JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

HANOI PEOPLE'S COMMITTEE
THE SOCIALIST REPUBLIC OF VIET NAM

THE STUDY
ON
HANOI WATER SUPPLY SYSTEMS
IN
THE SOCIALIST REPUBLIC OF VIET NAM

FINAL REPORT

MAIN REPORT

OCTOBER 1997

PACIFIC CONSULTANTS INTERNATIONAL
HOKKAIDO ENGINEERING CONSULTANTS CO., LTD.

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ESTIMATE OF PROJECT COST

Estimate of Base Cost : At 1997 Price Level

Currency Exchange Rate : US$ 1 = Dong 11,000

PREFACE

In response to the request from the Government of the Socialist Republic of Viet Nam, the Government of Japan decided to conduct the Study on Hanoi Water Supply Systems in the Socialist Republic of Viet Nam and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Viet Nam a study team headed by Mr. Toshifumi Okaga, Pacific Consultants International (PCI) and associated with Hokkaido Engineering Consultants, Co. Ltd. three times between March 1996 to August 1997.

The team held discussions with the officials concerned of the Government of Viet Nam, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Socialist Republic of Viet Nam for their close cooperation extended to the team.

October 1997

Kimio Fujita
President
Japan International Cooperation Agency

THE STUDY
ON
HANOI WATER SUPPLY SYSTEMS
IN
THE SOCIALIST REPUBLIC OF VIET NAM

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Mr. Kimio FUJITA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit the final report entitled the "The Study on Hanoi Water Supply Systems in The Socialist Republic of Viet Nam." This report has been prepared by the Study Team in accordance with the contract signed on February 16, 1996, November 27, 1996 and April 24, 1997 between the Japan International Cooperation Agency and Pacific Consultants International in associate with Hokkaido Engineering Consultants Co., Ltd..

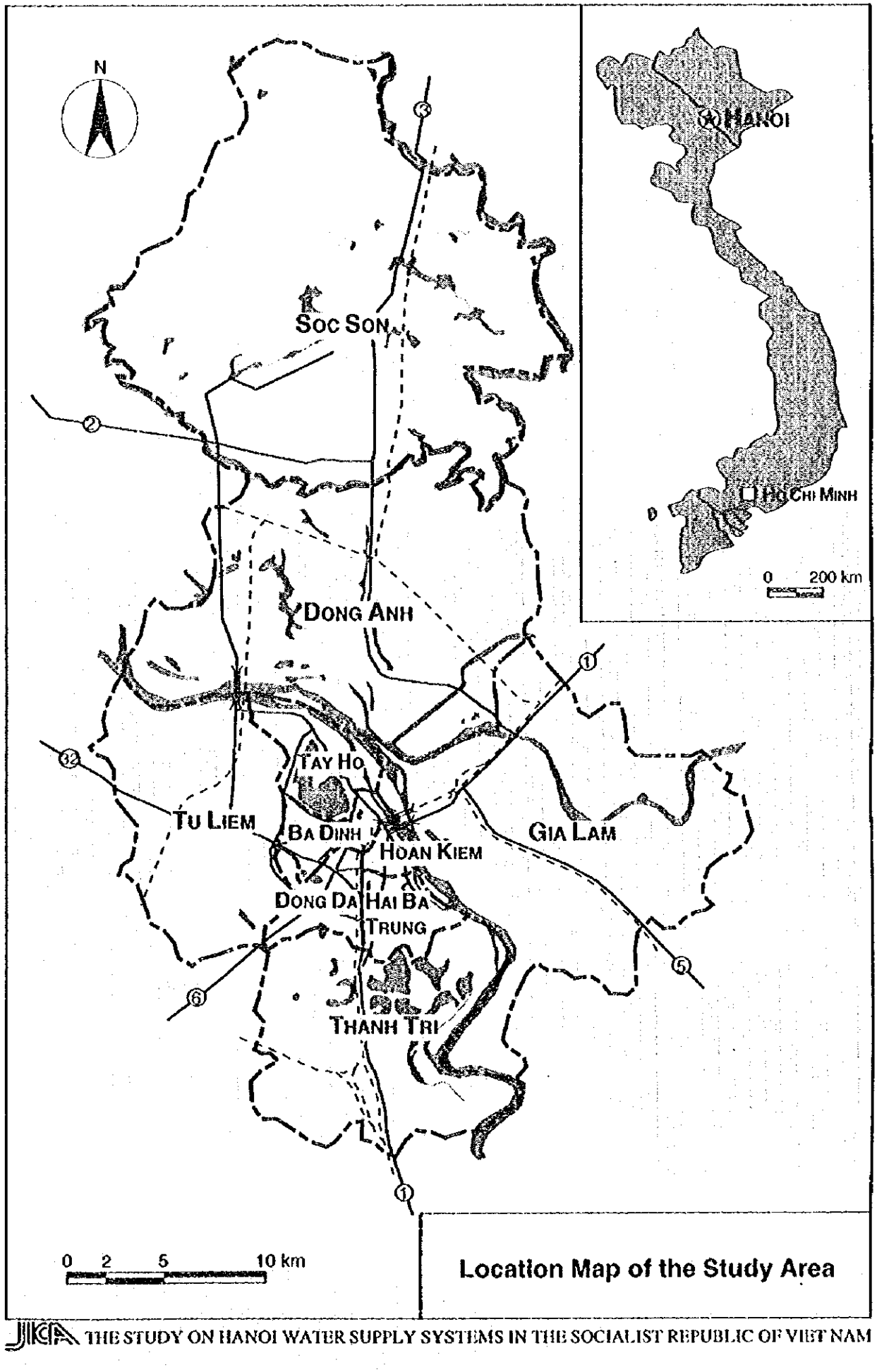
The report consists of the Executive Summary, Main Report, Supporting Report and Data Book. The Executive Summary summarizes the results of all studies. The Main Report presents the results of the whole study including analysis of existing conditions, study of water resources management, improvement plan of the existing facilities and the extension plan of the facilities, formulation of the water supply master plan and the feasibility study for the priority projects.

The Supporting Report describes in detail the technical aspects of the entire study. In addition, the Data Book has been prepared and submitted herewith. All members of the Study Team wish to express sincere appreciation to the personnel of your Agency, Advisory Committee, and Embassy of Japan in Viet Nam, and also to the officials and individuals of the Government of the Social Republic of Viet Nam for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the water supply systems and the socio-economic development in Hanoi.

Yours Faithfully

岡賀敏文

Toshifumi OKAGA
Team Leader of the Study Team



Location Map of the Study Area

SUMMARY

1 BACKGROUND

Hanoi is located in the upper stream of the Red River Delta. The city area including five suburban districts is 924.5 km² with a population of about 2,394,887 (1995). The city is undergoing rapid urbanization with high population growth rate in recent years. However, it is rather undeniable that the city virtually lacks environmentally and sanitarily acceptable water supply systems to meet its urbanization and growth of population.

With regard to the water supply system covering the urban districts, improvement and extension of the system have been implemented under the Hanoi Water Supply Project (FINNIDA assistance) since 1985 . The project has made continuous efforts for improving the Hanoi water supply over a decade.

In 1993 the project formulated a water supply master plan toward 2010, which covered only the urban districts.

In consideration of recent urbanization and foreign investments, Hanoi needs a more comprehensive water supply master plan covering the whole area of Hanoi city including the estranged suburban districts.

With this background, the Study on Hanoi Water Supply Systems was undertaken by Japan International Cooperation Agency responding to the request made by the Government of Vietnam.

The Study Area covers the whole Hanoi area. It is shown in Location Map.

The objectives of the study are :

A. To establish an overall and strategic master plan covering the whole Hanoi city area with the planning target year 2010.
B. To conduct a feasibility study for the priority projects identified in the Master Plan.
C. To conduct technology transfer to the Vietnamese counterpart personnel.

2 SUMMARY OF ISSUES

(1) Rate of Population Served

In the core of Hanoi City and its outskirts, at present, the rate of population served is as high as nearly 100%. On the other hand, however, in its suburban area, the rate is still low at approximately 14%. The rate of population served in the entire Hanoi city is estimated at 53% on an average.

Many people in non-piped water service areas desire clean and sufficient water conveniently supplied by piped water system. People in these areas get water from poor water sources such as shallow wells, rain water, irrigation ponds or channels. Their water consumption is quite low.

(2) Water Sources

Laws and regulations related to the development of the groundwater are still under preparation and have not been enacted yet. At present, the decline in groundwater levels at the wellfields in the center of Hanoi area due to excessive exploitation of groundwater has been pointed out.

(3) Water Quality

The treatment practice of the treatment plants is basically appropriate to the raw water quality, except plants in Phap Van, Tuong Mai and Ha Dinh, where high concentration of ammonia (8 - 25 mg/l) presents in raw water makes the current processes inadequate for their removal.

(4) Institution and Management

A. Unaccounted-for Water

The most serious problem in the water supply system in Hanoi is the extremely high level of Unaccounted-for Water (UFW, 70% of total production capacity). Administrative cause seems to amount to 45% and it is the major part of the total UFW.

B. Poor Marketing Activities

In 1995, the ratio of employees per 1000 consumers in Hanoi recorded, 16.6 higher than that of HCMC at 6.5 and Khanh Hoa at 11.6. This shows that HWBC has too many staff.

C. Potential Conflicts of Interest in Decision Making

Potential conflicts of interest do exist because the board of directors not only perform the ownership function on behalf of HPC, but also is responsible for managing HWBC toward profit based efficiency. Under the circumstances the board of directors would face a dilemma whether water charges should be kept at an affordable level or at the level that allow the company to cover costs and make future investments.

(5) Financial Status

A. Standard Difference from IAS

Financial practice of HWBC is still apart from the International Accounting Standard (IAS). On surface, by the financial statements submitted by HWBC, historical performance of HWBC has not been that bad, however, proper accounting process has not been applied. This results in difficulties in assessment of creditworthiness of the company.

B. Insufficient Water Tariffs

Historically, water tariffs in Vietnam has been kept lower than full cost recovery level. The water tariff is cross-subsidized by non-domestic customers, however, earliest effort to raise water tariff is required.

C. Lack of Expertise

In respect of finance, lack of staff expertise in HWBC is a major concern. In order to improve financial practices to international level, much expertise should be gained by managers and clerks of Finance Department and Business Department.

3 FRAMEWORK FOR THE MASTER PLAN

3.1 STUDY AREA

The study area covers approximately 924.5 km² consisting of five urban districts and five suburban districts in Hanoi as shown in Location Map.

The urban districts and the suburban districts differ in the water supply consumption conditions due to difference in living standards. The study area is categorized into three groups as below :

Group U : The core of Hanoi and its surroundings. The area has been supplied with piped water.
Group D : The future development area and Densely Inhabited Areas (DID).
Group R : Sparsely populated areas such as agricultural farm lands.

3.2 TARGET YEAR AND GOAL

The target year of the Master Plan is the year 2010. The following are tangible contents of the target year and goal.

(1) Improvement of the Existing Facilities

In order to strengthen financial status of the waterworks, the rate of UFW be improved by 30 % from the current status of 71%.

(2) Extension Program of the Water Supply Systems

Service conditions of the water supply are formulated as below :

	Group U	Group D	Group R
Rate of Population Served	100%	100%	85%
Unit Water Demand (Domestic Use)	180 l/c/day	165 l/c/d	90 l/c/d
Service Level	House connections	House connections	Public taps

(3) Institutional Strengthening

The urban water supply systems are proposed to be operated under self-standing conditions of the waterworks.

As for the rural water supply systems, the facilities are constructed with subsidies. After construction, the systems are to be transferred to HWBC/HWBC No.2.

4 FORMULATION OF THE MASTER PLAN

The Master Plan consists of improvement of the existing facilities and the extension projects to supply water for the non-water service area.

4.1 IMPROVEMENT OF THE EXISTING FACILITIES

In order to strengthen financial status of the waterworks, the rate of UFW is to be improved gradually.

At present, there is an on-going project (the World Bank 1A project) and some actual implementation plans for water supply improvement project in Hanoi. These on-going projects targeting up to 2000 are not included in formulation of this improvement plan in future.

The improvement of UFW will be projected for future as given in Table 1.

Table 1 Improvement of UFW

Year	1996	2000	2005	2010
Physical loss (%)	25	21	16	15
Administration loss (%)	46	32	21	15
Total (%)	71	53	37	30

Based on the production water by the on-going project in 2000, the production water will be saved by 23 % with about 83,490 m^3/day of distribution water of the existing facilities from 2001 to 2010.

The improvement plans are : (a) improvement of physical loss with renovation of old pipes on the distribution pipelines, (b) water meters are to be supplied and installed to all households in the service area and (c) water bill and tariff systems are to be modified to be a new structure.

The cost for the implementation work ((a)+(b)) is estimated at US$ 7,200,000.

4.2 EXTENSION PROGRAM

4.2.1 Water Demand Forecast

The water demand forecast and the projected water capacity for extension program are shown in Table 2.

Table 2 Water Demand Forecast

Year	2000	2005	2010
1. Population served	2,587,770	2,885,325	3,183,792
2. Ave. Daily Water Demand (m^3/day)	465,528	607,360	760,284
3. Ave. Daily Distribution Water (m^3/day) (physical loss : 15%)	547,679	714,539	894,451
4. Daily Max. Distribution Water(m^3/day) (peak factor : 1.35)	715,293	932,423	1,168,981
5. Capacity of Existing Facility (m^3/day)	500,000	500,000	500,000
6. Water for Extension Program (m^3/day)	215,293	432,423	668,981

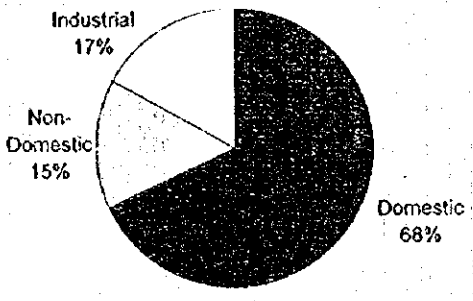
The per capita demand including all water use categories are shown in Table 3. This is an index for evaluation of the future conditions of water supply in Hanoi.

Table 3 Per Capita Water Demand

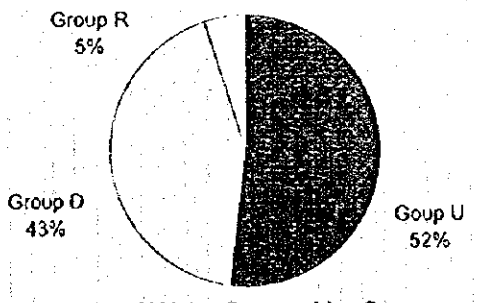
(l/c/d)

Year	2000	2005	2010
Group U (Urban area)	238	271	303
Group D (DID area)	232	279	316
Group R (Rural area)	60	75	90

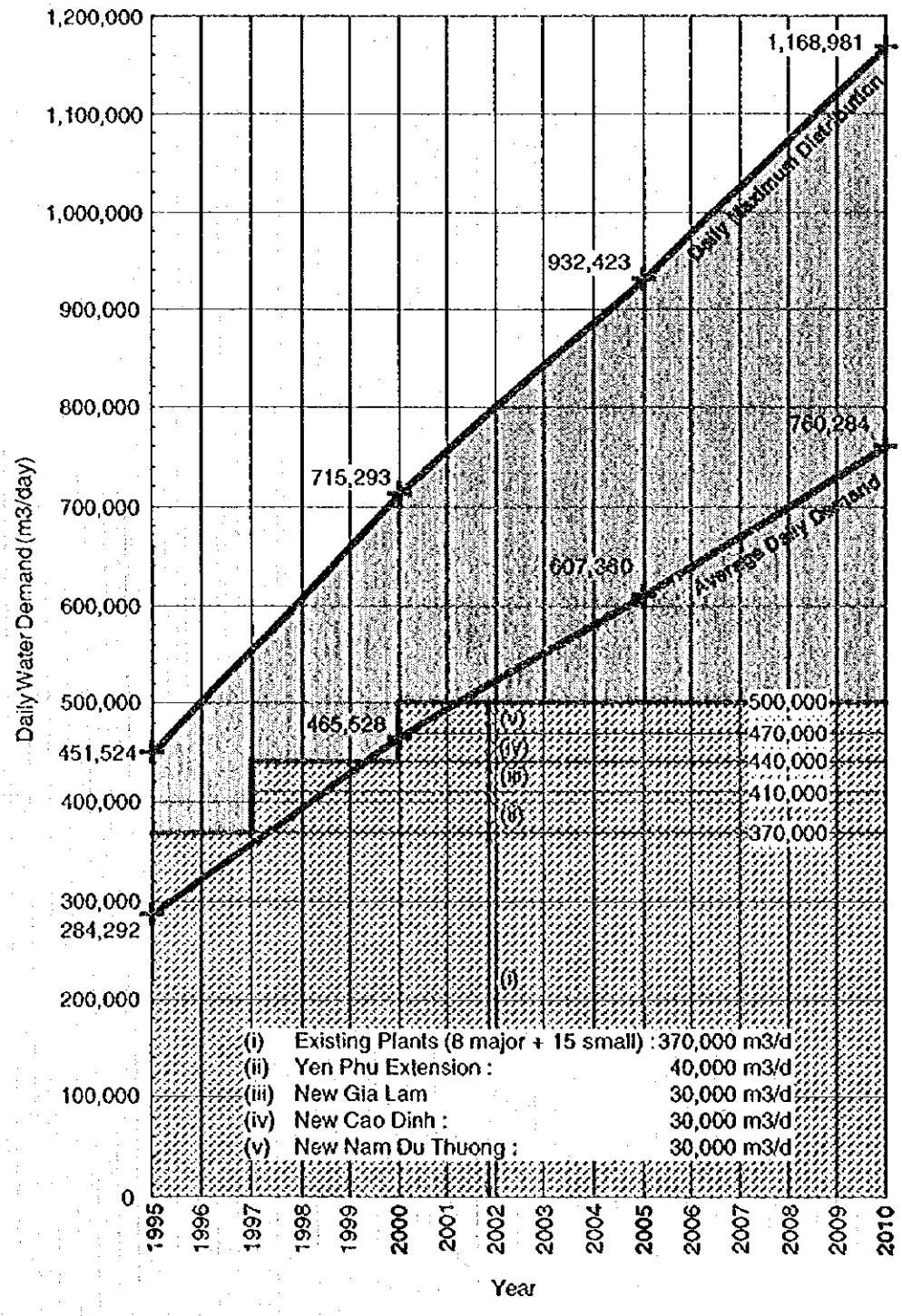
Ratio of water demand by usage and by group are presented below.



Ratio of Water Demand by Usage



Ratio of Water Demand by Group

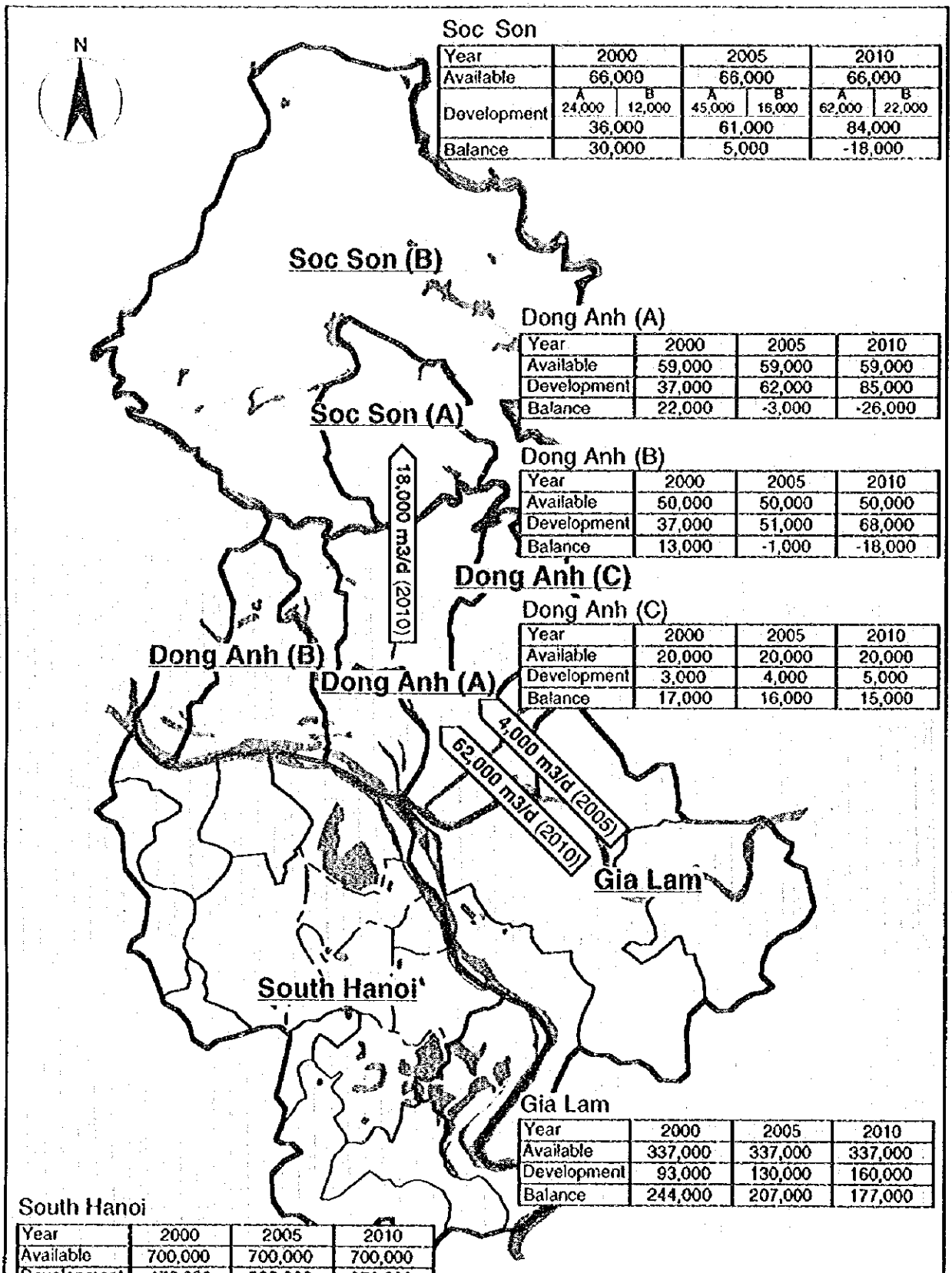


Water Demand Forecast
(Whole Hanoi City)

4.2.2 Water Sources

The available groundwater of 1,232,000 m^3/day will satisfy the demand of 1,072,000 m^3/day (including private wells) until the year 2010. Therefore, groundwater is available as the source for the water supply system in the whole area of Hanoi until the year 2010.

Although, the exploitable groundwater will meet the demand of Hanoi, some suburban districts such as Soc Son and Dong Anh may experience lack of the groundwater resources before 2010. These districts can supplement the shortage of groundwater from Gia Lam district.



Soc Son

Year	2000		2005		2010	
Available	66,000		66,000		66,000	
Development	A 24,000	B 12,000	A 45,000	B 16,000	A 62,000	B 22,000
	36,000		61,000		84,000	
Balance	30,000		5,000		-18,000	

Dong Anh (A)

Year	2000	2005	2010
Available	59,000	59,000	59,000
Development	37,000	62,000	85,000
Balance	22,000	-3,000	-26,000

Dong Anh (B)

Year	2000	2005	2010
Available	50,000	50,000	50,000
Development	37,000	51,000	68,000
Balance	13,000	-1,000	-18,000

Dong Anh (C)

Year	2000	2005	2010
Available	20,000	20,000	20,000
Development	3,000	4,000	5,000
Balance	17,000	16,000	15,000

Gia Lam

Year	2000	2005	2010
Available	337,000	337,000	337,000
Development	93,000	130,000	160,000
Balance	244,000	207,000	177,000

South Hanoi

Year	2000	2005	2010
Available	700,000	700,000	700,000
Development	478,000	569,000	670,000
Balance	222,000	131,000	30,000

Groundwater Balance & Plan of Water Source

4.2.3 Construction Plan

(1) Facilities

The facilities to be constructed include intake facilities, treatment plants, distribution facilities and networks.

The water supply system for the rural area is an independent water supply system by each commune. Treated water is to be supplied to consumers through public taps equipped with water meters. The public taps will be located within a distance of less than 100 m. Each tap will serve about 100 people.

Groundwater in Soc Son and Dong Anh may experience shortage. Groundwater of Gia Lam is planned to be transmitted to Soc Son and Dong Anh. The transmission pipeline is be constructed in year 2002 to 2003.

Construction schedule for the facilities is planned as shown in Table 4.

Table 4 Construction Schedule for the facilities

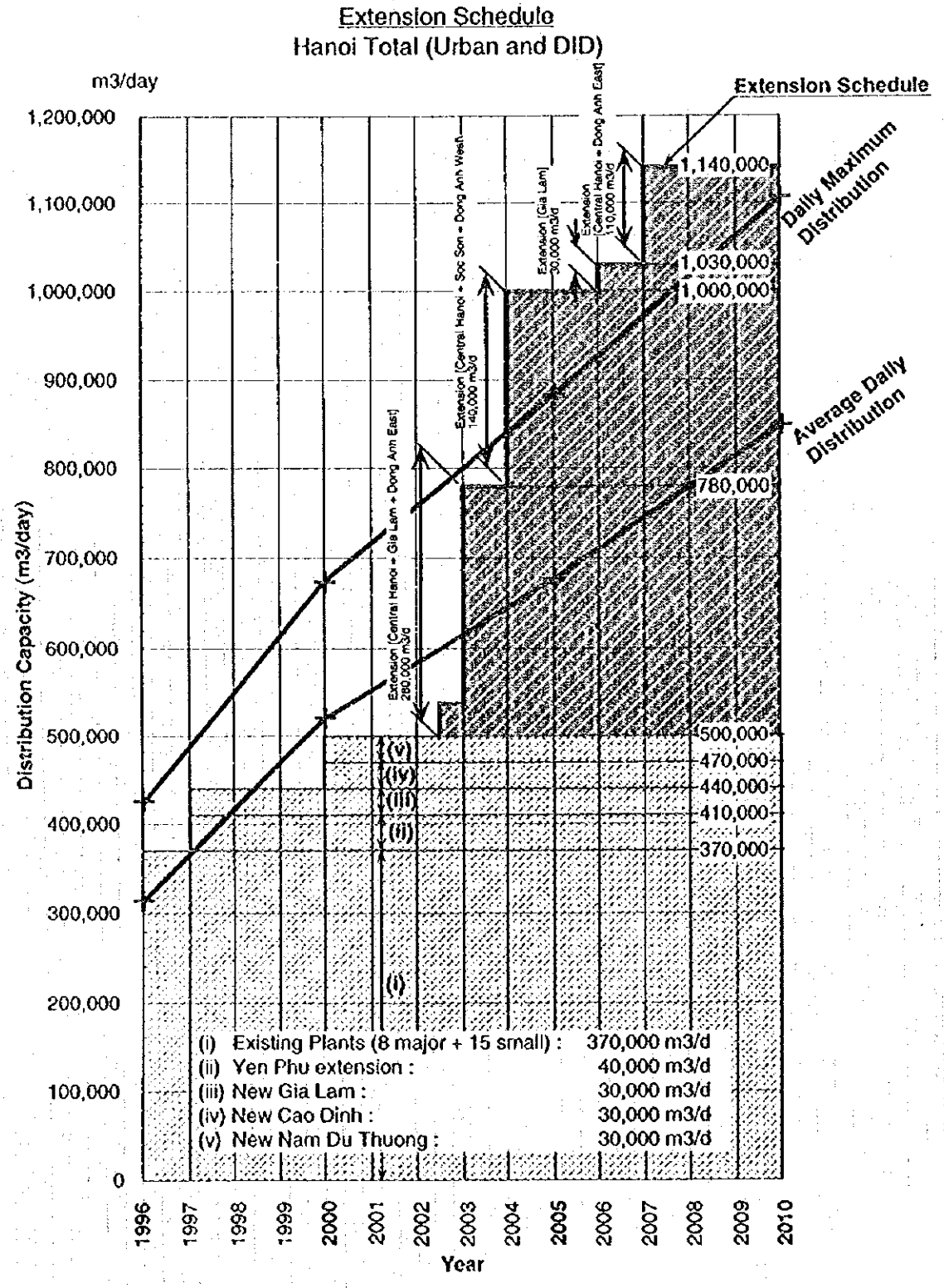
Project	Capacity of the facility till 2005 (m^3/day)	Capacity of the facility till 2010 (m^3/day)
HWBC (the south Hanoi)		
Construction of Water supply system	170,000	250,000
HWBC No.2 (the north Hanoi)		
Construction of Water supply system	330,000	390,000
Construction of the transmission main	62,000	62,000
Rural Waterworks		
Construction of Water supply system	63,600	63,600

(2) Disbursement Schedule of Construction Cost (Table 5)

Table 5 Disbursement schedule of construction cost

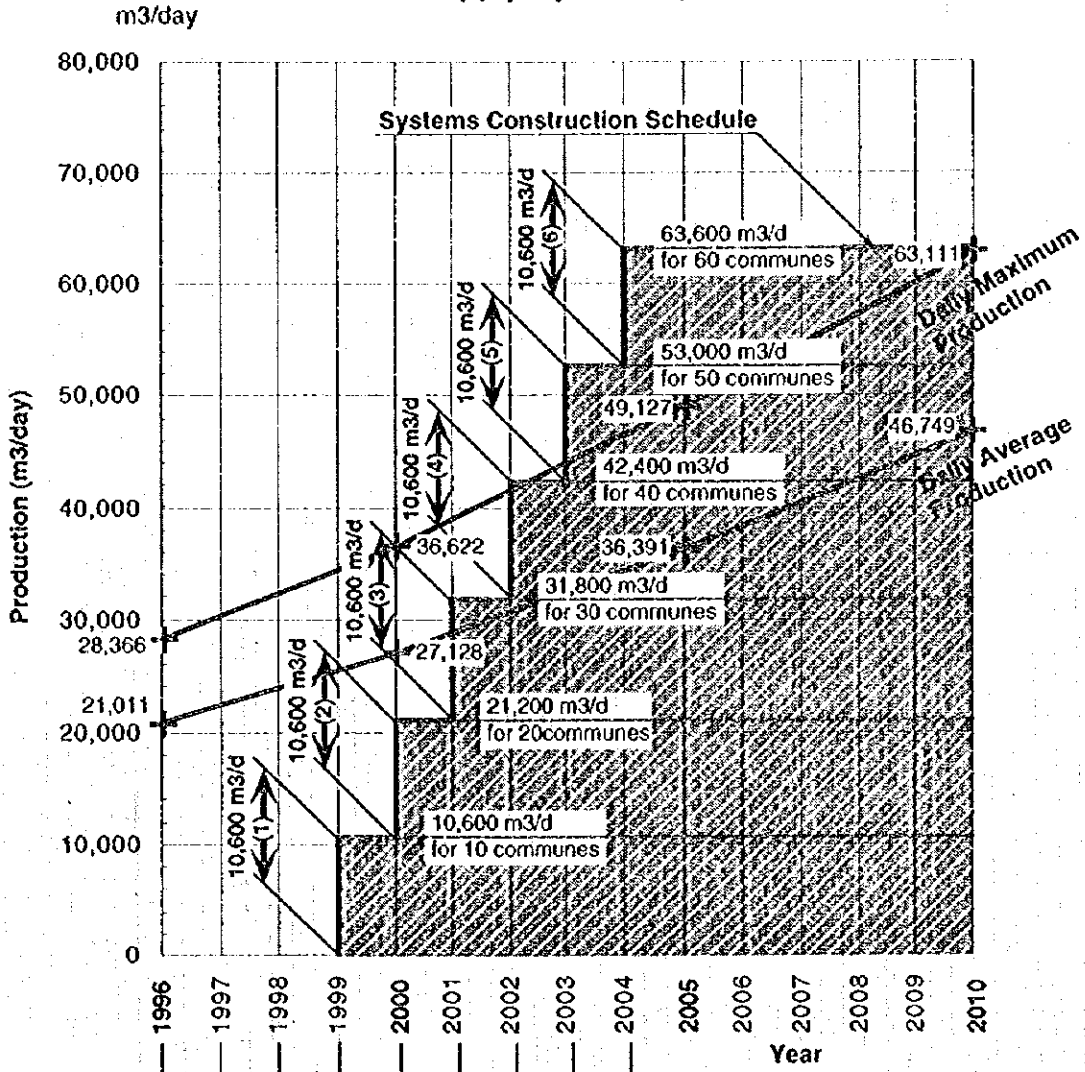
(Million US$)

Year	1999-2005	2006-2010	Total
HWBC	172	21	193
HWBC No.2	304	9	313
Rural Waterworks	33	0	33
Total	509	30	539



Extension Schedule
Hanoi Total (Urban and DID)

Construction Schedule
Rural Water Supply Systems (60 Communes)

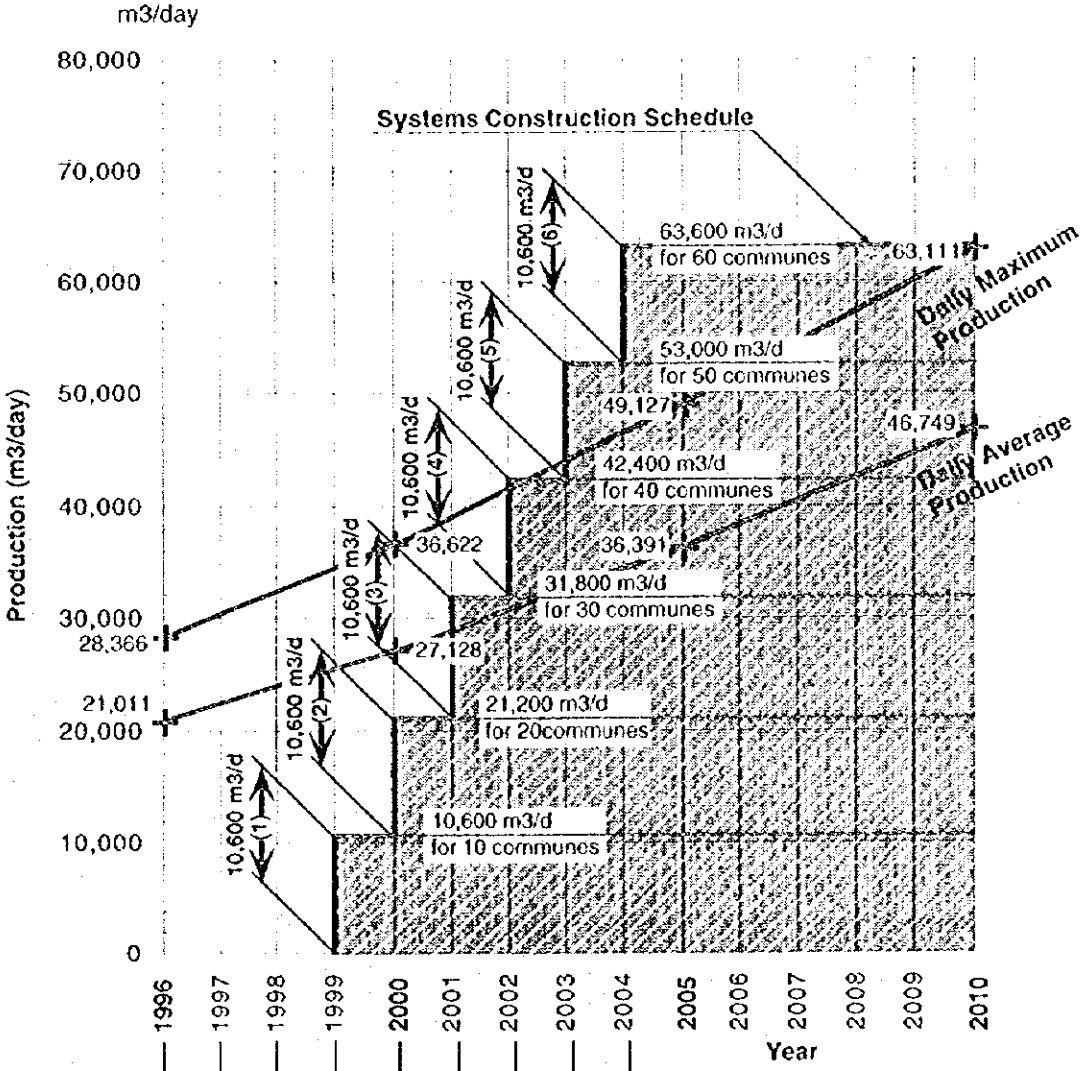


Investment Schedule

1996	0	
1997	0	
1998	(1) 10@$558,100 = for 10 communes	$5,581,000
1999	(2) 10@$558,100 = for 10 communes	$5,581,000
2000	(3) 10@$558,100 = for 10 communes	$5,581,000
2001	(4) 10@$558,100 = for 10 communes	$5,581,000
2002	(5) 10@$558,100 = for 10 communes	$5,581,000
2003	(6) 10@$558,100 = for 10 communes	$5,581,000
2004	Total (1 - 6) =	$33,486,000

Construction Schedule
Rural Water Supply Systems
(60 Communes)

Construction Schedule
Rural Water Supply Systems (60 Communes)



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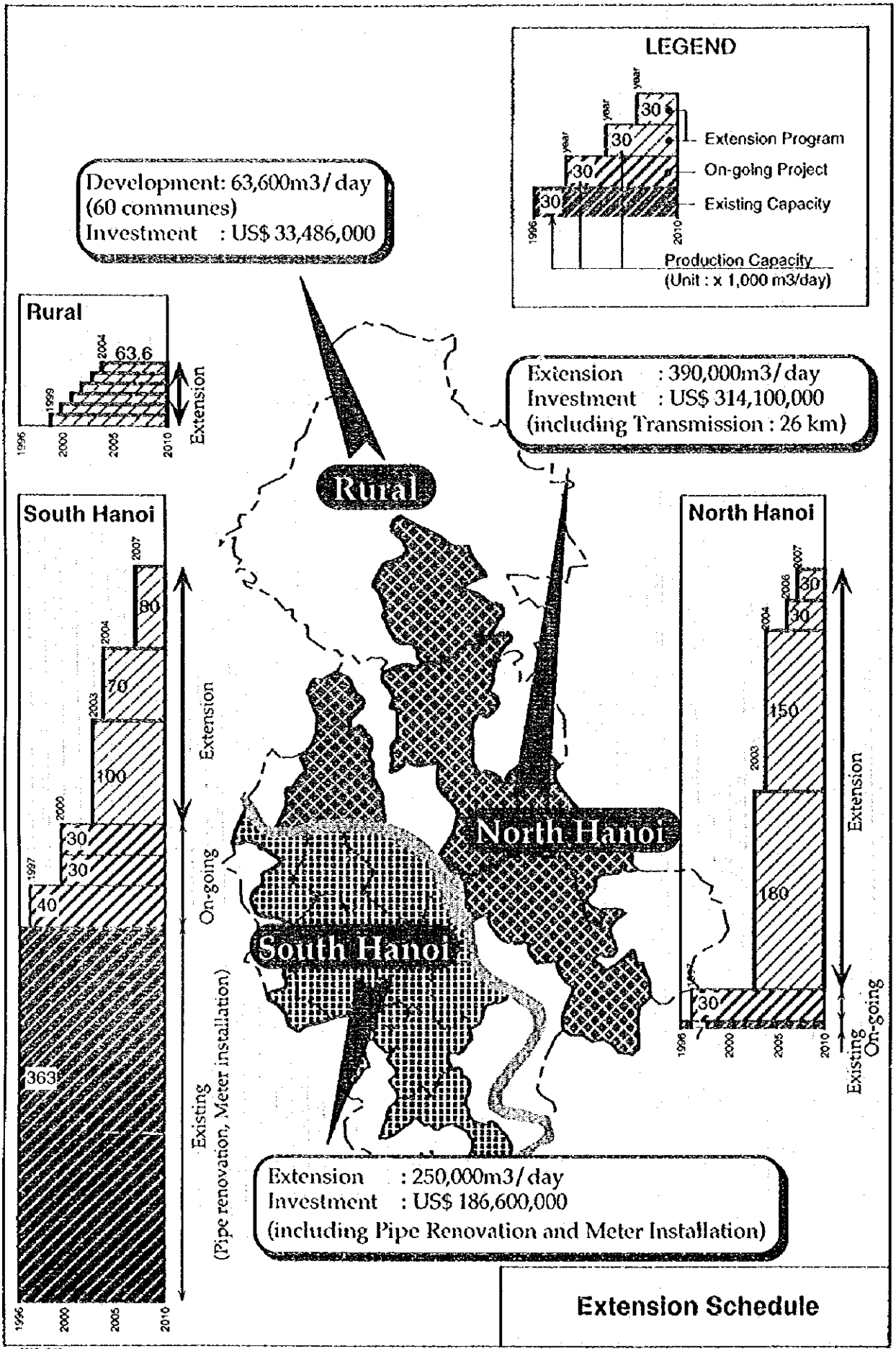
Construction Schedule
Rural Water Supply Systems
(60 Communes)



Extension Schedule

4.2.4 Financial Analysis

The financial analysis for each program is summarized in Table 6.

Table 6 Summary of Financial Analysis

	HWBC	HWBC No.2	Rural Waterworks
FIRR (%)	14.12	14.71	6.76
Breakeven Point	year 2006	year 2009	year 2018
Projected Fund Flow	quite smooth	quite smooth	smooth *1

Note : The projected fund flows statement demonstrates positive net cash positions owing to the subsidized half (1/2) of Investment cost (Construction).

Overall estimated FIRR of urban waterworks are just moderate until year 2030, but FIRR of rural waterworks is expected to be rather low of 6.7 % even with the construction cost subsidies.

Considering the present financial status of HWBC, fund raising ability in the three areas remains vulnerable at least until target year of 2010.

Estimated FIRRs are at least higher than the anticipated financing cost of 2.30%. Assumptions in the calculations are fairly conservative, like 15% administration loss even for the brand new water supply systems. Because of its primitive financial market in Vietnam, the yield curve is inverted, as such low FIRR for a long term project can be justified.

Affordability does not seem the problem according to the projection until 2010.

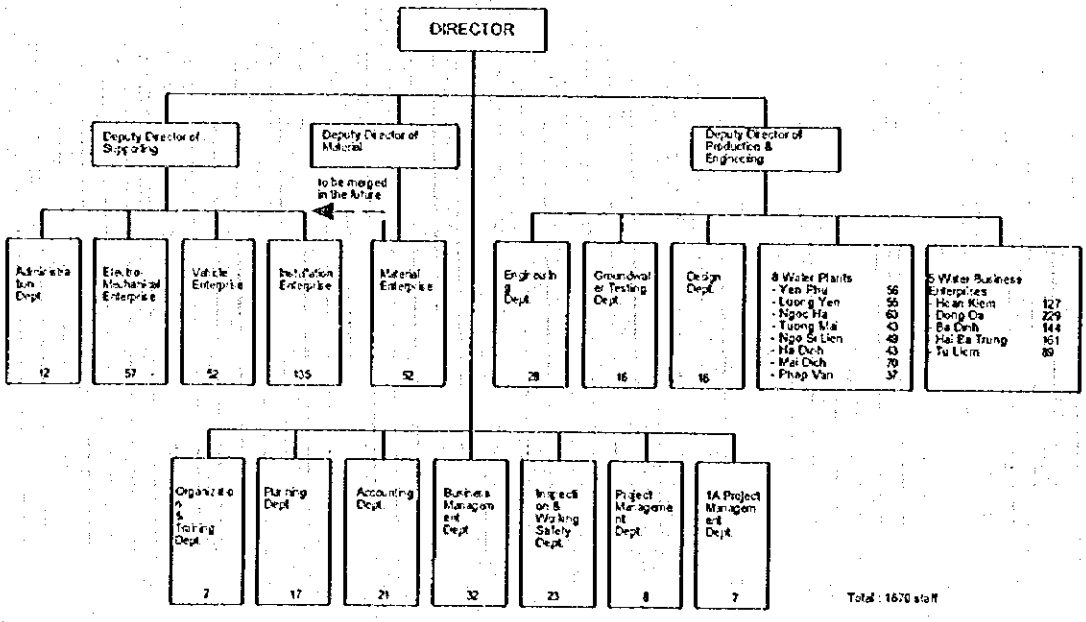
Therefore from the viewpoint of the financial aspect, the Master Plan is viable.

4.2.5 Institution and Management

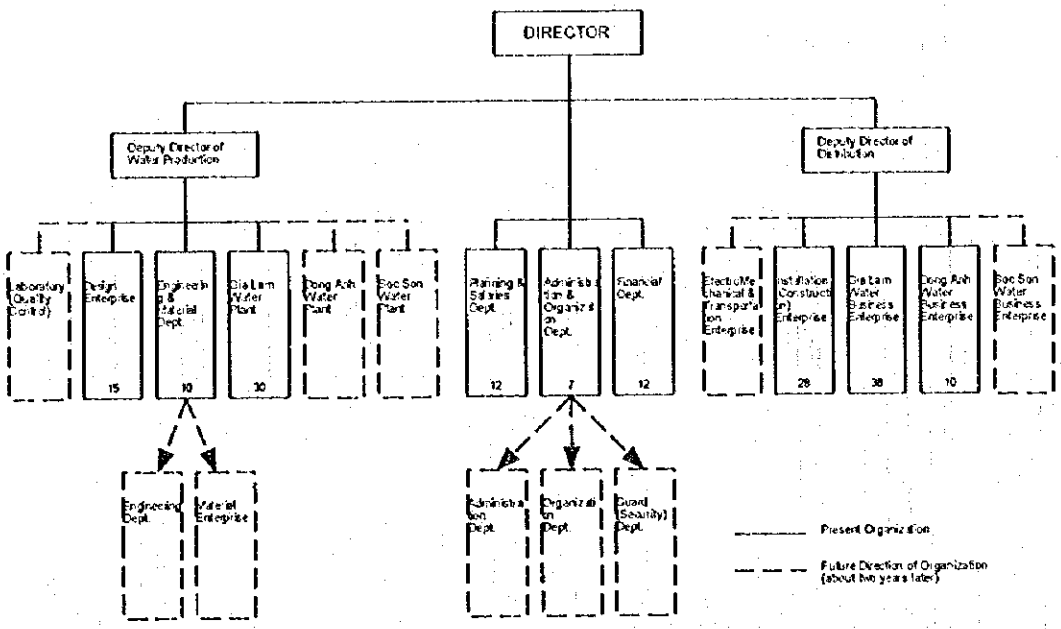
(1) Future Organizational Structure

Waterworks of Hanoi are divided by Red River as a boundary. The southern area of the Red River is administrated by the existing HWBC. The northern area (Soc Son, Dong Anh, Gia Lam) is to be administrated by HWBC No.2. As for the rural water supply for Group R, it is to be managed by HWBC/HWBC No.2.

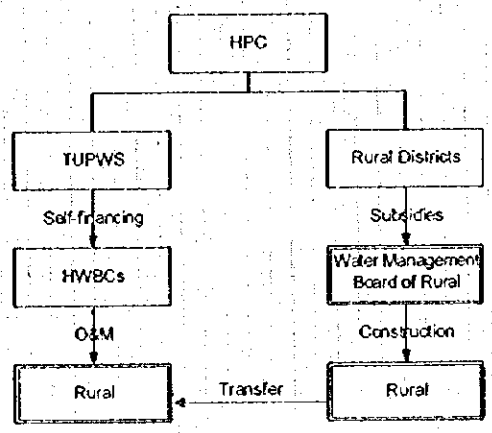
For the rural water supply, the construction management board would be organized in TUPWS. The facilities are to be constructed by the management board with subsidies. After construction, the systems are to be transferred to HWBC/HWBC No.2 for their operation and maintenance works.



The organization chart of HWBC in March 1997 and Future Direction



The organization chart of HWBC No.2 in March 1997 and Future Direction



Future Organization Structure of Rural Area

(2) Outlook for Work Force

Table 7 Outlook for the Number of Workers by Water Supply System

	HWBC	HWBC No.2	Rural	Total
Total Employees in year 2000	1,390	104	200	1,694
Total Employees in year 2005	1,361	617	600	2,578
Total Employees in year 2010	1,271	688	600	2,559

4.2.6 Initial Environmental Examination

The city center has expanded to the east (Gia Lam), the south-west (Thanh Tri) and the north-west (Tu Liem), resulting in urbanization of the areas that were formerly the suburban districts. Hanoi has a population of 2.39 million (year 1995) and about a half of the population are concentrating in five (5) urban districts with an average population density of 207 persons/ha.

Although an effort has been made to develop urban water supply systems, the rate of urbanization was too high to catch up with. Then consumers who could not be satisfied with insufficient and intermittent water supply service have uncontrollably developed their own wells or installed private water tanks in their houses. In these areas, serious depression of groundwater level or deteriorated drinking water quality resulting in hygienic problems are suspected. Whether public water supply systems are developed or not, Hanoi will rapidly grow and develop due to its ongoing economic expansion. However, Hanoi would not soundly develop if this water supply master plan would not be implemented.

Environmental impacts caused by the implementation of the Master Plan were identified according to the relations with existing environmental conditions at the sites proposed. Then the extent of impacts was examined using an impact matrix table, and the Master Plan in this study was comprehensively evaluated. In general, most impacts are considered to be positive. Negative impacts seem to be insignificant and most of them will be controlled or mitigated if the measures proposed in this study are undertaken appropriately.

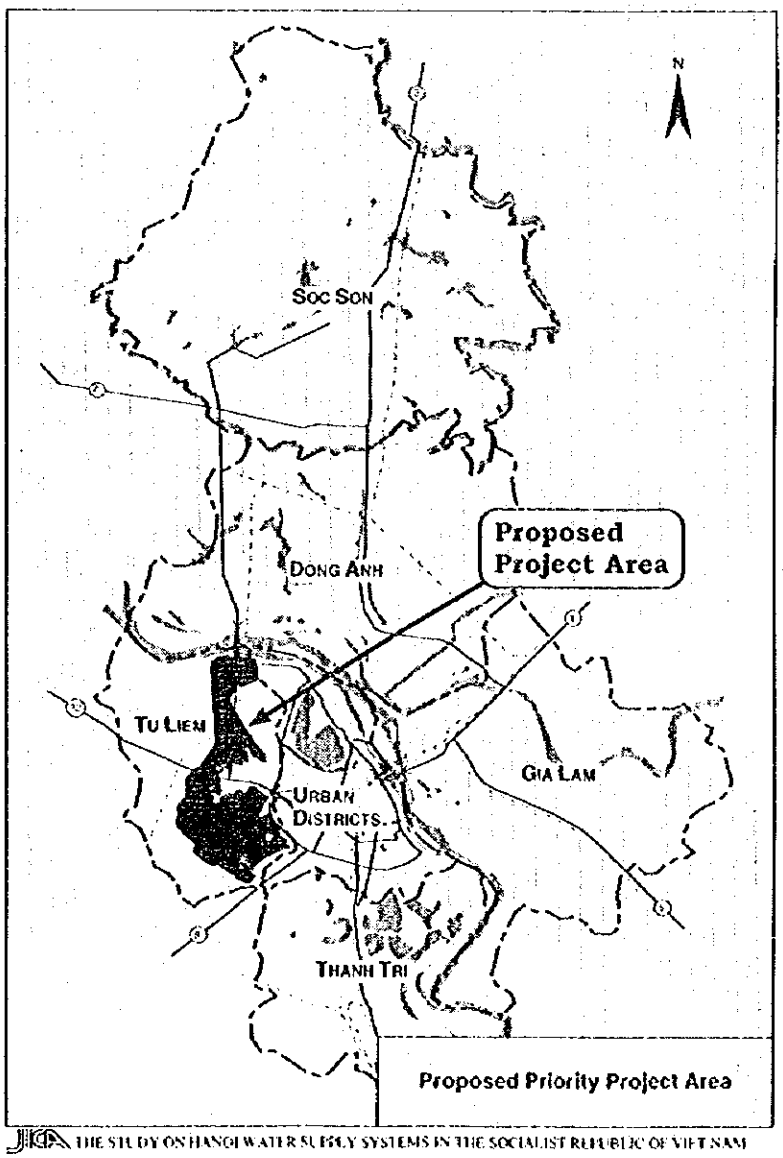
The total volume of groundwater discharge proposed in this Master Plan falls within the limited exploitable capacity that was predicted by the Vietnamese Geological Survey and has been accepted in Hanoi. However, as the groundwater discharge capacity is nearly reaching to the exploitable capacity, land subsidence and deterioration of groundwater quality seems to be the most important concern among all environmental factors. Therefore, all possible measures should be taken against those problems of groundwater, even if the risk of such environmental impacts is not significant.

5 PRIORITY PROJECT

5.1 PROJECT AREA

Urbanization of Hanoi tends to spread out from the central Hanoi toward west, north and south. The selected priority project area is planned to be developed in near future and is not supplied with piped-water at present.

In addition to supplying water to the project area, it is required to supplement the Mai Dich plant where the lowering of the groundwater level is observed. Moreover it is required to supply water to the new development area adjacent to the project area. The proposed project site is shown below.



5.2 WATER DEMAND

Average daily water demand in year 2005 is summarized in Table 8.

Table 8 Average Daily Water Demand in the Priority Project (Year 2005)

Category of Water Demand	Average Daily Water Demand (m^3/day)	Average Daily Water Distribution (m^3/day)
(1) Project Area	12,600	14,800
(2) Mai Dich Water Supply System	-	20,000
(3) Future Development Area	(11,000)	12,900
Total	-	47,700

Note: A physical loss of 15% is included in distribution volume, that is,
[Distribution] = [Water Demand] / (1-0.15)

5.3 PRELIMINARY DESIGN

5.3.1 Design Capacity

Design capacity of facilities is decided as below:

(a) Average Daily Distribution Capacity : **47,700 m3/day**

(b) Daily Maximum Distribution Capacity : **57,000 m3/day**
(Peak day factor : 1.35, It is not applicable to the capacity for supplement to Mai Dich)

(c) Daily Maximum Intake/Treatment Capacity : **60,000 m3/day**
(Plant loss : 5%)

5.3.2 Facility Plan

(1) Water Source Facilities

The groundwater is to be taken through deep wells to be equipped with submersible pumps (one pump to one well). The safe yield of one well is determined at 50 l/sec (180 m3/hr). Assuming 20 hours' operation of pump, 3,600 m3/day of water is available from a single well. Number of standby pump/well is proposed to be 30% of operating pumps.

(2) Treatment Facilities

Groundwater in the area contains iron and manganese, concentration of which is higher than the drinking water standard. Accordingly, the groundwater needs treatment. Treatment process, aim of which is removal of iron and manganese, is to be composed of aeration, sedimentation, filtration and disinfection.

(3) Sludge Treatment

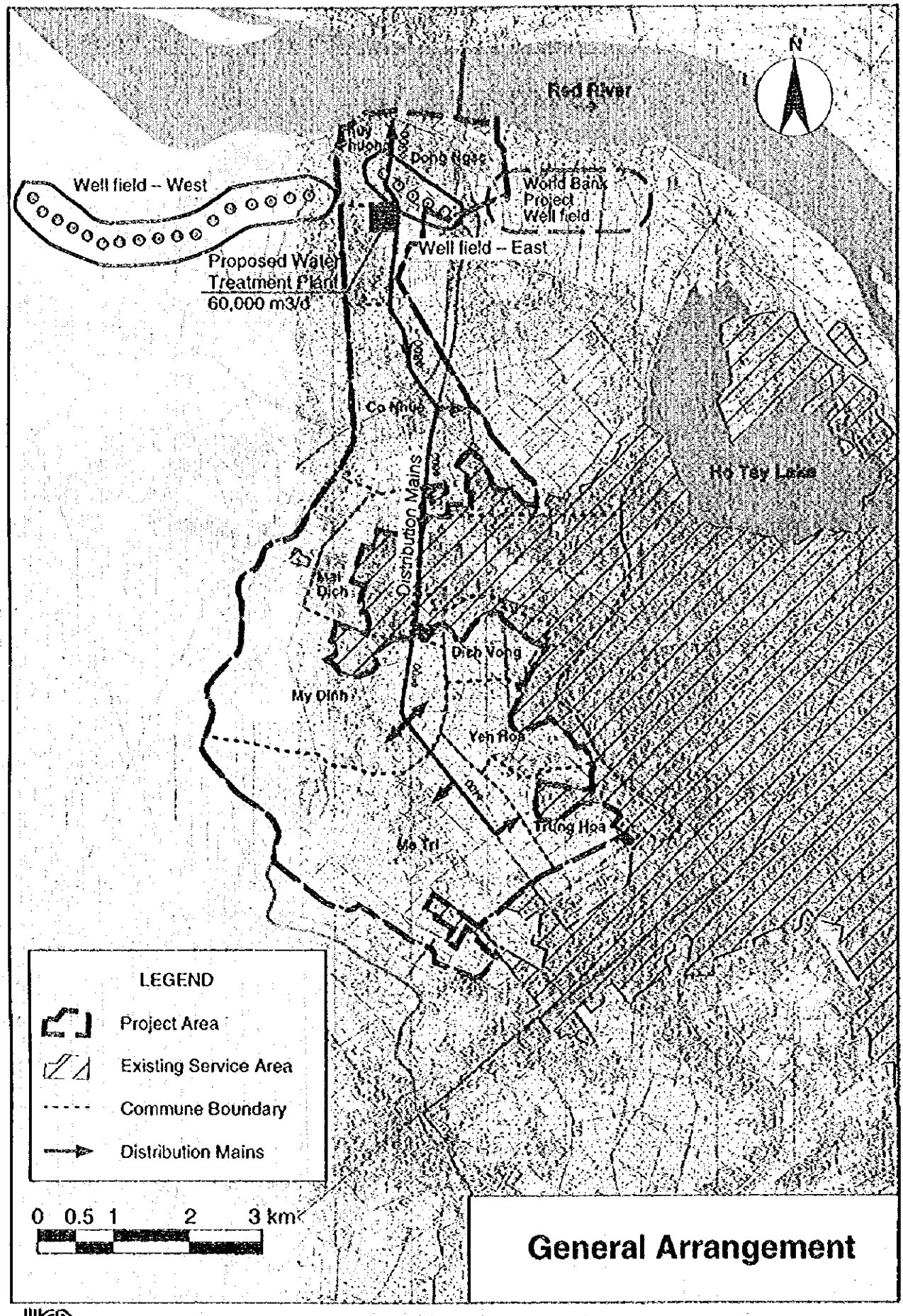
Sludge drained from filter-backwash water and drainage of coagulation/ sedimentation shall be treated in the yard of treatment plant, prior to disposal, from a viewpoint of environmental protection. The sludge treatment is planned to be processed by the sludge-drying bed system.

Clear water generated through the sludge treatment process is to be returned to the aeration towers to save raw water.

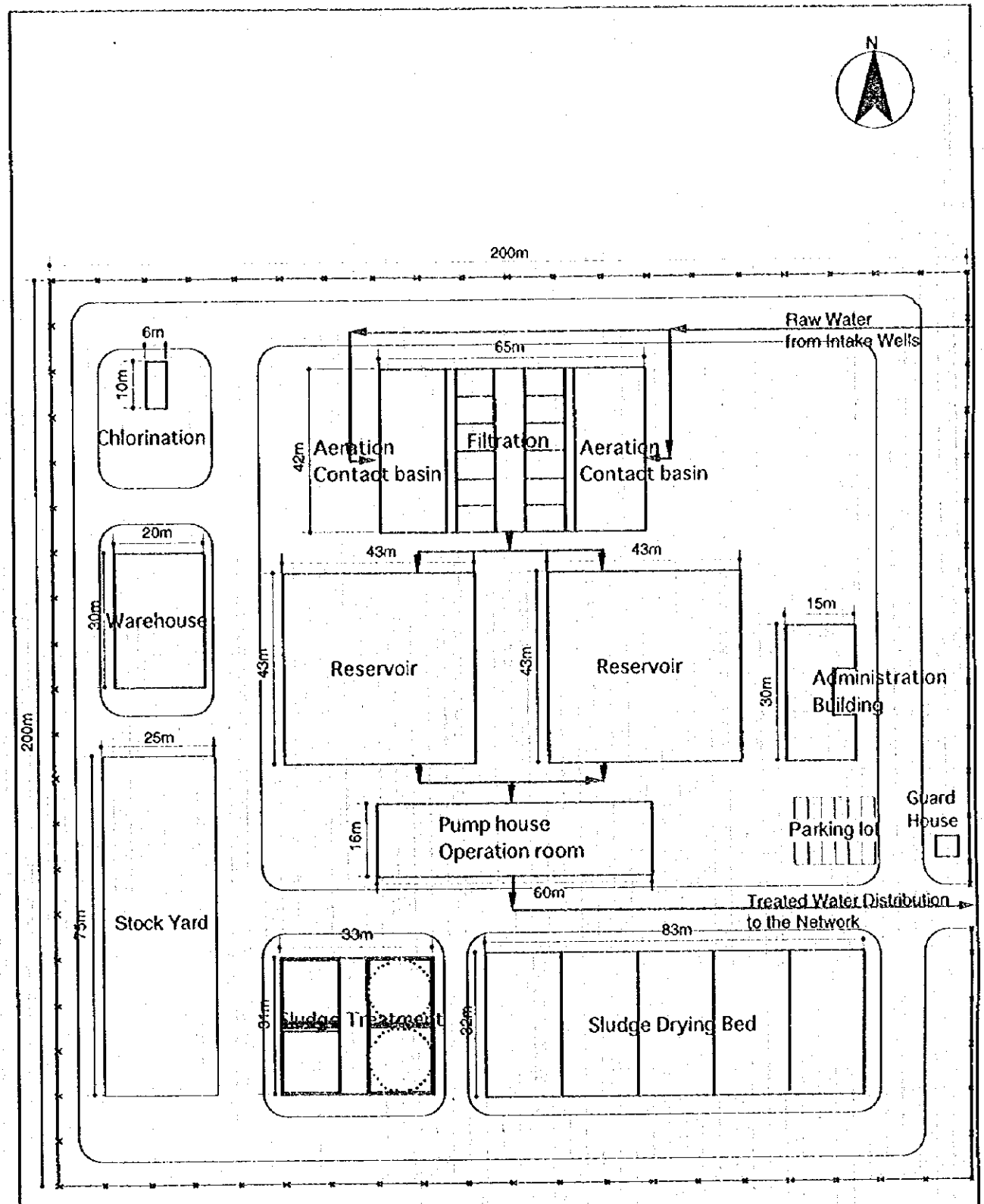
(4) Distribution Facilities

Ductile cast iron pipes with mortar lining (push-on type joint) will be used for diameters of 100 mm or larger. Polyvinyl chloride pipes (PVC pipes) with rubber ring joint type will be used in principle for 75 mm pipes or less.

The arrangement of water supply system facility is shown as the General Arrangement in the following page.



General Arrangement



Tentative Layout Plan of Treatment Plant (Q = 60,000 m3/d)

5.4 COST ESTIMATION

The total project cost is estimated to be 489,034 million VND: equivalent to US$ 44.46 million.

As for financing, price contingency shall be added to the above cost, for future price escalation (inflation). The total financing required will be 587,548 million VND: equivalent to US$53.42 million.

Table 9 Cost Estimation

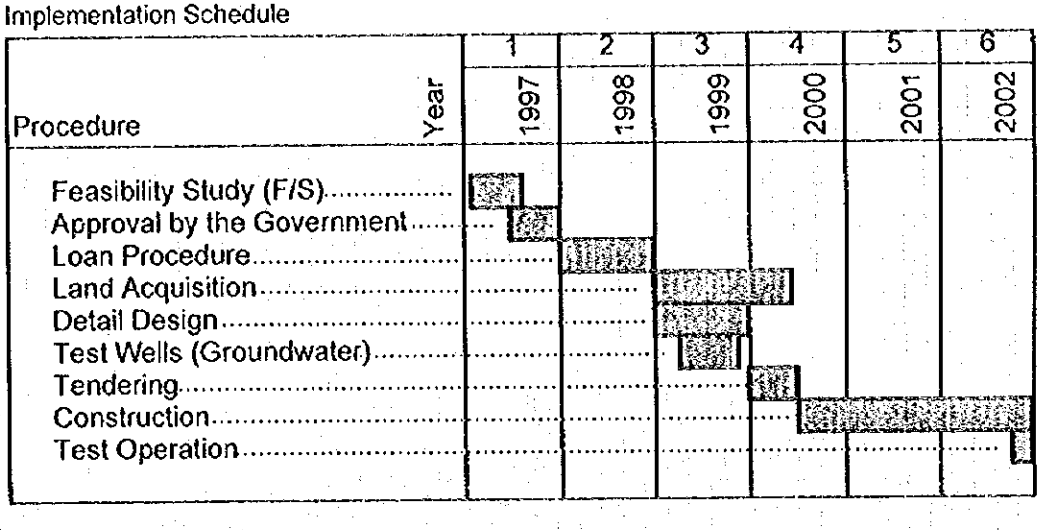
(Million VND)

Item \ Year	1999	2000	2001	2002
(a) Construction cost Cost = 332,150 mil VND	-	51,774	140,188	140,188
(b) Land cost Cost = 78,000 mil VND	52,000	26,000	-	-
(c) Engineering Cost = 41,518 mil VND	18,268	4,650	9,300	9,300
(d) Base cost (a + b + c) Cost = 451,668 mil VND = 41.06 mil US$	70,268	82,424	149,488	149,488
(e) Physical contingency Cost = 37,366 mil VND	1,826	5,642	14,949	14,949
(f) Total cost (d + e) Cost = 489,034 mil VND =44.46 mil US$	72,094 mil VND = 6.55 mil US$	88,066 mil VND = 8.01 mil UD$	164,437 mil VND = 14.95 mil US$	164,437 mil VND = 14.95 mil US$
(g) Price contingency Cost = 98,514 mil VND	11,632	15,774	30,982	40,126
(h) Total financing required (f + g) Cost = 587,548 mil VND = 53.42 mil US$	83,726 mil VND = 7.61 mil US$	103,840 mil VND = 9.44 mil US$	195,419 mil VND = 17.77 mil US$	204,563 mil VND = 18.60 mil US$

5.5 IMPLEMENTATION SCHEDULE

The priority project is scheduled to be implemented during six years as below :

Implementation Schedule



5.6 MANAGERIAL APPROACH

The priority project area should have one water treatment plant and one water business enterprise. Water treatment plants and business enterprises should be redefined as different internal profit units in order to motivate workers to reduce water leakage and increase water tariff collection ratio.

For the proposed facility which has a treatment capacity of 60,000 m^3/d, the work force engaged in the operation and maintenance of the priority project area is assumed at 35 staff at the water plant and 30 staff at the business enterprise.

5.7 FINANCIAL ANALYSIS

(1) Water Tariff

In tariff setting, two objectives should be achieved, one is to cover the necessary costs and the other is to keep the affordable price for all customers.

In the priority project, three types of water tariffs are projected in conformity with the three types of the water business transactions, namely, (a) Retail to the priority project area, (b) Wholesale to the Mai Dich and (c) Bulk Retail to the new development area. The tariff is shown in Table 10.

Table 10 Water Tariff by Categories

(VND/m3)

Year	Retail Tariff (Priority Project Area)				Wholesale Tariff (Mai Dich)	Bulk Retail Tariff (Development Area)
	Domestic	State & Public	Private & Foreign	Weighted Average		
2003	3,350	6,700	10,000	5,083	4,168	4,371
2005	3,750	8,135	11,340	5,818	4,771	5,003
2010	4,700	10,390	14,470	7,369	6,043	6,337

(Note) The above table is an extraction of only for the year 2003, 2005 and 2010 for reference.

Profit and Loss Statement for the period from 1999 to 2010 is presented below for reference. It is evident from the table, projected revenue can cover the expenditures (O&M, Depreciation and Interest) from the year 2004. According to the affordability analysis, the projected tariff is also kept within the affordable level. These justify the projected water tariff.

Table 11 Profit & Loss Statement (1999 - 2010)

(million VND)

Year	Revenue	O&M Costs	Depreciation	Interest Costs	Profit & Loss
1999			3,605	13,514	-17,119
2000			8,008	13,064	-21,072
2001			16,230	12,613	-28,843
2002			24,452	12,163	-36,615
2003	54,276	22,294	24,452	11,712	-4,182
2004	66,290	25,338	24,452	11,262	5,238
2005	76,087	29,597	24,452	10,811	11,227
2006	79,533	30,582	24,452	10,361	14,138
2007	83,549	31,624	24,452	9,910	17,563
2008	87,677	32,726	24,452	9,460	21,039
2009	91,960	33,891	24,452	9,009	24,608
2010	96,287	35,124	24,452	8,559	28,152

(2) Results of the Financial Analysis

(a) The proposed priority project will have moderate Financial IRR (FIRR) of 9.03%, which is higher than the suggested funding cost and is higher than the prevailing long-term interest rate in Vietnam.
(b) According to the Profit & Loss statement of the priority project until year 2030, the break-even point is estimated to be achieved by the year 2004, quite early given the start of operation in the year 2003.
(c) The repayment of the loan principal and interest can be covered by the anticipated free cash flows.
(d) The suggested water tariff is within the affordability target.

Therefore, from the view point of financial analysis, the priority project is feasible.

5.8 ECONOMIC ANALYSIS

The calculated EIRR (9.6%) is not so high at best. However, considering the 'said to be' around 10% opportunity cost of capital in Vietnam and the urgent social requirement of the project, this figure is within an acceptable level. Therefore, from the view point of EIRR, the priority project is feasible.

5.9 ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FOR THE PRIORITY PROJECT

The priority project area consists of some suburban settlements and agricultural lands at present. However, this area is the most potential area in the west Hanoi and is expected to be developed rapidly, Therefore, several development plans have been proposed in this area. At the north end of the project area, the Red River flows and provides the area with water for irrigation and also for recharging to groundwater. There are some small settlements, some official institutes and factories around the proposed water treatment plant. There is no restricted area for development in the project area.

New water supply system proposed by the project will increase sewage volume in

proportion to the increase of supplied water. It would affect the quality of water bodies in the area, if the sewage is not properly treated.

In general, most impacts caused by the project are considered to be positive, and negative impacts are predicted to be insignificant. No houses will be demolished or no people will be displaced by this project, though about six (6) hectares of site acquisition will reduce agricultural productivity and the farmers' earnings to some extent. Therefore the project is feasible from the viewpoint of environmental consideration if the negative impacts are carefully taken into consideration and necessary mitigation measures are implemented.

5.10 SOCIAL ANALYSIS

The following viewpoints were taken into consideration for social analysis :

(a) Impartial utilization of the water supply systems
(b) Receptivity on the Cultural Background

As a result, the project turned out to be positive in general. Therefore the priority project is recommendable.

6 RECOMMENDATION

(1) The Master Plan should be reviewed and updated periodically, every three to five years, reflecting the actual development of the city and actual increase of the population and water demand.

(2) To prepare drainage or sewerage systems in parallel with the development of water supply system.

(3) To continue systematic groundwater monitoring of water quality as well as water level and mitigate adverse effects due to human activities.

(4) To commence the surface water study for alternative water sources

(5) To prepare law and regulation to control groundwater

(6) To construct the new security main to facilitate emergency operation

(7) Financial assistance in construction for rural water supply facilities by Government or City

(8) To restructure HWBC and establish a new water business company

(9) Introduction of IAS system

(10) Development of human resources and its training

(11) To establish new organization, namely, one water treatment plant and one water business enterprise.

(12) To set water tariff so as to cover all the relating costs as well as to ensure affordability of water charge for all customers.

(13) Earlier implementation of the sewerage project in the priority project area.

CONTENTS

ABBREVIATION

ADB	Asian Development Bank
AFW	Accounted-for Water
BHN	Basic Human Needs
BIDV	Bank for Investment and Development of Vietnam
BOT	Built, Operation and Transfer
CMEA	Council for Mutual Economic Assistance
DID	Densely Inhabited District
DOMAH	General Department of Meteorology and Hydrology
EIA	Environmental Impact Assessment
EPZ	Export Processing Zone
FDI	Foreign Direct Investment
FINNIDA	Finnish International Development Agency
FYE	Fiscal Year
HCMC	Ho Chi Minh City
HPC	Hanoi People's Committee
HWBC	Hanoi Water Business Company
HWBC No. 2	Hanoi Water Business Company No. 2
HWSC	Hanoi Water Supply Company
HWSEP	Hanoi Water Supply and Environment Project
HWSP	Hanoi Water Supply Program
IAS	International Accounting Standard
IE	Industrial Estate
IEE	Initial Environmental Examination
IMF	International Monetary Fund
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
MOARD	Ministry of Agriculture and Rural Development
MOC	Ministry of Construction
MOF	Ministry of Finance
MOH	Ministry of Health
MOI	Ministry of Industry
MOLISA	Ministry of Labor, Invalids and Welfare
MOSTE	Ministry of Science, Technology and Environment

MPI	Ministry of Planning and Investment
NWTS	National Water Tariff Policy Study in Vietnam
O&M Cost	Operation and Maintenance Cost
ODA	Official Development Assistance
OECF	The Overseas Economic Cooperation Fund
RPHC	Readjustment Planning for Hanoi City 2020
SB	State Bank
SE	State-owned Enterprise
SSWSC	Soc Son Water Supply Company
TUPWS	Transportation and Urban Public Works Service
UDWWD	Urban Drainage and Waste Water Disposal System
UFW	Unaccounted-for Water
UPI	Hanoi Urban Planning Institute
URENCO	Hanoi Urban Environment Company
URP	the National Institute for Urban and Rural Planning
VND	Vietnamese Dong
WBE	Water Business Enterprise

PART I

GENERAL

PART I GENERAL

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CHAPTER 2 PRESENT CONDITIONS

CHAPTER 1 INTRODUCTION

1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Hanoi, the capital city of Vietnam, is located in the upper stream of the Red River Delta. The city area including 5 suburban districts is 924.5 km² with a population of 2,394,887 (1995).

The city is undergoing rapid urbanization with high population growth rate in recent years. However, it is rather undeniable that the city virtually lacks environmentally and sanitarily acceptable water supply systems to meet its urbanization and growth of population.

With regard to the water supply network covering the urban districts, improvement and expansion of the system have been implemented under the Hanoi Water Supply Project (FINNIDA assistance) since 1985. The project has made continuous efforts for improving the Hanoi water supply over a decade.

In 1993 the project formulated a water supply master plan up to 2010, which covered only the urban districts.

Although another augmentation of water supply was made in 1995 through a Japanese grant aid project in Gia Lam District, the suburban districts still remain excluded from the master plan 2010.

In consideration of recent urbanization and foreign investments, Hanoi needs a more comprehensive master plan which covers the whole area of Hanoi city including the estranged suburban districts.

With this background, the Study on Hanoi Water Supply Systems (hereinafter referred to as "the Study") was undertaken by Japan International Cooperation Agency (JICA) responding to the request made by the Government of Vietnam.

1.2 OBJECTIVES OF THE STUDY

The objectives of the study are :

(1) to establish an overall and strategic master plan covering the whole administrative Hanoi City area with the planning target year 2010.

(2) to conduct a feasibility study for the priority projects identified in the master plan.

(3) to conduct technology transfer to the Vietnamese counterpart personnel.

1.3 STUDY AREA

The study area covers 924.5 km^2 consisting of the five (5) urban districts (Ba Dinh, Hoan Kiem, Hai Ba Trung, Dong Da, Tay Ho) and five (5) suburban district (Thanh Tri, Tu Liem, Dong Anh, Soc Son and Gia Lam) in Hanoi City (April 1996).

Location of the study area is shown in Location Map.

1.4 STUDY ORGANIZATION

Transportation and Urban Public Works Service (TUPWS) of the Hanoi People's Committee was assigned as the counterpart executing agency of the Government of Vietnam. The Japan International Cooperation Agency (JICA) was assigned as the official agency responsible for the implementation of the technical cooperation program of the Government of Japan.

The Study was carried out by the Japanese consultant team retained by JICA and Vietnamese counterpart staff.

The Study was conducted from February 1996 to June 1997. The members involved in the Study are listed below :

(1) The Members of the Advisory Committee

Name	Field in Charge	Present Post
MAGARA Yasumoto	Chairman	Professor, Hokkaido University, Japan
OMURA Yoshiki	Member	Water supply Specialist, Institute for International Cooperation, JICA

(2) The Members of the Study Team

Name	Field in Charge
OKAGA Toshifumi	Team leader and water supply planning
YAMAZAKI Hideki	Water supply facility planning
YASUDA Makoto	Hydrogeology / Hydrology / Groundwater development planning
SAKAI Hitoshi	Institution building / Management
SEKI Kazunori	Urban planning / Social analysis
NARITA Motoo	Economic and financial analysis
KURIHARA Tsutomu	Water quality analysis / Environmental impact assessment
UMEZAWA Ko	Water leak protection planning
TOHDA Naoto	Coordinator for general affaires

(3) The principal members of the Counterpart Team

Name	Field in Charge	Position
Trinh Kim Giang	Group leader	Manager of HWBC
Ngo Thi Bich	Group leader	Manager of HWBC
Tran Lan Huong	Water supply planning	HWBC
Truong Ngoc Anh	Water resources development	HWBC
Bui Thi Khanh Toan	Institution/Management	Chief of Accountant, HWBC
Nguyen Kim Dung	Urban planning	HWBC
Do Lan Huong	Environment/Water quality analysis	HWBC
Nguyen Thu Nga	Financial analysis	HWBC
Truong Cong Thanh	Water supply facility planning	HWBC
Nguyn Phuong Dung	Water supply facility planning	HWBC

1.5 REPORTS

The study reports prepared are as follows :

1 Executive Summary
2 Main Report
3 Supporting Report
4 Data Book

The Main Report presents the summarized results of all the studies. In Part I , the basic information for the Study are described. Part II deals with formulation of the Master Plan and selection of Priority Project. The Feasibility Study of the priority project are was specified in Part III. Part IV is recommendations.

CHAPTER 2 PRESENT CONDITIONS

2 PRESENT CONDITIONS

2.1 SOCIO-ECONOMIC CONDITIONS

2.1.1 Overview

(1) Almost a decade has passed since Vietnam has concerted the efforts of the transition. Now Vietnam stands on the entrance of a new era in its international relations and economic development. Its economy and finances have been reformed considerably (although Vietnam remains one of the poorest countries in Asia, with per capita GNP below US$270 in 1995 according to the Economic Planning Agency, Japan), and integrated into the world economy. The economy is now beginning to benefit from official development assistance (ODA) and foreign direct investment (FDI) significantly.

(2) In comparison with other economies in the transition, starting conditions in Vietnam were rather favorable. Especially in the southern part of the country, the legacy of the market economy was revived quickly because of relatively low integration with the former Council for Mutual Economic Assistance (CMEA). In addition, neighboring countries in Asia provided affluent markets for Vietnamese exports and were seeking to invest their savings into Vietnam. With firm determination by the Vietnam's authorities, structural reform and financial stabilization policies were implemented in a consistent manner. The sudden collapse of the CMEA or the withdrawal of USSR support accelerated the departure from the previous paradigms and the replacement by the market-oriented principles.

(3) Agricultural Sector reforms were implemented in a wide range. Private enterprises were encouraged. Prices, exchange rates and foreign trade were liberalized to greater extent. Besides, bank financing of the fiscal deficit was eliminated, a hard budget constraint was put on state enterprises, over liquidity was controlled, and the attractiveness of the local currency Vietnamese Dong (VND), as a fiscal asset was enhanced by adopting positive real interest rates.

All above factors joined together to draw out an incremental output, in comparison with the wide decline in other transition economies in general.

2.1.2 Recent Trends of Growth and Forecast

(1) Vietnam economy has achieved an impressive growth rate since 1992. The real GDP growth rate accelerated from 5.1% during 1985 - 89 to 9.5% in 1995.

(2) By sector, industrial sector output increased in 9.5% in 1995 after 8.8% in 1994. Agricultural output was 4.7% increase in 1995 compared to 3.9% in 1994. Services output rose to 10.7% in 1995 following 10.2% in 1994.

(3) Vietnam has had remarkable success in bringing inflation under control. The increase rate in retail prices declined from 257.3% in 1985 - 89 to 5.2% in 1993. But thereafter, despite continuing commitments inflation accelerated again. At the end of 1995, inflation rate stood at 12.7%, after rice price led hike of 14.4% in 1994. The inflation rate is expected to stay high in 1996 and it seems difficult to cut down the level below 10%.

(4) The recent report by State Bank of Vietnam in 1996 presented the following macroeconomic forecast. The report has two variants: one variant targets Vietnam's per capita income in the year 2025 is estimated US$ 1,872, which means to reach the present economic level of Thailand. The other variant targets GDP per capita of US$ 3,559 by 2025, which seems rather ambitious.

GDP Simulation

	1994	2000	2005	2010	2015	2020	2025
Variant 1							
GDP (billion US$)	15.5	26.1	41.6	65.8	100	150	220
average growth, 5 years		9.1	9.8	9.6	8.7	8.4	8.0
per capita GDP (US$)	214	320	466	677	952	1,337	1,872
Variant 2							
GDP (billion US$)	15.5	26.9	46.1	81.2	148.9	259.4	417.7
average growth, 5 years		9.7	11.4	12.1	12.8	11.7	10
per capita GDP (US$)	214	330	515	839	1,418	2,320	3,559

Source : Vietnam Economic Review No.2 (32) 1996, the State Bank of Vietnam

2.1.3 Reform of Industrial Sector and State Enterprises

(1) Before Doi moi, Vietnam's industrial sector had been supported by large - scale aids from the USSR. As the result of cease of the aids, industrial production declined by about 10% in the time of 1988 ~ 1991.

Many reform policies had took place, and had affected the performance of the industrial sector and the restructuring. Almost all industrial prices were liberalized by the end of 1988, except cement, steel, and electricity that remained controlled. In addition, the official exchange rate of the currency was devalued and aligned closely to the rate in the parallel markets, and the subsidies for export were eliminated as well as foreign currency earnings were partially allowed to be retained. Trades were liberalized by which allowed production enterprises to trade directly abroad.

(2) The state enterprises were reformed that focused on ensuring autonomy in decision making, releasing the enterprise from the constraints of the plan of the Central Government. Also to the private sector, some market oriented policies were undertaken such as providing access to credit, introducing non-discriminating taxation and commercial legislation. These policies have resulted in impressive output gains.

On the other hand, in this process, activity moved away from cooperatives and poorly managed state enterprises toward private enterprises and better-managed state enterprises. Several key heavy industries and some consumer oriented state enterprises was vivid, while smaller or local state enterprises were eventually bankrupted.

(3) As the result of restructuring, including the shedding of labor and the creation of joint ventures that attracted foreign investment and new technologies, enterprises' output performance strengthened dramatically. The state enterprises has become a net contributor to the budget.

2.1.4 Conditions of Capital Raising

(1) Most of the major countries in transition including Vietnam have been enjoying rapid increase in their foreign exchange reserves, however, in Vietnam the trade deficit has been widening for the past four years. These imbalance has been offset or more than offset by the increasing inflow of Foreign Direct Investment or ODA.

(2) Capital raising in international finance market by the government and private companies of developing countries is continuing and is inevitable. The order of magnitude has been FDI, private debt flows and portfolio investment.

(3) From the start, FDI was recognized to play a central role in the transformation of the Vietnam's economy. Approval of the FDI Law on the international standard at an early stage was a strategically important signal of the nature and direction of the reform process. Nevertheless difficulties and delays have arisen due to troublesome approval and licensing procedures, disbursements of investment commitments started to increase in 1991 according to the IMF paper. Now, Vietnam has one of the highest ratios of FDI to GDP in the world.

(4) FDI new commitments in 1994 boomed to nearly US$ 4000 million (disbursements $650 mil.), and in the first half of 1995, it has already attained the level exceeding the total record of 1994. There is a story that this might be temporary and might be worn off at least temporarily, following the track of measures recently taken by the government to depress speculation in the real estate market and ensure greater financial discipline.

(5) It is expected that FDI will play an increasingly important role in the modernization and growth of the Vietnam's economy. In order to realize its purpose, Vietnam authorities have to make more efforts to improve FDI approval procedures and to be integrated with international communities such as ASEAN.

2.2 NATURAL CONDITIONS

2.2.1 Topography

The Red River delta is vast, approximately 150 km long and 80 km wide spreading in a northwest-southeast direction, reaching the Gulf of Tonking. The study area, Hanoi City, is situated on the upper part of the Red River delta and is about 100 km from the sea. Almost all the study area belong to the alluvial flat lowland of the delta with an elevation of around 10 m. The northernmost part of the study area which is in Soc Son district, however, belongs to the Tam Dao mountains and the highest peak reaches an elevation of 462 m.

2.2.2 Meteorology

Vietnam might be assumed to be wholly within the zone of the tropical monsoon climate. The Red River delta, where Hanoi City is situated, however, is not strictly tropical in the climatological sense, as due to its exposure to cold northern air during the season of the north-east monsoon called "winter". Winter, which is usually from November to April, coincides with the dry season. The minimum average monthly temperature is 15.3 ℃ in January, while the average yearly one is 23.4 ℃. The total rainfall during the winter is 328 mm, which is less than 20 % of annual one of 1,794 mm. On the other hand, summer is the rainy season, the maximum average monthly temperature is 29 ℃ in June, the total rainfall during this season is 1,466 mm, which is more than 80 % of annual one.

Table 2.2-1 shows monthly average meteorological values at Lang Station in Hanoi.

Table 2.2-1 Monthly average meteorological values at Lang Station in Hanoi

Month	Temperature(℃)	Rainfall(mm)	Evaporation(mm)	Humidity(%)
JAN	15.3	18	68	84
FEB	17.6	36	51	79
MAR	19.2	31	55	91
APR	23.6	121	66	83
MAY	27.4	194	94	81
JUN	29.0	250	99	82
JUL	28.4	214	101	81
AUG	28.6	325	86	82
SEP	27.1	290	91	78
OCT	24.4	181	95	73
NOV	21.4	115	88	76
DEC	18.4	7	94	79
YEAR	23.4(Ave.)	1,794(Total)	938(Total)	81(Ave.)

(FINNIDA "Master Plan" '93)

* Meteorological values in Table 2.2-1 are quoted from the " Water Master Plan, FINNIDA, 1993 ". The data period is not made clear and some discrepancies are found between the year values and the total values of every month. However, as the year values are estimated to have been used in the groundwater simulation analysis, these values are also used in this study as they are.

2.2.3 Hydrology

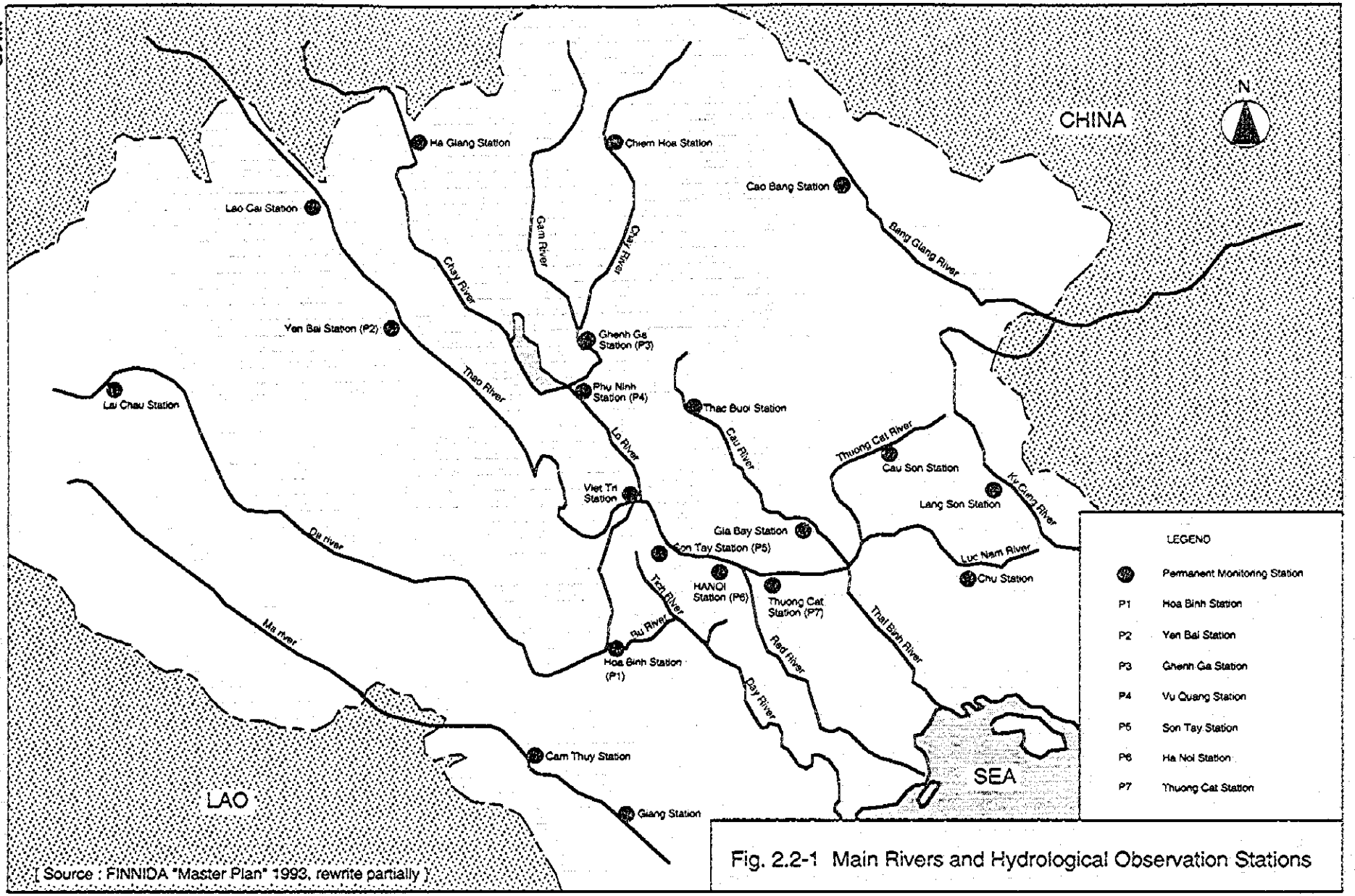
The Red River, which originates in China and flows into the Gulf of Tongking, is the largest river system in the north and second largest in the country. The total catchment area of the Red River is about 169,000 km^2, whose 86,560 km^2 is located in Vietnam. Its total length is 1,126 km, whose 556 km is in Vietnam. The Red River consists of three large rivers, Da, Thao and Lo rivers; all of them originate from high mountainous region in China. These rivers joint at Viet Tri and form the Red River. Fig. 2.2-1 shows the main rivers in and around the study area.

The long-term average annual run-off volume of the Red River at Son Tay is 118 billion m^3 according to water discharge of 3,740 m^3/s. Water of the Red River, however, has never been used for the public water supply of Hanoi City, because of the difficulties of intake and treatment owing to the large seasonal fluctuation of water level and the high turbidity.

The three main rivers in Soc Son district, Cau, Cong and Ca Lo rivers belong to the Thai Binh River system (39,000 km^2), though being included in the Red River basin (See, Fig. 2.2-2).

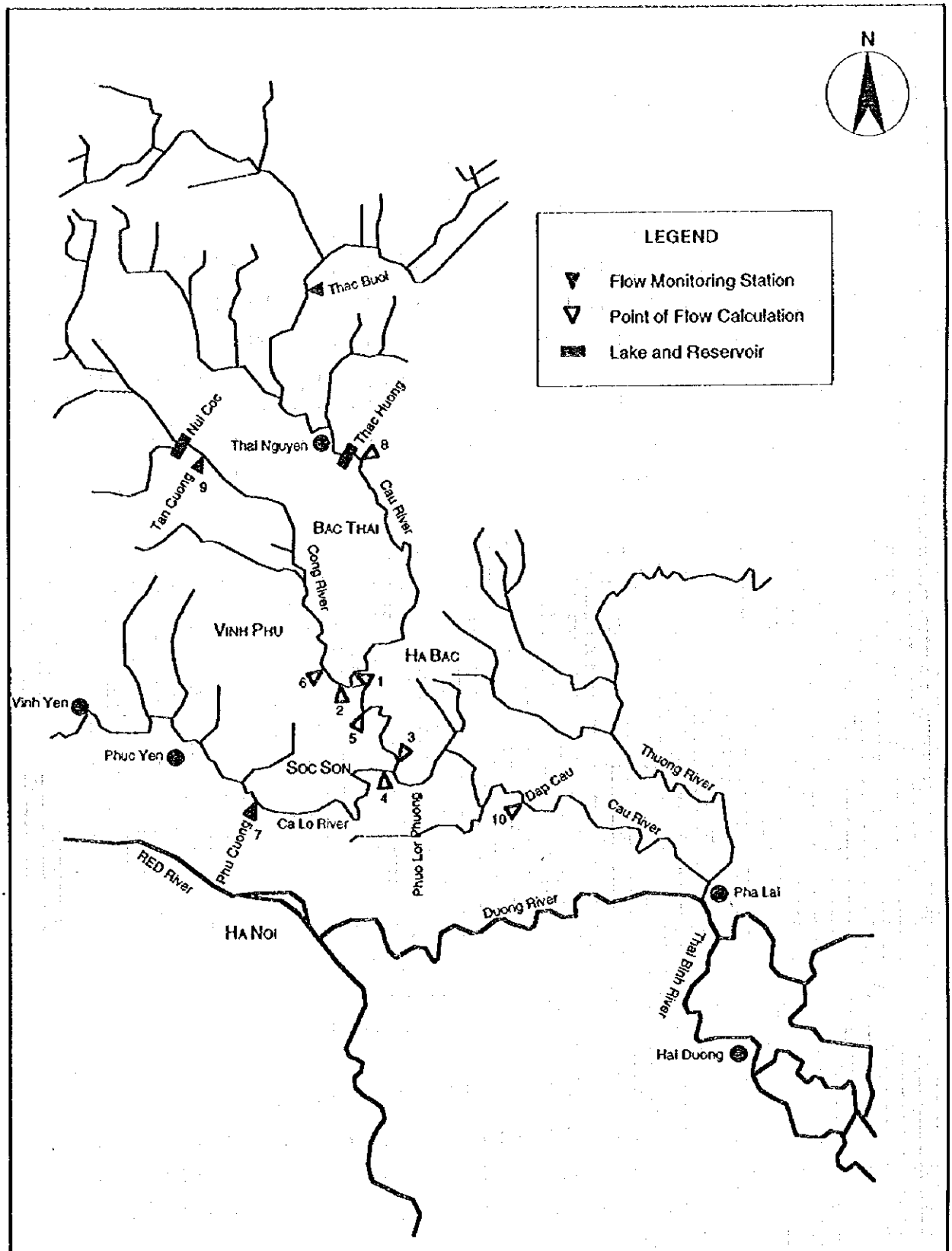
The largest river in Soc Son district is the Cau River, which originates in the highland region of Bac Thai province and flows along the eastern border of Soc Son district and down to the Duong River which is one of tributaries of the Red River. The average annual run-off volume of the Cau River at Thac Buoi is 1.6 billion m^3.

Water level observation has been going on since 1885 at Hanoi and since 1888 at Yen Bai. Since 1902 there has been relatively completed network of water level observation stations such as Hoa Binh, Tuyen Quang, Doan Hung, Son Tay and Cau Duong. Water discharge measurements, however, were started in 1932. In the upriver area of the Thai Binh River system, observation data since 1960 at Thac Buoi in Cau River is the longest term data.



[Source : FINNIDA "Master Plan" 1993, rewrite partially]

Fig. 2.2-1 Main Rivers and Hydrological Observation Stations



[Source : FINNIDA "Soc Son Feasibility Study, 1995]

Fig. 2.2-2
Thai Binh River System and
Hydrological Observation Stations

2.2.4 Geology and Hydrogeology

Fig. 2.2-3 shows Geological and Hydrogeological outline in the study area. Fig. 2.2-4 and Fig. 2.2-5 show Geological and Hydrogeological map and cross section.

The Red River delta is composed of deposits mainly transported by the Red River in the period of Quaternary, from the Pleistocene to the Holocene ages. These deposits reach average 80 m in thickness in the study area, although these are only 30 m in Soc Son district, and form good aquifers in their coarse-grained layers such as those composed of sand and gravel. The hills and mountains around the delta are mainly composed of Mesozoic (upper-middle Trias) rocks. The basement of the delta, however, is mainly composed of Tertiary (Pliocene) sediments.

This area contains two aquifers for groundwater resources. The one is distributed near the ground surface with 20-30 m thickness. This is the unconfined Holocene aquifer called upper aquifer (Qb) and is used for domestic water through shallow dug wells. In Soc Son district, however, almost all shallow dug wells are constructed in the stratum called upper Pleistocene confining layer, because the upper aquifer (Qb) is distributed scarcely. The other is distributed in 40-80 m deep with thickness of 40 m, although in 10-30 m deep with thickness of 20 m in Soc Son district and is underlain by the basement rocks directly. This is the confined Pleistocene aquifer called lower aquifer (Qa) and is used for public water supply and for industry through deep wells.

The lower aquifer, which is formed with the Lechi Formation overlying the basement rocks directly and with the lower part of the Hanoi Formation, is the main confined aquifer in the project area and extensively used for water supply purpose.

The Lechi Formation of Early Pleistocene age is mostly composed of layers of sand and gravel with well-rounded cobbles. At the top of formation there often is a thin silty layer separating this formation from the one above. The Hanoi Formation is of Middle Pleistocene age and its lower parts is composed of sand and gravel with cobbles and boulders.

The aquifer is 30-50 m thick generally. It is, however, 10-20 m thick and thinned

out gradually toward the mountains in Soc Son district. Average transmissivity of the aquifer in each area is as follows :

Table 2.2-2 Average transmissivity of Qa in each area

Area	Transmissivity (m^2/s)	No. of data
Soc Son district	4.25×10^{-3}	4
Don Anh district	7.00×10^{-3}	29
Gia Lam district	1.90×10^{-2}	3
South Hanoi	1.67×10^{-2}	13

Fig. 2.2-6 and 2.2-7 show the contour lines of the piezometric heads of the Qa aquifer, measured at the observation wells, in rainy season (August) and in dry season (February), in 1995, respectively. The fluctuations of the piezometric heads between the two seasons are uneven from place to place. The maximum reaches to five(5) m and it can be seen along the right bank of the Red River. The depression zone of the piezometric head is formed around the line linking Mai Dich to Phap Van / Tuong Mai wellfields. The flow lines expected from the piezometric contour lines show the following characteristics.

a) General flows from upstream to downstream of the Red River and from the Red River to the land especially in rainy season.
b) Flows from the surrounding area to the depression zone.
c) Flows from the surrounding area to the Ca Lo River.

Hydrogeological Division K2 of the Geological Survey of Vietnam has studied the groundwater resources of Hanoi area especially intensively since 1989 under the FINNIDA assistance. The groundwater exploitation, groundwater levels and groundwater quality, as well as the environmental impacts of groundwater abstraction have been regularly monitored through the established network of about 160 observation wells. A computerized groundwater model also has been established, with which it is possible to simulate groundwater conditions in future. After few years of calibration and trial runs, the groundwater model has been established and it gives reliable data for the assessment of groundwater resources in Hanoi area, particuraly in the south and west side area of the Red River*, though it is revised every year using new observation data.

Note(*): "the south and west side area of the Red River" in FINNIDA Master Plan '93 is almost coincide with "the south Hanoi (S.H)" in this study.

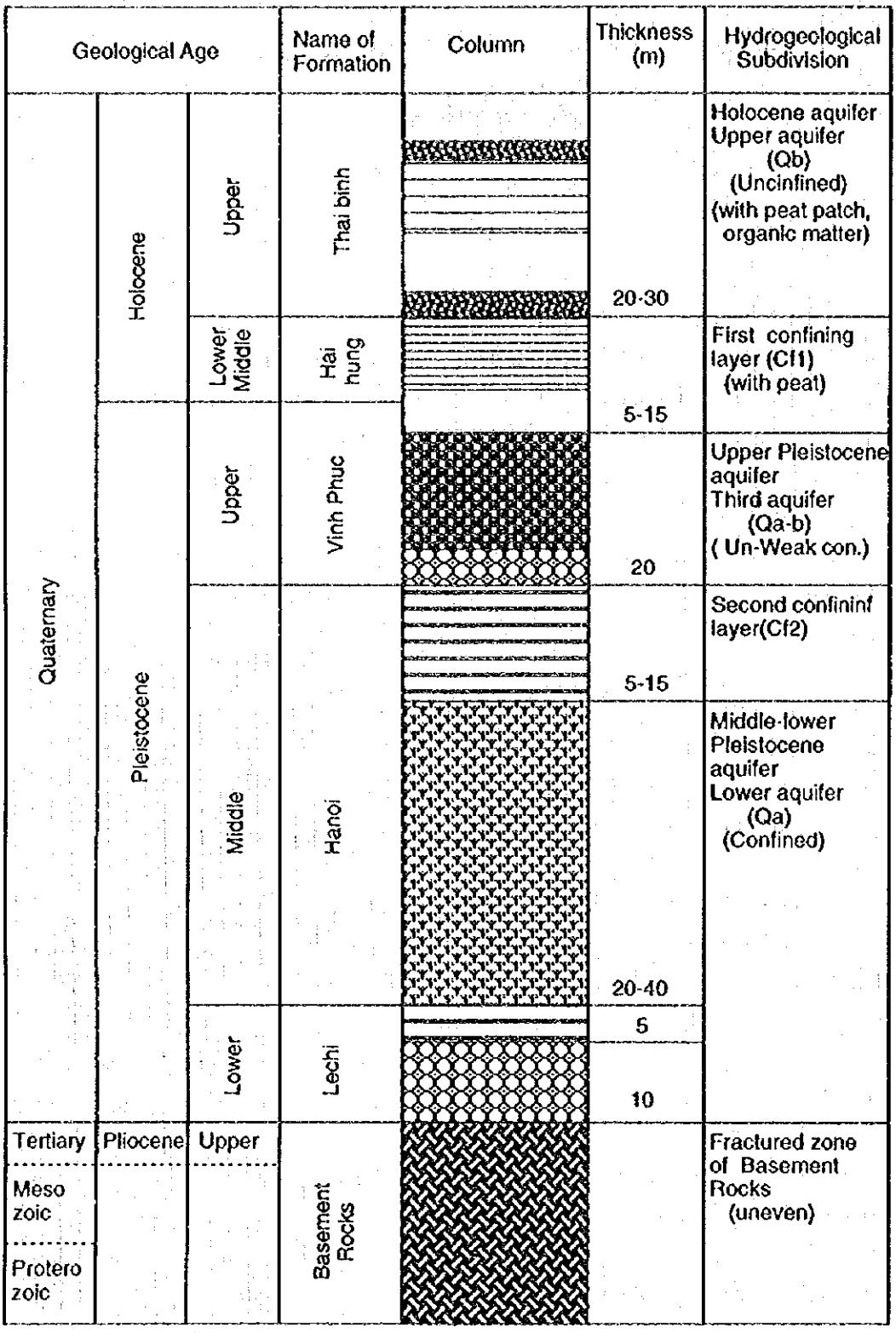


Fig.2.2-3
Geological, Hydrogeological Outline in the Study Area

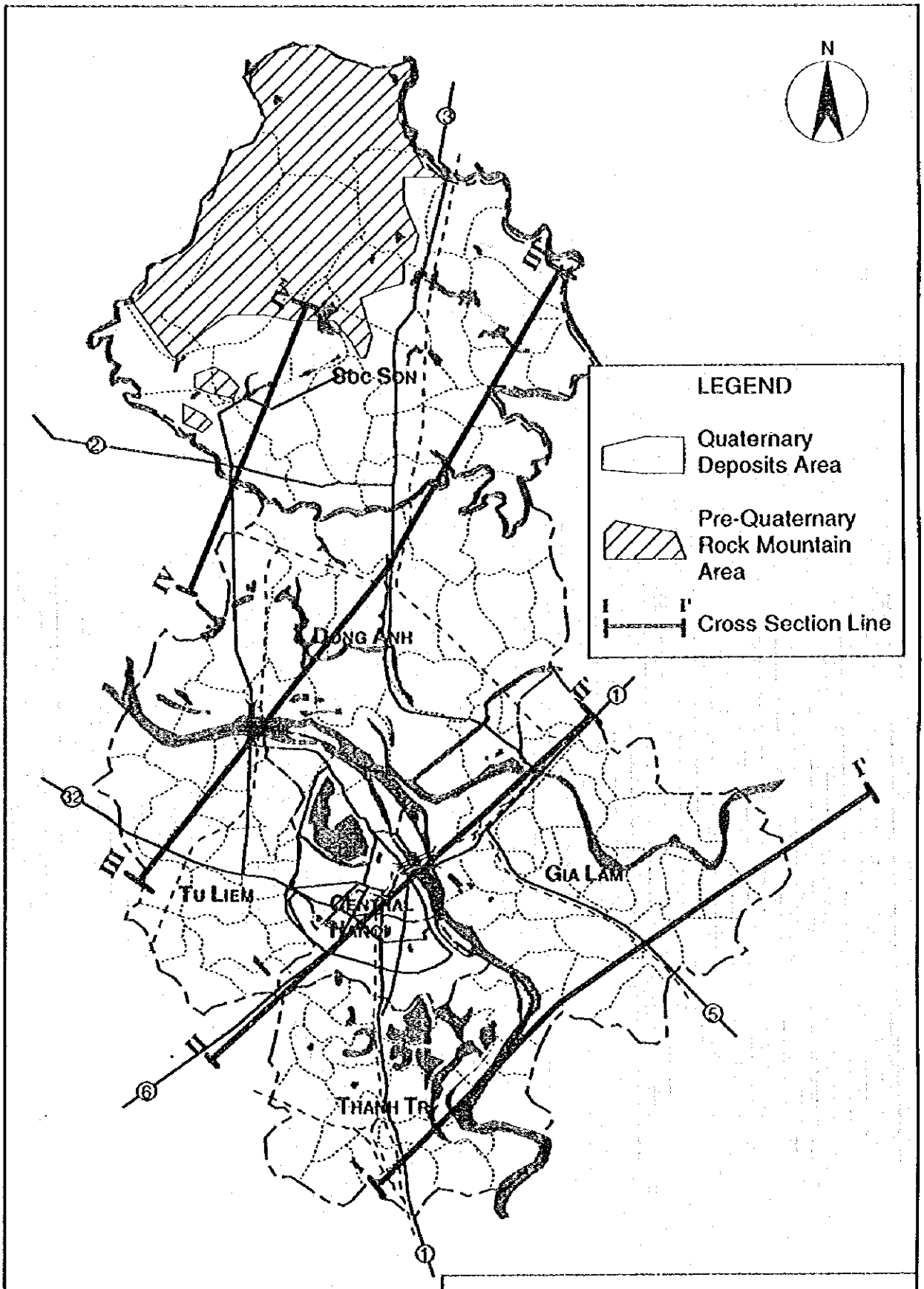


Fig. 2.2-4
Geological, Hydrogeological Map of the Study Area

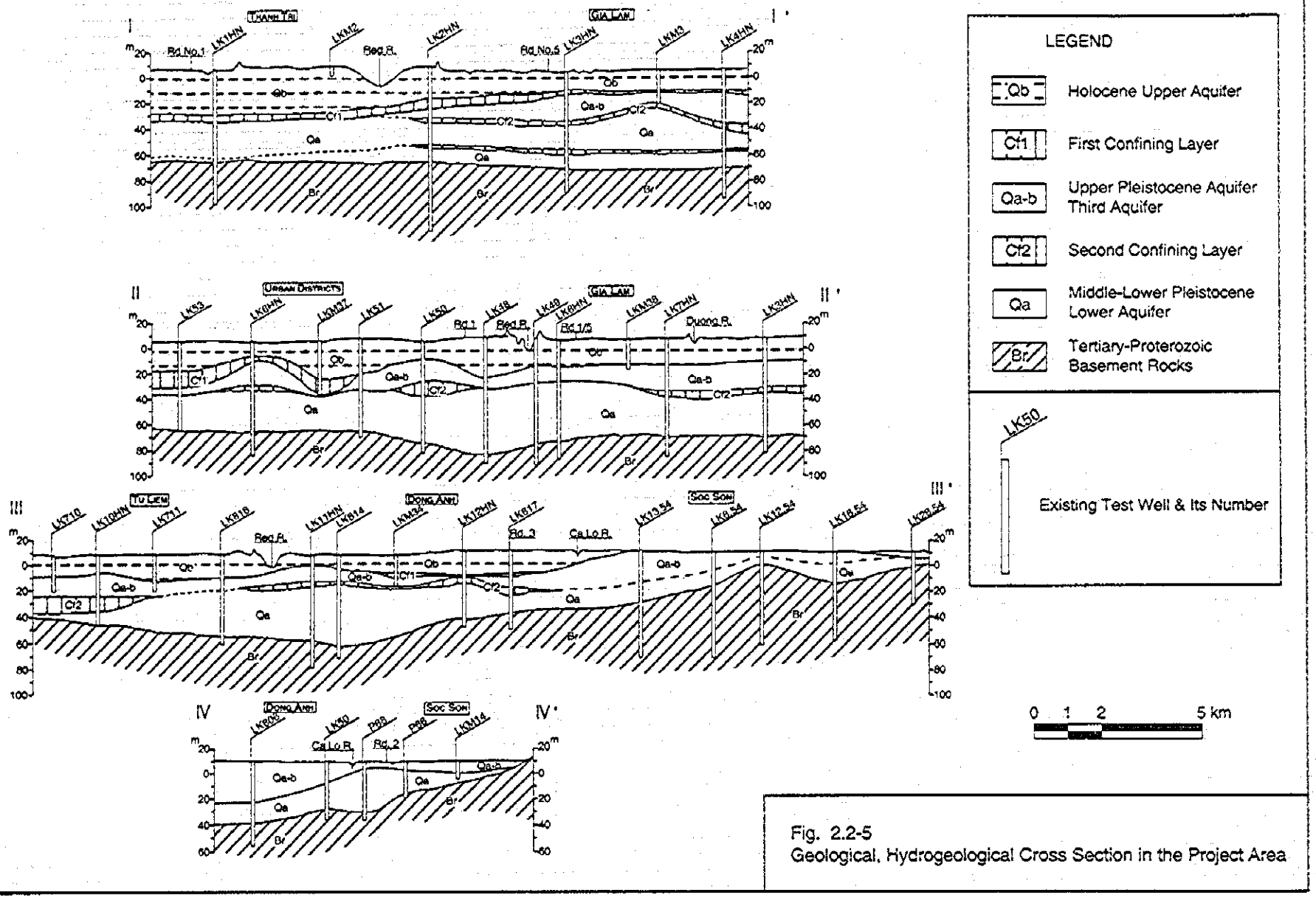


Fig. 2.2-5
Geological, Hydrogeological Cross Section in the Project Area

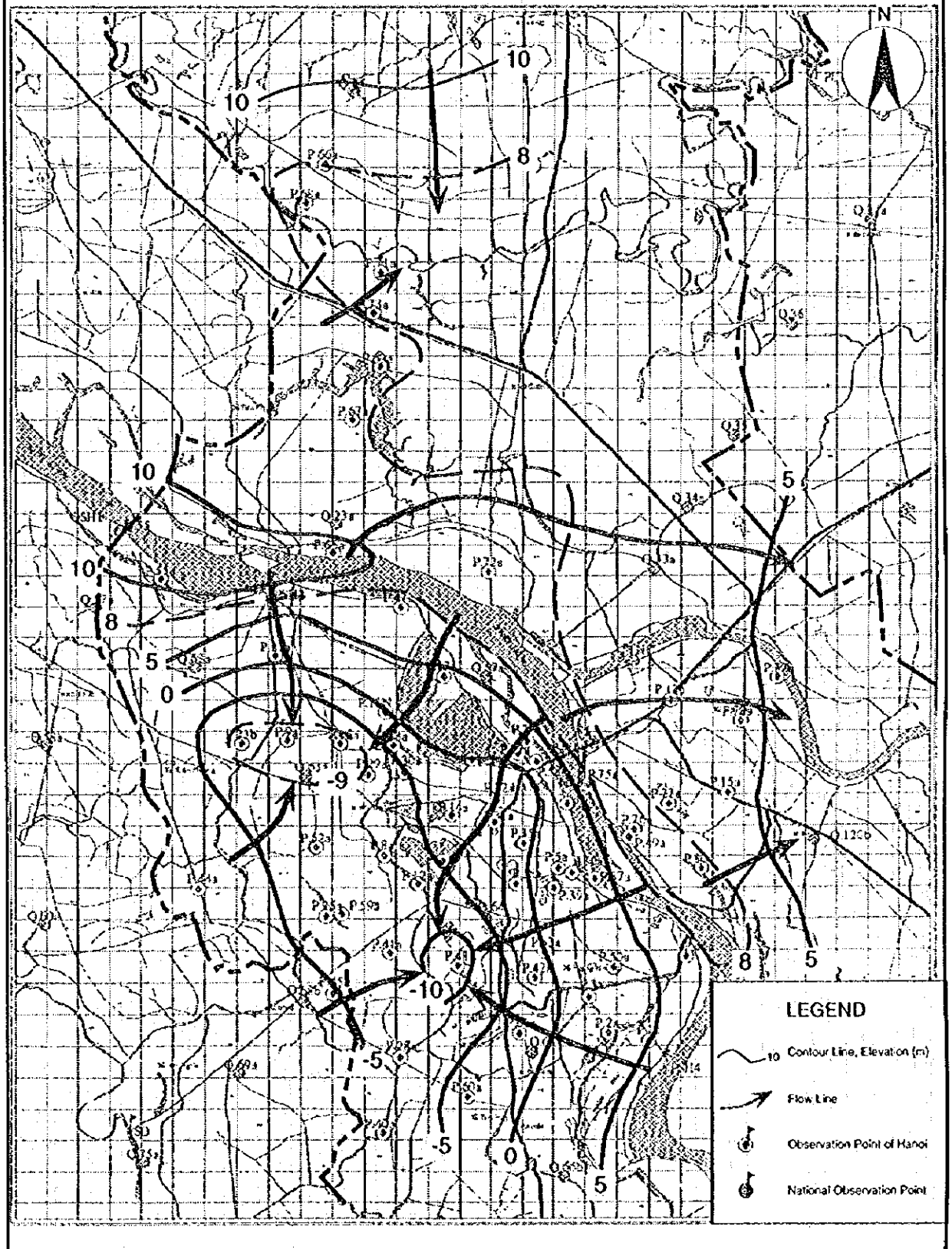


Fig. 2.2-6
Observation Wells and Piezometric Contour Line of Qa (Rainy Season 1995)

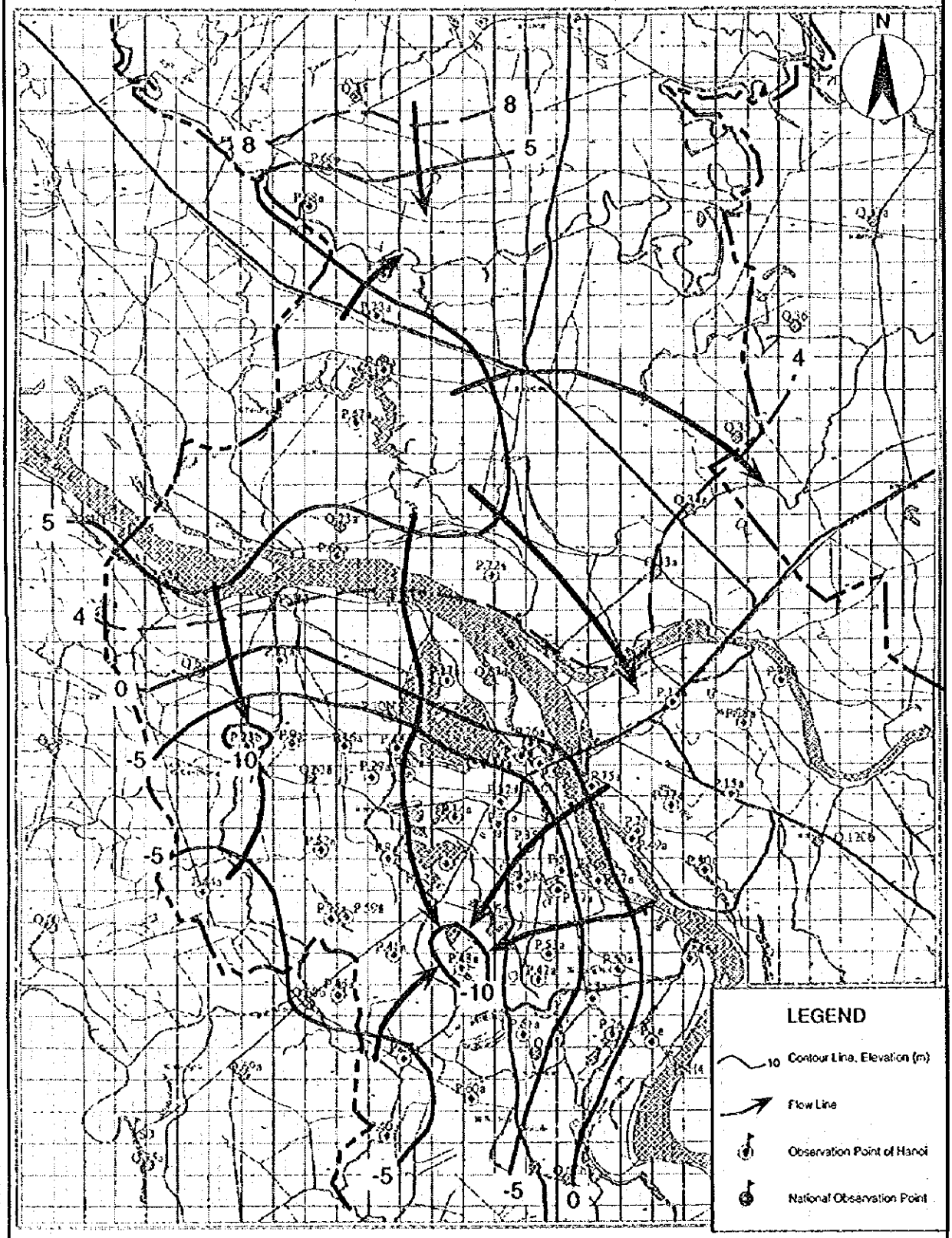


Fig. 2.2-7
Observation Wells and Piezometric Contour Line of Qa (Dry Season 1995)