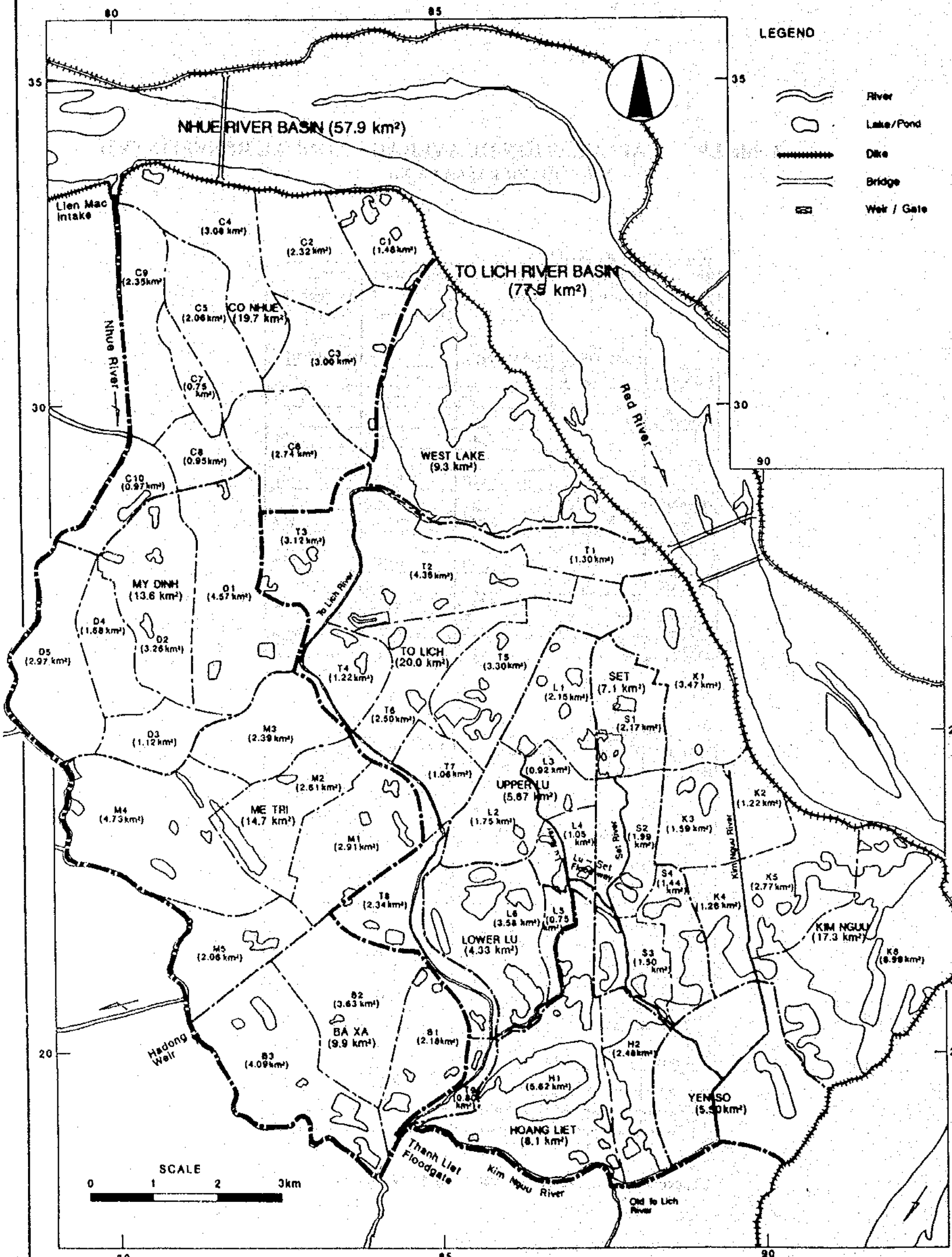

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Fig. 3.1 WATERSHEDS

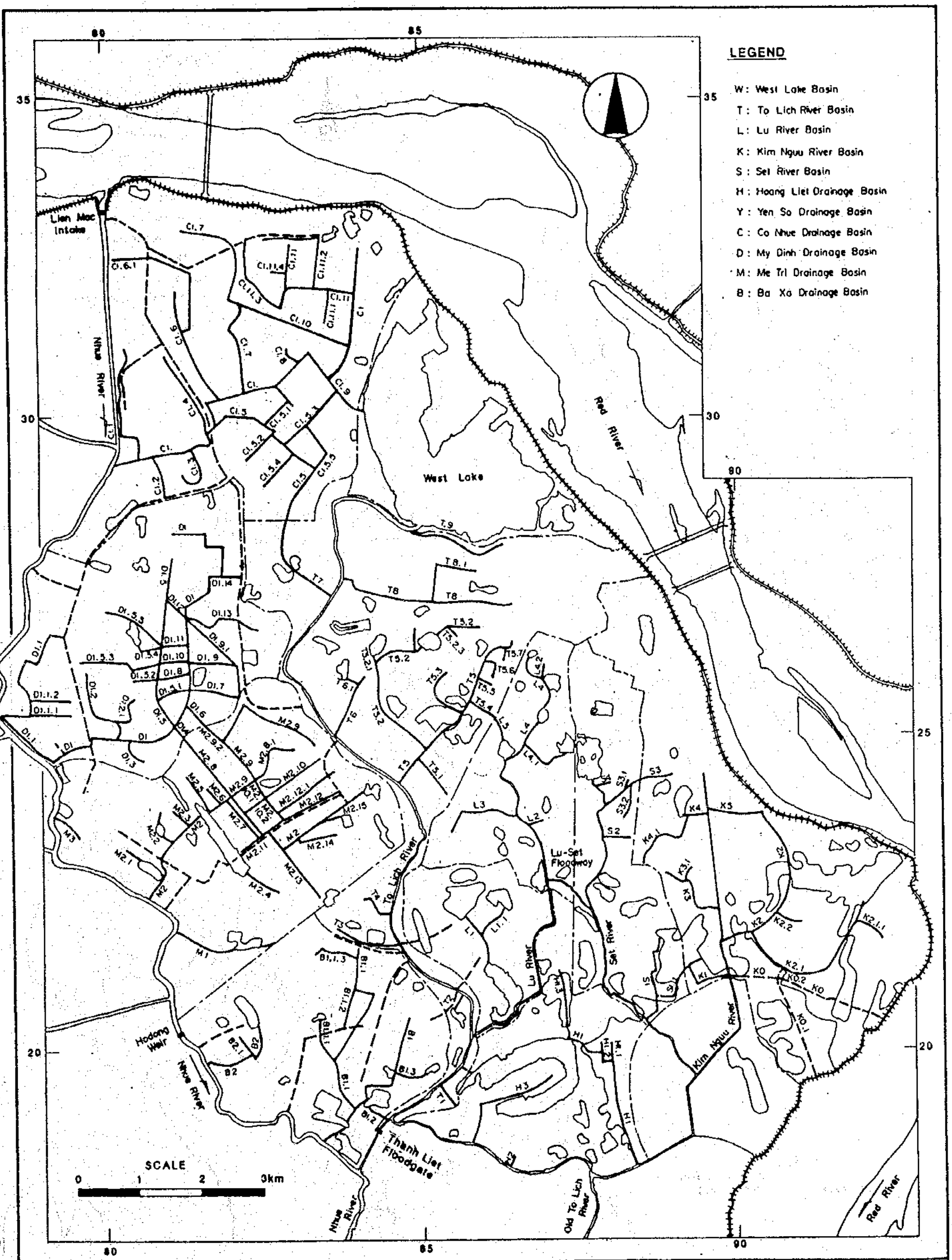

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Fig. 3.2
EXISTING RIVER, DRAINAGE AND IRRIGATION CHANNELS

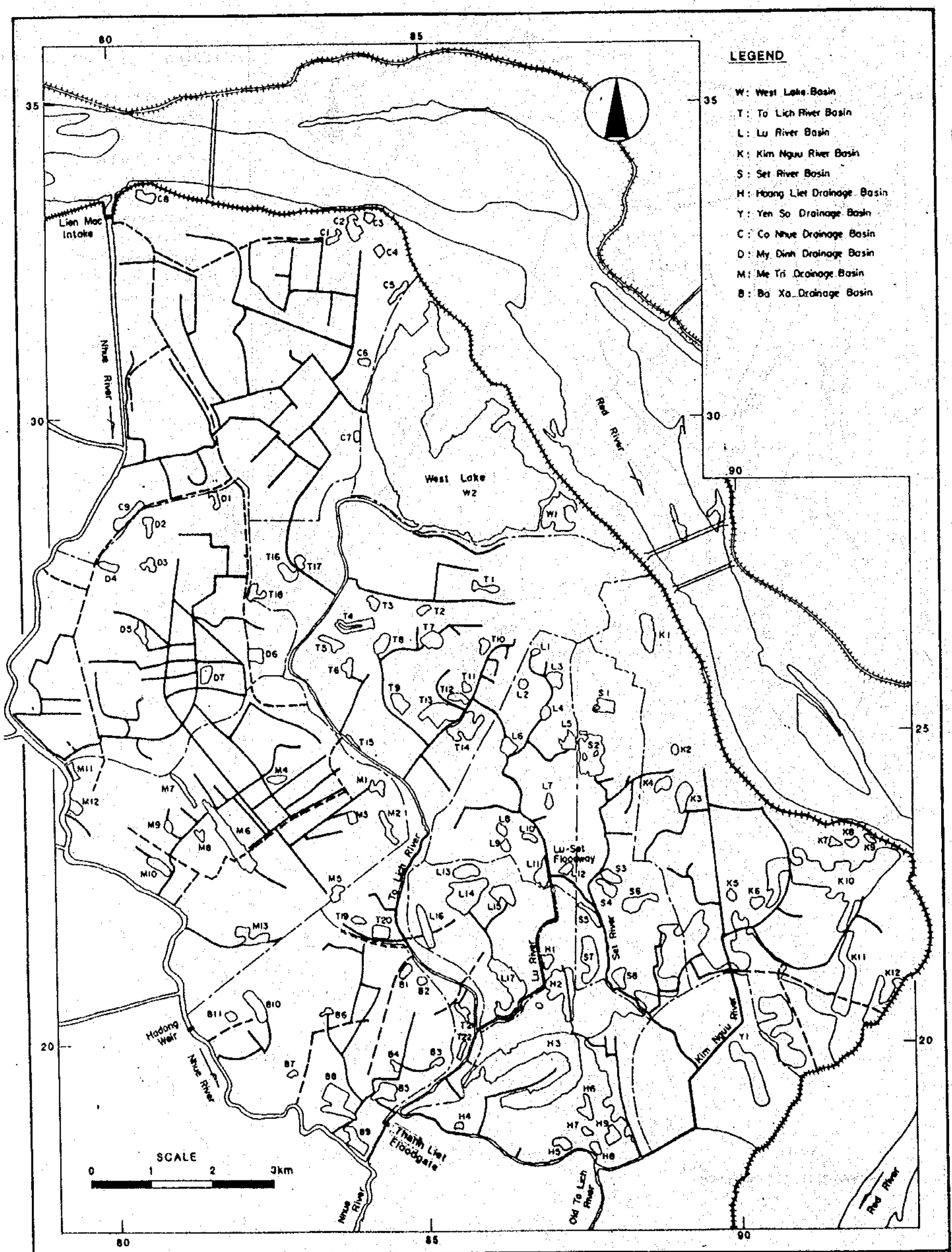

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Fig. 3.3
EXISTING LAKES AND PONDS

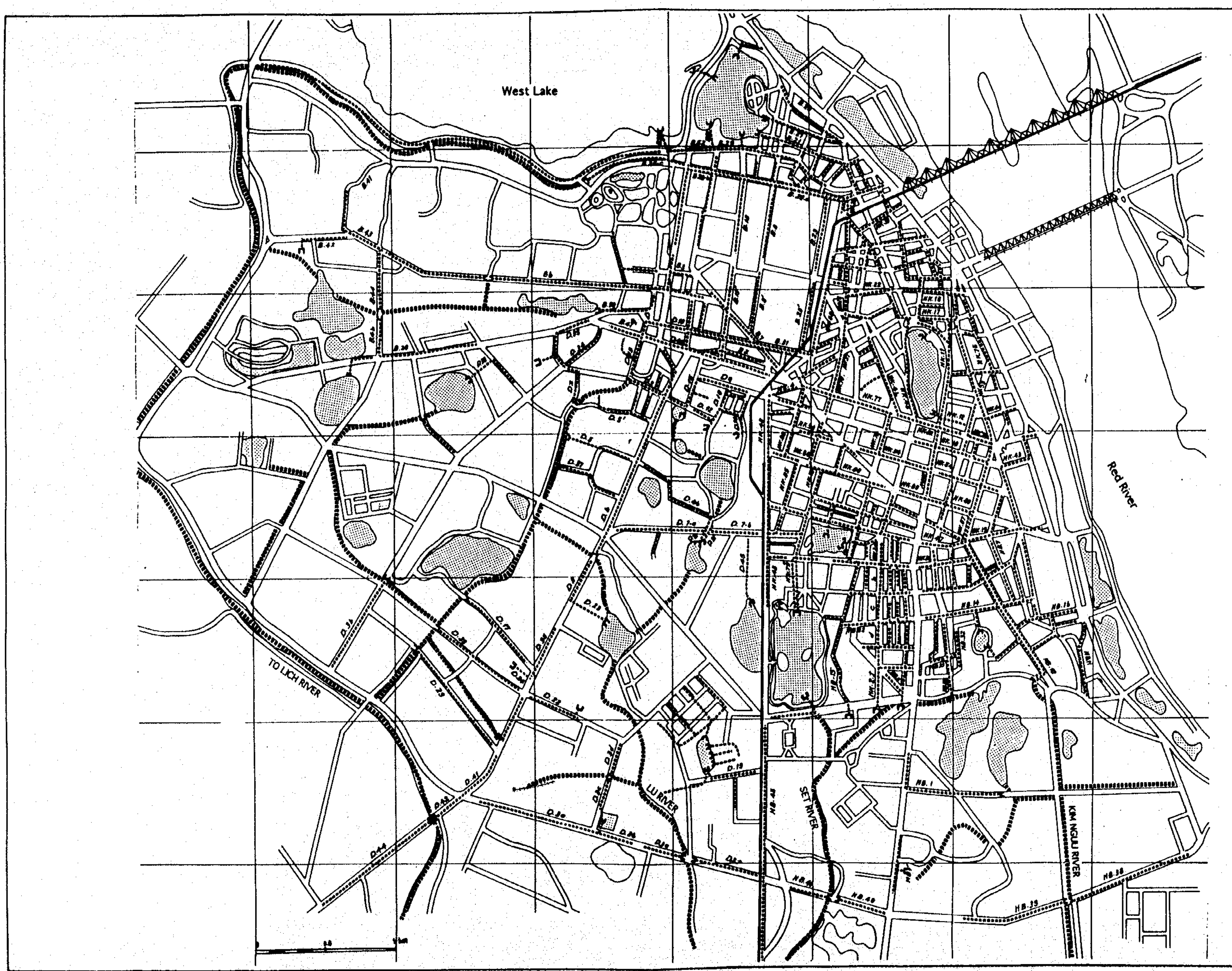

Fig. 3.4 EXISTING COMBINED SEWER SYSTEM

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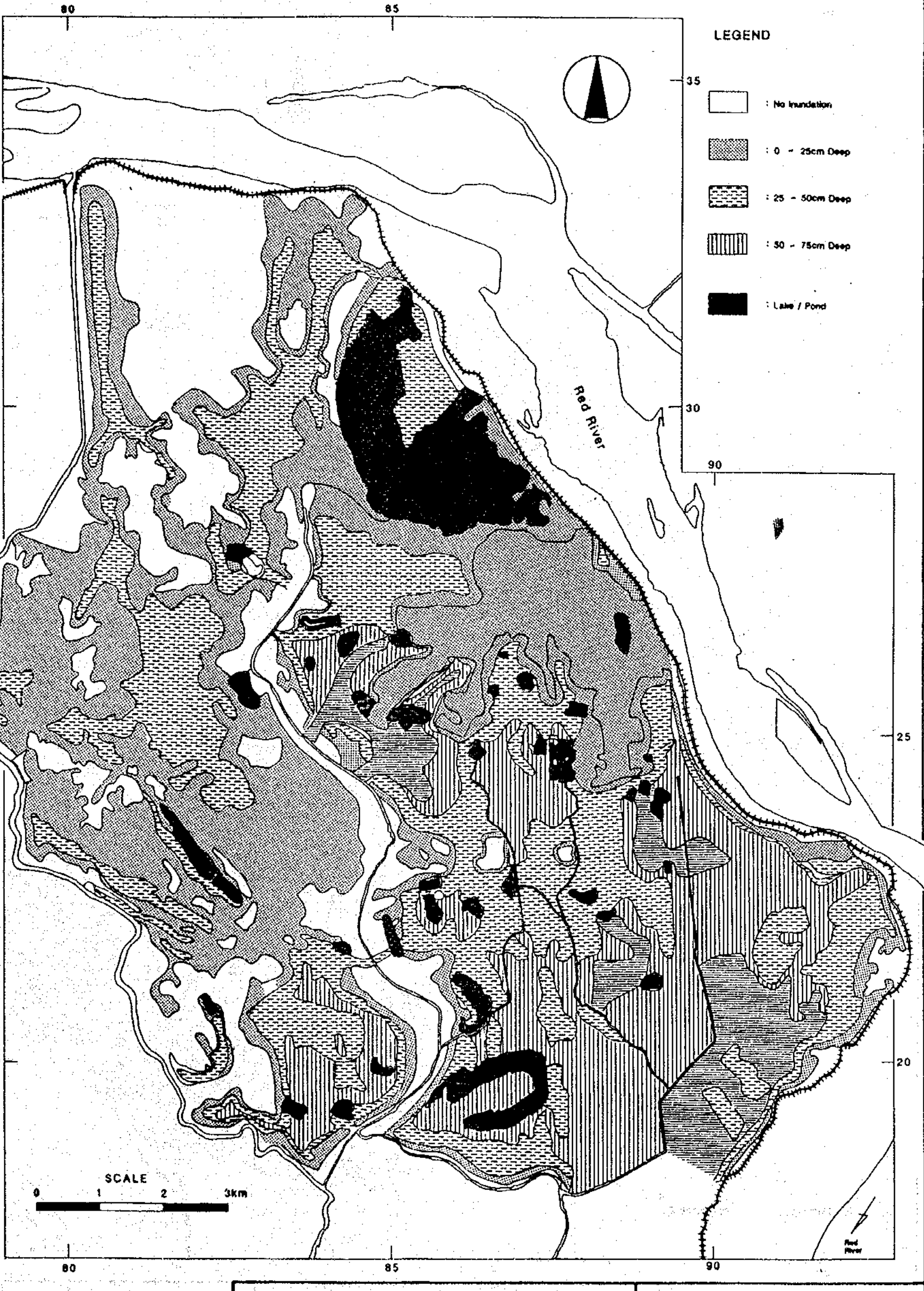

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Fig. 3.5

1984 FLOOD MAP

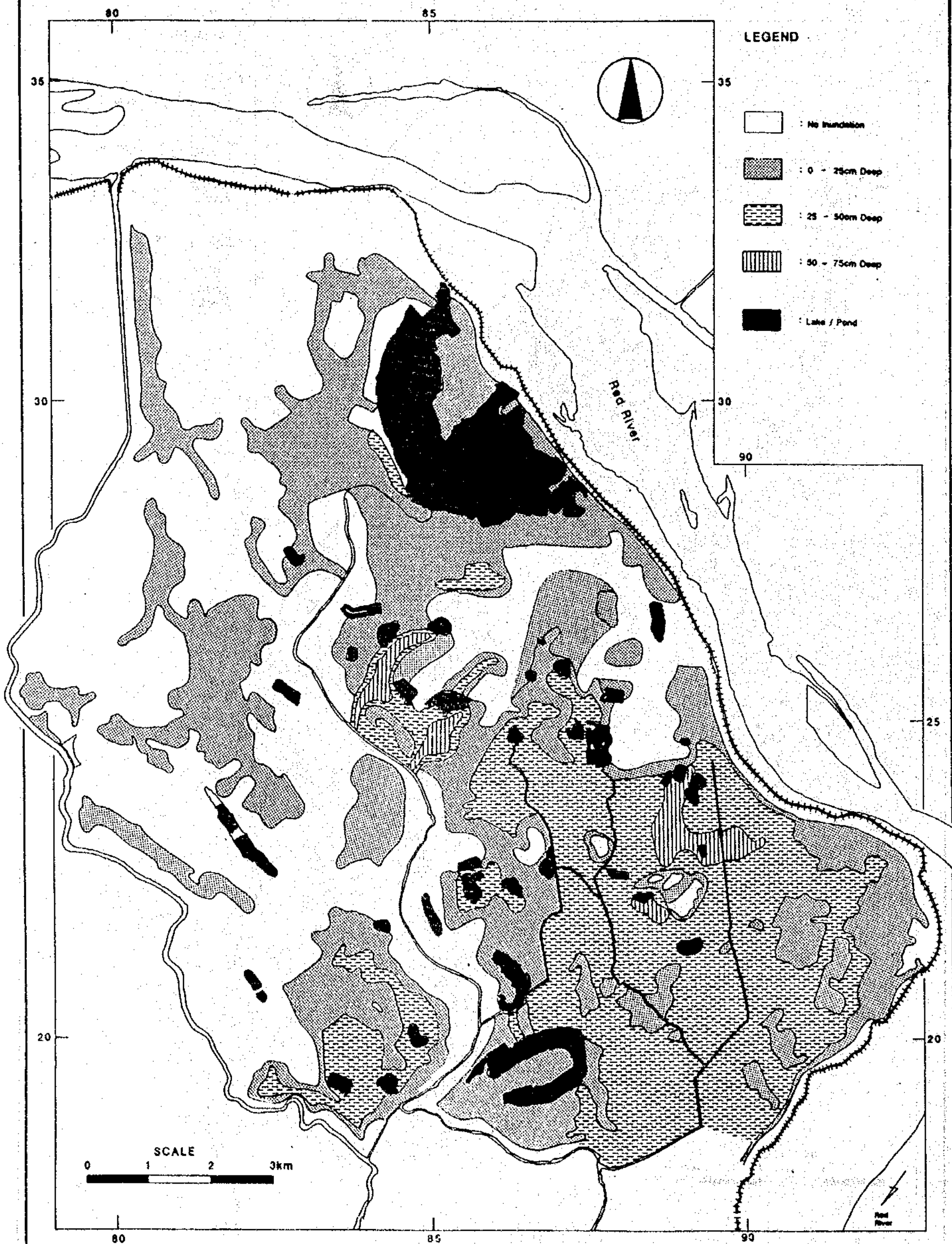

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Fig. 3.6

1989 FLOOD MAP

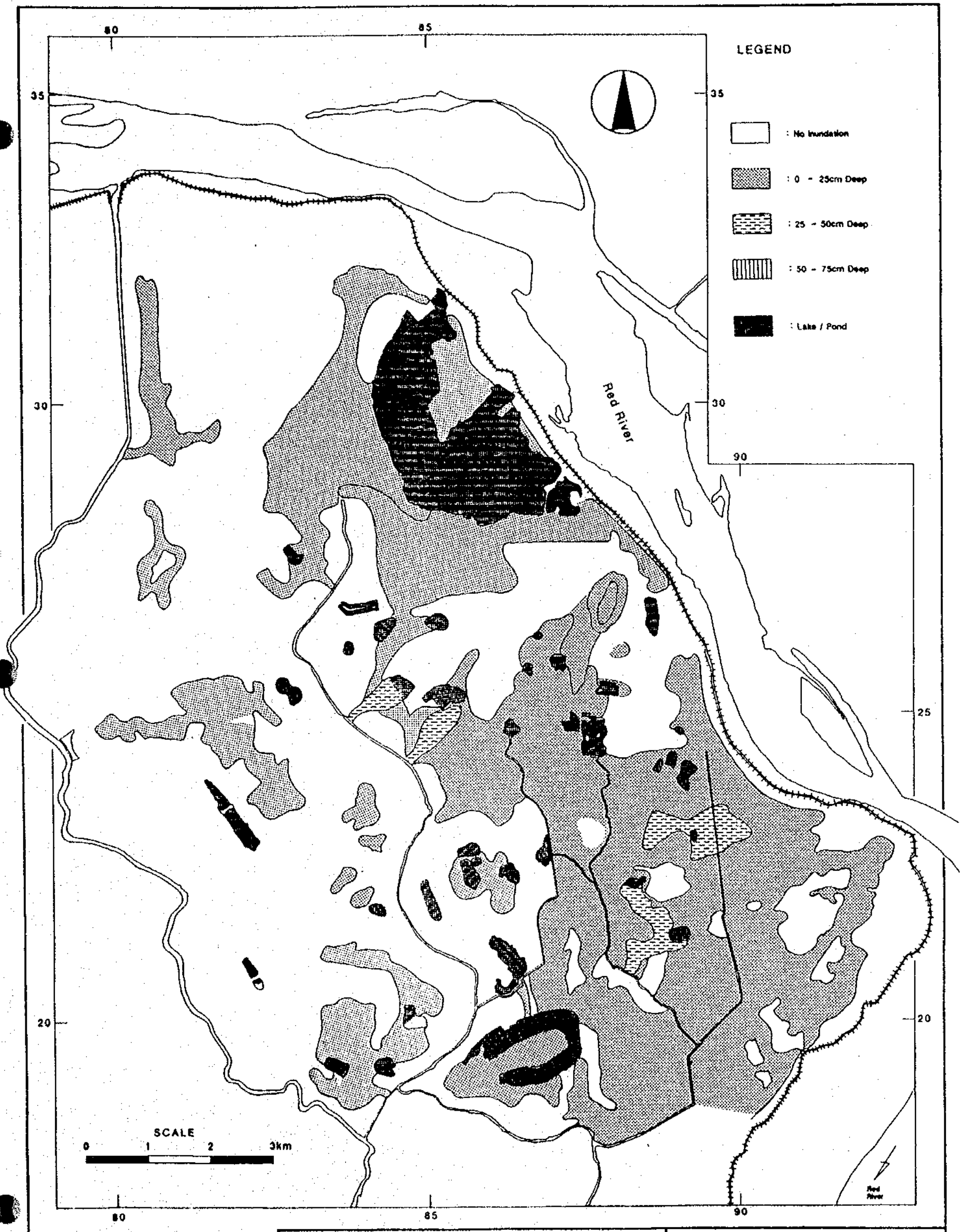

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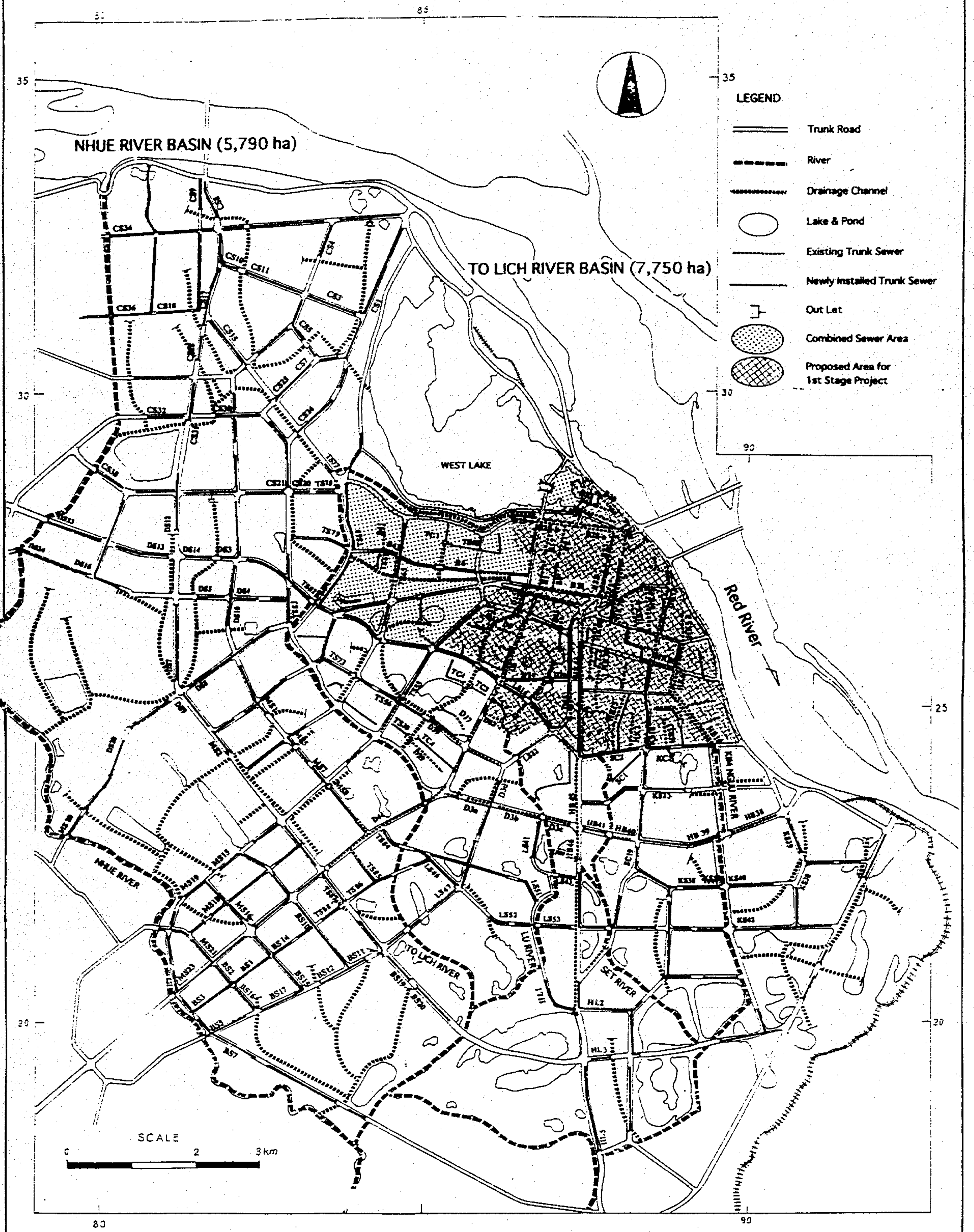
Fig. 3.7
ANNUAL FLOOD MAP



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERETION AGENCY	Fig. 3.8 LAYOUT PLAN OF THE URBAN DRAINAGE SYSTEM

Most Economical Combination within Each Alternative

Alter-native	Pump Capacity (m³/s)	Regulation Reservoir (130ha) Volume ($10^6 m^3$)	Regulation Reservoir (130ha) Bottom Elevation (m)	Cost ($ 10^6)	Remarks
1	110	3.60	0.7	121.1	Existing Condition
2	100	4.20	0.2	116.5	City Lake Dredging
3	90	4.51	0.0	118.2	Use of Linh
4	90	4.25	0.2	119.1	Dam Lake
5	90	4.38	0.1	116.8	Use of Linh Dam
6	90	3.87	0.5	112.5	& Dinh Cong

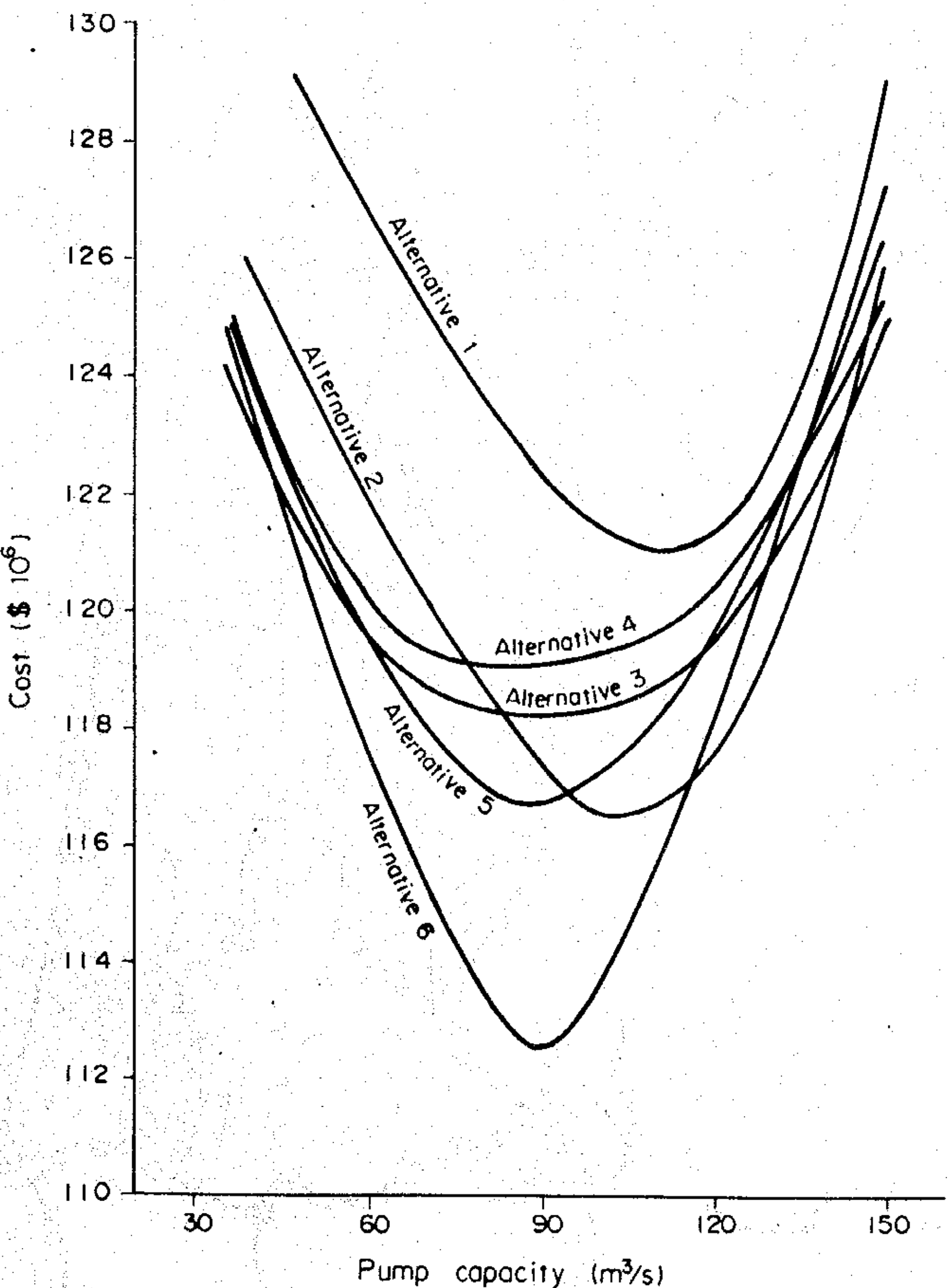


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Fig. 3.9
PUMP CAPACITY VS. COST CURVE

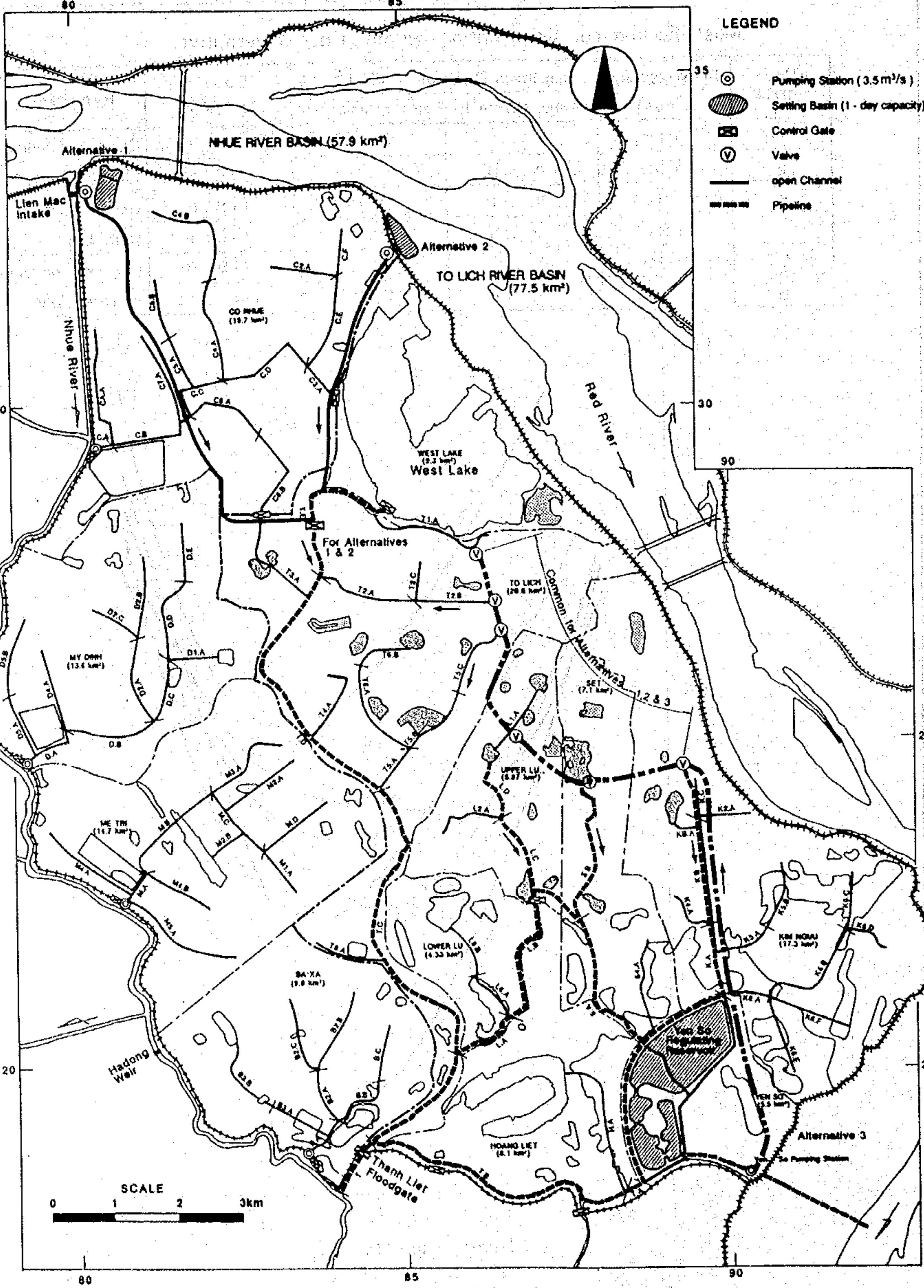

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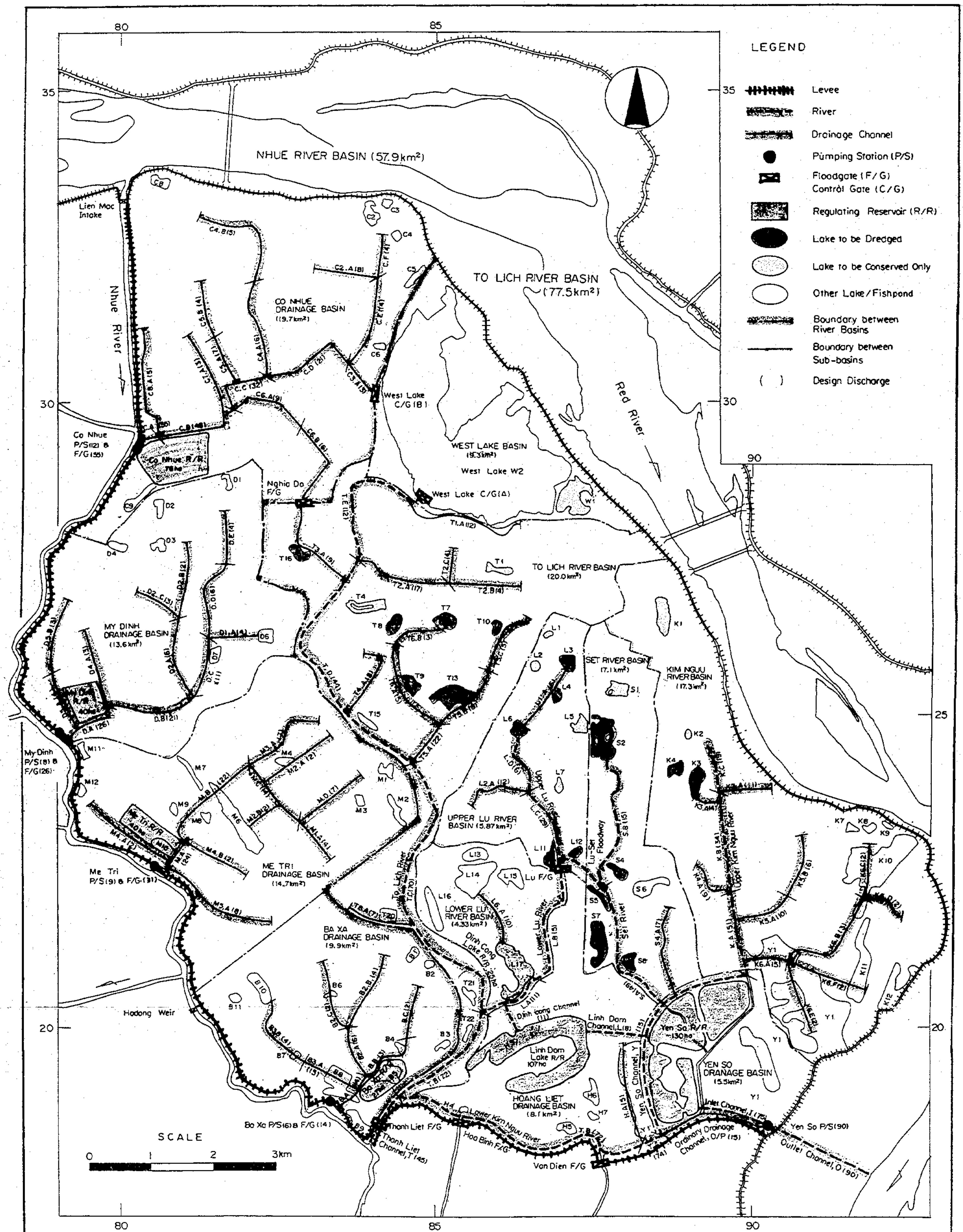
Fig. 3.10

ALTERNATIVE ROUTES FOR THE INTRODUCTION OF FLUSHING WATER



Note :
Study results in the Feasibility Study are also reflected on this plan.

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Fig. 3.11
LAYOUT OF THE DRAINAGE MASTER PLAN

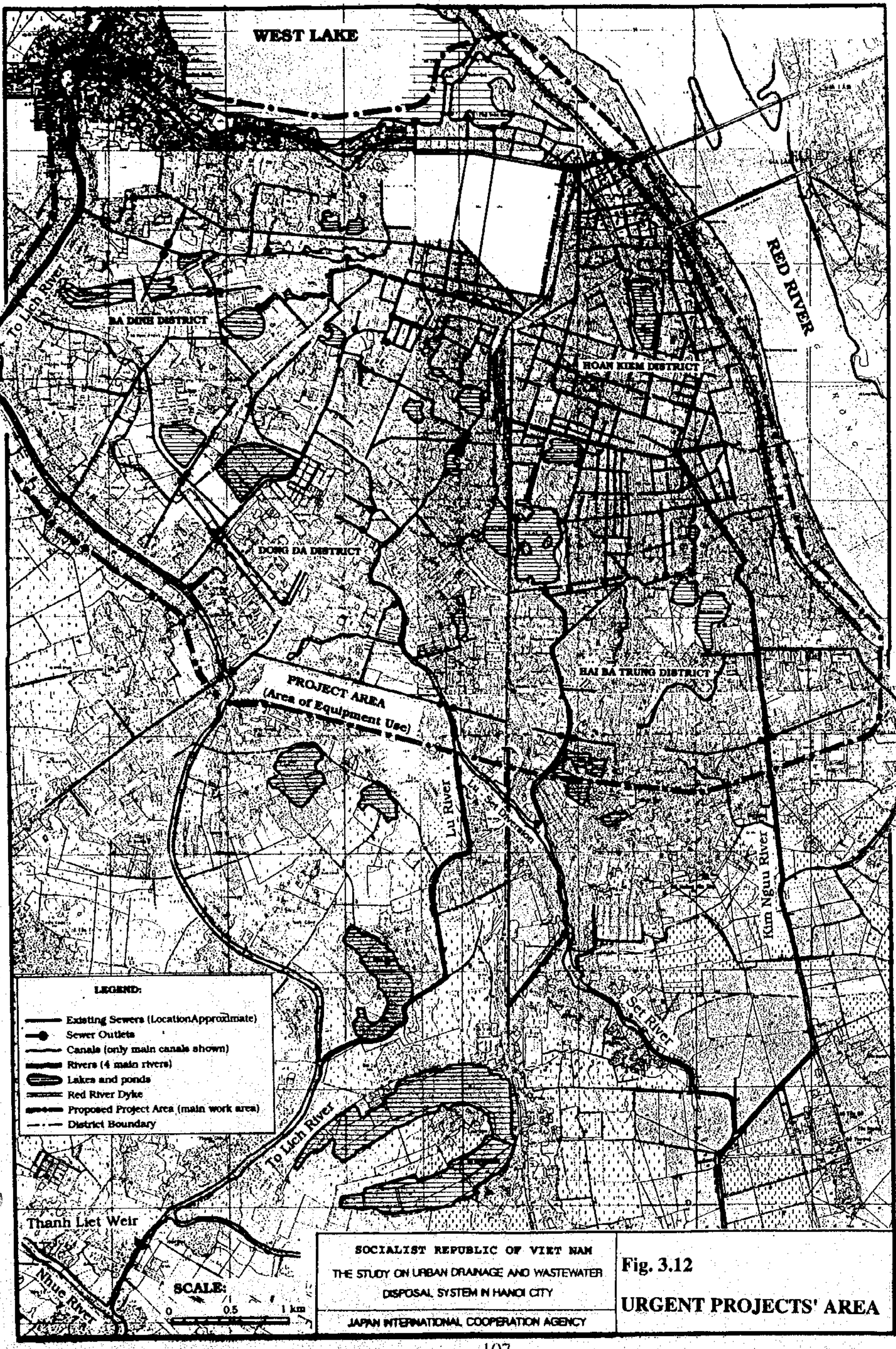

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Fig. 3.12
URGENT PROJECTS' AREA

TENTATIVE IMPLEMENTATION SCHEDULE

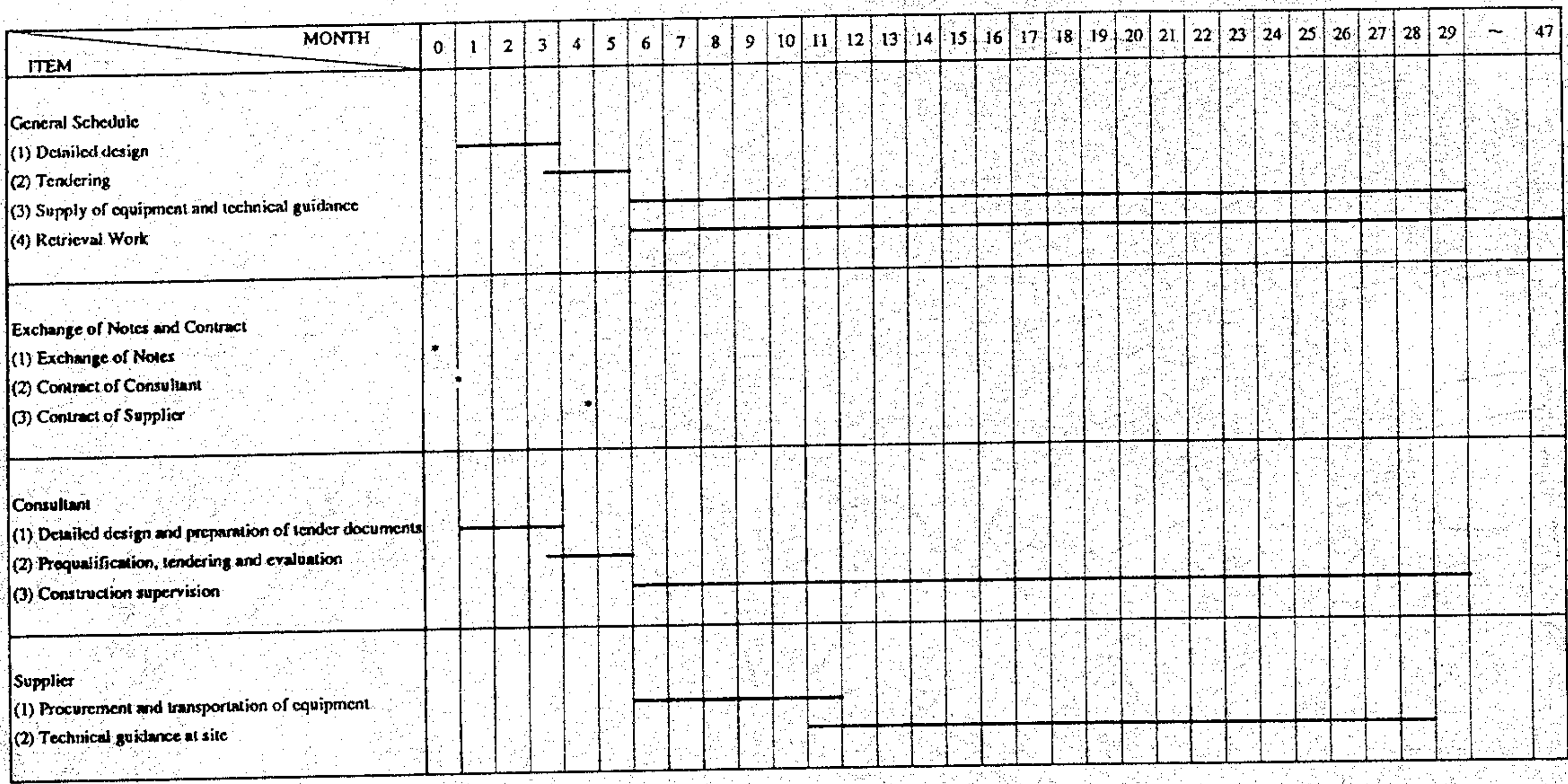

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Fig 3.13
TENTATIVE IMPLEMENTATION SCHEDULE

4. WASTEWATER DISPOSAL MASTER PLAN

4.1 Present Conditions

4.1.1 General

The study area is located on flat terrain on a river delta and hydrologically characterized by five rivers; Kim Nguu, Set, Lu, To Lich, and Nhue.

Wastewater is discharged into the water body through the sewers, open channels or ponds without adequate treatment. The majority of existing sewers were constructed prior to 1954. The hydraulic gradient of sewers is small and they are prone to silting. Generally the existing sewerage system is inadequate as a flood and wastewater disposal facility.

4.1.2 Sewerage System

(1) Collection System

Almost all wastewater is collected by a combined system, that handles both stormwater and wastewater. In a few areas, including Kim Lien, a separate system is adopted, although the treatment plant is currently non-operational.

As the majority of sewers were built before 1954, detailed data, including size and invert elevations, are not available.

(2) Level of Sewerage

The present amount of covered sewerage in the study area is about 28 % of the total area. The length of sewer per unit area is about 100 m/ha in the old city area, and 25-40 m/ha in the new urban area. The average of sewer coverage per area in the whole urban area is 38.1 m/ha, while the average of paved road coverage per area is 46.7 m/ha. (see Table 3.2 in Chapter 3).

This existing level of service is low when compared to a developed country's standard level of more than 100 m/ha.

(3) Wastewater Disposal System

There are three (3) existing wastewater treatment plants in the study area as follows.

	Kind of Wastewater	Constructed Year	Operation
Kim Lien Residential Quarters	Domestic	1965	No *1
Thuy Kue Tannery Factory	Industrial	Oct. 1992	No *2
Children Hospital	Domestic	Dec. 1981	Yes *3

*1 because of lack of adequate O/M

*2 because of lack of budget for O/M

*3 reopened from 1993 after repair of plant with cooperation of Sweden

4.1.3 Sanitation Facilities

On-site sanitation facilities are only used for the treatment of toilet waste . Other domestic wastes, including gray water and commercial wastewater, are directly discharged to drains.

A variety of toilets, ranging from flush/pour-flush toilet to vault/ double-vault latrine, bucket latrine and fishpond latrine, are used. Fishpond latrines, i.e. latrines which are suspended above bodies of water are more common in rural areas.

The population served by the various types of latrines has been estimated according to the UNDP study report as follows;

Type of latrine	Population served
Water borne	: 540,000
Double vault latrine	: 200,000
Bucket latrine	: 180,000
Public toilet(double vaults/septic)	: 80,000
Total	: 1,000,000

The level of sanitary facilities for the communities is very low. Untreated gray water is discharged into the neighboring channels, lakes/ponds or land. Pollution of the public water course is worsened in proportion to increases in the population density of the catchment area.

4.1.4 Collection System of Sewer Sludge and Solid Waste

Maintenance of sewers and channels in the urban area is carried out by SDC. The dredged sludge is disposed of in a temporary yard located near fish ponds in the Tu Liem district. Maintenance of open channels in suburban areas is carried out by local authorities.

Urban Environmental Company (URENCO) is responsible for collecting and processing urban refuse. The daily refuse volume collected by URENCO is estimated to be 2,191 m^3/day. However, This amounts to 30 % of the total volume with only 20 % of total nightsoil collected.

Due chiefly to the limited capacity of URENCO's present collection system, household refuse is dumped directly into the public water course, and sewers.

4.2 Basic Concepts for Formulation of Plans

4.2.1 Planning Conditions

(1) Target Year

The target completion year of the master plan is set at 2010 coordinating with Hanoi's integrated city plan prepared by URPI of MOC and UPI of HPC.

(2) Project Area

The area of the master plan covers the central part of Hanoi city between the Red River and the Nhue River, covering about 135 km^2. This includes an urban area of 50 km^2 and adjacent farmland of 85 km^2.

(3) Design population

Design population is estimated as follows;

		1922	2010
Urban area	:	956,271	1,112,800
Rural area	:	250,792	484,200
Total	:	1,207,063	1,597,000

(4) Unit Water Consumption

Unit water consumption rates are based on the method and criteria adopted in the Water Master Plan Study by FINNIDA.

(a) Unit Domestic Water Consumption

The per capita domestic water consumption is estimated on water use by category, for the present (1992) and future (2010), as follows;

Type of water supply	1992	2010
Public water supply area	90 l/c/d	180 l/c/d
Individual water supply area	50 l/c/d	100 l/c/d

(b) Unit Commercial Water Consumption

The unit commercial water consumption of the Study area is estimated by the daytime population, multiplied by the domestic water consumption rate (see (a) above) by multipliers set forth below (Source: Water Master Plan).

Type of commercial area	1992	2010
Small Industry :	6 l/c/d	15 l/c/d
Public Works :	37 l/c/d	40 l/c/d
Total :	43 l/c/d	55 l/c/d
Multiplier to Inhabited population :	2.1	3.3

(c) Unit Industrial Water Consumption

The estimated unit industrial water consumption is 40 m3/ha/d for 1992 and 35 m3/ha/d for 2010 (Source: Water Master Plan).

(5) Unit Wastewater Yield and Pollution Load

Based on the unit water consumption rates, unit wastewater yield is estimated on the assumption that the generation rate of domestic/commercial wastewater is 100 % of domestic and commercial water consumption and the generation rate of industrial wastewater is 80 % of industrial water consumption.

	1992	2010
Domestic wastewater (l/c/day)		
- Public water supplied area	90	180
- Individual water supplied area	50	100
Commercial wastewater		
- Small industry (l/c/day)	6	15
- Public works (l/c/day)	37	40
Industrial wastewater (m^3/ha/day)	32	28

The unit pollution load generation is estimated as follows;

	1992	2010
Domestic wastewater	40 g/c/d	60 g/c/d
Commercial wastewater (BOD)	200 mg/l	200 mg/l
Industrial wastewater (BOD)	400 mg/l	400 mg/l

The quality of industrial wastewater, shall be estimated in principle for each of the respective classifications, based on the existing data. Nevertheless, the Study has to adopt the above estimate as an average figure, since the data on the existing wastewater quality discharged from factories in Hanoi city are not available.

(6) **Total Yield**

The total yield of wastewater and pollution load is estimated as follows;

	1992	2010
Wastewater generation(1000m3/d)	173.9	378.4
Pollution load generation (ton/d)	64.2	119.7
Average wastewater quality of BOD (mg/l)	369	316

(7) Analysis of Existing and Future River Water Quality

The existing and future river water quality at respective sub-basins is analyzed in Table 4.1. The future river water quality is expressed in terms of BOD level at six representative river stations selected for each river basin. This represents the case where sanitation and sewerage remain undeveloped.

In the year 2010, the average river water quality of the To Lich River basin including the six sub-basins will worsen from 31 mg/l to a level of 54 mg/l of BOD. The worst river water pollution of 130 mg/l will occur in the Lu River sub-basin, followed by the To Lich River sub-basin at 89 mg/l, the Kim Nguu River sub-basin at 79 mg/l, and the Set River sub-basin at 54 mg/l.

The aggravation of BOD levels in river water occurs in proportion to the population density. Therefore, sanitation and sewerage development for the urban area of Hanoi city is a definite requirement.

(8) Wastewater Treatment Level

The quality of treated wastewater shall conform to the effluent standards of Vietnam, and will also, consider the environmental quality standards for rivers in Vietnam.

To improve public water courses and sanitary conditions of communities, the required wastewater treatment level is determined, according to its population density, as follows,

(a) Low population density area
- Population density : Not exceeding 50 person/ha
- Required removal efficiency : 75 %
- Target treated water quality : BOD level of 90 mg/l for domestic wastewater
  BOD level of 50 mg/l for industrial wastewater

(b) Medium population density area
- Population density : 50-350 person/ha
- Required removal efficiency : 80 %
- Target treated water quality : BOD level of 60 mg/l for domestic wastewater
  BOD level of 50 mg/l for industrial wastewater

(c) High population density area
- population density : More than 350 person/ha
- Required removal efficiency : 85 %
- Target treated water quality : BOD level of 50 mg/l for domestic wastewater
  BOD level of 50 mg/l for industrial wastewater

The above target treated water level of BOD is proposed disregarding the natural purification of rivers. 50 mg/l for industrial wastewater is achieved when an individual disposal system is used and 400 mg/l is achieved when a centralized disposal system is used.

In principle, high population density areas will be accorded the highest priority, as these areas pose the highest risk to endangerment of sanitary environments.

(9) Classification of Wastewater Disposal System

For treatment of wastewater, the following three (3) systems are considered appropriate:

(a) On-site disposal system : to treat wastewater individually at each house/ building/factory

This system include the following methods:
- Simple on-site treatment method : to treat toilet wastewater only
- High level on-site treatment method : to treat both toilet wastewater and gray water

(b) Community disposal system : to treat wastewater at each community zone, including housing/industrial estates and business centers

(c) Centralized disposal system : to treat wastewater using a public sewerage system

The formulation of the entire system will be a combination of the above, to be implemented by each areas requirements. Where appropriate, larger systems will be proposed instead of several smaller systems.

4.2.2 Zoning and Treatment Method

(1) Conceptual Zoning Plan

Sewerage development zones shall be delineated based on the following technical factors, especially considering the quantities of sewage and pollution load and geographic conditions.

- Zoning according to drainage basins
- Zoning according to land use (present and future)
- Zoning according to population density (present and future)
- Zoning according to wastewater and pollution load generation
- Zoning according to the configuration of wastewater disposal systems
- Zoning according to the sewage collection system, particularly the existing sewer systems

- Zoning according to the existing sewerage master plan prepared by UPI of HPC

The tentatively proposed conceptual zoning plan, based on the above, is shown in Figure 4.1. The plan envisages dividing the whole area into seven (7) zones. Characteristics of each proposed zone are summarized in Table 4.2.

(2) Wastewater Treatment Method

The relative merits of practical treatment methods were evaluated by comparing several typical treatment methods, taking into account overload flexibility, the level of technology required for operation and maintenance (O&M) work, adaptability for excess sludge disposal and land acquisition. This is shown in Table 4.3.

The process of typical wastewater treatment methods is shown in Figure 4.2.

The results of the comparison between the Oxidation Ditch (OD) method, conventional Activated Sludge (AS) method and the Stabilization Pond (SP) are summarized below:

Item	OD Method	AS Method	SP Method
Required Area of Facilities (ha) *1	18	9	200 *4
Required motors capacity (kw) *2	2,300	5,400	—
Sludge Production (m3/day) *3	7,400	11,700	— *5
Relative Construction Cost (OD:100%)			
- Machinery and Equipment	100%	150%	
- Civil Works	100%	60%	
- Total	100%	130%	30%
O&M Cost (OD:100%)	100%	120%	50%
	Recommended	—	—

*1 Required areas are only calculated for the main facilities of the five centralized wastewater plants.

*2 Required motors capacities are only calculated for the main facilities of the five centralized wastewater plants.

*3 Sludge production is calculated for the seven zones.

*4 Required areas are calculated only for Zones 2,3,4.

*5 There is no theoretic yield of excess sludge.

The Oxidation Ditch method (highest rating in Table 4.3) will be recommended. This method has been adopted in many developing countries and was evaluated as the most moderate all-round wastewater treatment method. The cost of sewerage disposal, therefore, is based on the cost of the Oxidation Ditch method, for this present study. The Schematic layout of the Oxidation Ditch method is shown in Figure 4.3.

The treatment plant capacity has been designed to reduce the BOD level of the wastewater from 316 mg/l to a level of 50 mg/l. This corresponds to the environmental standard in Vietnam.

(3) Sludge Dewatering Method

Using the Oxidation Ditch process, total excess sludge yield from the whole study area is estimated at 780m^3/d after sludge digestion tank treatment. Alternative studies on sludge dewatering facilities are examined as follows, in order to reduce the sludge weight and finally dispose of it at a dumping site.

Factors	Dry beds	Mechanical Dehydrator	Incinerator *1
Volume of Dried Sludge m^3/d	160	100-120 *2	20-30*3
Required Area of Facilities (ha)	7	2	4
Construction Cost (US$ million)	2	30	80
O&M Cost (US$ million/year)	0.06	0.90	2.40

Remarks *1: Dewatering facilities (dry beds/dehydrator) are necessary before incinerating.
*2: Volume of dried sludge is affected by the addition of a coagulant aid.
*3: Dependent on the water content of the dewatered sludge.

The Dry Bed method is recommended and dry beds are located adjacent to the wastewater treatment plant of zones 2 and 5.

4.3 Comparison of Alternative Plans

4.3.1 Alternative Studies on the Wastewater Disposal System

(1) Basic Parameters for Examination

The sewerage development plan in each zone is evaluated by the following alternative disposal systems.

- Combination of on-site and community disposal systems
- Small scale centralized disposal system
- Medium scale centralized disposal system
- Large scale centralized disposal system

Basic parameters for examining the above are as follows.

(a) Planned Wastewater Flow (Q) for Each Disposal System

- On-site/Community : Q < 1,000 m^3/d (Average flow = 100 m^3/d)
- Small scale centralized : Q < 18,000 m^3/d (Average flow = 10,000 m^3/d)
- Medium scale centralized : Q <100,000 m^3/d (Average flow = 50,000 m^3/d)
- Large scale centralized : Q >100,000 m^3/d (Average flow = 120,000 m^3/d)

(b) Sewer

Sewage collection system is assumed to be the separate system as far as newly developed. The length of the sewer is estimated as 100 m per unit sewered area (ha). The length of the conveyance sewer with a diameter of more than 1,000 mm is assumed as follows;

- On-site/Community	No sewer
- Small scale centralized	3 % of total sewer length
- Medium scale centralized	10 % of total sewer length
- Large scale centralized	25 % of total sewer length

(c) Construction Cost

Construction cost at the 1994 price level is estimated by the following,

- Unit cost of sewer : US$ 70/m for average diameter of 500 mm
- Unit cost of conveyance : US$ 200/m for average diameter of 1000 mm
- Unit cost of land acquisition : US$ 6,500/ha for farmland
- The cost of the plant for an on-site/community system is based on the price of the Japanese septic tank (Jokaso), which treats both nightsoil and gray water.
- The cost of a centralized disposal plant is estimated by the following formula in Japan:

$C_m = 66.2 \cdot Q^{0.872} \cdot k / 105$

$C_c = 165.7 \cdot Q^{0.590} \cdot k / 105$

where,

C_m : Construction cost for machinery & equipment (US$ million)
C_c : Construction cost for civil works (US$ million)
Q : Planned wastewater flow (1,000 m^3/day)

k : Multiplier considering reduced labor and material costs in Vietnam (0.6)

- The cost of the pumping station is based on the price of the following manhole type relay pumping station:

$$C = 8.5 \cdot Q^{0.598} / 105$$

where,
C : Construction cost (US$ million)
Q : Planned wastewater flow (m^3/min)

- Operation and Maintenance (O&M) cost for a centralized disposal plant is estimated as 3 % of the construction cost and 0.3 % for the sewer and pumping station.

(2) Preliminary Comparison Results

A preliminary comparison at 1994 prices of the particulars, construction and O & M costs of alternative systems is shown in Table 4.4.

The initial construction cost is lowest for medium scale centralized disposal systems and highest for on-site/community disposal systems. Annual O&M costs are the most expensive for on-site/community disposal systems, followed by small scale centralized disposal systems and finally, large scale centralized disposal systems.

4.3.2 Studies on an Optimum System According to Each Zone

(1) Alternatives Examined

The following alternatives were studied by zone in order to compare their relative merit.

	On-site /Community Disposal System	Centralized System Small-scale	Medium-scale	Large-scale
- Zone 1	◎	○	○	-
- Zone 2	-	○	○	◎
- Zone 3	-	○	◎	-
- Zone 4	-	○	◎	-
- Zone 5	-	○	◎	-
- Zone 6	-	○	◎	-
- Zone 7	◎	○	-	-

Note: ◎ : Examined and proposed to adopt
○ : Examined as alternative, - : Not applicable

In this comparative study, it is assumed that all houses, buildings and factories in the objective zones will be connected to the public sewerage system, except those connected to the on-site system. Construction costs of new sewers are not included in the existing combined sewered area, but are estimated separately under the stormwater drainage plan.

(2) Conclusion of Alternative Studies

A preliminary estimate of the costs of alternative systems at each zone is shown in Table 4.5. The right-hand column indicates the lowest cost option for each zone.

4.3.3 Study for Lake Water Quality Improvement

Pollutant load inflow of COD into the main lakes is tentatively based on the results of a water quality survey conducted during this study. It is assumed the pollutant load yield of COD is 50 % of the yield of BOD.

Lake	Pollutant Load of COD (kg/day)	
	1992	2010
West Lake & Truc Bac	9,600	14,540
Hoan Kiem	600	870
Hai Ba Trung	1,750	2,600
Tuyen Quang	1,790	2,690
Bay Mau	3,600	5,400
Trung Tu	2,670	4,380
Giang Vo	600	730
Thanh Cong	1,250	1,460

The available data does not sufficiently specify an indication of eutrophication in the lakes. However, untreated lake water quality will worsen in proportion to the increment of wastewater yield. Recently, wastewater inflow exceeds the self-purification capacity of most of the lakes. It is therefore necessary to undertake counter measures to prevent further pollution.

4.4 Proposed Master Plan

The proposed wastewater disposal plan shall be well coordinated various other public facilities and services and shall meet the environmental and socio-economic requirements, in particular those related to the Study area. The overall development plan of the wastewater disposal system is shown in Figure 4.4.

4.4.1 Structural Measures

(1) Wastewater Collection System

Based on the finding in subsection 4.3.2, the type of wastewater collection system for each zone is proposed as follows;

- Individual collection system : Zone 1 and 7

  Wastewater after treatment from polluters is discharged into bodies of water, via street drains or open channels.

- Separate system : Zone 5 and 6

The separate system collects sewage, from new sewers excluding stormwaters.

- Partially separate system : Zone 2, 3 and 4

The partially separate system consists of the existing combined sewered area and the separate sewered area with a newly constructed diversion chamber and interceptor.

Structural measures at each Zone are summarized as follows.

(a) Zone 1

Collection sewer will not be newly constructed, as each household and/or community should have their own on-site treatment facilities (eg. septic tank).

(b) Zone 2

	Separate System	Partially Separate System
Service Area (ha)	1,200	800
Served Population (2010)	229,600	153,100
Sewer (m)		
- Secondary & Tertiary	244,800	-
- Trunk	86,000	-
- Conveyance	61,200	-
Interceptor & Diversion Chamber (unit)	-	4
Relay Pumping Station (unit)	3	2
Lake Water Quality Improvement Works (LS)		
Flushing Water Facilities (LS)	1	-

(c) Zone 3

	Separate System	Partially Separate System
Service Area (ha)	160	11,900
Served Population (2010)	39,500	2936,900
Sewer (m)		
- Secondary & Tertiary	177,600	-
- Trunk	60,100	-
- Conveyance	37,700	-
Interceptor & Diversion Chamber (unit)	-	7
Relay Pumping Station (unit)	4	3

(d) Zone 4

	Separate System	Partially Separate System
Service Area (ha)	110	390
Served Population (2010)	46,200	163,900
Sewer (m)		
- Secondary & Tertiary	65,000	-
- Trunk	13,700	-
- Conveyance	8,700	-
Interceptor & Diversion Chamber (unit)	-	8
Relay Pumping Station (unit)	0	3

(e) Zone 5

	Separate System	Partially Separate System
Service Area (ha)	2,800	-
Served Population (2010)	240,900	-
Sewer (m)		
- Secondary & Tertiary	294,700	-
- Trunk	136,800	-
- Conveyance	73,700	-
Relay Pumping Station (unit)	2	-

(f) Zone 6

	Separate System	Partially Separate System
Service Area (ha)	3,160	-
Served Population (2010)	291,800	-
Sewer (m)		
- Secondary & Tertiary	343,400	-
- Trunk	159,400	-
- Conveyance	85,800	-
Relay Pumping Station (unit)	1	2

(g) Zone 7

Same as for Zone 1, sewer for collection of wastewater will not be newly constructed.

(2) Wastewater Treatment Plant and Sludge Dewatering Facilities

The oxidation ditch process is adopted as the wastewater treatment method in the Study area except the on-site/community disposal system zones (Zone 1 and Zone 7).

The design of layout plans of the treatment plant for each Zone are shown in Figure 4.5 to Figure 4.9 and the Kim Lien pilot plant is shown in Figure 4.10.

The sludge quantity yield from the whole Study area is estimated at 7,400 m^3/d. The sludge will be thickened and dewatered in order to reduce its weight, and finally disposed at a dumping site. The dry bed method is proposed for sludge dewatering. Sludge dewatering facilities are recommended to be located adjacent to the treatment plants of Zone 2 and Zone 5, considering land availability. Required features are estimated below.

	Dry Bed (1)	Dry Bed (2)
(a) Excess sludge (m^3/d)	479	298
	(Zone 2, 3, 4 & 7)	(Zone 1, 5 & 6)
(b) Location	Tran Phu Xa	Metri Xa
	(Zone 7)	(Zone 5)
(c) Number of beds (unit)	15	15
(d) Size per unit	50m x 55m x 1m (depth)	40m x 50m x 1m (depth)
(e) Required area (ha)	5	4
(f) Dried sludge (m^3/d)	89	66

Construction costs of the dewatering facilities are shared by each zone according to their excess sludge yield.

Total excess sludge is calculated at 780 m^3/d and dried sludge totaling 160 m^3/d is predicted. Designed sludge production (dried sludge) corresponds roughly to 2 % of the total sludge yield, after dewatering at the dry beds. The total number of dry beds is estimated at 30 (see Table 4.6). Construction of dry beds will be carried out step by step according to the proposed implementation schedule of the sewerage development plan. The cost thereof will be shared by each zone.

Proposed facilities of the wastewater treatment plant are summarized in Table 4.6. About 72% of the objective area will be covered by five centralized wastewater treatment systems of various sizes. This master plan proposes to apply the "oxidation ditch process" for water treatment and the "dry bed process" for sludge treatment. These are considered to be the most practical methods, but should be subject to further refinement according to each zone, in the subsequent feasibility study and detailed design stages. The location of treatment plants will also be a subject to further review according to the actual social condition.

According to the future land use conditions the number of on-site/community treatment facilities for Zone 1 and 7 is estimated as follows;

	Zone 1-1	Zone 1-2	Zone 7
Industrial area	14 plants	1 plant	10 plants
Commercial area	*	–	9 plants
Residential area	32 plants	1 plant	9,000 septic tanks

Note : Plant = Community plant installed for each community and/or estate (residential, industrial)

Septic Tank = Household septic tank for treatment of both toilet water and gray water

* Included in Industrial Area, - No facility

Development of residential/industrial estates will have obligation to install adequate wastewater treatment facilities in each area. For the installation of community plants for existing villages and septic tanks for households, it is proposed to establish a Revolving Fund System which would provide low-interest loans to communities and people so that they could build their own facilities. Nevertheless, there may arise the necessity of installing facilities under public projects, and also other types of needs, according to the actual progress of urbanization in that area. These should be examined in further studies.

(3) Lake Water Quality Improvement Works

The primary requirement for improving lake water quality is to reduce the inflow of pollution loads transported by wastewater. As well, the following are contemplated as subsidiary measures;

- Temporal shut-off of dry season wastewater inflow by providing a diversion basin

- Aeration facilities, including aerator, fountain and diffused aeration devices

- Provision of a settling basin if possible, with screens used to shut-off inflow of floating particles

- Dredging of sludges/sediment

(4) Cost Estimates

The proposed project cost and annual O&M cost for the sewerage development are summarized in Table 4.7.

The total project cost for the development of a centralized wastewater disposal system and an on-site/community wastewater disposal system is estimated at US$ 638 million and the total annual O&M cost is estimated US$ 8.0 million, as shown below.

(Unit: US$ million)

Description	Project cost	O&M cost	Replacement Cost
Centralized disposal system	567.096	6.203	131.239
On-site/community disposal system	70.830	1.834	25.826
Total	637.926	8.037	157.065

(5) Priority of Development among Zones

The priority of zones in developing the wastewater disposal system in the Study area is determined in Table 4.8. Zone 2-1 has first priority, followed by Zone 4 and Zone 3.

(6) Overall Implementation Schedule

The overall implementation schedule is tentatively shown in Figure 4.11. The required period to complete the sewerage development plan for each zone is as follows;

- Zone 1-1 : 19 years
- Zone 1-2 : 10 years
- Zone 2-1 : 9 years
- Zone 2-2 : 7 years
- Zone 3 : 13 years
- Zone 4 : 12 years
- Zone 5 : 8 years
- Zone 6-1 : 10 years
- Zone 6-2 : 8 years
- Zone 7 : 16 years

The above period includes time for feasibility studies, detailed design, construction work and commissioning tests for the wastewater disposal systems.

The disbursement schedule of the wastewater disposal system in the Study area is shown in Figure 4.12.

4.4.2 Non-Structural Measures

The following non-structural measures are proposed to be undertaken as activities associated with sewerage development.

(1) Government Support for Installation of Flush toilets

The following government support is necessary as local latrines; eg., pit latrine or bucket latrine, shall be upgraded to flush toilets w/septic tanks in accordance with the sewerage development.

(a) Financial back-up to people through provision of a soft loan with a revolving fund system for flush toilet installation.

(b) Sponsorship to educate the public regarding the necessity of flush toilets

(c) The enforcement of installing flush toilet installation, establishing legal regulations in newly developed areas.

These measures are particularly required in Zone 1 and 7 where on-site/ community treatment systems are proposed.

(2) "Care for Drainage/Sewerage" Campaign

Dumping of domestic solid waste is one of the main reasons of pollution in the rivers and lakes. "Care for drainage/sewerage" campaign shall be sponsored and carried out by the government. The campaign is to educate the people of the need of drainage/sewerage facilities and water disposal practices, in accordance with the regulations.

(3) Regulations for Installation of Effluent Pre-treatment

Regulations on the installation of wastewater pre-treatment by industries shall be enforced to reduce the pollutant load in the public wastewater disposal system.

(4) The improvement of Solid Waste and Nightsoil Collection System

The present refuse collection covers only 30 % of the total solid waste yield and 20 % of the total nightsoil in the Study area, as described in subsection 4.1.4. According to the URENCO's survey in 1991, total volume of existing solid waste is estimated at 2,948 m^3/d and so the generation rate per person is 0.0027 $m^3/ca./d$. Improvement of solid waste and nightsoil collection will require the reinforcement of the following equipment:

Items of Equipment	Existing Equipment	Required Equipment (unit)
-Tank lorries (6 to 8 m^3)	96	160
-Tippers with rear loading device (7 m^3)	60	100
-Street watering tankers (4 to 8 m^3)	23	25
-Vacuum tankers (3 to 4 m^3)	15	100
-Bulldozers and Excavators (75 HP)	7	10
-Vehicles for monitoring	4	10

Cost required for the procurement of the above equipment is tentatively estimated at US$ 15 million.

As well as the reinforcement of collection and transporting equipment, the system improvement will also include the reinforcement of facilities for processing the collected refuse (incl. composting plant) and also institutional reinforcement.

Table 4.1 REQUIRED REMOVAL EFFICIENCY & PREDICTED RIVER WATER QUALITY

Name of Input River Sub-Basin	Pollutant Load Runoff of BOD (ton/day)		Pollution Load of BOD Without Treatment (mg/l)		Pollution Load of BOD With Treatment (mg/l)					
					Removal Efficiency: 85 %		Removal Efficiency: 80 %		Removal Efficiency: 75 %	
	1992	2010	1992	2010	1992	2010	1992	2010	1992	2010
To Lich (up)	13.86	25.18	50	91	8	14	10	18	13	23
To Lich/Lu	26.43	51.08	46	89	7	13	9	18	12	22
To Lich(down)	39.95	69.07	31	54	5	8	6	11	8	13
Lu*	2.37	7.50	62	130	9	19	12	26	16	32
Kime Nguu	9.73	14.79	52	79	8	12	10	16	13	20
Set*	11.40	15.00	41	54	6	8	8	11	10	13
Old To Lich*	23.18	32.89	38	54	6	8	8	11	10	13
Average River Water Quality of BOD in To Lich River Basin (mg/l)			31	54	5	8	6	11	8	13

*: In flow BOD at river is presumed.

Table 4.2 CHARACTERISTICS OF ZONES

Item	ZONE 1		ZONE 2		ZONE 3	ZONE 4	ZONE 5	ZONE 6		ZONE7	Total/Average
	ZONE 1-1	ZONE 1-2	ZONE 2-1	ZONE 2-2				ZONE 6-1	ZONE 6-2		
Area (ha)	930	1,060	990	1,010	1,350	500	2,800	870	2,290	1,740	13,540
Future Population	40,300	46,500	303,800	129,200	299,400	190,300	243,900	114,200	180,100	49,100	1,596,800
Future Population Dencity (person /ha)	43.3 (111.0)	43.9	306.9	127.9	221.8	380.6	87.1	131.3	78.6	28.2	117.9
Future Wastewater Yield (m3/d)	8,260	7,910	73,370	36,000	70,360	44,720	56,450	29,830	43,220	8,290	378,410
- Domestic	6,539	5,585	54,660	23,026	53,892	34,254	42,063	20,480	31,151	6,330	277,980
- Commercial	1,722	642	16,689	6,951	16,467	10,467	12,147	6,230	9,035	977	81,327
- Industrial	0	1,680	2,016	6,020	0	0	2,240	3,121	3,035	984	19,096
Future Pollutant Load (kg/d)	2,765	3,591	22,455	11,507	21,257	13,511	17,962	9,378	13,827	3,463	119,716
Specific Yield (m3/d/ha)	8.88 (22.75)	7.46	74.11	35.64	52.12	89.44	20.16	34.29	18.87	4.76	27.95
Specific Load (kg/d/ha)	2.97 (7.62)	3.39	22.68	11.39	15.75	27.02	6.42	10.78	6.04	1.99	8.84
Raw wastewater Quality (BOD & SS :mg/l)	335 301	454 409	306 275	320 288	302 272	302 272	318 286	314 283	320 288	418 376	316 285
Name of Receiving Water	West Lake	Nhue	Kim Nguu	Kim Nguu	To Lich	Lu	Nhue	To Lich	Nhue	To Lich	
Proposed Removal Efficiency of BOD & SS(%)	80 80		85 80	85 80	85 80	85 80	75 80	75 80	75 80	75 80	
Treated Wastewater Quality (BOD:mg/l)			50	50	50	50	80	80	80		
- Domestic	60	50								90	
-Commercial/Industrial	50	50								50	
Proposed Wastewater Disposal System	On-site/ Community	Community	Large Scale Centralized		Mediun Scale Centralized	Mediun Scale Centralized	Mediun Scale Centralized	Mediun Scale Centralized		None-Treatment	
Alternative Wastewater Disposal System	Small Scale Centralized		Mediun Scale Centralized		Large Scale Centralized					On-site/ Community	

Table 4.3 COMPARISON OF TYPICAL WASTEWATER TREATMENT METHODS

Item		AS	EA	MA	OD	SP	AL	TF	RB
Flexibility	Shock Load	1	2	1	2	3	3	3	2
	Over Load	1	2	1	2	3	3	3	2
	Toxic/Hazardous	2	2	1	2	2	2	2	2
Workability	Workability of O&M	1	2	1	3	3	3	3	2
	Reliability of O&M System	3	3	3	3	3	3	2	1
	Complication	2	2	1	3	3	3	3	2
	Necessity of High Technology	2	2	2	2	3	3	3	1
Characteristics	Excess Sludge	1	3	1	3	3	3	2	1
	Stability of temperature	2	2	2	3	1	1	2	2
	Nitrification	2	3	1	3	2	3	3	3
	Actual Results	3	3	1	3	3	3	1	1
	Side effect against the circumference	2	2	2	2	1	1	1	2
Required Land	(OD : 100%)	3 (50)	2 (75)	3 (45)	2 (100)	1 (730)	1 (270)	2 (70)	3 (55)
Removal Efficiency		3	3	1	2	1	1	1	3
	(BOD) (%)	90	90	70	85	70	70	70	90
	(SS) (%)	85	85	70	80	70	70	70	85
Required Cost	Construction	1	1	2	2	3	3	3	1
	O & M	1	1	2	2	3	3	3	2
Evaluation		30	35	25	39	38	39	37	30

Remarks; 3 : Excellent 2 : Moderate 1 : Inferior

AS : Conventional Activated Sludge Process
EA : Extended Aeration Process
MA : Modified Aeration Process
OD : Oxidation Ditch Process
SP : Stabilization Pond Process
AL : Aerated Lagoon Process
TF : High Rate Trickling Filter Process
RB : Rotating Biological Contactor Process

Table 4.4 EXAMINATION OF ALTERNATIVE DISPOSAL SYSTEMS

Alternative Disposal System	Particulars	Construction Cost (US$/m3)						Annual O&M Cost (US$/m3)
		Treatment Plant				Sewerage	Total	
		Civil works	Machinery	Land Cost	Sub-total			
On-site/Community	- Q < 1000 m3 (Average:100 m3/d) - Septic tank with high level - Sewer for wastewater is not necessary - Pollutant Pay Principle - Excess sludge shall be frequently collected	600	1,500	1 0.02 ha	2,101		2,101	137
Small scale disposal	- Q < 30000 m3 (Average = 10000 m3) - Number of plants is 38 - served area at each plant is about 360 ha with conveyance sewer of 1100 m - Minimum number of Relay pumping station : 0 - Excess sludge shall be properly collected	368	470	1 2.0 ha	839	274 274	1,113	Plant: 25 Sewerage: 1 Total: 26
Medium scale disposal	- Q < 100000 m3 (Average = 50000 m3/d) - number of plants is 7 - served area at each plant is about 1500 ha with conveyance sewer of 8000 m - Minimum number of Relay pumping station : 1 - Storage yard/disposal facilities for excess sludge will be established at each plant	190	382	1 10 ha	574	332 318 14	905	Plant: 17 Sewerage: 1 Total: 18
Large scale disposal	- Q > 100000 m3 (Average = 120000 m3/d) - Number of plants is 3 - served area at each plant is about 3500 ha with conveyance sewer of 100000 m - Minimum number of Relay pumping station : 3 - Storage yard/disposal facilities for excess sludge will be established at each plant - Some counter measures are necessary in order to supply water into lakes or rivers during dry season	133	342	1 24 ha	476	451 423 28	927	Plant: 14 Sewerage: 1 Total: 16

Table 4.5 PRELIMINARY DIRECT CONSTRUCTION COST ESTIMATION

(Unit : US$)

	On-site/community Disposal System	Small Scale Centralized Disposal System	Medium Scale Centralized Disposal System	Large Scale Centralized Disposal System	Proposed system
ZONE 1-1					Community
Plant	13,800,000	10,555,737			(Medium Scale)
Sewerage	47,500	6,233,137			Disposal*
Total	13,847,500	16,788,874			13,847,500
ZONE 1-2					Community
Plant	8,444,425	7,265,243			(Large Scale)
Sewerage	8,593,518	17,003,077			Disposal*
Total	17,037,943	24,268,320			17,037,943
ZONE 2					Large Scale
Plant		87,281,768	61,391,196	52,917,322	Disposal
Sewerage		23,022,696	33,185,114	35,775,974	
Total		110,304,464	94,576,310	88,693,296	88,693,296
ZONE 3					Medium Scale
Plant		60,903,547	37,382,551		Disposal
Sewerage		16,257,613	23,685,512		
Total		77,161,160	61,068,063		61,068,063
ZONE 4					Medium Scale
Plant		40,338,709	29,111,564		Disposal
Sewerage		3,768,580	6,807,539		
Total		44,107,289	35,919,103		35,919,103
ZONE 5					Medium Scale
Plant		48,034,052	31,465,717		Disposal
Sewerage		35,903,660	45,930,643		
Total		83,937,712	77,396,360		77,396,360
ZONE 6					Medium Scale
Plant		60,555,847	38,499,159		Disposal
Sewerage		38,298,787	53,638,403		
Total		98,854,634	92,137,562		92,137,562
ZONE 7					On-site/
Plant	13,252,984	7,284,874			Community
Sewerage	0	30,497,177			Disposal*
Total	13,252,984	37,782,051			13,252,984
Grand Total					355,214,384

Remarks:
1) Cost of community disposal plant is estimated by wastewater flow of 100 m3/day at each plant.
2) Grand total does not included direct construction cost of On-site/Community deisposal system.

Table 4.6 SUMMARY OF THE PROPOSED FACILITIES OF THE WASTEWATER TREATMENT PLAN (OXIDATION DITCH PROCESS)

Item	ZONE 1	ZONE 2	ZONE 3	ZONE 4	Pilot Plant	ZONE 5	ZONE 6	ZONE7	TOTAL
1.Grit Chamber									
1.1 Number (Unit)		2	2	2	2	2	2		
1.2 Size (m)									
Depth		1.0	1.0	1.0	1.0	1.0	1.0		
Width		3.8	3.0	1.7	0.2	2.2	2.8		
Length		14.4	14.4	14.4	14.4	14.4	14.4		
2.Oxidation Ditch		97,553	78,294	43,776	5,600	56,468	71,859		
2.1 Number (Unit)		10	12	10	4	10	12		
2.2 Size (m)									
Depth		3	3	2.5	2	2.7	3		
Width		12	8	7	6	8	8		
Length		270	270	250	120	250	250		
3.Settling Tank									
3.1 Number (Unit)		5	4	5	2	5	4		
3.2 Size (m)									
Depth		2.6	2.6	2.4	2.6	2.4	2.4		
Diameter		32.0	32.0	22.0	12.0	25.0	32.0		
4. Designed Sludge (m3/d)	639	1,873	1,460	816	104	962	1,239	308	7,401
5. Chlorination Tank									
5.1 Number (Unit)		2	2	2	2	2	2		
5.2 Size (m)									
Depth		4.0	4.0	4.0	2.0	4.0	4.0		
Width		10.0	10.0	5.0	3.0	5.0	7.0		
Length		12.0	10.0	10.0	5.0	12.0	12.0		
6.Thickener									
6.1 Number (Unit)		5	4	5	2	5	4		
6.2 Size (m)									
Depth		5.0	4.0	4.0	4.0	4.0	5.0		
Diameter		40.0	43.0	30.0	16.0	35.0	37.0		
7.Thickened Sludge (m3/d)	223	656	511	286	37	337	434	108	2,590
8.Sukdge Digestion Tank									
8.1 Number (Unit)		4	4	2	2	4	2		
8.2 Size (m)									
Depth		6.0	5.0	5.0	4.0	5.0	10.0		
Diameter		40	38	40	16	38	30		
9. Excess Sludge (m3/d)	67	197	153	86	11	101	130	32	777
10.Area of Facilities (m2)		48,248	40,031	25,300	3,882	32,456	33,576		
11.Dry Bed (15 days)									
11.1 Number (Unit)		15				15			
11.2 Size (m)									
11.3 Required Area (m2)		40,000				30,000			70,000
11.4 Size (m)									
Depth		0.15				0.15			
Width		50.0				40.0			
Length		55.0				50.0			
12.Dryed Sludge (m3/d)		89				66			155
13.Proposed Land (m2)		140,000	80,000	50,000	10,000	100,000	70,000		450,000

Table 4.7 PROPOSED PROJECT COST AND ANNUAL O&M COST

(Project Cost)

(Unit: US$)

Sewerage Zone / Cost Item	ZONE 1-1	ZONE 1-2	ZONE 2-1	ZONE 2-2	ZONE 3	ZONE 4	ZONE 5	ZONE 6-1	ZONE 6-2	ZONE 7	Toatl
A.Direct Cost	15,608,000	17,038,000	57,198,000	35,375,000	62,904,000	38,275,000	77,397,000	30,705,000	61,433,000	13,253,000	295,340,000
1.Treatment Plant	13,800,000	8,444,000	35,499,000	17,418,000	37,383,000	23,663,000	31,466,000	15,721,000	22,778,000	13,253,000	170,785,000
2.Sewer		8,226,000	17,436,000	17,789,000	23,464,000	6,605,000	45,563,000	14,616,000	38,471,000		107,684,000
3.Diversion Chamber	48,000		48,000		38,000	19,000					153,000
4.Relay Pumping Station		368,000	336,000	168,000	184,000	184,000	368,000	368,000	184,000		1,440,000
5.Pilot treatment plant (Kim Lien)						5,448,000					5,448,000
6.Lake water Quality Improvemen Works (Weast lake is not inclueded)	1,760,000		3,879,000		1,835,000	2,356,000					9,830,000
B.Land Acquisition Cost	2,982,000	361,000	2,505,000	1,253,000	15,200,000	11,419,000	2,755,000	718,000	1,040,000	415,000	35,994,000
C.Engineering Services Cost (15 % of A)	2,341,000	2,556,000	8,580,000	5,306,000	9,436,000	5,741,000	11,610,000	4,606,000	9,215,000	1,988,000	44,302,000
D.Administration Cost (5 % of A+B)	930,000	870,000	2,985,000	1,831,000	3,905,000	2,485,000	4,008,000	1,571,000	3,124,000	683,000	16,567,000
E.Physical Contingency (20 % of A to D)	4,372,000	4,165,000	14,254,000	8,753,000	18,289,000	11,584,000	19,154,000	7,520,000	14,962,000	3,268,000	78,441,000
Sub-Total	26,233,000	24,990,000	85,522,000	52,518,000	109,734,000	69,504,000	114,924,000	45,120,000	89,774,000	19,607,000	637,926,000

(Annual O&M Cost)

Sewerage Zone / Cost Item (US$/year)	ZONE 1-1	ZONE 1-2	ZONE 2-1	ZONE 2-2	ZONE 3	ZONE 4	ZONE 5	ZONE 6-1	ZONE 6-2	ZONE 7	Toatl
A.Treatment Plant	414,000	253,000	1,065,000	523,000	1,121,000	873,000	944,000	472,000	683,000	1,136,000	7,484,000
B.Collection Sewer System	5,000	26,000	65,000	54,000	77,000	27,000	138,000	45,000	116,000		553,000
Toatl	419,000	279,000	1,130,000	577,000	1,198,000	900,000	1,082,000	517,000	799,000	1,136,000	8,037,000

(Replacement cost)

25years after Construction	ZONE 1-1	ZONE 1-2	ZONE 2-1	ZONE 2-2	ZONE 3	ZONE 4	ZONE 5	ZONE 6-1	ZONE 6-2	ZONE 7	Toatl
(US$)	9,200,000	4,550,000	25,699,000	12,613,000	25,736,000	18,441,000	21,606,000	11,227,000	15,917,000	12,076,384	157,065,384

Table 4.8 PRIORITY OF SEWERAGE DEVELOPMENT ZONES

Item	ZONE 1		ZONE 2		ZONE 3	ZONE 4	ZONE 5	ZONE 6		ZONE7	Total/Average
	ZONE 1-1	ZONE 1-2	ZONE 2-1	ZONE 2-2				ZONE 6-1	ZONE 6-2		
Area (ha)	930	1,060	990	1,010	1,350	500	2,800	870	2,290	1,740	13,540
Served Population	40,300	46,500	303,800	129,200	299,400	190,300	243,900	114,200	180,100	49,100	1,596,800
Served Population Dencity (person /ha)	43.3 (111.0)	43.9	306.9	127.9	221.8	380.6	87.1	131.3	78.6	28.2	117.9
Future Wastewater Yield (m3/d)	8,260	7,910	73,370	36,000	70,360	44,720	56,450	29,830	43,220	8,290	378,410
- Domestic	6,539	5,585	54,660	23,026	53,892	34,254	42,063	20,480	31,151	6,330	277,980
- Commercial	1,722	642	16,689	6,951	16,467	10,467	12,147	6,230	9,035	977	81,327
- Industrial	0	1,680	2,016	6,020	0	0	2,240	3,121	3,035	984	19,096
Future Pollutant Load (kg/d)	2,765	3,591	22,455	11,507	21,257	13,511	17,962	9,378	13,827	3,463	119,716
Specific Yield (m3/d/ha)	8.88 (22.75)	7.46	74.11	35.64	52.12	89.44	20.16	34.29	18.87	4.76	27.95
Specific Load (kg/d/ha)	2.97 (7.62)	3.39	22.68	11.39	15.75	27.02	6.42	10.78	6.04	1.99	8.84
Name of Receiving Water	West Lake	Nhue	Kim Nguu	Kim Nguu	To Lich	Lu	Nhue	To Lich	Nhue	To Lich	
Index of Influence to Receiving water Quality	4	7	1	5	1	1	8	6	9	10	
Proposed Wastewater Disposal System	On-site/ Community	Community	Large Scale Centralized	Large Scale Centralized	Mediun Scale Centralized	Mediun Scale Centralized	Mediun Scale Centralized	Mediun Scale Centralized	Mediun Scale Centralized	On-site/ Community	
Direct cost (Million US$)	13.848	17.038	53.319	35.375	61.068	35.919	77.396	30.705	61.433	13.253	399.354
Specific Direct Cost (US$/person)	344	366	176	274	204	189	317	269	341	270	250
(Million US$/ha)	0.015	0.016	0.054	0.035	0.045	0.072	0.028	0.035	0.027	0.008	0.029
Pollutant Load Runoff after Treatment (kg/d)	415	539	3,368	1,726	3,189	2,027	2,694	1,407	2,074	519	17,957
IRR (%)	4.4	-	5.7	-	8.2	6.7	1.9	2.1	1.7	-	
Benifit per cost index	169.72	179.15	357.97	276.49	295.87	319.73	197.27	259.61	191.31	222.10	254.81
Priority of Developed Zone	4	9	1	5	3	2	7	6	8	10	