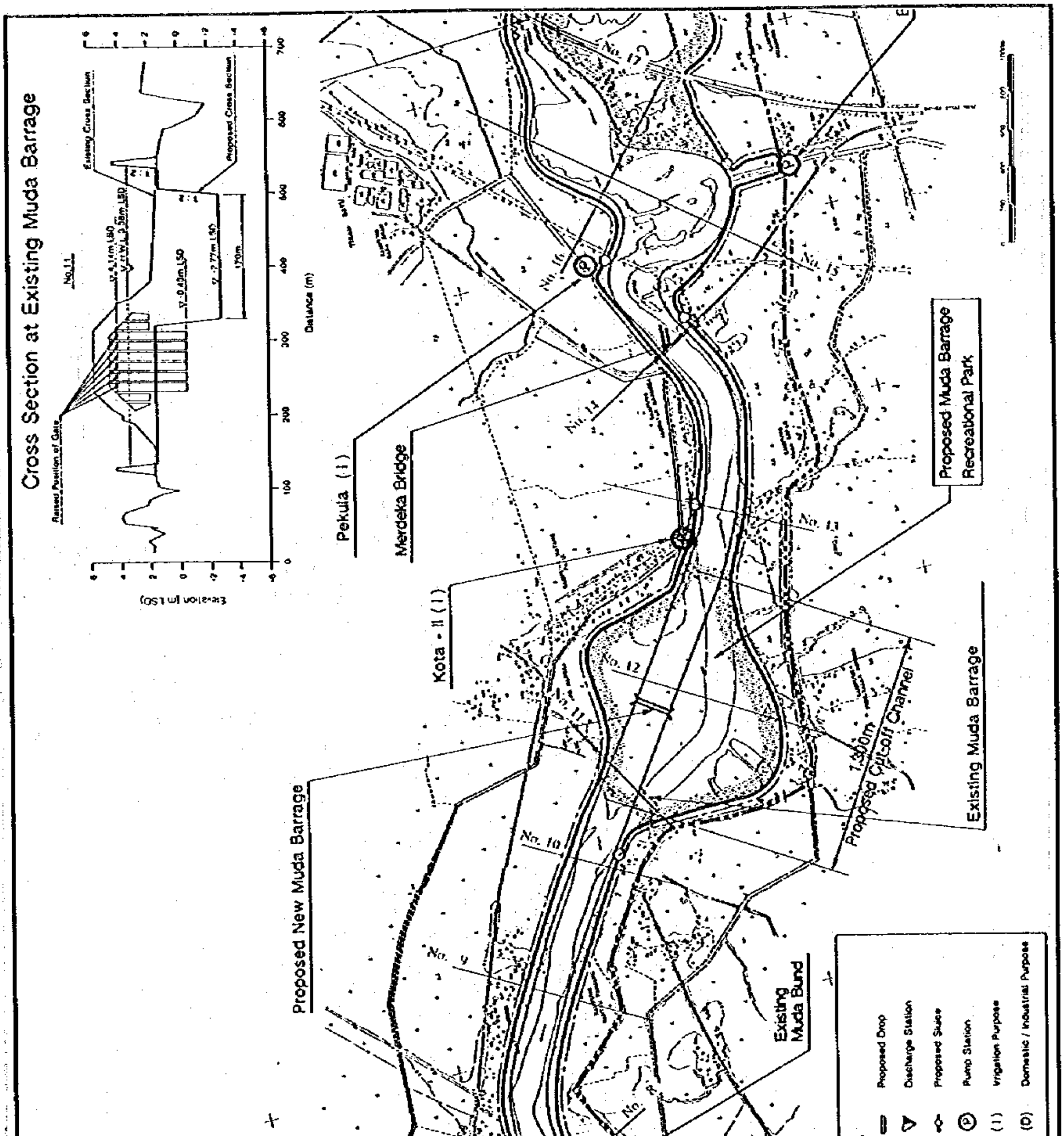


Case 1 Capital and Maintenance Dredging

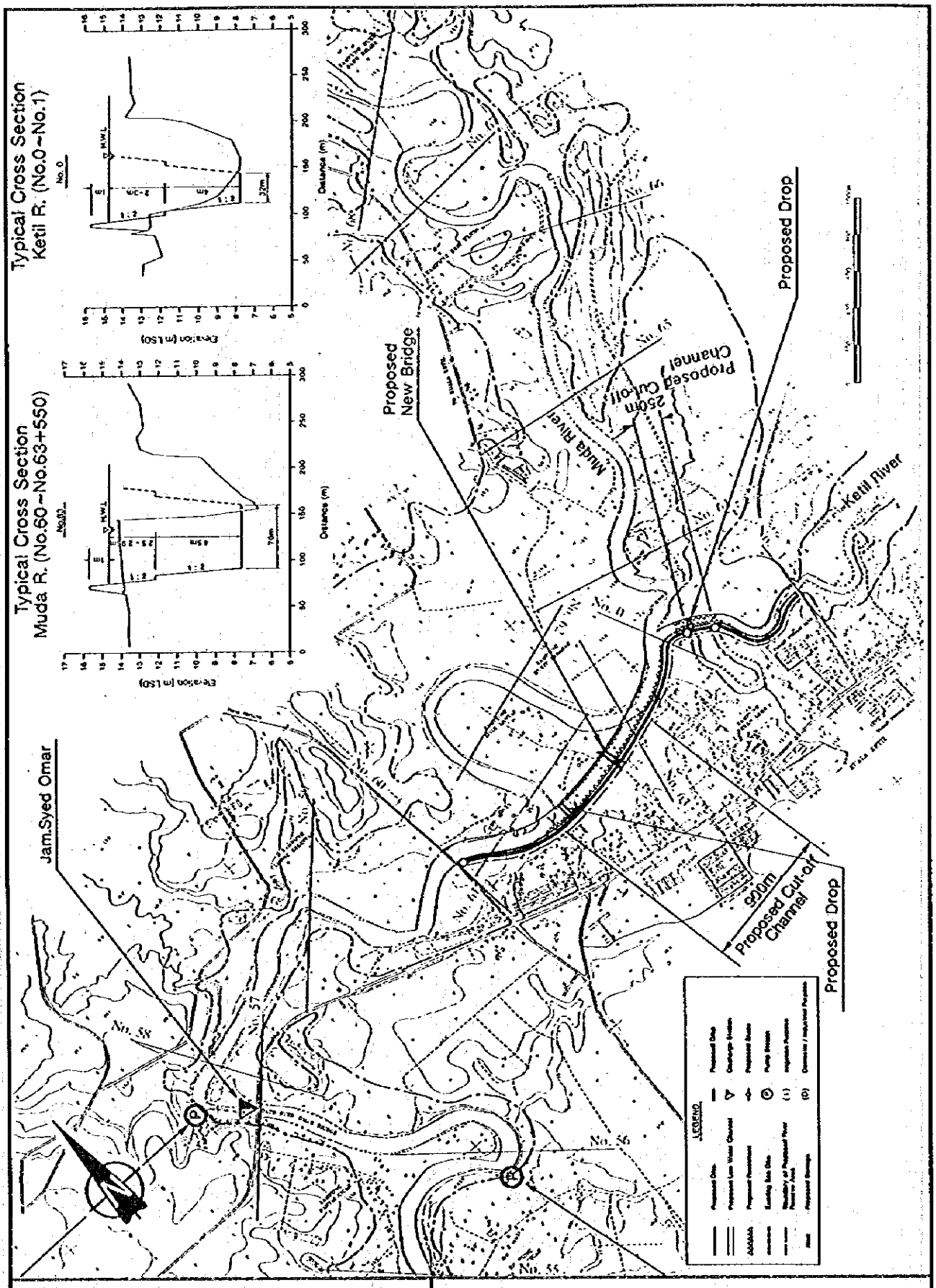


Case 2 Capital and Maintenance Dredging and Submerged Jetty

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.2.3 ALTERNATIVE PLAN OF MUDA RIVER MOUTH IMPROVEMENT
JAPAN INTERNATIONAL COOPERATION AGENCY	



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.2.4
JAPAN INTERNATIONAL COOPERATION AGENCY	RECONSTRUCTION OF MUDA BARRAGE



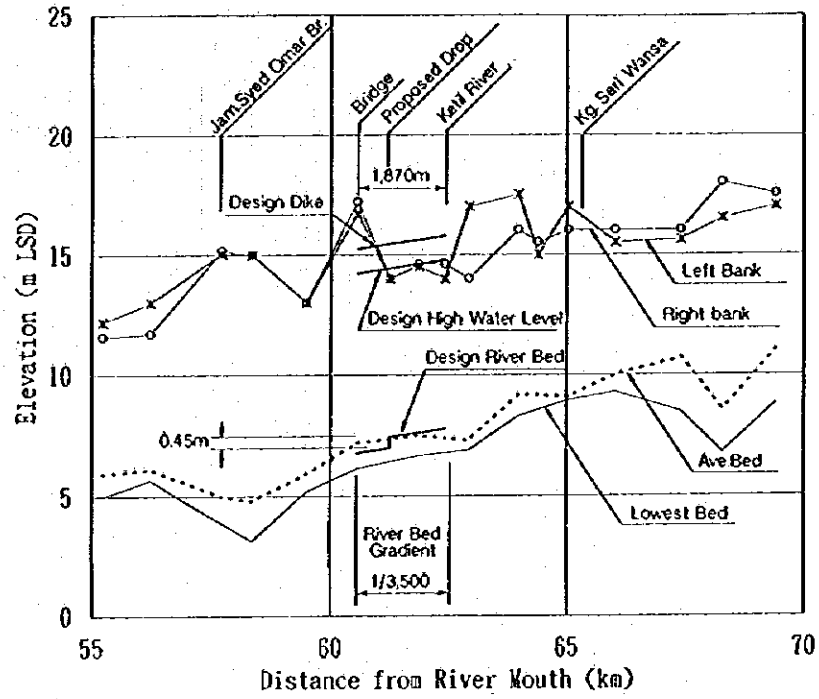
COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

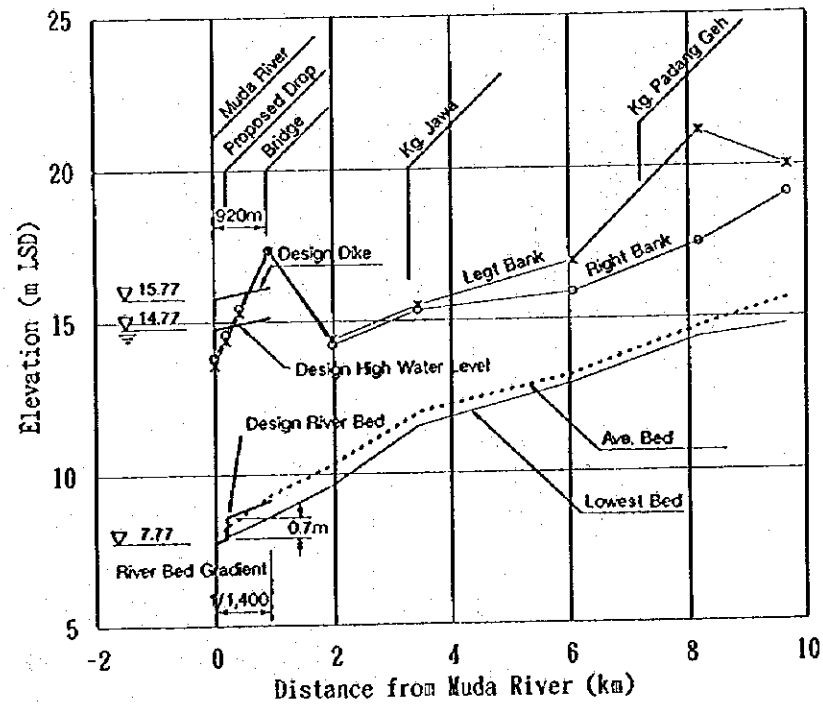
FIG. II.5.3.1

PLAN AND TYPICAL CROSS SECTION OF PROPOSED KUALA KETIL TOWN STRETCH IMPROVEMENT

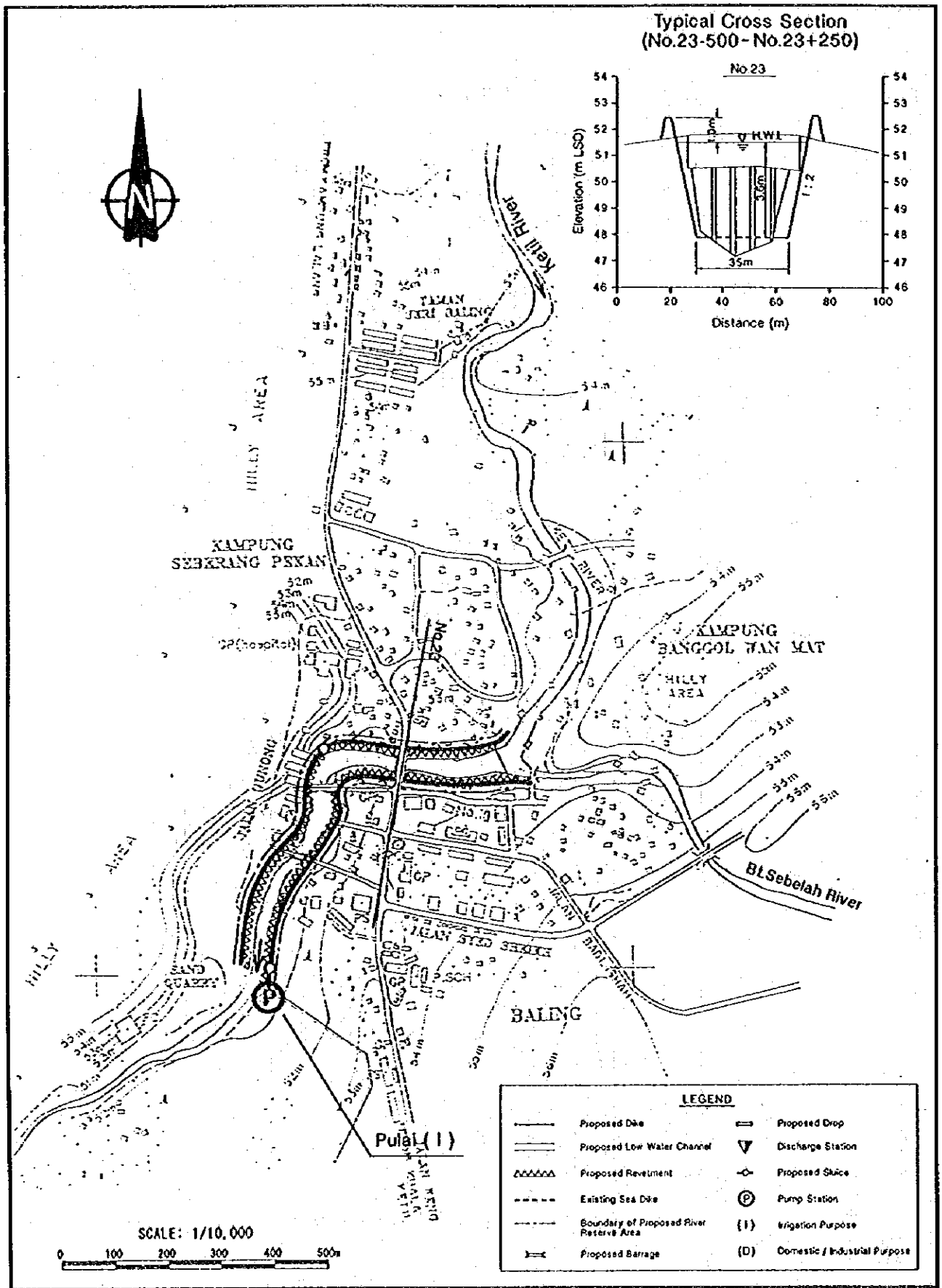
Muda River



Ketil River



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.5.3.2 LONGITUDINAL PROFILE OF PROPOSED KUALA KETIL TOWN STRETCH IMPROVEMENT

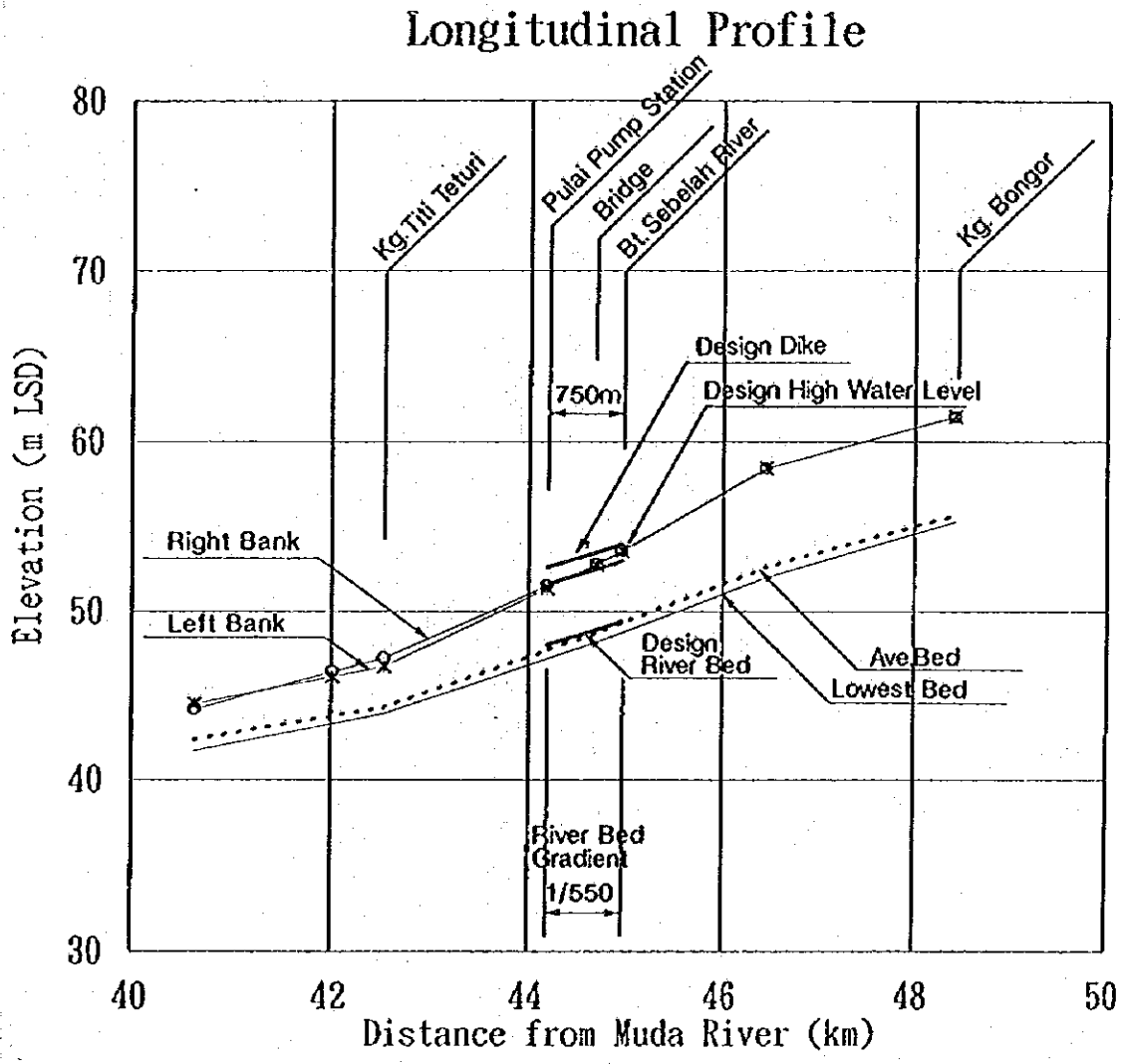


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

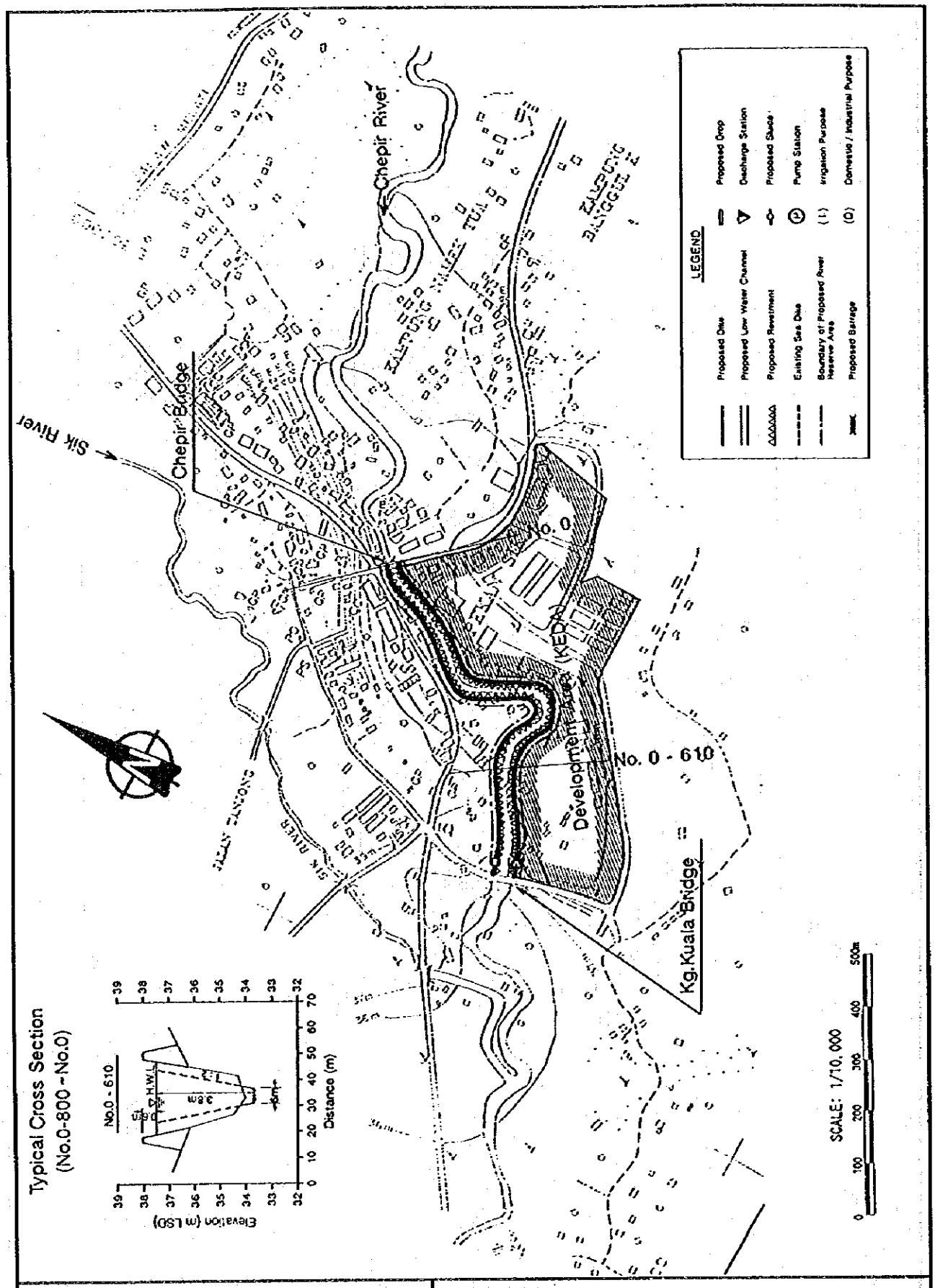
JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.5.4.1

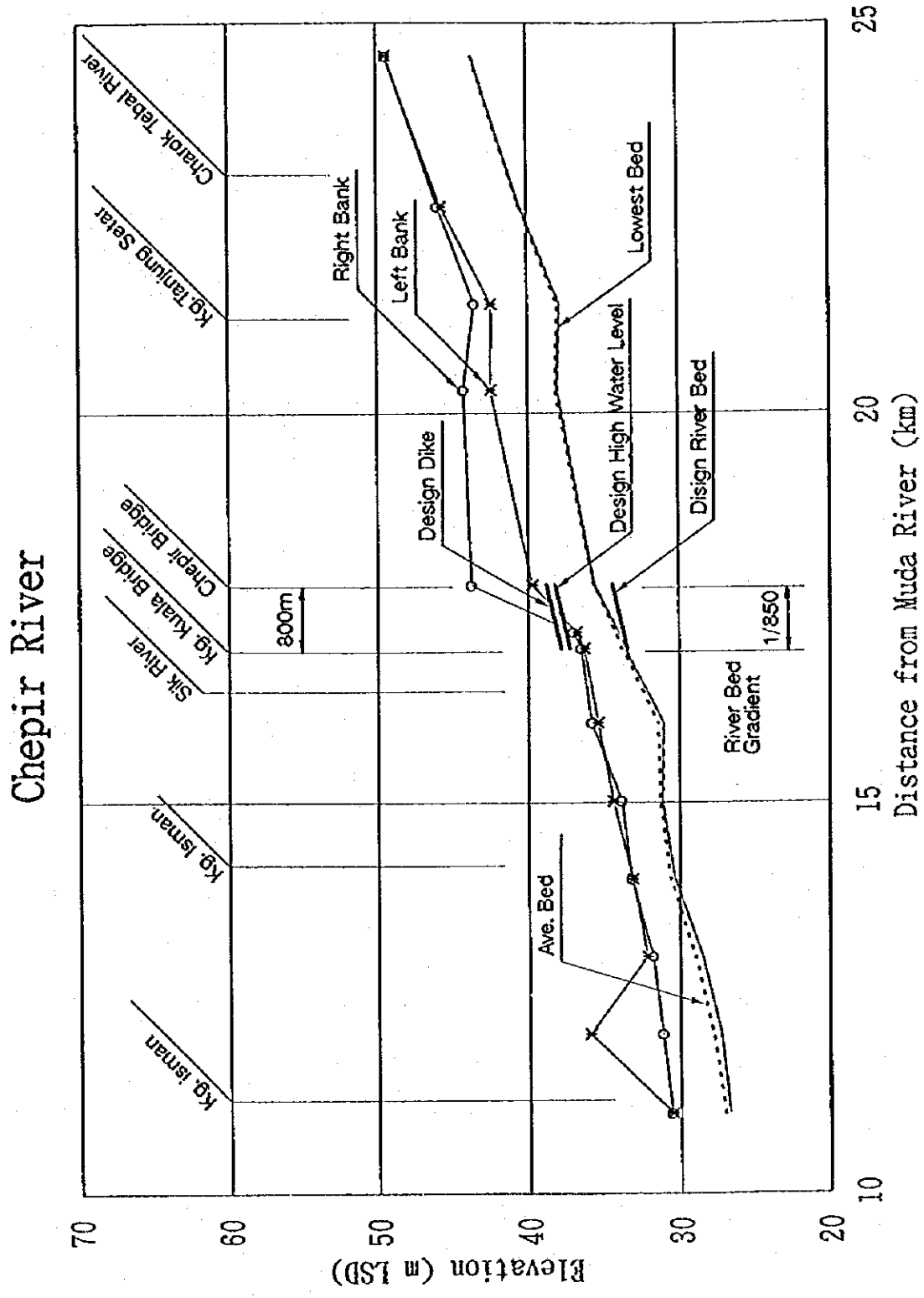
PLAN AND TYPICAL CROSS SECTION OF PROPOSED BALING TOWN STRETCH IMPROVEMENT



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.4.2 LONGITUDINAL PROFILE OF PROPOSED BALING TOWN STRETCH IMPROVEMENT
JAPAN INTERNATIONAL COOPERATION AGENCY	

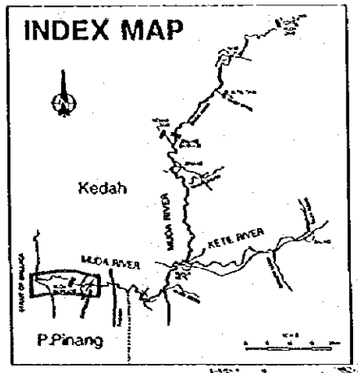


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN	FIG. II.5.5.1
JAPAN INTERNATIONAL COOPERATION AGENCY	PLAN AND TYPICAL CROSS SECTION OF PROPOSED SIK TOWN STRETCH IMPROVEMENT



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.5.5.2 LONGITUDINAL PROFILE OF PROPOSED SIK TOWN STRETCH IMPROVEMENT

INDEX MAP



Boundary of Proposed River Reserve Area

Boundary of Proposed River Reserve Area

Proposed New Muda Barrage

Existing Muda Bund

Existing Muda Barrage

Proposed Cut-off Channel

Kota - II (I)

Pekula (I)

Merdeka Bridge

Expressway Bridge

Expressway

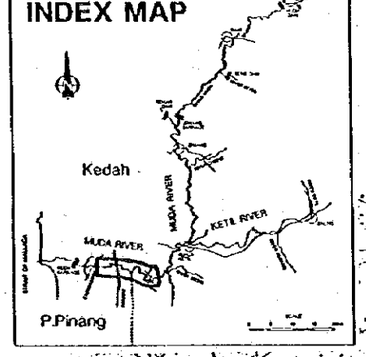
Existing Muda Bund

Proposed Bumbung Lima Recreational Park

Bumbung Lima (I)

Proposed Muda Barrage Recreational Park

INDEX MAP



Pinang Tunggal (I)

Sungai Petani (D)

Pinang Tunggal (D)

Kulim (D)

Pantai Perai (I)

Water Pipe & Pedestrian Bridge

Railway Bridge

Existing Muda Bund

Pinang Tunggal (I)

Lahar Tiang (D)

Boundary of Proposed River Reserve Area

Boundary of Proposed River Reserve Area

Sidam Kiri (I)

Perai Batu (I)

Water Pipe Bridge

Sidam Bridge

Ldg. Victoria

Sidam Kanan (I)

LEGEND

	Proposed Dike		Proposed Drop
	Proposed Low Water Channel	V	Discharge Station
	Proposed Revetment		Proposed Sluice
	Existing Sea Dike	P	Pump Station
	Boundary of Proposed River Reserve Area	(I)	Irrigation Purpose
	Proposed Barrage	(D)	Domestic / Industrial Purpose

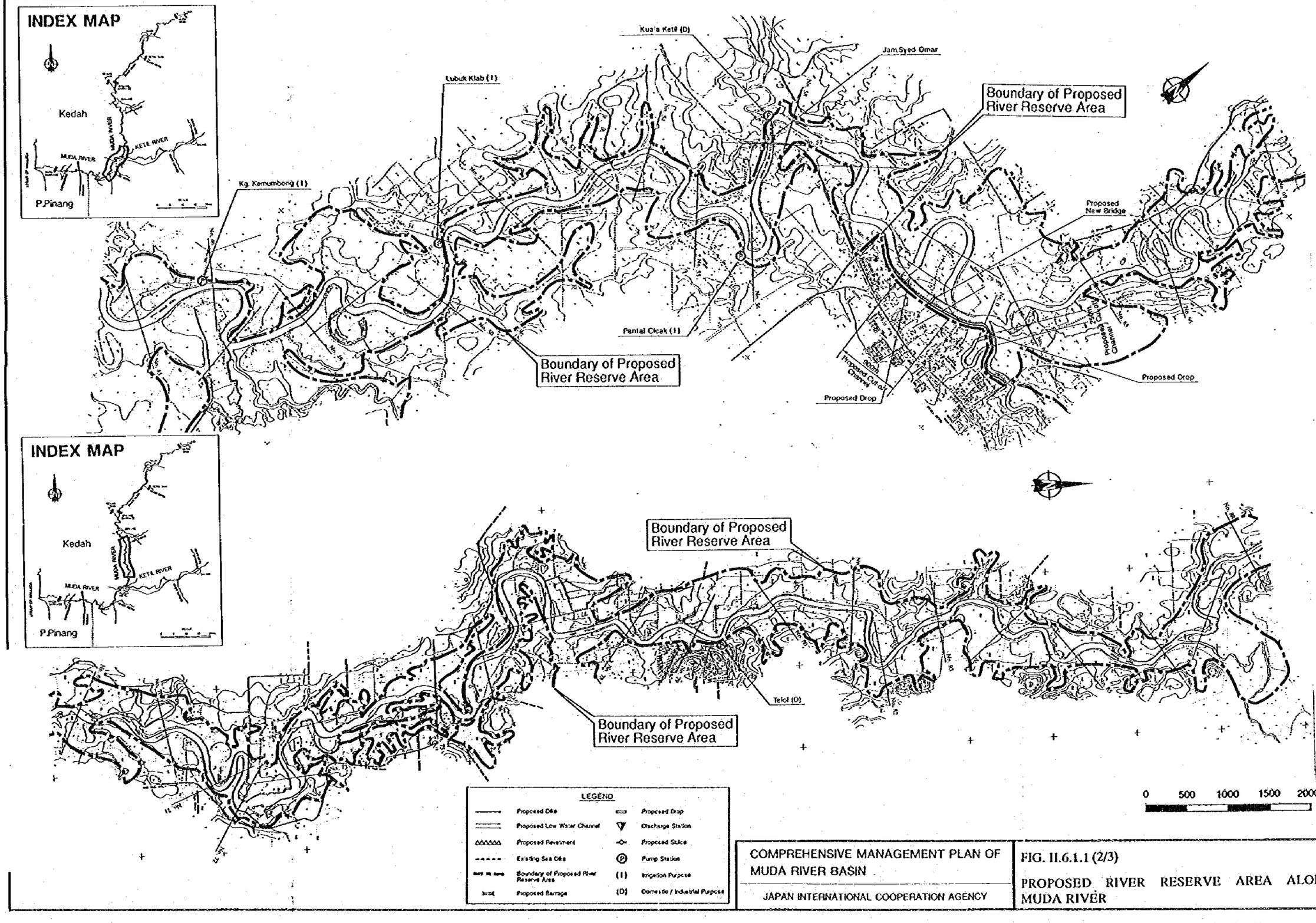
0 500 1000 1500 2000m

COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.6.1.1 (1/3)

PROPOSED RIVER RESERVE AREA ALONG MUDA RIVER

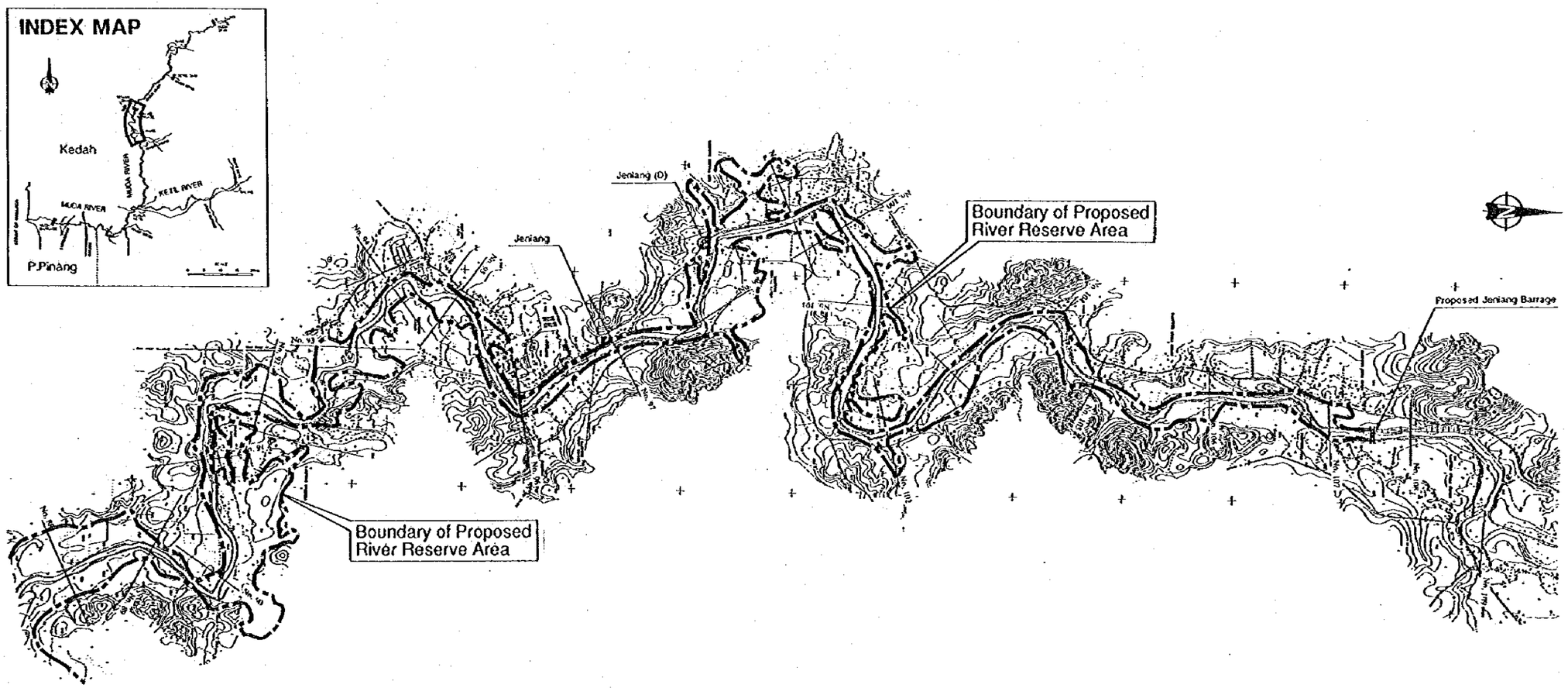


COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

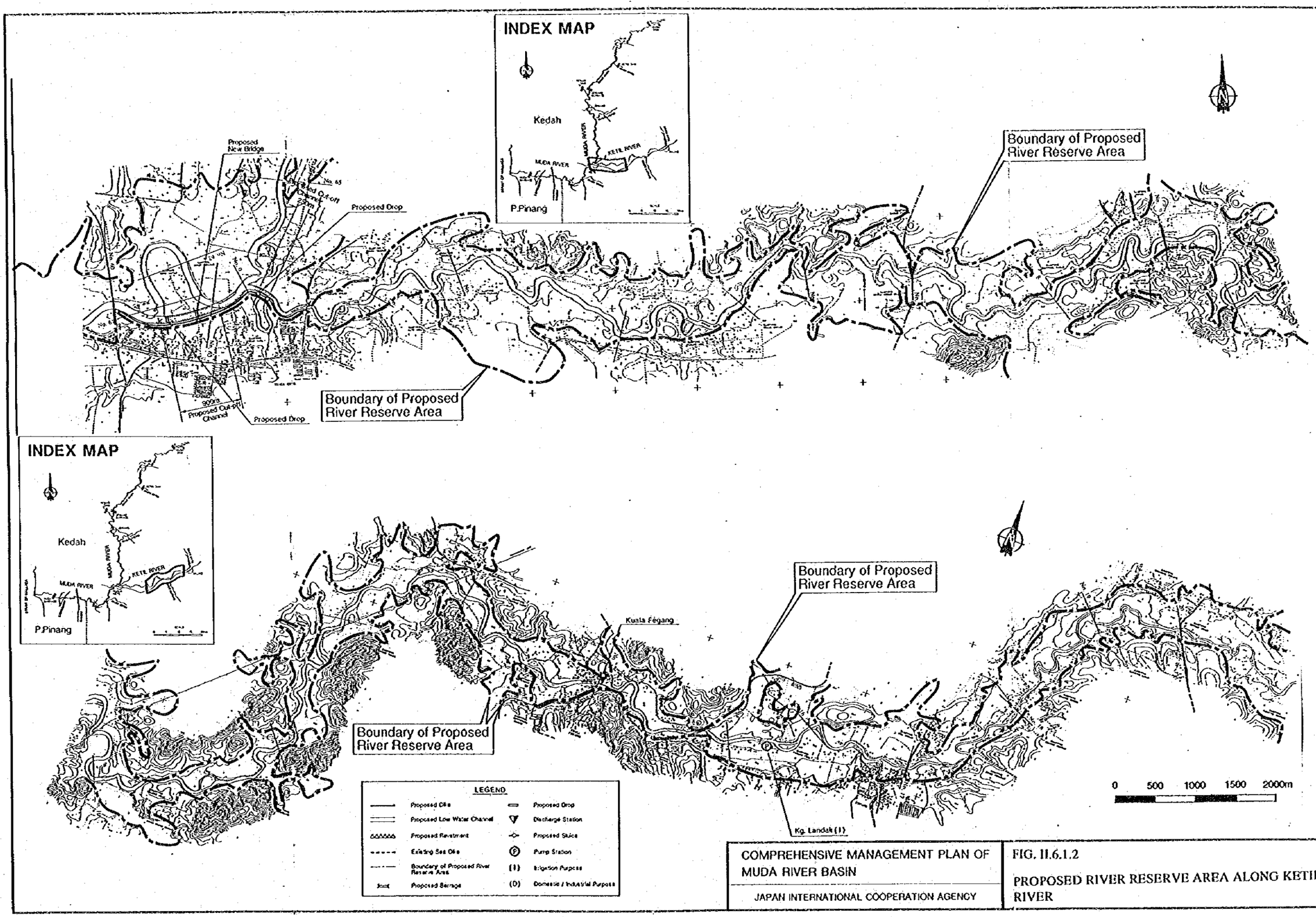
JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.6.1.1 (2/3)

PROPOSED RIVER RESERVE AREA ALONG MUDA RIVER



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	FIG. II.6.1.1 (3/3) PROPOSED RIVER RESERVE AREA ALONG MUDA RIVER



COMPREHENSIVE MANAGEMENT PLAN OF MUDA RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

FIG. II.6.1.2

PROPOSED RIVER RESERVE AREA ALONG KETIL RIVER

SECTOR III

WATER RESOURCES MANAGEMENT PLAN

SECTOR III
WATER RESOURCES MANAGEMENT PLAN

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LIST OF FIGURES

1. INTRODUCTION

This sector of the supporting report presents the analysis of the most effective use of water resources in the Muda river basin and proposes the water resources management plan for the basin. Water from the water resources in the Muda river basin are transferred by Saiong Tunnel of Muda Dam and Jeniang Transfer System to the Kedah river basin, and they are mainly used in the northern part of the State of Kedah and the southern part of the State of Perlis. Thus, not only the Muda river basin but the entire State of Kedah and parts of the states of Pulau Pinang and Perlis are included in the study area for developing the water resources management plan.

Section 2 presents the conditions of water supply and use in the states of Pulau Pinang, Kedah and Perlis which are discussed with careful consideration of environmental situations.

Section 3 estimates the projected water demand of each type of user in each area in the target year 2010. By the target year, water management structures will be integrated and/or newly constructed and irrigation schemes will be changed in line with "The National Agricultural Policy." Based on these expected changes and the basic amounts of water use estimated, the projected water demand of each type of user in each area is determined.

Section 4 develops a water balance simulation model in which the Muda river system as well as the Muda irrigation canal and the Kedah river system are dealt with, and basic indices such as safe supply, river use ratio, and drought damage at each scale of construction of water management structures are examined. Based on these indices, selected are the necessary water supply development structures to secure the water demand in 2010 under the design drought level of 10-year return period.

In Section 5, comprehensive operation rules for effective water use of the Muda river basin are formulated. In the process of formulating the rules, improvement of safe supply in the northern part of Muda (north to Pelubang Barrage) where Jeniang Transfer System cannot supply water and measures for drought damage mitigation during a period of excessive water deficit are explicitly considered. Merits and demerits of each rule are carefully evaluated, then the "Water Resources Management Plan in the Muda River Basin" is proposed.

2. PRESENT CONDITIONS OF WATER SUPPLY AND USE

2.1 Domestic and Industrial Water Supply and Use

2.1.1 Water Use and Service Area

The water resources of Muda River are used in the states of Pulau Pinang and Kedah and a part of the State of Perlis. In these areas, public water supply is administered

by the Water Supply Division of the State Public Works Department (PWD) in Kedah and Perlis, while the Penang Water Authority (PWA) manages it in Pulau Pinang.

PWA is a statutory body and is managed under a commercial accounting system. In 1993, the amount of water supply from the Muda and Kedah rivers was 372,000 m^3/day in the State of Kedah, 532,000 m^3/day in the State of Pulau Pinang and 25,000 m^3/day in the State of Perlis. The total population served with water through PWD and PWA pipeline networks is estimated at 1,028,000 in the State of Kedah, 1,071,000 in the State of Pulau Pinang and 150,000 in the State of Perlis in 1993. The service factor is estimated at 97% in Pulau Pinang, 67% in Kedah and 83% in Perlis.

In the upper reaches of the Muda river basin, Muda Dam with a catchment area of 984 km^2 is located. The water impounded by the dam is almost fully diverted to the reservoir of Pedu Dam located in the adjacent Kedah river basin and utilized for domestic/industrial water in the northern part of Kedah.

In the middle reaches, small-scale domestic/industrial water is extracted along the main stream and tributaries of the Muda river system. This water is supplied to the surrounding rural areas such as Sik, Jeniang and others. On the other hand, in the lower reaches, large-scale domestic/industrial water is extracted from the impounding stretch of Muda Barrage. The water is supplied to the State of Pulau Pinang and to southern part of the State of Kedah (refer to Fig. III.2.1.1).

2.1.2 Intake Facilities and Discharge

Along the Muda river system, twelve (12) intake facilities (excluding the one under construction) have been installed to supply domestic/industrial water for the surrounding demand areas such as George Town, Sg. Petani and others. Locations and features of the present and under construction intake facilities for domestic/industrial water are shown in Fig. III.2.1.2 and Table III.2.1.1, respectively. As shown in Fig. III.2.1.2, all major intake facilities such as Lahar Tiang and Sg. Petani are located in the impounding stretch of Muda Barrage. Total intake discharge of the major intake facilities occupies about 90% of the whole intake discharge for domestic/industrial water from Muda River.

Lahar Tiang Pump Station (intake capacity of 315,000 m^3/day) plays a quite important role for domestic/industrial water supply to the State of Pulau Pinang covering about 70% of the state total demand. Sg. Petani Pump Station (intake capacity of 68,300 m^3/day) is also regarded as important intake facility for domestic/industrial water in the southern part of the State of Kedah, particularly, Sg. Petani. Others are small-scale facilities installed by the "Adris Biwater" under the Malaysian Rural Water Supply Scheme Program, and their intake capacities are less than 20,000 m^3/day.

The monthly intake discharge at each intake along the Muda river system has been recorded, as shown in Table III.2.1.2 and Fig. III.2.1.3. Due to climatic characteristics, conspicuous change is not recognized in the intake discharge of each month. Although the largest intake discharge is recorded in March, and the smallest

is in November, the monthly variations are within a range of less than 7% of the annual average.

2.2 Irrigation Water Supply and Use

2.2.1 Water Use and Irrigation Schemes

There are sixty (60) schemes of paddy fields relying on the Muda and Kedah rivers as water sources. Among them, two (2) schemes (Muda irrigation area and a part of Seberang Perai) are the main granaries, eleven (11) schemes are the secondary granaries, and forty-seven (47) schemes are minor irrigation schemes (refer to Fig. III.2.2.1 and Table III.2.2.1). The definitions of main granaries, secondary granaries and minor irrigation schemes are given in SECTION 3.

The Muda irrigation scheme which is the largest irrigation scheme in Peninsular Malaysia occupies a flat alluvial coastal plain of about 97,000 ha, extending from the State of Kedah to the State of Perlis. The irrigation water for the Muda irrigation scheme is supplied by the discharge released from the reservoirs of Pedu Dam and Muda Dam and the natural flow discharge of Kedah River. The annual irrigated gross water demand for the Muda irrigation scheme is estimated at about 2,000 million m^3.

The Seberang Perai irrigation scheme of 8,000 ha is located around the Muda river basin abstracting irrigation water from the downstream of Muda River. It is the largest irrigation scheme in the State of Pulau Pinang, and the annual irrigated gross water demand is estimated at about 160 million m^3.

In addition to the above two main granaries, there are fifty eight (58) small-scale irritation schemes of 18,800 ha in total which are divided into thirty-four (34) schemes (8,400 ha) in the Muda river basin and twenty-four (24) schemes (10,400 ha) in the Kedah river basin. Most of the schemes are located in the fringes of Muda irrigation scheme and on the right bank of the Muda lower reaches. The annual irrigated gross water demand in these schemes is estimated at about 190 million m^3 in the Muda river basin and about 240 million m^3 in the Kedah river basin (refer to Table III.2.2.2).

In the upper reaches of the Muda river basin, the impounded water of Muda Dam is almost fully diverted to Pedu Dam, and utilized for Muda irrigation area and fringe irrigation areas. The annual diverted water volume is estimated at about 650 million m^3.

In the middle reaches, small-scale irrigation water is abstracted along the main stream and tributaries of the Muda river system, and supplied to surrounding secondary granaries such as Kg. Parit, Pulai and other minor irrigation schemes. The total area is about 3,200 ha (27 schemes) and the annual average abstraction from rivers to these schemes is estimated at about 30 million m^3.

In the lower reaches, there are several utilization of irrigation water within the impounding extent of Muda Barrage both in the States of Kedah and Pulau Pinang. The total irrigation area in the lower reaches is 13,000 ha, of which 8,000 ha is

occupied by the Seberang Perai irrigation scheme. The annual average abstraction in the lower reaches is estimated at about 150 million m^3 (refer to Table III.2.2.3).

2.2.2 Intake Facilities and Discharge

Along the Muda river system, one (1) dam and twenty-eight (28) intake facilities are installed to irrigate paddy fields of about 16,000 ha (excluding Muda irrigation area). Locations and principal features of irrigation intake facilities are shown in Fig. III.2.2.2 and Table III.2.2.4.

Bumbong Lima and Kota 2, and other two pump stations located along the impounding extent of Muda Barrage, are the major intake facilities for the existing irrigation schemes in the Muda river system. These four (4) facilities abstract more than 80% of the total irrigation water demand except for Muda irrigation area.

Table III.2.2.5 and Fig. III2.2.3 show the monthly fluctuation of intake discharge at each intake facility along Muda River in 1993. A majority of the existing irrigation schemes along Muda River have a double-cropping pattern. The month of the largest intake discharge is May, while the month of the smallest is August. It is estimated that the largest monthly intake discharge take about 180% of the annual average.

3. PROJECTION OF WATER DEMAND

3.1 Domestic and Industrial Water Demand

3.1.1 Methodology

The future domestic water demand is projected through the following conventional formulas:

Treated Water Demand = *(Population) x (Service Factor) x PCDC + (C/I Demand) + (Unaccountable Water) + (Industrial Water)*

Source Water Demand = *(Treated Water Demand) ÷ (TP Ratio)*

where,

PCDC	:	Per Capita Daily Consumption
C/I Demand	:	Commercial and Institutional Demand
TP Ratio	:	Treatment Plant water use ratio (assumed at 0.95)
Industrial Water	:	Assuming treated water demand is equivalent to sour water demand

In the above formulas, the treated water demand expresses the actual water consumption of users, while the source water demand is necessary water supplied from a water source to meet the treated demand.

3.1.2 Service Area and Population Served

From the viewpoint of public water supply plans projected by PWD and PWA, it was estimated that the water resources in Muda River would cover the following service areas in 2010 (refer to Fig. III.3.1.1 and Table III.3.1.1). In the Study, the water supply plan for the Muda river system is formulated on the premise of service areas.

(1) Service Area A (Within Muda River Basin)

The water demand is to be fully supplied from Muda River both in the present year 1993 and in the target year 2010.

(2) Service Area B (Outside Muda River Basin in Kedah and Perlis)

The demand in 1993 and 2010 is to be supplied from Muda River as well as Kedah River, and it is difficult to specify a definite value of water demand that solely depends on the source in Muda River. In this connection, a low flow simulation was carried out to clarify the supply capacity of the rivers (refer to SECTOR I, HYDROLOGY). The appropriate water supply volume from Muda River was determined in due consideration of the results of the simulation.

(3) Service Area C (Outside Muda River Basin in Pulau Pinang)

The source in Muda River supplies about 70% of the present total demand as of 1993. In addition to the present supply volume, the water resources in Muda River will cover 100% of the incremental demand in the year 2010.

The population served by Muda River is estimated on the basis of the population projected in each *Mukim* and the aforesaid service areas. Details of the population projection by mukim are described in SECTOR VII, SOCIO-ECONOMY.

The served population is shown in Tables III.3.1.2 and III.3.1.3. These tables show that about 3.5 million people, twice the number of population in 1993, will need water supply from Muda River and Kedah River in 2010. It is, herein, noted that the service factors for the population were decided considering the results of recent relevant studies and interview surveys from the related agencies (PWA in the State of Pulau Pinang and PWD in the State of Kedah).

3.1.3 Key Parameters for Projection

The domestic/industrial water demand is projected on the premises of the following parameters:

(1) Per Capita Daily Consumption

The present per capita consumption of major cities in Southeast Asia are as shown in Table III.3.1.4. The Study projected the following per capita consumption, based on the per capita consumption in the major cities in Table III.5.1.5 as well as the results of recent relevant studies (refer to Table III.3.1.5).

(1) Urban	300 liters/person/day (Pulau Pinang)
(2) Urban	280 liters/person/day (Kedah & Perlis)
(3) Semi Urban	200 liters/person/day
(4) Rural	160 liters/person/day

(2) Commercial/Institutional Demand

In the Study, commercial/institutional demand is expressed as a ratio of domestic water demand, and the following ratios were adopted in due consideration of historical data, recent relevant studies, as well as design criteria and standards (refer to Table III.3.1.5):

(1) Urban Area in State of Pulau Pinang	30%
(2) Urban Area in Other States	15%
(3) Semi-Urban and Rural Area	10%

As shown above, the commercial/institutional ratio for the urban areas in the State of Pulau Pinang is bigger than those in other cities. This increment is due to intensive demand in the tourism sector.

(3) Unaccounted Water

The present unaccounted water ratio in the State of Kedah is over 60%, while the ratios in other advanced countries are mostly less than 10% (refer to Table III.3.1.4). Thus, it is important to reduce the present unaccounted water ratio in the State of Kedah. In fact, the future unaccounted ratio for the State of Kedah is projected at 15-30% in other relevant studies (refer to Table III.3.1.5).

Taking the above conditions into consideration, the following unaccounted water ratios are projected in the target year 2010 in this Study:

(1) Urban	15%
(2) Semi Urban	20%
(3) Rural	30%

3.1.4 Industrial Water Demand

The recent studies projected the industrial water demand per unit area as 22,000-45,000 liters/ha/day (refer to Table 3.1.5). By referring to these projections, the industrial demand per unit area is assumed to be 33,000 liters/ha/day in the Study, and the future industrial water demand is projected as below:

Industrial Water Demand = (Projected Industrial Area) × 33, 000 liters/ha/day