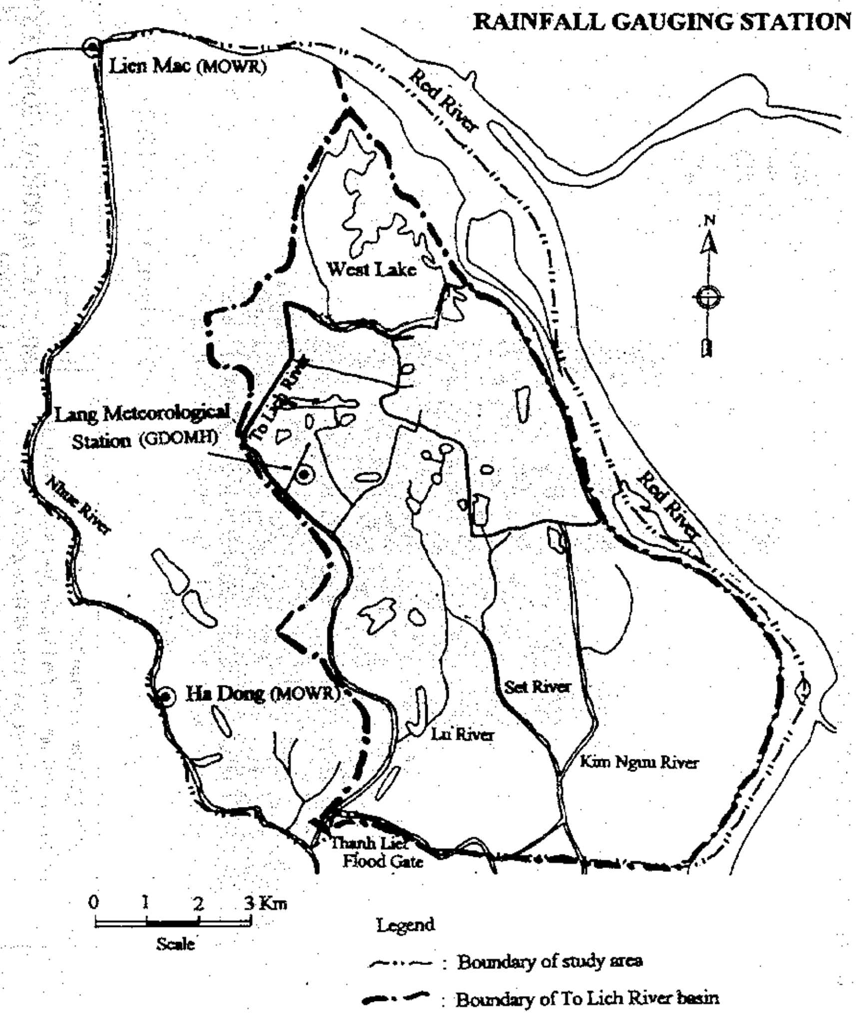
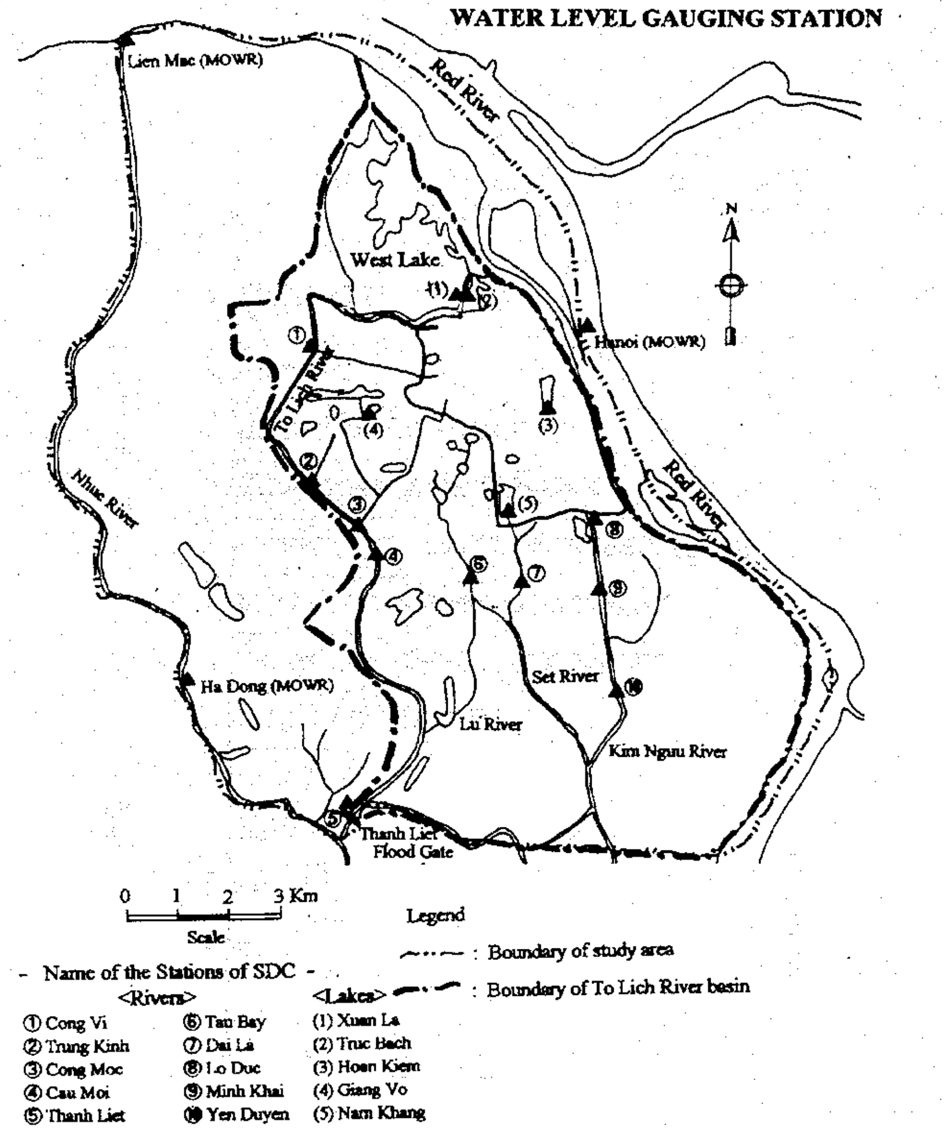
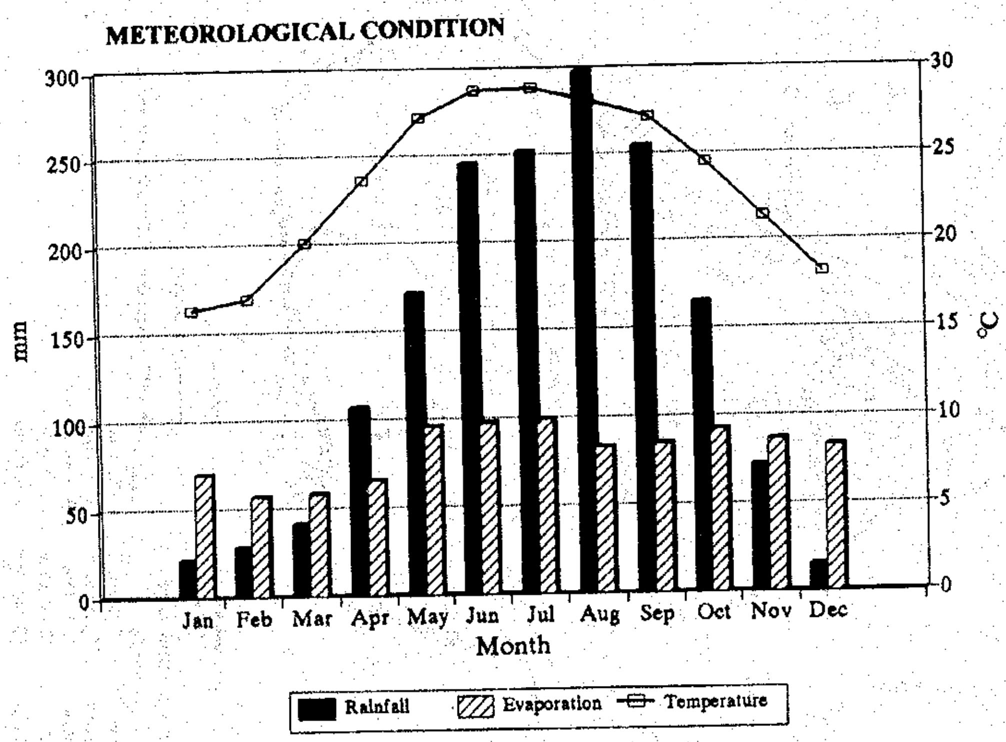


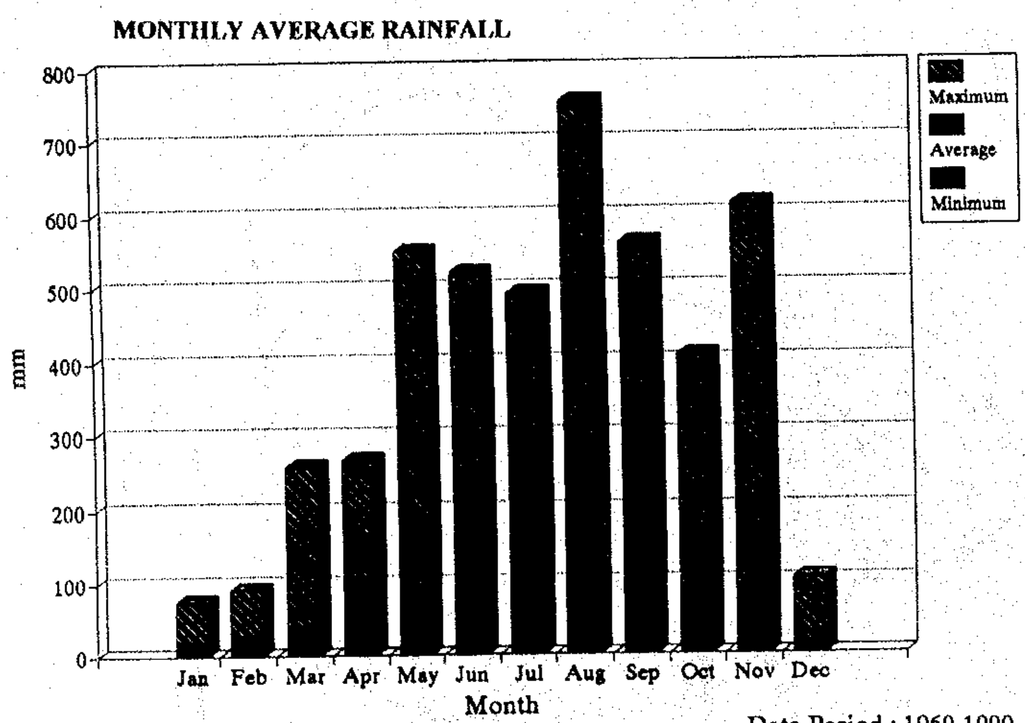


SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C2.1
LOCATION OF HYDROLOGICAL GAUGING STATIONS IN THE STUDY AREA

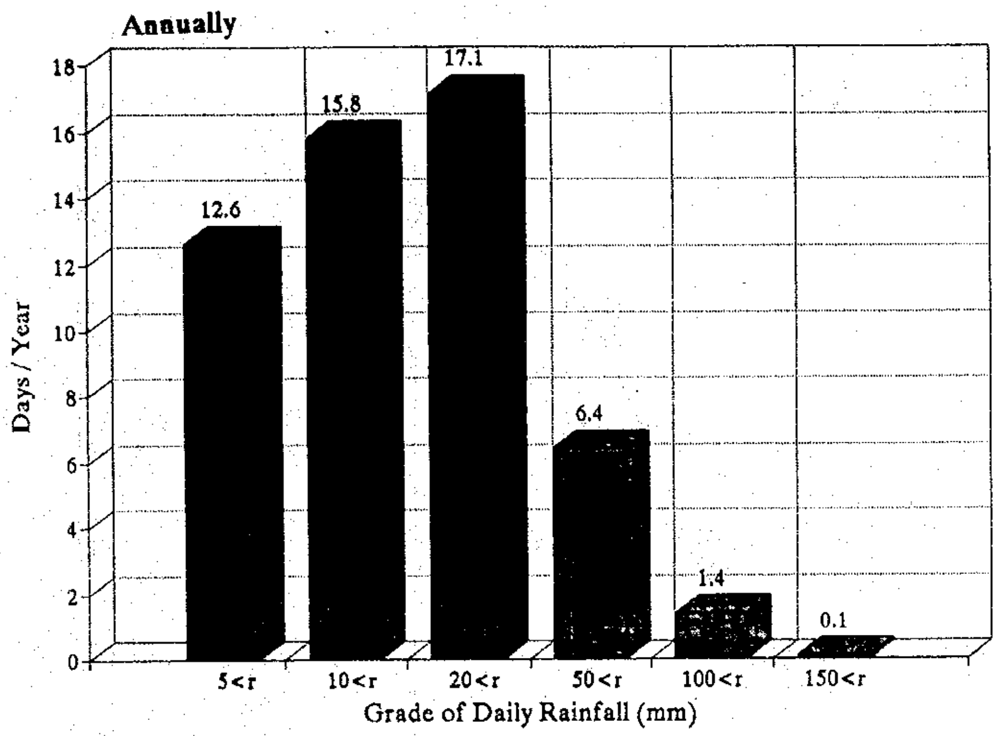




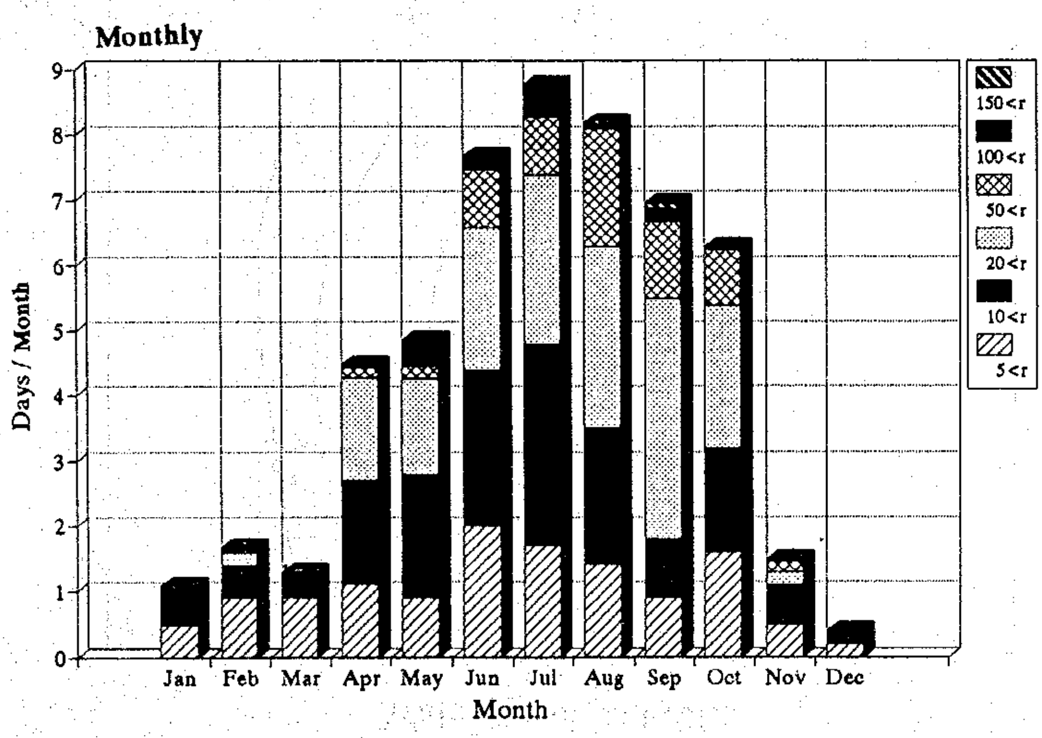
- Data Period : 1960-1990 -

SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C3.1 METEOROLOGICAL CONDITION IN HANOI
JAPAN INTERNATIONAL COOPERATION AGENCY	

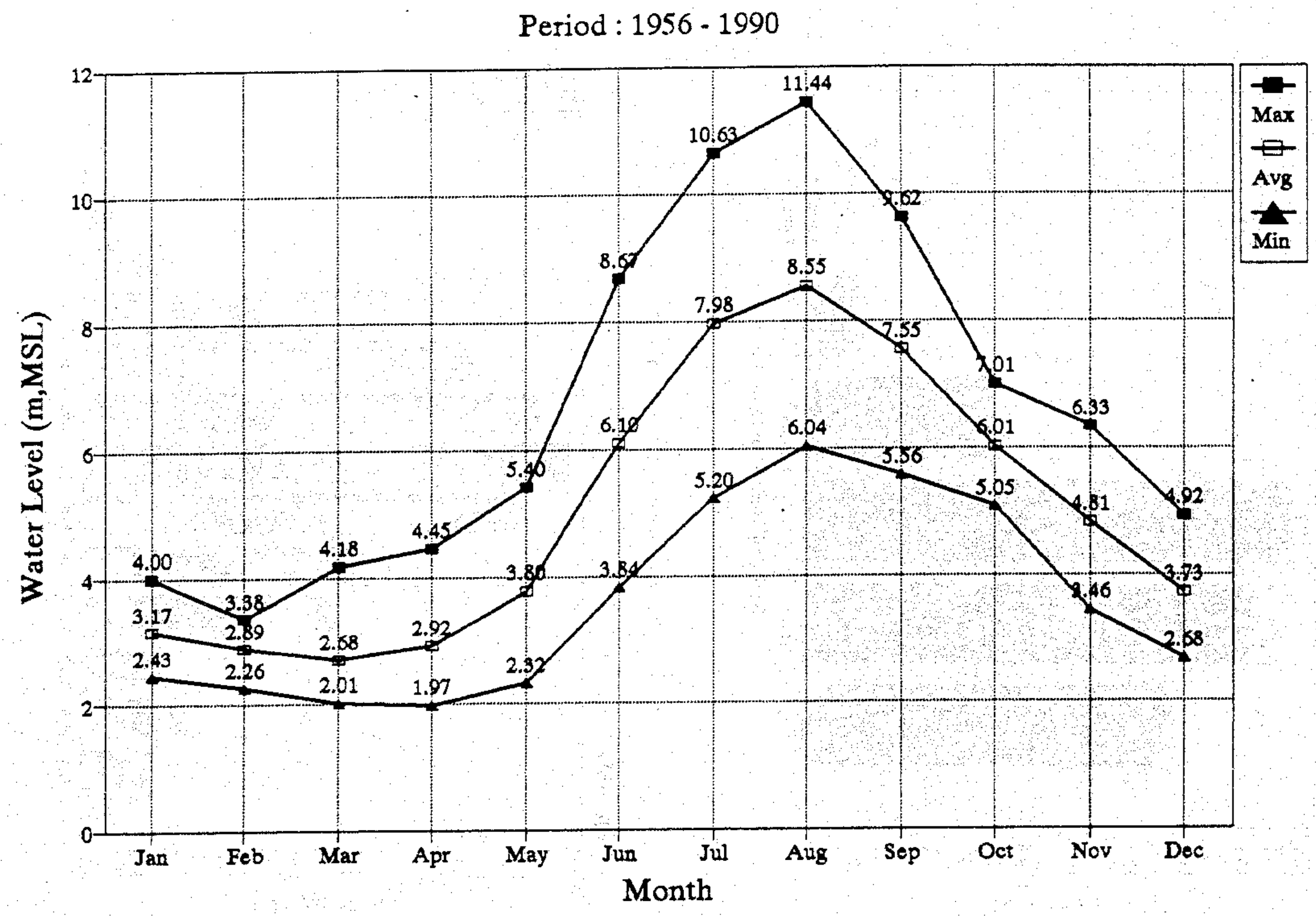
data period : 1886 - 1985



data period : 1886 - 1985



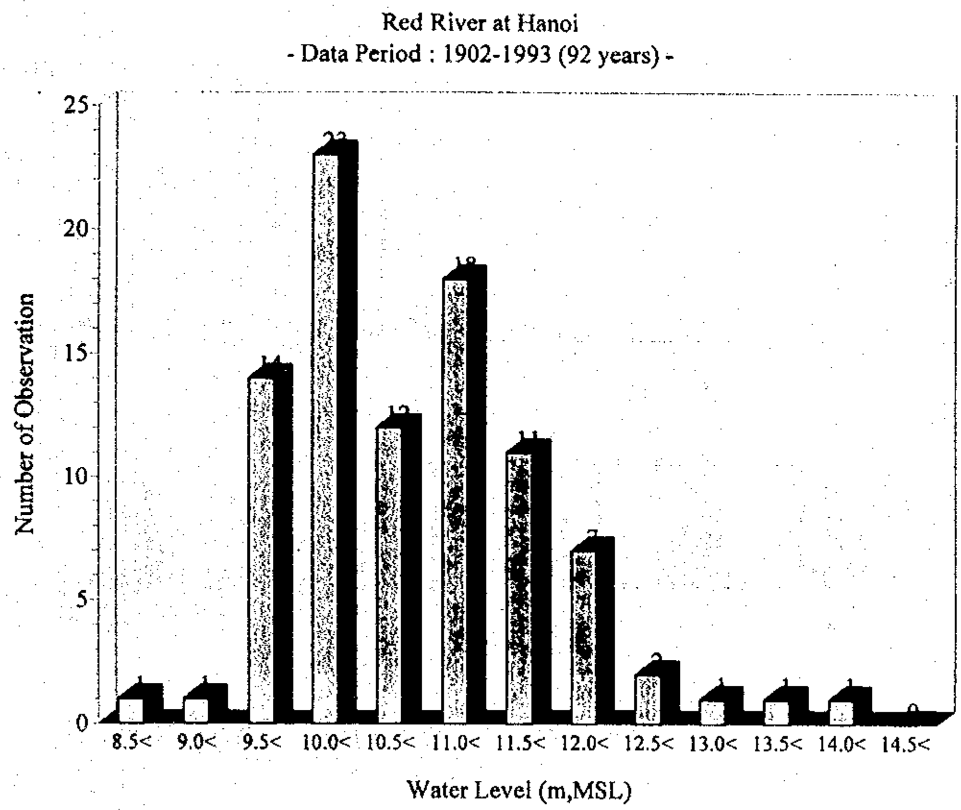
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C3.2 NUMBER OF RAINY DAYS ACCORDING TO RAINFALL DEPTH

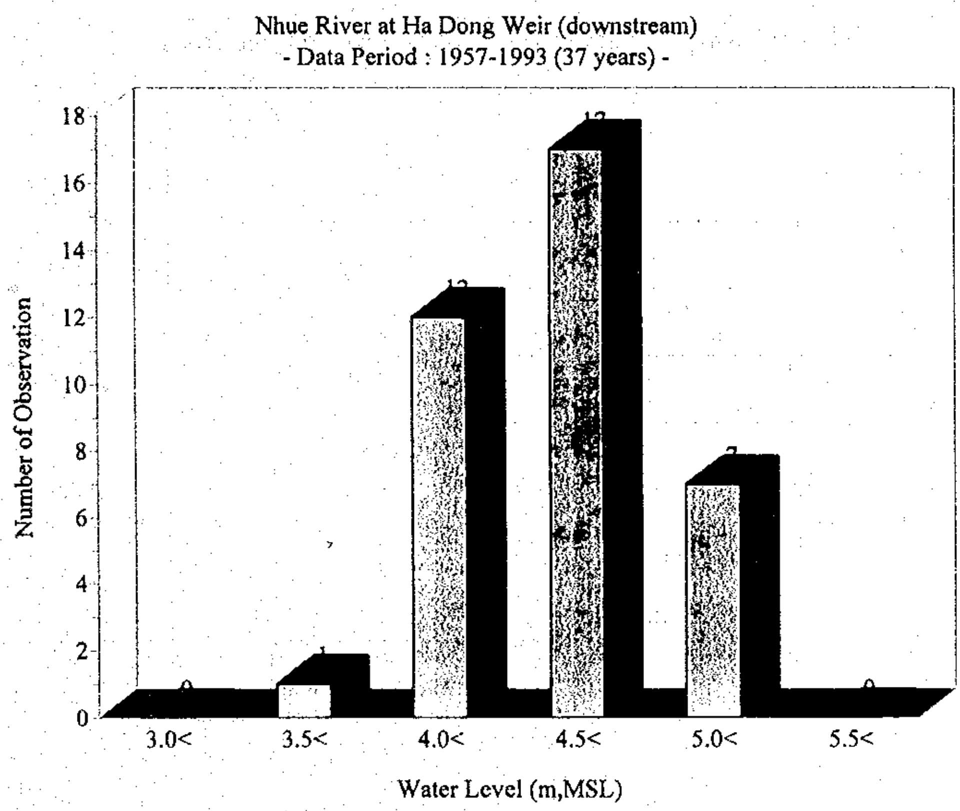


SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

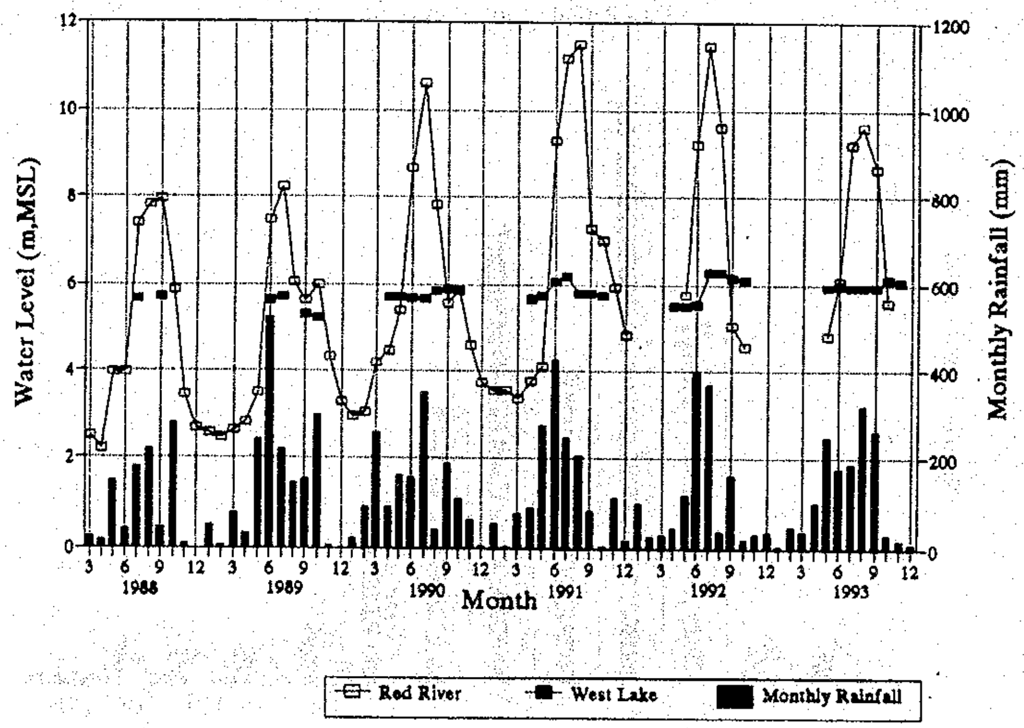
JAPAN INTERNATIONAL COOPERATION AGENCY

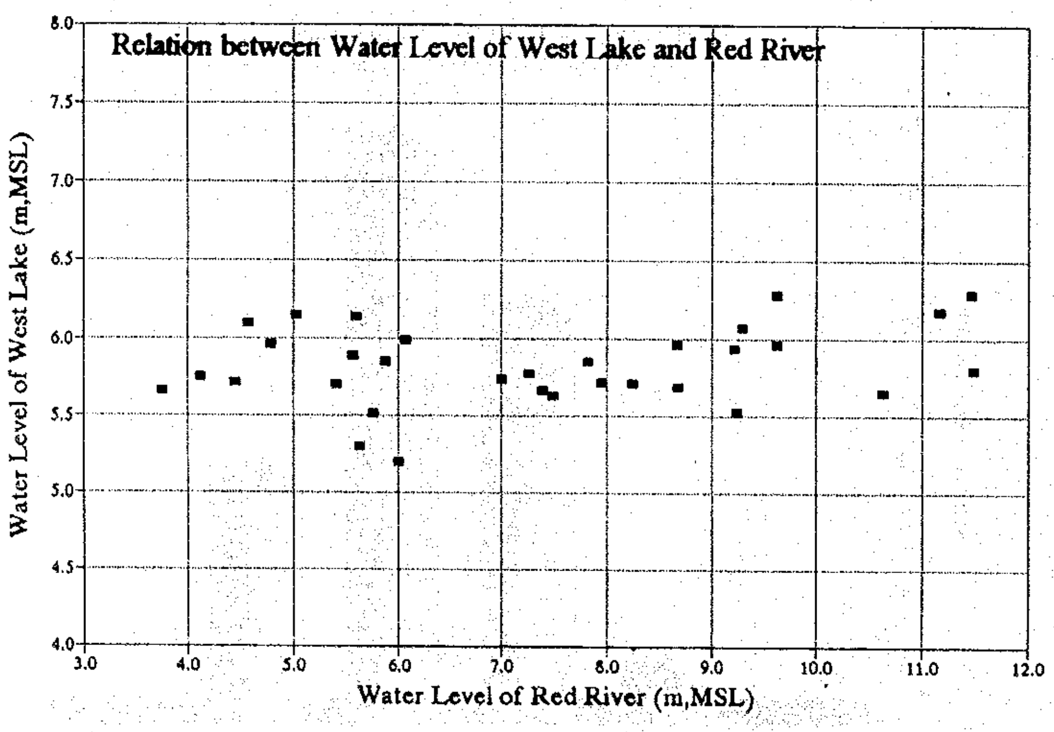
Fig. C3.3
MONTHLY AVERAGE WATER LEVEL OF RED RIVER AT HANOI





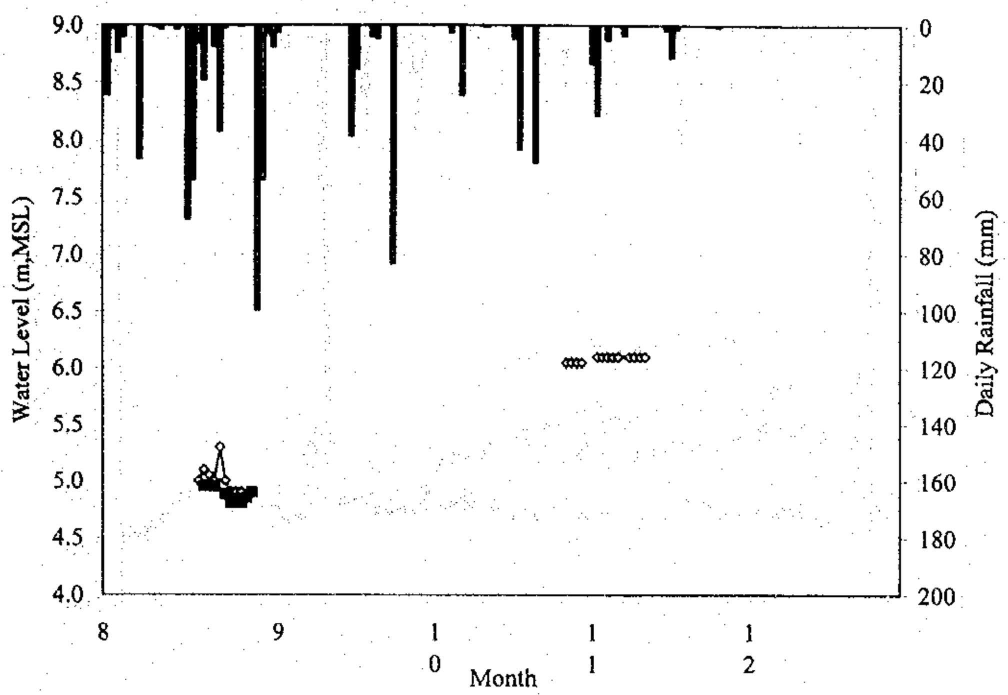
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C3.4 FREQUENCY OF ANNUAL MAXIMUM WATER LEVELS
JAPAN INTERNATIONAL COOPERATION AGENCY	



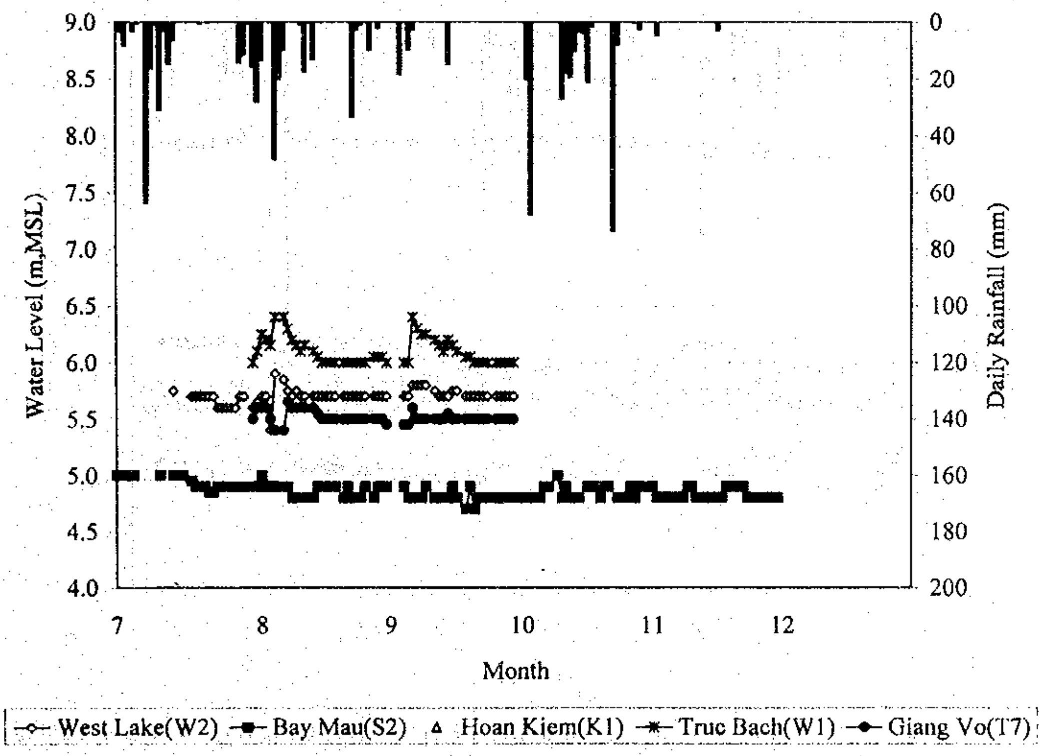


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C3.5 MONTHLY AVERAGE WATER LEVELS OF WEST LAKE AND RED RIVER

- 1987 -

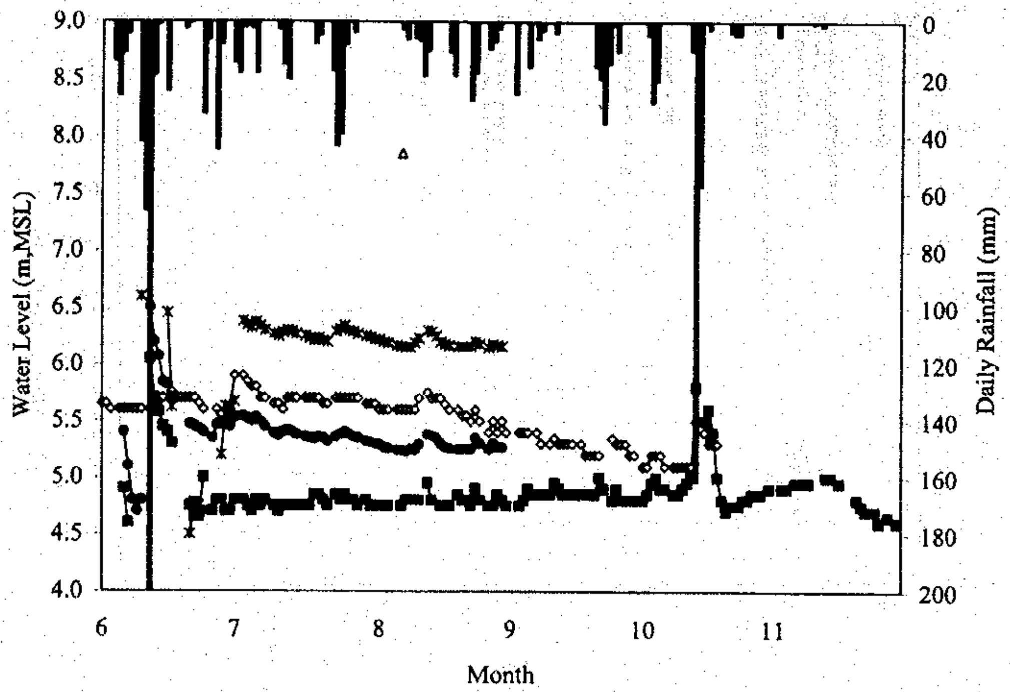


- 1988 -

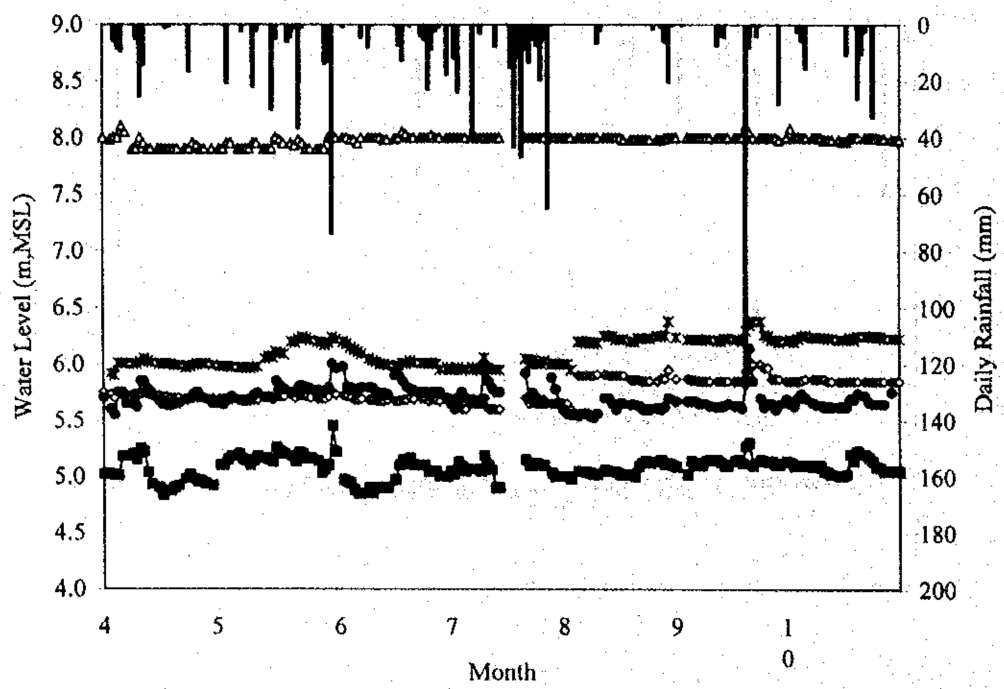


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C3.6 DAILY WATER LEVELS OF LAKES AND RAINFALL IN HANOI (1/4)

- 1989 -



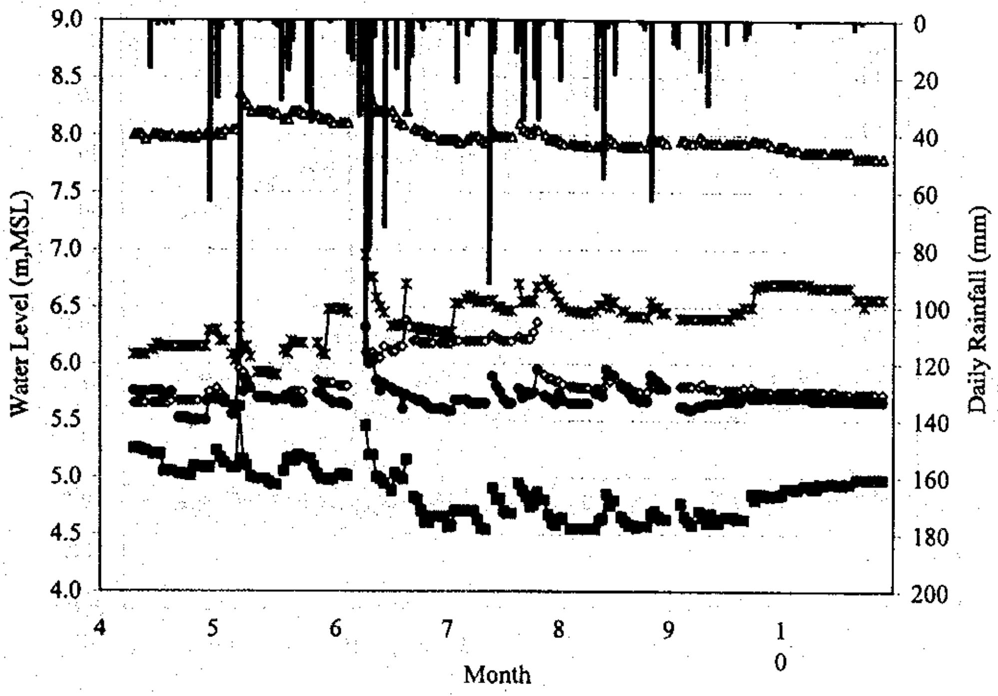
- 1990 -



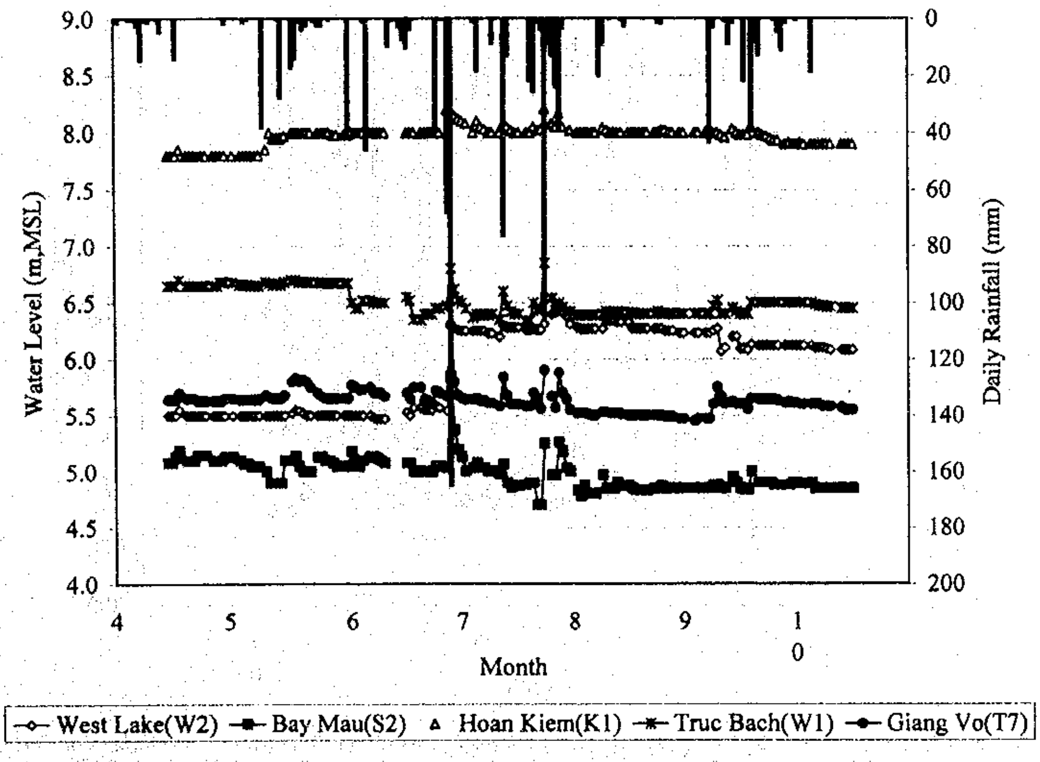
West Lake(W2) — Bay Mau(S2) — Hoan Kiem(K1) — Turc Bach(W1) — Giang Vo(T7)

SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C3.6 DAILY WATER LEVELS OF LAKES AND RAINFALL IN HANOI (2/4)
JAPAN INTERNATIONAL COOPERATION AGENCY	

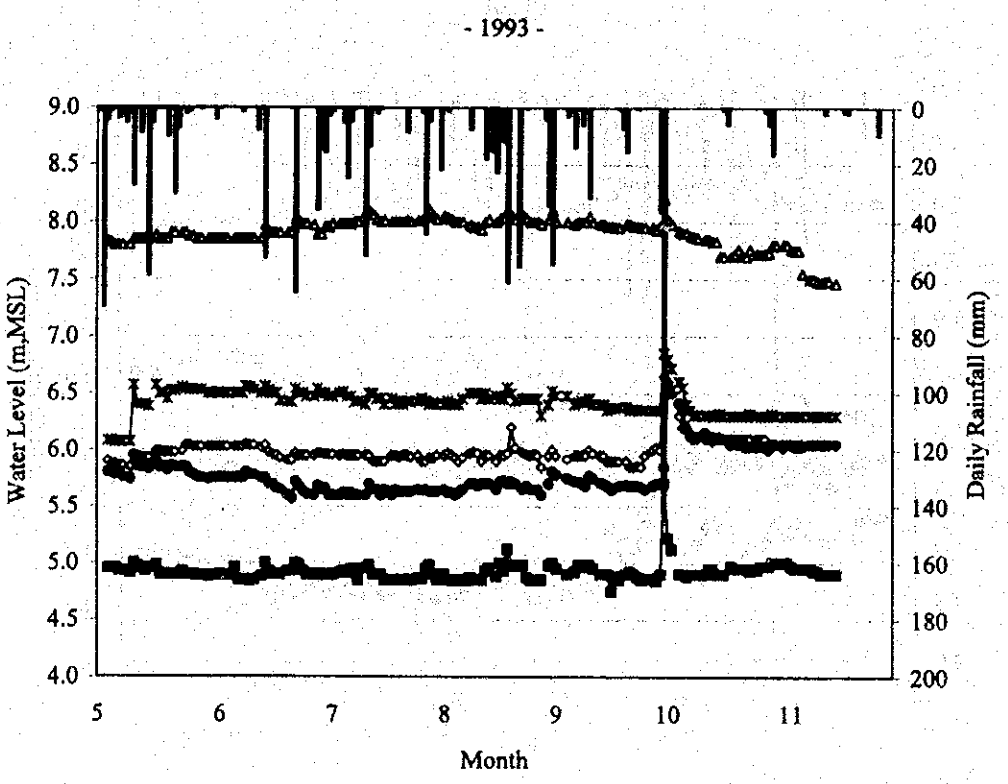
- 1991 -

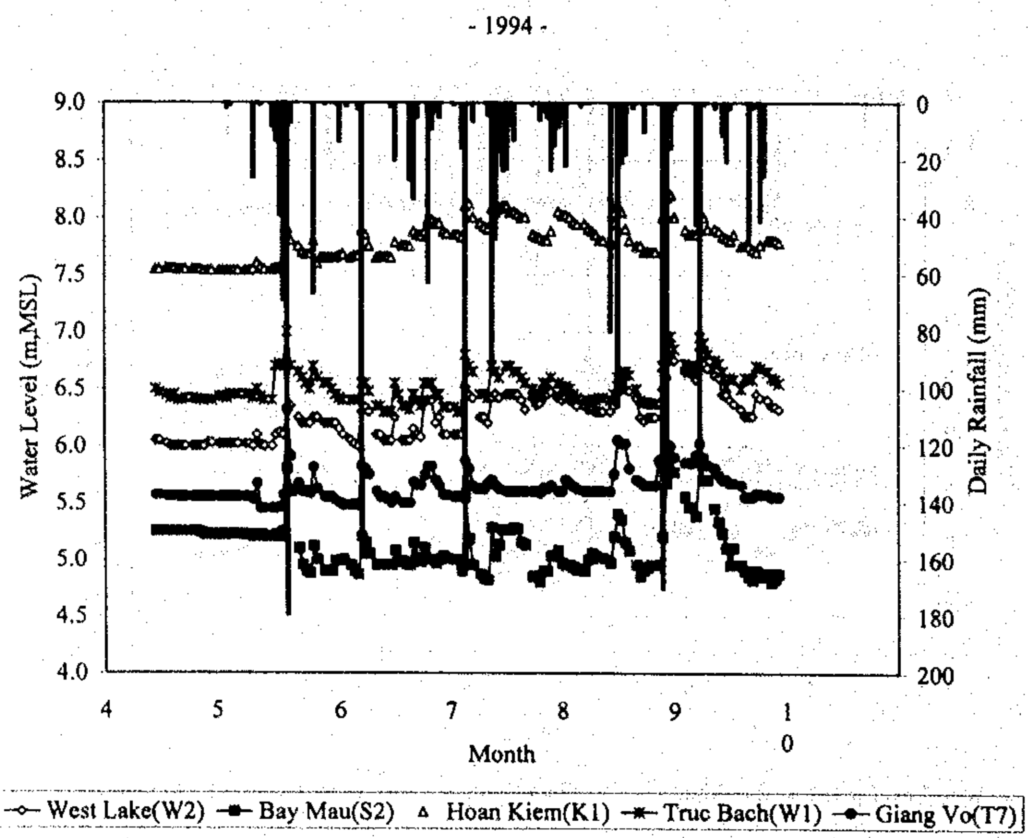


- 1992 -



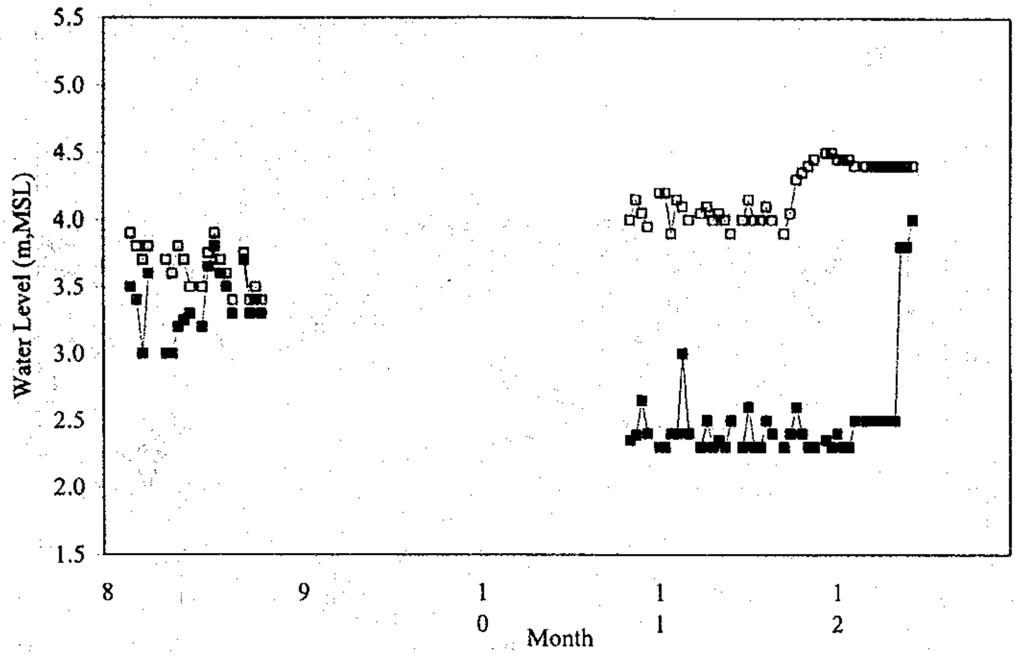
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C3.6 DAILY WATER LEVELS OF LAKES AND RAINFALL IN HANOI (3/4)
JAPAN INTERNATIONAL COOPERATION AGENCY	



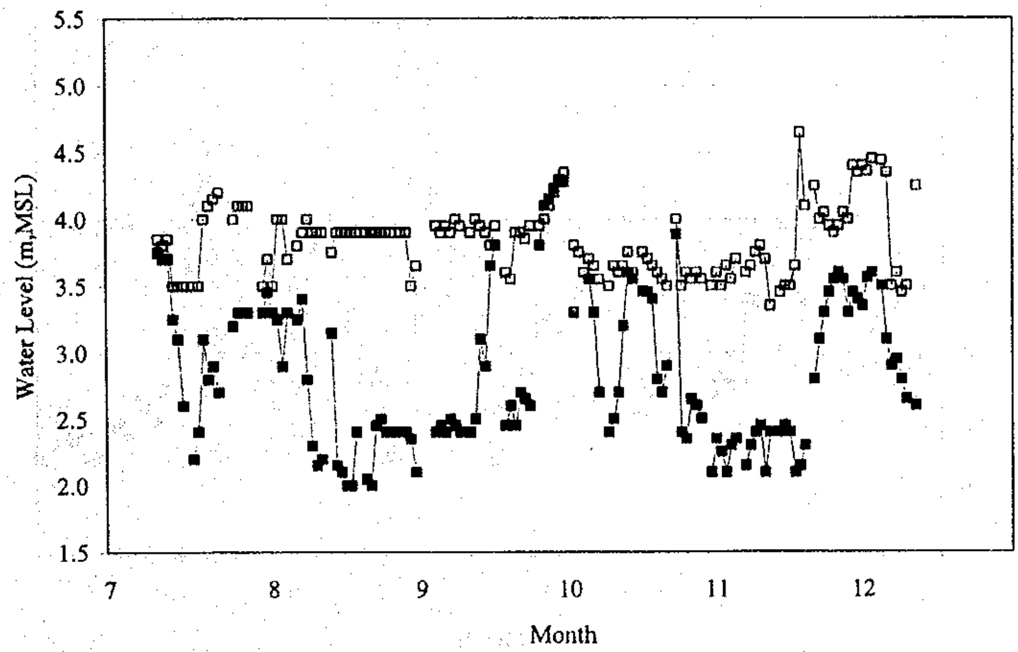


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C3.6 DAILY WATER LEVELS OF LAKES AND RAINFALL IN HANOI (4/4)
JAPAN INTERNATIONAL COOPERATION AGENCY	

- 1987 -

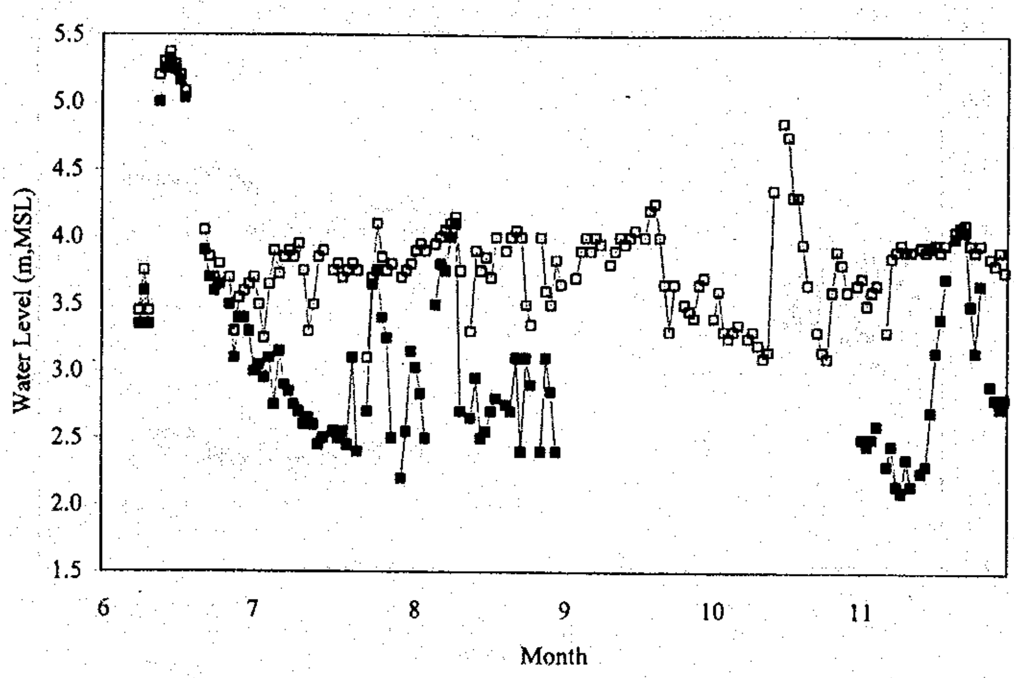


- 1988 -

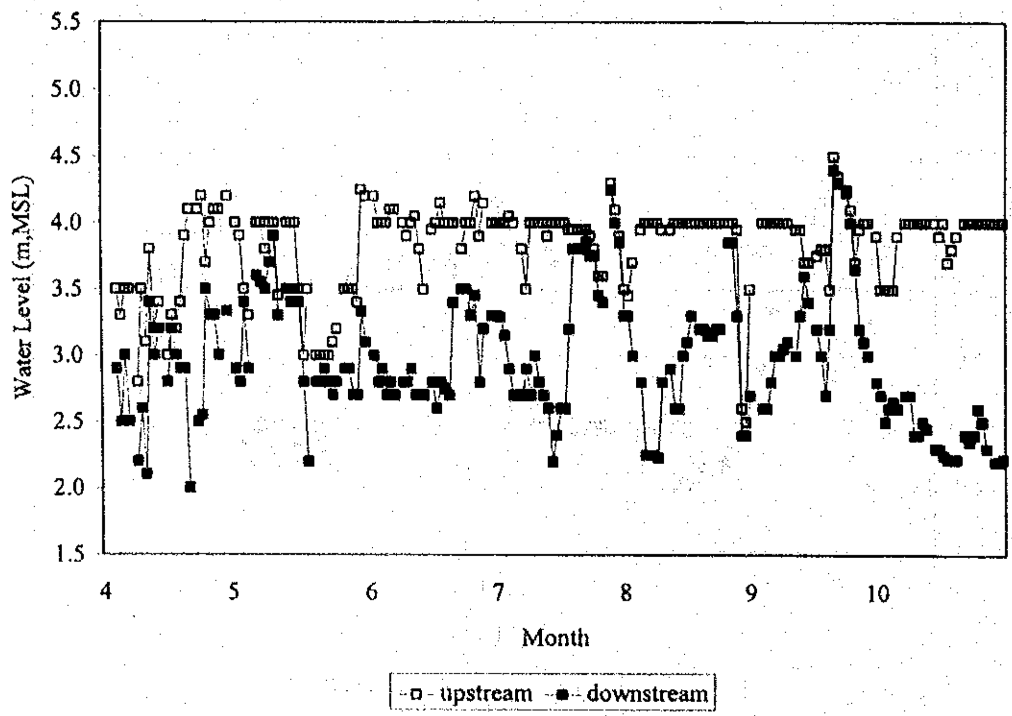


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C3.7 DAILY WATER LEVELS AT THANH LIET FLOODGATE (1/4)
JAPAN INTERNATIONAL COOPERATION AGENCY	

- 1989 -

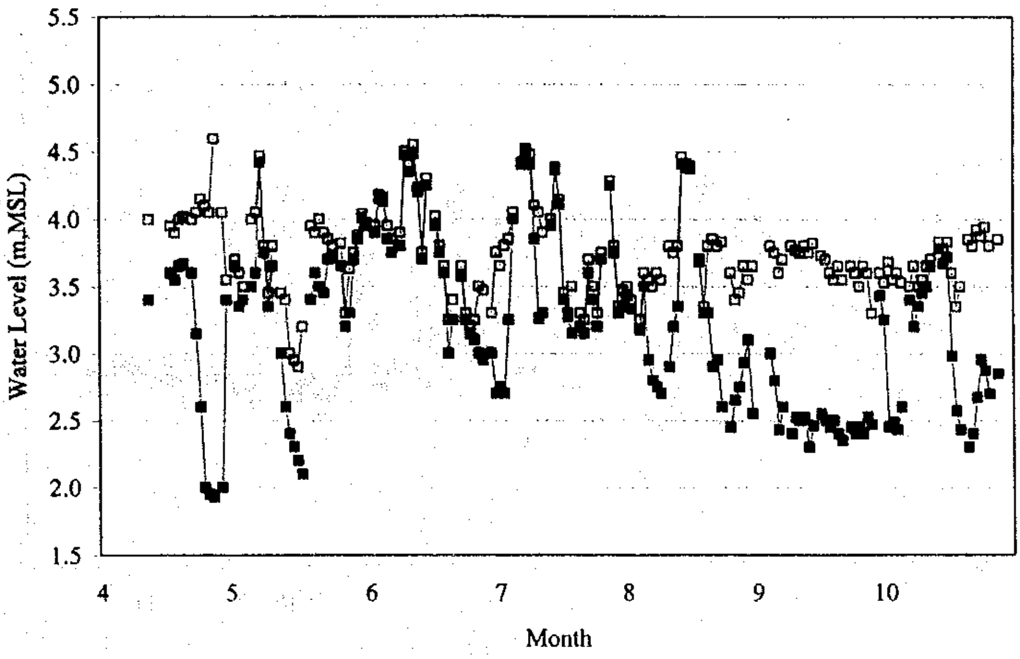


- 1990 -

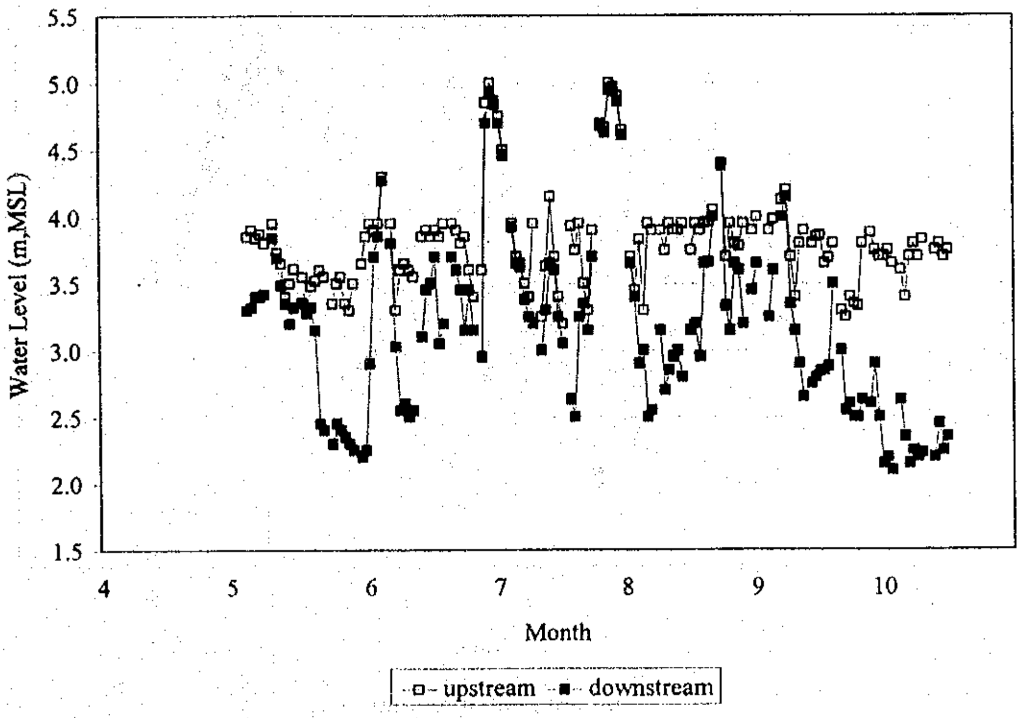


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C3.7 DAILY WATER LEVELS AT THANH LIET FLOODGATE (2/4)

- 1991 -

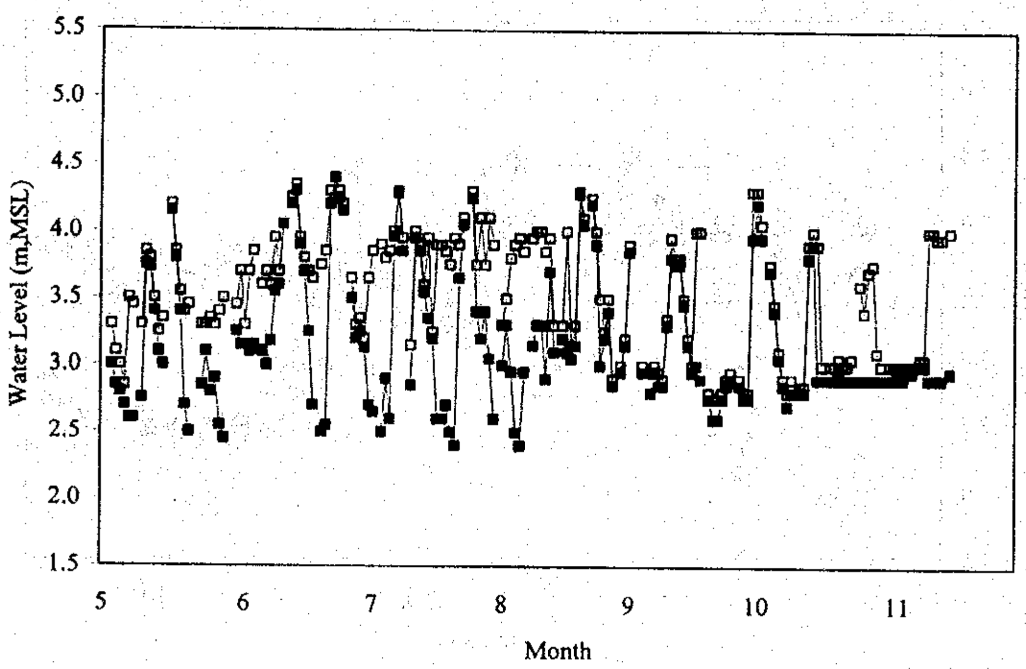


- 1992 -

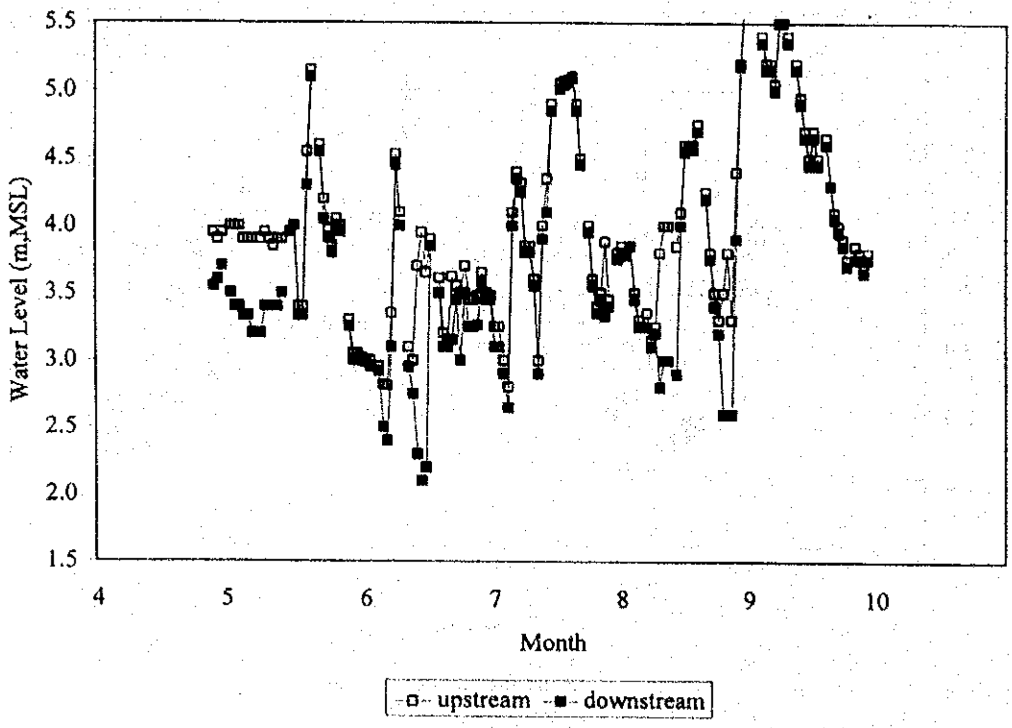


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C3.7 DAILY WATER LEVELS AT THANH LIET FLOODGATE (3/4)

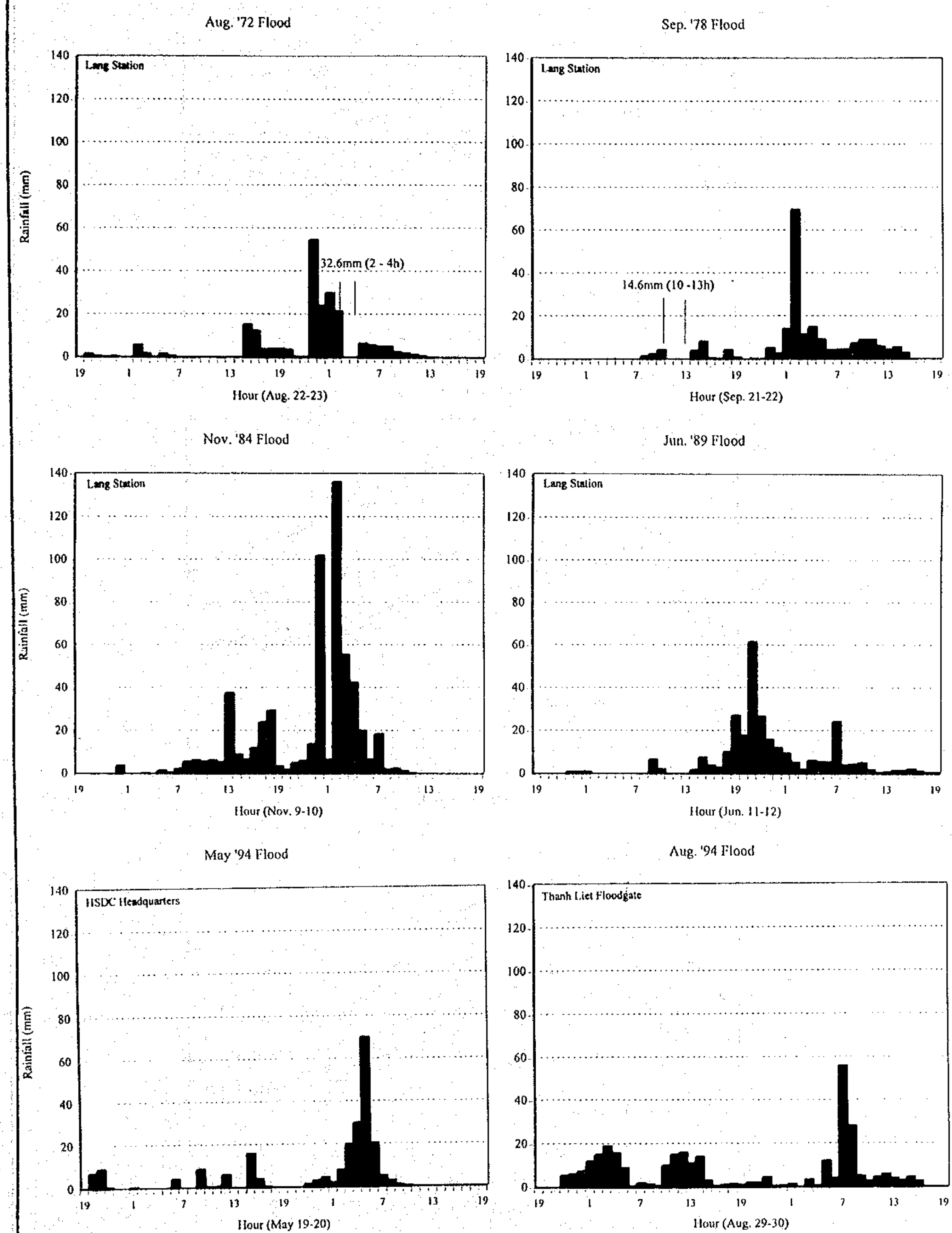
- 1993 -



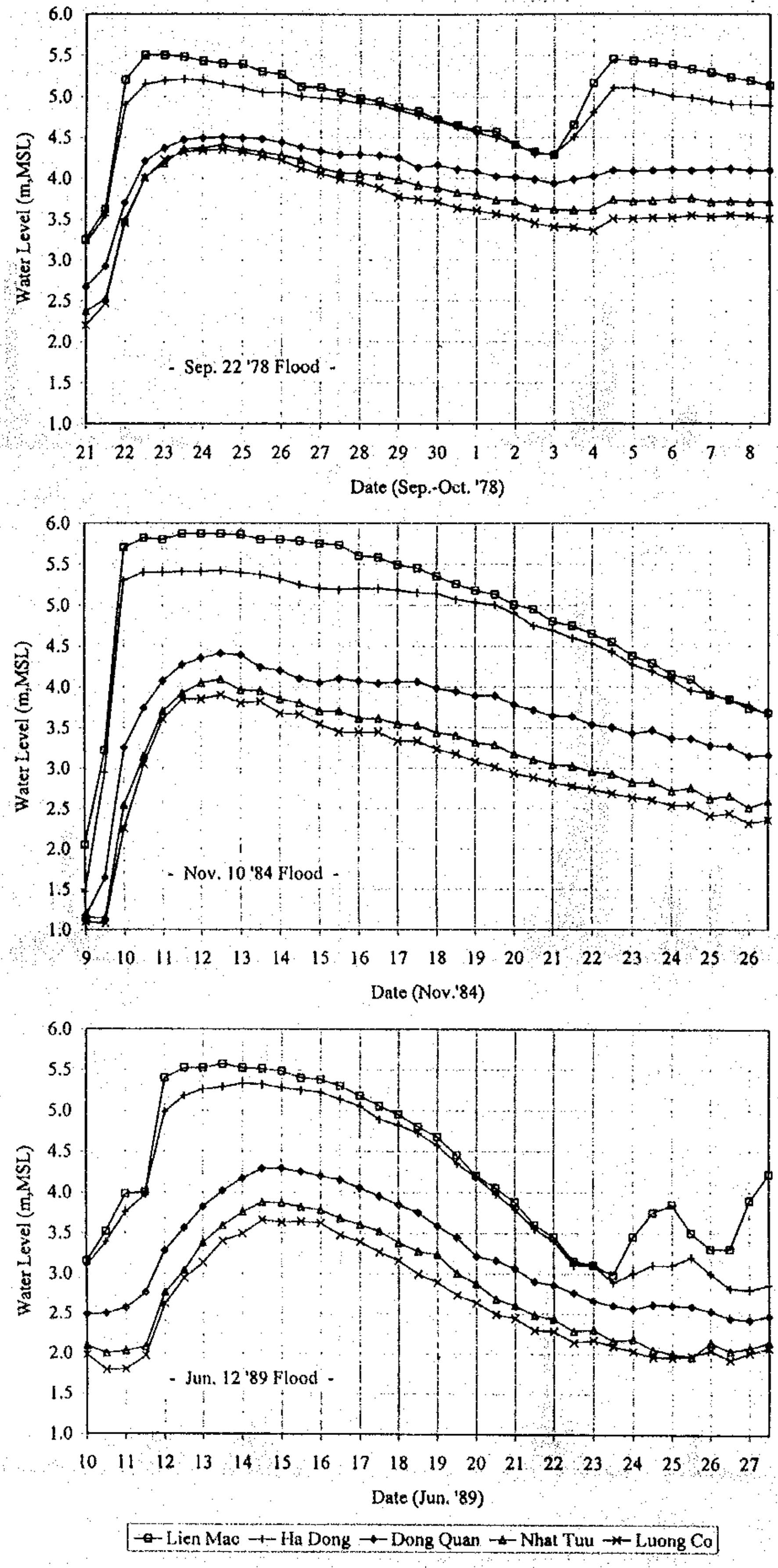
- 1994 -



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C3.7 DAILY WATER LEVELS AT THANH LIET FLOODGATE (4/4)

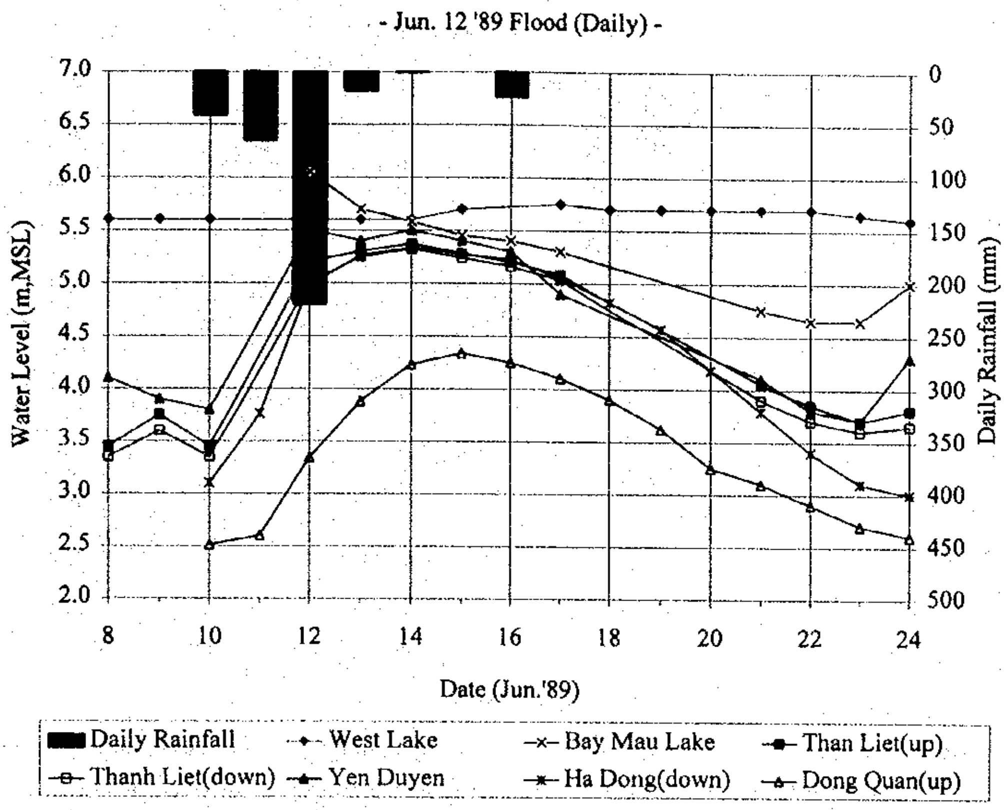


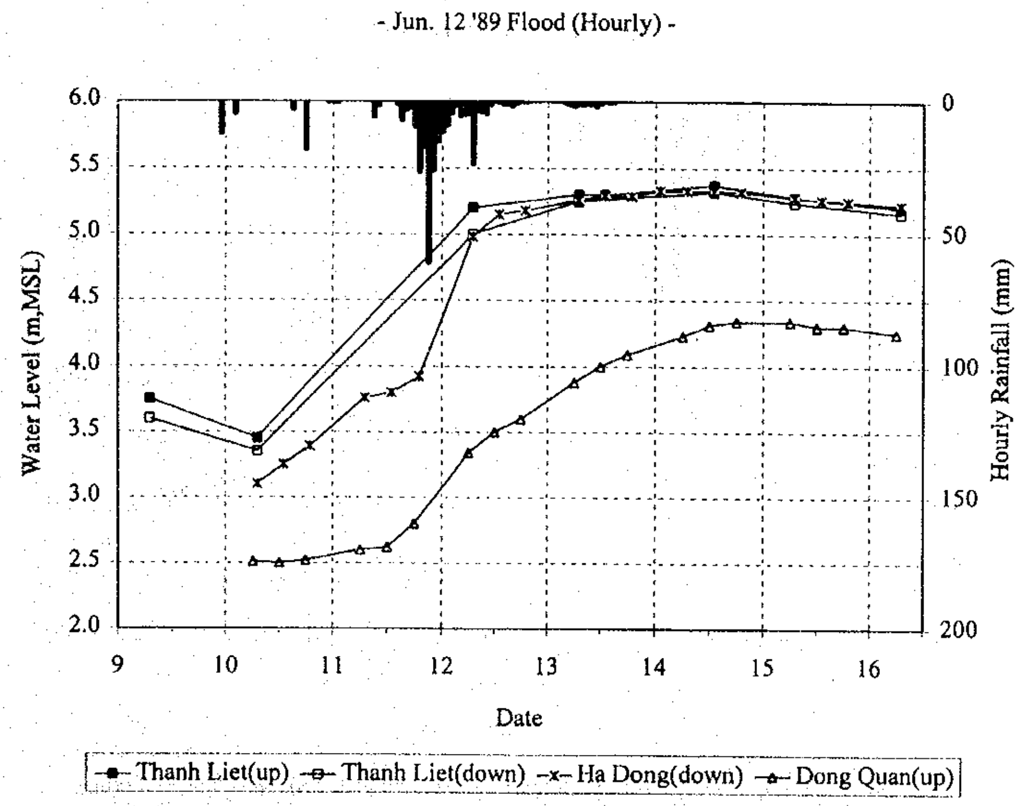
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C4.1 HOURLY RAINFALLS OF MAJOR PAST FLOODS



SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
JAPAN INTERNATIONAL COOPERATION AGENCY

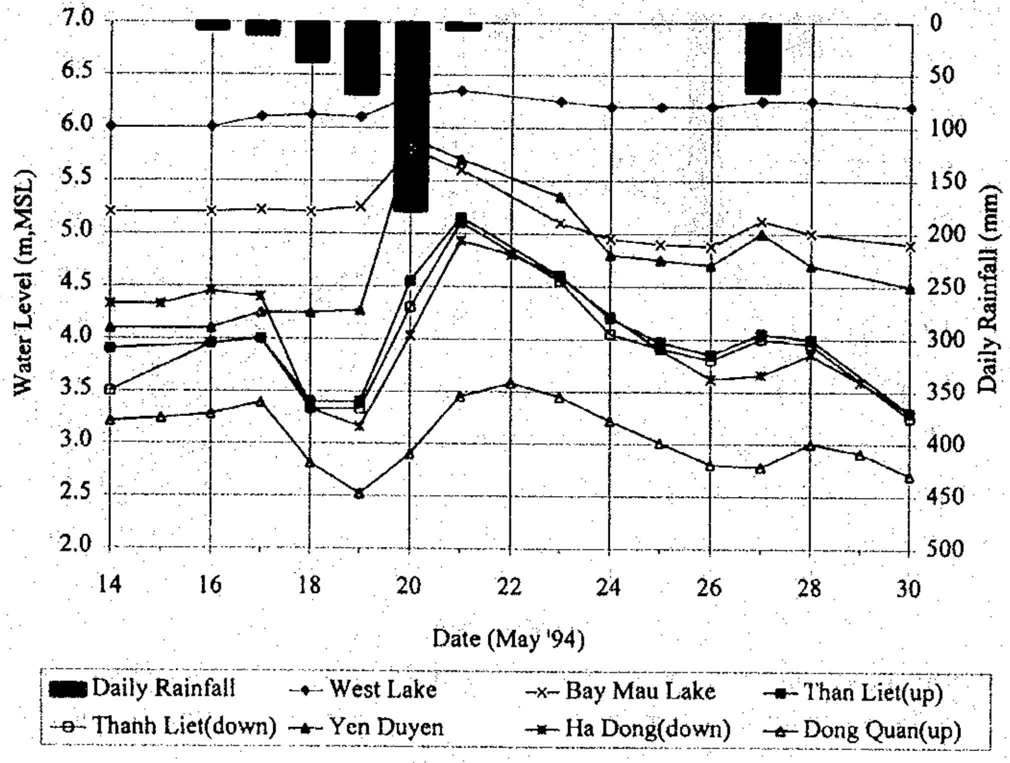
Fig. C4.2
WATER LEVEL AT WEIRS ON NHUE RIVER



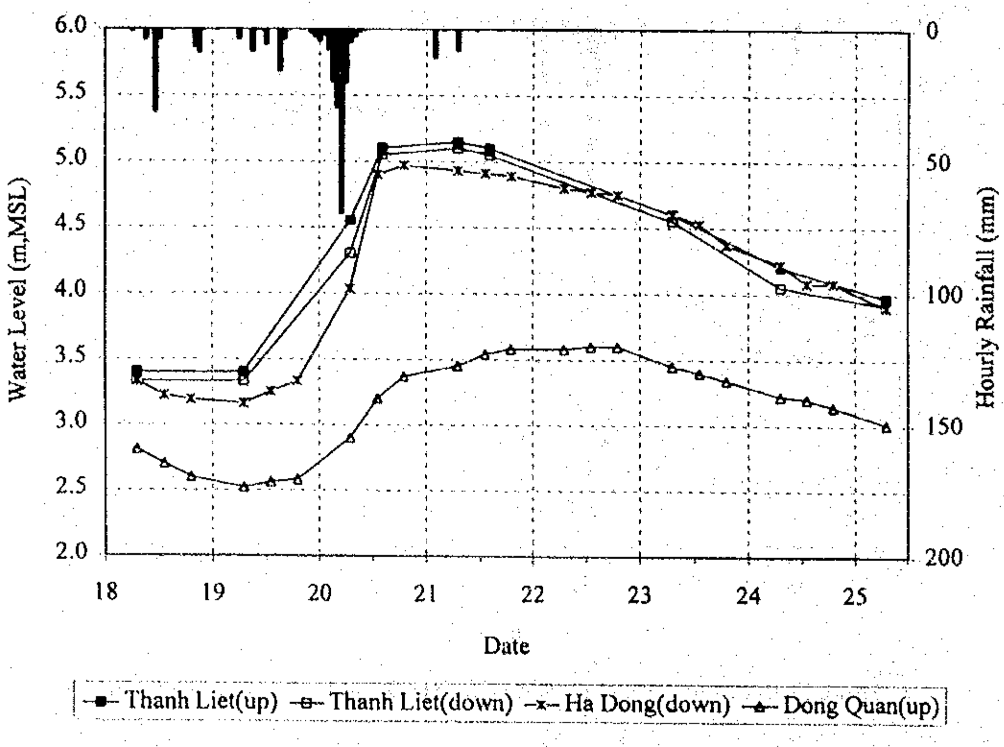


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C4.3 RELATION BETWEEN RAINFALL AND WATER LEVELS OF FLOOD (1/3)

- May 20 '94 Flood (Daily) -

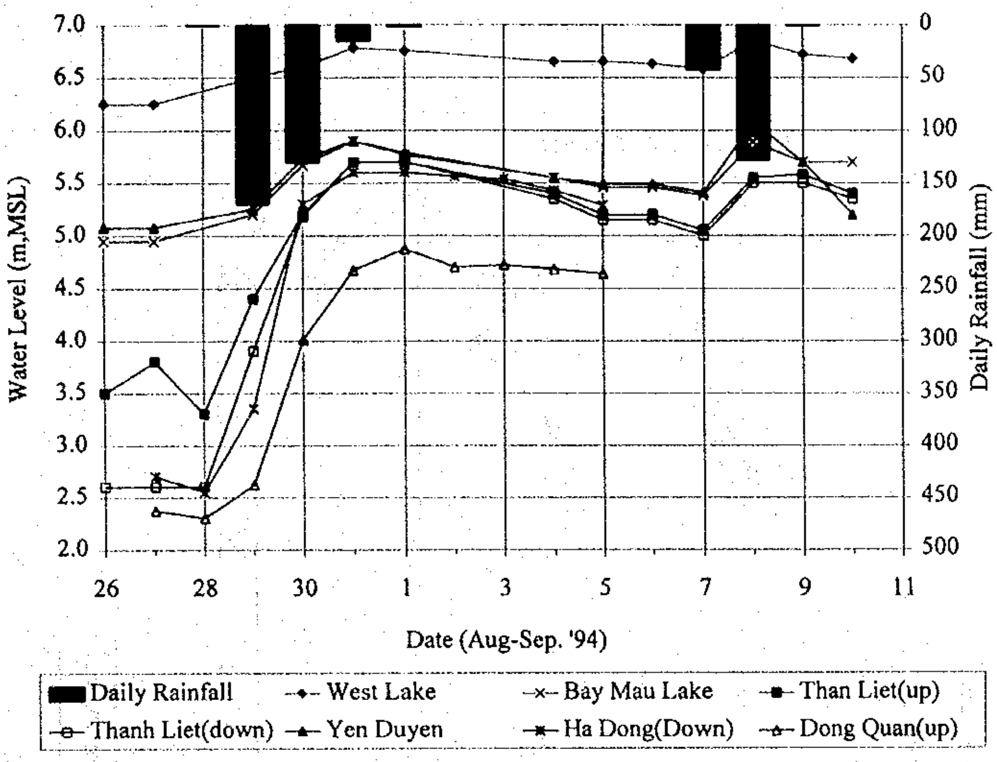


- May 20 '94 Flood (Hourly) -

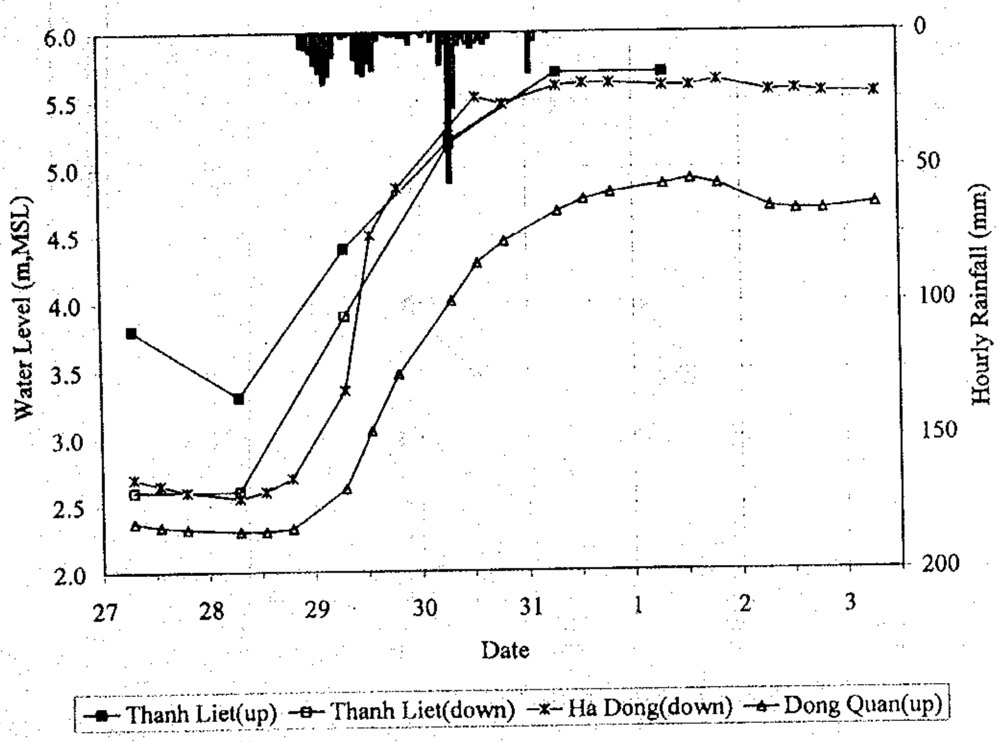


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C4.3 RELATION BETWEEN RAINFALL AND WATER LEVELS OF FLOOD (2/3)

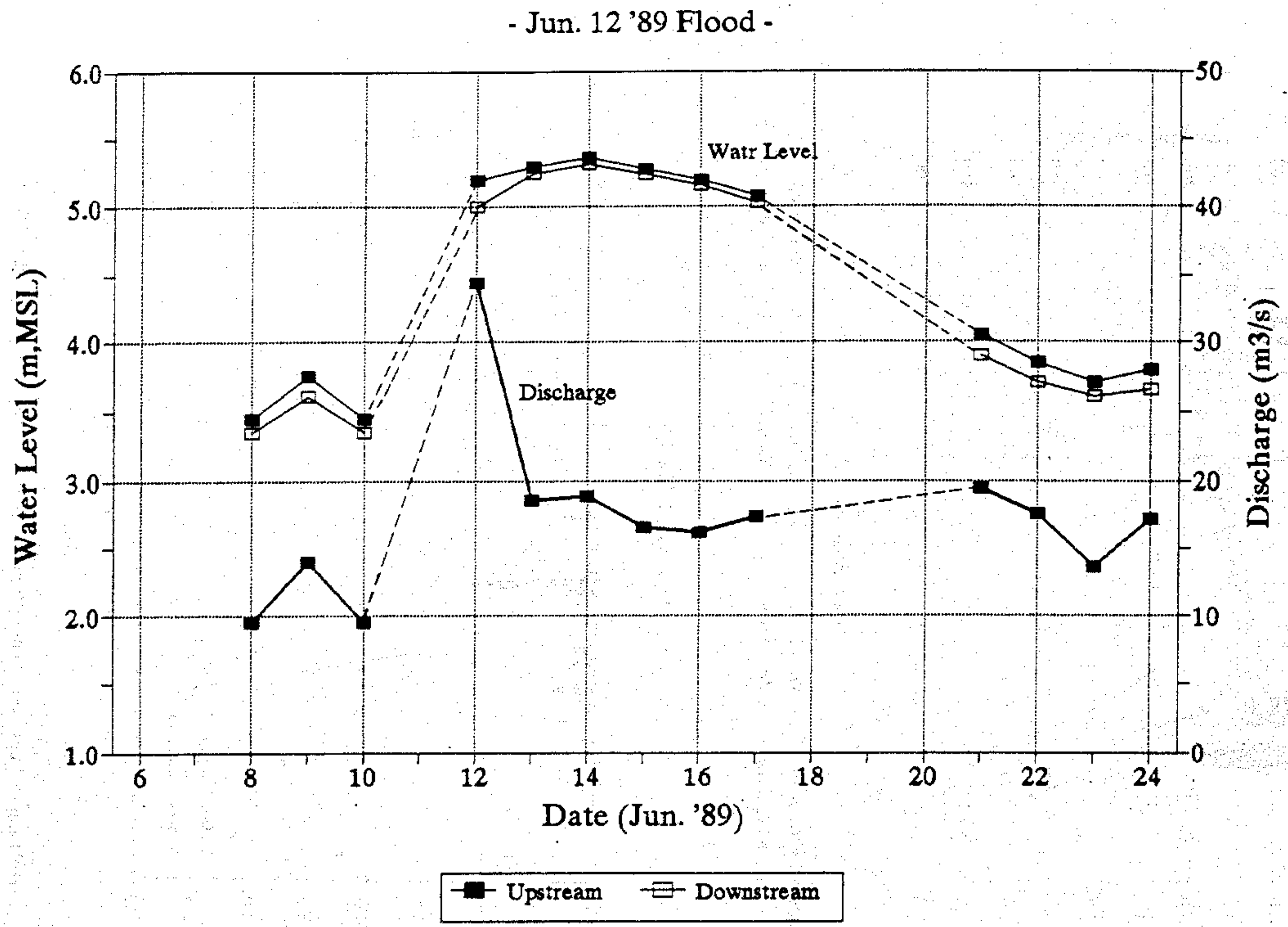
- Aug. 29 '94 Flood (Daily) -



- Aug. 29 '94 Flood (Hourly) -

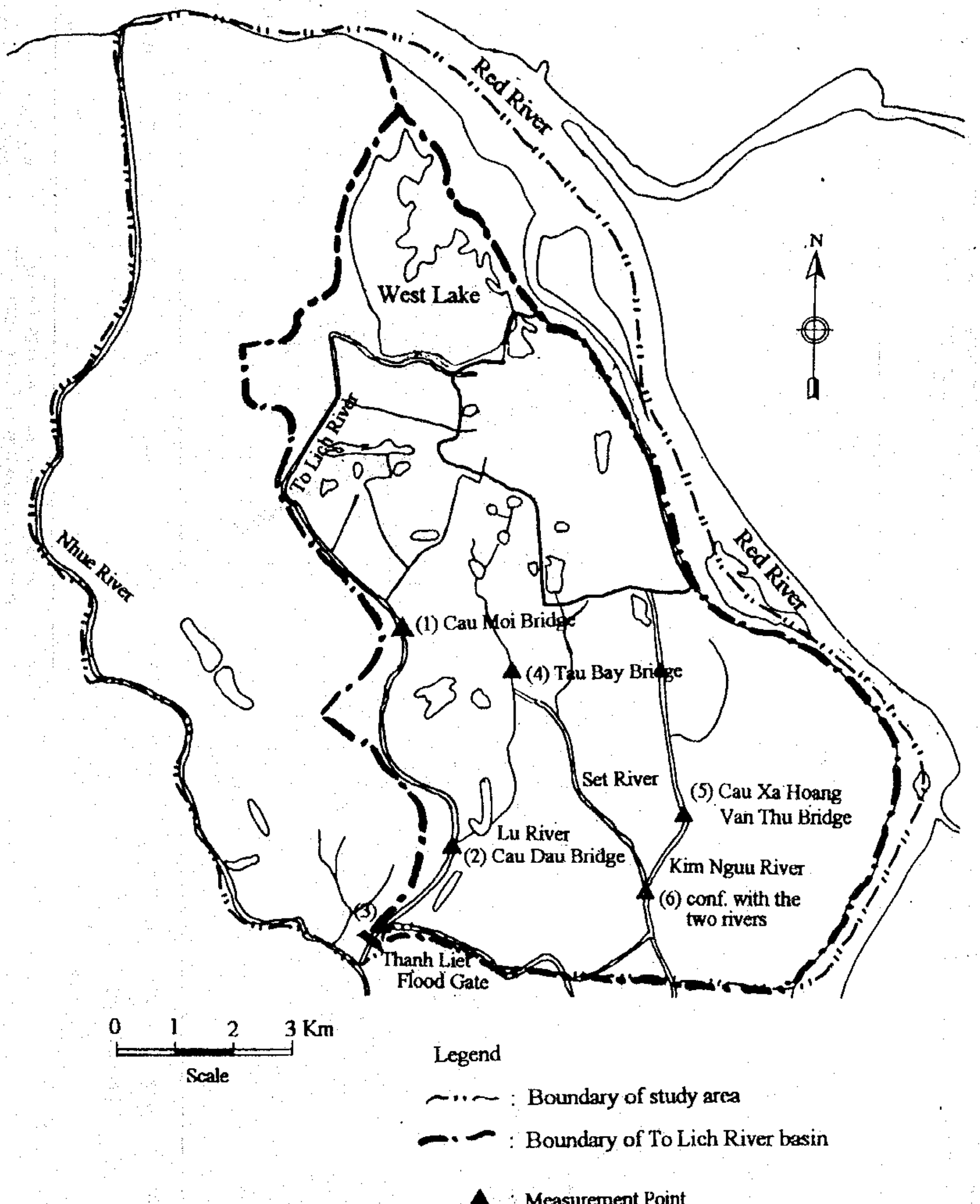


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C4.3 RELATION BETWEEN RAINFALL AND WATER LEVELS OF FLOOD (3/3)
JAPAN INTERNATIONAL COOPERATION AGENCY	

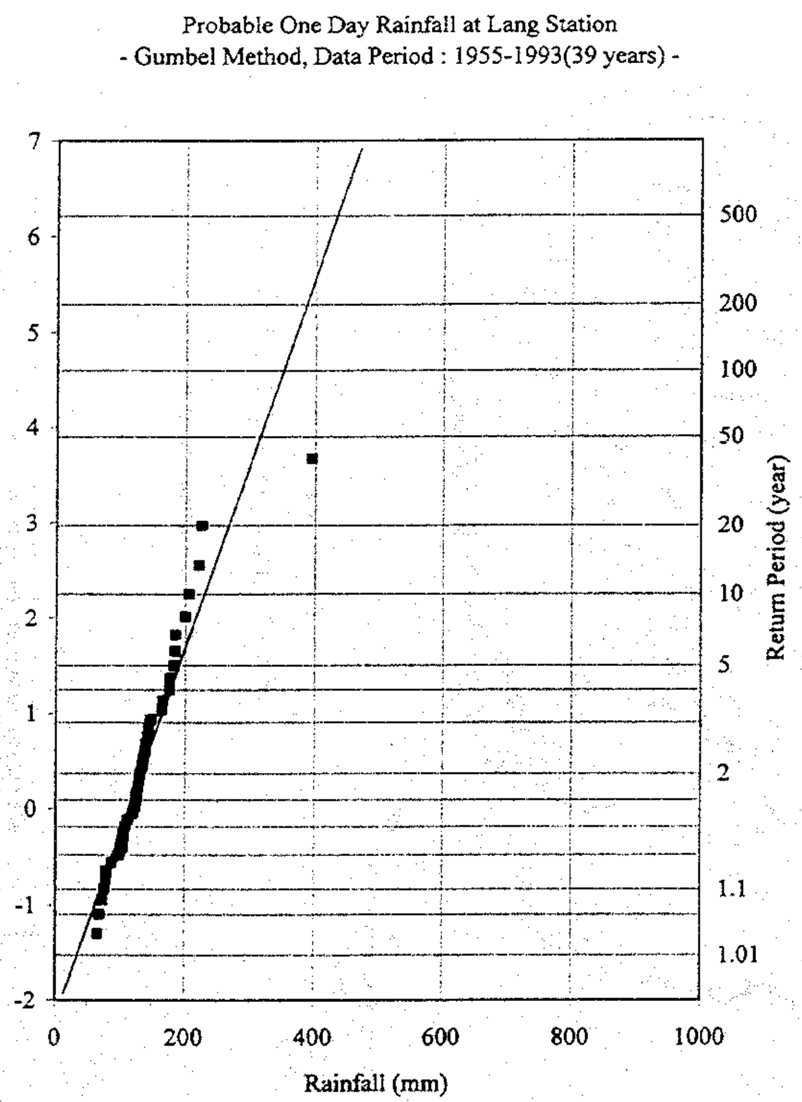


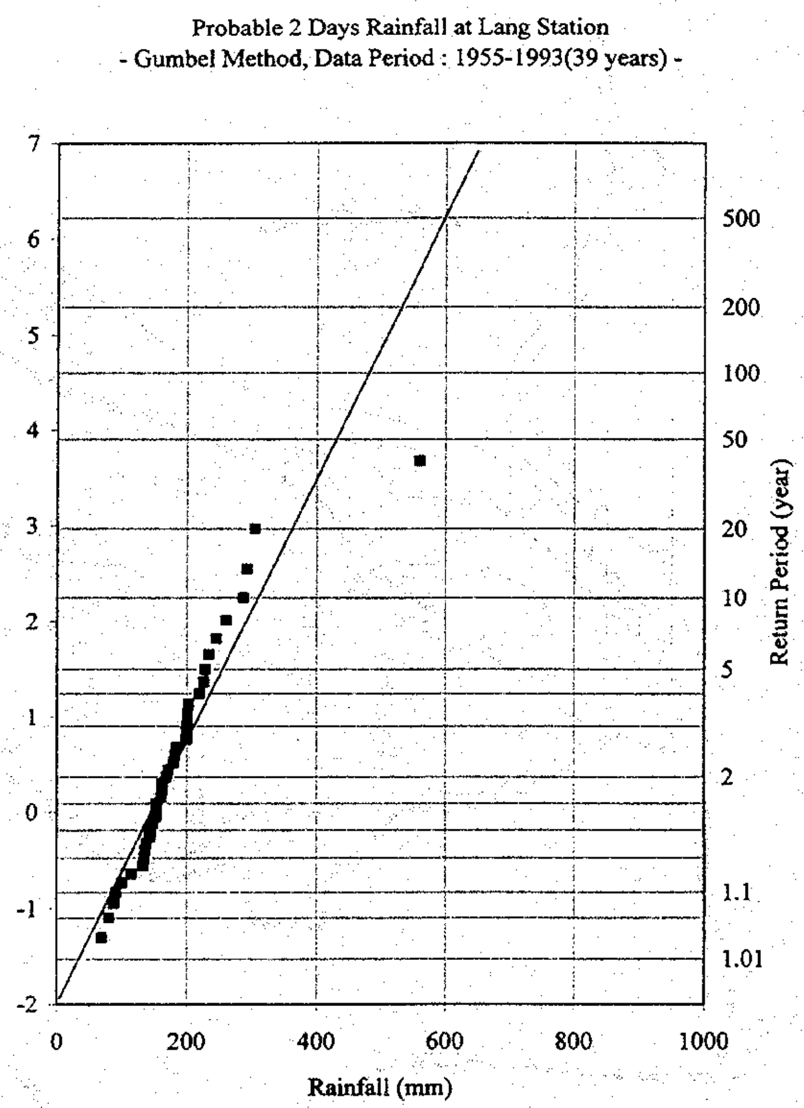
SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C4.4
ESTIMATED DISCHARGE OF FLOOD

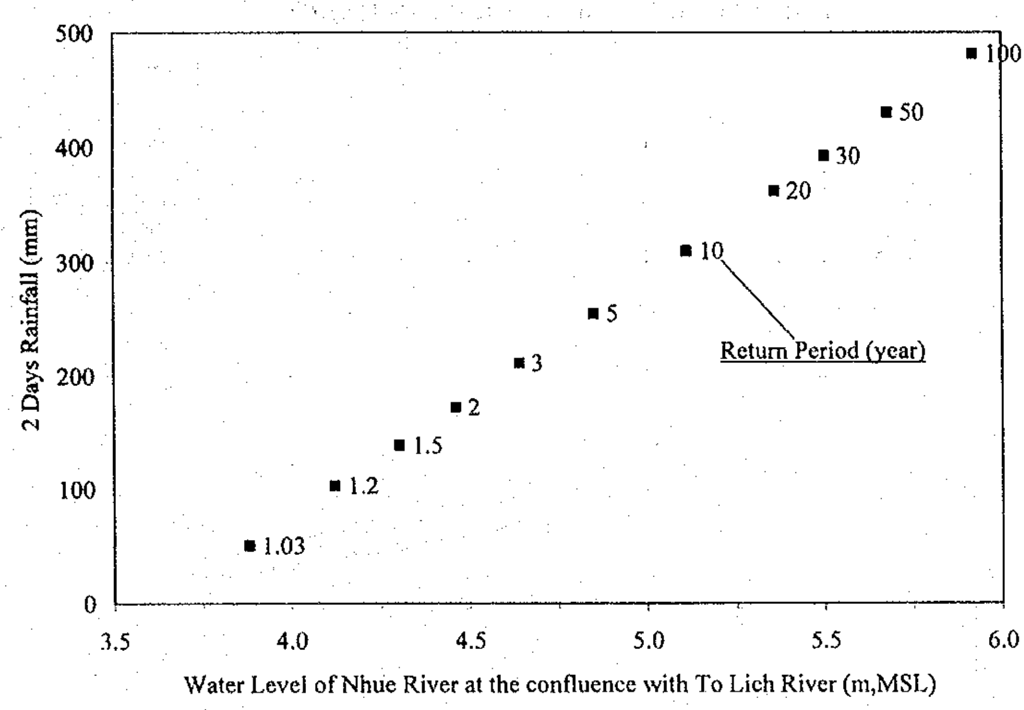


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C5.1 LOCATION OF LOW FLOW MEASUREMENT POINTS
JAPAN INTERNATIONAL COOPERATION AGENCY	





SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C6.1 PROBABLE ONE DAY AND 2 DAYS RAINFALLS
JAPAN INTERNATIONAL COOPERATION AGENCY	



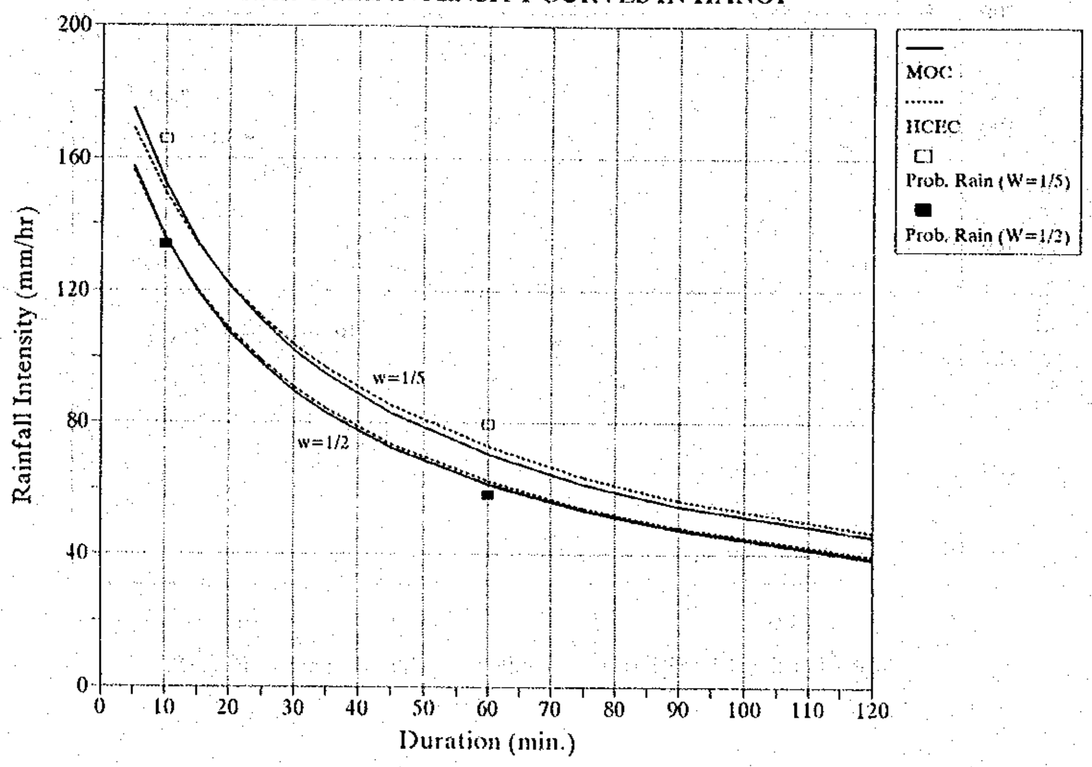
PROBABLE WATER LEVEL AND RAINFALL

Return Period (year)	Water Level of Nhue River at the confluence with To Lich River (m,MSL)	2 Days Rainfall at Lang Station (mm)
100	5.92	480.9
50	5.68	430.0
30	5.50	392.2
20	5.36	362.0
10	5.11	309.6
5	4.85	254.8
3	4.64	211.3
2	4.46	172.2
1.5	4.30	138.6
1.2	4.12	103.0
1.03	3.88	50.3

SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C6.2
RELATION BETWEEN PROBABLE WATER LEVEL AND RAINFALL

RAINFALL INTENSITY CURVES IN HANOI



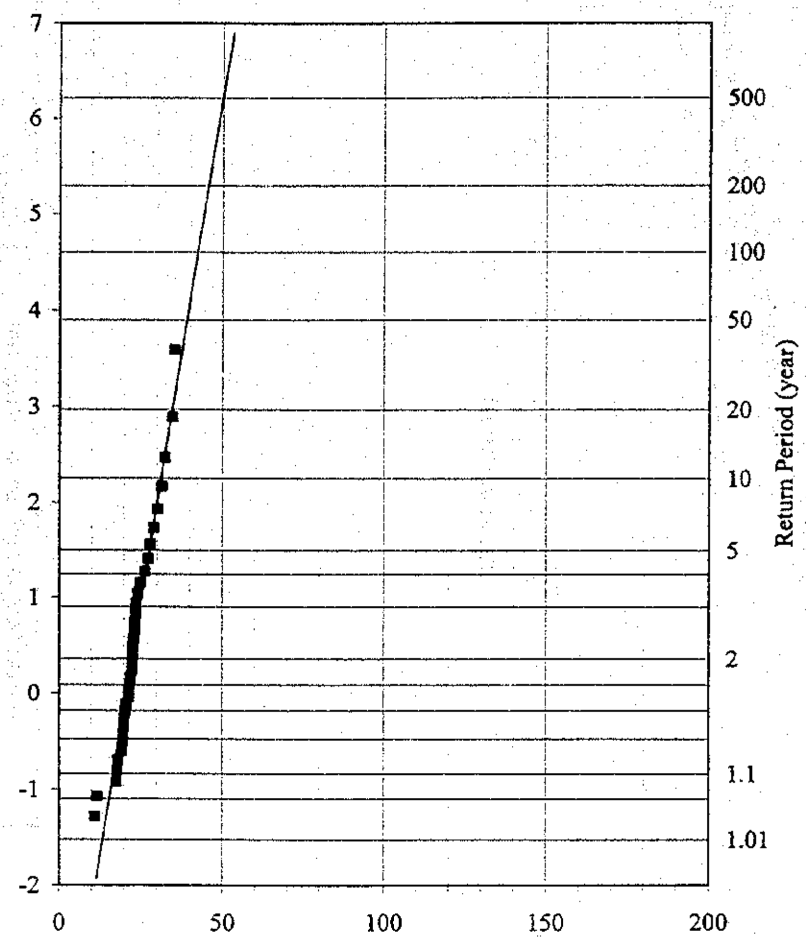
Rainfall Intensities proposed by MOC

unit ; mm/hr

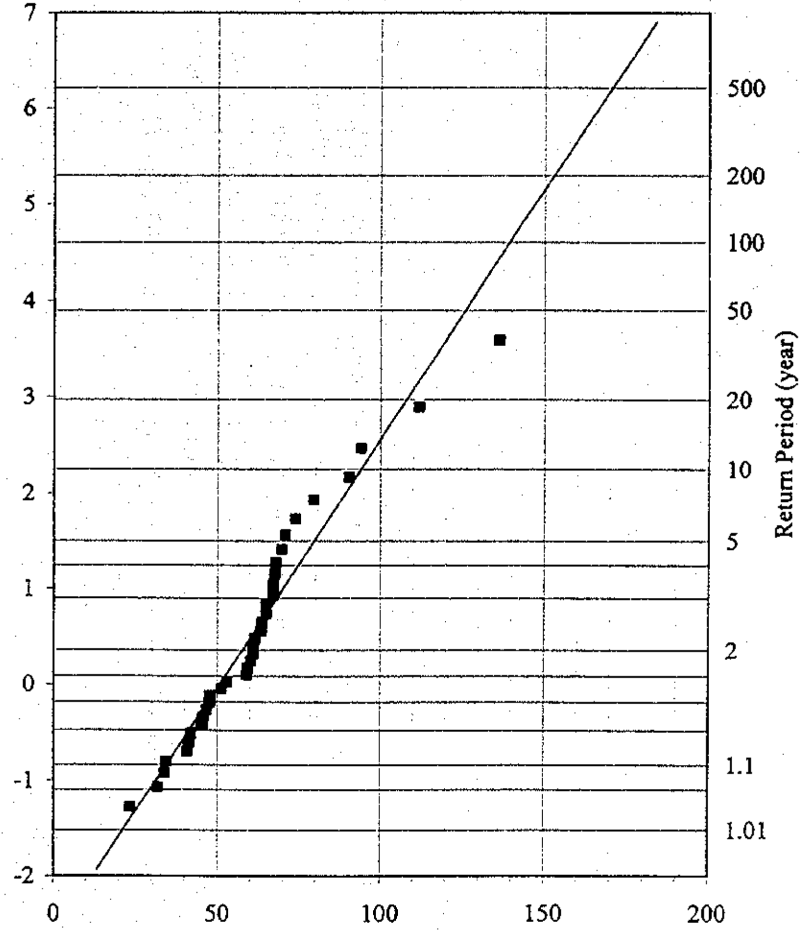
Duration (min.)	Return Period (year) 50	20	10	5	3	2	1
5	219	202	188	175	165	157	144
10	194	177	165	152	143	136	123
15	174	158	147	135	127	120	108
20	157	143	132	122	114	107	97
25	144	131	121	111	103	98	88
30	133	121	111	102	95	90	80
35	124	112	103	95	88	83	74
45	109	99	91	83	77	72	64
60	93	84	77	70	65	61	54
75	82	74	68	61	57	53	47
90	73	66	60	55	51	47	42
120	61	55	50	45	42	39	34
180	47	42	38	34	31	29	25
240	38	34	31	28	25	24	20
360	29	25	23	21	19	17	15
480	23	21	19	17	15	14	12

Fig. C6.3
RAINFALL INTENSITY CURVES IN HANOI

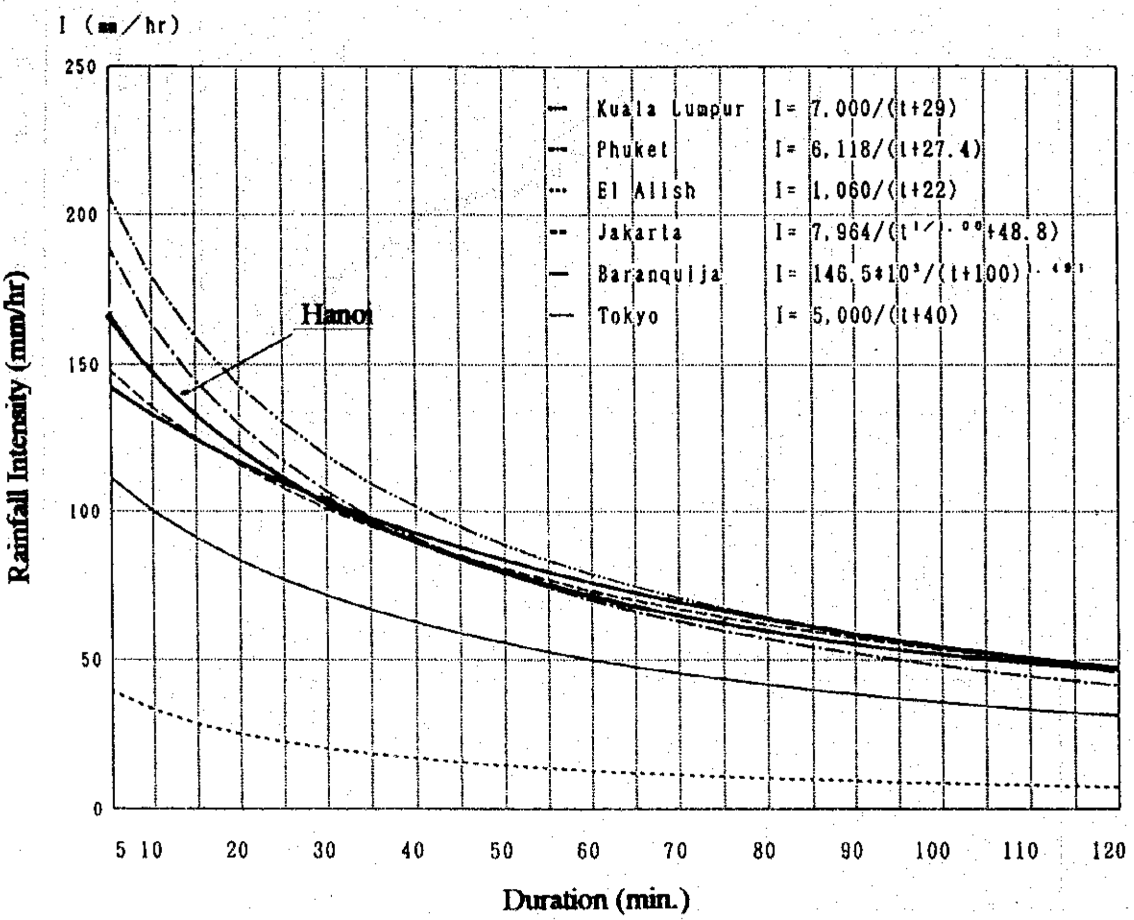
Probable 10 Minutes Rainfall at Lang Station
- Gumbel Method, Data Period : 1957-1992(36 years) -



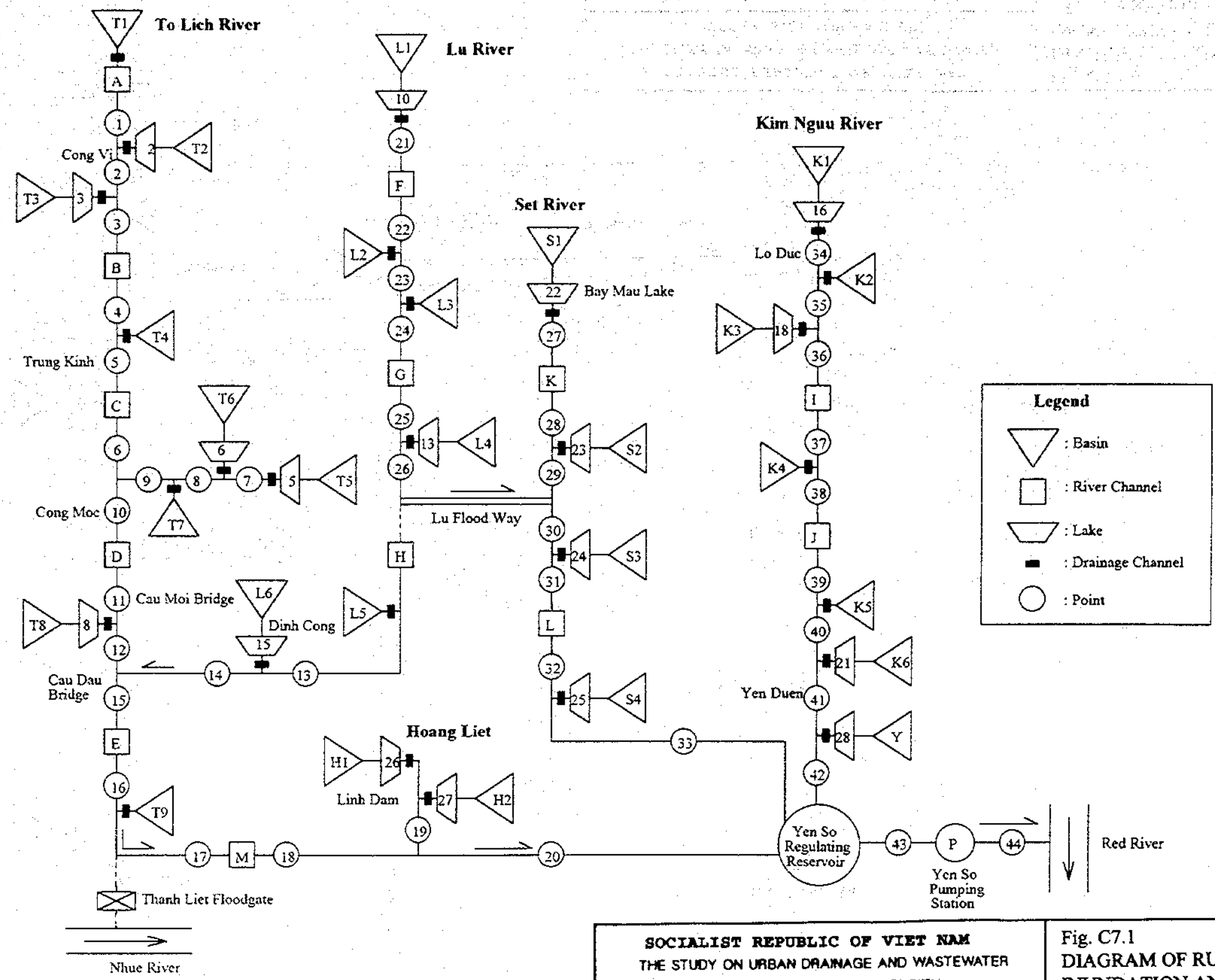
Probable 60 Minutes Rainfall at Lang Station
- Gumbel Method, Data Period : 1957-1992(36 years) -



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C6.4 PROBABLE 10 AND 60 MINUTES RAINFALLS



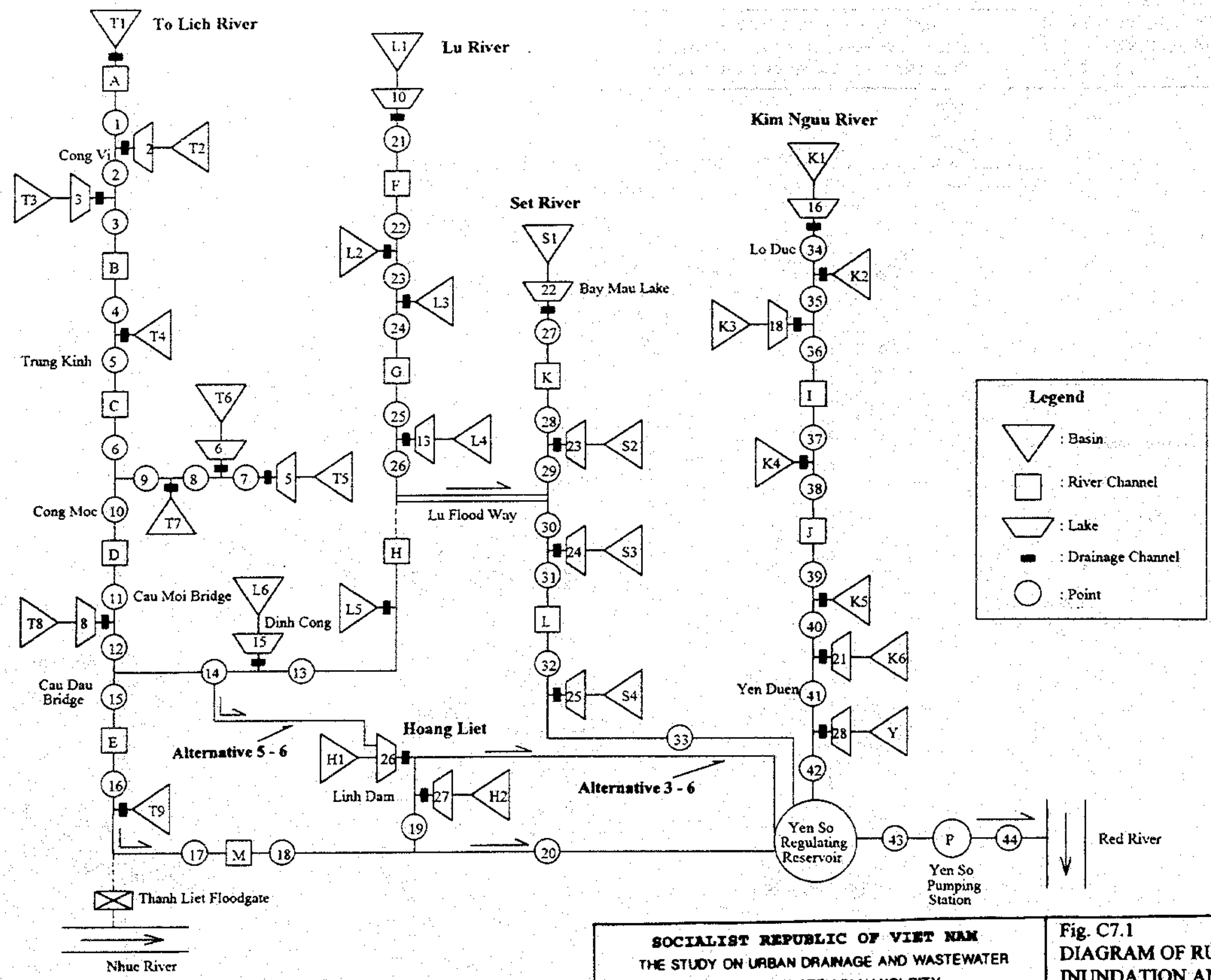
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C6.5 COMPARISON OF RAINFALL INTENSITY CURVES



SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

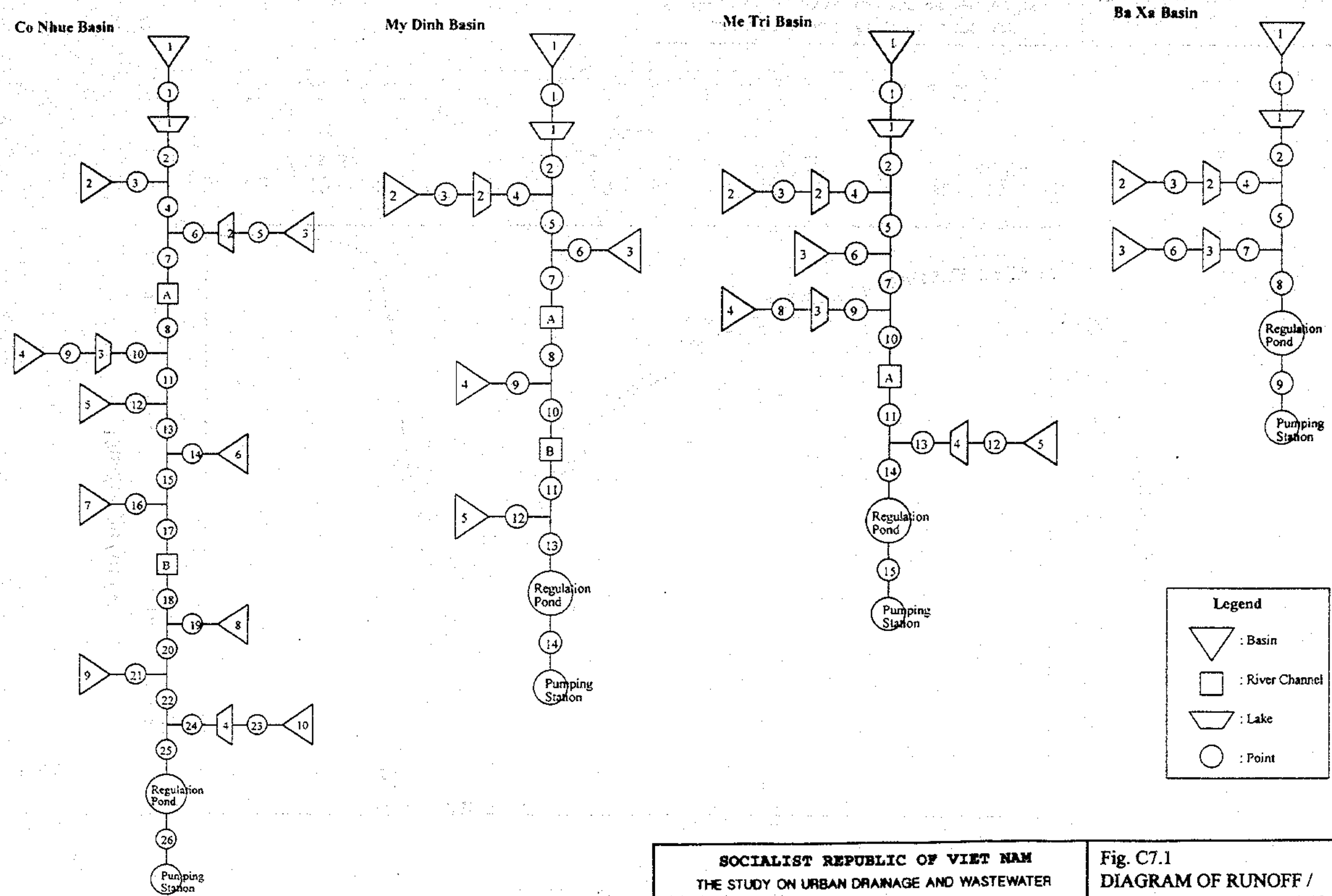
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C7.1
DIAGRAM OF RUNOFF / INUNDATION ANALYSES (1/3)
- To Lich River Basin (Alt.1 - 2) -



SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
JAPAN INTERNATIONAL COOPERATION AGENCY

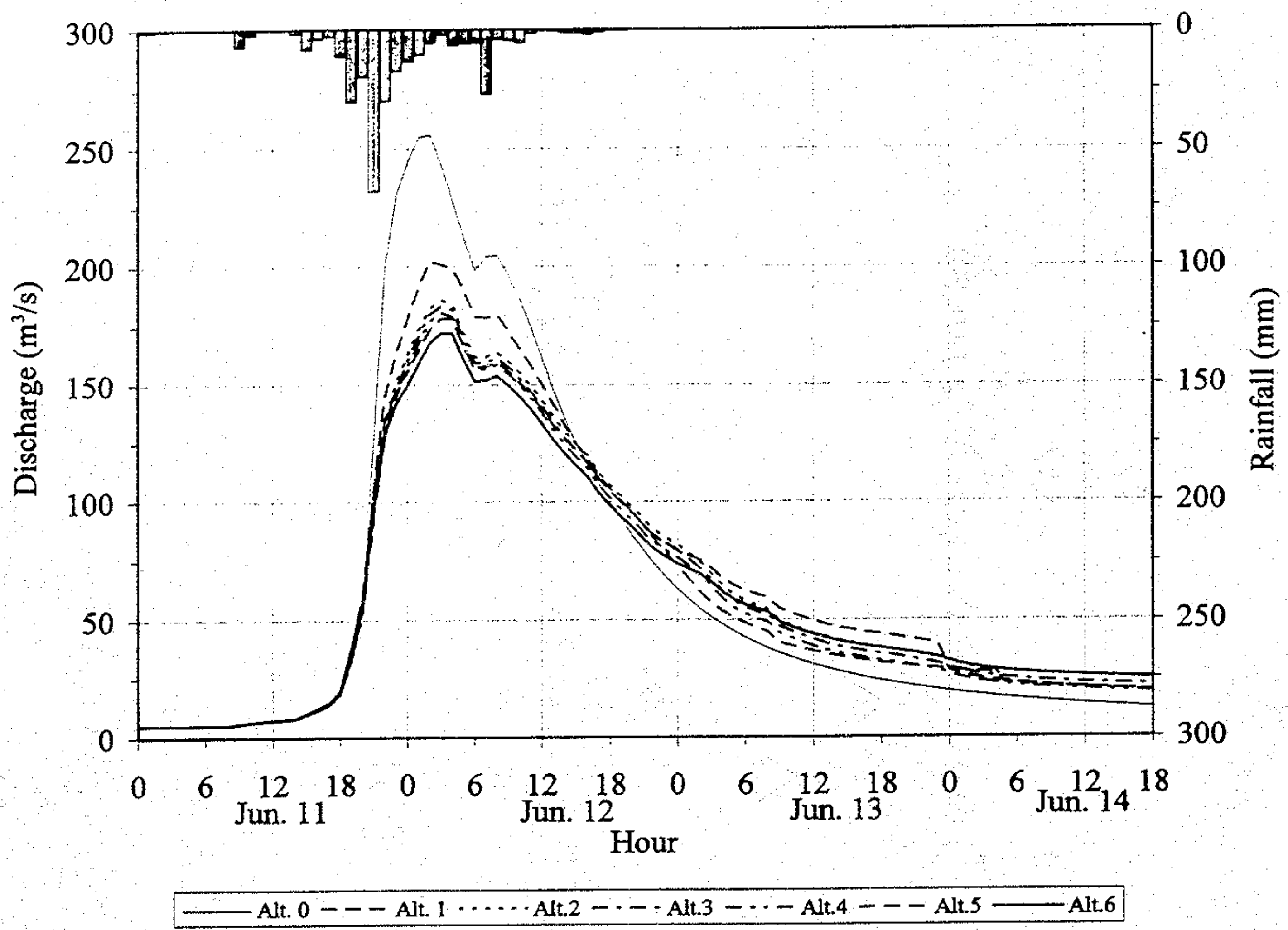
Fig. C7.1
DIAGRAM OF RUNOFF / INUNDATION ANALYSES (2/3)
- To Lich River Basin (Alt.3 - 6) -



SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C7.1
DIAGRAM OF RUNOFF / INUNDATION ANALYSES (3/3)
- Nhue River Basin -

Hydrographs of Alternatives at Yen So Site
Jun. 12 '89 Flood Type (W = 1/10)

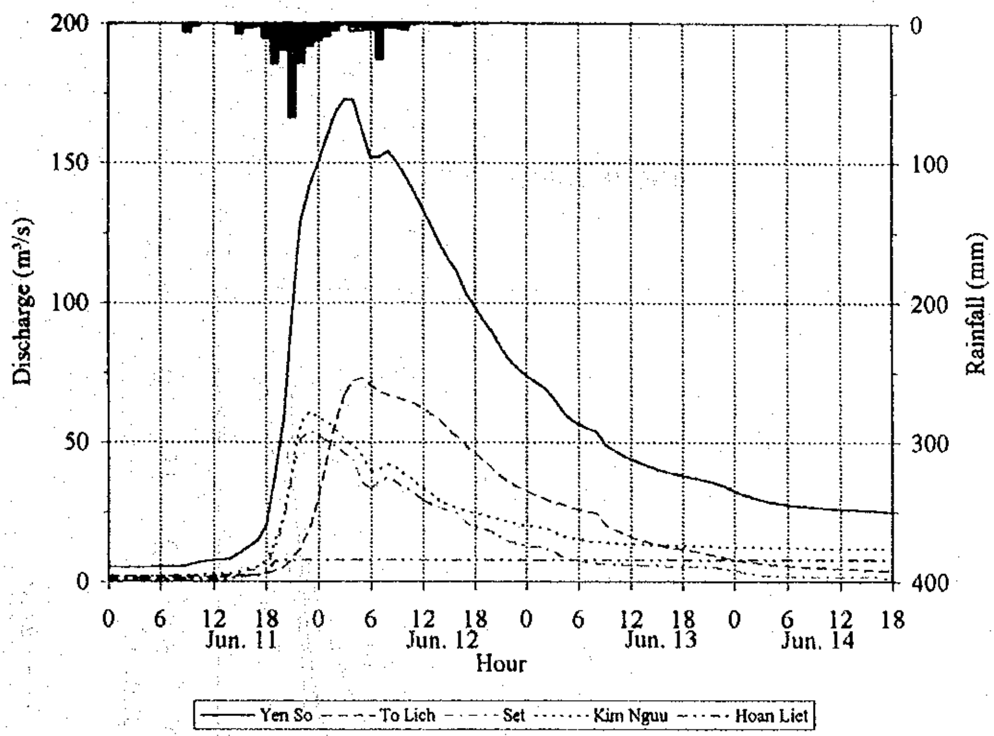


SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

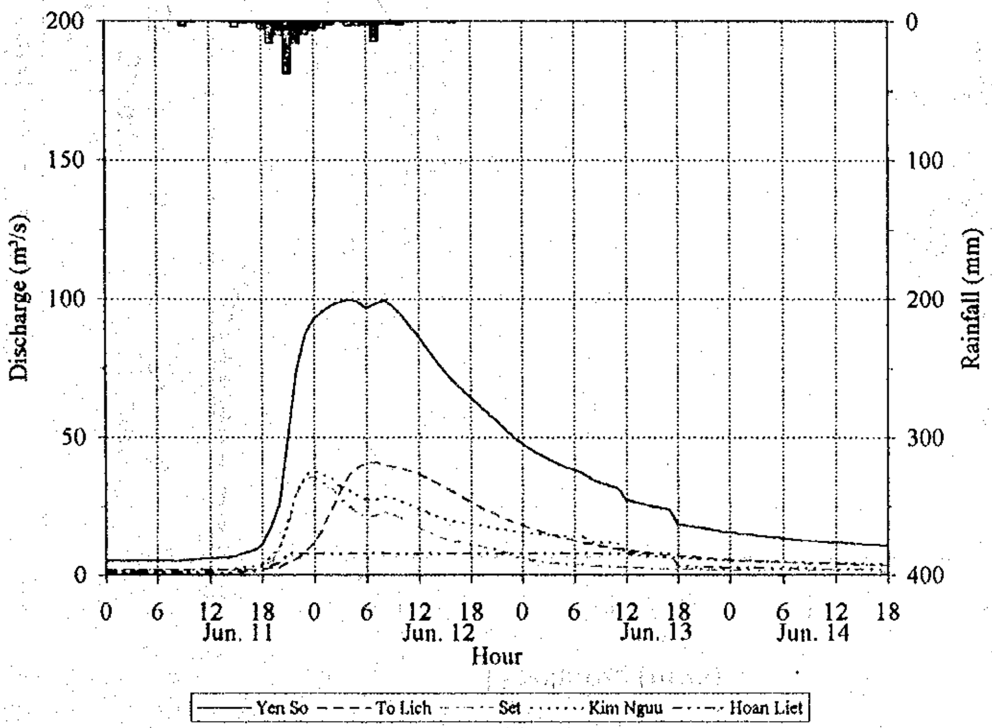
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C7.2
DESIGN HYDROGRAPHS OF THE TO LICH RIVER BASIN

Jun. 12 '89 Flood Type (W = 1/10)



Jun. 12 '89 Flood Type (W = 1/2)



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C7.3 DESIGN HYDROGRAPHS OF ALTERNATIVE 6

Design Hydrograph of Nhue River Basin
Jun. 12 '89 Flood Type (W = 1/10, Alt.1)

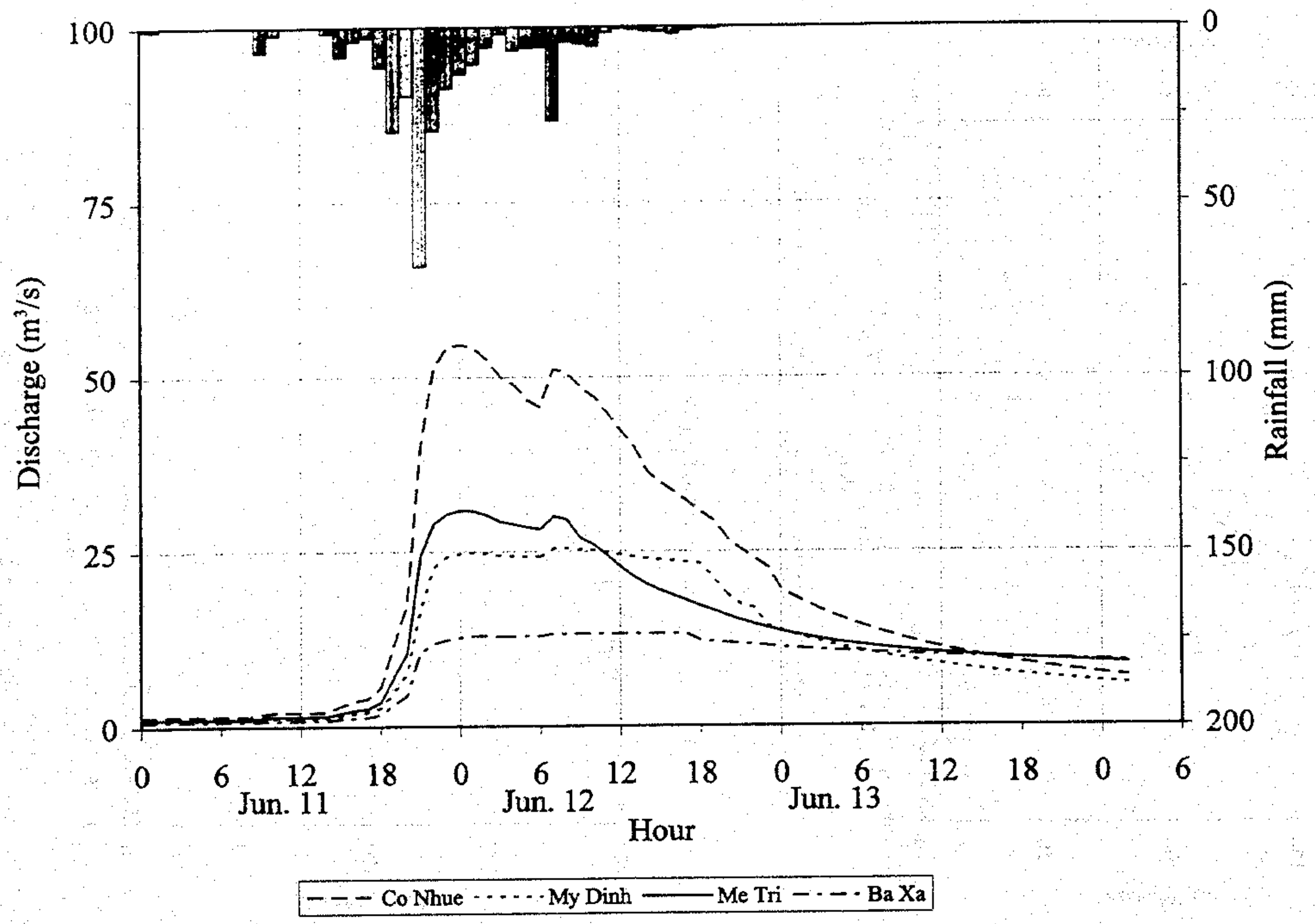


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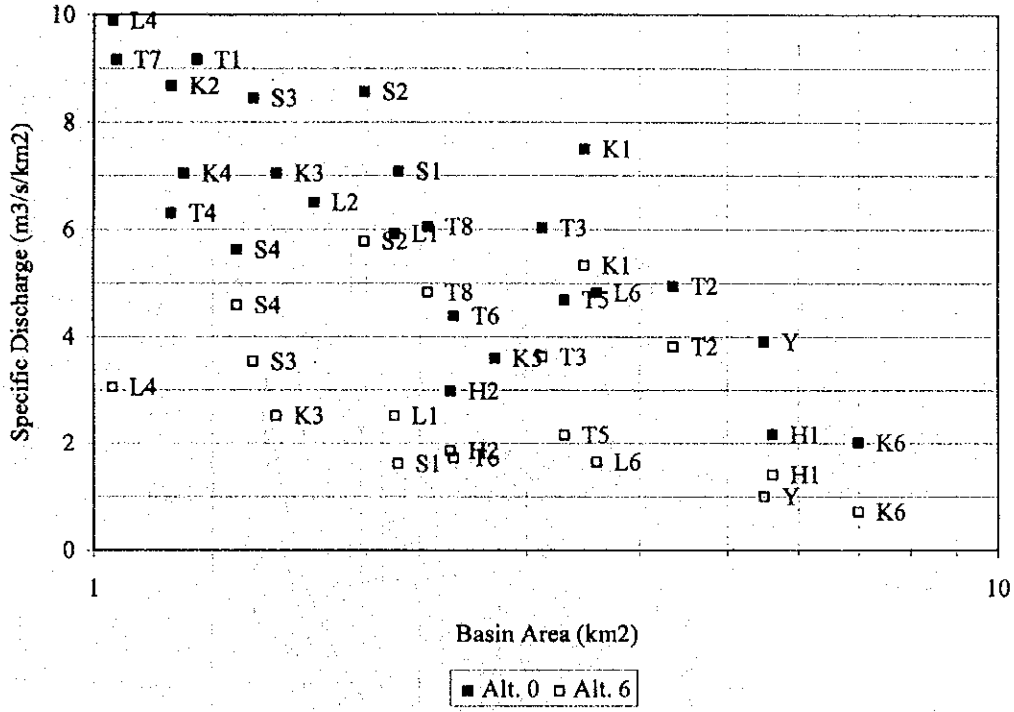
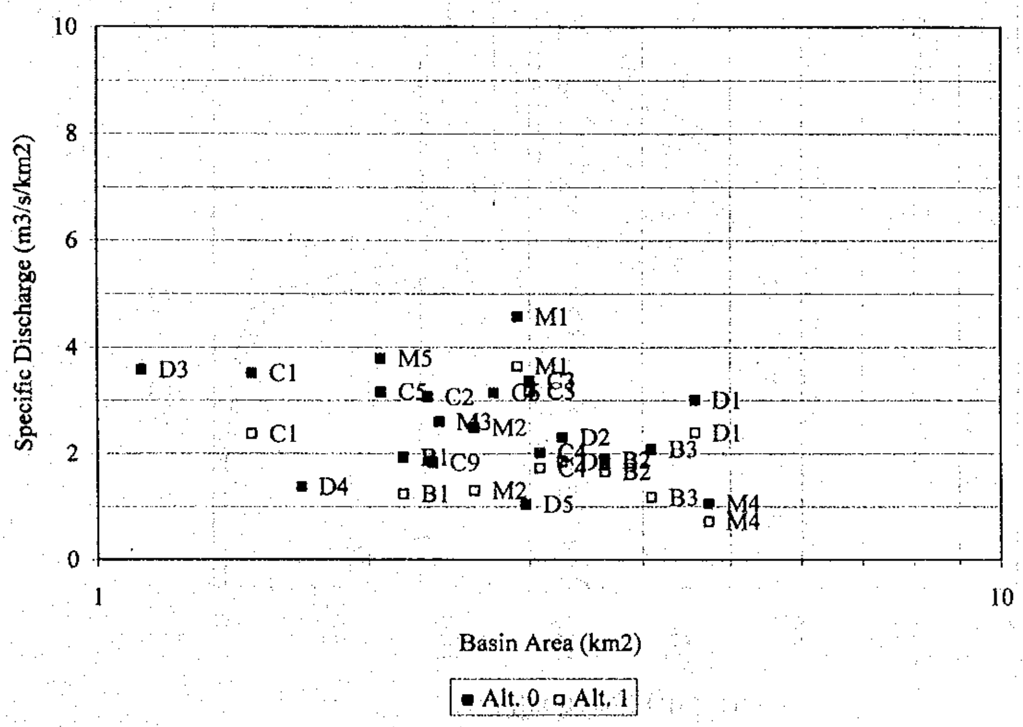
Fig. C7.4
DESIGN HYDROGRAPHS OF THE NHUE RIVER BASIN

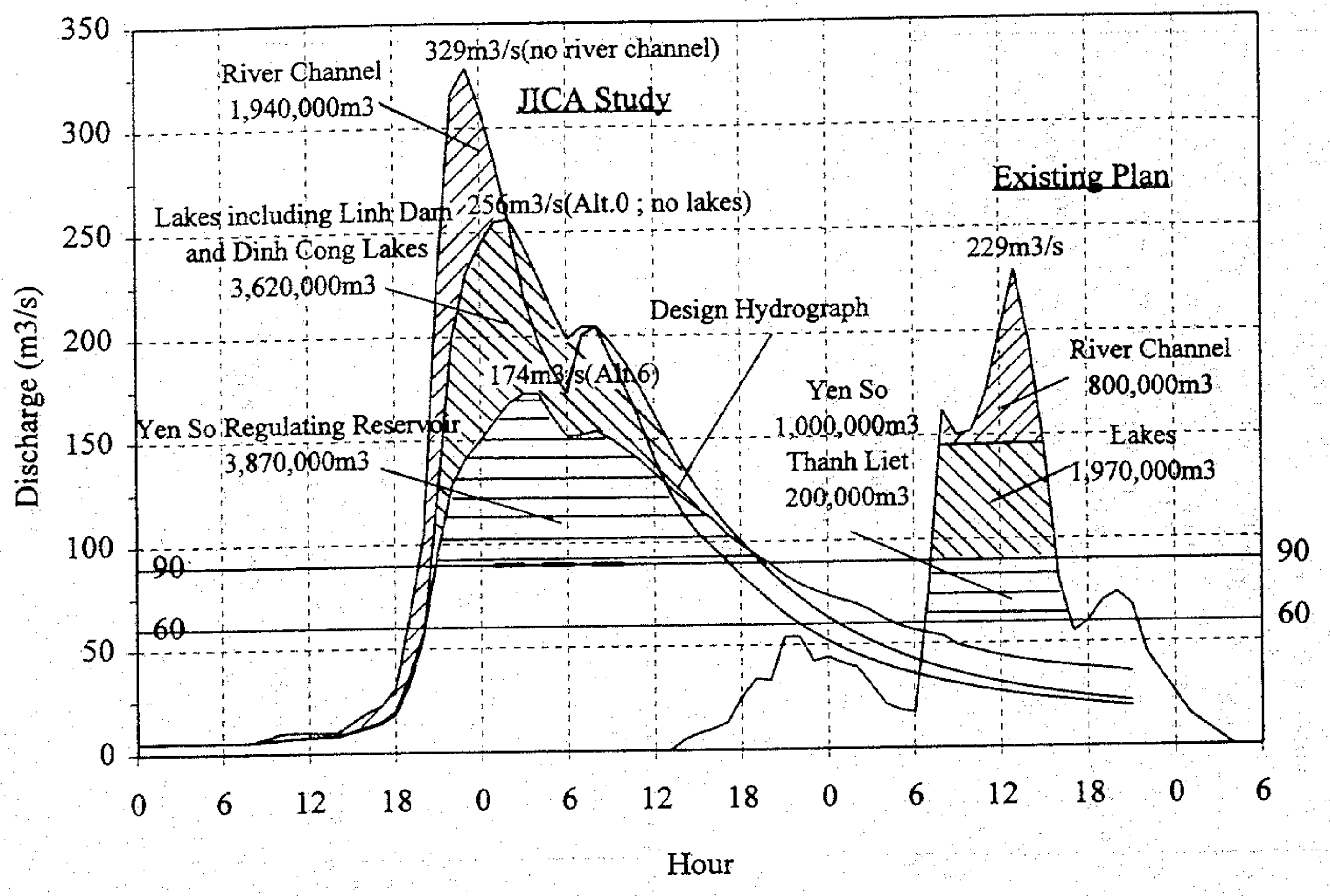
- To Lich River Basin -



- Nhue River Basin -



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C7.5 SPECIFIC DISCHARGES OF SUB-BASINS



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THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
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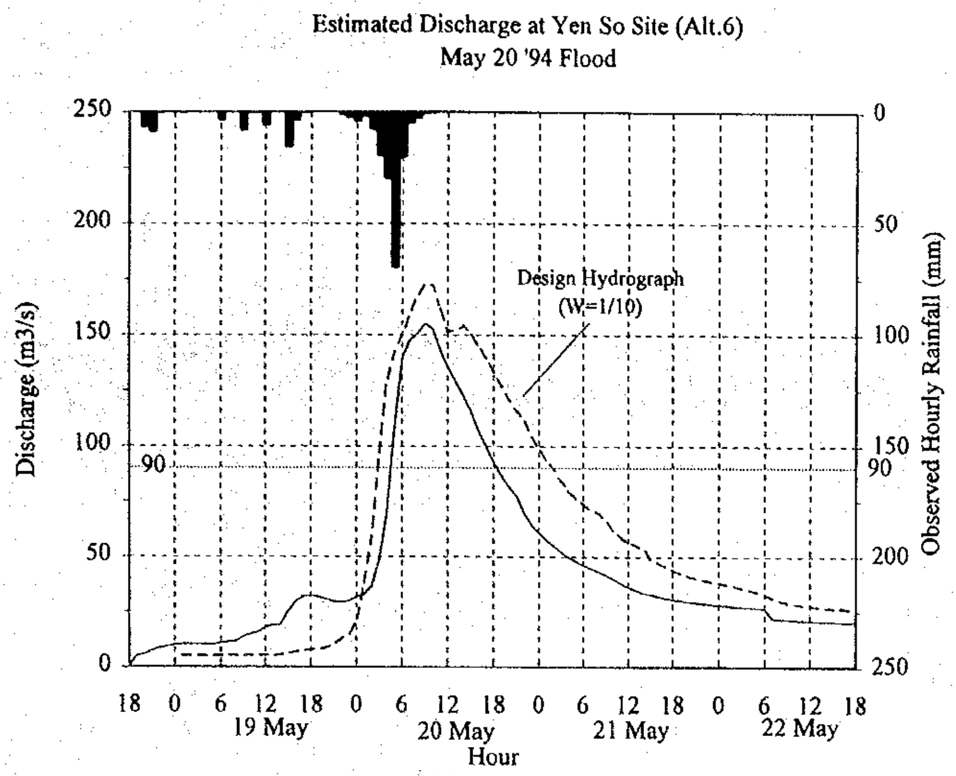
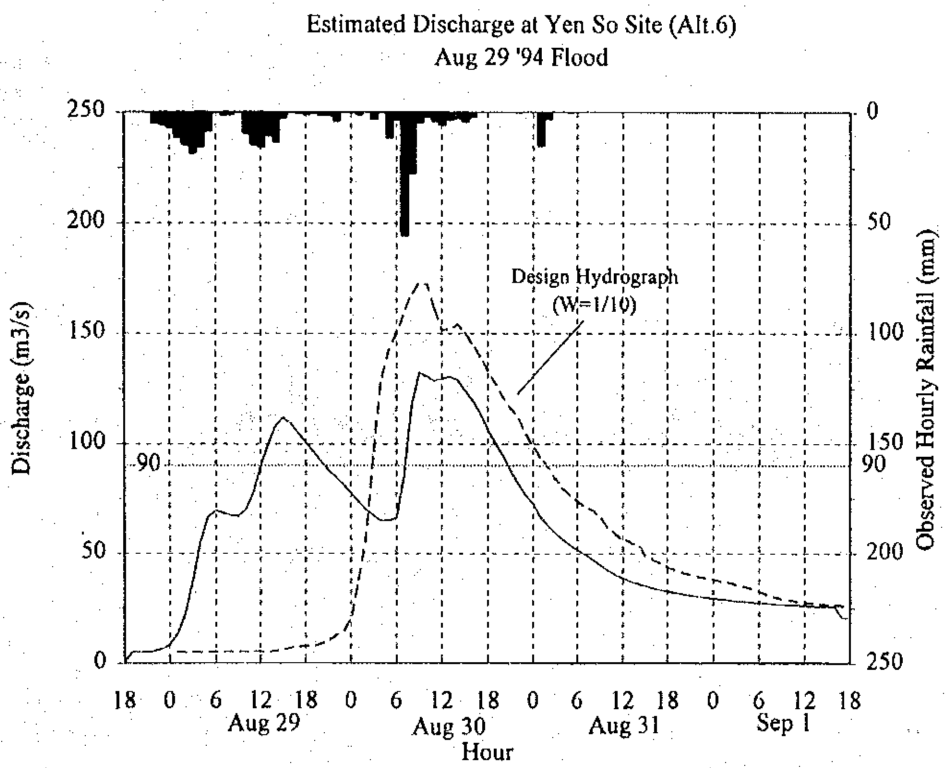
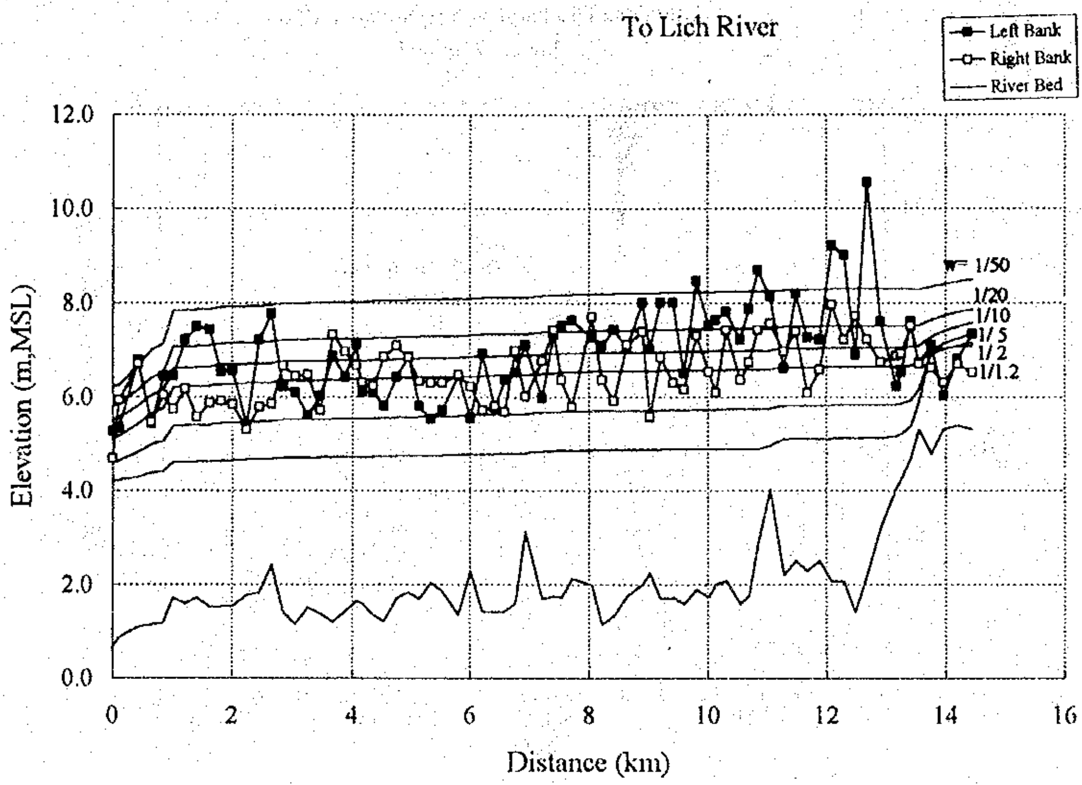
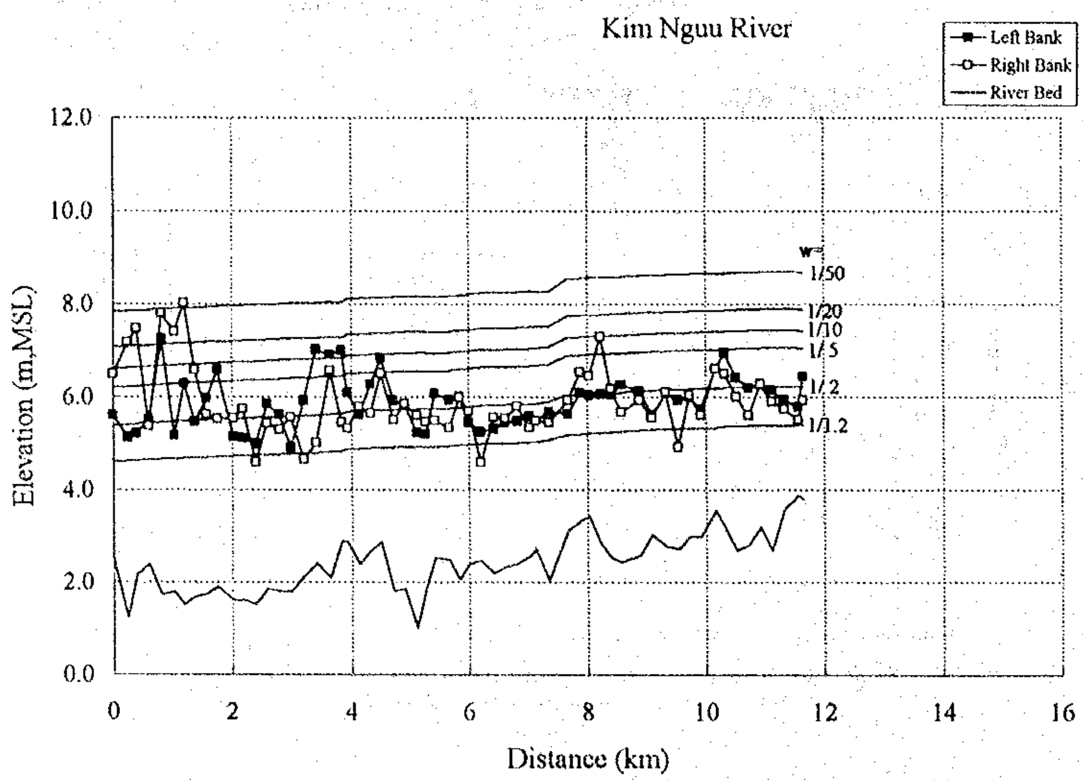
Fig. C7.6
COMPARISON OF RUNOFF CALCULATIONS



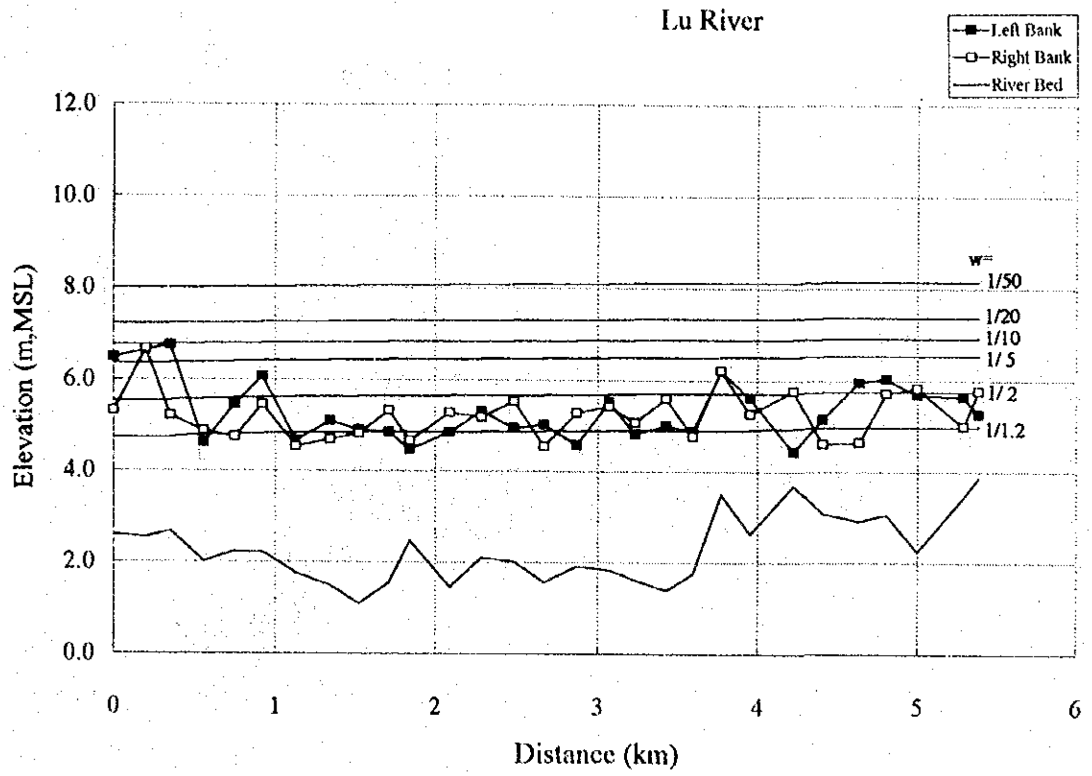


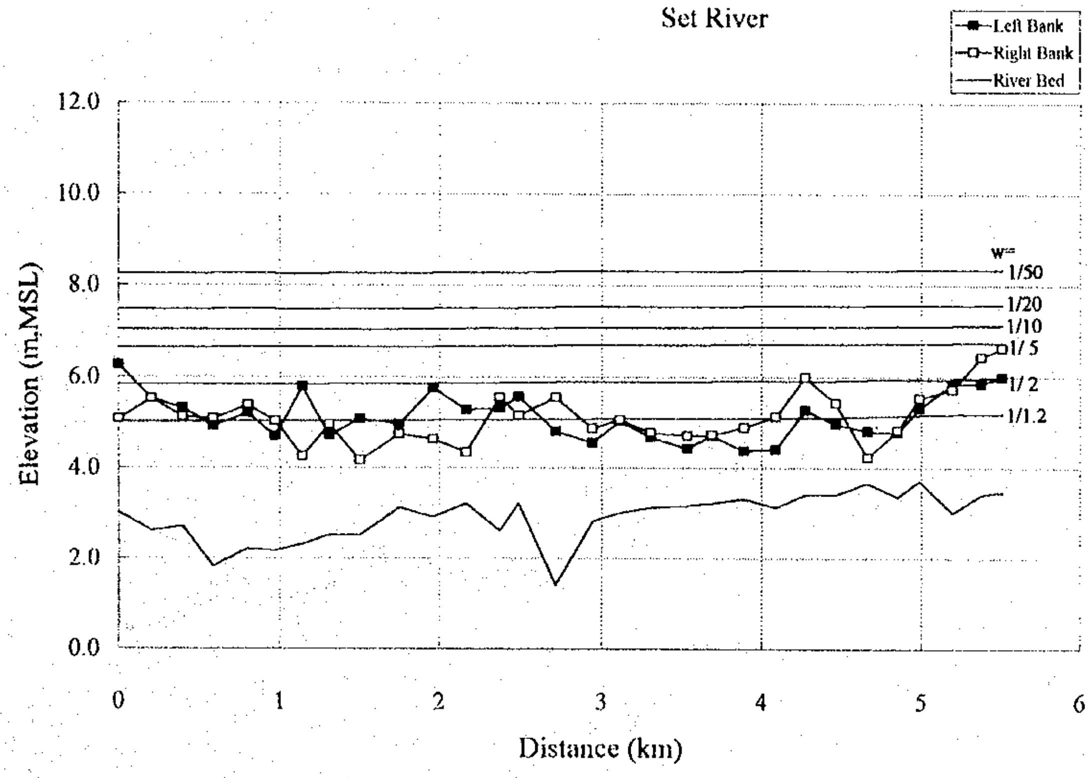
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C7.7 ESTIMATED HYDROGRAPHS OF 1994 FLOODS





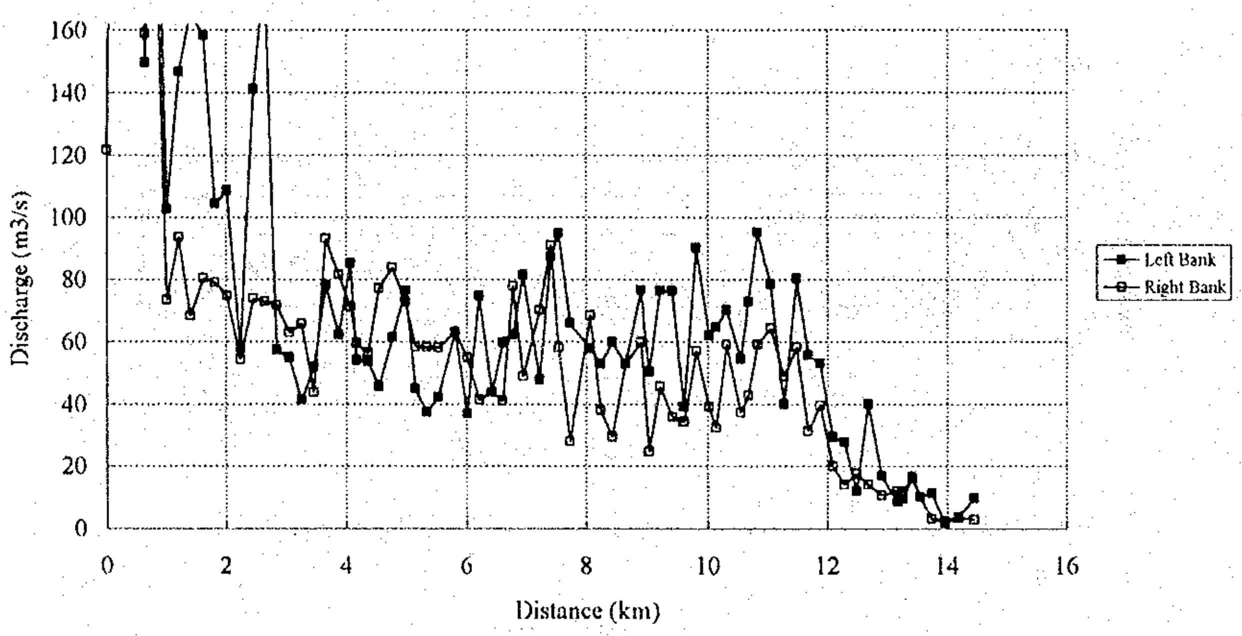
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C8.1 WATER LEVELS BY NON-UNIFORM FLOW CALCULATION (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	



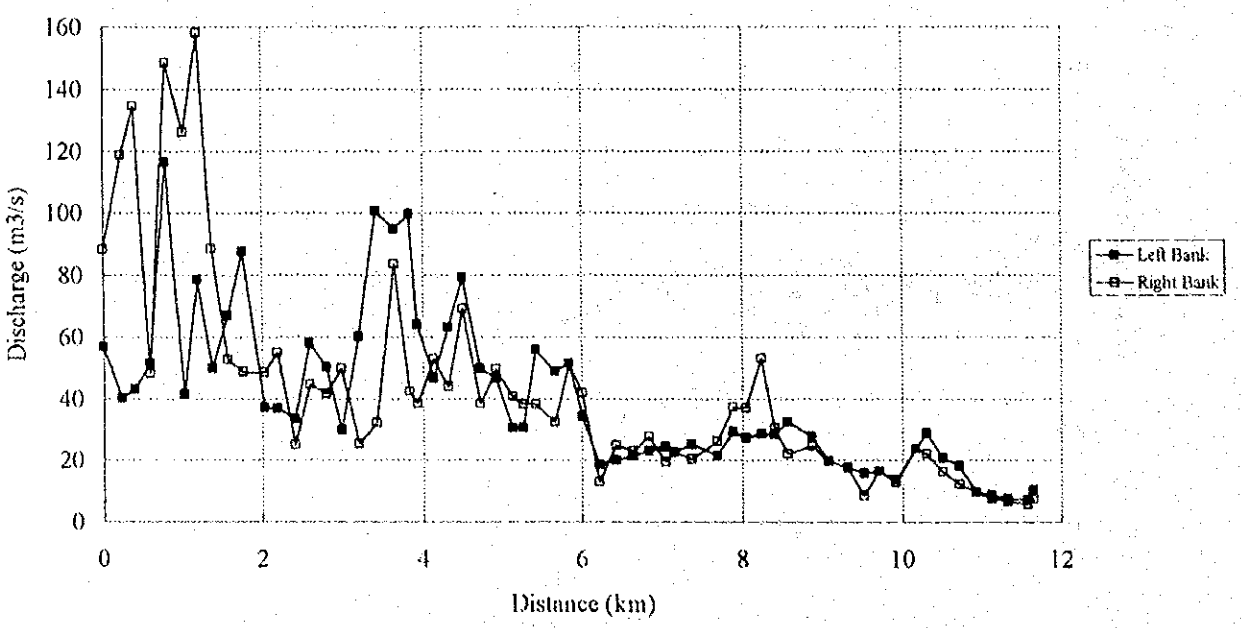


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C8.1 WATER LEVELS BY NON-UNIFORM FLOW CALCULATION (2/2)

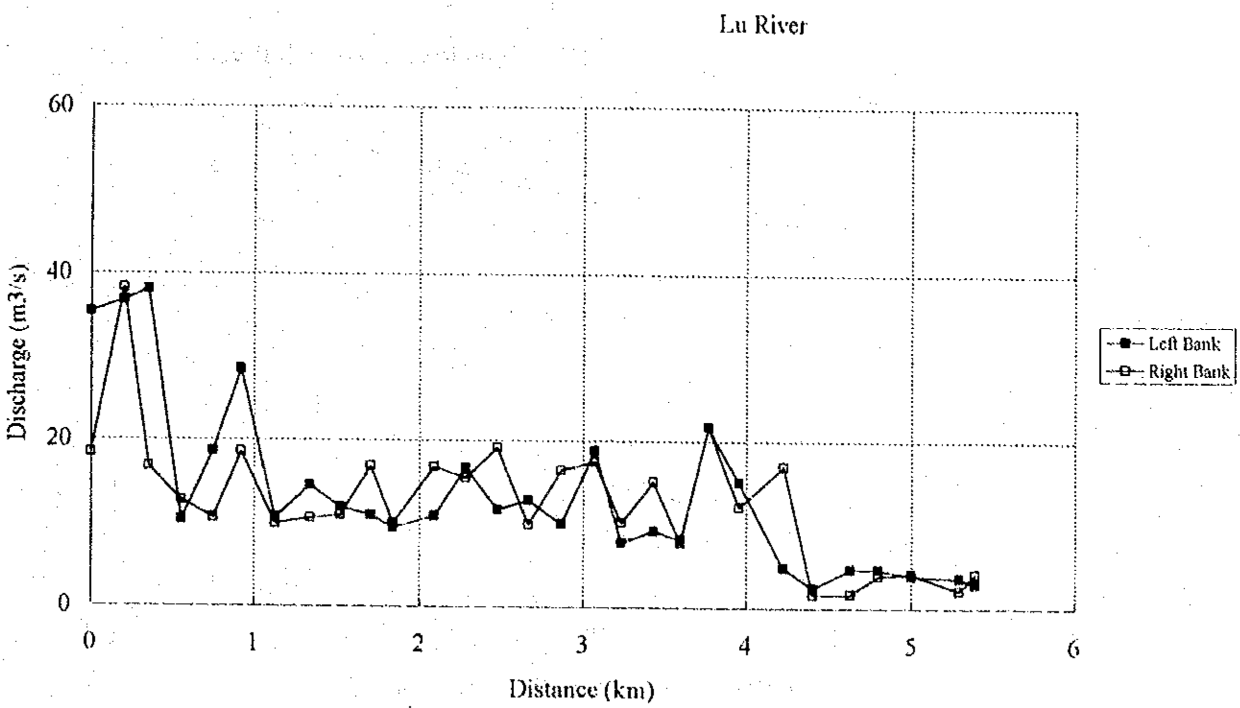
To Lich River

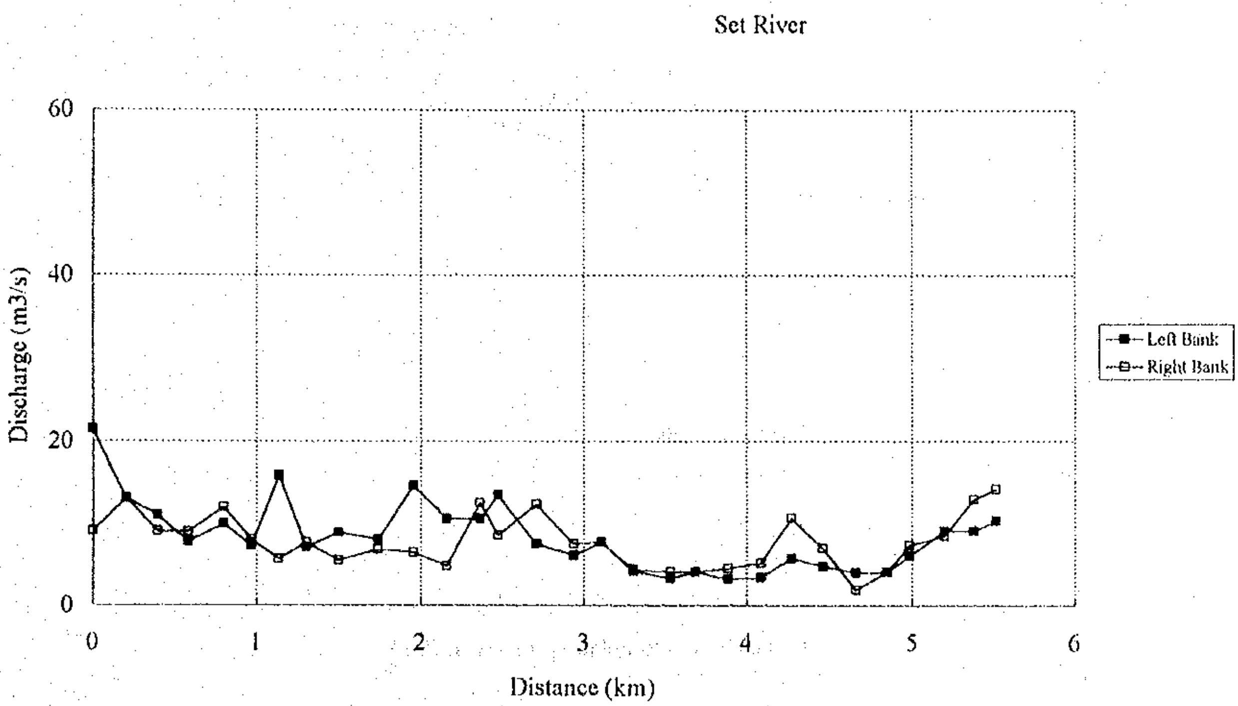


Kim Nguu River

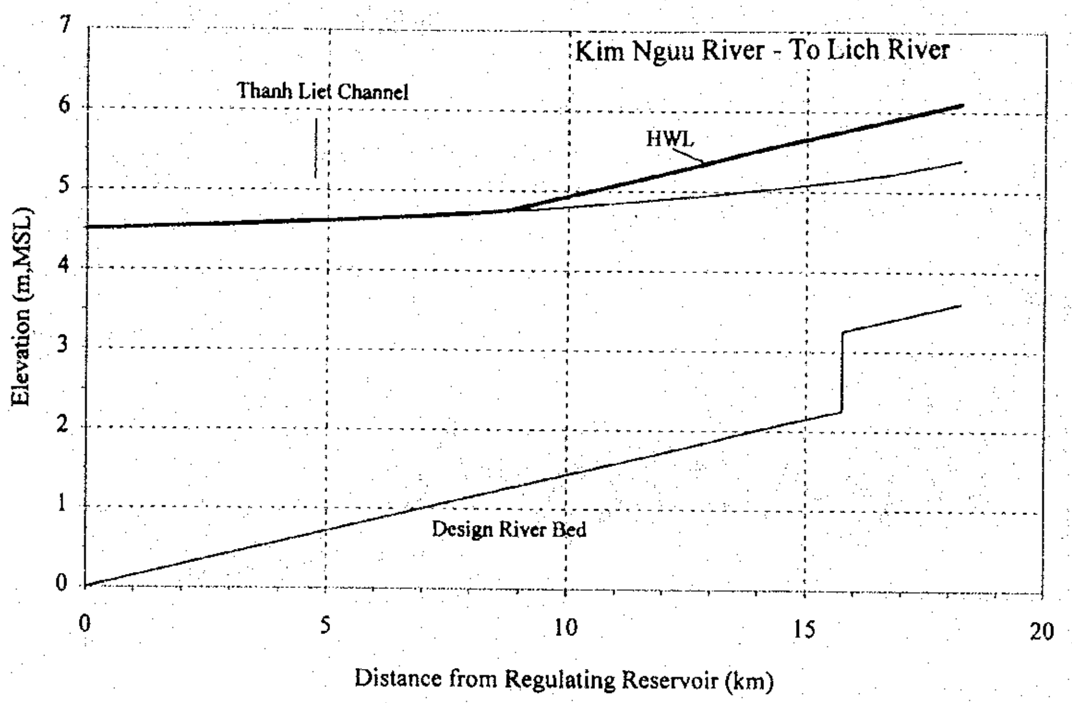


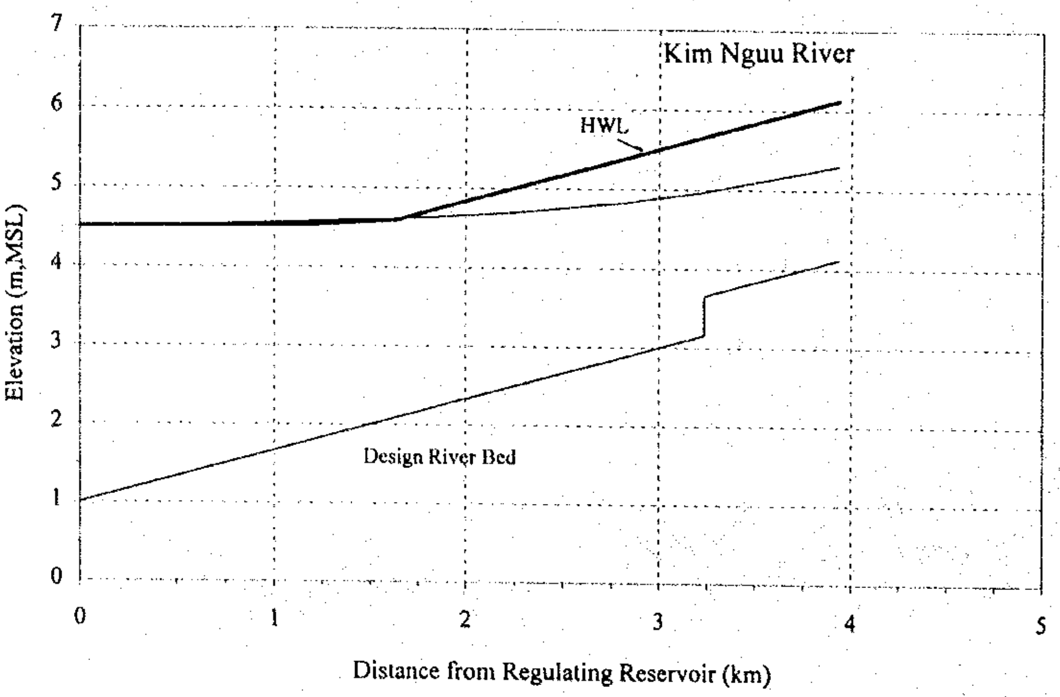
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C8.2 PRESENT BANKFUL CHANNEL CAPACITY (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	





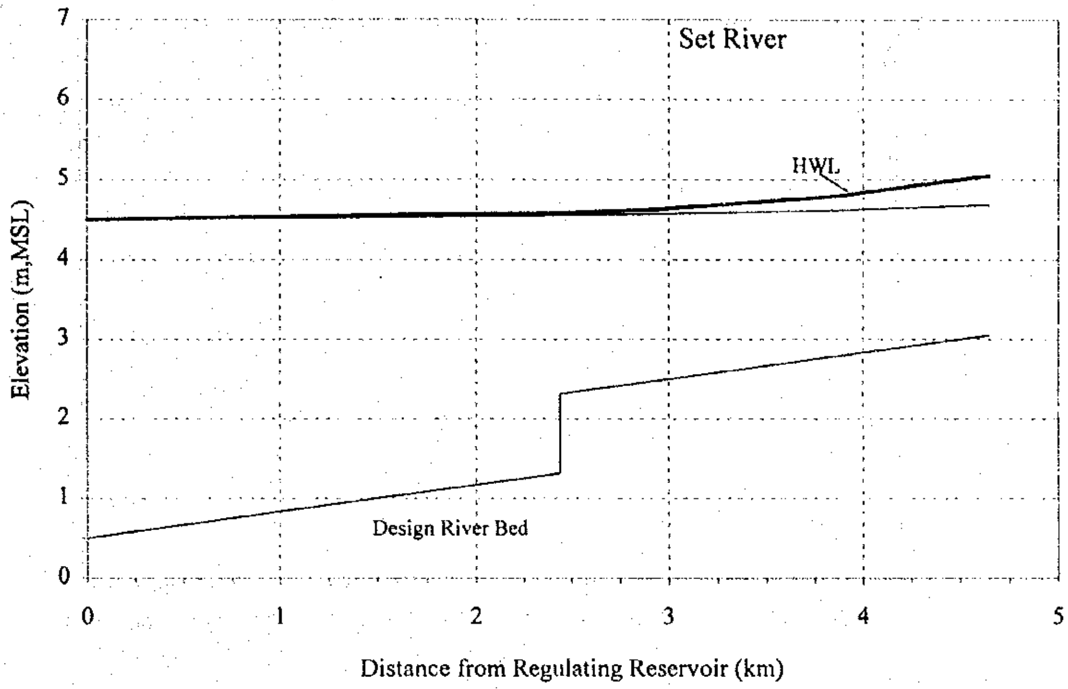
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C8.2 PRESENT BANKFUL CHANNEL CAPACITY (2/2)





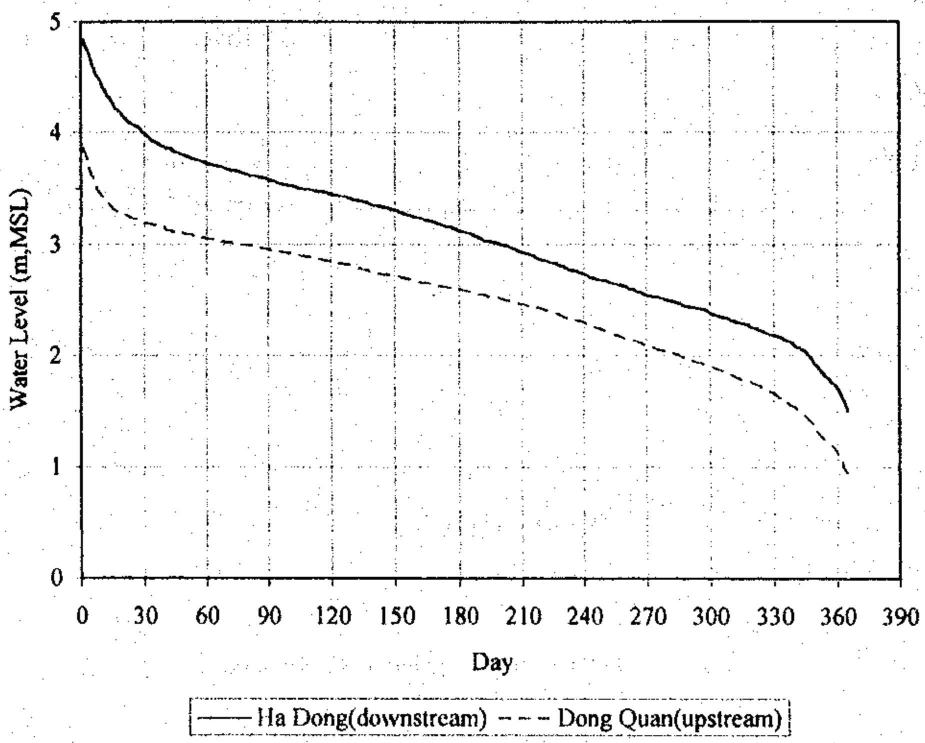
SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C8.3
INFLUENCE OF BACKWATER UNDER DESIGN SECTION (1/2)

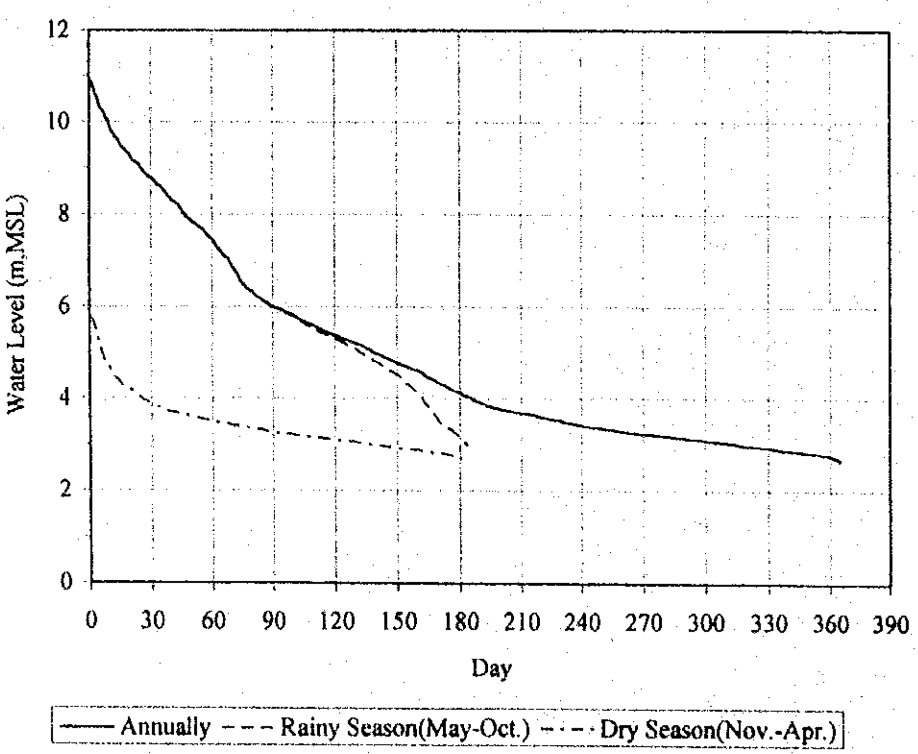


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C8.3 INFLUENCE OF BACKWATER UNDER DESIGN SECTION (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY	

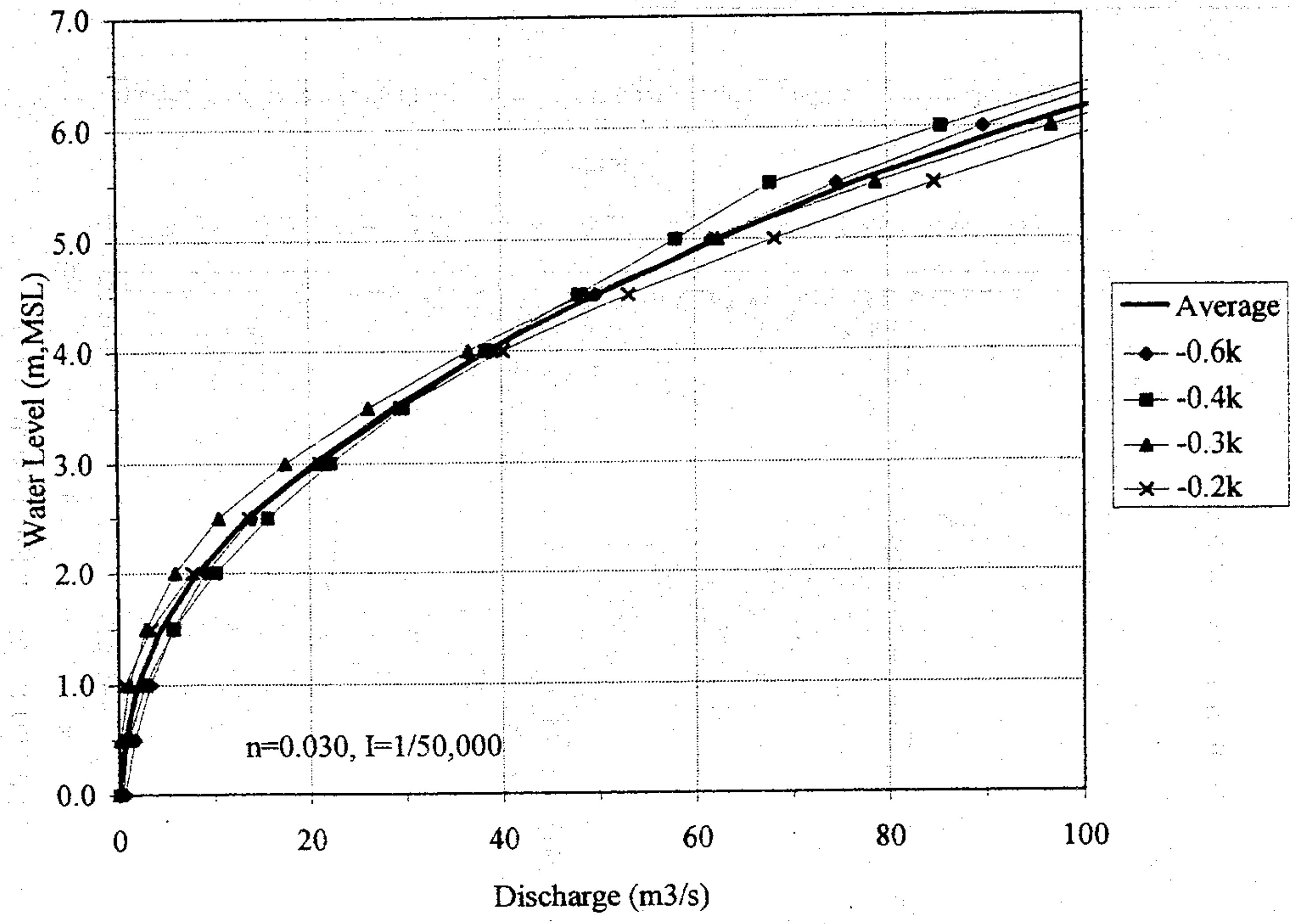
Average Flow Regime of Nhue River
Data Period : 1989 - 1993



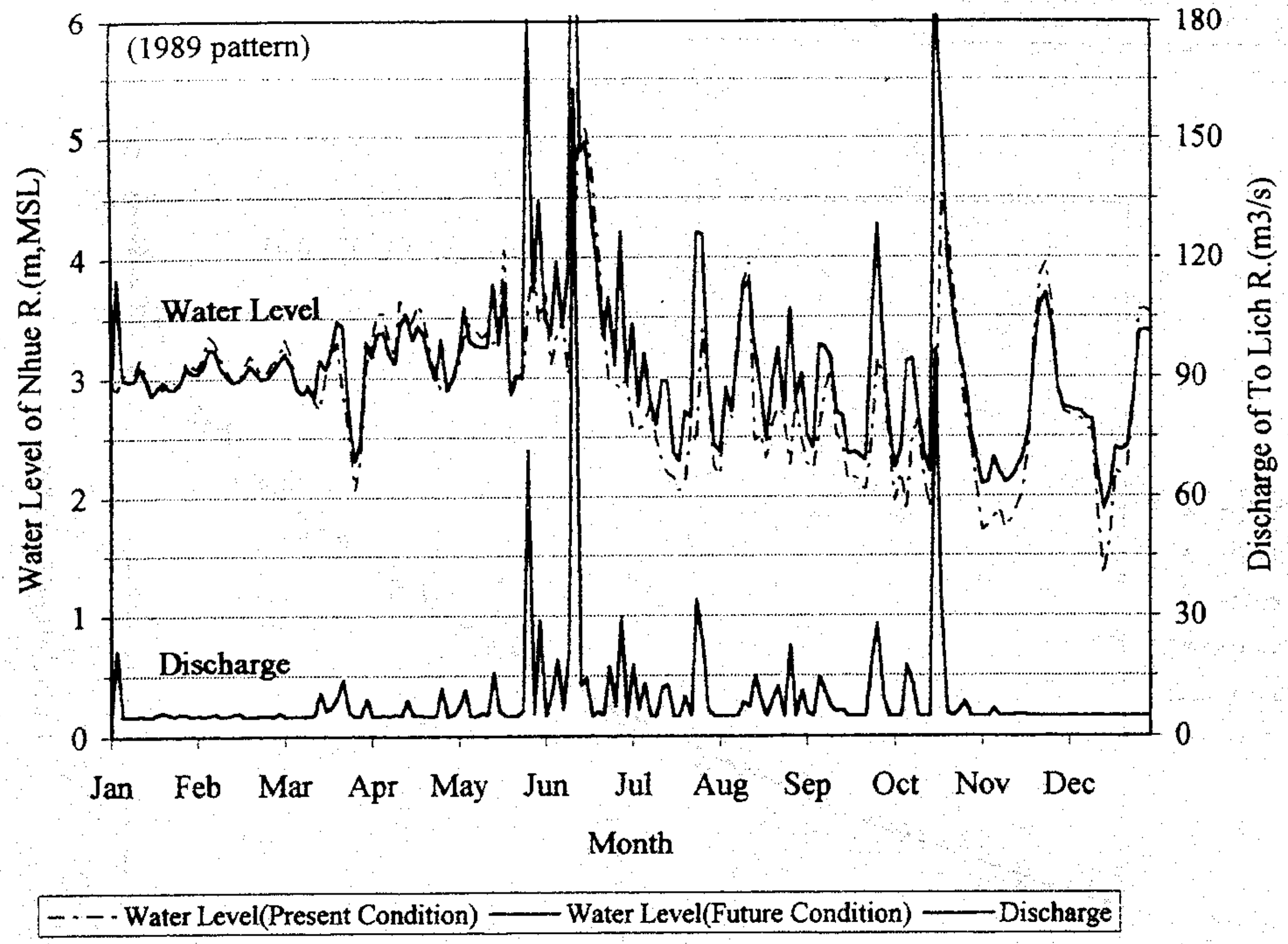
Average Flow Regime of Red River at Hanoi
Data Period : 1989-1993



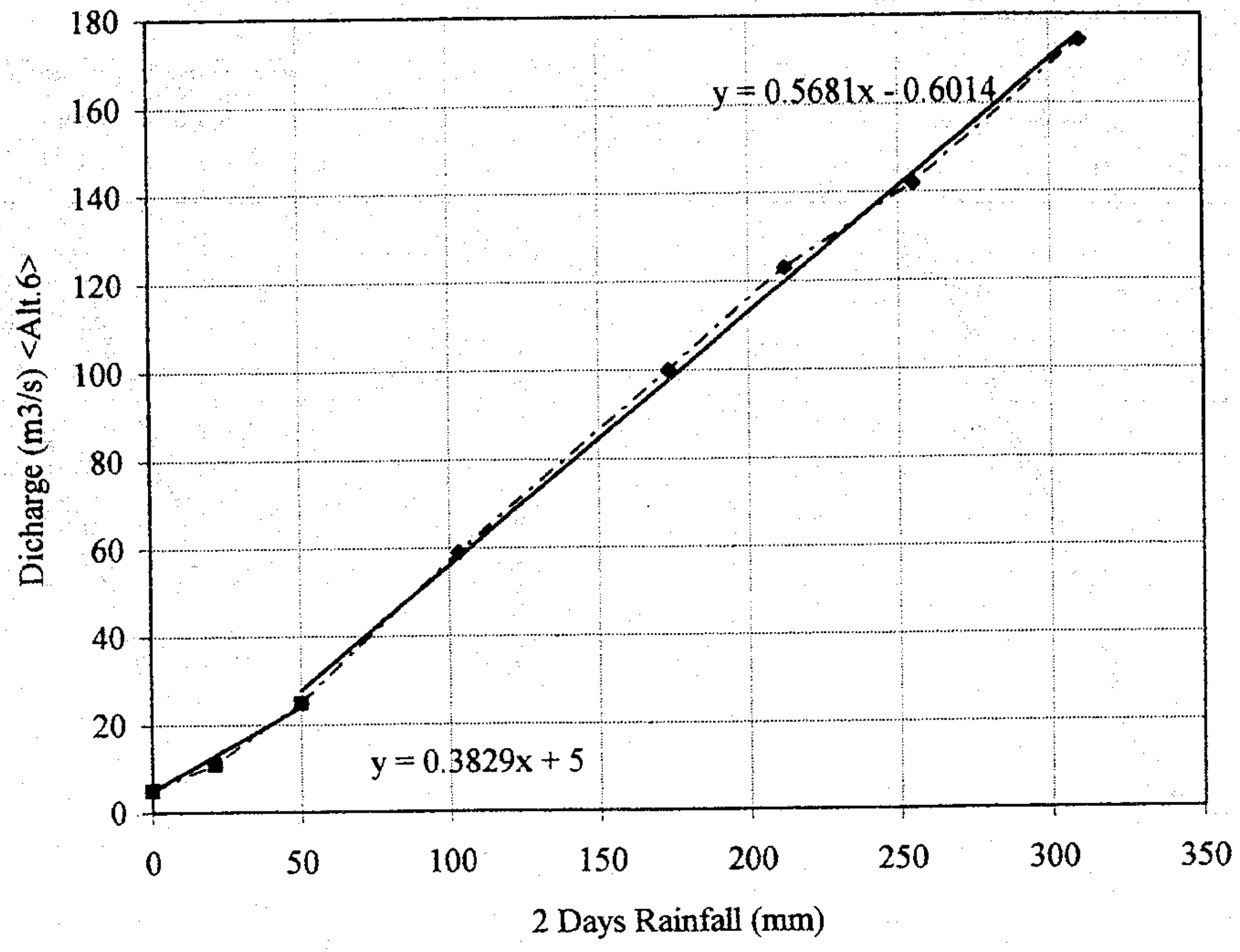
SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C10.1 AVERAGE FLOW DURATION CURVES
JAPAN INTERNATIONAL COOPERATION AGENCY	



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C10.2 DISCHARGE RATING CURVE OF NHUE RIVER AT THANH LIET FLOODGATE



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C10.3 WATER LEVEL OF NHUE RIVER AND DISCHARGE OF TO LICH RIVER



SOCIALIST REPUBLIC OF VIET NAM
THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY
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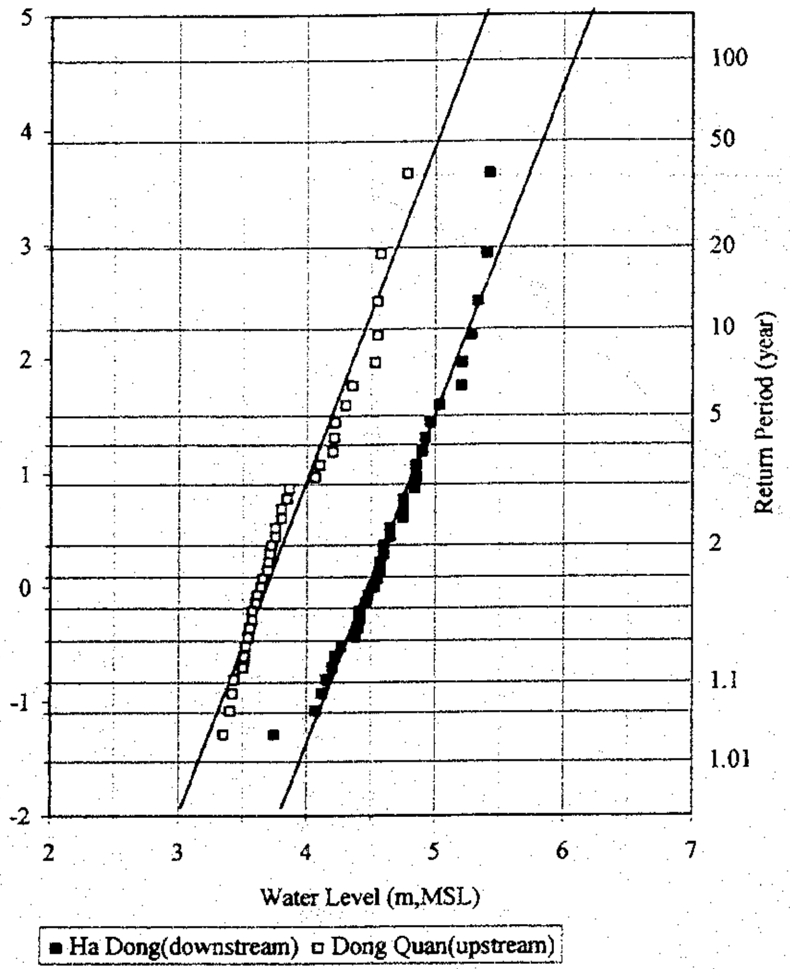
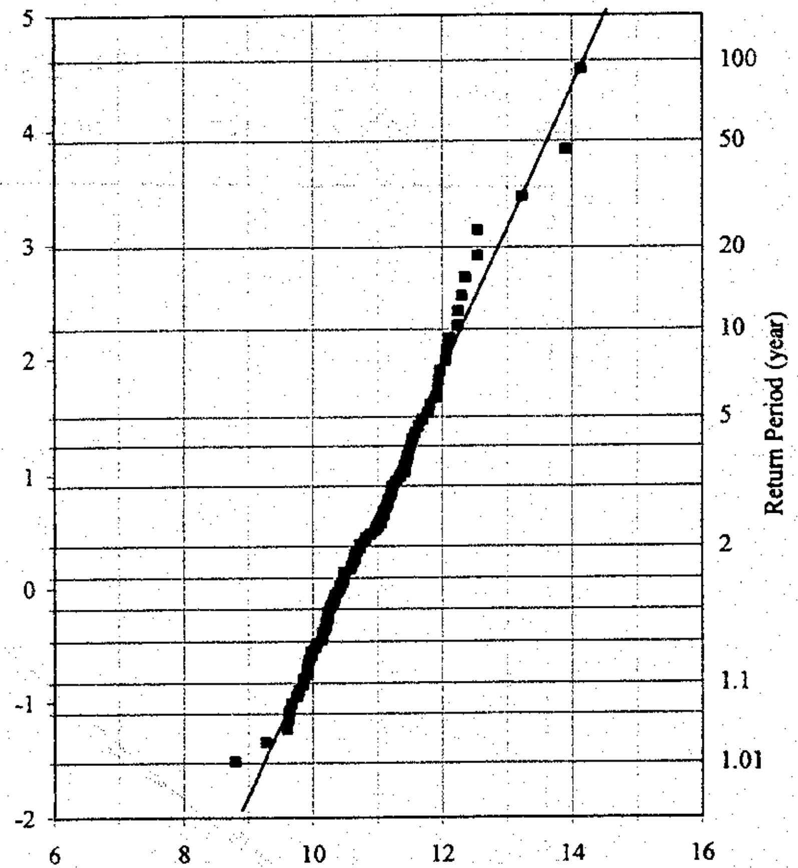
Fig. C10.4
RELATION BETWEEN RAINFALL AND DISCHARGE OF TO LICH RIVER

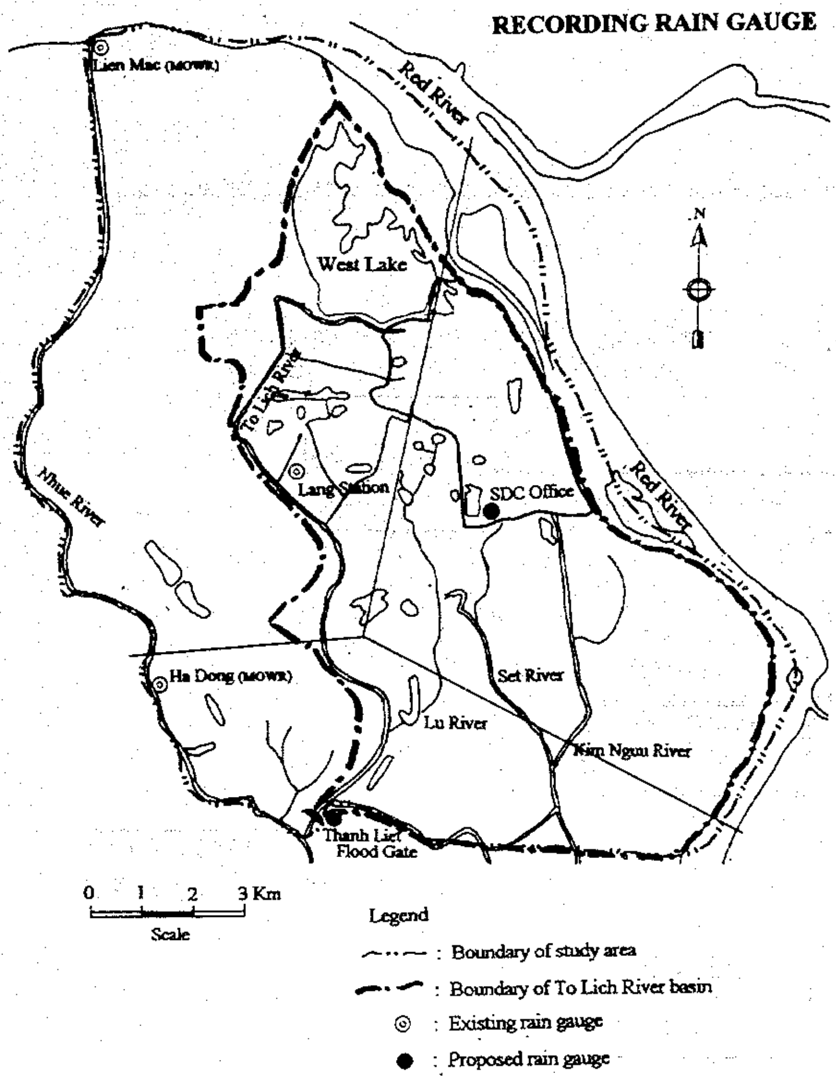
Probable Maximum Water Level of Nhue River
(Gumbel Method, Data Period : 1957-1993)

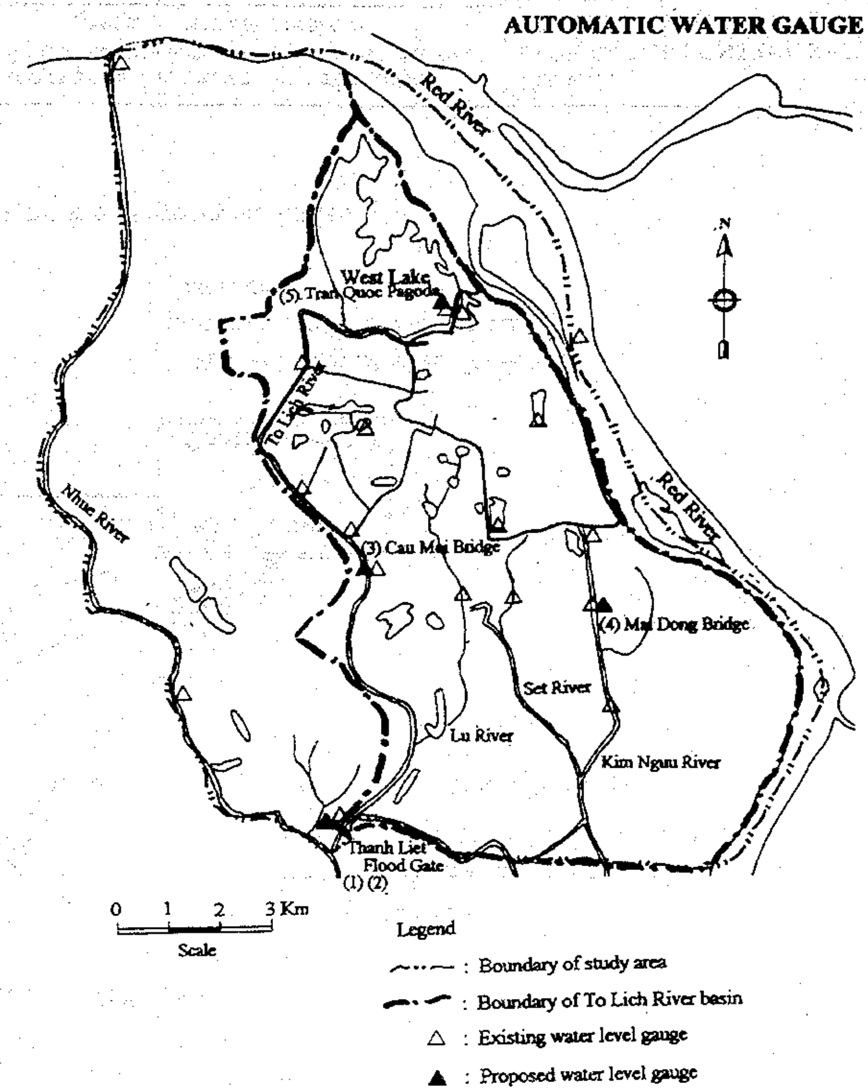


Probable Maximum Water Level
of Red River at Hanoi
(Gumbel Method, Data Period : 1902-1993)

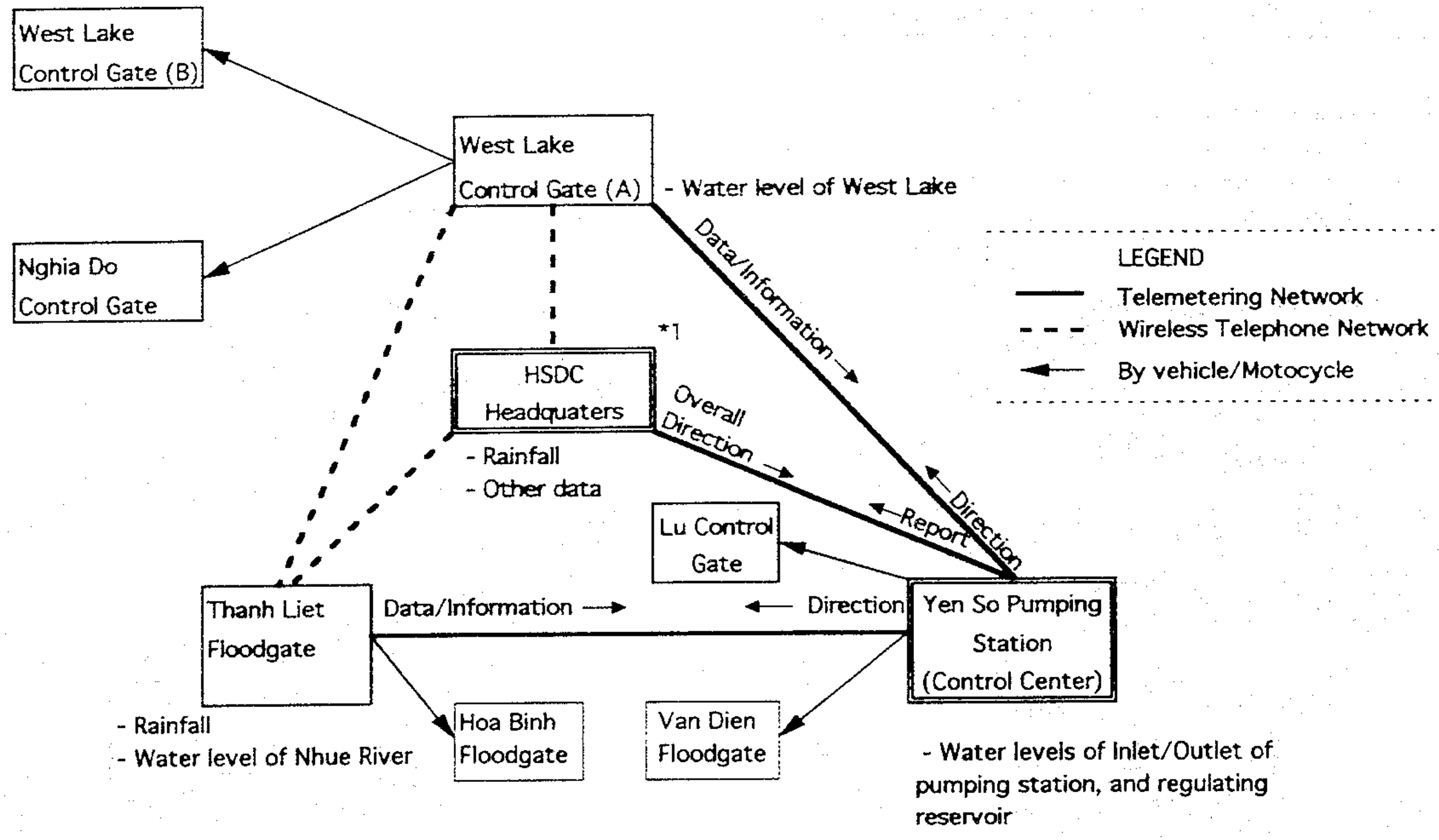


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C10.5 PROBABLE MAXIMUM WATER LEVELS





SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY	Fig. C11.1 PROPOSED INSTALLATION SITES OF HYDROLOGICAL GAUGING STATIONS
JAPAN INTERNATIONAL COOPERATION AGENCY	



*1 In charge of the overall direction to the whole system, and direction for emergency activities

SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C12.1 CONCEPT OF CONTROL SYSTEM FOR DRAINAGE OF TO LICH RIVER BASIN

THE STUDY
ON
URBAN DRAINAGE AND WASTEWATER
DISPOSAL SYSTEM
IN
HANOI CITY

APPENDIX (D)

DRAINAGE PLAN

FEBRUARY 1995

THE STUDY ON
URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM
IN
HANOI CITY

APPENDIX (D)
DRAINAGE PLAN

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D1. INTRODUCTION

This Appendix (D), Drainage Plan, compiles basic data, concepts, calculations, and detailed study results to establish the Master Plan and Feasibility Study for drainage issues in the study area (135.4 km^2) comprising a substantial part of Hanoi City. The contents of the Appendix (D) are as follows:

(1) Chapter D2 describes present conditions of the study area with respect to watersheds, channel and lake systems, sewer systems, flooding conditions, and sedimentation in the drainage channels and sewers;

(2) Chapter D3 compiles all the study results for the formulation of the Master Plan, consisting of sections titled Planning Conditions, Fundamental Planning, Alternative Studies, Proposed Master Plan, Flood Damage and Expected Benefit, and Associated Projects; and

(3) Chapter D4 deals with the Feasibility Study for a flood control and drainage project targeting the To Lich River basin selected as the priority project within the above Master Plan. This chapter comprises sections titled Preliminary Design, Implementation Schedule and Project Cost, and Organizations for Project Implementation and O/M.

D2. PRESENT CONDITIONS

2.1 Watersheds

The study area (135.4 km^2) is bordered by the Red River on the north and east, and the Nhue River on the west, and is situated at the upper eastern part of the Nhue River basin whose total catchment is approximately 1,075 km^2. (Immediately upstream of the confluence of the To Lich River, the catchment is approximately 188 km^2.) The study area is generally classified, by a series of natural levees extending along the right bank of the To Lich River, into two areas. The To Lich River basin (77.5 km^2) covering the center of Hanoi, and the basin directly discharging into the Nhue River (57.9 km^2) which still remains a suburb of the city. (See Figure D2. 1.) Both are further divided into the following river, lake, and drainage basins:

(1) To Lich River Basin (comprising 7 basins)

(a) West Lake basin, W	:	9.3 km^2	
(b) To Lich River basin, T	:	20.0 km^2	
(c) Lu River basin, L	:	10.2 km^2	
- Upper Lu	:	5.87 km^2	
- Lower Lu	:	4.33 km^2	
(d) Kim Nguu River basin, K	:	17.3 km^2	
(e) Set River basin, S	:	7.1 km^2	
(f) Hoang Liet drainage basin, H	:	8.1 km^2	
(g) Yen So drainage basin, Y	:	5.5 km^2	
Total		77.5 km^2	(Excluding West Lake basin, 68.2 km^2)

(2) Nhue River Basin (comprising 4 basins)

(a) Co Nhue drainage basin, C	:	19.7 km^2
(b) My Dinh drainage basin, D	:	13.6 km^2
(c) Me Tri drainage basin, M	:	14.7 km^2
(d) Ba Xa drainage basin, B	:	9.9 km^2
Total		57.9 km^2

2.2 Channel and Lake System

2.2.1 Rivers

There are four rivers and one floodway in the To Lich River basin listed below, while no major rivers are in the Nhue River basin (refer to Figure D2.2):

(a) To Lich River	:	14.6 km
(b) Lu River	:	5.6 km
(c) Kim Nguu River	:	11.8 km
(d) Set River	:	5.9 km
(e) Lu floodway	:	1.0 km
Total		38.9 km

These rivers play an important role in the drainage of the To Lich River basin and also are used as a water source for agriculture and fishery. The flow sections, presently, are relatively large except at some road crossing points. However, the increase of garbage dumping into rivers, and house encroachment, may not merely jeopardize the present drainage function but further decrease the water quality.

The flow capacities of river stretches were estimated using the non-uniform flow calculation as presented in Appendix (C) Hydrology, and are tabulated in Table D2.1. Since the flow capacities are largely affected by the Nhue River water stage, the water level of the To Lich River at the confluence to the Nhue River is, in this calculation, assumed to equal that of the Nhue River with the same probability as the discharge of the To Lich River. Table D2.1 is further summarized as follows:

River Stretch	Flood Probability Corresponding to Present Flow Capacity
To Lich River	3-yr to 5-yr
Lu River	1.2-yr
Kim Nguu River	1.6-yr
Set River	1.1-yr
Overall To Lich River System	1.2-yr

2.2.2 Drainage and Irrigation Channels

(1) Drainage Channels

Investigation of aerial photographs, topographic maps, and field reconnaissance have identified the drainage system in the study area, as shown in Figure D2.2 with their channel codes. The total length of the drainage channels, principally with breadths of more than 5 m, is 143.3 km as listed below:

(a) To Lich River Basin

- West Lake basin	:	—
- To Lich River basin	:	18.4 km
- Lu River basin	:	5.8 km
- Kim Nguu River basin	:	11.3 km
- Set River basin	:	5.8 km
- Hoang Liet drainage basin	:	6.6 km
- Yen So drainage basin	:	1.0 km
Total		48.9 km

(b) Nhue River Basin

- Co Nhue drainage basin	:	35.8 km
- My Dinh drainage basin	:	26.9 km
- Me Tri drainage basin	:	21.3 km
- Ba Xa drainage basin	:	10.4 km
Total		94.4 km

These drainage channels are not expected to cope with the prospected design discharges, especially at road crossing points where channel widths are excessively narrowed. To counter this, the drainage plan may entail widening of the crossings (bridges and box/pipe culverts) and digging of the channel beds. Other problems in the drainage channels are:

(a) Garbage dumping into channels;

(b) Water quality deterioration and pressure of offensive odors;

(c) Accumulation of floating weeds (e.g., water hyacinths) hindering the water flow;

(d) Deposition of sediments and sludge on the beds;

(e) Difficulty in access for channel maintenance due to the absence of channel-side roads; and

(f) House encroachment on the channels.

(2) Irrigation Channels

There are numerous irrigation channels, either trunks or branches, in the study area. In view of the nature of the study, however, only major trunk channels are delineated in Figure D2.2. Some of these have probably been converted into drainage channels due to the progress of urbanization in the subject irrigated areas.

2.2.3 Lakes and Ponds

Even limiting the area to over 1 ha, as many as 111 lakes have been identified from the aerial photographs (see Figure D2.3). The largest is a group of fishponds at Yen So (830.4 ha), which is followed by West Lake (567.0 ha). The total lake area is 21.8 km^2 representing about 16 % of the study area as follows:

River Basin	Catchment (km^2)	Lake Area (km^2)	Share of Lakes (%)
To Lich	77.5	20.1	26
- West Lake	9.3	5.9	63
- Others	68.2	14.2	21
Nhue	57.9	1.7	3
Total	135.4	21.8	16

These lakes and ponds have achieved quite important functions in terms of flood retardation in the study area, as well as wastewater treatment, fisheries, aqua-planting, rice growing, washing, recreation, and brick-making. However, the number and area of such lakes and ponds have remarkably decreased, especially in recent years, by land reclamations (whether legal or illegal) and the dumping of garbage. This also causes the water quality to worsen.

To clarify such conditions, a survey on the present usage and water quality in the 111 lakes and ponds was conducted (refer to Table D2.2). Based on the above survey, the existing lakes and ponds are classified as shown in Table D2.3. 6 lakes have been reclaimed and 19 will be reclaimed by the year 2010. 86 lakes will remain unchanged by the year 2010. The existence of these lakes and ponds will be taken into account in the formulation of the drainage plan, especially with respect to their flood retardation.

2.2.4 Relevant Structures

(1) Weirs and Gates

There are nearly ten weirs or gates in the study area, with the Thanh Liet weir at the rivermouth of the To Lich River being the most important. All of the weirs and gates were constructed for the purpose of irrigation (refer to Table D2.4).

(2) Drainage Pumping Stations

Five (5) drainage pumping stations have been provided in the study area with capacities ranging from 0.3 m^3/s to 3 m^3/s. (For the details, refer to Table D2.5).

(3) Irrigation Pumping Stations

There are a number of small-scale irrigation pumping stations in the study area as follows:

River Basin	Number
To Lich	Approx. 35
Nhue	Approx. 25
Total	Approx. 60

Major irrigation pumping stations are listed in Table D2.6 together with their locations, capacities, and dimensions.

(4) Road Crossings

The locations and dimensions of road crossings, comprising bridges and box/ pipe culverts, have been identified using aerial photographs, a geographic survey, and field reconnaissance. The results are shown in Table D2.7 which are summarized as follows:

River Basin	Channel Type	Road Crossing	
		For Vehicle	For Pedestrian
To Lich	River	33	18
	Drainage Channel	65	150
Nhue	Drainage Channel	50	101
Total	—	148	269

Most of the crossings spanning rivers are bridges with sufficient lengths approximately equal to the adjoining river widths . However, the openings of crossings in the drainage channels, whether bridges or culverts, are generally too small compared to the nearby channel sections. Certainly, this is the main cause of repeated local flooding in the study area, especially in the city area.

2.3 Sewer System

2.3.1 General Conditions

The study area is located on the flat terrain of a river delta and hydrologically characterized by five rivers: Kim Nguu, Set, Lu, To Lich, and Nhue. Wastewater is discharged into the water bodies through sewers, open channels, or ponds without any adequate treatment. The majority of existing sewers were constructed prior to 1954. The hydraulic gradient of the sewers is small, and they are prone to silting. As a result, the existing sewerage system is inadequate for flood disposal and environmental concerns.

2.3.2 Collection System

Almost all wastewater is collected with the combined system, handling both storm water and wastewater (see Figure D2.4). In a few cases, particularly in new suburban areas such as Kim Lien, a separate system is adopted although the treatment plant is presently not operational.

2.3.3 Existing Urban Sewerage System

(1) Service Coverage

The existing combined sewer system and sewered area are shown in Figures D2.4 and D2.5. The service coverage of the sewer system in the urban area is calculated by using an average figure of 0.12 m of sewer pipe per capita served, as shown in Table D2.8. As an index of service coverage, the per capita sewerage is only 0.15 m in urban areas and less than 0.1 m in rural areas.

(2) Level of Service

The per capita length of sewers is a useful, but not fully reliable, indicator for comparing the level of service. The sewered area of the study area is about 28 %. The length of sewer per area is about 100 m/ha in the old city area, and 25-40 m/ha in new urban areas. The average sewer coverage per area in the whole urban area is 38.1 m/ha. The average paved road coverage per area is 46.7 m/ha (Table D2.8). The existing level of service is low compared to developed country's standard level of more than 100 m/ha.

(3) Existing Flow Capacity of Urban Drainage Sewers

The existing capacity of the sewers is estimated as shown in Table D2.9. The runoff coefficient is to be an overall runoff coefficient calculated by runoff coefficients at each area with individual surface characteristics as shown in Table D2.10.

(4) Existing Pumping Stations

The number and capacity of the existing pumping stations for storm water are shown as a sewerage ledger in Table D2.11.

(5) Problems and Constraints under Present Conditions

The following problems and constraints are clarified under present conditions of the urban sewerage system:

(a) The existing capacity of the trunk sewers in the urban area is inadequate for even stormwater of a one (1) year return period, frequently affecting the city traffic system. This is because the paved road functions as the main drain, instead of a combined sewer, in the urban area;

(b) As the majority of sewers are built prior to 1954, detailed data, such as size and invert elevation, are not available;

(c) The hydraulic gradient of the sewers is small and are prone to silting; and

(d) As a result, the existing sewerage system is unable to function as flood disposal facility.

2.4 Flooding Condition

Through the interview survey carried out in this stage of the study, three flood maps were worked out as shown in Figures D2.6 to D2.8. These floods are:

Flood	2-day Rainfall		Nhue River Water Level *	
	Depth (mm)	Probability	Highest Stage EL (m)	Duration above EL 5.0 m (days)
Nov. 1984	560	Less than 1/100	5.4	10
Jun. 1989	287	Approx. 1/8	5.3	5
Annual	Approx. 150	Approx. 1/1.5	—	—

* At Ha Dong weir

The 1984 and 1989 floods are well-known events in the past decade, inflicting serious damage in the Hanoi area. As can be seen in Figures D2.6 and D2.7, most of the study area was under water during both events (although the 1984 flood was much severer in magnitude). The maximum inundation was about 1 m deep, lasting more than a week. Such serious damage may result from the complex of the following two types of flooding:

(1) Flooding caused by the prolonging backwater effect of the Nhue River which usually takes place in the low-lying suburban areas with ground elevations below approximately 6.0m in general; and

(2) Local flooding due to the poor capacities of the drainage channels, especially at road crossing points. This mainly occurs in the Hanoi City area above approximately EL. 6.0 m.

Shown in Table D2.12 are the estimated damages to the To Lich River basin, excluding the West Lake basin, during the 1984 and 1989 floods. The estimation was conducted on the assumption that the land use condition and production activity during the events are the same as those in the year 1994 and by the same procedure as described in Section 3.6. The total damages are estimated at about US$ 83 million and US$ 45 million for the 1984 and 1989 floods, respectively. Further, it is noted that the rate of indirect damage versus direct damage can be 0.35 according to the calculation results in Table D2.12.

Moreover, in the table, simulated inundation water levels derived from the same concepts and formula applied in the inundation analysis in Appendix (C) Hydrology are also presented. The coincidence of these two sets of water levels proves the presumptions of the inundation analysis.

2.5 Sedimentation in Drainage Channels and Sewers

A survey was conducted to clarify the sedimentation condition of the drainage channels and sewers under the management of HSDC. (For the locations, refer to Figure D2.9.) The sedimentation volumes in the respective locations are estimated as follows:

Location	Sedimentation Volume (m^3)
Drainage Channels	92,000
(a) To Lich River basin	46,000
- T - 5 drainage channel system	24,000
- T - 6 drainage channel system	3,000
- T - 8 drainage channel system	13,000
- T - 9 drainage channel system	6,000
(b) Lu River basin	18,000
(c) Kim Nguu River basin	21,000
(d) Set River basin	7,000
Sewers	24,000
Total	116,000