6. RECOMMENDATIONS

The Study Team has established a Master Plan for the Urban Drainage and Wastewater Disposal System in Hanoi City, discussed in the foregoing chapters. The Master Plan, fundamentally comprises two plans, one pertaining to drainage and the other wastewater disposal, though both are interrelated with each other. Recommendations for the Master Plan are stated as follows.

6.1 Drainage Aspect

(1) Structural Measures

Geographically, the study area (135.4 km^2) is clearly divided into two river basins. The To Lich River basin (77.5 km^2) composed mainly of urbanized areas containing the core zone of Hanoi City, and the Nhue River basin (57.9 km^2) which is mostly suburban . The Drainage Master Plan has been formulated for both river basins to cope with the following floods, based on the city's land use condition in the year 2010:

(a) floods with a 10-year return period for the river and drainage channel systems; and

(b) floods with a 5-year return period for the sewer systems.

The topography of the study area is characterized by its relatively low elevations compared with the high water levels of the surrounding Red River and Nhue River. Hence, the construction of pumping stations is inevitable. However, in order to unload the pump capacities economically, the provision of regulating reservoirs was examined and proposed in the study. In addition, the Drainage Master Plan incorporates the improvement of existing rivers/drainage channels, and the rehabilitation and new construction of sewers. The economics of the plan is tabulated below:

River Basin	Construction Cost (US$million)	O/M Cost (US$million)	EIRR (%)
To Lich	317	1.72	11.6
Nhue	207	0.73	9.3
Total	524	2.45	—

Note: Costs at the mid-1994 price level

As seen in the table above, the economic viability of the Drainage Master Plan is fairly high. Taking into account the rapid expansion and development of Hanoi City, it is highly recommended to implement this Drainage Master Plan in line with the schedule shown in Figure 5.1.

(2) Non-structural Measures

Non-structural measures, associated with legal and institutional aspects, should be considered simultaneously with the structural measures mentioned above. Recommended measures are:

(a) The control of the reclamation heights and the direction of providing storage ponds for new developments;

(b) Conservation of existing rivers/lakes, and preservation of paddy fields and fishponds;

(c) Preparation of flood maps; and

(d) Continuous observation of land subsidence in the study area.

Moreover, rainfall forecasting using radar is recommended to be examined in future for precise operation of the pumping stations and floodgates, and further for dissemination of flood warning.

6.2 Wastewater Disposal Aspects

(1) Structural Measures

(a) Zoning : as shown in Figure 4.1

(b) Priority of Development Zones

Priority of zones for sewerage development is recommended as followed, based on an index expressed as benefit (removed pollutant load in terms of BOD: kg) divided by the construction cost (million US$). See Table 4.8 for a comparison of the index.

- Zone 2-1, 4, 3 and 2-2 with a centralized disposal system
- Zone 6 and 5 with a centralized disposal system
- Zone 1 with a community disposal system
- Zone 7 with a non-treatment area and areas of an on-site disposal/ community disposal system

Wastewater treatment facilities in Zone 1 and 7 will be constructed by each polluter according to the pollutors-pay principle.

(c) Collection System

- Stormwater sewers are developed or improved before development of wastewater sewers, in order to firstly provide better drainage services.
- Effective utilization of the existing combined sewer system in the present urban core areas.

- Provision of a separate system for the newly developed area, in principle with the treatment plant.

- Provision of a semi-combined system with diversion chambers and an interceptor in areas of the existing combined system.

(d) Wastewater Treatment Plant

- Adoption of an oxidation ditch method for the centralized disposal systems.

  (Regarding the layout of treatment plants for each Zone, see Figure 4.5 to Figure 4.9)

- Rehabilitation of Kim Lien wastewater treatment plant using an oxidation ditch method. (Layout of the treatment plant is shown in Figure 4.10)

- Provision of a Japanese style community septic tank (Jokaso) or equivalent, for domestic wastewater in Zone 1.

- Provision of septic tanks for domestic wastewater in Zone 7.

- A laboratory with the following monitoring equipment will be located at each centralized treatment plant.
  - Water sampling equipment
  - PH meter
  - DO (Dissolved Oxygen) meter
  - MLSS (Mixed Liquor Suspended Solids) meter
  - ORP (Oxidation-Reduction Potential) meter
  - Conductivity meter
  - Thermometer
  - Flow meter

- Centralized wastewater treatment plants will have flexibility for the future improvement of facilities in order to re-use of treated wastewater, such as maintenance flow of rivers, amenity of water in parks and fire protection water.

(e) Upgrading/increase of public latrines in order to decrease overflow of untreated escreta.

(f) Upgrading/increase of individual latrines in order to decrease overflow of untreated escreta.

(g) Improvement of solid waste collection system

Collection system of solid wastes, such as garbage, nightsoil and excess sludge, shall be improved to reduce the surface pollutant load into sewers and illegal solid waste disposal into channels/rivers & lakes.

(2) Non-structural Measures

(a) Institutional Support

The following support by the government is recommended for sewerage development.

- Financial back-up of a soft loan with a revolving fund system for the encouragement of the installations of adequate septic tanks, individual wastewater treatment plants and pre-treatment plants for industries.

- Adoption of free or low-price charge system for the collection of excess sludge from high-level septic tanks, to encourage the use of this style of tank as opposed to simple-type tanks..

- Setting-up of regulations to support the operation/maintenance of the above structural measures.

(b) Relocation of Industries

Specific water-consumptive industries yielding heavily polluted effluent are to be relocated out of the urban area in view of the environmental pollution control.

(c) Intensification of Regulations for Effluent Pre-Treatment

Industrial wastewater containing heavily polluted effluent shall be individually pre-treated for up to 400 mg/l of BOD level at each factory in the centralized wastewater disposal system. Industries in on-site/community systems shall be treated up to 50 mg/l of BOD by each factory. Regulations for effluent pre-treatment, therefore, shall be effectively enforced and adequately intensified.

(d) Enforcement of the "Care for Drainage/Sewerage "Campaign and Sewerage Charge Collection

The "Care for Drainage/Sewerage "campaign shall be enforced to educate the people on public health and the necessity of sanitary facilities.

A well-organized sewer charge collection system shall be established in part to secure O& M costs for the proposed wastewater disposal system.

(e) Wastewater Monitoring Program

The Wastewater Monitoring Program, commenced by SDC/FINNIDA in May 1993, has been collecting valuable data and information. However, the ultimate success of the Program could be attained only if the observation is continued over a long period. The Program should be financially supported by HPC and incorporated in drainage/sewerage projects to be implemented henceforwards.

ANNEXES

Annex 1

SCOPE OF WORK

FOR

THE STUDY

ON

URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEMS IN HANOI CITY

IN

THE SOCIALIST REPUBLIC OF VIET NAM

AGREED UPON BETWEEN

HANOI PEOPLE'S COMMITTEE

AND

JAPAN INTERNATIONAL COOPERATION AGENCY

JUNE 10, 1993

HANOI, VIET NAM

Prof. Nguen Ngoc Le
Vice Chairman
Hanoi People's Committee

福田晴耕

Mr. Seikou Fukuda
Leader
Preparatory Study Team
Japan International
Cooperation Agency

Mr. Pham Hai
Director
Capital Construction Dept.
State Planning Committee

1. INTRODUCTION

In response to the request of the Government of the Socialist Republic of Viet Nam (hereinafter referred to as "Viet Nam"), the Government of Japan has decided to conduct the Study on Urban Drainage and Wastewater Disposal Systems in Hanoi City (hereinafter referred to as "the Study") in accordance with the relevant laws and regulations in force in Japan.

The Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of technical cooperation programs of the Government of Japan, will undertake the Study, in close cooperation with the authorities concerned of Viet Nam.

The present document sets forth the Scope of Work with regard to the Study.

2. OBJECTIVES OF THE STUDY

The objectives of the Study are:

1) To formulate a master plan of urban drainage and wastewater disposal systems including its phased implementation program; and

2) To conduct a feasibility study on urban drainage and/or wastewater systems for the prioritized project selected in the master plan

3. STUDY AREA

The study area shall cover the urban area of Hanoi City as shown in the attached Location Map.

4. SCOPE OF THE STUDY

The Study shall include the following;

(Phase I) Master Plan Study

(1) Data collection and analysis

a) Socio-economic conditions
b) Urban development plan
c) Population and its density
d) Industry
e) Land use and topographical maps
f) Meteorology and hydrology
g) Soil and geological conditions
h) Situation and possibility of ground subsidence
h) Environment and water quality

i) Flood records
j) Existing drainage and wastewater system, and related facilities

(2) Review of previous/on-going studies and existing projects

a) Urban plan for Hanoi City
b) Flood management plans for the Red River and the Nhue River including plan of the Yen So pump station
c) Improvement plans for To Lich, Lu, Set and Kim Nguu River
d) Others

(3) Field survey and investigation

a) Topography survey
b) Longitudinal and cross-sectional survey for drainage canals and rivers
c) Geological survey
d) Hydrological survey
e) Water quality
f) Survey for initial environmental examination
g) Socio-economics

(4) Evaluation for existing facilities

a) Drainage facilities
b) Wastewater facilities

(5) Planning policy and design criteria

a) Estimation of population
b) Land use
c) Target year
d) Estimation of design flood water level and design rainfall

(6) Preparation of flood simulation model

(7) Formulation of a master plan

a) Preparation of alternatives
b) Facility plan including telecommunication system
c) Non-structural measures
d) Estimation of costs for construction, operation and maintenance
e) Estimation of project benefit
f) Initial environmental examination
g) Organization and management plan
h) Implementation program
i) Selection of a project for the feasibility study
j) Proposal of a urgent project

(Phase II) Feasibility Study

(1) Necessary supplemental surveys and data collection

(2) Facility plan

(3) Environmental impact assessment, if necessary

(4) Construction plan

(5) Organization, operation and maintenance plan including institutional framework

(6) Cost estimation

a) Construction
b) Operation and maintenance

(7) Project evaluation

(8) Project implementation program

5. STUDY SCHEDULE

The schedule will be executed in accordance with the attached tentative schedule.

6. REPORTS

JICA will prepare and submit the following reports in English to the Government of Viet Nam.

(1) Inception Report
Thirty (30) copies at the commencement of the Study in Viet Nam.

(2) Progress Report (1)
Thirty (30) copies within five (5) months after the commencement of the Study.

(3) Interim Report (Draft Master Plan Report)
Thirty (30) copies within eight (8) months after the commencement of the Study.

(4) Progress Report (2)
Thirty (30) copies within thirteen (13) months after the commencement of the Study.

(5) Draft Final Report
Thirty (30) copies within sixteen (16) months after the commencement of the Study.

(6) Final Report
Fifty (50) copies within two (2) months after the receipt of the written comments on the Draft Final report from the Government of Viet Nam, while these comments are expected to be delivered to JICA within one (1) month after the submission of the Draft Final Report.

7. UNDERTAKING OF THE GOVERNMENT OF VIET NAM

(1) The Government of Viet Nam shall facilitate the carrying out of the Study in accordance with the prevailing laws and regulations stipulated by the Vietnamese State, as below:

1) To secure the safety of the Study Team

2) To permit the members of the Study Team to enter, leave and stay in Viet Nam for duration of their assignment therein, and exempt them from foreign registration requirements and consular fees;

3) To exempt the members of the Study Team from taxes, duties and other charges on equipments, machinery, and other materials brought into and out of Viet Nam for the conduct of the Study;

4) To exempt the members of the Study Team from income taxes and other charges of any kind imposed on or in connection with any emoluments or allowances paid to the members of the Study Team for their services in connection with the implementation of the Study;

5) To provide necessary facilities to the Study Team for remittance as well as utilizations of the funds introduced into Viet Nam from Japanese in connections with the implementation of the Study;

6) To obtain permission for entry into special area for the purpose of implementing the Study;

7) To secure permission which is considered and issued by the relevant authorities for Japanese Study Team to take out all data and documents including maps and photographs related to the Study out of Viet Nam to Japan; and

8) To provide medical services as needed and is expense will be chargeable on the members of the Japanese Study Team.

(2) The Government of Viet Nam shall bear claims, if any arises against members of the Study Team resulting from; occurring in the course of or otherwise connected with, the discharge of their duties in the implementation of

the Study, except when such claims arises from gross negligence or willful misconduct on the part of the members of the Study Team.

(3) Hanoi People's Committee (hereinafter referred as to "HPC") shall act as a counterpart agency to the Japanese Study Team and also coordinating body in relation with other governmental and non-governmental organizations concerned such as the State Planning Committee, the Ministry of Finance, the Ministry of Construction, the Ministry of Water Resources, the Ministry of Transport and Communications and the Ministry of Science, Technology and Environment for the smooth implementation of the Study.

(4) HPC shall, at its own expense, provide the Study Team with the following, in cooperation with other organizations concerned.

1) Available data and information related to the Study;
2) Necessary number of counterpart personnel including project coordinator throughout the Study period;
3) Credentials or identification cards;
4) Suitable office space for JICA Study Team and the Counterpart Team with necessary equipment and clerical services in Hanoi; and
5) Appropriate number of vehicles with driver(s) during the Study in Viet Nam.

8. UNDERTAKING OF JICA

For the implementation of the Study, JICA shall take the following measures.

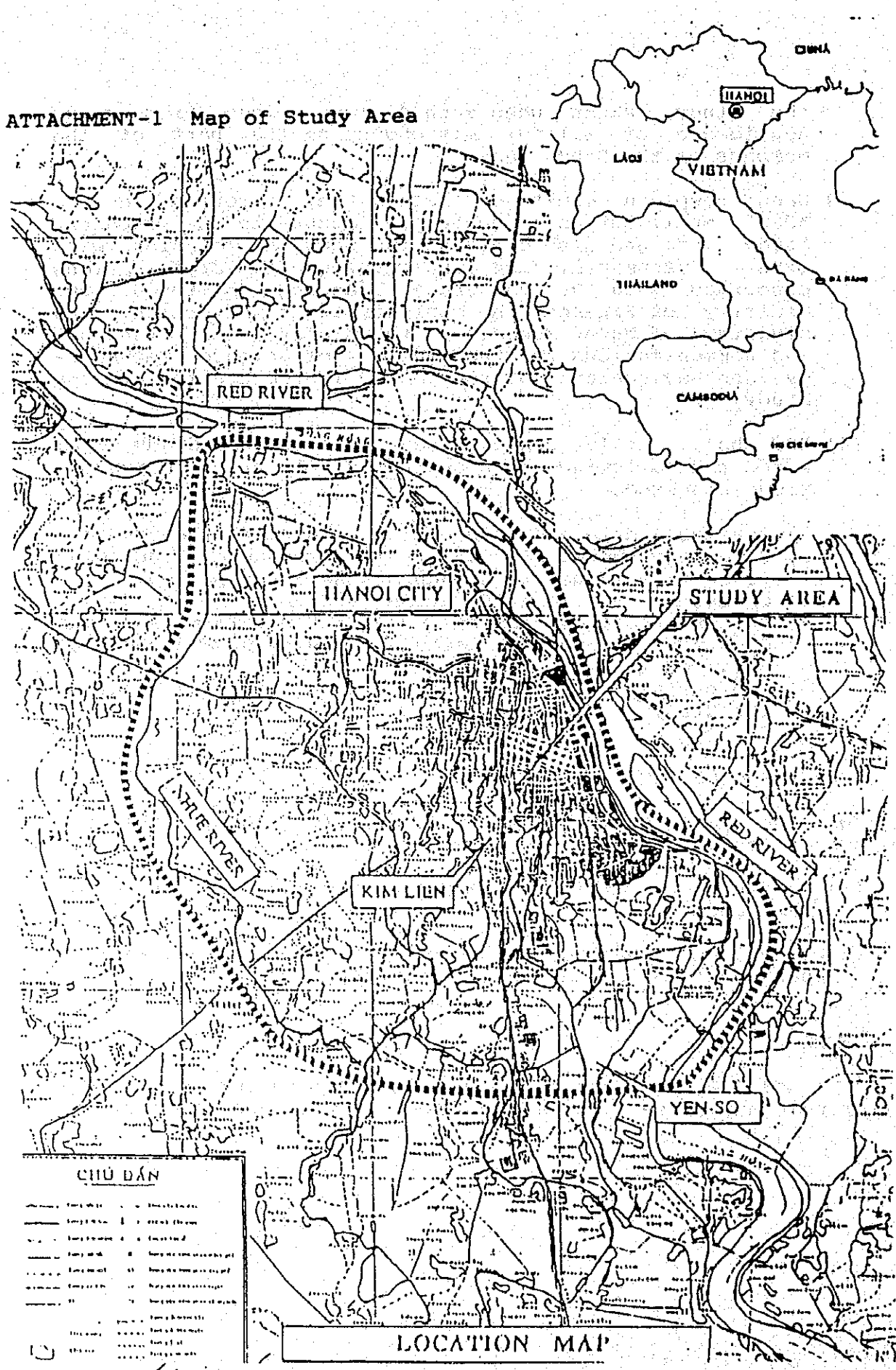
(1) To dispatch, at its own expense, the Study Team to Viet Nam; and

(2) To pursue technology transfer to the Viet Nam counterpart personnel in the course of the Study.

9. OTHERS

JICA and HPC shall consult with each other in respect of any matter that may arise from or in connection with the Study.

ATTACHMENT-1 Map of Study Area



Annex 2 List of Steering Board, Advisory Committee and Study Team Members

Steering Board:

1. Mr. Nguen Ngoc Le	Vice Chairman of HPC	Chairman (until June '94)
Mr. Dong Minh Son	Vice Chairman of HPC	Chairman (July '94 onward))
2. Dr. Nguen Thanh Binh	Director General, TUPWS	Standing Chairman
3. Mr. Pham Quoc Truong	Vice Director of TUPWS	Vice Chairman
4. Mr. Le Minh Chan	Director of SDC	Vice Chairman
5. Mr. Nquen Quang Lan	Vice Director of Foreign Economic Relation Dept. HPC	Member
6. Mr. Trinh Hong Trien	Deputy Chief Architect of Hanoi	Member
7. Mr. Pham Van Khue	Chairman of Hanoi Planning Committee	Member
8. Mr. Bui Van Dam	Vice Chairman of Hanoi Finance Dept.	Member
9. Mr. Bui Van Thieu	Vice Chairman of Hanoi Hydraulic Dept.	Member
10. Mr. Vu Kim Quyen	Deputy Director of Urban Management Dept., MOC	Member
11. Mr. Pham Hai	Director of Construction Dept., SPC	Member
12. Mr. Nguyen Dong	Director of Water Resources Planning and Management Institute, MOWR	Member
13. Mr. Mai Huu Dua	Vice Director of Environment Dept., MOSTE	Member

Note:

HPC	Hanoi People's Committee
TUPWS	Transport and Urban Public Works Service of Hanoi City
SDC	Sewerage and Drainage Company of Hanoi City
MOC	Ministry of Construction
SPC	State Planning Committee
MOWR	Ministry of Water Resources
MOSTE	Ministry of Science, Technology and Environment

Advisory Committee (JICA):

1. Mr. Seikou Fukuda	Ministry of Construction, GOJ	Chairman
2. Mr. Hiromi Nagao	Sapporo Municipality	Member

Study Team:

1.	Mr. Michito Kato	Team Leader
2.	Mr. Yasuhiko Uchida	River Planning
3.	Mr. Hideyuki Wakasa	Sewerage Planning
4.	Mr. Yasuhiko Kato	Hydrology
5.	Mr. Junji Kamata	Drainage Design
6.	Mr. Atsuya Saisho	Construction Plan
7.	Mrs. Helena Ahola	Environment/Water Quality
8.	Mr. Jun Tanimizu	City Planning
9.	Mr. Toshikazu Tai	Socio-Economy/Project Evaluation
10.	Mr. Nguen Dich	Topographic Survey
11.	Mr. Toshiyuki Sato	Geotechnical
12.	Mr. Hiroshi Sumikawa	Lake Water Aeration

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

PART II

FEASIBILITY STUDY ON THE TO LICH RIVER BASIN DRAINAGE PROJECT

FEBRUARY 1995

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

MAIN REPORT – PART II
FEASIBILITY STUDY ON
THE TO LICH RIVER BASIN DRAINAGE PROJECT

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1. INTRODUCTION

In the Master Plan, some ten projects relating not merely to flood control and drainage but also to wastewater disposal and other issues, were proposed and examined from the technical, social, and economic points of view. As a result, the drainage project for the To Lich river basin has been selected as the first priority project among them. In this context, the present report (Main Report – Part II, Feasibility Study on the To Lich River Basin Drainage Project) compiles the feasibility study results of the above Project. All the planning conditions and basic strategies applied to the Master Plan are also applied for this Study.

This report comprises the following chapters:

(1) Chapter 1 : Introduction

(2) Chapter 2: Background Information concerning the socio-economy, city development plan, hydrology, environment and water quality, geotechnical investigation, and topographic survey for the To Lich river basin.

(3) Chapter 3 : Preliminary Design presenting the design of drainage facilities such as the Yen So pumping station, Yen So regulating reservoir, rivers, drainage channels and sewers, the supply of dredging equipment, and the aeration plan for city lakes.

(4) Chapter 4 : Implementation Schedule, Cost and Organization for the smooth implementation of the To Lich River Basin Drainage Project.

(5) Chapter 5 : Project Evaluation discussing the evaluation of the Project from the economic, financial, and environmental points of view.

(6) Chapter 6 : Recommendations for the future development of the Project.

2. BACKGROUND INFORMATION

2.1 Socio-economy

2.1.1 National and Regional Socio-economy

Total population of whole Viet Nam was estimated to be around 68.3 million (1992), while that of Hanoi is 2.1 million corresponding roughly to 3.1% of the country's total.

The Regional Gross Domestic Product (RGDP) of Hanoi was estimated at 7,913 billion Dong at the current price (US$ 733 million) in 1993, which was approximately 6.3% of the National Gross Domestic Product (NGDP) of 125,074 billion Dong (US$ 11.58 billion). Per-capita GDP of Hanoi was estimated at 3,548,000 Dong (US$ 328 million) in 1993. The regional economy of Hanoi enjoyed an economic boom after the 1989 economic reform, and RGDP grew at an unprecedented high pace of 11.8% per annum, which was over 70% higher than the average NGDP growth rate of 6.8%.

The agriculture sector shares only 6% of RGDP, while the industry and trade sectors share 23% and 22%, respectively. The service sector including finance and insurance is predominant with 39% of RDGP. Compared to the components of NGDP, the economy of Hanoi City is characterized by a more comprehensive development and diversification from agriculture to industry, trade, and finance.

2.1.2 Administrative Units, Area and Population of the Project Area

The proposed Project area covers 7,750 ha of land, which comprises basically 4 urban districts and parts of 2 suburban districts of Hanoi City. This area accounts for about 57% of the total study area of the Master Plan. Figure 2.1 shows the project area with administrative boundaries.

The total population of the Project area in 1992 was estimated at about 994,000 with an average population density of 128 persons/ha. The population density of the 4 urban districts was as high as 245 persons/ha, while that of the suburban was 22 persons/ha.

The area and population of the Project area are presented below:

Districts		Area (ha)	Population in 1992	Population Density (persons/ha)
Urban Districts				
(1)	Dong Da	1,282	301,622	235
(2)	Ba Dinh	1,083	186,456	173
(3)	Hoan Kiem	351	147,266	420
(4)	Hai Ba Trung	1,022	283,811	278
	(Sub-total)	(3,738)	(919,155)	(245)
Suburban Districts				
(1)	Thanh Tri	2,658	48,893	18
(2)	Tu Liem	787	26,072	33
	(Sub-total)	(3,445)	(74,965)	(22)
West Lake Area		567	–	–
Total		7,750	994,120	128

2.2 City Development Plan

2.2.1 Present Land Use

As presented in the preceding section 2.1, the Project area consists of four urban districts, Dong Da, Ba Dinh, Hoan Kiem, and Hai Ba Trung, and two suburban districts, Tu Liem and Thanh Tri of Hanoi City, with a total area of 7,750 ha. At present, about 3,500 ha or 45% of the total area is used for residential purposes, which reflects the rapid urbanization of the Hanoi urban and suburban area. The ancient city area and governmental offices and public area occupy about 9% of the total area, while industrial area accounts for only 5%. About 26% of the total area or a little bit more than a quarter is occupied by lakes and ponds. The area for agriculture is relatively small (13%). The present land use in the Project area is summarized below:

Land Use	Area (ha)	%
Ancient City	82	1.1
Governmental Offices/Public	570	7.4
Residential (Urban and Suburban)	3,506	45.1
Industry	385	5.0
Lakes/Ponds	2,013	26.0
Agriculture	1,045	13.5
Green Area	149	1.9
Total	7,750	100.0

2.2.2 Future Land Use

The future land use in the Project area is summarized as follows:

Land Use	Area (ha)	%
Ancient City	82	1.1
Governmental Offices/Public	778	10.0
Residential (Urban and Suburban)	3,892	50.2
Industry	425	5.5
Lakes/Ponds	1,483	19.1
Agriculture	910	11.8
Green Area	180	2.3
Total	7,750	100.0

2.3 Hydrology

2.3.1 Flow Regime Analysis

(1) Flow Regime

(a) Nhue River

The flow regimes downstream of the Ha Dong weir and upstream of the Dong Quan weir on the Nhue River were studied by using daily water levels recorded for 5 years (1989-1993). The results are shown in Table 2.1.

The flow regime at the Thanh Liet floodgate in the table was estimated by interpolation. The discharges at the gate were also estimated using the discharge rating curve.

(b) Red River

The average flow regime of the Red River at the Hanoi station (on Long Bien bridge) was studied by using daily water levels recorded for 5 years (1989-1993). The results are shown in Table 2.1.

The Hanoi station is located about 100 km from the sea and the Yen So site is located approximately 7 km south of the Hanoi station. The water level at the Yen So site in the table was estimated by interpolation with the distance from the sea.

(c) Water Level of the Nhue River and Discharge of the To Lich River

The relationship between the water level of the Nhue River at the Thanh Liet floodgate and the discharge of the To Lich river (Alternative 6) was investigated annually as shown in Figure 2.2. The 1989 pattern was adopted as a typical case in terms of annual rainfall and storm.

(2) Probable Maximum Water Level

(a) Nhue River

The probable maximum water levels downstream of the Ha Dong weir and upstream of the Dong Quan weir on the Nhue River were calculated by Gumbel's formula, using annual maximum water levels for 37 years (1957-1993). The results are shown in Table 2.2.

(b) Red River

The probable maximum water levels of the Red River at the Hanoi station were calculated by Gumbel's formula, using long-term annual maximum water levels for 92 years (1902-1993). The results are shown in Table 2.2.

2.3.2 Proposed Flood Forecasting and Warning System

It is necessary to establish an effective flood forecasting and warning system in the To Lich river basin. The basic concept of the system is as follows.

(1) Rainfall Forecasting

It is required to forecast the hourly rainfall hyetograph pattern (one to three hours) to calculate the future flood runoff.

(2) Runoff Forecasting

Predicted hourly rainfall can be converted into future runoff through a flood runoff model.

(3) Control System for Drainage

It is required to establish a drainage control system connecting HSDC headquarters, Yen So pumping station, and other facilities as shown in Figure 2.3.

(4) Required Cost

The required cost for the flood forecasting and warning system in the To Lich River basin is estimated to be around US$ 300,000 as detailed below.

(a) Telemetering Network, 4 sites : US$200,000 (US$50,000 x 4 units) (HSDC headquarters, Yen So pumping station, Thanh Liet floodgate, and West Lake control gate)

(b) Runoff Forecasting System : US$100,000

2.4 Environment and Water Quality

2.4.1 Water and Sludge Quality

(1) Investigation Programs

Environmental aspects concerning lakes, rivers and channels which were proposed to be improved under the Project, were examined through various studies and site visits . The work started from those lakes which will be dredged during the first stage of the Project. All possible information and data on lakes were collected, and a lake register was established.

During the dry season, water samplings were carried out at 15 points: three points in lakes, eight points in main rivers, and four points in channels (Figure 2.4). The first sampling was done in the middle of December 1993 and second in the middle of January 1994.

During the rainy season, in-situ water quality analyses were performed on the lakes which were proposed to be dredged during the first stage of implementation of the To Lich River Basin Project. In-situ analyses especially for the needs of the pilot aeration project were continued in September 1994. In the same month water samples were also taken from a total of twenty lakes, including the three which were under the Wastewater Monitoring Programme carried out by HSDC.

(2) Results of the Dry Season Investigations

Results of the dry season investigations confirm that all the lakes, rivers and channels in Hanoi are at least moderately or even highly polluted by domestic and industrial wastewater. Pollution and eutrophication by organic matters decreases the water quality and, at the same time, increases sedimentation and causes a lack of oxygen. Turbidity and concentration of suspended solids are high in all places.

All the three lakes, Hoan Kiem, Van Chuong and Bay Mau which belong to the sampling program, are polluted. The situation is worst in the Van Chuong Lake, which is heavily polluted by industrial wastewater, e.g. from textile factories. Water quality at the outlet is at almost the same level as wastewater, e.g. with an average BOD of 76 mg/l and an average COD of 141 mg/l, as well as a high concentration of nutrients.

All the main rivers in Hanoi (To Lich, Lu, Set and Kim Nguu) are shallow and their flow is small especially during the dry season. All the rivers are polluted and their dilution capacity is inadequate. The average BOD value is about 40-65 mg/l and COD 76-163 mg/l. Water quality is the best in the lower reaches of the Nhue river, where the water volume is bigger and, therefore, the dilution capacity is higher than in other rivers. In the Nhue river the average BOD value is only 6 mg/l and COD 17 mg/l.

Wastewater is found in the channels mainly in the dry season. The water color is brown or black, and the presence of domestic wastewater produces a strong odor, little oxygen and a high concentration of nitrogen-ammonia.

Traces of heavy metals were discovered in water and sludge from all five points. The amount of sludge was surprisingly small, usually oily, and containing slight traces of black.

The color of the sludge varied from black/grey to dark black. Oil was present in the samples from Lo Duc and Bay Mau lakes. The content of sludge was heterogenous, including garbage, plastic, stones, sand and organic matter. A strong odor indicating present of organic or domestic wastewater was detected.. The bottoms of the channels contained no life except for sewage fungus.

Some concentrations of heavy metals are slightly high, but all are still under the Vietnamese standards. No mercury (Hg) and very little cadmium (Cd) was found. In general, the heavy metal concentrations were highest in the Lo Duc outlet and in Bay Mau lake.

(3) Results of the Rainy Season Investigations

Water quality results in August 1994 from lakes which are proposed to be dredged during the first stage, are as follows:

Parameter	Giang Vo	Dong Da	Thanh Nhan 1	Thanh Nhan 2
pH	7.4	7.9	8.6	8.3
Cond. uS/cm	432	470	412	456
DO mg/l	1.3	2.9	15.3	10.8
NH3-N mg/l	13.7	6.5	4.3	5.5
NO3-N mg/l	2.1	1.5	1.5	0.9
Turbidity NTU	24	46	60	53
SS mg/l	16	38	49	52
Color PtCo				
- unfiltered	–	–	320	288
- filtered	–	–	169	119

In August there was an oversaturation of oxygen in the lakes, causing algae to bloom, and water color to turn dark green. The next measurements were taken in September, when the oversaturation of oxygen was reduced due to storm waters flushing the lakes. The oversaturation of oxygen depends on the amount of rainfall and temperature.

The September results are presented in Table 2.3. Sampling was done after heavy rains and flood, which filled the lakes. The amount of nutrients was highest in the lakes, where the impacts of floods and discharged wastewater are greatest. Turbidity and suspended solids had already steadied after the first peak of storm waters. The amount of rainfall was exceptionally high during the 1994 rainy season, having a great impact not only on the water levels but also on water quality.

Due to floods and very high water levels in the lakes, the amount of nutrients decreased from August to September. The storm waters created a flushing effect in the water bodies.

The levels of turbidity and suspended solids remained high, especially peaking during the rains. There were not enough samples taken to analyze the impact of the storm waters on BOD and COD.

The water quality was visually checked paying special attention to the color of the water, which is usually green or green/grey. Algae causes the green color and the brown and grey color originates from the bottom sediment and surrounding areas.

At the end of September, to establish the needs of aeration, on-site analyzing of dissolved oxygen from selected lakes was undertaken. Measurements were done from different water layers, but stratification was not detected.

Generally all water areas seem to be polluted, untidy and foul smelling. A lack of sewers, wastewater treatment plants, and adequate solid waste and nightsoil collection cause the biggest environmental problem in Hanoi, especially the densely populated inner city area where there are no possibilities for on-site wastewater treatment plants.

2.4.2 Sediment and Bottom Fauna

A bottom survey was carried out in seven lakes, but only Giang Vo lake is proposed to be dredged. The thickness of sediment was surprisingly small in many lakes, making it necessary to carry out detailed studies and planning before any dredging.

Bottom types of the lakes which are proposed to be dredged during the first stage were studied. Near the shore there is very little sediment and in the bottom there is mostly sand and gravel (Giang Vo and Thanh Nhan 1) and clay (Dong Da). From Thanh Nhan 2 it was possible to take a sample from the middle of the pond, producing a thick layer of clayey sediment.

Living mussels, snails and small crabs were only found in Thanh Nhan 1. The bottoms of other studied lakes seemed to be dead. Only one previously published bottom fauna study from West Lake was found, therefore bottom fauna studies need to be carried out before dredging.

2.4.3 Water Plants and Vegetation on Banks

Special attention was paid to the vegetation both in water and on shores. In general, versatility is quite low with only a few species. The most common species in

the lakes are water hyacinth, water spinach, fern and duckweed. Some banks and even lakes are covered with vegetation, while some banks are bare and covered only with sand and garbage.

In inner city lakes, which are used for recreation, the amount of water plants is very small or non-existent. In lakes which are used for fish farming or flood controlling there is a lot of water plants, and in some lakes water hyacinths cover the whole water area. The harvesting of water plants is not always effective.

In some rivers, the amount of water hyacinths prevent flow. In channels, there are very little water plants, or any other life, because of the low water quality.

2.4.4 Condition of Lake Banks

The banks of Giang Vo and other lakes in the inner city area which are basically used for recreation, are usually paved with stones or concrete, and natural banks cannot be found. On the banks there are trees but the lawns are in bad condition. Very often houses or concrete covered yards reach down to the water.

Well-maintained areas are very difficult to find, because all shores, even in the city center, are full of garbage and used as public toilets. Banks in the city are all used for illegal land fillings and the dumping of garbage because the collection of solid waste has not been properly organized.

All banks are very dirty, uncomfortable and environmentally destroyed. Cleaning of the banks is not effective as the people don't pay any attention in keeping their environment clean and healthy. The people who are complaining about the condition of their surrounding, also throw their own garbage on the street and in the water.

There are plenty of latrines situated next to the water, and on the channel banks there are over-hung latrines. Wastewater from houses near to the lakes, rivers and channels is discharged directly to the water untreated.

As a result, it is very clear that wastewater and solid waste in the channels and channel banks, create a very serious threat not only to the environment, but also to the health of the people residing near to the polluted water.

2.5 Geotechnical Investigation

2.5.1 Stratigraphy

The geotechnical investigation conducted in this stage has clarified the stratigraphy in the study area as depicted in Figure 2.5. The clayey layers C1, C2 and C3 in the figure generally correspond to the alluvial deposits tb1 and hh, while the layers S1, S2, S3 and S4 mainly comprise sand, among which S2, S3 and S4 correspond to the alluvial deposits tb1, tb2 and hh, and S1 corresponds to the diluvial deposit vp.

2.5.2 Soil Mechanics

(1) Earthwork

The earthwork for the proposed project will be executed in the upper portion of the clayey layers C2 and C3 comprising silt, clay, and humic material. There may be no sandy lenses interrupting this upper portion. The N-value ranges between 4 and 7, the natural water contents 28 % and 37 %, the liquid limit 34 % and 45 %, the bulk density 1.80 and 1.96 kgf/cm^2, the cohesion 0.7 and 1.5 kgf/cm^2, and the sand contents 12 % and 35 %, showing rather hard properties. The permeability coefficient is in the 10^{-6} cm/sec order. (See Table 2.4.) The calculation indicates that the maximum possible excavation depth can be 10 m even without retaining walls, and that seepage from a fishpond 5 m behind the excavation field will require more than 3 months. Judging from the above, both manual and mechanical earthworks can be applied to the proposed project without special countermeasures, and also the excavated materials can be used for the embankment.

(2) Consolidation Settlement

The clayey layers C1, C2, and C3 may be subject to consolidation settlement. Based on the data obtained from the geotechnical investigation, and given at 5 tons/m^2 for the additional load of embankment, the final settlement is calculated approximately at 60 cm for 25 years. This settlement should be compensated when deciding the height of the extra embankment.

(3) Bearing Layer

The deepest sandy layer (S1) has N-values of more than 30, and can be the bearing layer for the structures to be proposed in the study. This layer is distributed 15 m and 35 m under the ground surface along the To Lich river and at the Thanh Liet weir, respectively. However, along the Kim Nguu river this layer was not confirmed. In the Yen So area, the surface of this layer lies at EL.-37 m with reduced undulation.

(4) Permeability

The permeability of the subsoil is examined based on the data attained through the in-situ and laboratory permeability tests. The permeability coefficients of the clayey layers are the 10^{-6}cm/sec order for C2 and C3, and the 10^{-7}cm/sec order for C1, while those of the sandy layers are the order of 10^{-4} cm/sec for S1, S2 and S3, and 10^{-5} cm/sec for S4. On this condition, unless the sandy lenses exist in the upper clayey layers (C2 and C3), only some meters excavation, keeping the water level approximately 2 m below the ground level, should not affect the safety of the Red River levee more than 1 km away from the excavation site. Moreover, there will be less change in the water stage of fishponds around the Yen So reservoir site.

2.6 Topographic Survey

The following works were executed during the period for the formulation of the Feasibility Study mainly to clarify topographic conditions of the Yen So area and cross-sections of bridges/culverts spanning the existing drainage channels:

(1) Longitudinal and cross-sectional survey of Lu-Set Floodway (1 km, 6 sections);

(2) Topographic survey for the proposed Thanh Liet floodgate site (3,000 m^2);

(3) Topographic survey for the proposed Yen So pumping station site (6,000 m^2);

(4) Topographic survey for the proposed Yen So regulating reservoir site (600 ha);

(5) Dimensions survey including spot elevations of bridges/pipe culverts over the drainage channels and cross-sectional survey at the upstream site of each bridge/pipe culvert (160 bridges and 160 sections);

(6) Topographic survey for the estimation of sludge volume of seven (7) lakes : Thien Quang, Giang Vo, Nam Dong, Van Chuong, Hoang Kiem, Bay Mau, Truc Bach lakes (spot sounding at 750 points);

(7) Installation of datum points for the execution of said works by leveling (23 km);

(8) Counting the number of houses along the drainage channels (50 km along both sides of channels); and

(9) Three cross-sectional survey across Linh Dam lake (4 km).

Table 2.1 AVERAGE FLOW REGIMES

NHUE RIVER

Regimes		Ha Dong (downstream) 15.2k H (m,MSL)	Dong Quan (upstream) 41.0k H (m,MSL)	Thanh Liet Floodgate 19.9k H (m,MSL)	Estimated Discharge by Discharge Rating Curve Q (m3/s)
High	(95-days)	3.55	2.94	3.44	28
Normal	(185-days)	3.10	2.58	3.01	21
Low	(275-days)	2.53	2.06	2.45	13
Lowest Low	(355-days)	1.81	1.23	1.70	6

Data Period : 1989-1993 (5 years)

RED RIVER

Regimes		Hanoi Station <Long Bien Bridge> (m,MSL)	Yen So Site (m,MSL)
Annually(365 days)			
High	(95-days)	5.93	5.51
Normal	(185-days)	4.03	3.74
Low	(275-days)	3.22	3.00
Lowest Low	(355-days)	2.81	2.62
Rainy Season (May - October)			
High	(46-days)	8.02	7.46
Normal	(92-days)	5.96	5.54
Low	(138-days)	4.84	4.50
Lowest Low	(174-days)	3.37	3.13
Dry Season (November - April)			
High	(46-days)	3.65	3.39
Normal	(91-days)	3.26	3.03
Low	(136-days)	3.01	2.80
Lowest Low	(171-days)	2.82	2.62

Data Period : 1989-1993 (5 years)

Table 2.2 PROBABLE MAXIMUM WATER LEVELS

NHUE RIVER

Return Period (year)	Ha Dong (downstream) 15.2k H (m,MSL)	Dong Quan (upstream) 41.0k H (m,MSL)	Thanh Liet Floodgate 19.9k H (m,MSL)	Estimated Discharge by Discharge Rating Curve Q (m3/s)
100	6.07	5.25	5.92	91
50	5.83	5.01	5.68	83
30	5.65	4.84	5.50	78
20	5.50	4.69	5.36	74
10	5.25	4.45	5.11	66
5	4.99	4.19	4.85	59
2	4.60	3.80	4.46	50
1.2	4.27	3.47	4.12	42

Data Period : 1957-1993 (37 years)

RED RIVER

Return Period (year)	Hanoi Station Long Bien Bridge> (m,MSL)	Yen So Site (m,MSL)
100	14.17	13.18
50	13.61	12.65
30	13.19	12.27
20	12.86	11.96
10	12.28	11.42
5	11.67	10.85
2	10.76	10.00
1.2	9.99	9.29

Data Period : 1902-1993 (92 years)

Table 2.3 RESULTS OF WATER QUALITY IN LAKES DURING RAINY SEASON 1994

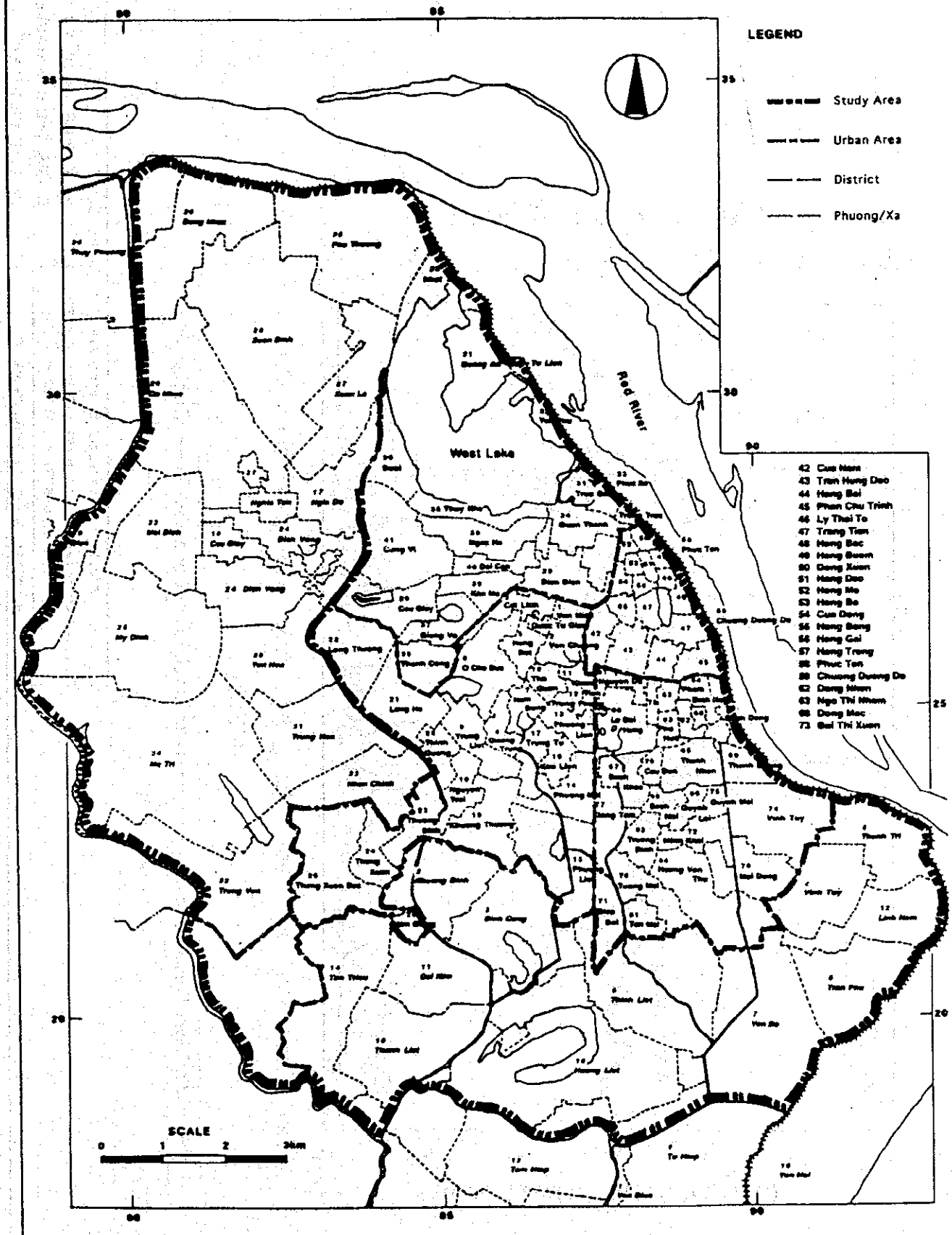
Name of Lake	Results on-site				Results in Laboratory of HSDC						Results in Environmental Laboratory		
	Temp. (oC)	pH	Conductivity (μS/cm)	DO (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TBD (FTU)	SS (mg/l)	Colour (no filt) (Pt Co)	Colour (filt) (PtCo)	PO4-P (mg/l)	COD (mg/l)	BOD (mg/l)
T7 Giang Vo Inlet	30.8	8.21	351	6.14	4.90	1.10	40	26	213	111	–	–	–
T13 Dong Da	30.2	8.05	342	4.20	2.40	0.00	43	35	85	137	0.30	51	17
K3 Thanh Nhan 1	28.0	7.67	345	1.09	0.49	1.60	42	31	154	123	0.60	77	28
K4 Thanh Nhan 2	27.0	7.64	314	1.69	0.34	1.60	59	49	298	147	0.42	65	29
W1 Truc Bach Inlet	29.0	7.56	395	6.45	0.30	2.60	20	23	148	48	–	–	–
W1 Truc Bach Outlet	29.5	7.61	340	8.90	0.80	2.30	43	20	–	–	–	–	–
T4 Thu Le	31.2	8.82	282	7.33	0.00	1.70	15	12	161	189	0.04	37	10
T8 Ngoc Khanh	31.0	8.64	334	7.48	0.55	0.90	43	32	226	153	0.70	66	18
T9 Thanh Cong	31.5	8.75	324	10.31	0.90	4.50	47	33	250	86	0.32	48	12
T16 Nghia Do	30.8	8.93	235	6.67	0.65	0.70	29	22	142	198	0.06	32	11
L5 Ba Mau	28.1	7.57	391	1.13	0.93	0.60	32	22	169	90	0.71	73	24
L6 Trung Tu	27.1	7.48	460	0.21	9.20	1.00	24	19	140	94	1.07	95	21
S1 Thuyen Quang	28.4	7.72	258	1.48	3.91	1.50	23	18	94	40	0.57	62	19
S2 Bay Mau Inlet	28.2	7.62	539	0.61	4.40	1.40	68	11	189	150	–	–	–
S2 Bay Mau Outlet	30.3	8.97	349	11.57	4.40	1.20	30	16	175	122	–	–	–
K1 Hoan Kiem	28.4	10.02	121	8.10	0.76	0.00	47	50	229	79	0.33	86	18
L3 Van Chuong	27.8	7.61	398	1.22	0.52	0.00	32	27	159	90	0.48	120	33
L7 Kim Lien	27.9	7.95	285	3.10	8.80	0.50	21	15	125	91	0.58	74	19
K2 Hai Ba Trung	28.9	7.77	218	1.45	0.74	1.70	14	8	67	38	0.48	55	24
Y1 Yen So	29.4	8.00	285	3.85	4.40	0.00	66	42	350	134	1.00	65	16
H3 Linh Dam	28.0	7.53	198	0.91	1.60	0.00	21	14	120	81	0.27	50	18
L17 Dinh Cong	28.7	8.12	220	1.97	1.25	0.30	20	13	124	91	0.12	40	12

Table 2.4 SUMMARY OF SOIL TEST RESULTS FOR EACH LAYER

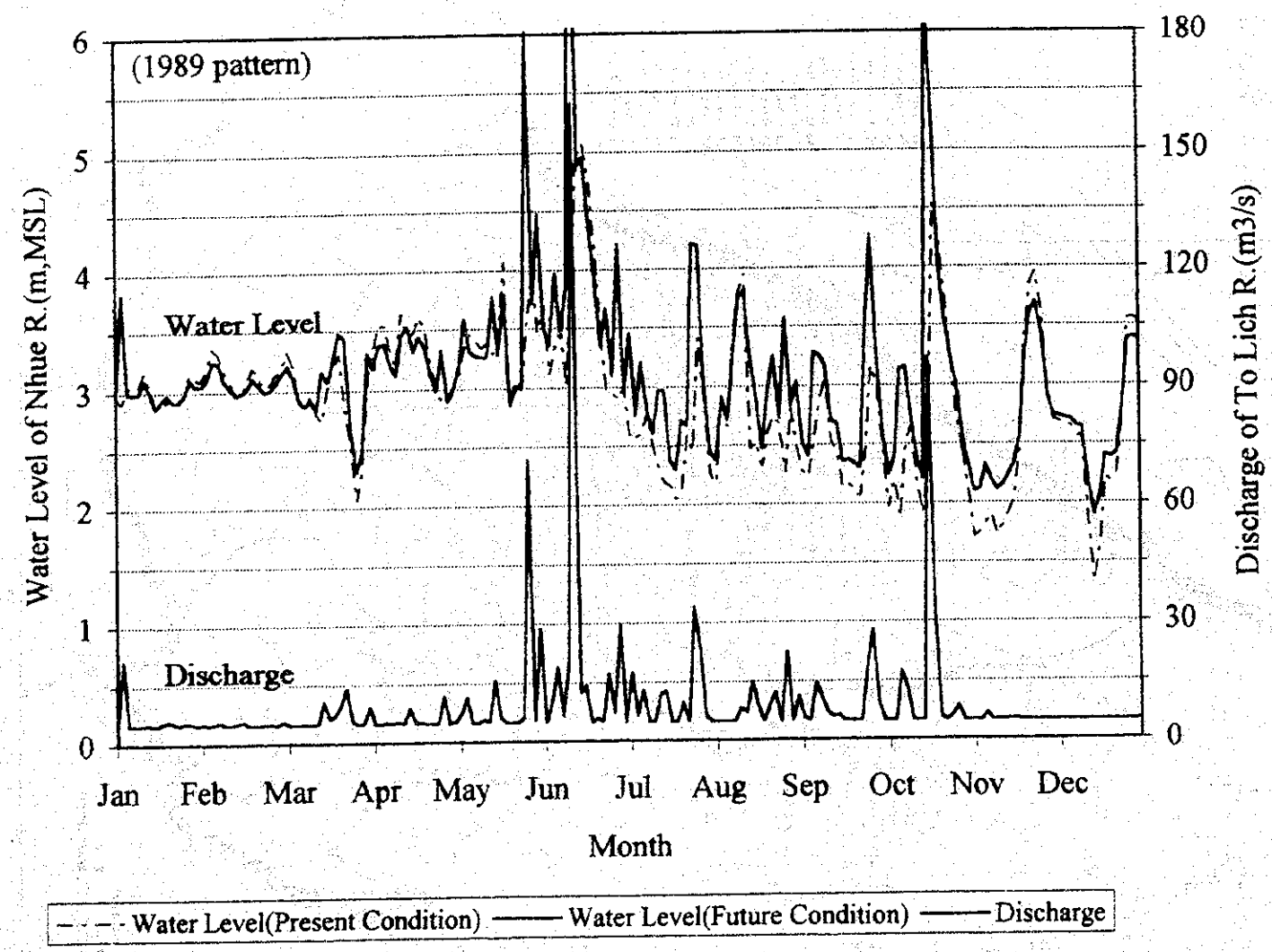
* Layer	** Area	Composition (%) Grain Size (mm) 2	0.05	0.005	Water Content (%) Liquid Limit	Natural	Plastic Limit	Bulk Density γ (g/cm³)	Specific Gravity (g/cm³)	Natural Porosity e0	Permeability Coefficient (cm/s)	Compression Index Cc	Consolidation Coefficient Cv (cm²/day)	Cohesion c (kg/cm²)	Soil Classification	Average of N-value (N/30cm)
S_4	②	2	27	43	28	28	25	10	1.91	2.71	0.77	4×10^{-5}	0.14	590		Sand-Clayey Silt	13
C_3	①	0	33	26	41	39	35	24	1.83	2.71	1.03	4×10^{-6}	0.13	190	1.5	Silt-Sandy Clay	7
	②	0	35	39	26	34	28	13	1.96	2.75	0.77	5×10^{-8}	0.07	118	1.5	Clay-Sandy Silt	7
	③	0	21	47	32	41	35	22	1.80	2.71	0.87	2×10^{-6}	0.13	70	0.7	Clay-Sandy Silt	4
	④	0	12	43	45	45	37	24	1.85	2.71	1.01	8×10^{-9}	0.14	79	1.2	Sand-Silty Clay	5
S_3	①	0	71	25	4	—	26	—	1.86	2.61	0.77	3×10^{-4}	—	—	—	Silty Sand	19
C_2	①	0	31	39	30	53	53	33	1.63	2.63	0.94	2×10^{-6}	0.30	88	1.2	Clay-Sandy Silt	6
	②	0	33	46	21	40	48	23	1.63	2.64	1.08	8×10^{-6}	0.44	220	1.0	Clay-Sandy Silt	8
	③	0	24	50	26	42	49	28	1.68	2.64	1.21	4×10^{-6}	0.30	110	0.8	Sand-Clayey Silt	4
S_2	③	0	89	9	2	—	26	—	1.85	2.64	0.79	4×10^{-4}	—	—	—	Sand	12
	④	0	89	9	2	—	25	—	1.83	2.63	0.80	6×10^{-4}	—	—	—	Sand	12
C_1	①	0	11	53	36	35	31	22	1.86	2.70	0.91	4×10^{-7}	0.08	142	1.0	Sand-Clayey Silt	11
	③	0	44	38	18	38	35	26	1.82	2.70	1.00	5×10^{-7}	0.16	194	1.7	Clay-Sandy Silt	17
S_1	①	2	58	23	17	—	19	—	1.77	2.69	0.81	3×10^{-5}	—	—	—	Clay-Silty Sand	30
	③	0	90	9	1	—	26	—	1.87	2.65	0.79	7×10^{-4}	—	—	—	Silty Sand	37

* S_4, S_3, S_2, S_1 ····· Sandy Layer , C_3, C_2, C_1 ····· Clayey Layer

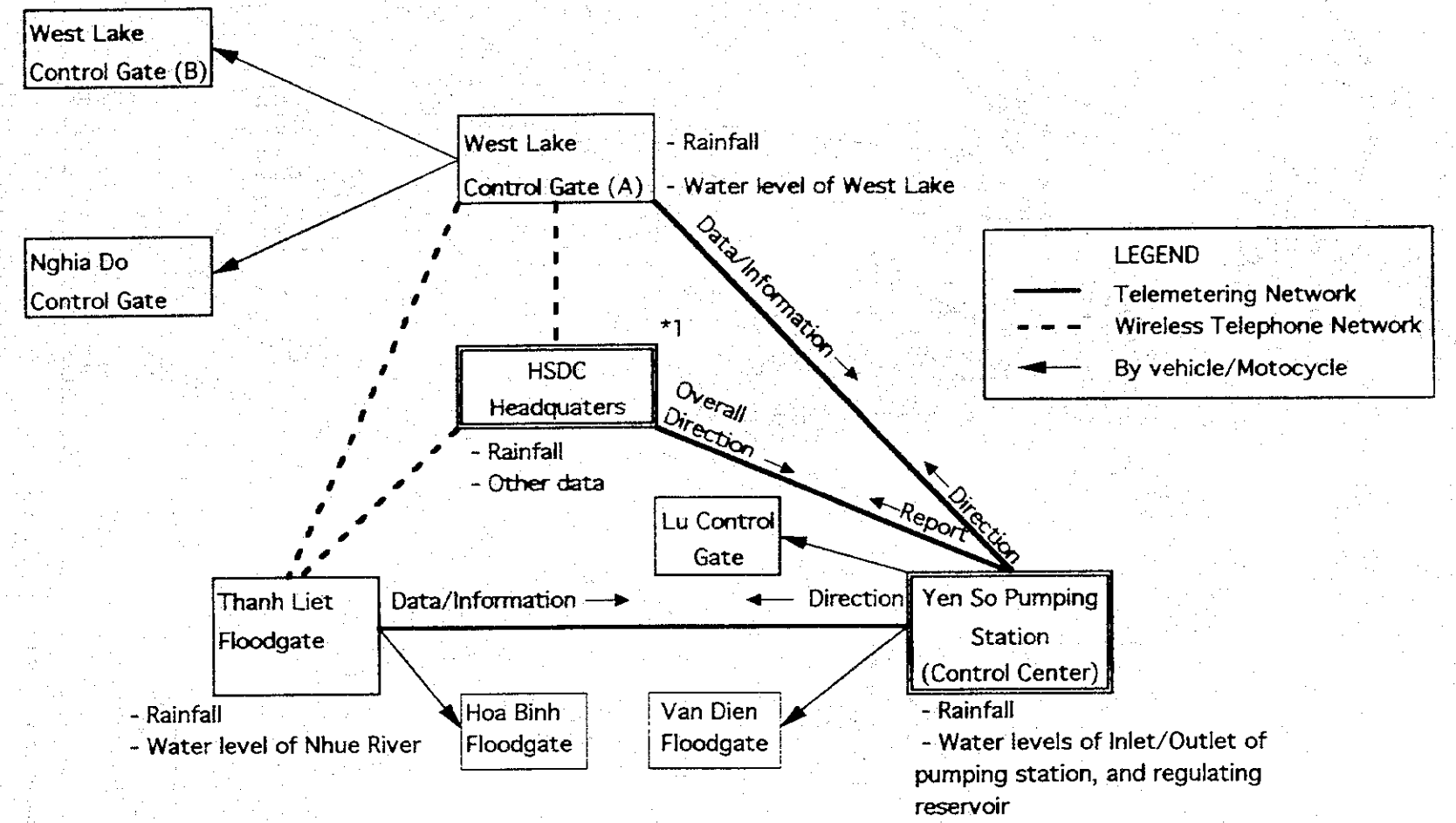
**① Along To Lich River. (B.H. No.1, 3～6) ② Along Upper Kim Nguu River. (B.H. No.7, 8) ③ Yen So Site, (B.H. No.2, 9～13, 15～17) ④ Hoang Liet Site (B.H. No14)



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2.1 ADMINISTRATIVE BOUNDARIES

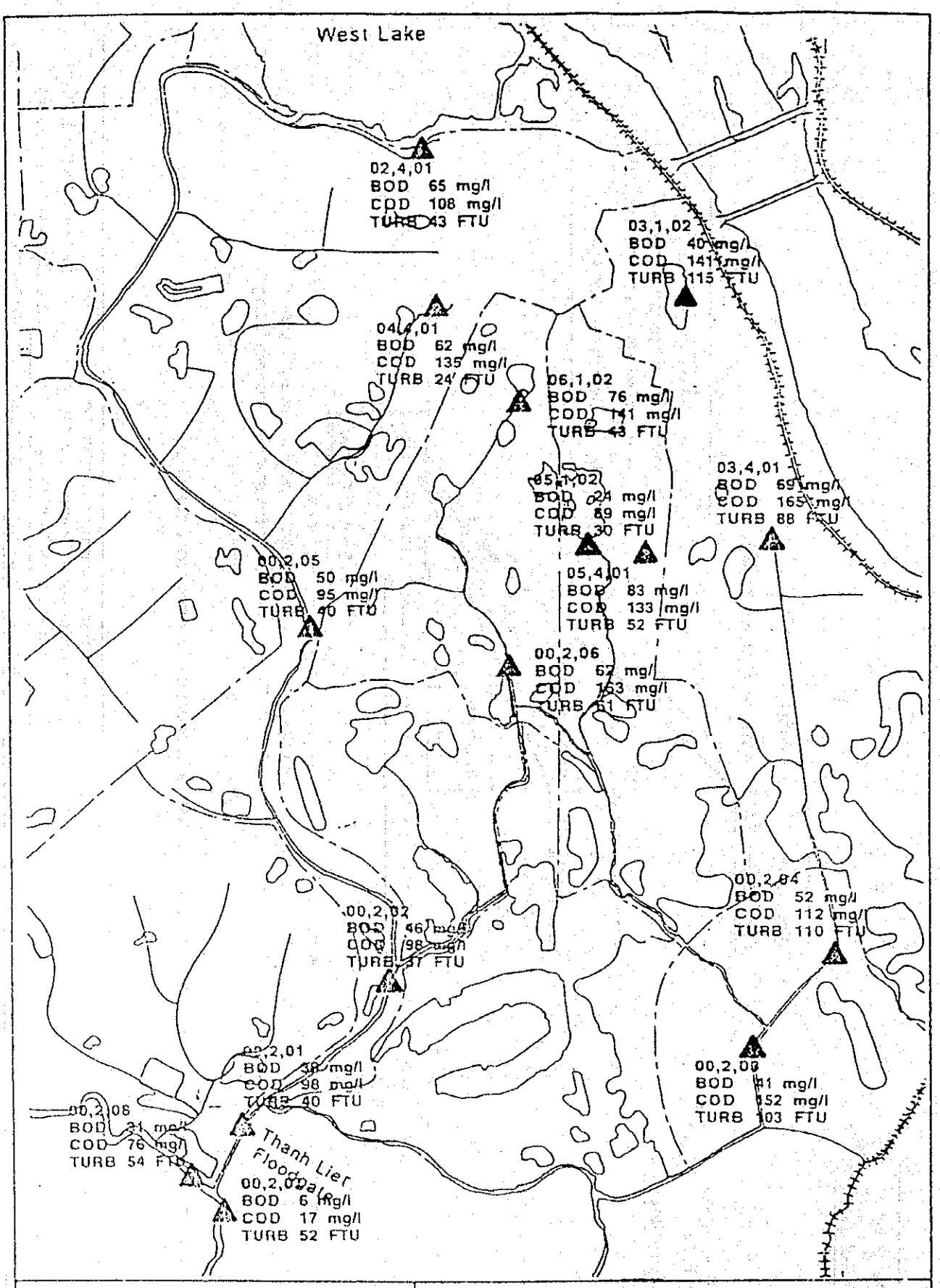


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2.2 WATER LEVEL OF NHUE RIVER AND DISCHARGE OF TO LICH RIVER



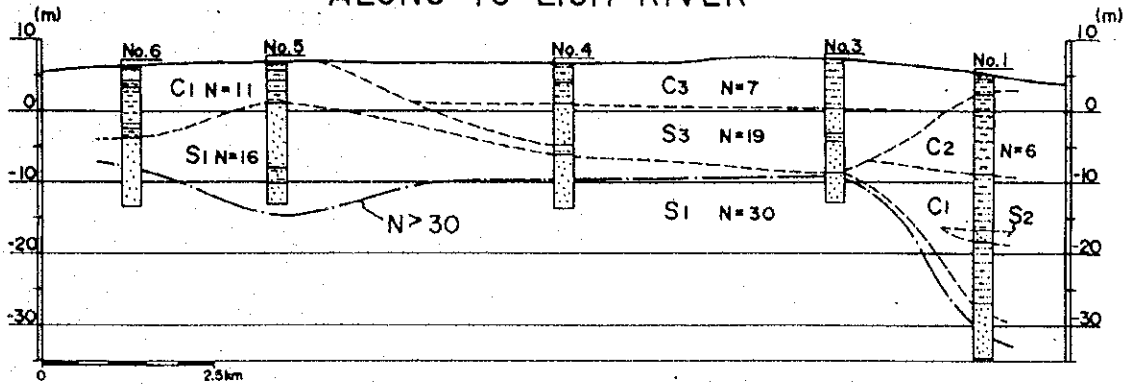
*1 In charge of the overall direction to the whole system, and direction for emergency activities

SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2.3 CONCEPT OF CONTROL SYSTEM FOR DRAINAGE OF TO LICH RIVER BASIN

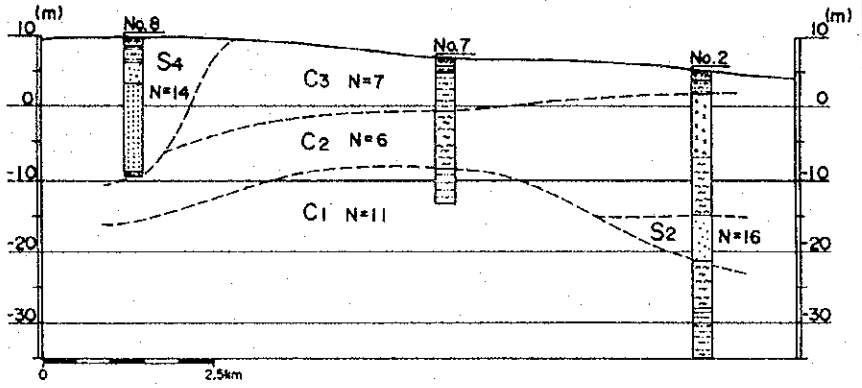


SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2.4 RESULTS OF BOD, COD & TURBIDITY SURVEY DURING DRY SEASON 1993 - 1994

ALONG TO LICH RIVER



ALONG UPPER KIM NGUU RIVER



LEGEND

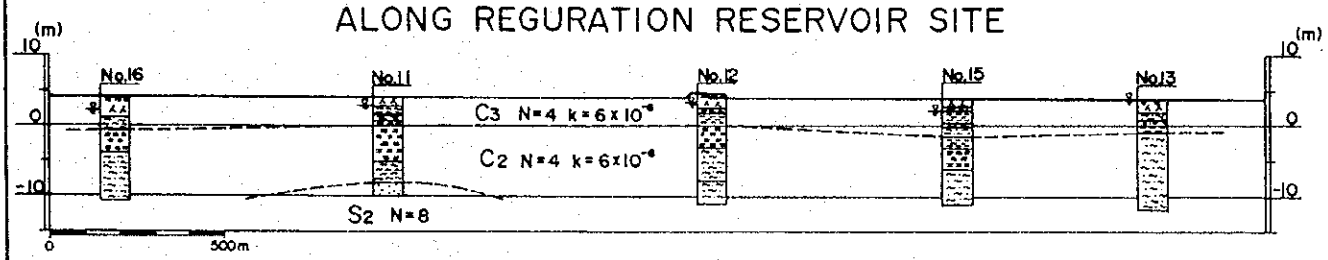
C3, C2, C1 } Clayey Layer

S4, S3, S2, S1 } Sandy Layer

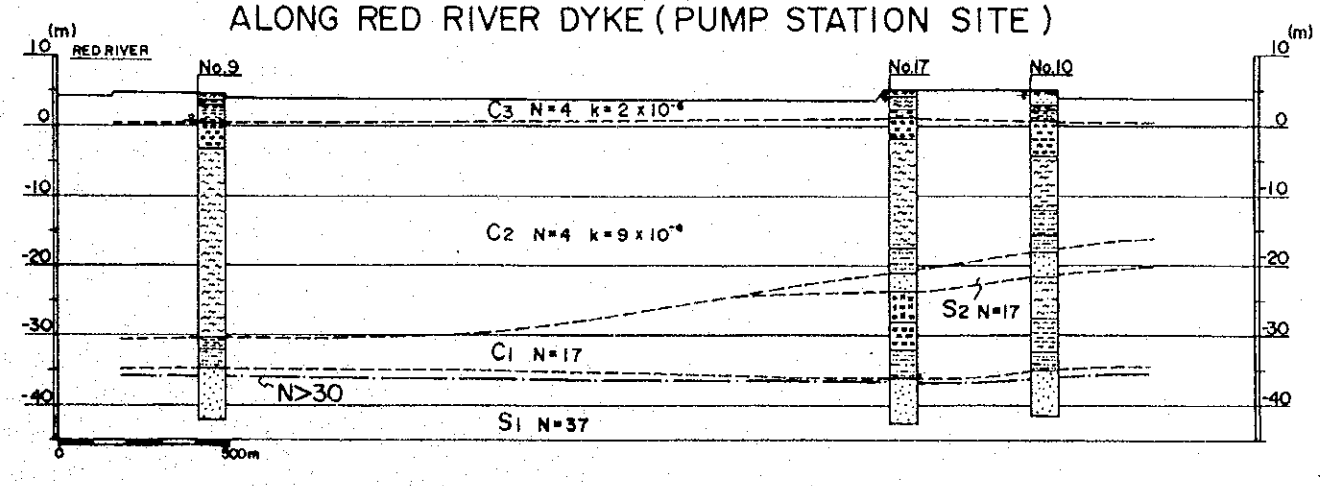
N: N-value (counts/30cm)

K: coefficient of Permeability In-situ Test (cm/s)

ALONG REGURATION RESERVOIR SITE



ALONG RED RIVER DYKE (PUMP STATION SITE)



SOCIALIST REPUBLIC OF VIET NAM THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2.5 GEOTECHNICAL PROFILES

3. PRELIMINARY DESIGN

3.1 Design of Drainage Facilities

3.1.1 Yen So Pumping Station

(1) Location of Pumping Station

Two alternative locations for the Yen So pumping station were examined: one is the original location proposed by the Vietnamese side, and the other is a new site approximately 1.5 km south of the original location. However, the study has verified the advantage of the original plan for the following reasons:

(a) A bearing layer for the structures of the pumping station is found almost at the same elevation of -37 m in both locations;

(b) The outlet channel for the original location can be aligned to an existing channel, while that for the new site should pass through part of a village; and

(c) The original location has already been approved by HPC.

(2) Inlet and Ordinary Drainage Channels

In principle, floodwaters will be conveyed to the Yen So pumping station through the regulating reservoir, not directly from the river system. For this purpose, an inlet channel is provided from the reservoir to the pumping station. This layout has the following advantages:

(a) By operating pumps, the water stage of the reservoir, before floods, can be drawn down lower than the river water stage to ensure a larger flood control water depth; and

(b) A large regulating reservoir stabilizes the pump operation.

On the other hand, when the Thanh Liet floodgate is closed due to high levels of the Nhue river, all drainage water, including wastewater from the city area, comes to the Yen So site. It is not recommended that the reservoir receives this contaminated water because:

(a) The reservoir will be used for recreation and fishery, requiring very good water quality; and

(b) The water quality at the beginning of a flood is particularly bad.

Hence, the provision of an ordinary drainage channel directly connecting the river system to the pumping station is proposed to keep the water quality of the reservoir as clean as possible. (Refer to Figure 3.1.)

(3) Outlet Channel

An outlet channel will be constructed outside the Red River levee to produce a flow rate of 90 m^3/s. It is noted that there is a local levee, with an approximate

elevation of 11.0 m (about 3 m lower than the main levee), protecting a village from the Red River's medium-scale floods. Therefore, the outlet channel should be provided with embankments on both sides whose crest elevations are approximately 11.5 m (higher than the local levee), to prevent overflow.

(4) Operation of Pumps, Reservoir and Floodgate

Figure 3.2 shows the operation of pumps of the Yen So pumping station, the Yen So regulating reservoir, and the Thanh Liet floodgate for the design flood. The following table shows the simulated annual operation of the pumps, the reservoir, and the Thanh Liet floodgate taking the year 1989 as an example.

Item	Days/Volume
Duration of Operation	
(a) Gate closure and pump operation	45 days
(b) Use of reservoir	24 days
Water Volume to be Drained	
(a) Pump drainage	
- Through ordinary drainage channel	50 x 10^6 m^3 (17%)
- Through reservoir	63 x 10^6 m^3 (21%)
Sub-total of (a)	113 x 10^6 m^3 (38%)
(b) Natural drainage through the Thanh Liet floodgate	181 x 10^6 m^3 (62%)
(c) Total	294 x 10^6 m^3 (100%)

(5) Power Source and Type of Pumps

The following table shows the alternative types of pumps in accordance with the power source applicable to the Yen So pumping station:

Power Source	Pump Type	
	Mixed Flow Horizontal Shaft Traditional Pump	Submergible Pump
Engine Drive	Alternative 1 (9 m^3/s x 10 units)	—
Motor Drive	Alternative (9 m^3/s x 10 units)	Alternative 3 (3 m^3/s x 30 units)

A comparison of Alternatives 1 to 3 is made in Table 3.1. As shown in the tables, the submergible pumps should be recommended for the Project as they are economical, and construction is relatively simple and quick. However, the final selection of the pump type will be made in the detailed design stage.

3.1.2 Yen So Regulating Reservoir

(1) The Re-routing of the Kim Nguu River Course

The existing Kim Nguu river course is proposed to be re-routed alongside the northern and western perimeter of the Yen So regulating reservoir (see Figure 3.1) in order to:

(a) save construction costs by avoiding the need of a 200 m long siphon structure which would be required at the intersection of the existing Kim Nguu river and the proposed inlet channel ;

(b) reduce the total length of the separating levees required between the river courses and the reservoir (from 5.0 km to 3.4 km); and

(c) assure ease of construction.

(2) Spillways

Spillways will be constructed on the separating levee at three locations, with lengths of 65 m, 50 m, and 50 m, respectively where the To Lich (Lower Kim Nguu), Set, and Upper Kim Nguu rivers join the Yen So channel. The crest elevations of the spillways are all 3.0 m, using 1.0 m high rubber gates to shorten the spillway lengths. (Refer to Figures 3.1 and 3.3.) The lengths, height, and shape of the spillways should carefully be determined in the detailed design stage. For this end, it is recommended to carry out a hydraulic model test.

(3) Layout in Reservoir

The Yen So regulating reservoir is used not only for flood control, but for recreation and fishery, therefore, the design is divided into three lake portions by irregularly shaped green zones. The lakes are connected to each other by bridges, creating an aesthetic arrangement of lakes and islands.

3.1.3 The Linh Dam and Dinh Cong Lakes

The Linh Dam and Dinh Cong lakes are intended to be excavated to complement the regulation function of the Yen So reservoir. This idea definitely requires two new channels to connect the Dinh Cong lake to the Linh Dam lake, and the Linh Dam lake to the Yen So site, resulting in a change of flow direction for the Lower Lu river basin (4.33 km^2). Presently this is discharged to the To Lich river, but in this plan, it will be discharged to the Yen So site directly. The major dimensions of the two lakes are tabulated below:

Item		Linh Dam Lake	Dinh Cong Lake
Area	(ha)	107	25
Bottom Elevation	(EL. m)	2.5	2.5
Normal Water Level	(EL. m)	3.5	3.5
High Water Level	(EL. m)	4.5	4.5
Flood Control Volume	(m^3)	1,070,000	250,000

3.1.4 Floodgates and Control Gates

Seven floodgates and control gates will be re-constructed or newly constructed for the Project. Their features are presented in Table 3.2.

3.1.5 River and Drainage Channel Improvement

(1) Alignment

The proposed courses of rivers and drainage channels are aligned to the existing ones with the exception of several modifications of extreme bendings. Plans of the rivers and drainage channels are shown in Figure 3.4.

(2) Profile

In principle, the high water levels in the urbanized area are designed to be slightly lower than (at least approximately equal to) the both side's ground elevations to prevent any water stagnation in the basin. However, in the downstream stretches (suburban area), the high water levels exceed the ground elevations by about 0.5 m as the Yen So reservoir temporarily stores floodwater of up to EL. 4.5 m. This may only cause limited damage to the fishponds and agricultural lands on both sides. The freeboards of dikes are 0.6 m in the backwater stretches and 0.3 m in the others.

(3) Determination of Flow Section

The flow section of each river or channel stretch is determined using Manning's uniform flow calculation formula with roughness coefficients of 0.030 and 0.025 for earth-made and reveted channels.

(4) Maintenance Roads

To facilitate maintenance, patrols, and repair work, roads are provided on either bank of the rivers and drainage channels. These roads will also be useful during the construction work. The effective widths are as follows:

(a) Rivers : 3 m on both side
(b) Drainage channels : 3 m and 1.5 m

3.1.6 Lake Improvement

(1) Lake Dredging

18 major lakes in the city area will be dredged in the Project to regulate floodwaters, and also to enhance the environment around the lakes. The dimensions of the works are listed in Table 3.3.

(2) Lake Conservation

For the other eleven (11) environmentally valuable lakes in the city area, the following conservation measures will be carried out in the Project:

(a) Excavation of sludge on the lake bottoms;
(b) Provision of riprap for protection of the slopes and prevention of house encroachment;
(c) Environmental measures; and
(d) Aeration of water in selected lakes.

3.1.7 Sewer Rehabilitation and Construction

(1) Existing Combined Sewer System

The existing combined sewer system in the urban area is shown in Figure 3.5. The results of a hydraulic calculation for sewers show almost all trunk sewers as not having the capacity to cope with rainfall of a 5-year return period. In particular, the sewers in the old city area which were built before 1954, cannot cope with the stormwater of a one-year return period.

(2) Proposed Sewer Rehabilitation and Construction

The proposed works are an augmentation of the existing sewer capacity and the addition of new sewer pipes in selected areas where flooding is habitual and urgent improvement is evident. The layout plan of the sewer rehabilitation and construction is shown in Figure 3.6, consisting of W1 of the West lake basin, K1 of the Kim Nguu river basin, S1 of the Set river basin, and L1 of Upper Lu river basin, totaling an area of 1,053 ha.

3.2 Supply of Dredging Equipment

This Supply of Dredging Equipment refers to the Urgent Project studied in the Master Plan. All the study results therein also apply to this Feasibility Study.

3.3 Aeration Plan for City Lakes

3.3.1 Selection of Target Lakes

Table 3.4 was prepared to evaluate the eligibility of nine lakes as pilot lakes. The higher the total points in the table, the higher the priority. The lakes that are given higher priorities are Thuen Quang, Bay Mau, Thanh Cong, Ba Mau, and Thanh Nhan-1. The lake Bay Mau is excluded because it is too large for a pilot lake. Consequently, the first choice will be Thuen Quang, and the second Thanh Cong.

3.3.2 Improvement of Selected Two Lakes

There are several tectonics used to improve the quality of lake water, but the most effective and economical improvement methods should be adopted for the pilot lakes. One method is to remove suspended solids including phytoplankton from the lake water through coagulation and sedimentation. The other is to prevent the excessive increase of phytoplankton and to stop the dissolution of nutrients from the mud on the lake bottom.

(1) Improvement of Thuen Quang Lake

One of the above two methods will be applied to the lake Thuen Quang to improve its condition. However, a conceptual design ad cost estimate will be prepared for both methods.

(a) Description of Lake

Area	:	5.0 ha
Water Depth	:	3.5 m
Volume	:	175,000 m^3

(b) Coagulation and Sedimentation Facilities

- Facilities

Sewage and lake water are taken into a tank, as shown in the figure, then neutralizer, coagulant and organic flocculent are added by a pump to flocculate the suspended solid in the water. After that, the sludge settles by sedimentation in a settlement pond. Clean supernatant will be returned to the lake.

- Purification effect

The removal of phytoplankton produced in the lake. Because phytoplankton absorbs nitrogen and phosphate that flow into lakes, removal of the plankton indirectly cleans the water. The organic pollutants in the inflowing sewage generally adhere to the suspended solid. Therefore, removal of the suspended solid eventually removes the organic pollutants from sewage.

(c) Aeration Facility

- Facilities

Three floating aerators will be constructed in the pond, and the surface water will be aerated.

- Purification effect

Neutralization of lake water;

Reduction of BOD and COD (oxidation of organic matters by O_2 of aeration);

Homogenization of DO content;

Destruction of plankton cells;

Prevention of the growth of plankton by stirring the lake water;

Prevention of the dissolution of nutrients from the lake bed helped by the DO supply;

Improvement of fish habitat;

Prevention of odor; and

Improvement of outlook.

(2) Purification of Thanh Cong Lake

This lake is also located in Hanoi city. The description of the lake is as follows.

Area	:	6.8 ha
Depth	:	2.0m
Volume	:	136,000 m^3

The aeration method explained in the previous item (1) will also be applied to this lake.

Table 3.1 SUMMARY OF COMPARISON ON POWER SOURCE AND TYPE OF PUMPS

Item		Alternative 1: Engine-drive mixed-flow horizontal-shaft pump (9 m3/s x 10 units; 2,000 mm dia.)	Alternative 2: Motor-drive mixed-flow horizontal-shaft pump (9 m3/s x 10 units; 2,000 mm dia.)	Alternative 3: Submergible pump (3 m3/s x 30 units; 1,200 mm dia.)
Pumping Station		80 m wide x 35 m long = 2,800 m2 (Foundation work is costly due to weight, and requirement of accuracy of the machinery.)	80 m wide x 30 m long = 2,400 m2 (Foundation work is costly due to weight, and requirement of accuracy of the machinery.)	120 m wide x 20 m long = 2,400 m2 (Foundation work is comparatively cheap.)
Building		Besides an operations building, a pump shed nearly 10 m high is necessary for the pumping station.	Besides an operations building, a pump shed nearly 10 m high is necessary for the pumping station.	Only an operations building is necessary.
Mechanical and Electrical Work	Applicability to Ordinary Drainage	Not good	Sophisticated operations are necessary for the volumetric control of the pump.	Easy, because of a large number of small pumps.
	Safety against Power Interruption	No problem	Power supply at Mai Dong substation 2.5 km away from the pumping station is stable. Moreover, a 50% capacity emergency generator system will be installed. There is no danger of power interruption.	
	Operation	In addition to the description for Alternative 2, noise and vibration are expected with the pump operation.	Vacuum pump operation is inevitable prior to starting the main pumps.	Easy
	Maintenance	Frequent repair work is expected, entailing high maintenance cost.	Easy	Repairing the insulation devices is difficult on site, hence space pumps will be provided.
Cost ($ 1,000)	Initial Cost	55,300	51,400	43,600
	Oil/Electricity Charge	3,900	2,300	2,300
	Total	59,200	53,700	45,900
Construction Period		Rather long	Rather long	Short
Judgement		---	---	Recommended

Table 3.2 FLOODGATES AND CONTROL GATES

Name	Location	Purpose	Design Discharge (m3/s)	Dimensions	Gate Type
1. Thanh Liet Floodgate	T 0.4 K	To prevent backwater from the Nhue River and to secure natural drainage to the river.	45	12 m wide x 7 m high x 2 gates	Steel roller gate
2. Hoa Binh Floodgate	K 1.1 K	To prevent backwater through the Hoa Binh channel, and to secure irrigation water to the channel.	—	5 m wide x 3 m high	- do -
3. Van Dien Floodgate	K 3.7 K	To prevent backwater through the Old To Lich River, and to secure irrigation water to the river.	—	5 m wide x 3 m high	- do -
4. West Lake Control Gate (A)	T 14.6 K	To contain floodwater from the basin, and to release the water after the flood.	12	4 m wide x 3 m high x 2 gates	- do -
5. West Lake Control Gate (B)	West bank of West Lake	To contain floodwater from the basin, and to secure irrigation water to the downstream reaches.	—	3 m wide x 3 m high	- do -
6. Lu River Control Gate	L 3.2 K	To divert floodwaters toward the Lu-Set floodway, and to release maintenance water to the Lower Lu river when necessary.	—	3 m wide x 3 m high	- do -
7. Nghia Do Control Gate	T3.A Drainage Channel 1.6 K	To prevent backwater from the Nhue River basin, and to intake irrigation water from the basin.	—	3 m wide x 3 m high	- do -

Table 3.3 LAKE IMPROVEMENT

Lake No.	Lake Name	Area (ha)	Perimeter (km)	Low Water Level in Rainy Season EL (m) Present	Low Water Level in Rainy Season EL (m) Proposed	Ground Level EL (m)	Dimensions of Dredging Depth *1 (m)	Dimensions of Dredging Volume (1,000 m3)	Proposed Type of Improv-ment	Characteristics Flood Control Effect	Characteristics Quality of Environment Surrounding	Characteristics Accessability	Characteristics Recent Dredging by HPC
T 7	Giang Vo	8.4	1.1	5.5	3.5	6.2	2.0	168	A	Large	High	Easy	
T 8	Ngoc Khanh	4.5	0.9	5.1	3.5	5.9	1.6	72	B	Medium	Medium	Easy in future	X
T 9	Thanh Cong	6.5	1.2	4.9	3.5	6.0	1.4	91	A	Medium	High	Easy	X
T10	Hao Nam	2.8	0.5	5.2	3.5	5.8	1.7	48	B	Small	Low	Easy	
T13	Dong Da	18.6	1.8	4.7	3.5	5.6	1.2	223	B	Large	High	Possible	
T16	Nghia Do 1	5.2	0.8	5.0	3.5	6.2	1.5	78	A	Medium	High	Easy	X
L 3	Van Chuong	4.1	0.8	5.2	3.5	5.7	1.7	70	B	Medium	Low	Easy	
L 4	Tho Quang	1.5	0.6	5.3	3.5	5.6	1.8	27	B	Small	Low	Hard	
L 6	Trung Tu	5.1	0.9	4.9	3.5	5.9	1.4	71	B	Medium	High *2	Easy	
L11	Phuong Liet 1	5.6	1.2	4.5	3.5	5.3	1.0	56	C	Medium	Medium	Hard	
L12	Phuong Liet 2	1.9	0.6	4.5	3.5	5.2	1.0	19	C	Small	Low	Easy	
S 2	Bay Mau	23.1	2.0	5.0	3.5	5.9	1.5	347	A	Large	High	Easy	X
S 4	Trai Ca	4.7	1.1	4.2	3.5	5.4	0.7	33	C	Medium	Low	Hard	
S 5	Lang Tam	1.9	0.9	4.5	3.5	5.4	1.0	19	C	Small	Low	Hard	
S 7	Thanh Liet	13.2	1.4	4.3	3.5	5.0	0.8	106	C	Large	Low	Hard	
S 8	Dam Set	3.6	0.6	4.0	3.5	5.0	0.5	18	C	Small	Low	Hard	
K 3	Thanh Nhan 1	8.5	1.2	4.7	3.5	6.2	1.2	102	A	Large	Medium	Easy	
K 4	Thanh Nhan 2	4.0	0.8	4.7	3.5	6.2	1.2	48	B	Medium	Medium	Easy	
	Total	123.2	18.4	--	--	--	--	1,596	--	--	--	--	4

*1 Dredging will be done by the depth corresponding to the balance between the present and proposed normal water levels that aims to conserve the present lake use and environments.

*2 The lake is separated from the drainage channel whose water quality is badly polluted, so that connection between them for flood control purpose is not recommended presently.

Table 3.4 COMPARISON OF LAKES

Lake Name	①	②	③	④	⑤	⑥	Total
S-1 Thuen Quang	3	2	3	3	1	2	14
T-4 Thu Le	1	1	1	3	1	3	10
S-2 Bay Mau	1	3	3	3	2	2	14
L-5 Ba Mau	3	2	3	1	1	2	12
T-9 Thanh Cong	2	2	2	3	2	2	13
T-16 Nahia Do	2	2	1	1	2	3	11
K-3 Thanh Nhan-1	2	2	2	2	1	3	12
K-2 Hy Ba Trung	3	2	2	2	1	1	11
T-7 Gian Vo	3	2	2	2	1	1	11

① Area : 3 ($\leq$ 5ha), 2 (5 ~ 10 ha), 1 ($\geq$ 10 ha)

② Level of Contamination : 3 (Heavy), 2 (Moderate), 1 (Light)

③ Distance from Center of City :
3 (Near Center), 2 (Middle Distance),
1 (Long Distance)

④ Utilization Level for Recreation : 3 (High), 2 (Middle), 1 (Low)

⑤ Dredging : 2 (Finished), 1 (Not Finished)

⑥ Recommended by Departments of Civil Engineer and/or HSDC and/or Study Team:
3 (Recommended by the three),
2 (Recommended by one department and Study Team),
1 (Recommended by Study Team only)