社会開発調査部報告書

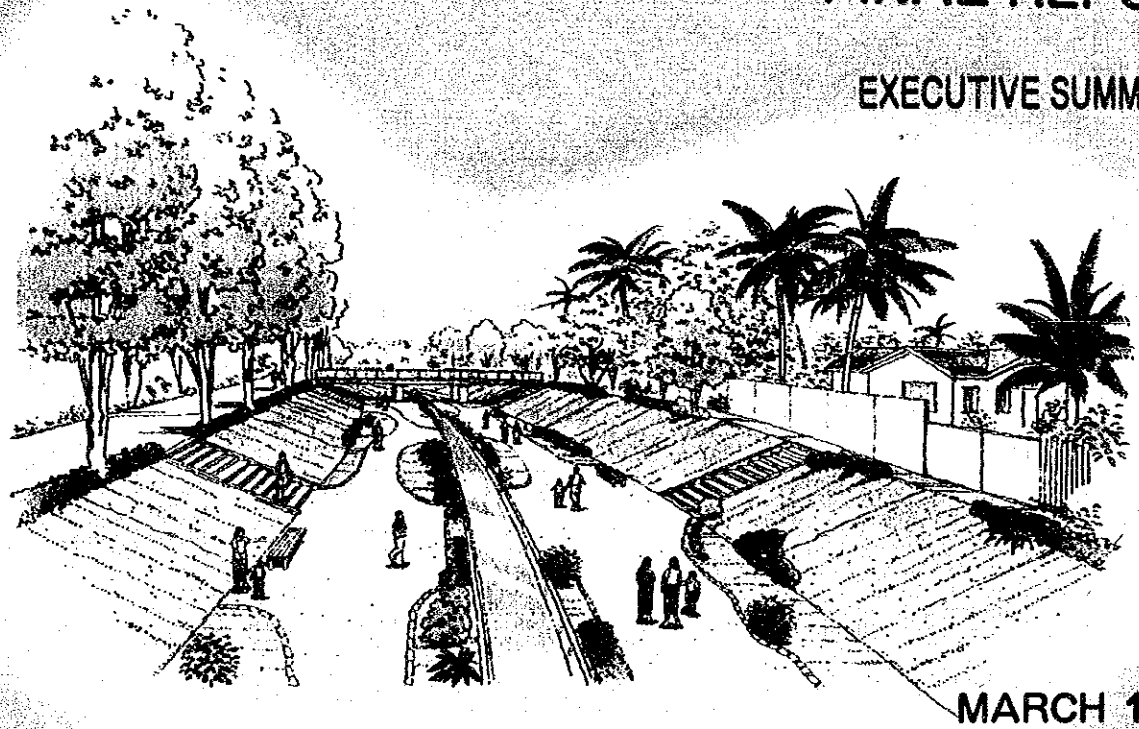
No. 32

LAO PEOPLE'S DEMOCRATIC REPUBLIC

FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE

FINAL REPORT

EXECUTIVE SUMMARY



MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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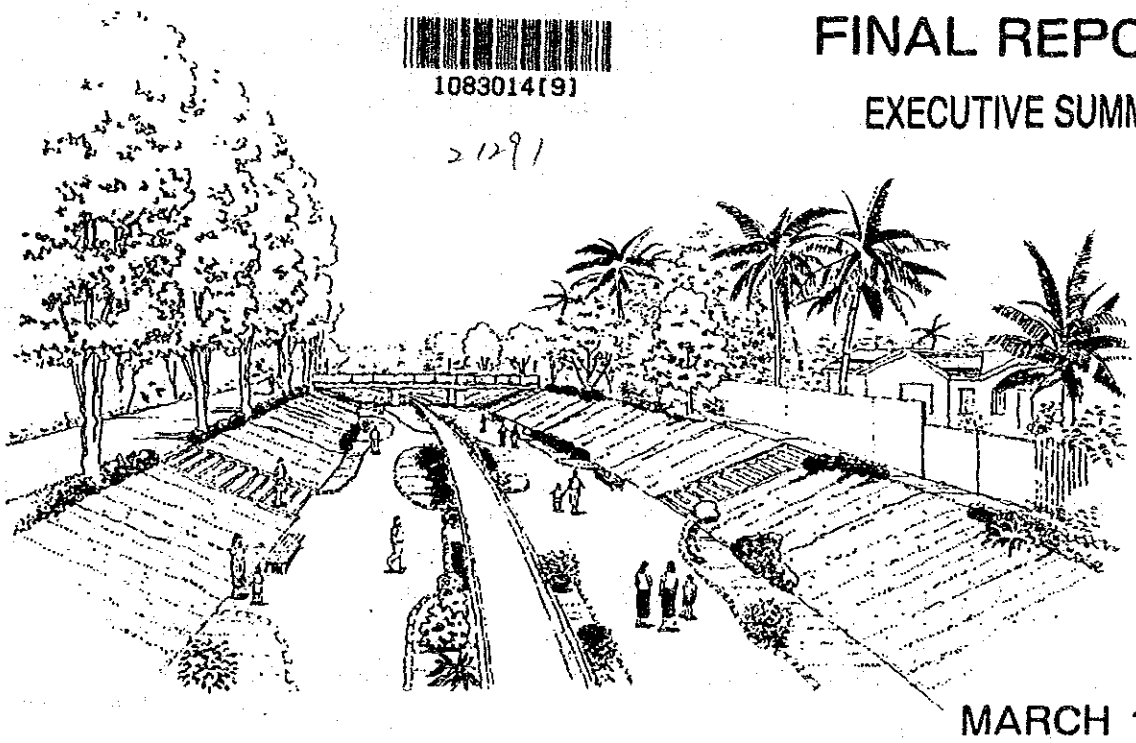

MARCH 1990

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PREFACE

In response to a request from the Government of Lao People's Democratic Republic, the Japanese Government decided to conduct a feasibility study on the improvement of drainage system in Vientiane and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Laos a survey team headed by Mr. Norio Takayanagi, Nippon Koei Co., Ltd. from April 1989 to February 1990.

The team held discussions with concerned officials of the Government of Laos, and conducted field surveys. 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 Lao People's Democratic Republic for their close cooperation extended to the team.

March 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

FEASIBILITY STUDY ON
IMPROVEMENT OF DRAINAGE SYSTEM
IN VIENTIANE

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

March 1990

Dear sir,

Letter of Transmittal

We are pleased to submit to you the Final Report for Feasibility Study on Improvement of Drainage System in Vientiane. This report proposes improvement measures of storm water drainage in Vientiane to the Government of the Lao People's Democratic Republic for implementation.

The report presents a basic plan for storm water drainage improvement in the entire Study Area and feasibility plans for the identified priority area. The study recommended improvement of several existing drainage channels and construction of retarding basins in order to counter the extensive inundation damage caused by storm rainfalls.

The Report consists of the Main Report with Summary and three volumes of Supporting Reports. The Summary briefs the findings and the feasibility plans recommended in the Study. The Main Report contains full description of the study results, conditions of the study, recommended drainage improvement plans, conclusions and recommendations. Supporting Reports contain background data and technical details.

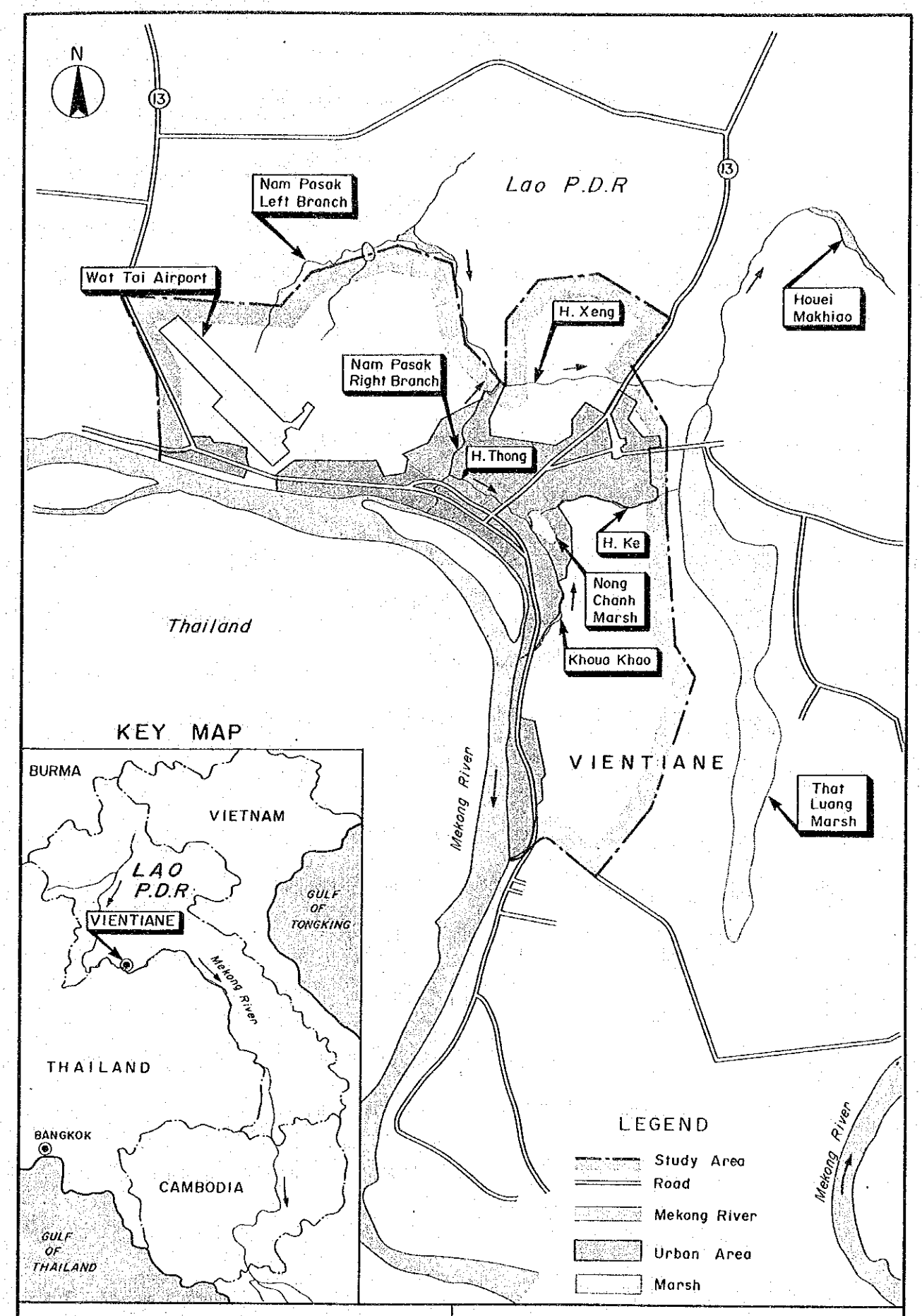
All members of the Study Team wish to express sincere gratitude to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction and Embassy of Japan to the Lao P.D.R., as well as officials of the Government of the Lao P.D.R. for their assistance. The Study

Team sincerely hope that the study results will contribute to development of well-being in Vientiane.

Yours sincerely,

N. Takayanagi

Norio Takayanagi
Team Leader



FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE

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GENERAL MAP

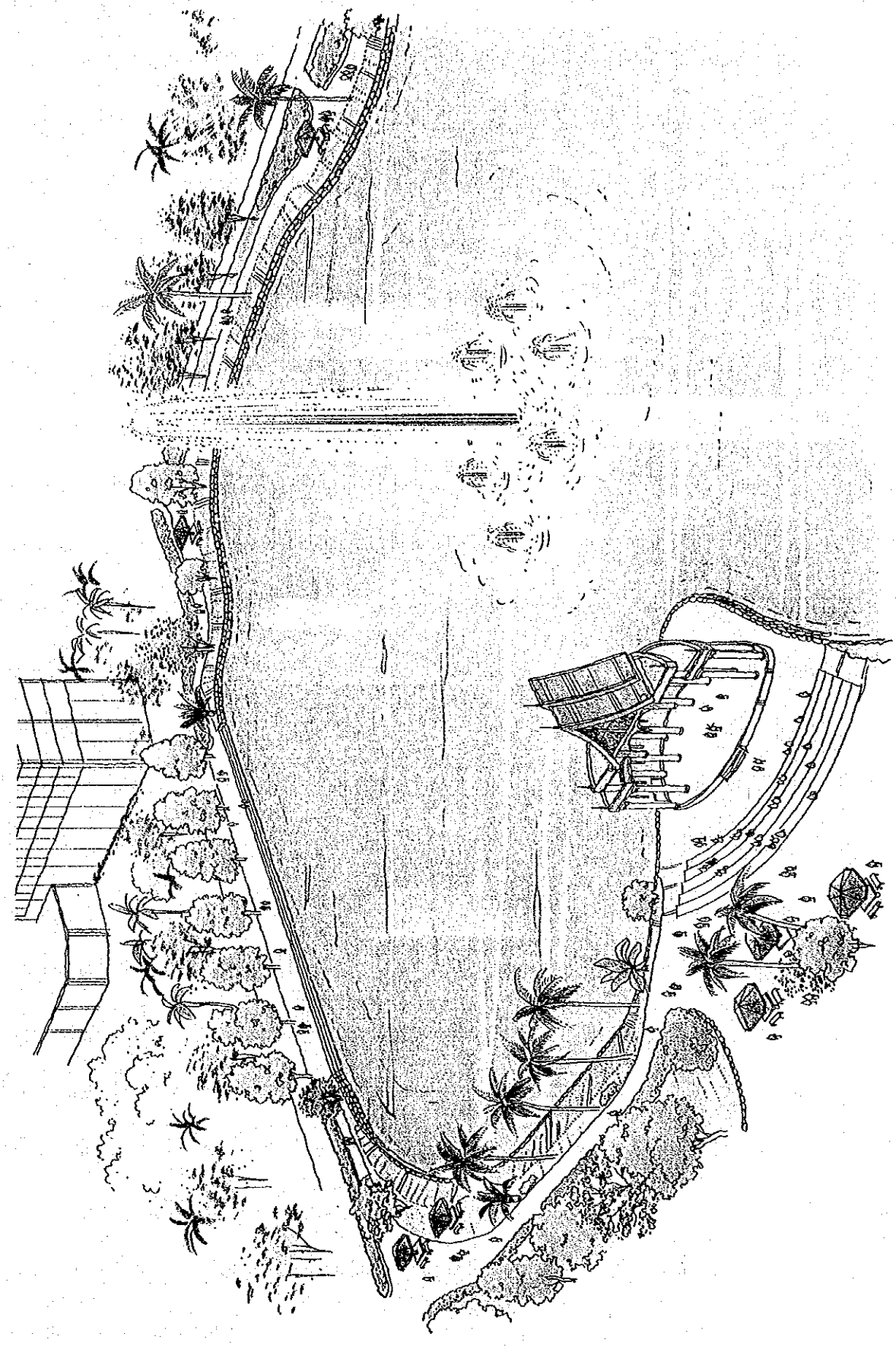

Plate 1 Image of Improved Nong Chanh Marsh

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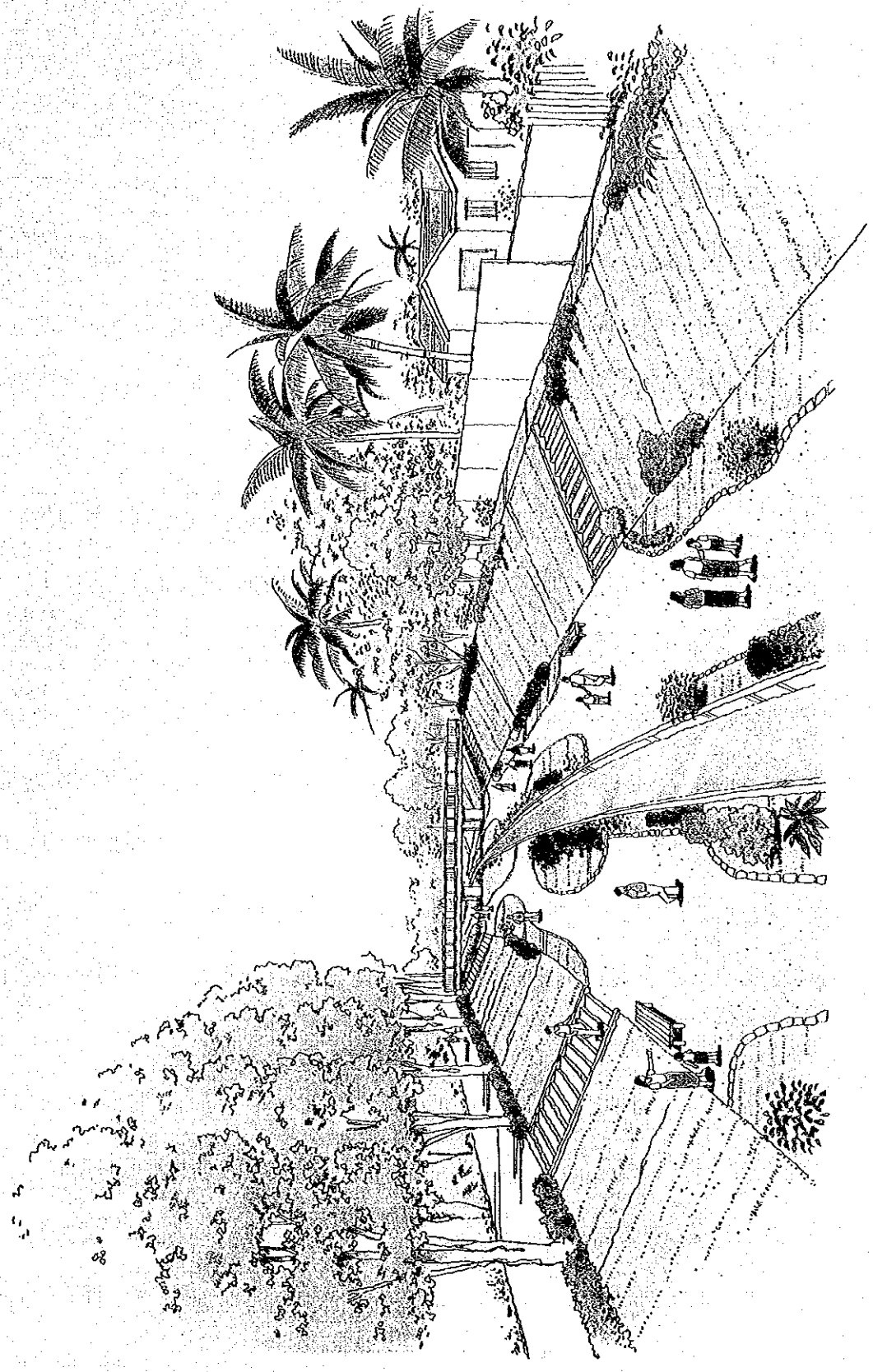

Plate 2 Image of Improved Drainage Canal

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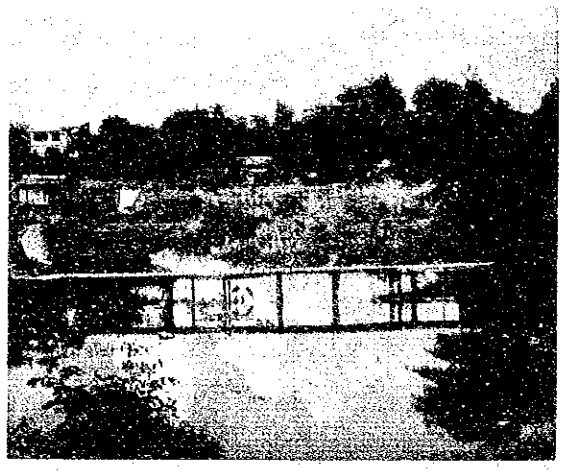
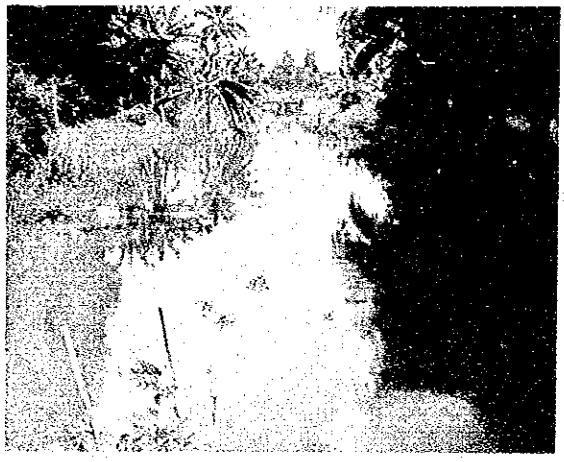
Hong Thong



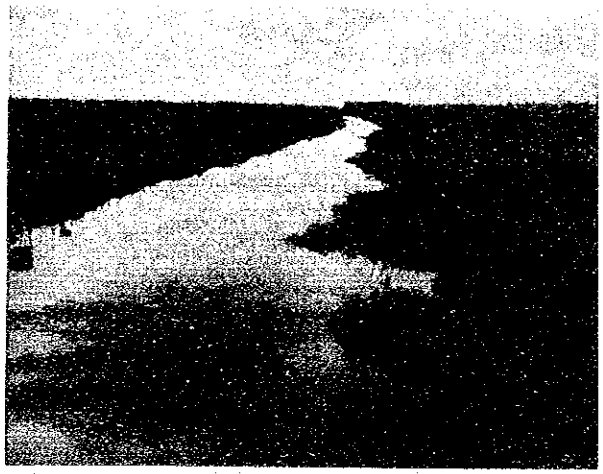
Junction of the Hong Thong with Khoua Khao

Nong Chanh Marsh



Hong Ke in the Middle Reach

Khoua Khao near Nong Chang Marsh



Drainage Canal in That Luang Marsh

Plate 3 (1) Drainage Canals in Vientiane

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
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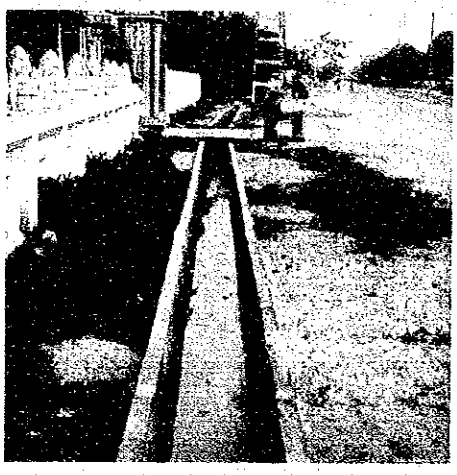
Hong Xeng near the Junction with Nam Pasak

Upstream Reach of Nam Pasak Left Branch



Lateral Canal near Wat Tay Airport

Drainage Canal in Sub-area M

Nam Pasak Right Branch

Nong Douang Marsh

Plate 3 (2) Drainage Canals in Vientiane

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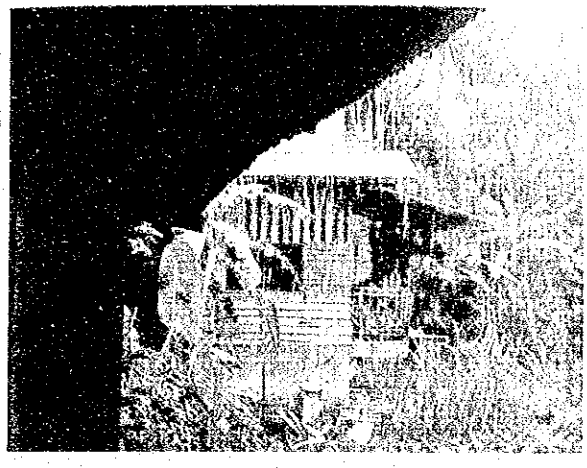

Storm Rainfall on 12/9/1989

New Market (Talat Mai) Inundated

An Inundated Local Restaurant (Sub-area H)

Temple (Wat) Inundated
(Sub-area H)

An Inundated Backyard of a House
(Sub-area H)

A Houseyard Inundated
(Sub-area H)

Plate 4 (1) Inundation in Study Area

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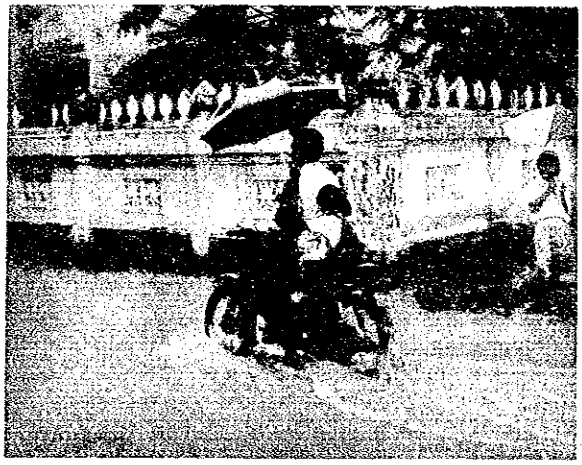
Central City Area Inundated
(Sub-area H)

A Trunk Road Inundated
(Sub-area L)



Motor Cyclist in Inundated
Urban Street (Sub-area L)

Pedestrians in an Inundated
Rural Road (Sub-area P)

Submerged Paddy Field
(Outside of Study Area)

Gas Station Suspended Operation
due to Inundation (Sub-area H)

Plate 4 (2) Inundation in Study Area

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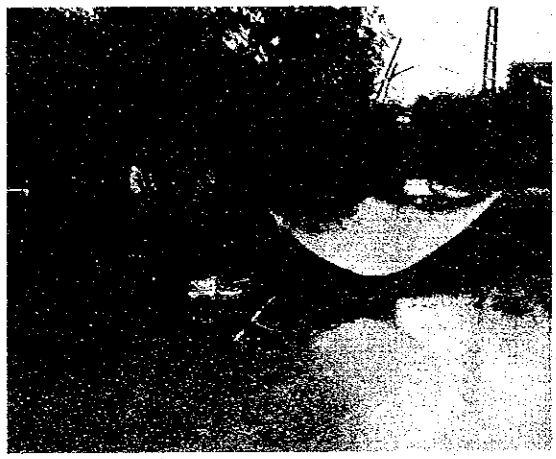
Pak Bon, Popular Water Plant,
Sold Along Hong Ke

View of a Bank with Sod Facing
(Saam Haa Park)

Fish Pond with Tree on the Banks
(Sub-area M)



Girls Catching Fish by a Hand Net

A Man Harvesting Lotus Stalks
(Nong Tha Nay)

A Man Catching Fish by Bow (Nong Bon)

Plate 5 (1) Water and People in Vientiane

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
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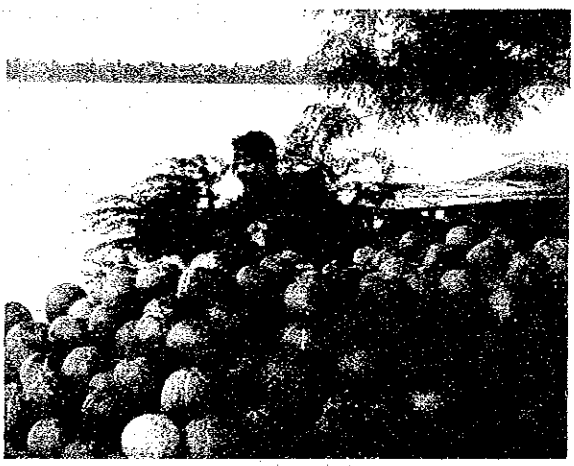
Young Girls Playing on a Boat (Nong Chanh)

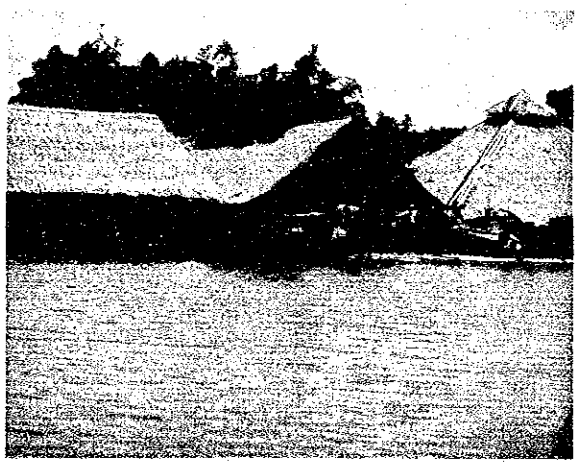
Children Swimming in a River (Nam Pasak)

Lotus Blossoms

Children Having Fun by Splashing Water (Nong Tha Nay)



A Fruit Seller on the Bank of the Mekong



A Floating Restaurant (Nam Ngum Reservoir)

Plate 5 (2) Water and People in Vientiane

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FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
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FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE

SUMMARY

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SUMMARY

1. Authority

The Scope of Works agreed upon by the government of Lao P.D.R. and JICA on 14 December 1988 is the basis of the Study and fully defines the Study.

2. The Objectives of the Study

The objectives of the Study are defined by the Scope of Works as follows;

(1) To formulate a basic plan for the storm water drainage system improvement in the Study area of 56.2 km^2 in the urbanized part of Vientiane municipality and to identify the priority project,

(2) To conduct a Feasibility Study on the identified priority project and

(3) To carry out technology transfer to the Laotian staff through the implementation of the Study.

3. Population

The census conducted in 1985 provides the latest data on population. The population in the Study area in 1988 was estimated on the basis of the census for four districts relevant to the Study area. Future populations in the Study area were projected on the basis of the natural and social growth rates. The estimated present population and projected future populations are shown below;

(1,000 persons)

Area	1985	1990	2000	2010	2020
National	3,585	4,016	4,825	5,645	6,426
Vientiane	377	474	680	931	1,221
Study area	149	164	201	251	305

4. GDP and GRDP

GDP in 1985 was estimated to be Kip58,774 million. The per capita GDP is estimated to be US$173. GDP is contributed largely by agricultural production. Shares by sectors are estimated to be 65.2% for agriculture, 14.0% for industry and 20.8% for services in 1986.

Future GDPs and GRDPs were projected on the basis of the economic development plan of the government, the projection made by the World Bank and economic trends. The projected figures at 1986 constant prices are summarized below;

GDP/GRDP	1990	2000	2010	2020
GDP (10^6 Kip)	77,300	133,900	249,400	497,000
Municipality				
GRDP (10^6 Kip)	22,500	52,200	122,200	293,200
Per capita (US$)	500	820	1,380	2,530
Study area				
GRDP (10^6 Kip)	15,800	32,700	71,100	160,000
Per capita (US$)	1,020	1,710	2,990	5,520

5. Climate

The climate of Vientiane is classified as tropical, with significant monsoon characteristics. The south-western monsoon causes rainfall from mid-May until around mid-October. This period is known as the rainy season. Heavy monsoonal storms occur in this rainy season.

Temperatures in Vientiane range from a low of about 16 to 18°C during the coolest months of December and January to a high of 31 to 32°C during the hottest months of March through May. The annual rainfall at Vientiane ranges from 1,100 mm in a dry year to 2,300 mm in a wet year. The average annual rainfall is around 1,600 mm, of which about 86 per cent occurs during the period of May through September.

6. Hydrology

Remarkable storms in the Study area are brought by the south-west monsoon and tropical depression. A monsoonal storm has high intensity and short duration. The duration is normally around 3 hours or less.

In order to supplement the existing meteoro-hydrologic data, the Study team installed the following recording devices.

Automatic rainfall gauge	:	1 no.
Automatic water level recorders	:	2 no.
Staff gauges	:	12 no.

The data taken by these equipment were utilized for hydrological analysis.

The estimated probable one-day rainfall depths are as follows;

Return period	Rainfall
2-year	104.0 mm
5-year	132.1 mm
10-year	150.6 mm
20-year	168.4 mm
100-year	208.7 mm

7. Land Use

At present the urban area occupies about 29 km^2 out of the Study area of 56.19 km^2. The urban area is projected to increase by 9 km^2 by the year 2000. The remaining 18 km^2 is green area and water area. These areas are to be maintained up to the year 2020. The increase in population after the year 2000 will be accommodated in the urban area of 38 km^2 by an intensification of land use.

The existing and projected areas by land use, are as follows;

Land Use	1989 (ha)	2000/2020 (ha)
Residential	2,164.4	2,658.3
Public and business	400.6	575.1
Industrial	38.2	107.4
Water	166.7	116.5
Green	2,499.3	1,772.2
Others	349.4	389.1
Total	5,618.6	5,618.6

8. Soil

The surface layer is identified to be clay loam generally about 1 m deep. The second layer is clay, silt and gravel from a depth of 2 to 7 meters. Sandy gravel layer appears at a depth of about 8 to 10 meters. The layers have N-values of more or less 10 for 7 to 8 meters. The N-value becomes more than 50 at 10 meters deep.

A survey conducted on the existing slope revealed that the maximum stable slope is 1:2.0. If the sand and gravel content is high, a slope of 1:3 is advisable.

9. Existing Drainage System

The Study area of 56.2 km^2 is drained by the following 10 rivers and canals. Plate 3 shows some of the main canals in the Study area. The following table summarizes the features of the canals;

Drainage	Catchment area (km^2)	Length (km)	Slope
Hong Ke System			
Hong Thong	1.88	1.8	1 : 1,400
Khoua Khao	1.96	2.5	1 : 1,500
Hong Ke	5.69	3.0	1 : 1,600
Hong Xeng System			
Nam Pasak (L)	58.90	9.3	1 : 3,400
Nam Pasak (R)	2.14	4.7	1 : 1,400
Hong Kai Keo	2.76	1.3	1 : 1,400
Wat Tay	7.79	5.0	1 : 2,500
Hong Xeng	8.22	3.3	1 : 5,000
Souane Mone	7.51	4.4	1 : 2,000
Nong Hay	4.50	4.0	1 : 2,000

The flow capacities of these rivers and canals are small. The flow capacities per unit catchment area thereof are around 0.2 $m^3/s/km^2$. This small flow capacity is one of the causes of the frequent inundation which has not yet been improved because of the following.

(1) Storm water tends to inundate and stagnate in the river basin, which prolongs the time taken to reach the relevant main canal. Consequently the peak discharge of the channels is small.

(2) The main canals do not have distinctive channels in some stretches and the stream flow submerges low lands such as paddy fields along the river course. This decreases the peak discharge considerably.

Recent urbanization has increased the peak discharge and improvement of the drainage system has become necessary.

Growth of bushes and silting in the channels, together with the existence of narrow sections, have decreased the flow capacities. Extreme meandering is another factor which decreases the flow capacity in the case of the Nam Pasak right branch.

10. Water Quality and Environment

The water quality in the Study area is poor. The average figures for water quality indicators are as follows;

Item	Annual	Rainy season	Dry season
DO (mg/l)	1.8	1.6	2.0
COD-Mn (mg/l)	8.0	6.6	10.0

The influx of domestic effluent and the disposal of garbage are the causes of poor water quality. The stagnation of the water creates poor sanitary conditions in the Study area.

The thick growth of bushes on river banks and poor water quality diminish the appeal of the water front for the people. The water area might otherwise be an amenity zone for the water-loving Laotian people.

11. Inundation

Inundation occurs frequently in the Study area. Plate 4 shows the inundation of roads, houses, temples and paddy fields on 12 September, 1989, after a storm rainfall of 84 mm/day occurred in Vientiane. A heavy storm of about 10 year return period occurred on May 14, 1988 with a rainfall of 162 mm. It brought extensive inundation in the Study area. According to the results of the inundation survey conducted by the Study team, the average depth was estimated to be about 60 cm all over the survey area.

In 1988, almost 80% of the 853 surveyed households suffered inundation 3 to 4 times a year. The average inundation depth thereof was 34 cm.

12. Principles for the Basic Plan

The following principles are employed in the formulation of the Basic Plan for drainage improvement;

(1) The present study deals with relieving the Study area of the inundation caused by storms occurring in the Study area. Flooding of the Mekong is outside of the Scope of Works for this Study.

(2) The existing drainage systems have several problems and yet play the most important role. The improvement thereof is the most appropriate means of relieving inundation, with the least possibility of causing a serious social problem.

(3) The OMR of the proposed system should be simple and should not require complex technology. In this connection, materials available in the country should be used in the construction.

(4) The system proposed should enhance the sanitary condition and amenity as well as drainage condition. Because the Study area is located in the midst of the national capital.

(5) The system proposed should conserve the environmental condition in and around the Study area as much as possible.

(6) The improvement plan should be consistent with the urban development plan of the Municipality.

13. Zoning

The Study area of 56.2 km^2 is divided according to the existing main drainages and watershed areas into 17 subareas marked from A through Q. The demarcation of the zoning is presented in Fig. 3.1.

14. Design Storm

A preliminary study on several different protection levels proved that protection against the 10-year storm is the most advantageous scale of the project with the target year of 2020. Therefore the 10-year storm is adopted as the design storm for the main canals. For lateral canals that connect to the main canals, a design storm with a 2-year return period was evaluated to yield the maximum benefit. The 2-year design storm was thus selected.

These selected design storms for the drainage plan are consistent with the flood protection level of the Mekong river (25 years), as planned by the Mekong Committee.

15. Concepts for Planning

In the light of the planning principles, the following concepts are adopted.

(1) The existing rivers and canals which collect and convey storm water shall be utilized as the main canals because they are located at the most appropriate sites in view of socio-economy, topography and environmental conditions.

(2) The existing marshes and ponds shall be utilized as a retarding basin as much as possible to lessen the loads of peak discharge to the canals and to improve the environmental condition.

(3) Direct discharge to the Mekong river from the Study area should be considered if proven effective.

(4) Discharge by means of gravity is a preferable method as it incurs the least operation and maintenance cost. Pumps and gates will be considered where the provision thereof would have obvious advantages.

16. Alternative Basic Plans

In line with the planning concepts, alternative plans were contemplated for the 10 rivers and canals and three marshes; Nong Chanh, Nong Bon and Nong Douang. The alternative plans envisaged are as follows;

(1) Plan-1 : All the water is to be disposed to That Luang marsh and the Houei Makhiao through the existing main canals by gravity. The width of each main canal will be enlarged.

(2) Plan-2 : All the water is to be disposed to That Luang marsh and the Houei Makhiao through the existing main canals. Some canal gradients will be made steeper by excavation. A retarding pond will be provided at the end of the Hong Ke. The water once impounded will be discharged to That Luang marsh by pumps.

(3) Plan-3 : All the water is to be disposed to That Luang marsh and the Houei Makhiao. Several new canals will be provided along the main roads to dispose of water to That Luang marsh. Also, ponds provided at the terminals of the canals for peak cut will help to purify the water.

(4) Plan-4 : Water is to be disposed to That Luang marsh, the Houei Makhiao and the Mekong. A pumping station is provided at the end of the Khoua Khao to dispose water to the Mekong.

(5) Plan-5 : Water is to be disposed to That Luang marsh, the Houei Makhiao and the Mekong. Pumping stations are provided at the end of the Khoua Khao and the Nam Pasak right branch.

(6) Plan-6 : Water is to be disposed to That Luang marsh, the Houei Makhiao and the Mekong. Pumping stations are provided at the end of the Khoua Khao, Nong Douang retarding basin and the end of the Nong Hai.

(7) Plan-7 : Water is to be disposed to That Luang marsh, the Houei Makhiao and the Mekong river by means of gravity. Gates will be provided at the outlets to the Mekong. The canal widths are enlarged to secure water retarding space.

The concepts of the plans are illustrated in the figures from Fig. 5.1(1) through 5.1(4).

17. Comparative Study and the Adopted Plan

The proposed alternative plans were assessed from various aspects. The assessed items were: the contribution to the improvement of sanitary condition; the creation of good scenic views; water quality conservation; the generation of amenity space; the ease in material procurement; ease in maintenance; the possibility of other functions; workability; project life; spatial equity of the benefit; the adaptability to other plans and ease in the land acquisition.

In addition the cost to be incurred by each alternative was preliminarily estimated. Alternative-4 was judged to be the most preferable plan which yielded the least cost. In the light of this, Alternative-4 is selected as the proposed plan. The Government of Lao P.D.R. duly decided not to discharge the drainage water by pumps to the Mekong at the outlet of the Khoua Khao. Accordingly a gate is provided at the site instead of a pumping station. The Government decided also to utilize the Nam Pasak right branch as the irrigation canal, and its flow direction was reversed. The plan finally adopted is illustrated in Fig. 5.2.

18. Priority of the Project

The systems which constitute the adopted plan were compared to decide the priorities. The comparisons were made on the basis of benefit and costs ratio estimated preliminarily. The results of the comparison are grouped into 3 categories. The first priority projects are the Hong Ke system, the Nam Pasak system, Hong Kai Keo and the system for the subarea K. The priorities are summarized as follows;

Priority	System	Subarea
1st	Hong Ke, Nam Pasak, Hong Kai Keo and Hong Xeng	C, D, E, F, G, H, I, L and K
2nd	Wat Tay and Hong Xeng	J, O, M and N
3rd	Nong Hay and Souane Mone	A and B

Consequently the Hong Ke system, Nam Pasak system, Hong Kai Keo system and the system for Sub-area K are selected as the Priority Project. Fig. 5.3 shows the selected Priority Project.

19. Feasibility Study on the Hong Ke System

The Hong Ke system comprises the Hong Thong with the morning market culvert with a length of 270 m, the Khoua Khao, Nong Chanh and the Hong Ke. The system eventually drains to That Luang marsh.

The design water level of That Luang marsh is designated to be El.166.0 m on the basis of the past flood events. The ground elevation of the morning market is El. 168.5 m. The harmless water levels of the Hong Thong and the Khoua Khao are assumed to be El. 168.0 m and El. 167.0 m, respectively. Consequently the design maximum water levels are selected as follows;

That Luang marsh	El. 166.0
Nong Chanh marsh	El. 167.0
Inlet of culvert	El. 168.0
The Khoua Khao	El. 167.0
The Hong Thong	El. 168.0

The potential peak discharges of 10-year storm are estimated as shown below;

Hong Thong	Upper reach	6.6 m^3/s
	Lower reach	20.9 m^3/s
Khoua Khao	Upper reach	9.2 m^3/s
	Lower reach	17.5 m^3/s
Hong Ke	Upper reach	42.9 m^3/s
	Lower reach	70.5 m^3/s

Alternative drainage plans were considered to regulate and discharge the flood safely within the maximum water levels as described above. The conceivable alternative plans are the following different combination of the regulating spaces;

Unit : m^3

Case	Case 1	Case 2	Case 3	Case 4	Case 5
Canal					
Hong Thong	No storage		16,000		16,000
Khoua Khao	ditto		32,000		32,000
Nong Chanh	ditto	80,000	60,000	120,000	120,000
Hong Ke	ditto				
Total Storage	0	80,000	108,000	120,000	168,000

The construction costs to be incurred by the alternative plans are compared mutually, and case 1, 3 and 5 are identified as the least costly alternatives. The case 5 conserves the maximum amenity space of water area in Nong Chanh retarding basin. And the environmental impact of case 5 is the minimum because the reduction of marsh area thereby is the minimum. In view of this case 5 is adopted as the feasibility plan for the Hong Ke system.

Various alternative structures such as revetment, culvert, bridge and channel sections were applied for the selected feasibility plan, and the preferable structures were selected for the proposed facilities. Adopted features of the Hong Ke system are summarized as follows;

Design water level:

That Luang	El. 166.0
The Nong Chanh retarding basin (FWL)	El. 167.0
The Nong Chanh retarding basin (LWL)	El. 166.0
The Hong Thong storage pond (FWL)	El. 168.0
The Hong Thong storage pond (LWL)	El. 167.0
The Khoua Khao storage pond (FWL)	El. 167.0
The Khoua Khao storage pond (LWL)	El. 166.0

The Hong Ke channel:

Design discharge (max.)	58.1 m^3/s
Design discharge (min.)	31.8 m^3/s
Length	2,570 m
Width (max.)	34 m
Revetment works (concrete block)	5,140 m
Main bridge (4 bridges)	81 m
Movable aqueduct (100 lit./sec)	40 m

The Nong Chanh retarding basin:

Storage volume	120,000 m^3
Surface area	12 ha
Length of spillway (weir)	21.0 m
Type of gate (steel)	Sluice
Nos. of gate leaf	1 leaf
Revetment works (stone masonry)	2,000 m

Culvert in the Hong Thong:

Design discharge	15.5 m^3/s
Length	270 m
Nos. of lanes	2
Required flow section	12.0 m^2
Elevation of sill (outlet)	El. 166.0
Elevation of sill (inlet)	El. 166.3

The Hong Thong storage channel	
Storage volume (compound section)	16,000 m^3
Revetment works (concrete block)	2,260 m
Concrete headrace channel to the Nong Chanh retarding basin (single section)	400 m
Nos. of bridge	7
The Khoua Khao storage channel	
Storage volume (Compound section)	32,000 m^3
Revetment works (Concrete block)	2,500 m
Nos. of bridge	10
The lateral canal (Saya Settathirath)	3 km

Profile and sections of the proposed Hong Ke system is presented in Fig. 6.9(1) - Fig. 6.9(5).

The financial cost is estimated to be US$15,753 x 10^3 at October 1989 constant price. The economic cost of US$12,891 x 10^3 is derived applying conversion factors estimated. Meanwhile the annual benefit is estimated to be US$1,996 x 10^3 in 2020 as the damage reduction of the project. The eventual economic rate of return of 7.3% is obtained.

The preconstruction works would require 12 months for detailed design and other works. The actual construction would be completed within 24 months.

20. Feasibility Study on the System for Sub-area L (Nam Pasak)

The Nam Pasak system comprises channel improvement of the Nam Pasak right branch. No retarding basin is conceivable.

The design water level of the Hong Xeng at the confluence is designated to be El. 167.2 m. The harmless water levels of the Nam Pasak are El. 167.6 m at the confluence of the Hong Thong and El. 168.0 m at the upper-most reach.

Meanwhile the potential peak discharge of 10-year storm is estimated to be 23.3 m^3/s in the lowest reach of the Nam Pasak. Alternative drainage plans were considered to discharge the flood safely within the designated maximum water levels as described above. The conceivable alternative improvements are the case with shortcuts and the case without shortcut. The hydraulic features of the two proposed alternatives are as follows;

Item	Alternatives	
	Case 1 (short-cut plan)	Case 2 (existing route plan)
Design discharge (m^3/s)		
Upstream reach	6.8*	8.9*
Downstream reach	23.3	23.3
Water surface El. (El. m) at the upstream end of channel	168.0	168.0
Channel bottom width (m)		
Upstream reach	3.0	5.0
Downstream reach	7.0	8.0
River course length (m)		
Upstream reach	1,300	1,920
Downstream reach	1,920	2,830

Note *: At the section 1,920 m upstream from the confluence

From consideration of the construction cost to be incurred by the alternative plans, the plan with shortcut was identified as the less costly alternative. Since the difference in other impacts such as environmental are believed to be insignificant, Case 1 was adopted as the priority project.

Various alternative structures were considered and compared for the selected plan. The finally adopted features of the Nam Pasak system are summarized below;

Design water level (Hong Xeng)	El. 167.2
Design discharge (max.)	23.3 m^3/s
Design discharge (min.)	6.8 m^3/s
Length of channel (compound)	3,220 m
Nos. of shortcut channel	5
Total length of shortcut channel	1,140 m
Width of shortcut (max)	10.4 m
Revetment works (concrete block)	6,440 m
Nos. of bridge	7

The profiles and sections of the proposed Nam Pasak system are presented in Fig. 7.3.

The financial cost is estimated to be US$7,526 x 10^3 at October 1989 constant price. The economic cost of US$5,313 x 10^3 is derived by applying the conversion factors estimated. Meanwhile the annual benefit is estimated to be US$410 x 10^3 in 2020 as the damage reduction of the project. The eventual EIRR is estimated to be 4.2%.

The preconstruction works would require 12 months. The construction would works require 24 months.

21. Feasibility Study on the System for Sub-area I (Hong Kai Keo)

The Hong Kai Keo system comprises the Hong Kai Keo drainage canal and the Nong Bon retarding basin. The design water level of the Hong Xeng at the confluence is designated to be El. 166.9 m on the basis of the flood records. The land to be urbanized is to be reclaimed and is assumed to be elevated at least to El. 168.0 or higher. Accordingly the harmless water level of the Nong Bon is assumed to be El. 167.5 m. The hydraulic features of the proposed Hong Kai Keo system is assumed as follows;

Canal, pond chainage	Catchment (ha)	Design discharge (m^3/s)
Nong Bon Pond		
Outlet	160.8	16.8
Hong Kai Keo		
HKK 840 - 1,340	32.8	20.2
HKK 0 - 840	31.2	23.5

Various alternative structures were considered and compared for the proposed plan. The adopted features of the Hong Kai Keo system are summarized below;

Design water level:

The Hong Xeng	El. 166.9 m
Nong Bon retarding basin (FWL)	El. 167.5 m
Nong Bon retarding basin (LWL)	El. 166.5 m

The Hong Kai Keo canal:

Design discharge (downstream)	20.2 m^3/s
Design discharge (upstream)	23.5 m^3/s
Length	1,300 m
Bed slope	1 : 1,300
Width (channel bed)	6 m
Bank slope	1 : 2.5
Low flow channel (W x H m)	2.0 x 0.5 m

Nong Bon retarding basin

Water surface area	50,000 m^2
Flood control space	50,000 m^3
Concrete weir crest el.	El. 167.0
Concrete weir length	20 m
Flush gate	Sluice 1 m x 1.5 m x 1 leaf
Stoplog width	4 m

Maintenance road

Elevation		El. 168.0 m
Width		5 m
Pavement		Asphalt
Road crossing culvert		1 m x 1 m

Bridge

Nong Soan Tha road	type	Concrete slab
	width	4 m
	load	TL-14
Phong Sa Ath road	type	Concrete slab
	width	2 m

Profile and sections of the proposed Hong Kai Keo system is presented in Fig. 8.1.

The financial cost is estimated to be US$5,458 x 10^3 at October 1989 constant price. The economic cost of US$4,648 x 10^3 is derived by applying conversion factors estimated. Meanwhile the annual benefit is estimated to be US$310 x 10^3 in 2020 as the damage reduction of the project. The eventual EIRR is estimated to be 3.5%.

Preconstruction works would require 12 months. The construction period is estimated to be 12 months.

22. Feasibility Study on the System for Sub-area K

The drainage improvement of subarea K could be achieved by the improvement of lateral canals and culverts embedded under the national highway route 13. The number of the lateral canals to be improved is 6 nos. The number of box culverts to be improved is 3 nos. The principal features are presented as follows;

Lateral No. 1

Design discharge	0.51 m^3/s
Length	310 m
Width	0.6 m
Slope	1 to 370

Lateral No. 2

Design discharge	0.68 m^3
Length	390 m
Width	0.8 m
Slope	1 to 670

Lateral No. 3

Design discharge	1.05 m^3/s
Length	270 m
Width	1.0 m
Slope	1 to 670

Lateral No. 4

Design discharge	0.39 m^3/s
Length	230 m
Width	0.7 m
Slope	1 to 670

Lateral No. 5

Design discharge	2.26 m^3/s
Length	230 m
Width	1.3 m
Slope	1 to 670

Lateral No. 6

Design discharge	0.26 m^3/s
Length	310 m
Width	0.6 m
Slope	1 to 670

Culvert No. 1

Design discharge	1.42 m^3/s
Length	20 m
Width	1.25 m
Height	1.25 m

Culvert No. 2

Design discharge	2.26 m^3/s
Length	20 m
Width	1.5 m
Height	1.5 m

Culvert No. 3

Design discharge	0.26 m^3/s
Length	20 m
Width	1.0 m
Height	1.0 m

Profile of proposed drainage for the Subarea K is presented in Fig. 9.1.

The financial cost is estimated to be US$3,710 x 10^3 at October 1989 constant price. The economic cost of US$3,159 x 10^3 is derived by applying conversion factors estimated. Meanwhile the annual benefit is estimated to be US$200 x 10^3 in 2020 as the damage reduction of the project. The EIRR for this system is estimated to be 3.5%.

Preconstruction works would require 12 months. The construction period is estimated to be 24 months.

23. Implementation Program

The Department of Communication, Transportation, Post and Construction, the Municipality of Vientiane, will be the executive agency of the project. And all the main works are assumed to be constructed by contractors after competitive tendering. The construction of the lateral canal and the OMR of the drainage system shall be conducted by the Laotian Government.

All the projects costs will be disbursed over 28 years according to the priorities. The total investment cost including O&M equipment costs except for O&M material, staff and labor is estimated to be US$75,452 x 10^3 at October 1989 constant prices. The proposed implementation schedule is shown in Fig. 10.1, and the necessary budget is summarized in Table 10.2.

The overall EIRR of the proposed Basic Plan is estimated to be 5.8%.

24. Recommendations

In order to implement the drainage improvement plan smoothly and effectively, several undertakings are necessary and are recommended as follows;

(1) The Hong Ke system attested to be economically viable and technically sound. With urbanization and intensification of the land use in the area, the inundation damage will increase remarkably. In view of this, implementation of the proposed Hong Ke system should be undertaken urgently.

(2) In order to make improvement of the main drainage system effective, the improvement of lateral canals is one of the most important works to be carried out by the Government of Lao P.D.R. The Municipality should accelerate the progress of this improvement work.

(3) Other related urban plans should be consistent with the proposed drainage improvement plans so that safety against inundation and enhancement of amenity contemplated in this Study can be secured.

(4) In order to realize the drainage master plan smoothly and effectively, the reinforcement of the executive agency and budgetary arrangement will be indispensable. The channels of communication with concerned agencies should be enhanced to achieve better coordination with other related plans.

(5) The water quality of the drainage water is poor due to the influx of domestic sewerage. The pollutant loads may increase with the growth in

population and economic activities in the Study area. In order to secure the amenity for the local residents and to improve the sanitary condition, the water quality should be improved. In this connection, the introduction of sewerage systems and garbage collection and treatment system should be considered. Amongst these, garbage treatment is considered to be of the most urgent need.

(6) The continuous maintenance and cleaning of the proposed drainage canals will contribute to the improvement of the water quality. The siltings of the suspended solid should be trapped and removed periodically. The dilution of polluted water by introducing fresh water from the Mekong and/or groundwater will be effective during the dry season. The artificial agitation of water by means of pumping will increase DO and be effective in improving water quality. These measures should be adopted as soon as convenient. In this connection the periodic monitoring of water quality is recommended, as well as the continuous data collection on storm rainfall and water levels by the instruments installed by the Study team.

(7) The drainage plan should be consistent with the development plan of the Houei Makhiao river basin, since the plan proposes the discharge of storm water to the Houei Makhiao. This river has large retarding spaces enough to accommodate the water without causing any significant adverse effect thereto. In this connection, data collection and recording should be commenced as soon as possible for hydrology, topography and socio-economy including water quality and environment.

(8) At present, the management of rivers is not integrated and no regulation have been enacted on the water right with regard to quality and quantity. The situation may cause institutional difficulty in the drainage management. It is recommended that the Government establishes an integrated institution and regulations for the improvement and OMR of drainage systems.

TABLES

Table 10.2 Disbursement Schedule of the Basic Plan
(Current price as of October 1989)

Unit: US$1,000

	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	Overall Period
Hong-ke system	13,237	1,800	180	180	180	176	15,753
(Hong-ke, Hong Thong,Khoua Khao)							
- Main work	11,929						11,929
- Lateral improvement	1,308	1,800	180	180	180	176	3,824
Nam-pasak system	0	7,526	0	0	0	0	7,526
- Main work		6,593					6,593
- Lateral improvement		933					933
Sub-area I	0	0	3,360	690	690	718	5,458
(Hong Kai Keo)							
- Main work			2,670				2,670
- Lateral improvement			690	690	690	718	2,788
Sub-area K	0	2,430	320	320	320	320	3,710
- Main work		630					630
- Lateral improvement		1,800	320	320	320	320	3,080
Sub-area O	0	0	0	0	5,469	0	5,469
(Hong Xeng)							
- Main work					5,469		5,469
- Lateral improvement							0
Sub-area M	0	0	0	11,522	740	753	13,015
(Wat Tay, Hong Xeng)							
- Main work				10,782			10,782
- Lateral improvement				740	740	753	2,233
Sub-area J	0	0	5,675	770	770	772	7,987
(Hong Xeng)							
- Main work			4,905				4,905
- Lateral improvement			770	770	770	772	3,082
Sub-area D	0	0	4,740	700	700	715	6,855
- Main work			4,040				4,040
- Lateral improvement			700	700	700	715	2,815
Sub-area P	0	0	0	0	840	842	1,682
- Main work							0
- Lateral improvement					840	842	1,682
Sub-area A	0	0	0	0	0	2,395	2,395
(Nong Hay)							
- Main work						2,395	2,395
- Lateral improvement							0
Sub-area B	0	0	0	0	0	5,602	5,602
(Soune Mone)							
- Main work						2,551	2,551
- Lateral improvement						3,051	3,051
Overall Basic Plan	13,237	11,756	14,275	14,182	9,709	12,293	75,452
- Main work	11,929	7,223	11,615	10,782	5,469	4,946	51,964
- Lateral improvement	1,308	4,533	2,660	3,400	4,240	7,347	23,488

Note: Including O&M equipment cost except cost for O&M material and stuff & labour

FIGURES

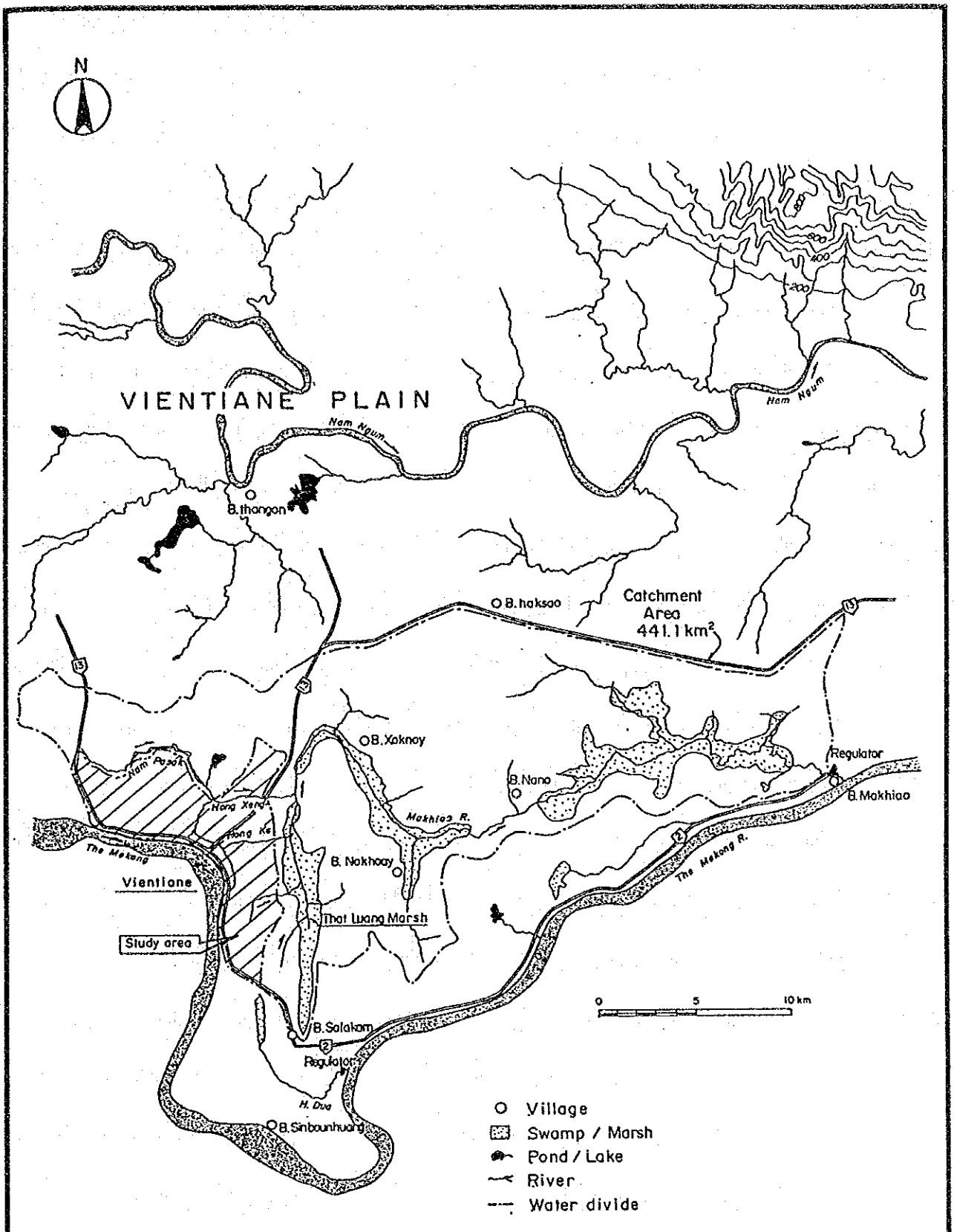

Fig. 2.1 Study Area and Vientiane Plain

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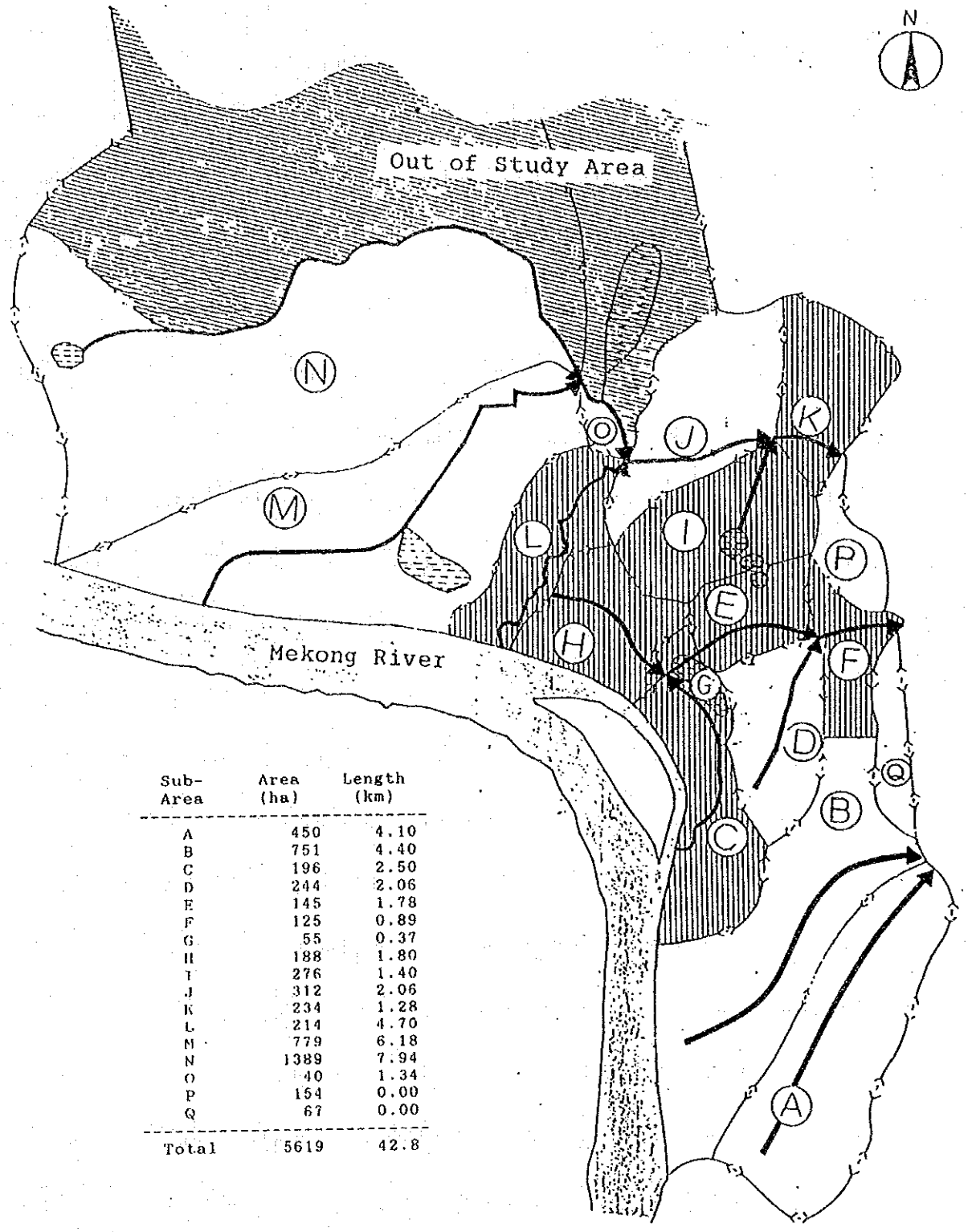

Sub-Area	Area (ha)	Length (km)
A	450	4.10
B	751	4.40
C	196	2.50
D	244	2.06
E	145	1.78
F	125	0.89
G	55	0.37
H	188	1.80
I	276	1.40
J	312	2.06
K	234	1.28
L	214	4.70
M	779	6.18
N	1389	7.94
O	40	1.34
P	154	0.00
Q	67	0.00
Total	5619	42.8

Fig. 3.1 Demarcation of Sub-areas

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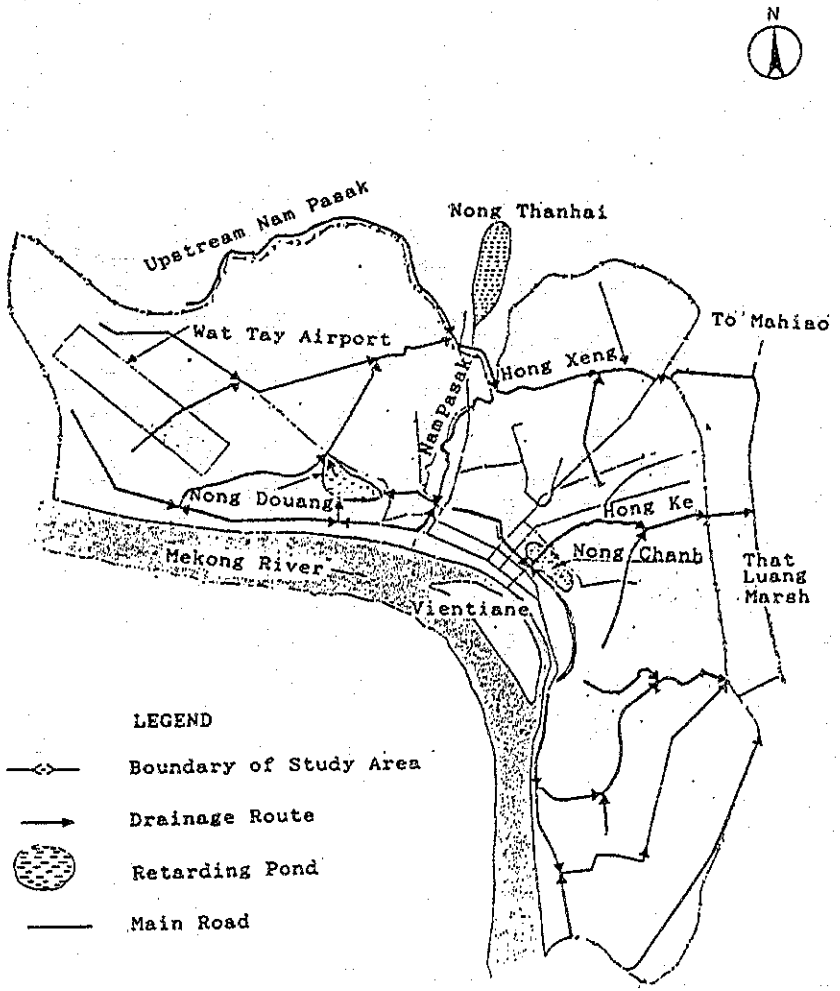
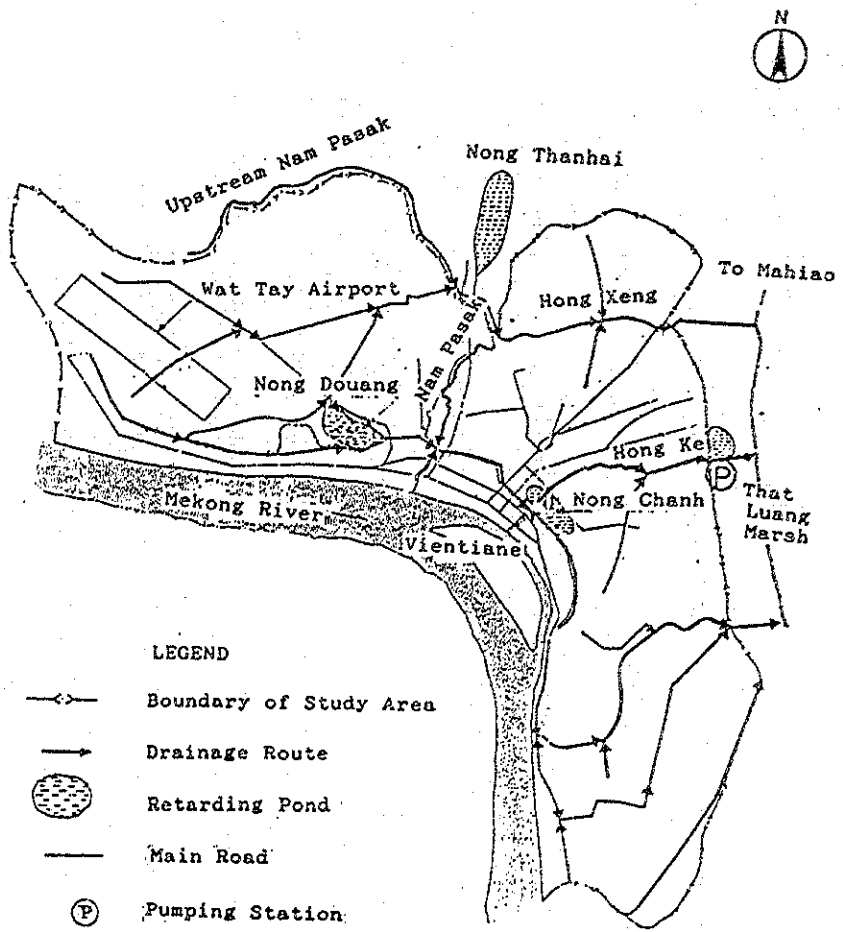


Proposed Alternative Plan (Concept-1)



Proposed Alternative Plan (Concept-2)

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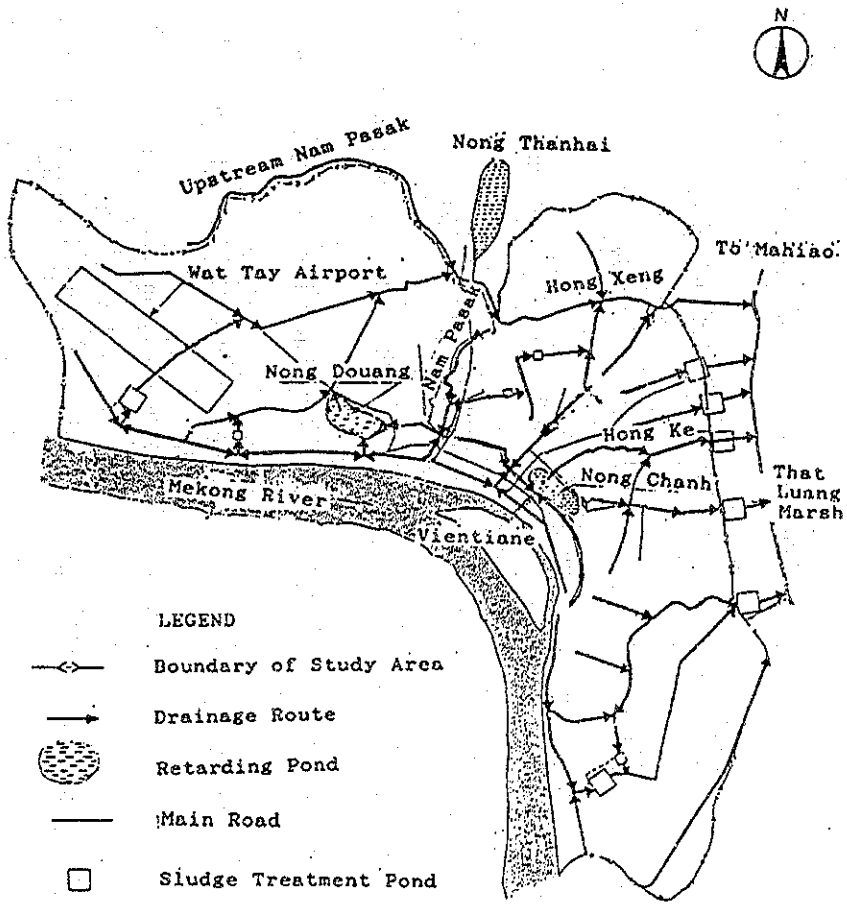
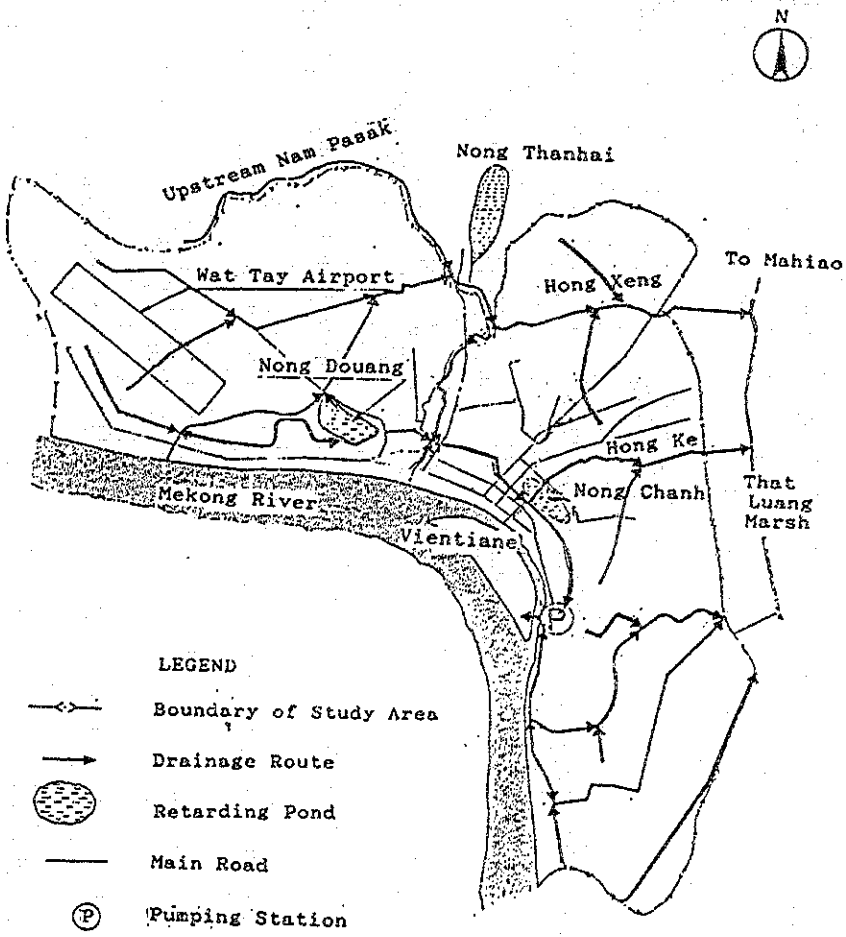
Fig. 5.1 (1) Alternative Basic Plans



Proposed Alternative Plan (Concept-3)



Proposed Alternative Plan (Concept-4)

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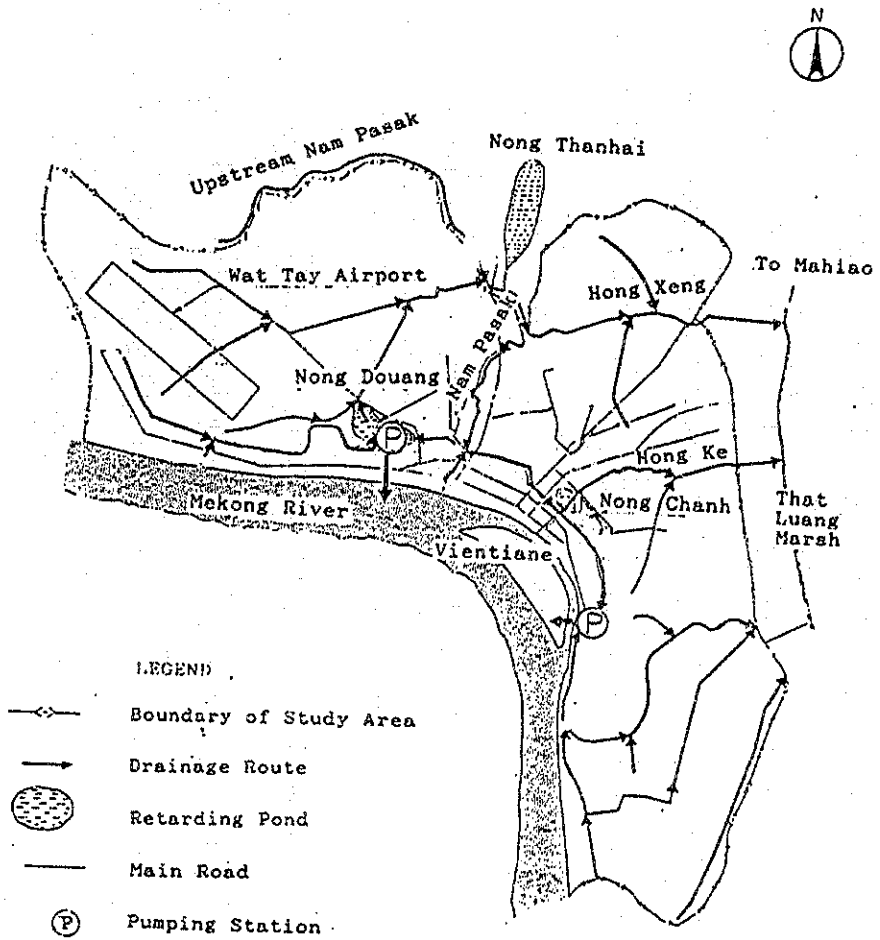
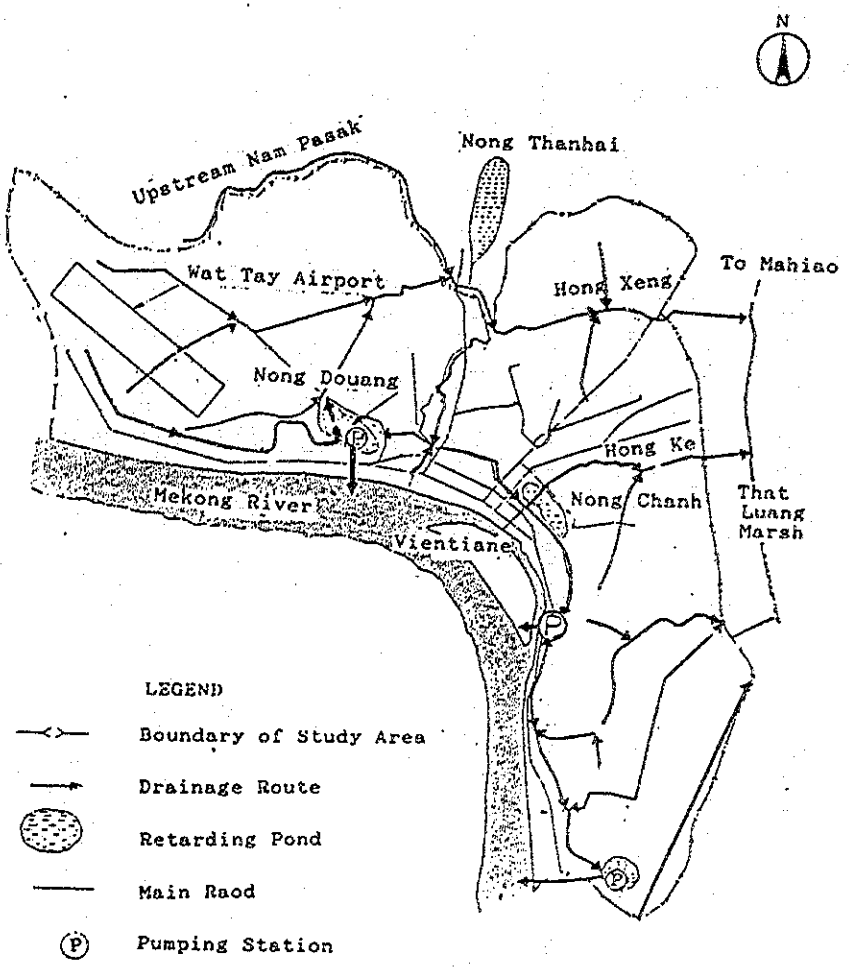
Fig. 5.1 (2) Alternative Basic Plans



Proposed Alternative Plan (Concept-5)



Proposed Alternative Plan (Concept-6)

Fig. 5.1 (3) Alternative Basic Plans

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
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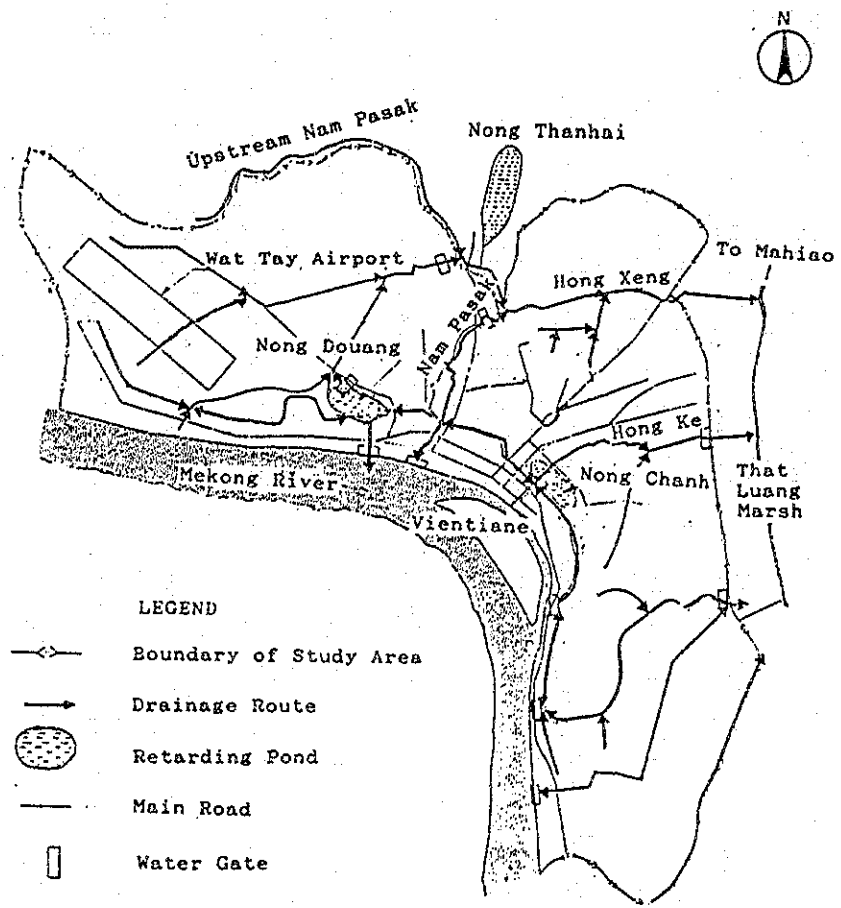

Proposed Alternative Plan (Concept-7)

Fig. 5.1 (4) Alternative Basic Plans

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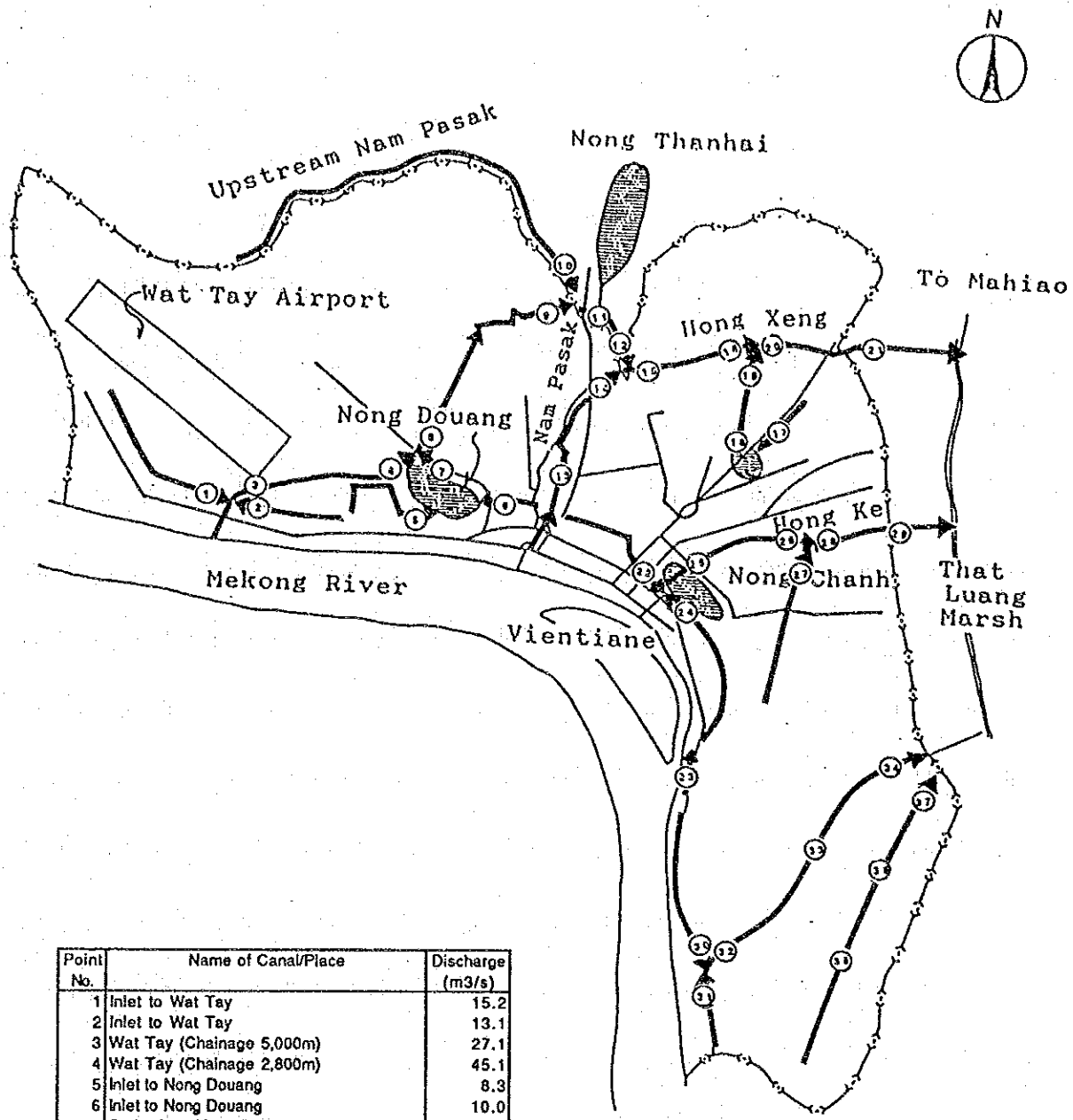

Point No.	Name of Canal/Place	Discharge (m3/s)
1	Inlet to Wat Tay	15.2
2	Inlet to Wat Tay	13.1
3	Wat Tay (Chainage 5,000m)	27.1
4	Wat Tay (Chainage 2,800m)	45.1
5	Inlet to Nong Douang	8.3
6	Inlet to Nong Douang	10.0
7	Outlet from Nong Douang	8.2
8	Wat Tay (Chainage 2,800m)	45.7
9	Wat Tay (Chainage 0 m)	55.8
10	Upstream Nam Pasak	30.0
11	Upstream Nam Pasak	84.2
12	Upstream Nam Pasak	119.0
13	Nam Pasak (Chainage 2,600 m)	6.8
14	Nam Pasak (Confluence with Honbg Xeng)	23.3
15	Hong Xeng (Chainage 3,344 m)	131.5
16	Hong Xeng (Confluence with H. Kai Keo)	139.7
17	Inlet to Nong Bon	17.6
18	Outlet from Nong Bon	16.8
19	Hong Kai Keo (Confluence with H. Xeng)	23.5
20	Hong Xeng (Chainage 1,600 m)	154.8
21	Hong Xeng at sluice gate	159.1
22	Hong Thong (Inlet to Nong Chanh)	20.9
23	Khoua Khao at Upstream	9.2
24	Khoua Khao (Inlet to Nong Chanh)	17.5

Point No.	Name of Canal/Place	Discharge (m3/s)
25	Outlet from Nong Chanh	42.9
26	Hong Ke (Chainage 800 m)	60.8
27	Dong Pai Na (Confluence with Hong Ke)	5.9
28	H. Ke (Chainage 800 m after confluence)	61.2
29	Hong Ke (Outlet to That Luang)	70.5
30	Thadeua Road (Souane Mone Area)	14.5
31	Thadeua Road (Souane Mone Area)	7.2
32	Inlet to Drainage Canal	19.3
33	Irrigation Drainage (Chainage 2,700m)	28.6
34	Outlet to That Luang Marsh	38.2
35	Irrigation Drainage(Chainage 1,370m)	21.2
36	Irrigation Drainage(Chainage 2,730m)	31.5
37	Outlet to That Luang Marsh	36.3

Fig. 5.2 Proposed Basic Plan

LAO PEOPLE'S DEMOCRATIC REPUBLIC
FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
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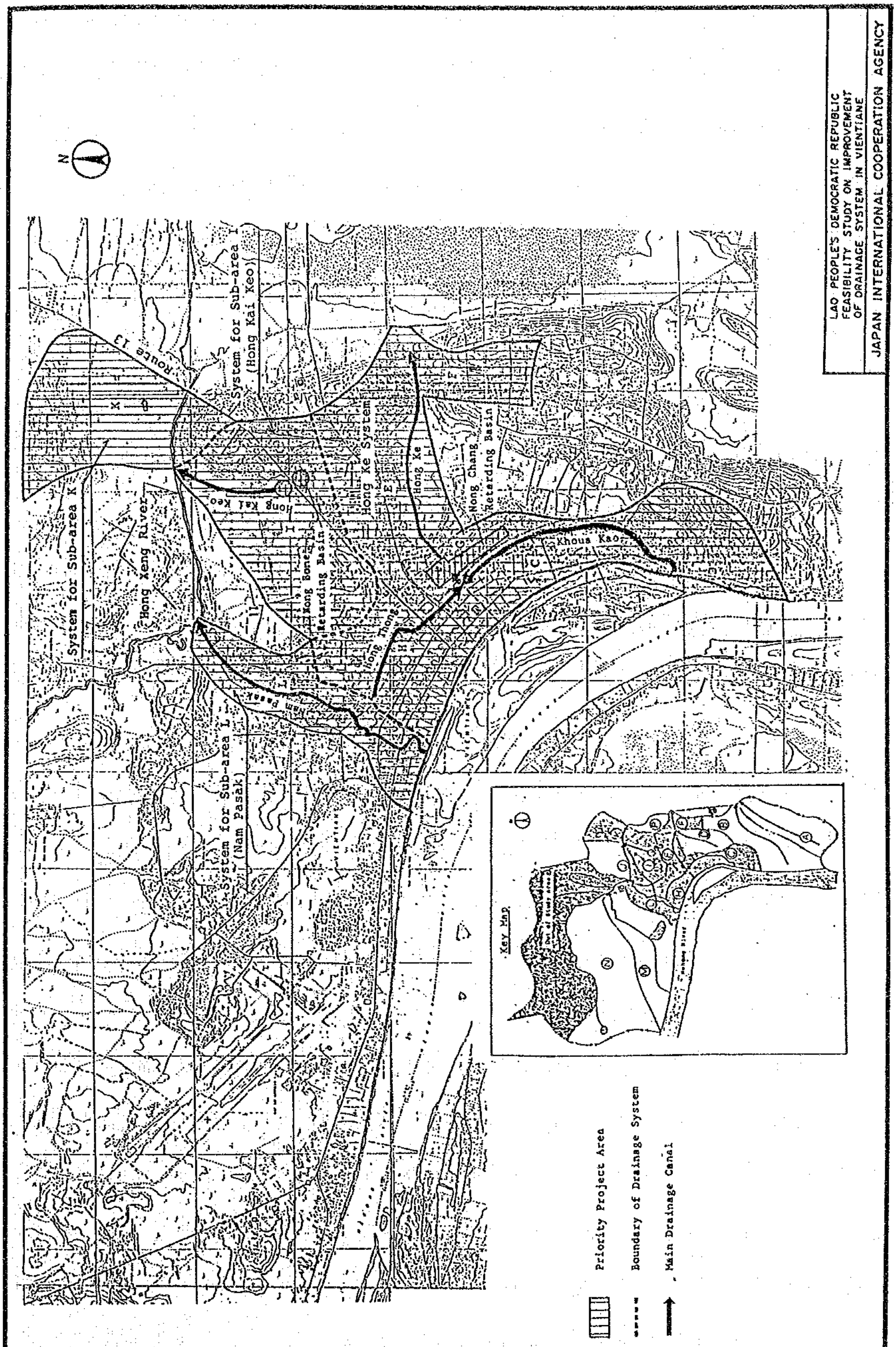

Fig. 5.3 Area of Priority Project