JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

LAO PEOPLE'S DEMOCRATIC REPUBLIC
MINISTRY OF PUBLIC WORKS AND TRANSPORT
PUBLIC WORKS AND TRANSPORT INSTITUTE

THE STUDY ON IMPROVEMENT OF WATER ENVIRONMENT IN VIENTIANE CITY

FINAL REPORT

Volume I: Main Report

SEPTEMBER 2011

CTI ENGINEERING INTERNATIONAL CO., LTD.
IDEA CONSULTANTS, INC.

GED
JR
11-165

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

LAO PEOPLE'S DEMOCRATIC REPUBLIC
MINISTRY OF PUBLIC WORKS AND TRANSPORT
PUBLIC WORKS AND TRANSPORT INSTITUTE

THE STUDY ON IMPROVEMENT OF WATER ENVIRONMENT IN VIENTIANE CITY

FINAL REPORT

Volume I: Main Report

SEPTEMBER 2011

CTI ENGINEERING INTERNATIONAL CO., LTD.
IDEA CONSULTANTS, INC.

THE STUDY ON IMPROVEMENT OF WATER ENVIRONMENT IN VIENTIANE CITY

COMPOSITION OF FINAL REPORT

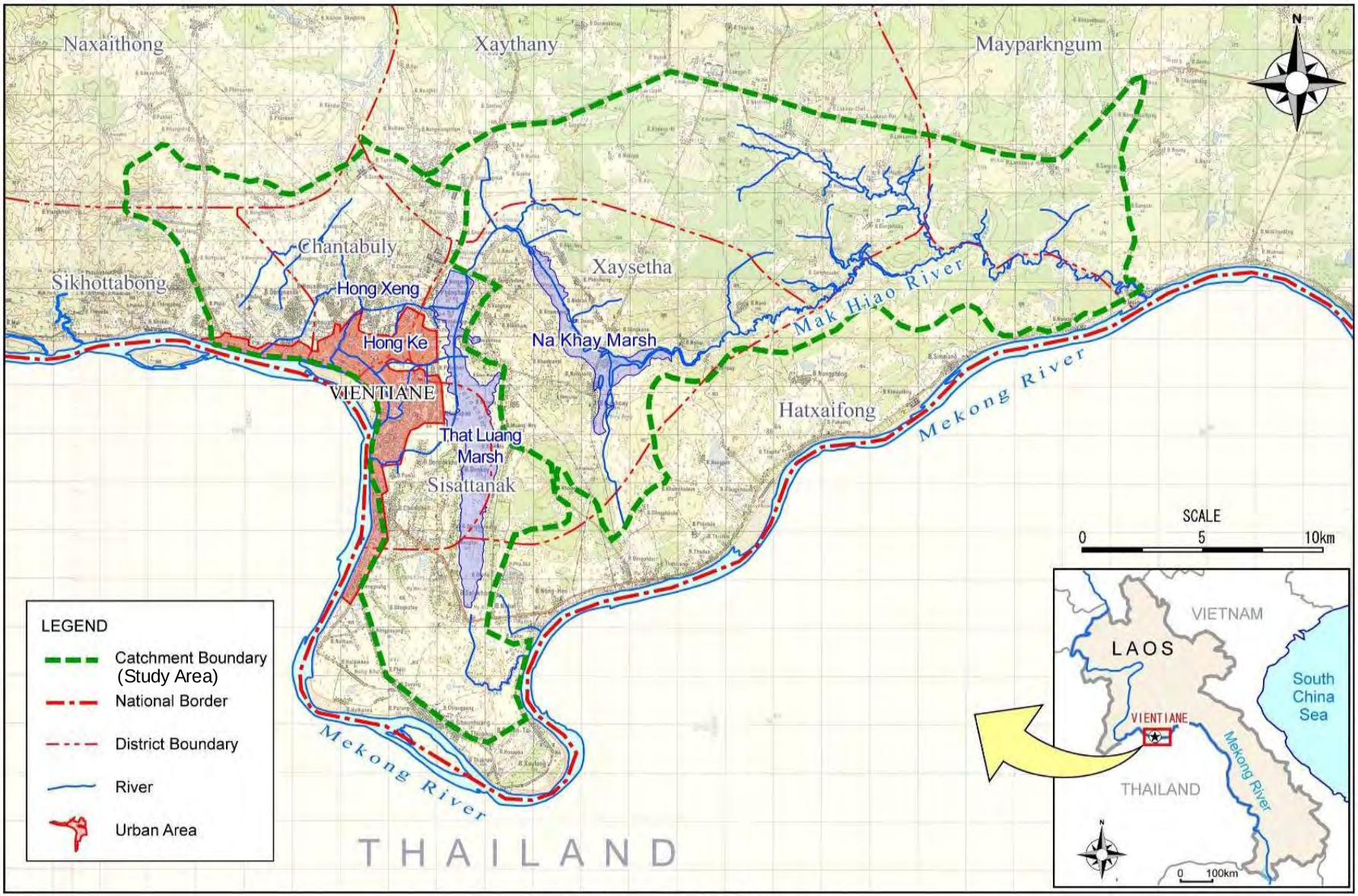
Volume I	**:**	**Main Report**
Volume II	**:**	**Summary**
Volume III	**:**	**Data Book**

Currency Exchange Rates used in this Report

USD 1.00	= KIP 8,000.00 = JPY 80.66
JPY 1.00	= KIP 99.17
EUR 1.00	= KIP 11,208.66

(As of 03 November 2010)

Note: Tables and figures without indication of source(s) were made based on the data/information collected directly or analyzed independently by JICA Study Team.



LOCATION MAP

EXECUTIVE SUMMARY

1. Study Background and Objectives

The drainage network in Vientiane, the capital of Lao People's Democratic Republic (Lao PDR) with a population of about 0.7 million in 2005, has improved with assistance from various donors since the early 1990's. However, the water quality in the drainage canals and marshes has been getting worse and water quantity has been increasing due to the increasing discharge of domestic wastewater from urban areas as a result of the improved living standards, as well as the rapid economic and population growth.

Considering the present situation of Vientiane, the Government of Japan dispatched a Study team in the middle of January 2009 to formulate the master plan of improvement of the water environment in the city. The Study includes the formulation of improvement measures against the worsening environmental hygiene and the the formulation of environmental conservation measures for the Mak Hiao River.

The specific objectives of the Study are:

(1) To formulate a master plan of water environmental management to improve the hygienic condition of the environment, including conservation of the natural purification functions in the Mak Hiao river basin considering the existing condition of water environment in the Study Area; and

(2) To transfer knowledge and technologies in the formulation of a water environment management plan to the Lao counterparts through the implementation of the Study.

The ultimate plan of the Study is to utilize the formulated Master Plan mentioned above in urban development projects in Vientiane and to ensure public health for its residents.

2. Study Area and Work Schedule

The Study Area covers the entire Mak Hiao river basin which encompasses the major urbanized areas of Vientiane, as shown in the table below.

Area and Population of the Study Area

Year	Vientiane	Study Area	Major Drainage Area	
			Hong Ke	Hong Xeng
Area (km^2)	3,920	412.5 (10.5%)	9.64 (2.3%)	53.02 (12.9%)
Pop. in 2005	692	328 (47.4%)	51 (15.5%)	112 (34.1%)
Pop. in 2020	1,074	462 (43.0%)	44 (9.5%)	164 (35.6%)

Unit: Population values × 1,000
Note: Figures in parentheses under the column Study Area show percentiles to those of Vientiane, while figures in parentheses under the column Major Drainage Area show percentiles to those of study area.
Sources: Preparatory Survey on Industrial Zone Development in The Lao People's Democratic Republic, Progress Report, 2009, JICA, and JICA Study Team

The study period is about thirty (30) months, from January 2009 until June 2011.

3. Major Issues on Water Environment in Vientiane

Various issues related to water environment have been raised in the course of the Study, and their clarifications and solutions are crucial for the smooth preparation of the strategy and the master plan of improvement of water environment. Based on the survey results and future projections, improvement issues on water environment could be categorized into the following technical and institutional areas.

Water Environment in the Study Area

(1) Present and Future Water Environmental Condition in the Urban Drainage System

Surface water along the urban drainage canals has been deteriorating due mainly to domestic organic pollutants mostly generated from the daily activities of residents as well as commercial activities. Based on the simulation results, this condition would much worsen in future. Among the urban drainage canals, Hong Thong and Hong Pasak, which receive wastewater discharged from the urban center of Vientiane, have the most seriously deteriorated water quality with BOD concentrations of 20 to 30 mg/l at present. In future, more serious BOD concentrations exceeding 30 mg/l are projected in the entire stretch of the urban drainage system including Hong Ke and Hong Xeng.

(2) Aquatic Life in the Urban Drainage Canals

The urban drainage canals are combined open sewers conveying both rainwater and wastewater generated in urban areas of Vientiane. They consist of two major systems: 1) the system starting from Hong Wattay and Hong Pasak connecting to Hong Xeng; and 2) the system starting from Hong Thong and Hong Khoua Khao connecting to Hong Ke. These two drainage systems finally empty into the That Luang Marsh.

Even at present, various species of fish go upstream through these canals in the rainy season. The people enjoy fishing and catching fish using a net, which is not now too popular as in previous time. Conservation of the still existing rich water environment for future generations, and the improvement of water environment, could be an urgent issue for fish habitation even in the dry season.

(3) Sanitary Condition in the Community and Household Level

To clarify the actual sanitary condition of individual houses in Vientiane, a prefeasibility study was conducted in 2010 under this master plan study. Simultaneously, a rapid assessment study was also conducted under the WSP (Water and Sanitation Program) of the WB (World Bank) for similar purposes. The survey results reveal that more than 95% of households and buildings in the survey areas have sanitary facilities consisting of septic tank or soak pit. However, both surveys reveal that the maintenance work of desludging of septage has not been properly and periodically done. In addition, these facilities receive only night soil so that domestic wastewater is discharged without any treatment, which is the major source of water contamination in the canals.

One CBS (Community-Based Sanitation) was constructed in an urban village as a pilot project under this master plan study. The results of the pilot project and the prefeasibility study indicate that the possibility of further expansion of CBS facilities could not be found for the urban area of Vientiane due to the high installation ratio of individual sanitation facilities and the difficulty of securing land from the limited space of private lands for the installation of CBS.

Institutional and Legal Issues in Water Environmental Management

(1) Weakness of Institutional Management of Environment

The capability of institutions is not sufficient for the proper management not only of the water environment but all other environments as well. This might be due to the shortage of experienced staff in the central government, as well as the local governments, and budgetary constraint on government services for water quality monitoring and drainage maintenance. Under the present circumstances, the capacity of WERI-WREA, in particular, which is expected as the national environmental research laboratory, shall be strengthened especially in the testing of environmental parameters such as water, air and so on.

(2) Development Need for Regulations and Guidelines

International donors such as SIDA and ADB have been assisting in the improvement and establishment of environmental legal systems including basic laws and important bylaws. The preparation of additional administrative instructions and guidelines are indispensable for smooth implementation and effective regulation by these laws.

(3) Necessity of Practicable Water Quality Standards

The existing standards of surface water quality stipulate that BOD concentration shall be less than 1.5 mg/l in any surface water. However, this level of BOD concentration is over-strict for any kind of public water body. Requirements of water quality in other countries are normally designated in accordance with usage. If such standards are adopted, various realistic and practical approaches could be applied for realistic improvements.

(4) Strengthening/Establishing Implementing/Coordinating Agencies to Integrate the Related Government Agencies and Donors/NGOs

There are various donors and NGOs as well as government agencies involved in water environmental improvement activities. However, there is no coordination agency/organization to help them focus their activities with clear and concrete directions. This kind of organization or network is indispensable for the initiation of a comprehensive approach, since wastewater management is reflected from the socio-economic conditions and is complicated.

(5) Disclosure and Dissemination of Information for Awareness Development

To solve the problems caused by the general public, such as water quality deterioration by domestic wastewater, the awareness of people is very important. Hence, the disclosure of environmental information is the key to dissemination and public awareness on the environment. Presently, there is no such organization or institution that can disclose enough information which people can easily access. The establishment of such kind of organization and its daily activities to provide appropriate information and conduct activities to enhance people's awareness could result in their supporting the appropriate and timely action of the government agencies concerned.

4. Master Plan of Water Environment Management

The master plan of water environmental management has been formulated in this Study on the basis of the strategy mentioned above whose components are: (1) the structural water improvement plan; (2) the institutional and legal improvement plan; and (3) the environmental education/hygiene education promotion plan.

In the structural water improvement plan, the future development scenario describes how the water environment changes in the target year 2020 based on the projected rapid urban development. To cope with water quality deterioration, alternatives for selection of the optimum strategy include cases of environmental deterioration due to inaction, conventional sewage treatment approach, and realistic wastewater treatment measures. The optimum strategy has been selected through the comparative studies, considering consistency with the future socioeconomic development in Vientiane.

Structural Water Improvement Plan

There are two distinct seasons in Vientiane, the dry and the wet season. The most urgent issue is the water quality deterioration in the dry season, since domestic wastewater is directly discharged without any treatment through the open sewer system. Water pollution in the dry season could then be regarded as one of the serious urban environmental improvement issues of Vientiane.

The master plan proposes comprehensive countermeasures in accordance with the causes of pollution and the applicability of countermeasures. These are mainly: (1) administrative instructions to control the highly polluted effluent from the slaughterhouses in Hong Wattay, in particular; (2) installation of simple small-scale wastewater treatment plants with local interceptors along the drainage canals of Hong Pasak, Hong Khoua Khao and others; and (3) installation of in-stream treatment plant along the bank of Nong Chanh against the highly polluted water of Hong Thong. These countermeasures are as summarized in the following table.

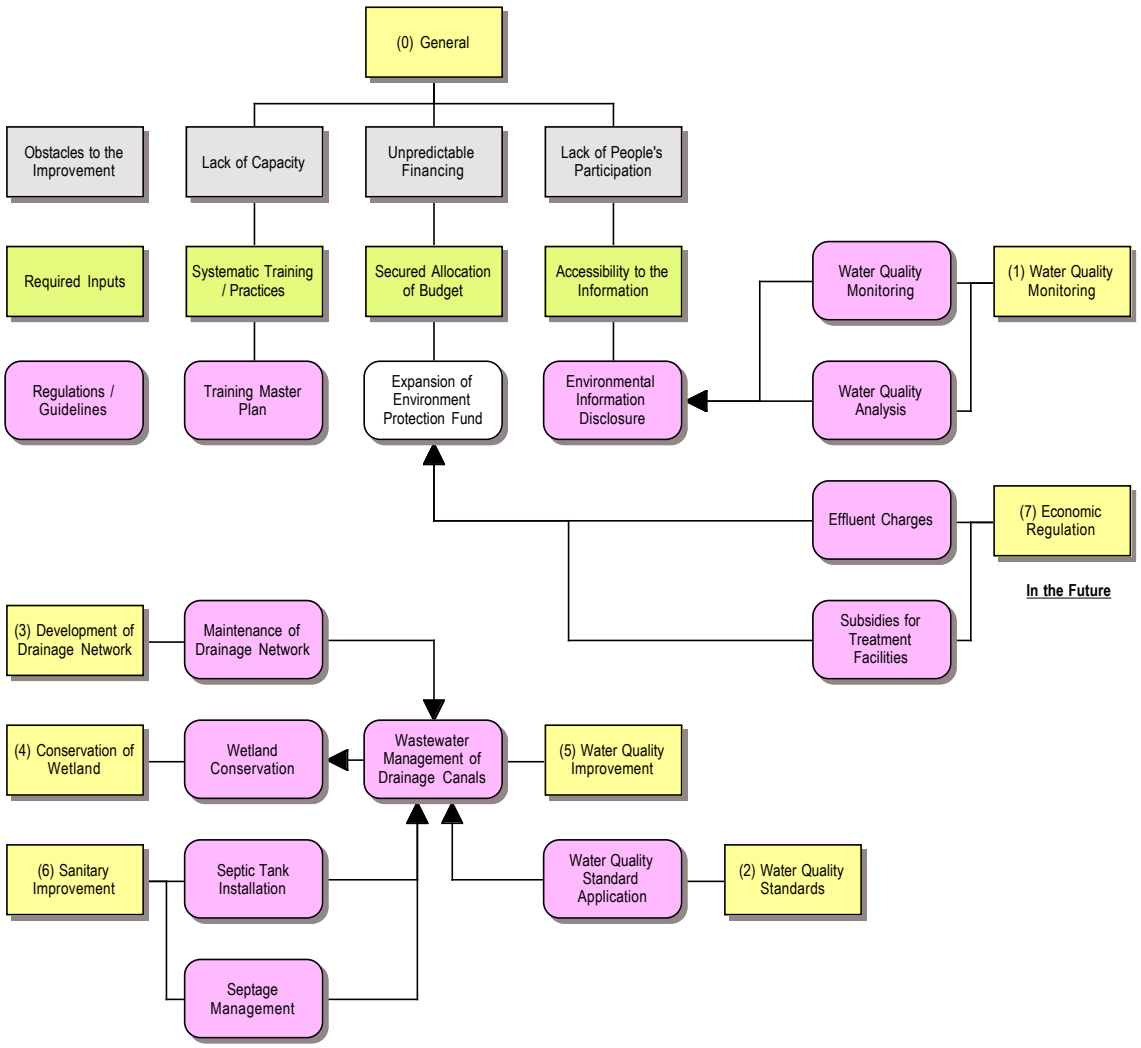
Structural Water Quality Improvement Components

Mak Hiao River Basin		Alternatives in Time Frame	
Divided area	Sub-areas	M/P (Until the year 2020)	10 to 20 years after M/P
Hong Ke and Hong Xeng drainage areas	Storm water drainage		
	Remaining marshes & drainage canal system	Conservation and improvement of remaining marshes for flood retardation	Canal improvement to increase drainage capacity, if necessary
	Wastewater management		
	Built-up area	(1) Villages with available spaces and without proper sanitation facilities: Installation of CBS (2) Villages without available spaces: Installation of septic tank at the time of rebuilding or new construction	(1) Villages with available spaces and without proper sanitation facilities: Installation of CBS (2) Villages without available spaces: Installation of combined individual sewer system at the time of rebuilding or new construction
	Rural-type aggregated community	Installation of septic tank at the time of rebuilding or new construction	Installation of combined individual sewer system at the time of rebuilding or new construction
	Drainage canal	Construction of decentralized treatment facilities: - Construction of simple wastewater treatment plants that would collect wastewater by local interceptors - Construction of in-stream contact aeration facilities - Application of vegetation measures for strengthening natural purification functions	
	Conservation of existing marshes	Conservation of marshes remaining in the drainage areas such as Nong Bo, Nong Tha, and Nong Chanh (natural purification function as well as flood retarding mentioned above)	
New large-scale developments	Industrial estate and new city development	Storm water drainage	
		Construction of storm drainage system	
		Wastewater management	
		Construction of wastewater treatment facilities at the downstream end of developing areas or inside individual factories	
Other areas	Newly expanded built-up area	Storm water drainage	
		Construction of storm drainage system, if necessary	
		Wastewater management	
		Installation of CBS or septic tank at the time of rebuilding or new construction	Installation of combined individual sewer system at the time of rebuilding or new construction
	Rural villages	Wastewater management	
		Installation of septic tank at the time of rebuilding or new construction	Installation of combined individual sewer system at the time of rebuilding or new construction

Institutional and Legal Improvement Plan

Various international donors, such as ADB and SIDA, had proposed or finalized several kinds of policy measures for water environmental conservation, including environmental education, environmental information, national land use plan, and public expenditure policy, in addition to direct regulation. However, there are still needs to develop regulations and guidelines for the effective and smooth implementation of various laws and bylaws established.

In the master plan, draft guidelines are proposed focusing on drainage management and sanitary improvement. The relationship between necessary regulations and guidelines is as illustrated below.



Relation among Regulations/Guidelines

Environmental Education/Hygiene Education Promotion Plan

Actions only by administrative bodies are not enough for preventing deterioration of water quality of rivers/canals discharging from Vientiane, which could cause irreversible destruction of the environment. Thus, this promotion plan aims to enable participation of residents (community people and children) in water environmental conservation by cooperating with administrative bodies through enhancement of awareness in environmental conservation by environmental education.

Targeting pupils in a primary school and general residents in the communities, environmental education activities have been made simultaneously with the pilot project of construction of community/school based sanitatary facilities (CBS and SBS). Based on the experiences in conducting the above pilot projects, the following expansion of activities in environmental education including the training of trainers has been proposed in the master plan.

Activity Promotion Roadmap on Environmental Education

Phasing	Activities	Target Area
Phase 1 (2010-2011)	- TOT (training of trainers) based activities are conducted for teachers, students and villagers in the 1st pilot school and community activities in line with the construction.of SBS/CBS	Hong Pasak and Hong Thong drainage areas
Phase 2 (2012-2015)	- The 2nd pilot schoolsy and community activities were selected. They will have TOT by trainers trained in the 1st pilot school and community activities to disseminate the activities in line with the construction of wastewater treatment facility.	Hong Ke and Hong Xeng drainage areas
	- Related organizations will monitor and assist in the activities as well as carry out public relations activities.	
Phase 3 (2016-2020)	- Pilot schools and communities will be increased gradually, so that the activities will be implemented and expanded sustainably and broadly in line with the dissemination of wastewater treatment facilities.	Hong Ke and Hong Xeng drainage areas and other Vientiane urban areas
	- Related organizations will monitor and assist in the activities as well as carry out public relations activities.	

5. Recommendations

In the course of the Study for the period of two and half years, various points and issues to be improved were clarified. Most of these issues were incoporated into the master plan as subjects to be solved or improved. Urbanization in Vientiane has been rapidly progressed, and natural environment in the urban areas has been deteriorated in parallel. The natural environment, however, still significantly remains in Vientiane in remediable level, so that it shall be urgent issues to conserve the remaining natural environment and to restore the lost one. In finalizing this report, those points and issues are summarized to provide some help in the future improvement of water environment.

(1) Early Implementation of the Structural Water Environment Improvement Plan

Rapid urbanization in Vientiane has been progressing in a very fast pace. As frequently described, water environment improvement shall consist of the integrated man-made treatment facilities and the natural purification functions of marshes, ponds and river courses as natural assets given to the Vientiane residents from the physical improvement viewpoint. In this regard, the first step of the improvement works shall be started as early as possible, so that the residents can understand the importance of conservation of their precious environment. This process could be easily linked to the enhancement of people's awareness on environmental improvement.

(2) Prevention of Concrete Covering on Drainage Systems

Hong Thong receives wastewater and rainwater from the most congested areas of Vientiane, similar to Hong Pasak. Hong Thong joins Hong Khoua Khao near the Nong Chanh Marsh, and changes its name to Hong Ke. Hong Thong has been covered with concrete slabs in almost all its stretch. Although the concrete covering is one of the alternatives to make people disregard the offensive odor and deteriorated scenery of worsened water quality, difficulties on the improvement of water environment will come out due to the invisibility of existing conditions of water quality and the inability of conducting improvement works as well as monitoring their effects. Conducting possible improvement measures on the water environment in a step-by-step

manner would rather be recommended than removing the deteriorated environment from the urban residents' vision.

(3) Conservation of Marshes/Wetlands

Wastewater discharged from urban areas flows down through the drainage system and empties into the That Luang Marsh. The Mak Hiao River receives the surface water from the marsh, runs through the Na Khay Marsh and various pondage stretches, and finally joins the Mekong mainstream. Due to the natural purification function of wetlands and ponds along the river course and dilution with natural runoff and irrigation tailwater, the BOD concentration of 3 mg/l will still be computed at the rivermouth of the Mak Hiao even in 2020, but this BOD concentration could still be regarded as good water quality.

Rapid urbanization, however, has been progressing in/around the That Luang Marsh, so that it is necessary to conserve the marsh areas and their functions and protect them against the urbanization of Vientiane. Furthermore, the remaining marshes in the urban areas, such as Nong Chanh, Nong Bo, and Nong Tha, shall be conserved as well. Unless conservation measures are undertaken, a similar urbanization process, where various wide mashes had existed in the past have been reclaimed into urban areas, would occur in the remaining marshes mentioned above.

In order to conserve these remaining marshes and wetlands, the following two conservation approaches are necessary.

(a) Prohibition of Encroachment by Developments and Sustainment of Existing Water Surface

Various types of land developments have reduced water surface of marshes and wetlands accompanying land filling. In order to prevent these activities, peripheral road encompassing the marsh/wetland area shall be constructed as a role of border piling system of pubic water body, and land use control shall be done inside of the road announcing the necessity of the conservation and the necessary control to the public. As a result, natural water purification functions could be conserved from viewpoints of the water environment improvement.

(b) Onsite Treatment of Wastewater Inflow from Surrounding Development Areas

Deterioration of water quality in the marshes/wetlands by the untreated wastewater inflow from the surrounding areas is a major factor to decrease the environmental values of marshes/wetlands. Wastewater treatment facilities targeting domestic wastewater as well as human waste shall be installed in the new development areas surrounding the marshes/wetlands as one of the environmental conservation measures in the marsh/wetland areas.

(4) Strengthening of Administrative Guidance

There are noticeable point sources in the Study Area. Some small-scale enterprises discharge highly polluted wastewater, and neighboring residents complain about the offensive odor and accumulated sludge. Strengthening of administrative guidance by the responsible agency shall thus be necessary to solve such problems. The enterprises have to follow the effluent standards through installation of proper devices for wastewater treatment, with administrative guidance. To attain the situation of clean water quality, efforts by various stakeholders, such as residents and governmental organizations, are indispensable. Thus through these well-functioning efforts, the related governments could gain high reliability scores from the people.

(5) Strengthening of Maintenance Work and Monitoring Activities for the Drainage Network

A major part of the drainage canals had been improved as concrete-lined channels mainly supported by ADB in the 2000's. At present, sediment has accumulated at the bottom of the channels due to the inflow of small particles from the surrounding areas, and various plants have grown in these channels based on the accumulated sediment. These plants have some water purification functions against water quality deterioration, composed of acceleration of settling suspended solids and contact oxidation by biofilm attached to the plants.

The local government of Vientiane as the administrator of the drainage canal system shall conduct maintenance works in the drainage system without any donor's technical and financial support. The management works consist of: 1) dredging of accumulated sediment at the bottom of each channel, if necessary; 2) proper management of plant growth in each channel based on site monitoring in due consideration of their natural purification functions; and 3) clarification of encountered issues based on periodical water quality monitoring in cooperation with WREA.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

ABBREVIATIONS

Organizations

ADB	:	Asian Development Bank
BORDA	:	Bremen Overseas Research and Development Association
CIDA	:	Canada International Development Agency
DANIDA	:	Danish International Development Assistance
DI	:	Department of Industry
DMH	:	Department of Meteorology and Hydrology
DOE	:	Department of Education
DOH	:	Department of Health
DPRA	:	Development Project Responsible Agency
DPWT	:	Department of Public Works and Transport
EDCF	:	Economic Development Cooperation Fund
EQMHCC	:	Environmental Quality Monitoring and Hazardous Chemical Center
EU	:	European Union
IEC	:	International Electrotechnical Commission
ISO	:	International Organization for Standardization
ITSUP	:	Institute for Technical Studies
IUCN	:	International Union for Conservation of Nature and Natural Resources
JICA	:	Japan International Cooperation Agency
LIRE	:	Lao Institute for Renewable Energy
MCTPC	:	Ministry of Communication, Post, Transport and Construction
MIC	:	Ministry of Industry and Commerce
MOE	:	Ministry of Education
MOH	:	Ministry of Health
MONRE	:	Ministry of Natural Resources and Environment
MPWT	:	Ministry of Public Works and Transport
DHUP	:	Department of Housing and Urban Planning
DOR	:	Department of Road
PTI	:	Public Works and Transport Institute
MRC	:	Mekong River Committee
NEC	:	National Environment Committee
NRIES	:	National Research Institute for Educational Science
PPA	:	Pupils' Parents Association
SEED	:	Social Environmental Education and Development
SIDA	:	Swedish International Development Cooperation Agency
SRTM	:	Shuttle Radar Topography Mission
STEA	:	Science, Technology and Environment Agency (the former organization of WREA)
STEO	:	Science, Technology and Environmental Office (the former organization of WREO)
UN	:	United Nations
UNDP	:	United Nations Development Programme
UN-HABITAT	:	United Nations Human Settlements Programme
UNICEF	:	United Nations Children's Fund
UWSIP	:	Urban Wastewater Strategy and Investment Plan
WB	:	World Bank
WHO	:	World Health Organization
WREA	:	Water Resource Environment Agency

DOE	:	Department of Environment
WERI	:	Water Resources and Environment Research Institute
WREO	:	Water Resources and Environmental Office
WTO	:	World Trade Organization
WWF	:	World Wide Fund for Nature
VEU	:	Village Environment Unit
VUDAA	:	Vientiane Urban Development Administration Agency

Programs and Projects

EMSP	:	Environmental Management Support Project
NUDSIP	:	National Urban Development Strategy and Investment Plan
SEMII	:	Strengthening Environmental Management Project Phase II
WSP	:	Water and Sanitation Program
VIUDP	:	Vientiane Integrated Urban Development Project
VUISP	:	Vientiane Urban Infrastructure and Service Project

Technical Terms

BOD	:	Bio-chemical Oxygen Demand
B/C	:	Cost Benefit Ratio
CBS	:	Community Based Sanitation
COD	:	Chemical Oxygen Demand
DDT	:	Dichloro-diphenyl-trichloro-ethane
DEM	:	Digital Elevation Map
DEWATS	:	Decentralized Wastewater Treatment System
DO	:	Dissolved Oxygen
EA	:	Environmental Assessment
EC	:	Electric Conductivity
EEA	:	Environmental Education and Awareness
EIA	:	Environmental Impact Assessment
EMP	:	Environment Management Plan
ESIA	:	Environmental and Social Impact Assessment
IEE	:	Initial Environmental Examination
IESE	:	Initial Environmental and Social Examination
ORP	:	Oxidation Reduction Potential
QA/QC	:	Quality Assurance and Quality Control
SBS	:	School Based Sanitation
SIA	:	Social Impact Assessment
SMMP	:	Social Management and Monitoring Plan
SS	:	Suspended Solid
STP	:	Sewage Treatment Plant
TDS	:	Total Suspended Solid
TKN	:	Total Kjeldahl Nitrogen
WTP	:	Wastewater Treatment Plant

Others

AP	:	Affected People
CD	:	Capacity Development
C/P	:	Counterpart
D/S, d/s	:	Downstream
ECC	:	Environmental Compliance Certificate

EEA	:	Environmental Education and Awareness
EL	:	Environmental Law
EPF	:	Environmental Protection Fund
EPL	:	Environmental Protection Law
F/S	:	Feasibility Study
FY	:	Fiscal Year
GDP	:	Gross Domestic Product
GIS	:	Geographic Information System
GPS	:	Global Positioning System
GRDP	:	Gross Regional Domestic Product
HIA	:	Health Impact Assessment
HWWS	:	Hand-Washing with Soap
JOCV	:	Japan Overseas Cooperation Volunteers
Lao PDR	:	Lao People's Democratic Republic
MDGs	:	Millennium Development Goals
M/P	:	Master Plan
NGO	:	Non-governmental organization
ODA	:	Official Development Assistance
O&M	:	Operation and Maintenance
PET	:	Polyethylene Terephthalate
PDCA	:	Plan-Do-Check-Act
PI	:	Public Involvement
PM	:	Prime Minister
PO	:	Project Owner
PPP	:	Polluter Pays Principle
QA	:	Quality Assurance
QC	:	Quality Control
SEA	:	Southeast Asia
SLSC	:	Sub-Least Square Criterion
SOP	:	Standard Operations Procedure
STP	:	Sewage Treatment Plant
TCP	:	Teacher-Children-Parent
TOR	:	Terms of Reference
TOT	:	Training of Trainers
U/S, u/s	:	Upstream
UV	:	Ultraviolet
VEU	:	Village Environment Unit
WQMNS	:	Water Quality Monitoring Network System

CHAPTER 1. INTRODUCTION

1.1 Background

In Vientiane, the capital of Lao People's Democratic Republic (Lao PDR) which had the population of about 0.7 million in 2005, drainage facilities installed mainly with aid from the Asian Development Bank (ADB) were improved in 1996 – 2006 to a certain extent based on the Feasibility Study on Improvement of Drainage System in Vientiane by JICA in 1989. However, the water quality of surface water and the remaining marshes has been getting worse and water quantity has also been increasing due to the inflow of domestic wastewater from the urban areas as a result of the improved living standards, rapid economic growth, and population increase. The trend of urbanization would continue in parallel with large-scale infrastructural developments like the industrial park, the facilities for the Southeast Asian Games (SEA Games), and new projects for urban development and so on.

Considering the present condition in Vientiane, the Government of Lao PDR had requested assistance from the Japanese Government. The Study on Improvement of Water Environment in Vientiane City (the Study) was thus launched by the Government of Japan in December 2007 in order to formulate the master plan for improvement of water environment in Vientiane, which will include the formulation of countermeasures against the worsening hygienic environment and the formulation of environmental conservation measures for the That Luang Marsh which plays the very important role of natural purification of river water.

1.2 Objectives

The objectives of the Study are as follows:

(1) To formulate a master plan of water environmental management to improve the hygienic condition of the environment, including conservation of the natural purification functions in the Mak Hiao river basin considering the existing condition of water environment in the Study Area; and

(2) To transfer knowledge and technologies in the formulation of a water environment management plan to the Lao counterparts through the implementation of the Study.

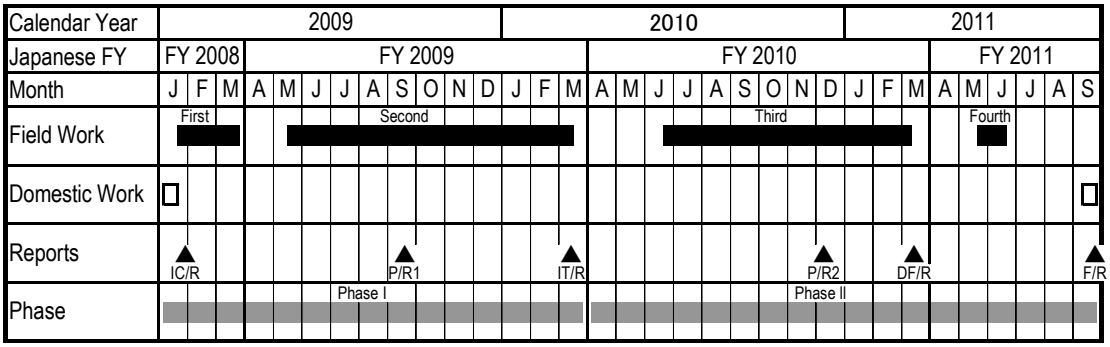
The study results shall be incorporated in the urban development plan of Vientiane aiming to enhance public health in the city.

1.3 Study Area

The Study Area covers the whole Mak Hiao River basin, which includes seven (7) districts, namely; Sikhottabong, Chantabury, Sisattanak, Xaysetha, Hatxaifong, Xaythany, and Mayparkngum. The Mak Hiao River, which runs through major urbanized areas of Vientiane, drains mainly storm water in the rainy season and wastewater in the dry season. Its drainage area consists of 412.5 km^2 in total, which makes up 10.5% of the entire Vientiane area of 3,920 km^2.

1.4 Work Schedule

The Study has been carried out in accordance with the schedule shown in **Fig. 1.4.1**. The study period was about thirty (30) months.



(Legend) IC/R: Inception Report, P/R1: Progress Report (1), P/R2: Progress Report (2), IT/R: Interim Report, DF/R: Draft Final Report, F/R: Final Report
Phase I: Basic study and preparation of the Draft Master Plan
Phase II: Implementation of Pilot Project and Pre-feasibility Study

Fig. 1.4.1 Overall Study Schedule

1.5 Staffing Schedule

The list of experts comprising the JICA Study Team is shown in **Table 1.5.1**.

Table 1.5.1 List of Experts of the JICA Study Team

Name	Designation or Field Specialty
Kanehiro MORISHITA	Team Leader / Integrated Water Management and Drainage Iimprovement
Makoto YAJIMA	Co-Team Leader / Water Environment Policy and Project Evaluation
Yasuhiko KATO	Environmental Education
Tsuyoshi ITO	Water Environment Management Planning
Kyoko MISHIMA	Ecological Conservation / Environmental and Social Considerations
Kazuhiro NAKAMURA	Hydrology / Hydrogeology / Rainfall Analysis
Hitoshi SHIMOKOCHI	Sanitation / Water Quality Analysis / Water Quality Improvement Planning
Makoto KODAMA	Drainage Planning
Yunshan BAI	GIS Engineer
Kazuyoshi FUJIMOTO	Administrative Coordinator

1.6 Work System

A steering committee was established to coordinate all relevant authorities on water environment management with the Secretariat of PTI. **Table 1.6.1** summarizes the roles and responsibilities of the Steering Committee.

Table 1.6.1 Roles and Responsibilities of the Steering Committee

Objectives	● To provide support and advice necessary for the Study. ● To provide consulting services on the basic direction of the Study. ● To provide coordination with the relevant organizations
Activities	● Confirmation of the direction of the Study ● Consultation and approval of the various reports submitted by the JICA Study Team ● Evaluation of technology transfer
Committee Members	Ministry of Public Works and Transport (MPWT), Vientiane, Public Works and Transport Institute (PTI), Water Resources and Environment Administration (WREA), Department of Housing and Urban Planning (DHUP), Department of Public Works and Transport (DPWT), Health Department of Vientiane, Agriculture and Forestry Department of Vientiane, Industry and Commerce Department of Vientiane, Environment Office of Vientiane, Vientiane Urban Development Administration Authority (VUDAA), Vientiane New Town Project, Education Department of Vientiane
Frequency of Steering Committee Meetings	Three (3) times in Phase 1 Three (3) times in Phase 2 Steering committee meetings are to be held after the submission of every report.
Secretariat	PTI
Venue of Meetings	MPWT
Cost	To be shared among the participating members
Roles of the Secretariat	● Preparation of agenda, contacting participants and scheduling ● Preparation of meeting materials and management of meetings ● Explanation of the study and preparation of minutes
Roles of the Study Team	● Support to the preparation of agenda and handouts ● Support to the explanation of the Study and minutes of meetins

The working relationship among the JICA Study Team and the other agencies concerned is as shown in **Fig. 1.6.1**.

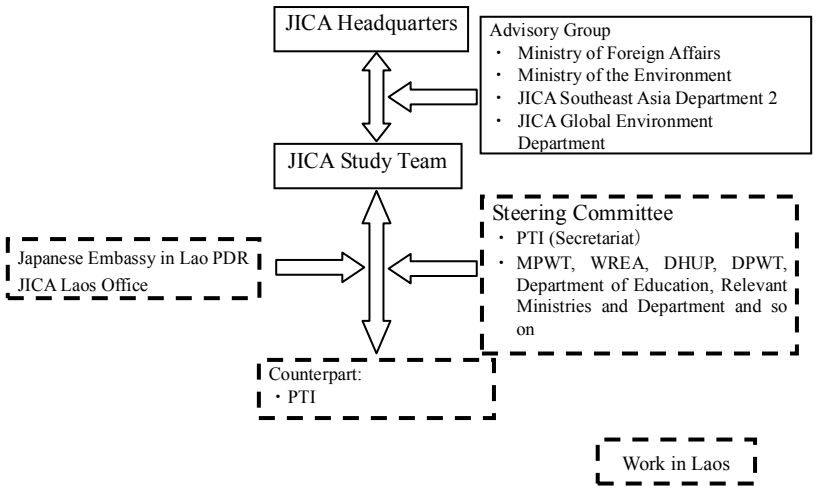


Fig. 1.6.1 Working Relationship of Agencies concerned in the Study

1.7 Reports

The JICA Study Team had prepared and submitted reports to the Government of Lao PDR in both hard and digital copies, as listed in **Table 1.7.1.**

Table 1.7.1 List of Reports Submitted

Report	Time to submit	Number of Copies	Contents
1. Inception Report	End of January 2009	25 (in English)	Objectives, contents, methodology and schedule of the Study.
2. Progress Report (1)	Middle of September 2009	25 (in English)	Progress of the Phase I Study
3. Interim Report	Beginning of March 2010 (at the end of Phase I)	25 (in English)	Results of the Master Plan Study
4. Progress Report (2)	End of November 2010	25 (in English)	Progress of the Phase II Study
5. Draft Final Report	End of March 2011 (at the end of Phase II)	25 (in both English and Lao)	All results of the Study
6. Final Report	End of September 2011	25 (in both English and Lao)	All results of the Study

CHAPTER 2. BASIC CONDITION OF THE STUDY AREA

2.1 Socio-Economic Condition

2.1.1 Socio-Economic Condition of Lao PDR

(1) The Millennium Development Goals in Lao PDR

The Government of Lao PDR had agreed on the Millennium Development Goals (MDGs) for 2015. The progress as of 2008 has been reported jointly by the Government of Lao PDR and the United Nations. Among the 15 targets set for 2015, they were evaluated as 9 targets would be met "Probably," 3 targets "Potentially," and 3 targets "Unlikely."

Table 2.1.1 Progress of MDGs in Lao PDR

Targets		Evaluation: Will the Target be met?
MDG#1	**Eradicate Extreme Poverty and Hunger**	
Target 1A	Halve the proportion of people whose income is less than US$1 a day between 1990 and 2015	Probably
Target 1B	Achieve employment and decent work for all, including women and young people	Probably
Target 1C	Halve the proportion of people who suffer from hunger between 1990 and 2015	Unlikely
MDG#2	**Achieve Universal Primary Education**	
Target 2A	Ensure that children everywhere, boys and girls alike, will be able to complete a full course of primary schooling by 2015	Potentially
MDG#3	**Promote Gender Equality and Empower Woman**	
Target 3A	Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	Unlikely
MDG#4	**Reduce Child Mortality**	
Target 4A	Reduce the under-five mortality rate by two-thirds between 1990 and 2015	Probably
MDG#5	**Improve Maternal Health**	
Target 5A	Reduce the maternal mortality ratio by three-quarters between 1990 and 2015	Unlikely
Target 5B	Achieve universal access to reproductive health by 2015	Potentially
MDG#6	**Combat HIV/AIDS, Malaria and Other Diseases**	
Target 6A	Halt the spread of HIV/AIDS and begin to reduce by 2015	Probably
Target 6B	Achieve universal access to treatment for HIV/AIDS for all those who need it by 2010	Probably
Target 6C	Halt and begin to reduce the incidence of malaria and other major diseases by 2015	Probably
MDG#7	**Ensure Environmental Sustainability**	
Target 7A	Integrate the principles of sustainable development into country policies and programs, and reverse the loss of environmental resources	Probably
Target 7B	Reduce biodiversity loss, achieving a significant reduction in the rate of loss by 2010	Probably
Target 7C	Halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015	Potentially
Target 7D	Achieve a significant improvement in the lives of at least 100 million slum dwellers by 2020	Probably
MDG#8	**Develop a Global Partnership for Development**	
Target 8A	Develop further an open, rule-based, predictable, nondiscriminatory trading and financial system	No Target Set
Target 8B	Address the special needs of Least Developed Countries	No Target Set
Target 8C	Address the special needs of landlocked countries	No Target Set
Target 8D	Deal comprehensively with the debt problem	No Target Set
Target 8E	Make available the benefits of new technologies, especially information and communications	No Target Set

Note: Probability of achievement is evaluated with the following order: Probably > Potentially > Unlikely
Source: Millennium Development Goals Progress Report - Lao PDR 2008, prepared jointly by the government of the Lao PDR and the United Nations

(2) National Socio-Economic Development Plan

The current national development plan is the Sixth National Socio-Economic Development Plan which covers 2006-2010. Its goals are as follows:

- Accelerate economic growth and improve the people's quality of life, restructuring the economy and employment in building a market economy, based on the country's rich resources and international integration.
- Further build the market economy with a socialist orientation. Continue to enlarge and develop effective external economic relations.
- Create breakthrough changes in education and training in terms of quality and quantity, utilizing the advances in science and technology, protecting the environment, and taking human, scientific and technological players as vehicles for development.
- Develop culture and society in synchrony with economic growth.
- Continue poverty reduction, creating jobs, and eliminating social evils.
- Continue strengthening the socio-economic infrastructure as fundamentals for development in the Sixth Five-Year Plan and for the next (Seventh) Five-Year Plan.
- Maintain political stability and social security, protecting sovereignty, territorial integrity and national security.

The following table shows the targets of the Sixth Plan (2006-2010) versus the targets and achievements of the Fifth Plan (2001-2005).

Table 2.1.2 Sixth Five-Year Plan Targets and Fifth Five-Year Plan Targets and Achievements

Item	Sixth Plan (2006-2010)	Fifth Plan (2001-2005)	
	Targets	Targets	Achievements
GDP growth	7.5-8%	7-7.5%	6.24%
Exports growth	18.1%	8.6%	4.9%
Trade deficit as % of GDP	5.0%	6.0%	9.4%
Inflation rate	6-6.5%	<10.0%	9.6%
Budge deficit as % of GDP	6.07% (5 yr ave.)	6.0%	7.4%
GDP per capita (2005)	US$700-750	US$500-550	US$491
Total population (2005)	6.17 million (2010)	5.9 million	5.61 million (2005)
Population growth rate	1.91% (5 yr ave)	-	2.0% (5 yr ave)
Proportion of poor households (2005)	<15%	20-25%	28.7%
Primary school enrolment (2005)	90.6%	86.0%	84.2%
Infant (<1 yr) mortality (2005)	55/1,000	60/1,000	70/1,000
Child (<5 yr) mortality	75/1,000	98/1,000	98/1,000
Access to clear water	70% of total communities	-	-
Forest cover	>50%	-	-

Note: The Sixth Plan sets much more targets than those shown in the table.
Source: Sixth Five-Year National Socio-Economic Development Plan (2006-2010), Committee for Planning and Investment

(3) Population

It has been agreed among the JICA study projects presently implemented for Lao PDR and/or Vientiane that socio-economic macro data including forecasts of population and GDP growth rate should incorporate those employed in the Preparatory Survey on Industrial Zone Development in The Lao People's Democratic Republic, which preceded the Study.

The Preparatory Survey carried out a population projection with the following results:

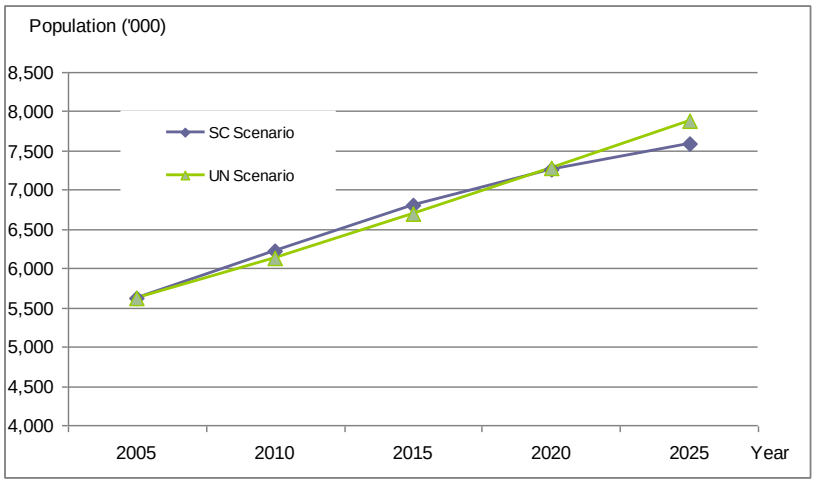
Table 2.1.3 Population Projection of Lao PDR until 2020

	2005[1)]	2010	2015	2020
Population ('000)	5,622	6,133	6,696	7,286
Annual average growth rate (%)	—	1.8	1.8	1.7

Note: [1)] Data of Population and Housing Census 2005
Source: Preparatory Survey on Industrial Zone Development in The Lao People's Democratic Republic, Interim Report, 2009, JICA

The projection was made as follows:

- Two prevailing scenarios of population projection were compared: (1) the SC Scenario, i.e., the normal scenario of the Steering Committee of the Population and Housing Census (Chairman: Vice Prime Minister; Members: representatives of 10 related Ministries); and (2) the UN Scenario, namely; the medium variant of the UN Population Division.
- In the SC Scenario, the annual growth rate drops rapidly from 2.1% in 2010 to 0.4% in 2030 due to the rapid decrease of total fertility rate.
- In the UN Scenario, the annual growth rate drops gradually from 1.8% in 2010 to 1.3% in 2030 due to the gradual drop of total fertility rate.
- The UN Scenario was selected because it looks natural and most likely outcome, considering the stage of economic development of Lao PDR.



Source: Preparatory Survey on Industrial Zone Development in The Lao People's Democratic Republic, Progress Report, 2009, JICA

Fig. 2.1.1 Population Projection in Two Scenarios

(4) GDP

As mentioned above, the forecast of GDP growth also refers to the GDP growth rate projected by the Industrial Zone Survey, as follows:

Table 2.1.4 Projection of GDP Growth Rate in Lao PDR until 2020

	2009	2010	2011-20
GDP growth rate (%)	5.5	6.0	7.5

Source: Preparatory Survey on Industrial Zone Development in The Lao People's Democratic Republic, Interim Report, 2009, JICA

The projection was made as follows:

- Three scenarios were prepared: high, middle and low growth scenario.

- GDP growth rate gradually lowers after the economy is saturated: the growth rate in 2021-2025 is more moderate than that in 2011-2020.
- GDP increases at 6.0-9.0% in the high growth scenario, at 6.0-7.5% in the middle growth scenario, and at 5.5-6.0% in the lower growth scenario, considering trends of economic circumstances including Lao PDR's status in ASEAN, foreign direct investments, progress of hydropower plant projects and mining development projects, and agriculture projects.
- The middle growth scenario was selected as the optimum, considering the past performance and the consistency of projections by donors and necessary investment amount to achieve each GDP growth target.

While the projected population growth rate of the Industrial Zone Survey in 2010 is very similar to the target of the Sixth Plan (1.8% and 1.91), the projected GDP growth rate in 2010 of the Industrial Zone Survey shows some discrepancy with the target of the Sixth Plan (6.0% and 7.5-8%). The reason is that the Industrial Zone Survey considers the Global Financial Crisis since October 2008, which is expected to lower the growth in 2009 and 2010.

2.1.2 Socio-Economic Condition of the Study Area

(1) Population in the Study Area

At first, the population of the Study Area in 2005 is calculated against that of Vientiane in 2005, which is presented in *"Population and Housing Census 2005"*. Then, the population for each village is increased/decreased until 2020 at the same annual average rate between 1995 and 2005. As a result, the total population of Vientiane implied in this calculation is larger than that projected by the Industrial Zone Survey because the annual average growth rate in 2005-2020 is assumed to be lower than that in 1995-2005 in the Industrial Zone Survey.

When the projection of the Industrial Zone Survey is considered, the population in the Study Area should be adjusted with the ratio of the two projections for Vientiane in the same year in order to coincide with that of the Industrial Zone Survey.

The result of the population projection is as summarized in the following table.

Table 2.1.5 Population Projection of the Study Area in 2020

(Unit: 1,000)

Year	Vientiane City Industrial Zone	Vientiane City Water Environment	Adjustment Ratio	Study Area Before Adjustment	Study Area After Adjustment	Hong Ke Sub-basin After Adjustment	Hong Xeng Sub-basin After Adjustment
(1)	(2)	(3)	(4) = (2) / (3)	(5)	(6) = (5) ×(4)	(7)	(8)
2005	692	692	1.000	328	328	51	112
2020	1,074 [1)]	1,284	0.837	551	462(499) [2)]	44	164

Note: [1)] Since the Industrial Zone Survey presented only the data in 2015 and 2025, the data in 2020 was calculated by applying the annual average growth rate between the two years.
[2)] Value in parentheses includes population of new development area assumed by the Study Team
Source: Preparatory Survey on Industrial Zone Development in The Lao People's Democratic Republic, Interim Report, 2009, JICA

Projected population of each village in year *n* can be calculated as follows:

$$P_n = P_{2005} \bullet \left(1 + R_{1995 \to 2005}\right)^{(n-2005)} \bullet A_n$$

where,

P_n : Projected population of a village in year *n*
$R_{1995 \to 2005}$: Annual average growth rate of the Village between 1995 and 2005
A_n: Adjustment ratio in year *n* to coincide with the projection by the Industrial Zone Survey. For example, $A_{2020} = 0.837$.

(2) GRDP of Vientiane

As mentioned above, the estimation of GRDP of Vientiane refers to that of the Industrial Zone Survey.

The Industrial Zone Survey carried out the GRDP estimation, as follows:

Table 2.1.6 GRDP Estimation of Vientiane until 2020

(Unit: constant in 2008 price, billion KIP)

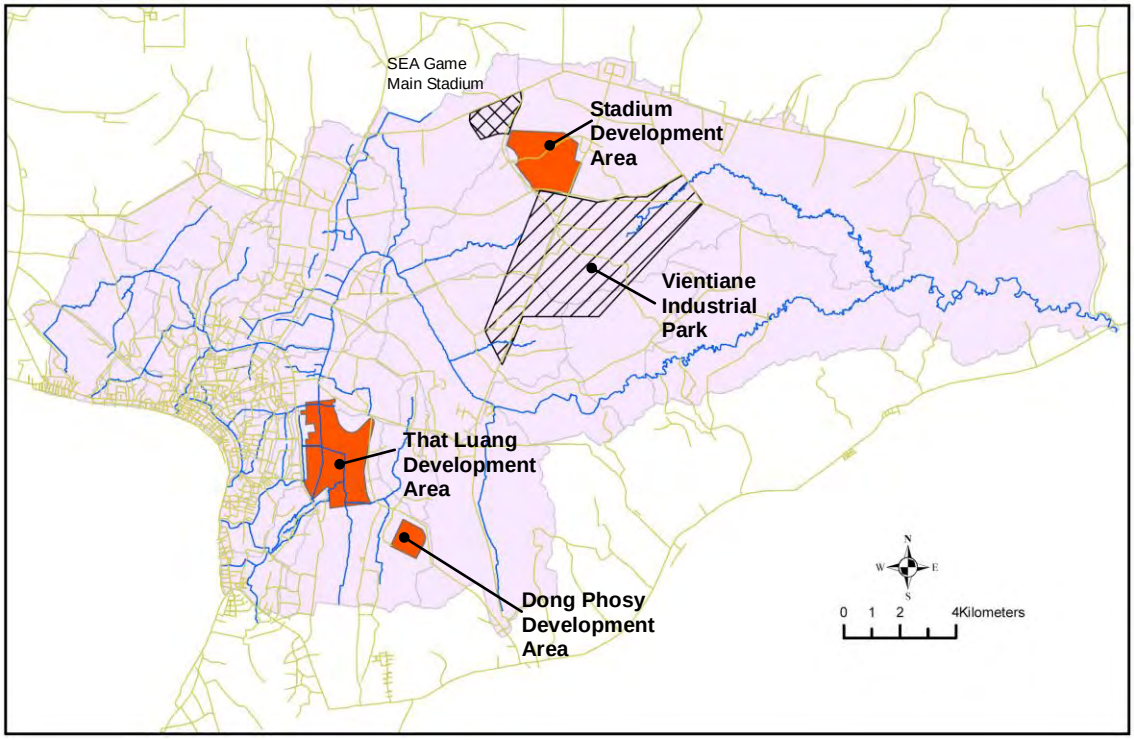
Year	GDP	Vientiane	
		GRDP	Share (%)
2008	46,215	10,574	23.0
2015	74,196	17,807	24.0
2020	105,284 [1)]	25,789	24.5

Note: [1)] Since the Industrial Zone Survey presented only the data in 2015 and 2025, the data in 2020 was calculated by applying the annual average growth rate between the two years.
Source: Preparatory Survey on Industrial Zone Development in The Lao People's Democratic Republic, Interim Report, 2009, JICA

Since no official GRDP by province has been prepared in Lao PDR, it was estimated using the "Lao Expenditure and Consumption Survey 2002/03 (LECS 3)" and the "Report of Economic Census, 2006." Vientiane's share of GDP or GRDP was projected to increase to 24.5% in 2020.

(3) Development Plan in the Study Area

In the study area, the new development plan for four areas (i.e., That Luang Development Area, Dong Phosy Development Area, Stadium Development Area and Vientiane Industrial Zone), is being formulated. The locations of these areas are shown in the following figure.



Sources: PTI and JICA Study Team

Fig. 2.1.2 Location of New Development Area

The present land-use plans have been formulated as shown in the following table, but the population projection is not available or under preparation.

The plan for the Vientiane Industrial Park has been prepared under the JICA Study –Preparatory Study on Industrial Zone Development in the Lao People's Democratic Republic."

Table 2.1.7 Outline of New Development Plan in the Study Area

Area		Area (ha)					
		Total	Resi-dential	Indus-trial	Pub.faci-lities	Untrans-ferable	Others
1	That Luang Dev. Area	670.0	230.2	-	71.1	368.1	0.6
2	Dong Phosy Dev. Area	100.0	41.1	-	4.1	54.8	0.0
3	Studiam Dev. Area	430.0	129.9	58.7	58.2	150.9	32.3
4	Vientiane Industrial Park	2,000.0	286.0	1,540.0	-	-	174.0[1)]
	Total	3,200.0	687.2	1,598.7	133.4	573.8	206.9

Note [1)] Commercial, Amenity and Logistic Area
Sources: PTI and JICA Study Team

(4) Cultural Heritage in the Study Area

Based on the interview with the Ministry of Information and Culture, the historical heritage in the project area is as summarized below.

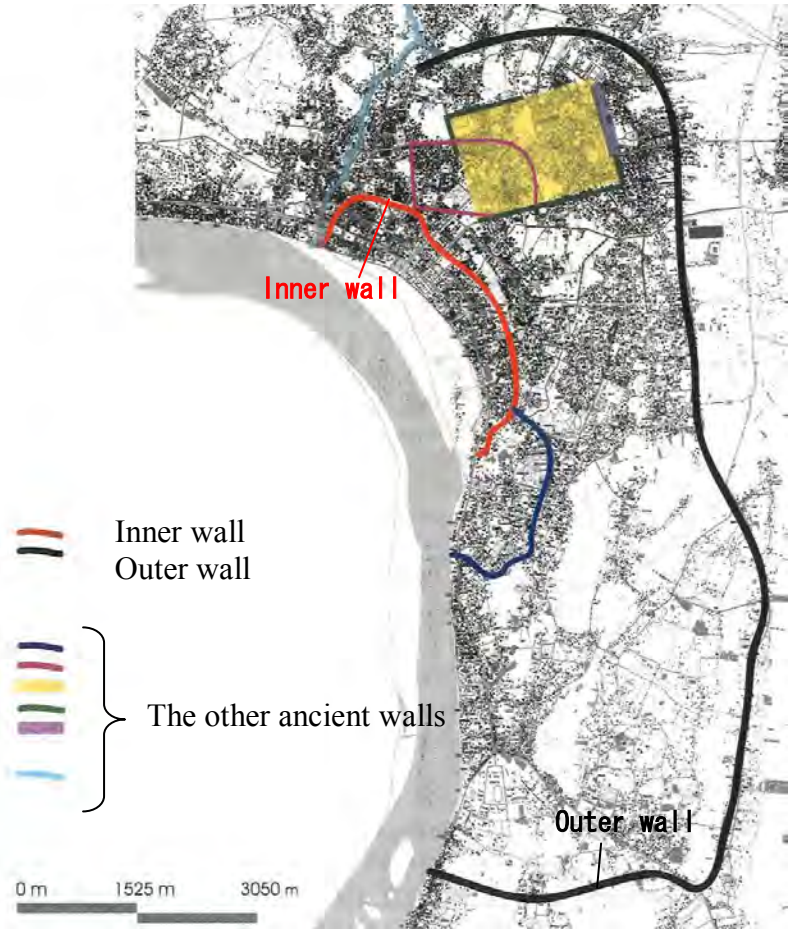
The history of Vientiane was started in the sixteenth century when the Lanexang Kingdom moved its capital from Luang Prabang to Vientiane. The kingdom built a city wall (inner wall) around the area facing the Mekong River and settled inside of the wall; therefore, the inside area of the inner wall is identified as the oldest area in Vientiane. After the city wall was expanded to the south, the third city wall (outer wall) was built outside of the inner wall. The outer wall remains even today

while the inner walls have disappeared; the first wall was replaced by a road and the second expanded wall collapsed because it was made of earth.

Regarding the outside of the city wall, some information related to the historical heritage has been obtained although some stupas were discovered at the east and south of the That Luang Marsh.

Various historical heritages have been found during some construction works in the current city, especially inside of the inner city wall, such as the study for the construction of Vientiane No. 1 Road (grant aid of Japan), which contributed a lot to the scientific history of Vientiane. The greatest discovery during the construction was "City Pillar" which symbolized the center of the city. A skull with a copper plate on its head, a palace wall, and utensils such as balance and lamp were discovered from the upper ground layer, 1-1.5 m in depth from the surface.

Heritages found during construction have been treated in accordance with the "Law on National Heritage" (No. 15/SCNA, 2005).



Source: The Project of Inventory Architecture Heritage, Urban and Landscape in Vientiane City (PTI in cooperation with French government), 1999-2003, Chayphet Sayalath

Fig. 2.1.3 Location of City Walls Built by the Lanexang Kingdom

2.2 Regulations and Institutions

2.2.1 Laws/Regulations on Water Environment

(1) National Strategy on Environment

The National Strategy on Environment up to the year 2020 and the action plan for the years 2006-2020 were established in 2004 with assistance by SIDA. This strategy has the following objectives in order to realize environmental management:

- To implement measures for sustainable development;
- To conserve forest resources;
- To secure sustainable use and equitable access to water resources;
- To use land with securing ecosystem;
- To promote environmental and social impact assessment;
- To conserve historical and cultural heritage;
- To promote international cooperation; and
- To promote environmental education.

According to ADB's "Water Resources Policy Framework Report, May 2009," this strategy shows no clear assignment of responsibility to a single agency; rather, the responsibility is divided among a range of agencies. Further, environmental objectives and standards have not been established nor included in the action plan. The report says "... little progress has been achieved in the listed actions in the first three years of the current 5-year plan."

The Action Plan of the National Environment Strategy (2005-2020), which covers the years 2011 to 2015, is under preparation as of June 2011. The National Strategy on Chemical Management (2016-2025 or 2030) and its Action Plan (2016-2020), and the National Strategy on Waste Management (2016-2025 or 2030) and its Action Plan (2016-2020) are planned to be formulated in 2015. The work for these strategies and action plans will start in October 2011. Their budgets will be requested, and is expected to be approved in September. If the budget is enough, the plans may be finished earlier than planned.

(2) Environmental Protection Law (EPL)

The basic environmental law of Lao PDR is the Environmental Protection Law (EPL), which was promulgated in 1999. The EPL stipulates the framework of environmental management and the responsibilities of related organizations, of which the central one is STEA (reorganized into WREA in 2007). It specifies necessary principles, rules and measures for managing, monitoring, restoring, and protecting the environment in order to protect public, natural resources and bio-diversity, and to ensure the sustainable socio-economic development of Lao PDR.

The basic principles specified by the EPL are as follows:

1) Environmental protection shall be the priority consideration, and environmental remediation and restoration are considered to be less preferable, but also important activities;

2) The national socio-economic development plan shall include a program to protect the environment and natural resources;

3) All persons and organizations residing in the Lao PDR shall have an obligation to protect the environment;

4) Whoever causes damage to the environment is liable under the laws for such damage; and

5) Natural resources, raw materials and energy shall be used in an economical manner, which minimizes pollution and waste and supports sustainable development.

Development projects and operations that have or will have the potential to affect the environment should submit an environmental assessment report to the agency in charge of environmental management and monitoring for issuance of an environmental compliance certificate before starting the projects. The STEA issued general regulations on procedures and methods for environmental assessment.

The EPL is now under the process of revision for the following reasons:

- Socio-economic conditions have changed greatly since its promulgation 10 years ago;
- STEA, which is responsible for environmental management and monitoring at the central level, was reorganized into the WREA in 2007, hence it is required to clarify its responsibilities; and
- Lao PDR is now applying to join WTO, which requires the transparency of the legal system to its member countries.

The bill for the revision of this law was sent to the National Assembly in the middle of 2009 and it was expected to be approved in 2010. However, the bill is still under discussion by the National Assembly as of June 2011.

The main purposes of the revision are as follows:

- To clarify the responsibilities of WREA and the other ministries concerned;
- To strengthen the provisions on environmental monitoring and inspection;
- To strengthen the articles on EIA to give WREA the full authority over review, approval and compliance inspection; and
- To include the legal requirements for the Strategic Environmental Impact Assessment (SEIA) to ensure that environmental impacts are taken into account in the development of policies and plans at national and provincial levels.

(3) Decree of Environmental Impact Assessment

The revised Decree on Environment Impact Assessment (No. 112/PM) was finally approved by the Prime Minister in March 2010. Although the draft of the revision was titled as "Decree of Environmental and Social Impact Assessment" (ESIA), the decree was finally titled as EIA, which is the same as the old one. All public and private investment projects, both domestic and foreign, which are operated in Lao PDR have to follow the process to minimize impacts for sustainable development. The main points of the process are overviewed below.

(a) Screening

In accordance with the screening criteria set under the Prime Minister's Order No. 697/PM.WREA, which was issued in March 2010, the requirement of Initial Environmental Examination (IEE) or Environmental Impact Assessment (EIA) is decided depending on the project type and its scale. In the case of small-scale projects with minor environmental and social impacts (Category 1), IEE is required, while large scale projects which are complicated or create significant impacts (Category 2) require EIA. The screening criteria are tabulated in **Appendix 2**.

In case that the project did not meet the criteria but may cause impact; for example, the project may cause cumulative or trans-boundary impact, or affect a conservation area, the developer submits an application to WREA for screening. WREA conducts the screening and issue its answer regarding the requirement of IEE or EIA within 15 working days.

(b) Public Participation

The Decree ensures the rights of affected people and other stakeholders to know information about the project and the process of impact assessment. The people and the stakeholders are also encourage to attend meetings to discuss the subjects related to the process of IEE and EIA, which include the report of IEE and EIA, compensation, resettlement and restoration of living condition, implementation of environmental and social activities as well as implementation of the Environmental Management and Monitoring Plan (EMMP) and the Social Management and Monitoring Plan (SMMP).

The local administration and the project developer must organize village dissemination meetings at the time of data collection for IEE or EIA to provide information on the development plan and the possible impact of project implementation. Also, during preparation and review of the report on IEE or EIA, WREA, the local administration, the development project responsible agencies and the project developers must organize consultation meetings with affected people and stakeholders to hear their comments on the reports.

(c) Initial Environmental Examination (IEE)

In case the IEE is required as a result of the screening, the developer shall prepare a report on the IEE, which shall include measures to prevent and minimize the impact, and submit it to the development project responsible agency. The responsible agency reviews the report within 50 working days in coordination with the local administration and concerned agencies; and then sends its written comments to WREA reporting the results of review. Based on the report, WREA issues the Environmental Compliance Certificate to permit project implementation if the project meets the requirements.

(d) Environmental Impact Assessment (EIA)

In case the screening results indicate that the EIA is required, the developer shall determine the scope of EIA study and submit the Terms of Reference (TOR) to WREA. WREA reviews the TOR within 15 working days and notify the developer if it is acceptable.

After approval of the TOR, the developer shall conduct EIA and submit the EIA report, which includes EMMP and SMMP to WREA. WREA reviews the report within 95-120 working days in coordination with local concerned agencies and administrations. After reviewing, WREA notify the project developer to organize a provincial or capital consultation meeting in coordination with the local administration. The developer improves the report in conformity with the results of the meeting and sends it to WREA for considering and issuing the Environmental Compliance Certificate.

In case that the project is complicated and needs experts from specific fields, WREA shall establish a panel of experts to review the report.

(e) Approval

WREA issues the Environmental Compliance Certificate approving the reports on IEE, EIA, EMMP and SMMP. If the project does not start within two (2) years from the date of approval, the certificate will expire automatically.

(f) Management and Monitoring

In the case of the project of Category 1, which requires IEE, the project developer shall implement monitoring and mitigation measures by themselves and report to WREA, the development project responsible agency, relevant agencies and local administrations. The responsible agency shall monitor the outputs of the implementation of the measures; and then report to WREA and the local administrations regularly.

In the case of a Category 2 project with EIA, the developer shall establish their own offices to implement the EMMP and SMMP respectively and submit reports to WREA, the development project responsible agency, relevant agencies and local administrations. Local administrations also have to establish environmental management units to inspect the implementation of EMMP and SMMP. WREA has the duty to provide technical advice to, build capacity for, and provide training for the units. If the project is complicated and has potential to cause significant impacts, the government may form a National Steering Committee to monitor the implementation of EMMP and SMMP.

(4) Regulation on the Wastewater Discharge from Industrial Processing Factories

This is a regulation by the Minister of Industry and Handicraft (presently, the Ministry of Industry and Commerce) issued in 2005. The main provisions of the regulations on industrial factories are as follows:

- To prohibit discharging directly or indirectly into public water body, wastewater that may have adverse impacts on ecology of water body, health of people or use of water;
- To require getting approval on wastewater treatment system before starting construction of factories from the Director of Industry Department of the Ministry or Province, as well as submit a treatment approach, waste management and treatment system plan;
- To require installing wastewater treatment system, volume measurement equipment, and other necessary facilities for monitoring, and sample analysis;
- To require frequent monitoring and analysis of wastewater, and to report the analysis results to the Director of Industry Department of the Ministry or Province; and
- To require recording the daily use of chemical substances and explaining the purpose of their use.

On the other hand, factory environmental inspectors (staff member of Industry Department of the Ministry or Province) have the following authorizations:

- To enter all places of industrial processing factories for the purpose of inspection, observation, measurement, sampling and monitoring wastewater discharge to public water bodies; and
- To collect all information about the manufacturing process, which are relevant to the water source and type.

If a factory environmental inspector finds any factory discharging any wastewater or other wastes into any public area, which is harmful or affect the ecology and people's health, living things or any property, he/she will cancel certification of wastewater discharge from the factory and notify the factory's owner. The Director of Industry Department of the Ministry or Province can suspend

or terminate wastewater discharge of any factory that violates this regulation until the improvement of wastewater treatment system complies with the standards.

Factories found violating this regulation will be punished as follows:

- First: warning, suspension of import and export, or suspension of production
- Second: fine of 5 to 10 times of the certificate fee
- Third: fine of 10 to 15 times of the certificate fee, and punishment of other relevant regulations

Some stipulations of this regulation overlap the EPL, the EIA regulations and the Decree on EIA for the Industrial Sector (hereinafter called collectively as the "Environmental Regulations"). For example, the Environmental Regulations require an environmental compliance certificate, and submission/approval of an environmental management plan (EMP) for factories which discharge wastewater. According to the Department of Industry, the wastewater discharge certificate system is not working at present and inspection is conducted in accordance with the Environmental Regulations.

(5) Water Supply Law

The law on general water environment is the "Water and Water Resources Law," which was promulgated in 1996. This law stipulates the principles on the management, utilization and development of water and water resources from the viewpoint of the river basin for the purpose of securing the quantity and quality of water matching the needs in the people's lives, together with keeping its sustainability. Provisions on water supply and wastewater, however, are not clear in this law. Thus, a draft of a new law called the "Water Supply Law" was developed by DHUP of MPWT with the assistance of the World Bank, whose major objectives were not only the promotion of privatization in water supply services but also the control of privatization. This law is implemented under the MPWT.

The Water Supply Law was approved by the National Assembly in November 2009, but almost all of the stipulations concern the water supply services. Sanitation and sewerage matters are planned to be stipulated by decrees which will be prepared from now on. Since the law was approved, the revision work on the Water Resources Law by WREA has started with assistance from the ADB. The final draft of the framework for the new water resources policy was already submitted in May 2009 but it is not officially approved yet as of June 2011.

(6) Decree on Compensation and Resettlement of People Affected by Development Projects

This decree was issued in 2005 with the assistance of SIDA and it is controlled by WREA. In case that the affected people (AP) have to resettle due to a development project, the project owner should compensate them in accordance with this decree. Key points of the decree are:

- This decree applies to all development projects including government and domestic private or foreign development projects.
- Participatory approach is stressed in the process.
- Project owners must provide appropriate funding to assist, support, and relocate APs.
- Compensation should be through provision of "land for land," which means that the compensation should guarantee at least the same living and business conditions.
- Those who do not have any legal land use certificate can be assured that they are not worse-off due to the project.

- Before the provision of compensation, project owners should establish a joint committee, with representatives from all stakeholders, to assess the loss to APs.
- Where relocation to a group resettlement site is considered necessary, project owners should mitigate the adverse impacts on host community.
- APs should be exempted from all administrative and legal fees incurred pursuant to the grievance redress procedures.
- The project owners should make provisions for post-evaluation six (6) months to one (1) year after completion of the implementation of resettlement.

The decree has its implementing regulations. Detailed procedure for compensation is delegated to the guideline. The guideline, however, is not approved yet and its draft is used for actual applications. All the cases to which the decree was actually applied are hydropower plant constructions.

(7) Water Quality Standards

Existing water quality standards include those for drinking water, surface water, and underground water. In addition, detailed wastewater standard is set as one of the effluent standards in Lao PDR. Although these water quality standards have been consulted with related organizations mentioned below, they are basically established by WREA.

The revision work for the Environmental Standards in Lao PDR, which include not only water quality standards but also air quality as well as noise, was started in 1999. It involves 13 related agencies or 37 members. A Technical Consultation Workshop was held in December 2008 for the TWG members. A National Consultation Workshop was also held in April 2009, inviting 170 people including representatives from central and provincial government agencies. Concerning the surface water standard, it is agreed to use the same standard employed by the MRC countries in May 2009. Finally, the revised Standards were issued as "Present Authorized Environmental Standards" on December 7, 2009.

The following standards are the Present Authorized Standards and are closely related to water quality of the rivers and the drainage canals in the Study Area.

(a) Drinking Water Quality Standard

In Lao PDR, the water quality standards for drinking water had been actually developed by the Department of Hygiene and Prevention under the Ministry of Health in cooperation with WHO/UNICEF. The drinking water quality standards include those for the following items:

- Standard in general
- Standard for water in containers (PET bottle, etc.)
- Standard for underground water

(b) Surface Water Quality Standard

The present Authorized Surface Water Quality Standard is shown in the following table. Since such standard has not been stipulated so far in Lao PDR, it is newly provided.

Table 2.2.1 Present Authorized Surface Water Quality Standard

No.	Parameter	Unit	Standard Value
1	Color, Odor, Taste	-	Natural Level
2	Temperature	℃	Natural Level
3	pH	-	5 - 9
4	DO	mg/l	6
5	COD_{Cr}	mg/l	5
6	BOD_5	mg/l	1.5
7	Coliform Bacteria	MPN/100 ml	5,000
8	Faecal Coliform	MPN/100 ml	1,000
9	NO_3-N	mg/l	< 5.0
10	NH_3-N	mg/l	0.2
11	C_6H_5-OH	mg/l	0.005
12	Cu	mg/l	0.1
13	Ni	mg/l	0.1
14	Mn	mg/l	1.0
15	Zn	mg/l	1.0
16	Cd	mg/l	0.005
17	Cr^{+6}	mg/l	0.05
18	Pb	mg/l	0.05
19	Hg	mg/l	0.002
20	As	mg/l	0.01
21	CN^-	mg/l	0.005
22	Radioactivity - Gross α	Becquerel/l	0.1
23	Radioactivity - Gross β	Becquerel/l	1.0
24	Total organochorine	mg/l	0.05
25	DDT	μ g/l	1.0
26	α BHC	μ g/l	0.02
27	Dieldrine	μ g/l	0.1
28	Aldrin	μ g/l	0.1
29	Heptachlor & Heptachlor epoxide	μ g/l	0.2
30	Endrin	μ g/l	ND

Source: The Agreement of National Standards of Environment in Laos, March 2009, Prime Minister Office and WREA

This surface water standard is so aggressive that its provisions are very difficult to observe for the rivers in Vientiane, considering present situations. For example, BOD_5: 1.5 is usually observed in mountain streams in rural areas. More realistic and reasonable values for BOD is examined and employed in the Master Plan of the Study.

In addition, although a concrete standard value is set for each parameter of the Present Authorized Surface Water Quality Standard of Lao PDR, these standards do not corresponded to every water quality class.

The following table shows the recent Surface Water Quality Standards for a river (water quality class: Class 3, Class 4, and Class 5) in some Asian countries. The Class 3, 4, 5 of water quality could be informative for the rivers and the drainage canals in the Study Area considering the actual usages in such countries for their water bodies and present water quality situations.

Table 2.2.2 Surface Water Quality Standard for Some Water Classes in Asian Countries

Standard Name	Environmental Standards for Conservation of Living Environment (Water Quality in River)	Revised Water Usage and Classification/Water Quality Criteria	Surface Water Quality Standard
Country	Japan[1)]	Philippines[2)]	Thailand[2)]
Water Quality Class	C (Class 4)	C (Class 3)	C (Class 3)
Beneficial Use	Fishery water quality class 3 (fishery for carp and crucian)	Fishery water for the propagation and growth of fish and other aquatic resources	Medium clean used for human consumption, with passing through an ordinary treatment process
	Industrial water quality class 1 (water purified using sedimentation and other ordinary means)	Industrial water quality class 1 (Industry for manufacturing processes after treatment)	Agriculture
		Recreation water class 2 (boating, etc. without primary contact recreation	
Main Parameter	C (Class 4)	C (Class 3)	C (Class 3)
(1) BOD_5	≤ 5 mg/l	≤ 7-10 mg/	< 2 mg/
(2) DO	≥ 5 mg/l	≥ 5 mg/	> 4 mg/
(3) pH	6.5 – 8.5	6.5 – 8.5	5.0 – 9.0
(4) SS	≤ 50 mg/l	-	-
(5) Total Coliform	-	≤ 5,000 MPN/100 ml	≤ 4,000 MPN/100 ml
Water Quality Class	D (Class 5)	D (Class 4)	D (Class 4)
Beneficial Use	Industrial water quality class 2 (purified water using chemical additives and other advanced means)	Industrial water quality class 2 (Industry for cooling, etc.)	Fairly clean used for consumption, but requires special treatment process
	Agricultural water	Agricultural and irrigation uses and livestock watering, etc.	Industry
Main Parameter $_5$	D (Class 5)	D (Class 4)	D (Class 4)
(1) BOD_5	≤ 8 mg/l	≤ 10-15 mg/	< 4 mg/
(2) DO	≥ 2 mg/l	≥ 3 mg/	> 2 mg/
(3) pH	6.0 – 8.5	6.0 – 9.0	5.0 – 9.0
(4) SS	≤ 100 mg/l	-	-
(5) Total Coliform	-	-	-

Note: [1)] Japan has unique five ("AA" to "D") water quality classes for a river in the Ambient Surface Water Quality Standard.
[2)] The above other two countries have four ("A" to "D") water quality classes for a river in the Ambient Surface Water Quality Standard.

(c) Effluent Standards of Wastewaters

The presently Authorized Effluent Standards of Wastewater have standards for each of the following items:

- Wastewater from factories
  - Factories in general
  - Sugar mill factory
  - Textile and garment factory
  - Pulp mill factory
  - Paper mill factory
  - Slaughterhouses
- Specific effluents of wastewater
  - Organic industry
  - Inorganic industry: Electroplating
  - Battery plants

- Wastewater discharge from large-scale farming
- Wastewater discharge from bus station
- Wastewater discharge in urban area (with 5 classifications)

The following table shows the presently Authorized Wastewater Discharge Standard for Factories in General.

Table 2.2.3 Presently Authorized Wastewater Discharge Standard for Factories in General in Lao PDR

No.	Parameter	Unit	Maximum Allowable Concentration
1	BOD_5	mg/l	40
2	NH_3-N	mg/l	4
3	TSS	mg/l	40
4	pH	mg/l	6 – 9.5
5	TDS	mg/l	3,500
6	C_6H_5OH	mg/l	0.3
7	P	mg/l	1.0
8	Ag	mg/l	0.1
9	Zn	mg/l	1.0
10	S	mg/l	1.0
11	Cl_2	mg/l	1.0
12	Cl^-	mg/l	500
13	Fe	mg/l	2.0
14	F	mg/l	15
15	CN	mg/l	0.1
16	Cu	mg/l	0.5
17	Pb	mg/l	0.2
18	Oil and fat	-	5
19	Ni	mg/l	0.2
20	Hg	mg/l	0.005
21	Mn	mg/l	1.0
22	As	mg/l	0.25
23	B	mg/l	1.0
24	Cd	mg/l	0.03
25	Cr^{6+}	mg/l	0.1
26	Total Cr	mg/l	0.5

Source: The Agreement on National Environmental Standards in Lao, December 7, 2009, Prime Minister's Office and WREA in Lao PDR

The above Effluent Standards of Wastewater could be applied to almost all the industries in Lao PDR. The proposed draft is the same with that in the existing Regulation on the Wastewater Discharge from Industrial Processing Factories except BOD_5 (30 mg/l in the old standard) and TSS (30 mg/l in the old standard). Also, the following table shows the Standards of the Wastewater Discharge in Urban Area.

Table 2.2.4 Present Authorized Standards of the Wastewater Discharge in Urban Area in Lao PDR

No.	Parameter	Unit	Permissible Values				
			A	B	C	D	E
1	BOD_5	mg/l	20	30	50	60	200
2	Suspended Solid	mg/l	30	40	50	50	60
3	Settleable Solids	mg/l	0.5	0.5	0.5	0.5	-
4	Total Dissolved Solids (TDS)	mg/l	3,000	2,500	2,000	1,500	-
5	COD	mg/l	120	130	150	350	400
6	Sulfide	mg/l	1.0	1.0	3.0	4.0	-
7	Total Kjeldahl Nitrigen (TKN)	mg/l	35	35	40	40	-
8	Fat oil and grease	mg/l	20	20	20	20	100
9	Temperature	℃	40	40	40	40	40
10	pH	-	6-9.5	6-9.5	6-9.5	6-9.5	6-9.5

Source: The Agreement on National Environmental Standards in Lao, December 7, 2009, Prime Minister's Office and WREA in Lao PDR

Table 2.2.5 Building Categorization

No.	Building Type / Building Usage	Criteria	Category
1	Suite (Apartment, Condominium)	< 100 rooms 101-500 rooms 501 rooms <	D C B
2	Hotel/Guest House	< 60 rooms 61-200 rooms 201 rooms <	D C B
3	Dormitory	10-50 rooms 51-250 rooms 251 rooms <	C D B
4	Hospital, Clinic	No Service 1-30 beds 30 beds <	C B A
5	Building for Living (Village), Temple	5,000-10,000 m^2 10,001 m^2 <	E D
6	Disco, Fitness Center, Swimming Pool, Sports Center	1,000-5,000 m^2 5,001 m^2 <	B D
7	School, Educational Institute, College, University	5,000-2,5000 m^2 2,5001 m^2 <	B A
8	Office (Government, Private, International) Private Company, Theater	5,000-10,000 m^2 10,001-55,000 m^2 55,001 m^2 <	C B A
9	Shopping Center, Supermarket	5,000 – 25,000 m^2 25,001 m^2 <	B A
10	Market	500 – 1,000 m^2 1,001 – 1,500 m^2 1,501-2,500 m^2 2,501 m^2 <	D C B A
11	Restaurant	< 100 m^2 500-1,000 m^2 1,001-1,500 m^2 1,501-25,00 m^2 2,501 m^2 <	E D C B A

No.	Building Type / Building Usage	Criteria	Category
12	Service Center (Motorbike, Car)	500-1,000 m^2 1,001-1,500 m^2 1,501-2,500 m^2 2,501 m^2 <	D C B A
13	Transport Station, Airport	5,000-10,000 m^2 10,001-55,000 m^2 55,001 m^2 <	C B A
14	Slaughterhouse in Urban Area	500-1,000 m^2 1,001-1,500 m^2 1,501-2,500 m^2 2,501 m^2 <	D C B A

Source: The Agreement on National Environmental Standards in Lao PDR, December 7, 2009, Prime Minister's Office and WREA in Lao PDR

When it is applied to the Study, the definition of the drainage canal in the Study Area is not clear, and therefore wastewater management in the canals might be ineffective. On the other hand, water quality in the canals are getting worse mainly due to untreated or insufficient treated wastewater from the houses, factories, and the farmlands.

(8) Standard Procedure of Law-Making

Except those required to be issued urgently, it usually takes 4 to 5 years to develop a new law since it approves the necessity of development. For example, the Water Supply Law also required such period. Detailed process is as follows:

[Planning Phase]

1) Proposal by a technical agency
2) Approval by the Minister
3) Approval by the Meeting at Prime Minister's Office
4) Listed up in the law development table of the Ministry of Justice

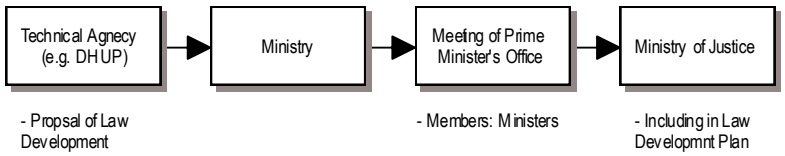


Fig. 2.2.1 The Standard Process of Law-Making 1: Planning Phase

[Law Development Phase]

1) 1st Draft made by the technical agency: technical coordination with stakeholders
2) Approval by the Minister
3) Checked by the Ministry of Justice from the viewpoint of legal technique and consistency with the other laws: 2nd Draft
4) Revision by the Ministry with the comments of the Ministry of Justice: 3rd Draft
5) Consultation in the committee of the National Assembly (4th Draft): if the law is expertise and technical one, consultation is made in the committee with the request by the technical agency without directly sent to the General Meeting of the National Assembly.
6) Approval by the Meeting at the Prime Minister's Office
7) Discussion in the General Meeting of the National Assembly

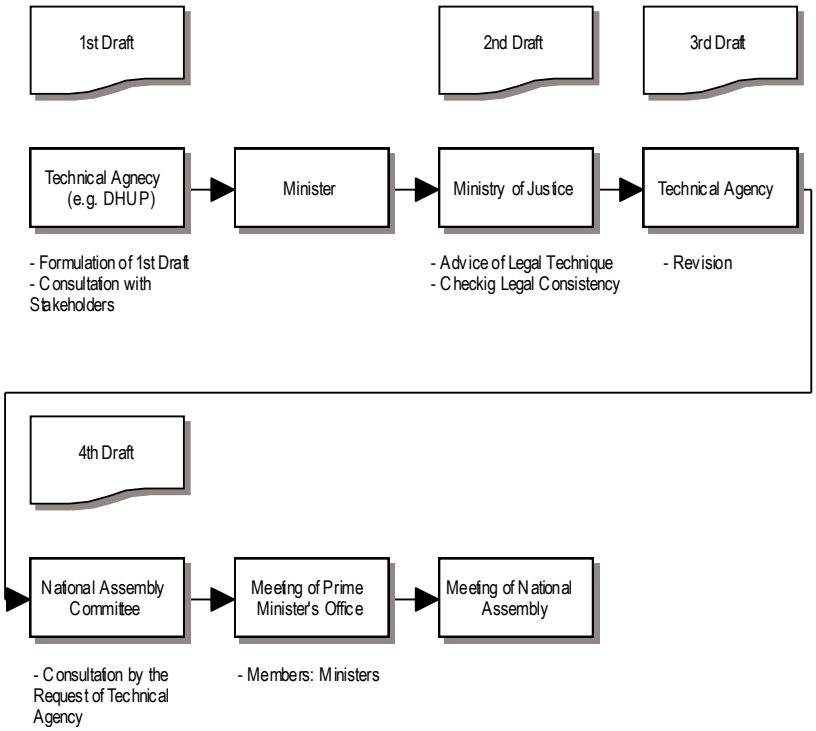


Fig. 2.2.2 The Standard Process of Law-Making 2: Development Phase

2.2.2 Organizations/Institutions Related to Water Environment

Organizations and institutions related to water environment are tabulated as follows:

Table 2.2.6 Organizations/Institutions Related to Water Environment

Layer	Name	Abbreviation	Title Number
Central	National Environment Committee	NEC	(1)
	Water Resources and Environment Administration	WREA	(2)
	Department of Environment	DOE	(2)
	Environmental Quality Monitoring and Hazardous Chemical Center	EQMHCC, (WREA Lab)	(3)
	Ministry of Public Works and Transport	MPWT	
	Department of Housing and Urban Planning	DHUP	(4)
	Public Works and Transport Institute	PTI	(5)
	Ministry of Industry and Commerce	MIC	
	Department of Industry	DI	(9)
	Ministry of Health	MOH	(10)
Vientiane	Water Resources and Environment Office	WREO	(6)
	Vientiane Urban Development and Administration Authority	VUDAA	(7)
	Department of Public Works and Transport	DPWT	(8)
	Department of Industry and Commerce	DIC	(9)
	Department of Health	DOH	(10)
Others	Environment Protection Fund	EPF	(11)

(1) National Environment Committee

The National Environment Committee (NEC) was established in 2002, where the chairman is the Vice Prime Minister, Vice Chairman is the President of WREA, the Secretariat is WREA and members include Vice Ministers and Vice Presidents of related organizations. NEC's

responsibility is to coordinate the plans, management and monitoring on environment at the national level. Its organization is shown in the following figure and table.

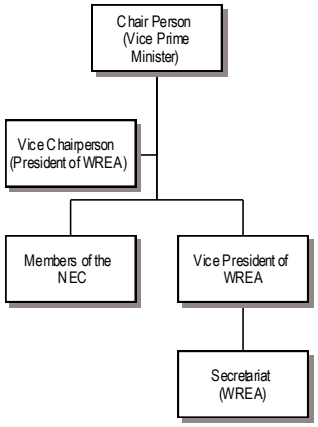


Fig. 2.2.3 Organizational Structure of NEC

Table 2.2.7 Members of NEC

• Vice Minister of Agriculture and Forest	• Vice Minister of Interior	• Vice Chairman Lao Front for National Construction
• Vice Minister of Finance	• Vice Minister of Defense	• Vice President of Buddhist Fellowship Organization
• Vice Minister of Industry and Commerce	• Vice Minister of Foreign Affairs	• Vice President of Cooperation Planning and Investment
• Vice Minister of Communication, Transport, Post, and Construction	• Vice Chairman of Law Committee, National Assembly	• Vice President of Tourism Agency
• Vice Minister of Education	• Vice President of Supreme Court	• President of Lao National Mekong Committee
• Vice Minister of Publish and Culture	• Vice President of Lao Women Union	• President of Water Resource Secretariat
• Vice Minister of Labor and Social Welfare	• Vice President of Federation of Trade Union	• Director General of Development and Environment Education Center, National University of Laos
• Vice Minister of Justice	• Vice President of LAO PDR Youth Union	(Total: 23 members)

Source: WREA

(2) Water Resources and Environment Administration (WREA) and Department of Environment (DOE)

WREA directly relates to the formulation of policies and plans on water resources and environment. It has six departments; namely, Cabinet, Department of Water Resources, Department of Environment (DOE), Department of Environmental and Social Impact Assessment, Department of Meteorology and Hydrology, and Water Resources and Environment Research Institute (WERI). Among them, DOE promotes the formulation of environmental laws, especially standards. The present organizational structure of WREA and DOE, which was officially approved on March 16, 2009, is as shown below.

By the way, the National Assembly approved that WREA be reorganized to Minstry of Natural Resources and Environment (MONRE) in June 2011. Details of the reorganization are not clear as of June 2011. WREA is used in this report.

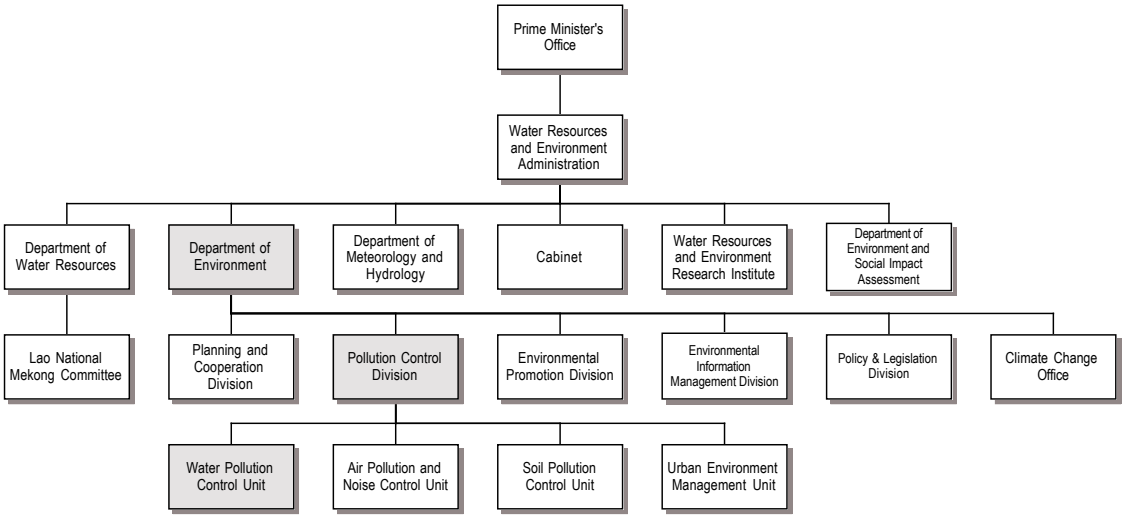


Fig. 2.2.4 Organizational Structure of WREA and DOE

Detailed organization, responsibility and staff numbers of DOE are summarized in the following table. The actual number of full time staff members of the Water Pollution Control Unit is only two (2). This actually shows a severe shortage of human resources for water environmental management in Lao PDR.

Table 2.2.8 Main Responsibilities and Number of Staffs of DOE

Division/Office	Main Responsibility	Full-time Staff
Planning and Cooperation Division	Budget management, personnel management, human resources management, etc.	11
Pollution Control Division	Formulation of national environmental standards, coordination of related governmental agency in terms of environmental management	10 (Water Pollution Control Unit: 2)
Environmental Promotion Division	Public relations of environmental conservation, environmental education	5
Environmental Information Management Division	Data management of environment and natural resources, analysis of environmental information	7
Policy & Legislation Division	Development and proposal of draft strategy, action plan, legislation, guidelines, and standards related to environment to higher authority for approval	7
Climate Change Office	Formulation of strategy for climate change, coordination of international agreement for climate change	11
	(Total)	51

Source: DOE

Concerning water quality analysis, the WREA has a small laboratory facility, which belongs to the Environmental Quality Monitoring and Hazardous Chemical Center under the Department of WERI, but the analysis equipment and human resources of the laboratory are very limited at present.

In the provincial level, there are the provincial water resources and environmental offices, which correspond to WREA in the national level.

(3) Environmental Quality Monitoring and Hazardous Chemical Center (EQMHCC, WREA Lab)

The Environmental Quality Monitoring and Hazardous Chemical Center (EQMHCC) which is commonly known as WREA Lab, is under the direct supervision of WERI. EQMHCC's responsibilities are:

- To control water quality (river water, ground water, wastewater);
- To conduct research on the pollution control and prevention technology;
- To disseminate environment toxicology and to make the Lao society aware of the negative impacts from the use of hazardous chemical products; and
- To provide services on the above mentioned tasks.

It has 11 staff members in total and all of them have a Bachelor's degree. They face a lot of problems on monitoring practices because their capacity is still under development. Furthermore, the WREA Lab is developing/updating the quality assurance/quality control (QA/QC) system and Standard Operation Procedures (SOPs) aiming at obtaining the ISO/IEC 17025 certificate.

A proposal for the capacity development of WREA Lab was submitted to JICA in September 2010. This proposal includes training on basic management such as reporting, storing testing data, etc., which will be covered by QA/QC management. European donors conduct capacity building mainly for general matters. They are expecting that Japanese trainings will focus on technical matters through on-the-job training (OJT) for improving the daily exercises on Lab work.

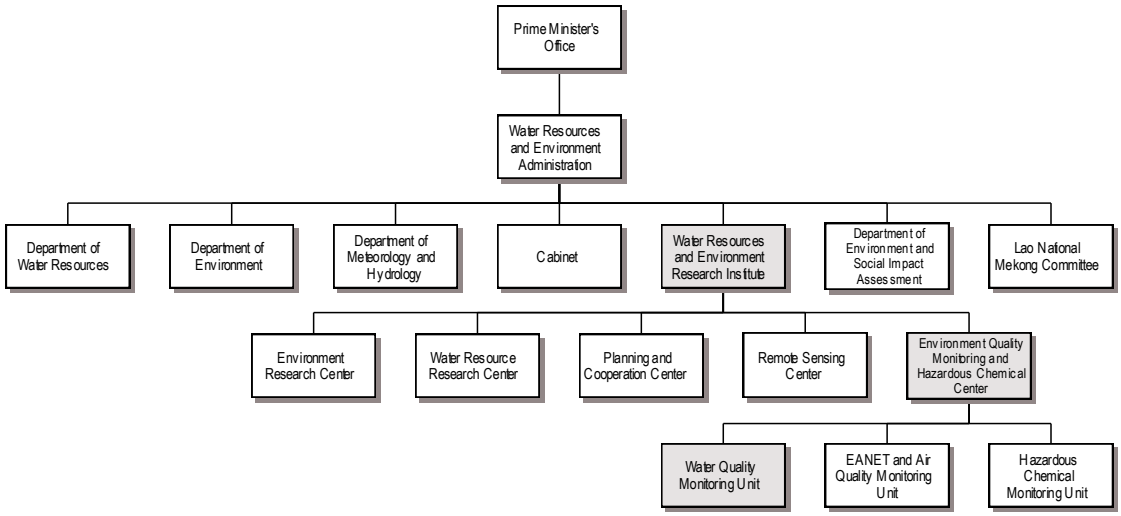


Fig. 2.2.5 Organizational Structure of WREA and EQMHCC

(4) Department of Housing and Urban Planning (DHUP) of Ministry of Public Works and Transport (MPWT)

DHUP consists of the following divisions: Water Supply, Urban Planning, Urban Development, and Housing. The Urban Development Division is responsible for management and control of implementation of plans for basic urban infrastructure and environment, including urban services, such as drainage, wastewater and solid waste.

The organizational structure of DHUP is as shown in the following Figure.

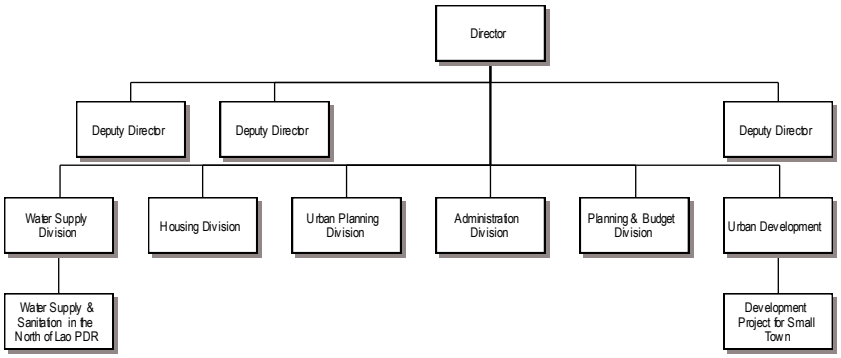


Fig. 2.2.6 Organizational Structure of DHUP

(5) Public Works and Transport Institute (PTI) of MPWT

PTI, the main counterpart agency for the Study, is the main technical agency for urban planning in Lao PDR and it offers services of studies and evaluation on urban planning as well as trainings on environmental management. Detailed organization, responsibility and staff numbers of PTI are as summarized in the following figure and table.

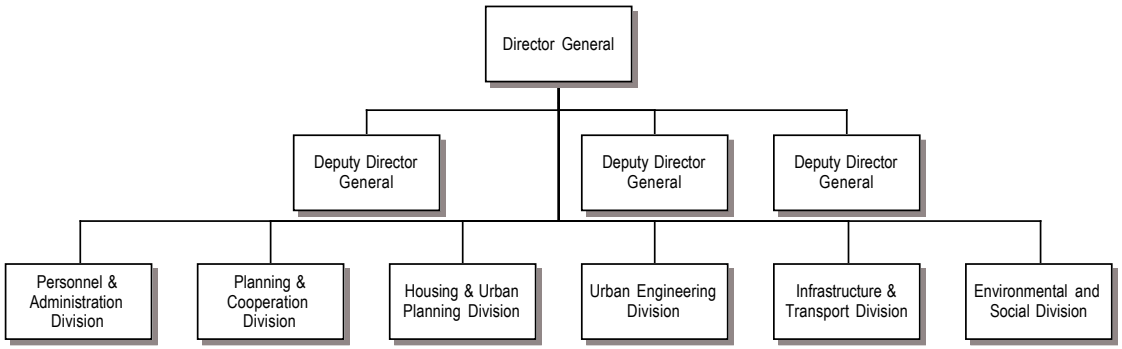


Fig. 2.2.7 Organizational Structure of PTI

Table 2.2.9 Main Responsibilities and Number of Staffs of PTI

Division	Main Responsibility	Present Full-time Staff
Personnel & Administration Division	Personnel management, general affairs, and budget management	10
Planning & Cooperation Division	Dissemination and public relations, and cooperation in the field of public works and transport sector	7
Housing & Urban Planning Division	Research and development in the field of housing, and formulation of urban planning in all levels of government	11
Urban Engineering Division	Topographic survey and mapping, and R&D in the field of urban engineering	14
Infrastructure & Transport Division	Planning of roads, bridges, airports, etc. and formulation of traffic plans	7
Environmental and Social Division	Research, planning and evaluation on environmental impacts	8
	(Total)	57

Source: PTI

According to the Urban Planning Law, urban plans have two levels; namely, master plans and regional (detailed) plans. At least three public consultation meetings are required in the formulation. Master plans include a general zoning and land use plan, which is prepared by PTI and approved by the Prime Minister. Generally speaking, since a Village government has no

capacity to formulate detailed plans at the Village level, PTI prepares them. However, due to the shortage of personnel, PTI can accept little of the work. Thus, almost all the Villages have no such detailed plan.

(6) Water Resources and Environment Office (WREO) of Vientiane

Water Resources and Environmental Offices (WREOs) are Provincial or Vientiane's (the same layer of the Province) counterparts of the WREA.

The WREO of Vientiane has three (3) units; namely, the Administration Unit, the Water Resources Unit, and the Environment Unit. There are one (1) Director and two (2) Deputy Directors and each unit has five (5) staff members. The WREO is under the Governor of Vientiane. Its organizational structure is as shown in the following figure.

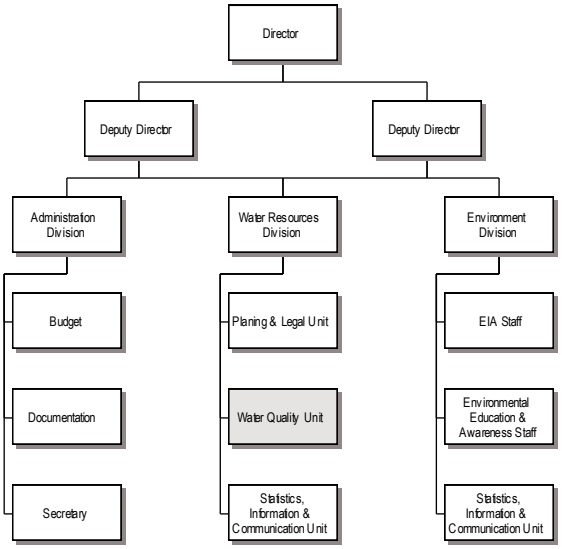


Fig. 2.2.8 Organizational Structure of WREO of Vientiane

All staffs except some in the Administration Unit hold university diplomas. However, their academic backgrounds are only on general environment and they do not have enough experience on specialized environmental works. Although they have a lot of opportunities for training prepared by the central government, there is no master plan of staff training. Fifty percent (50%) of all staffs can communicate in English without so much difficulty.

The total number of district staff members in the nine (9) Districts is 12. At least one staff member is located in each District Office to perform all fields of tasks involving all kinds of environmental quality and water resources.

The WREO of Vientiane makes no initiative for coordination with other related organizations whenever a new law or regulation is made. Usually, WREO is asked to participate in a workshop or a working group to share information or make comments.

(7) Vientiane Urban Development and Administration Authority (VUDAA)

The VUDAA in Vientiane was established in 1997 and the same kinds of authority were established at the same time in four (4) other provinces which were relatively developed in economy for the promotion of local administration. The VUDAA includes 189 villages in four (4) districts; namely, Chanthabuly, Sikhottabong, Xaysetha and Sisattanak. Under the control of the Governor of Vientiane, the VUDAA offers various administrative services,

management, formulation and implementation of urban plans included in the urban master plan prepared by PTI.

The present number of staff of VUDAA is 72 in the head office, 25 in the Landfill Management Unit, 205 in the Road Cleaning Unit and 106 in the Solid Waste Management Unit. Heavy equipment at the dump site consists of 2 dump trucks, 1 loader, 1 excavator and 2 bulldozers, which were procured under a Japanese grant aid –the Project for Improvement of the Solid Waste Management System in the Vientiane Urban Area" in 1998. Due to improper maintenance, however, their performance capacity had deteriorated.

The organizational structure of VUDAA is as shown in the following figure.

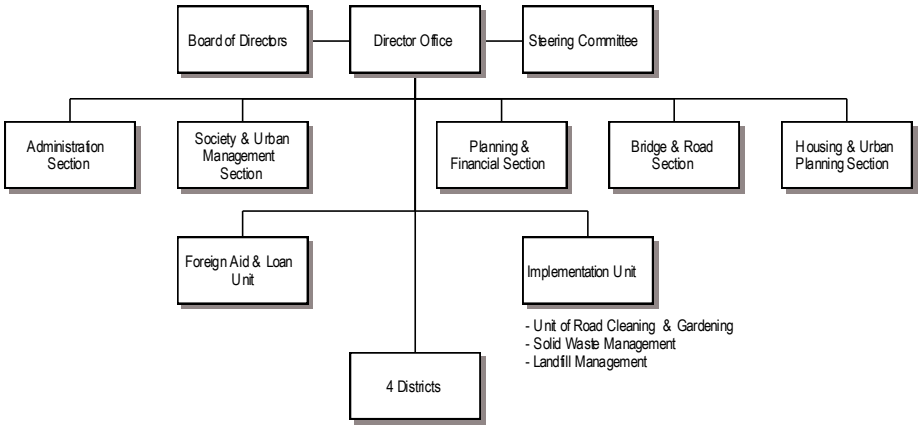


Fig. 2.2.9 Organizational Structure of VUDAA

The Director of VUDAA can conduct the following items at his/her discretion with the guidance of the Governor of Vientiane:

- Management and construction of roads;
- Management and construction of drainage facilities;
- Collection of solid waste, and management and construction of dumping sites;
- Public health and environmental conservation;
- Management and design of parks;
- Coordination of land use and development with related agencies;
- Provision of information and technology to districts, villages and organizations;
- Various kinds of explanation and tax collection; and
- Other matters deemed necessary by the Governor.

Among the tasks listed above, two items closely related to water environment are described in detail hereinafter.

[Sanitary Toilet]

VUDAA and DPWT control the desludging companies in their respective jurisdictions. Presently, a total of 9 companies (17 vacuum cars) are doing business in the VUDAA jurisdiction. There is no regulation from the viewpoint of sanitation for such business. Companies just apply for a business license with the District Office. No clear delineation of responsibility for sanitary toilet management is stipulated between VUDAA and DPWT.

There is a pond for night soil dumping. It is located in the new dumping site at Na Pa Souk Village, which is 32 km away from the center of Vientiane. Its size is 200m × 200m without a

treatment facility. Night soil was formerly dumped at the EU Pond but the pond was moved to the new site because many claims against foul odor were raised.

[Solid Waste]

One unit of VUDAA and five units of private companies are providing services of solid waste collection using a total of 45 collection vehicles. The service of the VUDAA unit covers 32,345 households and that of the private companies covers 10,020 households. Since the total number of households in the VUDAA jurisdiction is 63,312, the remaining 13,405 households are not covered by the VUDAA collection service. There is a regulation on the solid waste collection service and the licensing system.

The new dumping site at Na Pa Souk Village started operations in 2008. The total area is 748 ha and presently, 100 ha is being used.

The fee of solid waste collection is 24,000 KIP per household per month. The median of the total monthly income of a household amounts to 5,000,000 KIP in the target area of the Pre-F/S. Thus, the cost is 0.48% of the total income of a household.

(8) Department of Public Works and Transport (DPWT) of Vientiane

DPWT has the responsibility on administrative works for the remaining 391 villages of Vientiane not covered under the VUDAA's jurisdiction. DPWT's responsibility includes the following items:

- Establish medium- and long-term plans on public works and transportation
- Management of construction works;
- Management of transportation works;
- Management of transportation vehicles;
- Management of technical safety;
- Management of housing; and
- Management of public areas

The organizational structure of DPWT is as shown in the following figure.

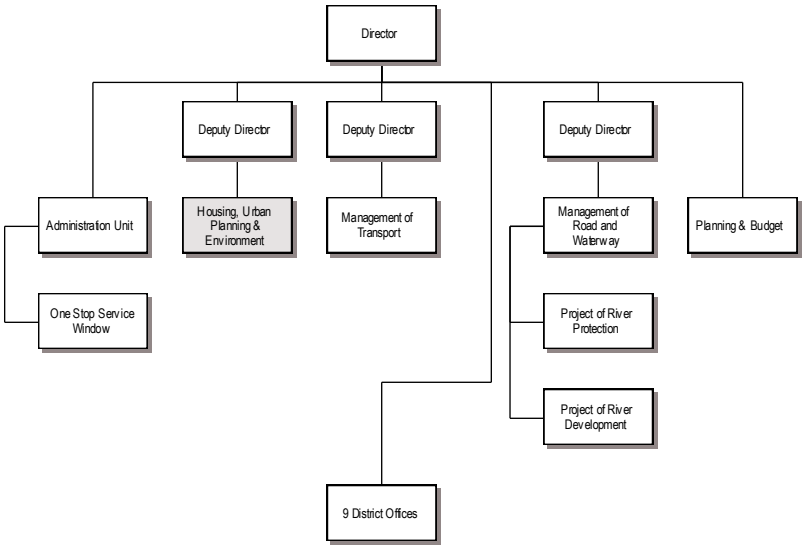


Fig. 2.2.10 Organizational Structure of DPWT

Newly established in DPWT is the "Housing, Urban Planning and Environment Unit," which also works on matters involving environment and water resources. The number of staff is four, and a decree has yet to be formulated to define its detailed responsibility on environmental affairs.

(9) Department of Industry (DI) of Ministry of Industry and Commerce (MIC) / Department of Industry and Commerce of Vientiane

[DI of MIC]

Among the DI organizations, the Industrial Environment Division closely relates to water environment. The organizational structure of DI is shown in the following Figure.

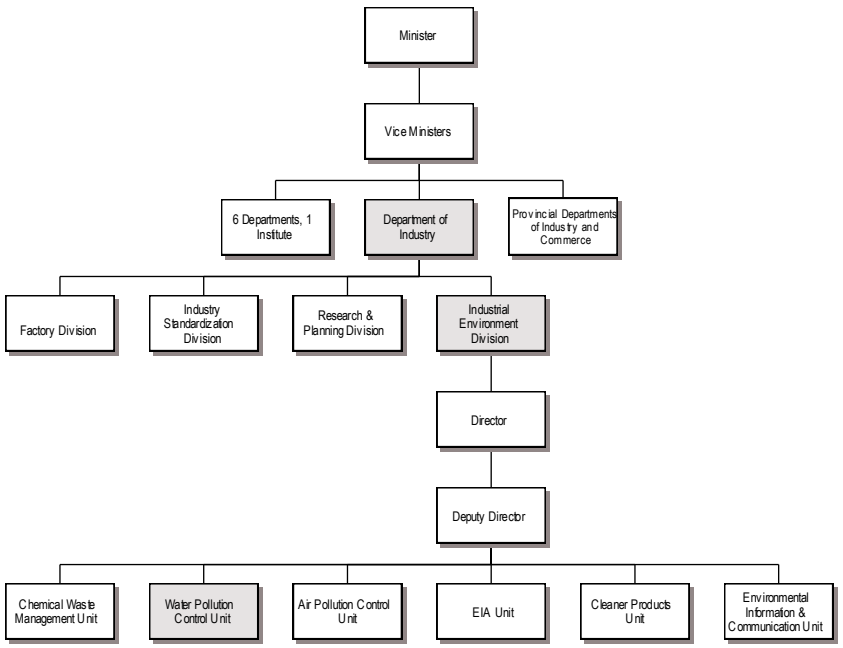


Fig. 2.2.11 Organizational Structure of DI

The Industrial Environment Division has 6 units and 6 staff members in total. No staff member is assigned to a particular unit, but they are designated as industrial wastewater inspectors. In Lao

PDR, there were 24,227 factories in 2008. Among them, the large-scale ones (total labor force: over 200 employees) are 832 in number, the medium-scale ones (50-200 employees) are 431, and small-scale ones (less than 50 employees) are 22,964. The Ministry's Department of Industry has the responsibility on the large-scale ones and some of the medium-scale ones with problems, while the Provincial Department of Industry and Commerce is responsible for medium-scale ones and small-scale ones. No regular meetings are held with WREA, but when an environmental problem comes about, the two departments work together.

Factories without problems are inspected 2 times a year, while factories presenting problems are inspected every month. The inspector conducting an inspection of a factory is accompanied by staffs of the Provincial DI, Provincial WREO, District Office of Industry and Commerce, the Village Head and the responsible staff of the factory. Wastewater samples are sent to the laboratory of WERI or the Ministry of Irrigation, after which, a wastewater analysis report is sent to the factory together with the comments by DI.

So far, three factories were found to have violated the regulations and thus penalized. For example, when a paper mill violated the regulation, its discharge of wastewater was temporarily suspended and was required to install a treatment facility.

Since large-scale factories are required to submit an environmental management plan (EMP) according to the Decree of EIA for the Industrial Sector, the inspections are made according to the EMP.

[Department of Industry and Commerce of Vientiane]

In the Department of Industry and Commerce, the Industry and Handicraft Division has the responsibility on wastewater discharge from factories. It has 10 staff members. It also issues business certificates to factories. In Vientiane, there are 2,060 factories, which are middle to small-scale ones, and controlled by Vientiane. Industrial wastewater inspection is held 2 to 3 times a month and at the same time with the business inspection, which is once in 1 up to 3 years when the factory's business certificate is renewed and only for factories that discharge wastewater as indicated in the application for business certificate.

Manpower is not enough and there is no basic plan of training. Forty percent (40%) of the staff can communicate in English without much difficulty. A meeting with all departments of Vientiane as well as the DI of MIC is held every week, but no regular meeting is held with WREO.

(10) Ministry of Health (MOH) and Department of Health (DOH) of Vientiane

[MOH]

The National Center for Environmental Health and Water Supply, which is under MOH, has the responsibility of water supply and sanitation for rural areas as well as hygiene education and dissemination in both urban and rural areas.

The final draft of the water resources policy and action plan was prepared by WREA in October 2010 and waiting for approval by the Prime Minister. The MOH had made and is preparing many kinds of regulations/guidelines on hygiene and sanitation with support by foreign donors, but the problem is that the one already prepared were not enforced. According to the Director of the Center, the reasons are:

- Resources including manpower and budget are not enough;
- Role and responsibility are not clearly defined;

- People are not aware of those regulations/guidelines because the method of dissemination is not enough; and
- After an action plan is finished, its results are not reviewed and evaluated.

[DOH]

The Environment Hygiene and Clean Water Section of DOH have the following responsibilities:

- Promotion of sanitation for public toilets, hotels and restaurants
- Clean drinking water for rural areas (urban area by DPWT)

The section has five staffs. In case that more manpower is required, it will be assisted by the other sections.

According to the Deputy Director of DOH, presently, high maternal and infant mortality in rural areas is by far a big problem for DOH.

(11) Environment Protection Fund (EPF)

The Environment Protection Fund (EPF) was established in 2005 as a financially autonomous organization to strengthen environmental protection, sustainable natural resources management, biodiversity conservation and community development in Lao PDR.

Sources of the Fund are the World Bank Grant of 4 million USD and the ADB Loan of 5.8 million USD. In the last 5 years, 5.5 million USD has been expensed: 3.5 million USD for projects, and 2.0 million USD for administration costs. Three million USD will be added to the Fund in three years by the World Bank.

The EPF provides financial support by means of: non-refundable grant, preferential loans, interest rate subsidies, or a combination of these. Details of the commitment of EPF sub-grant are shown below for 2009.

Table 2.2.10 Commitment of EPF Sub-Grant in 2009

Activities	# projects	Budget (Thousand USD)
Implementation and Capacity Enhancement	9	992
Community and Biodiversity Investment	13	417
Pollution Control	8	52
Water Resources	2	59
Land Management	1	28
Total	33	1,547

Source: EPF Annual Report 2009, Environment Protection Fund

The EPF shall not provide any form of support to any project developer towards the financing of costs for mitigating or compensating environmental and social impacts of that project, unless it is an Eligible Activity [Article 15(3) of EPF Decree]. Creation of other funds for environmental protection, natural resources management, and/or biodiversity conservation separate from the EPF is not permitted [Article 17(4)].

The Board of Directors (Chairperson: Deputy Prime Minster) has the overall responsibility of effectively promoting and achieving the overall objective of the EPF. The board consists of representatives of line-ministries, mass organizations, local authorities, trade and industry councils, research institutes and civil society.

The Executive Office (EO) implements the daily operations, management and administration of the EPF. The EO is headed by an Executive Director appointed by the Board, who manages the

Financial and Administrative Unit, the Sub-Project Operations Unit, the Public Information Unit, and the Monitoring and Evaluation Unit.

The organizational structure of EPF is as shown below.

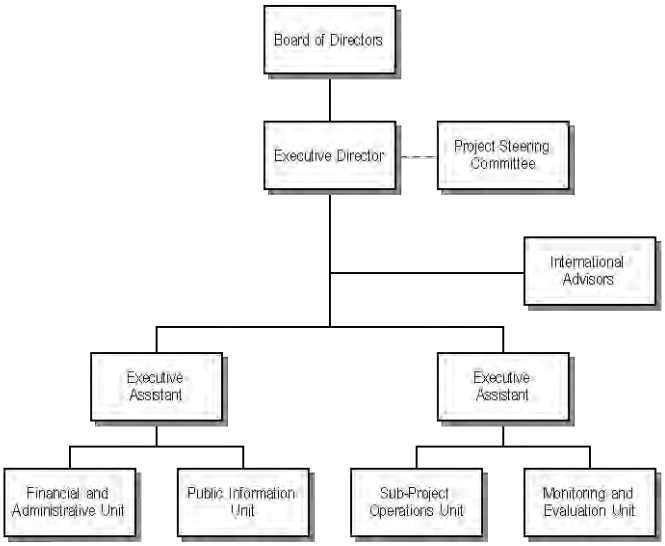


Fig. 2.2.12 Organizational Structure of EPF

2.2.3 Related Projects of Other Donors

(1) Environmental Management Support Project (EMSP) by Finnish Environment Institute (SYKE)

The Strengthening Environmental Management Project, Phase II (SEM II) supported by SIDA finished its five-year project duration in September 2010 with the issuance of a completion report, and the EMSP started in October of the same year. Although the donor has changed from Sweden to Finland, the EMSP can be considered as SEM III. This project focuses on the water quality and the project's duration is 2010 to 2014 (four years). With a budget of EUR9,960,000 (EUR9,500,000 by the Government of Finland and the remaining EUR460,000 by the Government of Lao PDR), it has the following five components:

- Component 1: Integrating environmental issues into strategic planning
- Component 2: Environmental permitting, monitoring and enforcement
- Component 3: Strengthening of environmental management at the provincial level
- Component 4: Communication and information services
- Component 5: Environmental laboratory services

The project will be implemented for WREA, especially for the Department of Environment, Department of ESIA and WERI as well as the Provincial WREO.

(2) Rapid Assessment of Household Sanitation Services in Vientiane City by the Water and Sanitation Program (WSP) of the World Bank

This study was executed in the middle of 2010 ~~to~~ conduct a rapid assessment of the adequacy of existing domestic sanitation facilities in Vientiane, especially in middle- and low-income areas where investments in these facilities are likely to be modest," with the aim to present an overview of the current status of household sanitation services in Vientiane and to provide useful information and recommendations that can guide future actions.

Interviews were undertaken with main stakeholders at central and local level and a total number of 33 individuals representing 17 organizations were visited during the course of the rapid assessment. In addition, a household survey was executed in 16 villages of the four urban districts and a total of 548 houses were visited in the survey. The final report was publicized in June 2011.

2.3 Hydrology

2.3.1 Natural Condition

(1) Rainfall

There are two meteorological stations near the study area which observe daily rainfall. The specification and location of these stations are shown in **Table 2.3.1** and **Fig. 2.3.1** respectively. For understanding the basic hydrological condition, rainfall data covering the study area was collected. Historical rainfall data from 1951 through 2004 at Vientiane station was collected from hydrological year books published by MRC (Mekong River Committee) and recent data was offered from DMH (Department of Meteorology and Hydrology, Lao PDR). As to Nong Khai in Thailand, all rainfall data was provided by MRC publication office.

Table 2.3.1 Specification of Meteorological Station

Station	Location		Period	Remarks
	Latitude	Longitude		
Vientiane (Lao PDR)	17°51'52"	102°34'20"	1951 - 2009	Daily rainfall was collected.
Nong Khai (Thailand)	17°52'34"	102°45'40"	1952 - 2009	Daily rainfall was collected.

Source: DMH

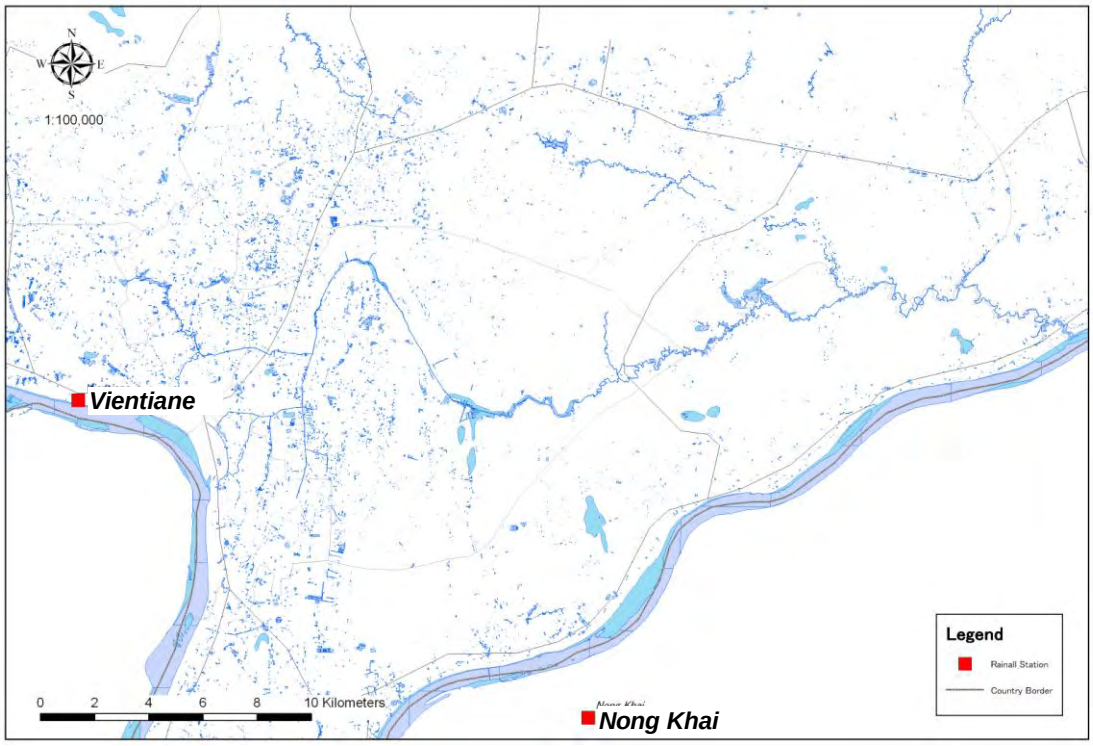


Fig. 2.3.1 Location of Meteorological Stations

Hyetographs at Vientiane and Nong Khai are shown in **Fig. 2.3.2**. At both stations, average annual rainfall was around 1,600 mm and average maximum daily rainfall was around 110 mm. Concerning the variation trend of rainfall, yearly rainfall has been increasing clearly in recent years, but in contrast maximum daily rainfall has been decreasing in the last two decades at Vientiane station. At Nong Khai, there is no trend of yearly rainfall, but maximum daily rainfall is decreasing similarly with Vientiane. Also, average distributions of monthly rainfall at both

stations are shown in **Fig. 2.3.3**. The last decade of distribution is different from 1960's, especially in August and September, late rainy season; rainfall intense is higher than last decade.

There was no co-relation of rainfall characteristics between Vientiane and Nong Khai as shown in **Fig. 2.3.4**. Therefore, different rainfall parameters were given to the upper and lower basins for the runoff analysis.

Table 2.3.2 Statistical Data on Rainfall

unit: mm

Item	Yearly Rainfall		Maximum Daily Rainfall	
	Vientiane	Nong Khai	Vientiane	Nong Khai
Maximum Value	2,290	2,164	224	467
Minimum Value	1,117	1,074	64	51
Average Value	1,664	1,599	112	110
Standard Variation (normal distribution)	273.8	282.2	32.3	63.0

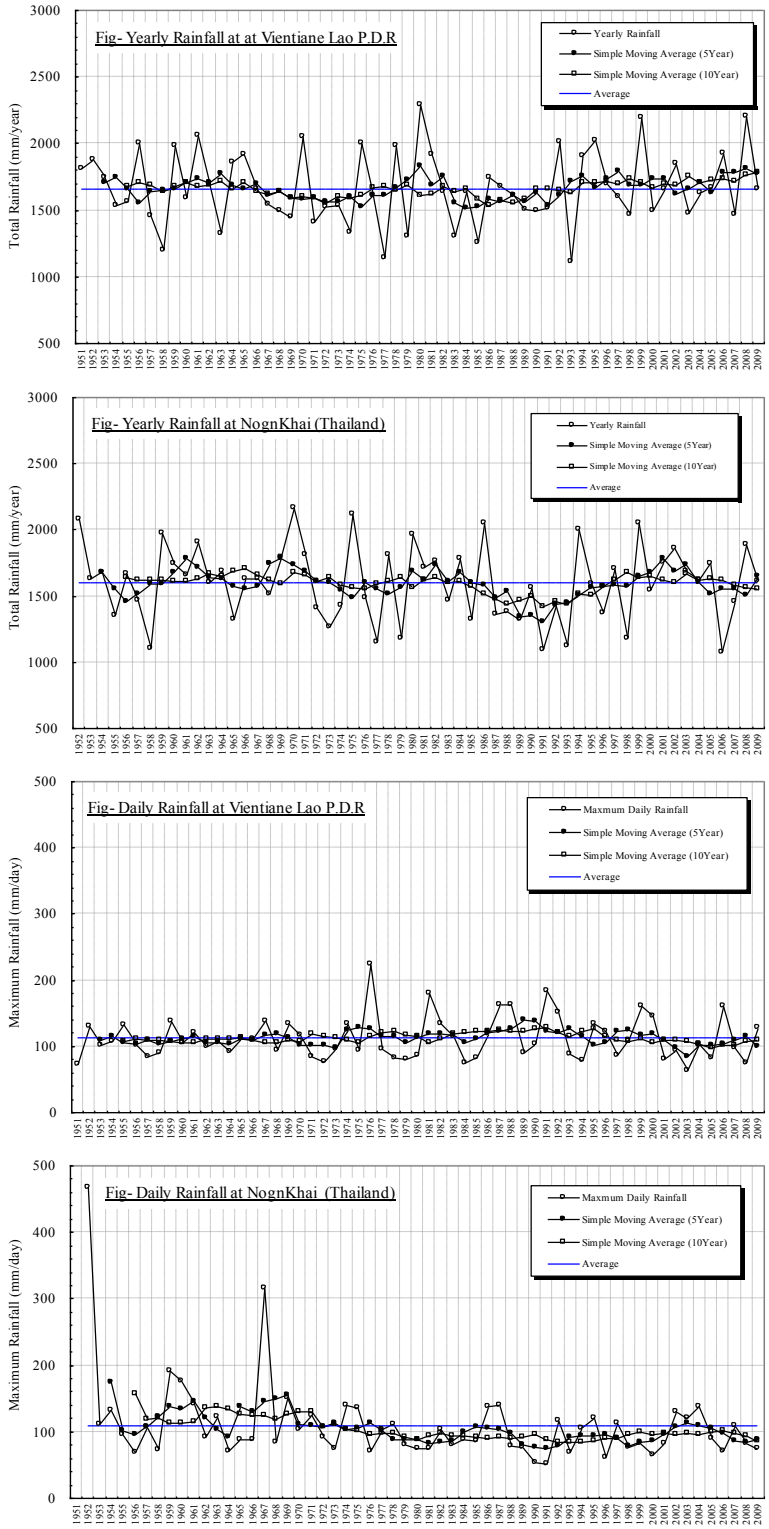
**Number of Samples: Vientiane is 59, Nong Khai is 58*

Sources: MRC and DMH

(2) Evaporation and Temperature

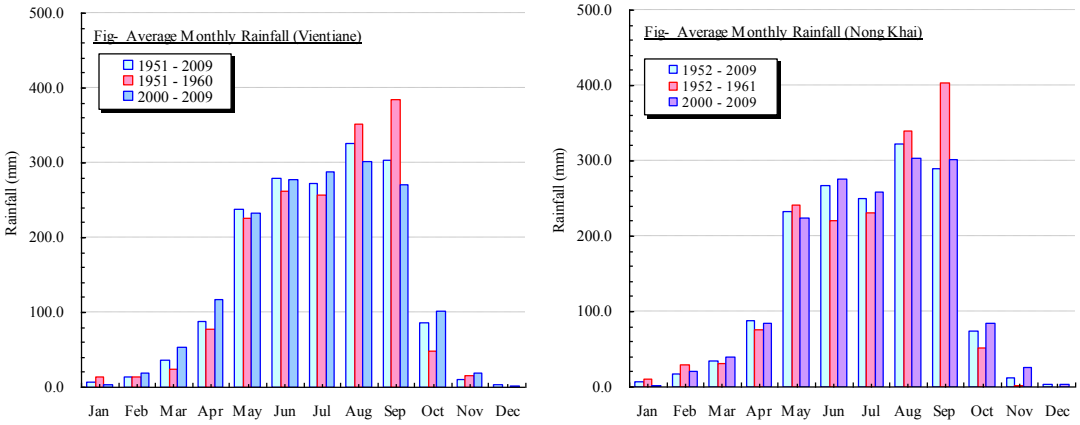
For understanding the meteorological conditions in the study area, evaporation data from 1960 to 2009 at Vientiane meteorological station was collected. As shown in **Fig. 2.3.5**, the monthly average evaporation in the last decade was larger than that of the 1960's, which might have resulted from rapid urbanization and loss of natural area such as marsh and paddy/vegetable field.

Also, temperature data from 1971 through 2009 at Vientiane was collected. As shown in **Fig. 2.3.5**, monthly average temperature in the last decade was obviously much higher than the 1970's. It seems that this was caused by rapid urbanization as discussed in more detail in Subsection 2.3.1(3). Comparing temperature and evaporation, there is an apparent co-relation between them; however, the co-relation between temperature and rainfall is not clear.



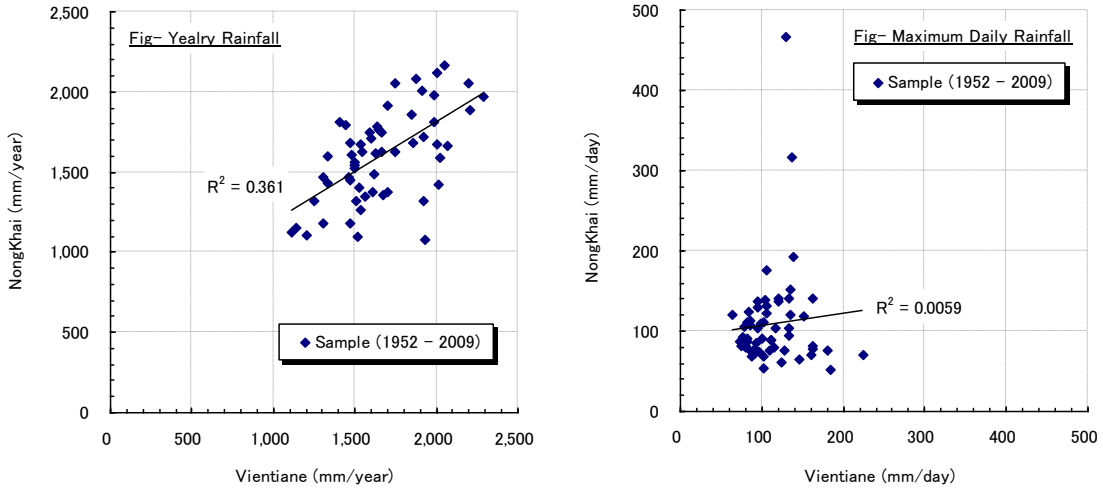
Sources: MRC, and DMH

Fig. 2.3.2 Hyetograph (Vientiane and Nong Khai)



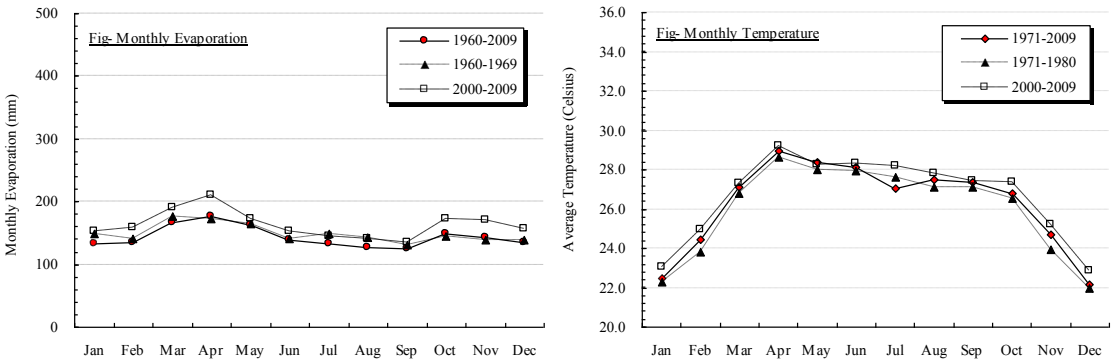
Sources: MRC, and DMH

Fig. 2.3.3 Distribution of Monthly Rainfall



Sources: MRC, and DMH

Fig. 2.3.4 Co-relation between Vientiane and Nong Khai (1952-2009)



Sources: MRC, and DMH

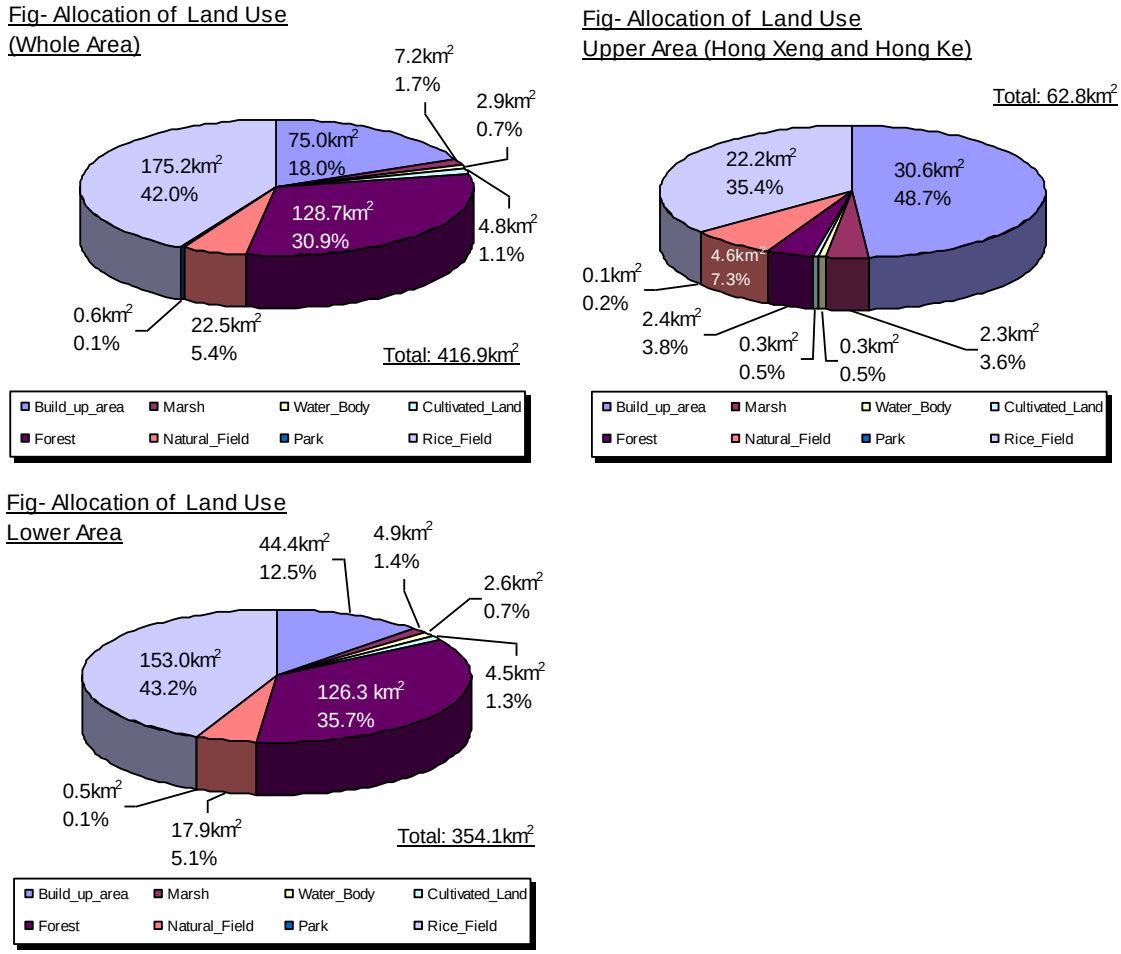
Fig. 2.3.5 Monthly Evaporation and Temperature (Vientiane)

(3) Topography and Land use

To clarify the topographical features in the study area, a contour map and a land use map were prepared. The contour map based on the DEM (Digital Elevation Map) developed in the SRTM Project[1] and the land use map investigated and published in 2000 by the Geography Bureau in Lao PDR are shown in **Fig. 2.3.7** and **Fig. 2.3.8** respectively.

According to the contour map based on the DEM whose resolution is 90 m mesh, the land slope around the study area is very gradual. Especially, the land slope of That Luang marsh and Na Khay marsh is almost flat, which results in the retention of river flow in the dry season.

Regarding land use in the study area, urban areas occupy the upper reaches of the Mak Hiao River, and paddy fields and forest occupy the middle/lower river basin. To understand the transition of land use, the land use map and the satellite image shown in **Photo 2.3.1** taken in 1990 were compared. According to the comparison, it is apparent that a built-up area have developed and expanded to the marsh/paddy fields. Also, because 10 years have passed since the last land use investigation, it seems that the built-up area has expanded due to rapid economic growth in Lao PDR.



Source: National Geographic Department

Fig. 2.3.6 Land Use Ratio (2000)

[1] SRTM (Shuttle Radar Topography Mission)

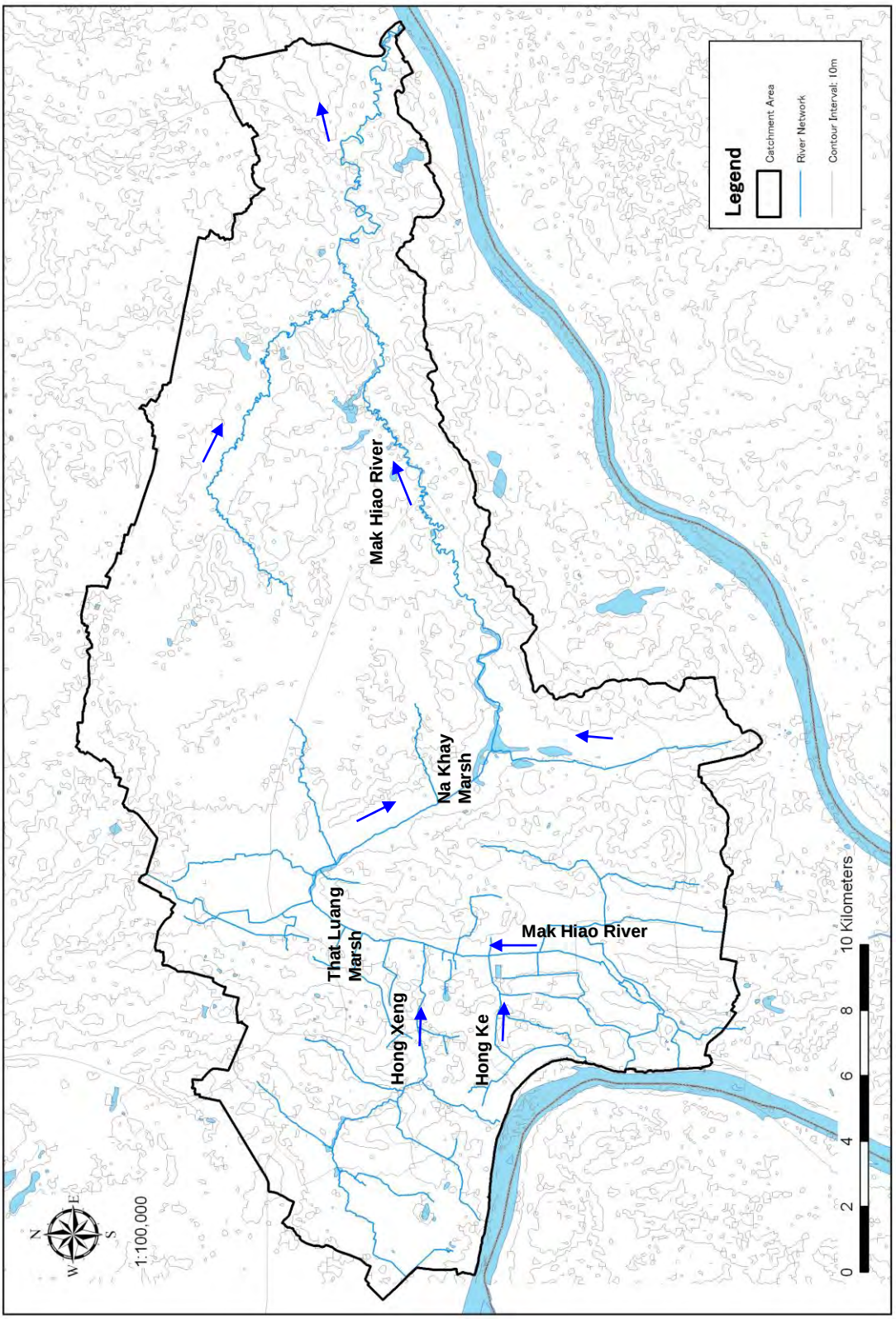
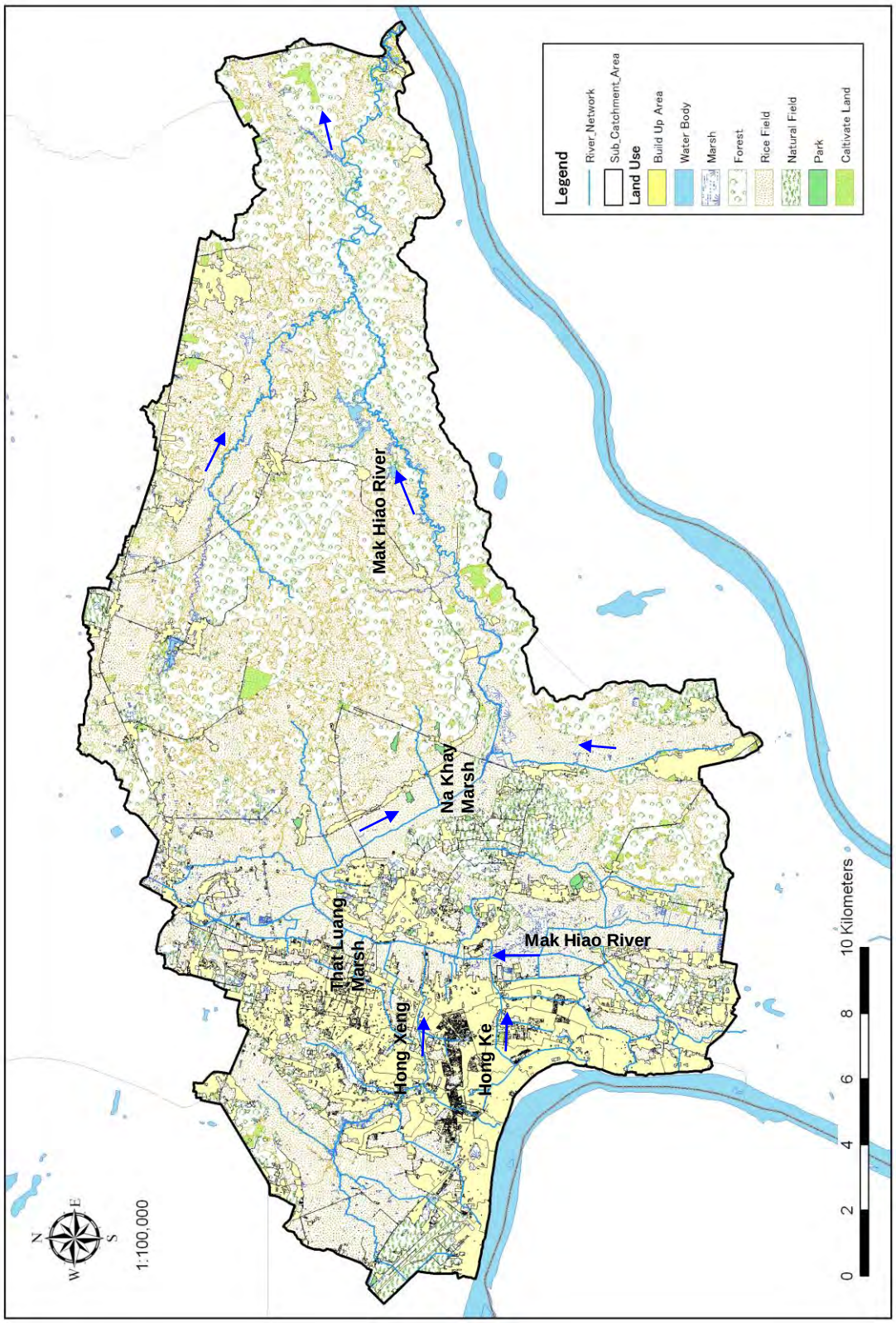


Fig. 2.3.7 Contour Map (Interval: 10m)

Source: National Geographic Department



Source: National Geographic Department

Fig. 2.3.8 Land Use (Year 2000)

Photo 2.3.1 Aerial Image (Year 1990)

Soure: PTI

(4) Catchment Area

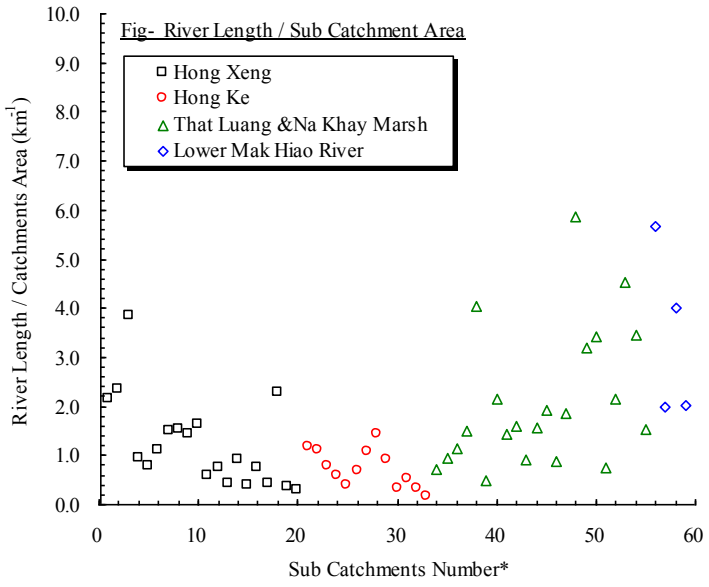
Based on the contour map showing the existing river and drainage network, the catchment area was decided as shown in **Fig. 2.3.10**. Besides, since the target year of the project is set at 2020, a catchment area considering near future condition was set up as shown in **Fig. 2.3.11.** The total number of sub-catchment areas is 59 in both cases and the total area of sub-catchments are 412.59 km^2 and 412.94 km^2 respectively. The sub-catchment areas are numbered from upstream to downstream. Differences of catchment areas are described in detail in **Subsection 2.3.2**,

(5) River and Channels

The river/channel network and catchment area is shown in **Fig. 2.3.10** and **Fig. 2.3.11.** According to the figures, the Mak Hiao River meanders in the alluvial plane particularly in the downstream stretch of Na Khay Marsh. On the other hand, in the upstream area of the Mak Hiao River composed of Hong Xeng and Hong Ke, the channels flow straightly due to the improvement work of the ADB project. In That Luang and Na Khay marshes where paddy fields and croplands are developed, the Mak Hiao River also flows straightly because of irrigation use.

The relation between river/channel length and sub-catchment area is shown in **Fig. 2.3.9**. If this value seems large, it means that river/channel meanders. The values of Hong Ke and a part of Hong Xeng are smaller than that of downstream due to the channel improvement work.

As for the longitudinal profile, the slope of Hong Xeng and Hong Ke is approximately 1/2,000 (refer to **Section 2.4**) and that of the downstream stretch of the Mak Hiao River is approximately 1/5,000. The slope in That Luang and Na Khay marshes is almost flat, which makes the flowing time longer. Thus, the self-purification rate of the stretch will increase in proportion to the flowing time.



Refer to **Fig. 2.3.10*

Fig. 2.3.9 River Length/Catchment Area (Existing Condition)

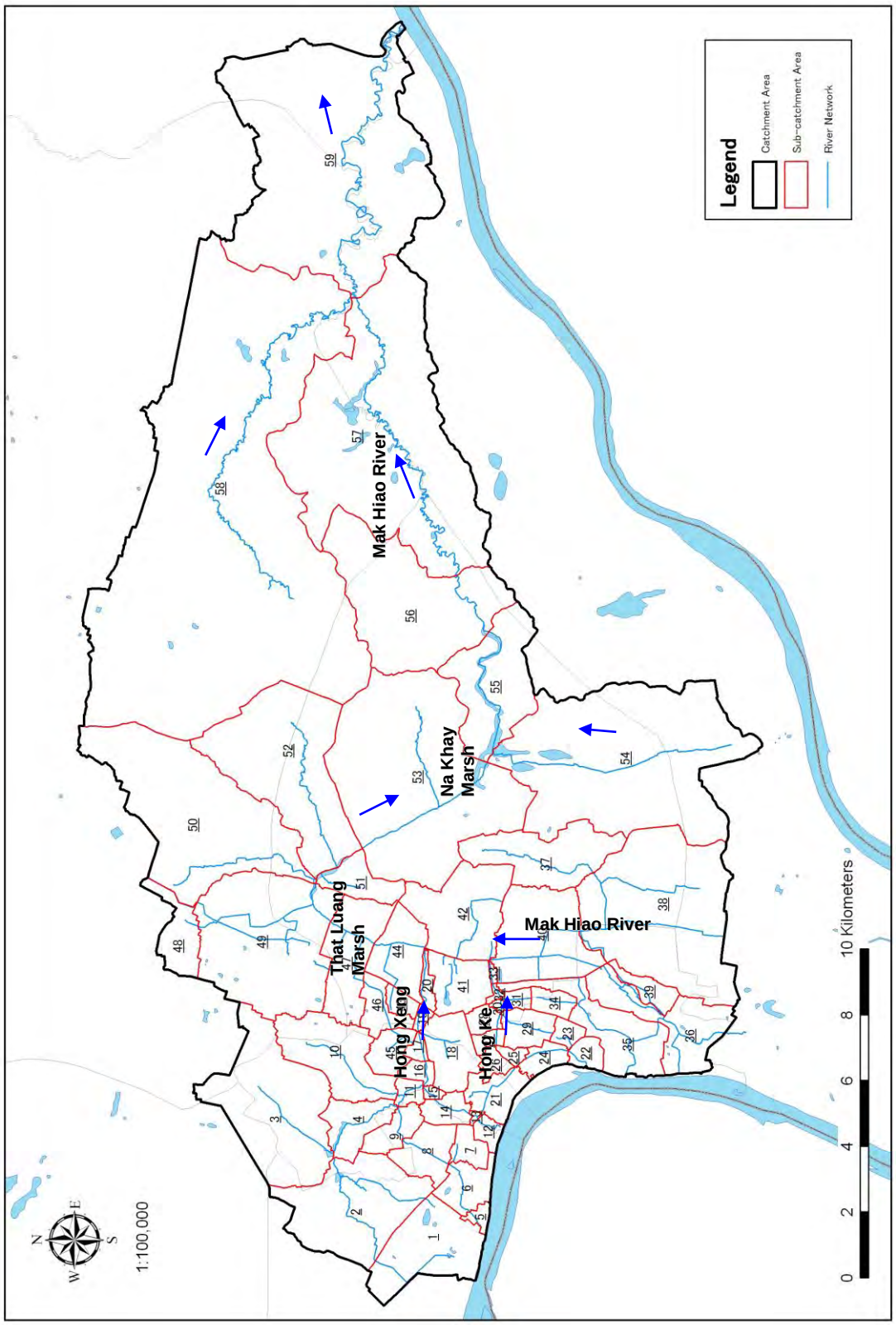


Fig. 2.3.10 Mak Hiao River Basin (Existing Condition)

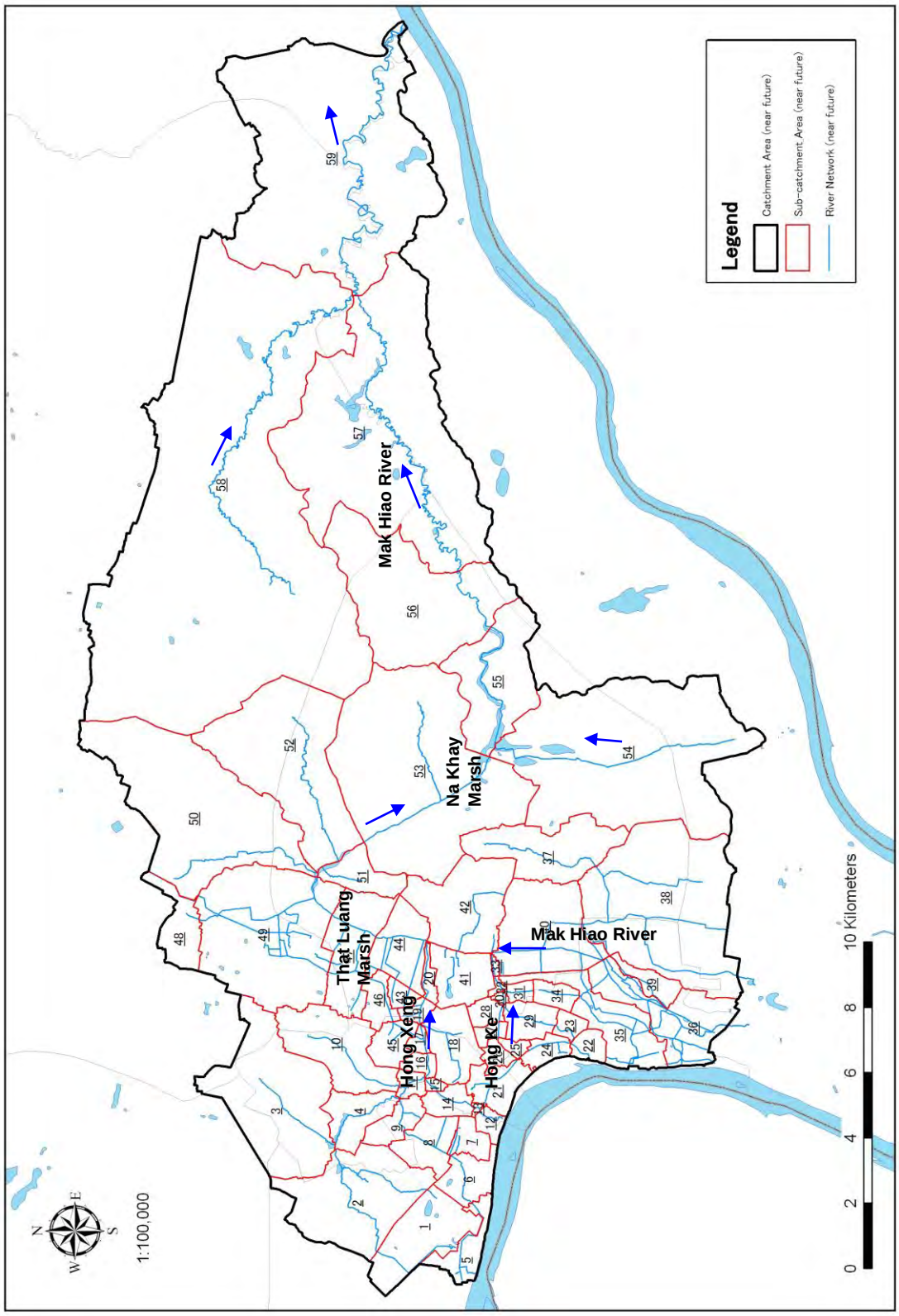


Fig. 2.3.11 Mak Hiao River Basin (Near Future Condition)

(6) Water Level

In the study, water level observed in the Mak Hiao River basin could not be collected due to its unavailability.

(7) Summary

The above surveys are summarized as follows:

- Average yearly rainfall at Vientiane and Nong Khai is around 1,600 mm
- At Vientiane, yearly rainfall has been increasing in recent years. In contrast, at Nong Khai, there is no variation trend of yearly rainfall.
- Maximum daily rainfall at Vientiane and Nong Khai is around 110 mm.
- At both stations, maximum daily rainfall has been decreasing.
- Monthly rainfall intensity in late rainy season, August to September, has been increasing.
- There is no co-relation between Vientiane and Nong Khai.
- Evaporation and temperature at Vientiane has been increasing due to rapid urbanization and loss of natural zone.
- Land slope in the study area is gradual (1/5,000 to 1/2,000) as a whole. Especially, the land slope in That Luang Marsh and Na Khay Marsh is almost flat, which makes flow velocity lower and flow time longer.
- The Mak Hiao River meanders in the alluvial plane particularly at the downstream of Na Khay Marsh.
- In the middle of river basin, the river flows straightly due to irrigation use.
- Also, in the upstream stretch of the Mak Hiao River composed of Hong Xeng and Hong Ke, flows straightly due to the improvement of channel by the ADB project.

2.3.2 Storm Analysis

In order to evaluate the safety level of Hong Xeng and Hong Ke basins which were improved under the ADB project, runoff analysis was conducted by using the rational model which is suitable for a small sub-catchment area like the study area.

(1) Probable Rainfall

For evaluating the provable rainfall considering latest rainfall conditions, statistical analysis was conducted. In the study, three probable rainfalls (at Vientiane, Nong Khai and average rainfall over watershed which was determined with the Thiessen method as shown in **Fig. 2.3.12),** were calculated. The result of analysis is shown in **Table 2.3.4**. Also the probable rainfall in the previous study[2] is shown in **Table 2.3.5**. In the previous study, the Gumbel method was employed for evaluating probable rainfall and 10-year probability was used for flood mitigation plan.

[2] Feasibility Study on Improvement of Drainage System in Vientiane, March 1990

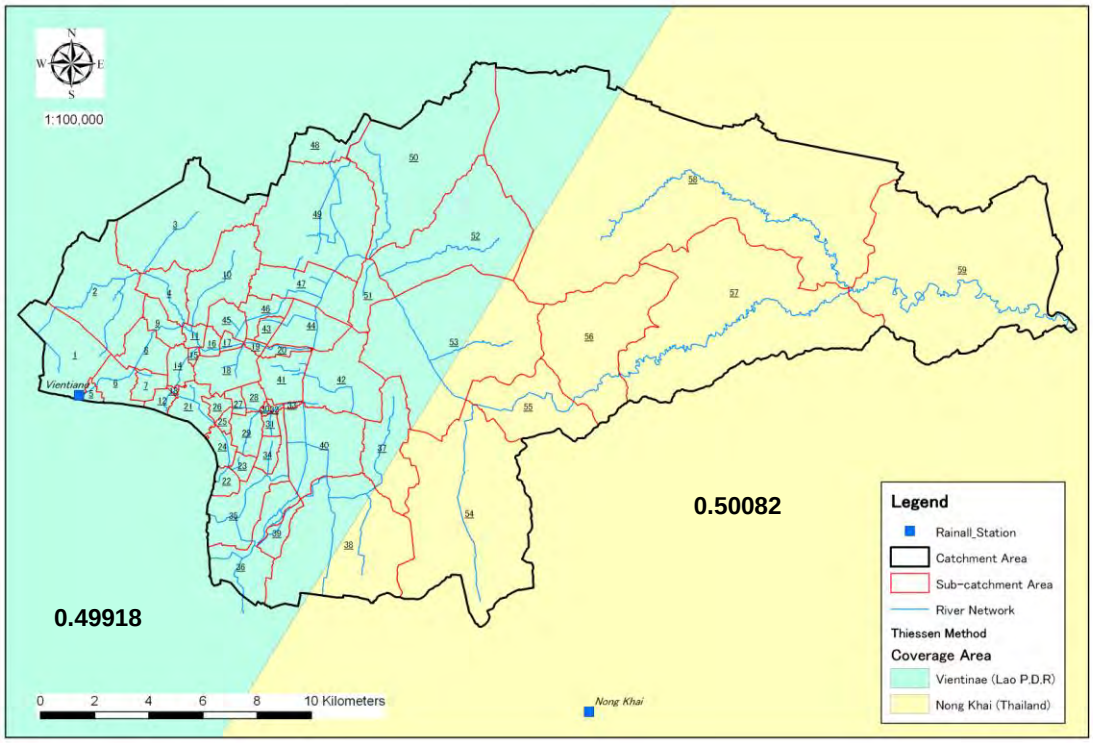


Fig. 2.3.12 Thiessen Polygon

Table 2.3.3 Thiessen Coefficient

Thiessen Coefficient	
Vientiane (Lao PDR)	0.49918
Nong Khai (Thailand)	0.50082

Compared with the previous results, the probable rainfall calculated in the study is a bit larger by approximately 3% due to the addition of intensive rainfall observed in the late 1990's. On the other hand, the SLSC which indicates a goodness of fit at Nong Khai meteorological station is relatively lower because of sudden intensive daily rainfall like those in 1952 and 1967 (refer to **Fig. 2.3.2**).

Table 2.3.4 Probable Daily Rainfall (2009)

Probability Density Function	Probable Rainfall (mm/day) Return Periods					SLSC*	
	2 years	5 years	10 years	20 years	50 years	99%	50% (center)
Vientiane (Lao PDR): Sample data 59 (1951 to 2009)							
Exp	101.2	133.6	158.0	182.5	214.8	0.033	0.049
Gumbel	106.7	135.6	154.7	173.0	196.7	0.022	0.035
Sqrt Et	105.0	133.0	153.3	173.9	202.5	0.021	0.038
Gev	105.2	134.0	154.5	175.3	204.2	0.019	0.034
LogP3	105.5	134.2	154.2	174.3	201.7	0.019	0.035
Iwai	106.1	134.5	153.7	172.2	196.6	0.022	0.038
IshiTaka	105.9	134.5	154.0	172.9	197.9	0.021	0.037
LN3Q	105.4	134.0	154.0	173.8	200.4	0.019	0.037
LN3PM	106.1	134.8	154.1	172.8	197.4	0.022	0.037
Nong Khai (Thailand): Sample data 58 (1952 to 2009)							
Exp	94.1	141	176.5	212.1	259	0.115	0.190
Gumbel	102.0	143.9	171.6	198.2	232.7	0.143	0.288
Sqrt Et	97.2	131.6	157	183.2	219.8	0.109	0.222
Gev	93.0	130.1	164.4	207	281.1	0.036	0.068
LogP3	-	-	-	-	-	-	-
Iwai	-	-	-	-	-	-	-
IshiTaka	-	-	-	-	-	-	-
LN3Q	94.2	135.3	169.4	207.3	264.1	0.045	0.085
LN3PM	-	-	-	-	-	-	-
Average-rainfall over watershed in study area: Sample data 58 (1952 to 2009)							
Exp	81.3	115.7	141.7	167.7	202.1	0.068	0.113
Gumbel	87.1	117.8	138.1	157.6	182.9	0.096	0.189
Sqrt Et	84.1	109.9	128.6	147.9	174.6	0.079	0.160
Gev	81.5	109.7	134.5	164.1	213.2	0.024	0.046
LogP3	-	-	-	-	-	-	-
Iwai	-	-	-	-	-	-	-
IshiTaka	-	-	-	-	-	-	-
LN3Q	81.4	111.7	137.2	165.8	208.9	0.022	0.047
LN3PM	-	-	-	-	-	-	-

**SLSC*: *Sub-Least Square Criterion,* ( ) *Coverage of Samples*
"-" indicates that calculation of probability density is not suitable

Table 2.3.5 Probable Daily Rainfall (F/S in 1990)

Method	Probable Rainfall (mm/day) Return Periods				
	2 years	5 years	10 years	20 years	50 years
Gumbel	104.0	132.1	150.6	168.4	191.4
Pearson III	102.3	128.5	147.2	166.0	191.9
Iwai	105.3	132.2	150.9	169.5	194.5

(2) Outline of the Storm Analysis

(a) Rational Formula

Storm runoff was computed with the rational formula which calculate the peak discharge at evaluation point. The formula is as shown below.

$$Q = \frac{1}{3.6} f r_c A$$

where, Q: runoff (m^3/s), f: runoff coefficient,
r_c: rainfall intensity during concentration time (mm/hr),
A: catchment area (km^2)

(b) Runoff Coefficient

Based on the land use, runoff coefficients were calculated at each sub-catchment area with weighted mean of runoff coefficient of each land use.

$$f = \frac{f_1 \times A_1 + f_2 \times A_2 + f_3 \times A_3 + \cdots f_N \times A_N}{A_1 + A_2 + A_3 + \cdots A_N}$$

where, f: runoff coefficient. f_N: standard runoff coefficient of each land use
A_N: each land use area (km^2)

Table 2.3.6 Standard Runoff Coefficient

Standard Runoff Coefficient						
Dense Urban	Sparse Urban	Field	Paddy Field	Mountain	Water Body	Other
0.9	0.8	0.6	0.7	0.7	0.0	0.5

Source: The Japanese Ministry of Land, Infrastructure, Transport and Tourism Technical Criteria for River Works: Practical Guide for Planning

(c) Rainfall Intensity

In the study, the existing rainfall intensity curve developed in 1990 was not updated because the latest hourly data was not available. To make a comparison between the old one with the latest daily probable rainfall (refer to **Subsection 2.3.1(1)**), it was necessary to revise the short term probable rainfall because the latest rainfall intensity was stronger by approximately 3%. Therefore, the existing rainfall intensity curve was corrected using the correction coefficient shown in the following table.

$$r_c = \frac{a}{t^n + b} \times c_c$$

where, r_c :rainfall intensity during concentration time (mm/hr)
t: concentration time (min), n, a, b: coefficients,
c_c: correction coefficient (ratio of probable rainfall in this study / F/S study)

Table 2.3.7 Parameters of Rainfall Intensity Formula

Return Period	Coefficients			Correction Coefficient
	n	a	b	
1/2	1.0	5,835	65.40	1.026
1/5	1.0	8,171	63.90	1.026
1/10	1.0	9,629	62.15	1.027
1/20	1.0	10,983	60.43	1.027
1/50	1.0	12,685	58.31	1.028

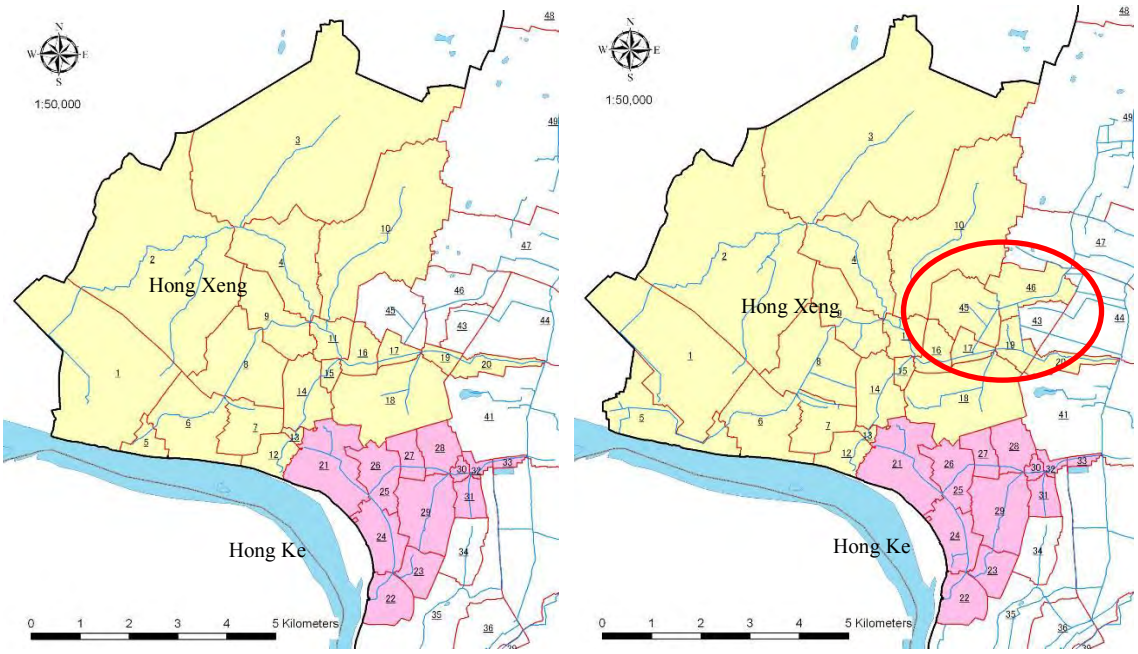
(d) Catchment Area

As mentioned in **Subsection 2.3.1(4)**, the basin border in the near future will be different from the existing one. In the study, storm runoff analysis was conducted under the near future condition as shown in **Fig. 2.3.13(b)**. Concerning runoff coefficient, it was set up on the assumption that urban area should extend by approximately 1.3 times in proportion to the increase of population according to the result of the projection of future population in Vientiane (refer to **Table 4.3.1**.).

Major differences between the catchment areas in 2009 and 2020 are as follows:

Catchment boundaries of sub-catchment area No. 1, No. 5, No. 7, No. 8, No. 19, No. 35, No. 36, No. 43, No. 44 and No. 46 are modified based on the improvement plan of drainage channels by VUDAA.

Catchment areas No. 45 and No. 46 are included in the Hong Xeng catchment area, instead of discharging directly into That Luang Marsh based on the improvement plan of drainage channels by VUDAA.



(a) Existing Condition (b) Near Future Condition

Fig. 2.3.13 Catchment Borders of Hong Xeng and Hong Ke

(3) Results

The runoff peaks calculated by rational method at main points are shown in **Fig. 2.3.14**. Compared with the previous results estimated in the feasibility study in 1990, most of the values are larger. The reasons are as follows:

- Rainfall intensity is higher than that in the previous study as a result of considering latest rainfall.
- In the previous study, the storage effects of a small marsh and a pond in the catchment area were considered. However, there is no marsh and pond to pool rainfall and slow runoff at the present land use condition.
- Due to the improvement plan of drainage network by VUDAA, sub-catchment numbers 45 and 46 will be connected to Hong Xeng and sub-catchment area number 5 located at the upstream of Hong Wattay will be extended.

Hong Xeng

Return period	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
1/2	30	35	53	83	5	18	88	95	18	105	108
1/5	30	49	75	104	8	26	111	123	24	135	139
1/10	30	58	89	118	9	31	126	141	27	155	159
1/20	30	67	103	131	11	35	139	157	30	173	178
1/50	30	79	120	147	12	41	158	179	34	197	202
1/10(90‘)	30.0	-	55.8	119.0	6.8	23.3	-	139.7	23.5	159.1	-

Hong Ke

Return period	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲			
1/2	17	21	46	12	52	3	56	57			
1/5	23	29	65	16	74	4	80	81			
1/10	28	35	78	20	88	5	95	96			
1/20	32	40	90	23	102	6	109	111			
1/50	38	47	106	26	119	7	128	130			
1/10(90‘)	20.9	17.5	42.9	5.9	-	-	70.5	-			

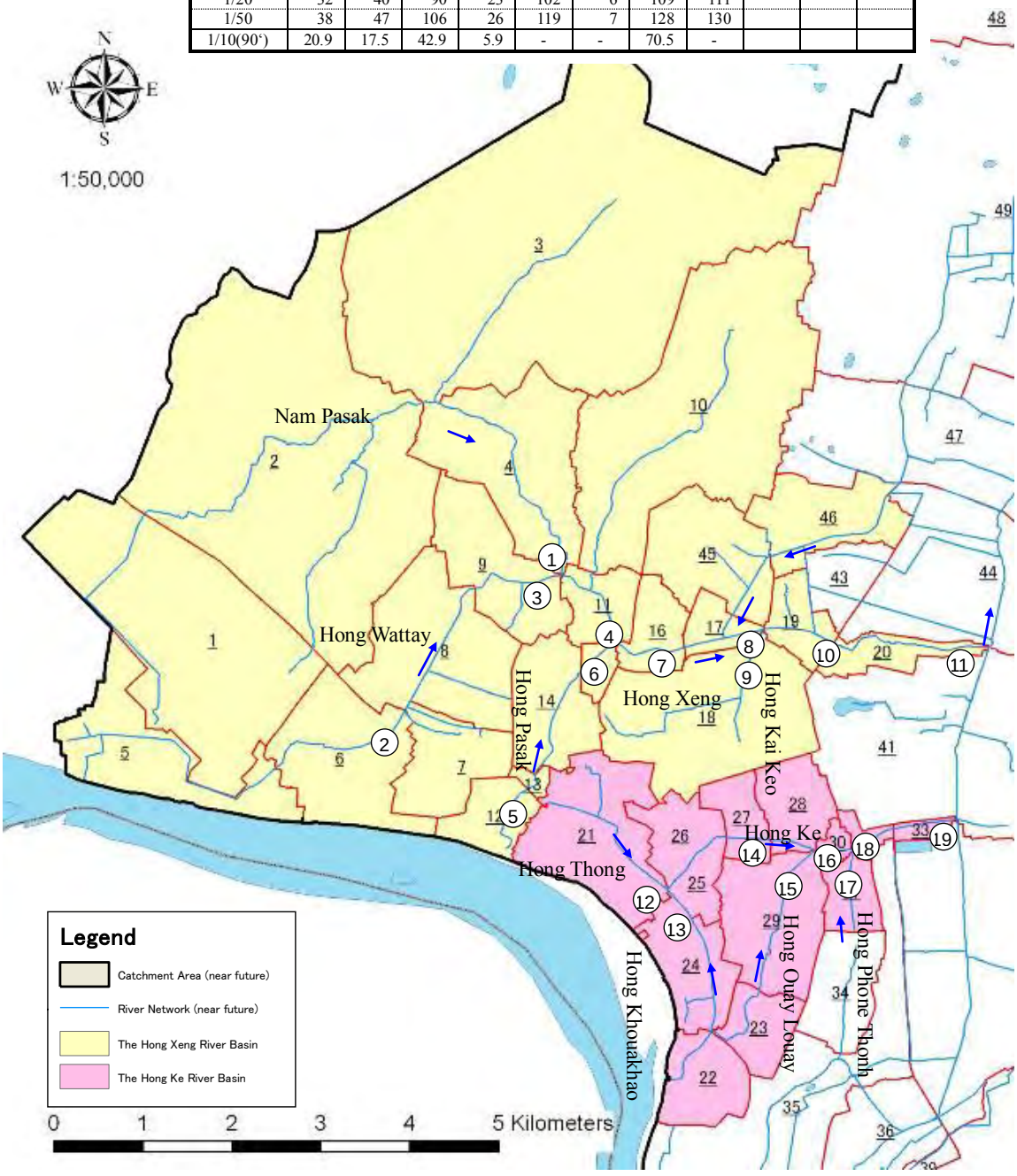


Fig. 2.3.14 Result of Storm Analysis

2.3.3 Low Flow Analysis

(1) Outline of the Analysis

For water quality analysis, the lower water discharge at water sampling points was measured when the water quality surveys were conducted since water volume is an indispensable factor of estimation of BOD (Biological Oxygen Demand). However, observed data includes observation error due to the difficulties in measuring some cross sections of the Mak Hiao River and its tributaries, and/or in measuring very low velocity especially in dry season. Therefore, a runoff analysis model for low flow using tank model method was constructed in order to evaluate the water volume in dry season and thus supplement the observed data.

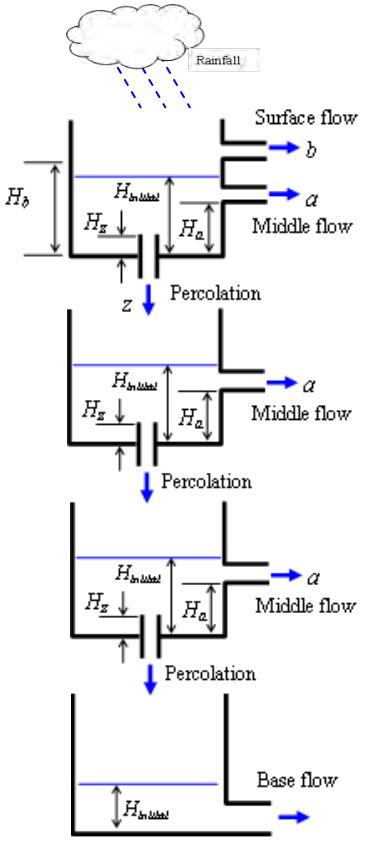
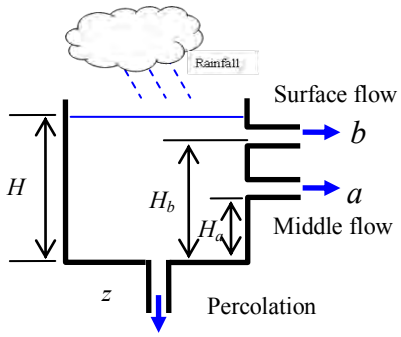


Fig. 2.3.15 Tank Model Method

(2) Tank Model

(a) Calculation Technique

Tank model is one of the non-linear runoff analysis models and is often employed for low flow analysis due to its good reproducibility of discharge. The tank model is comprised of serial tanks (four-stage tank in this case) as shown in **Fig. 2.3.15**. As shown in **Fig. 2.3.16**, outflow from side holes of each tank are calculated by water head and runoff coefficients, which describe surface flow, middle flow and percolation. Each tank is a component representing the retention and retarding of water.



Example 1
a=0.2, b=0.3, z=0.1
H=**100**, H_a=60, H_b=100
Runoff = (**100**-60)×0.2＋(**100**-100)×0.3＋**100**×0.1=18

Example 2
a=0.2, b=0.3, z=0.1
H= **200**, H_a=60, H_b=100
Runoff = (**200**-60)×0.2＋(**200**-100)×0.3＋**200**×0.1=78

a, b, z : runoff coefficient

Fig. 2.3.16 Basic Procedure of Tank Model

Besides, domestic discharge from each sub-catchment which is estimated by population is considered as output like low-flow since domestic discharge occupies a large part of the water volume in dry season. Domestic discharge is calculated by the following formula.

$$D_i = p_i \times w_c \div (1{,}000 \times 86{,}400)$$

where, D_i: domestic discharge (m^3/s), p_i: population in sub-catchment, w_c: water consumption per day (l/person), here 180l

In the study, a river storage effect at the middle/downstream of the Mak Hiao River was considered with a similar tank model method as shown in **Fig. 2.3.17** since the land slope and riverbed slope are almost flat and there is high possibility of retention and/or retarding of water according to geological study [refer to **Subsection 2.3.1(3)**].

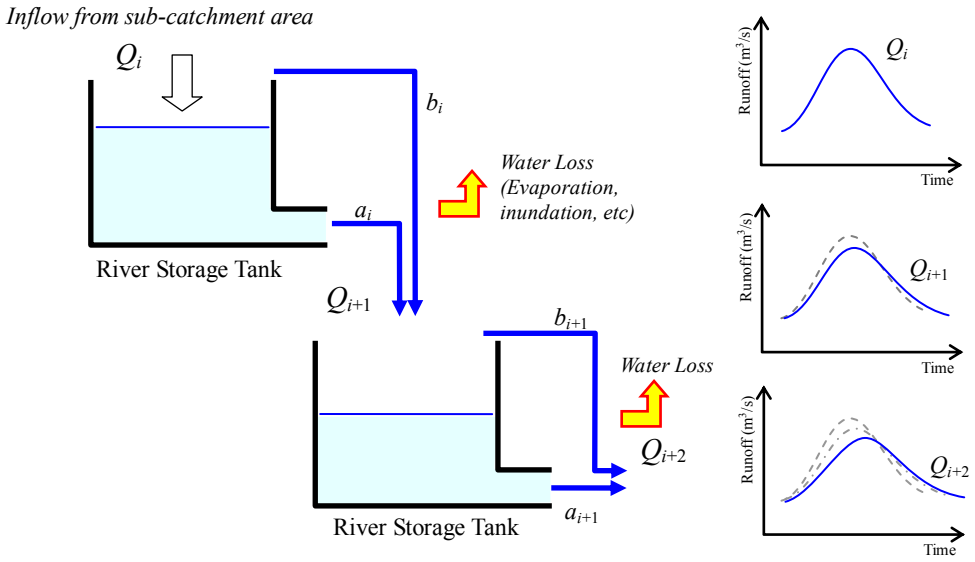


Fig. 2.3.17 Tank Model for River Storage Analysis

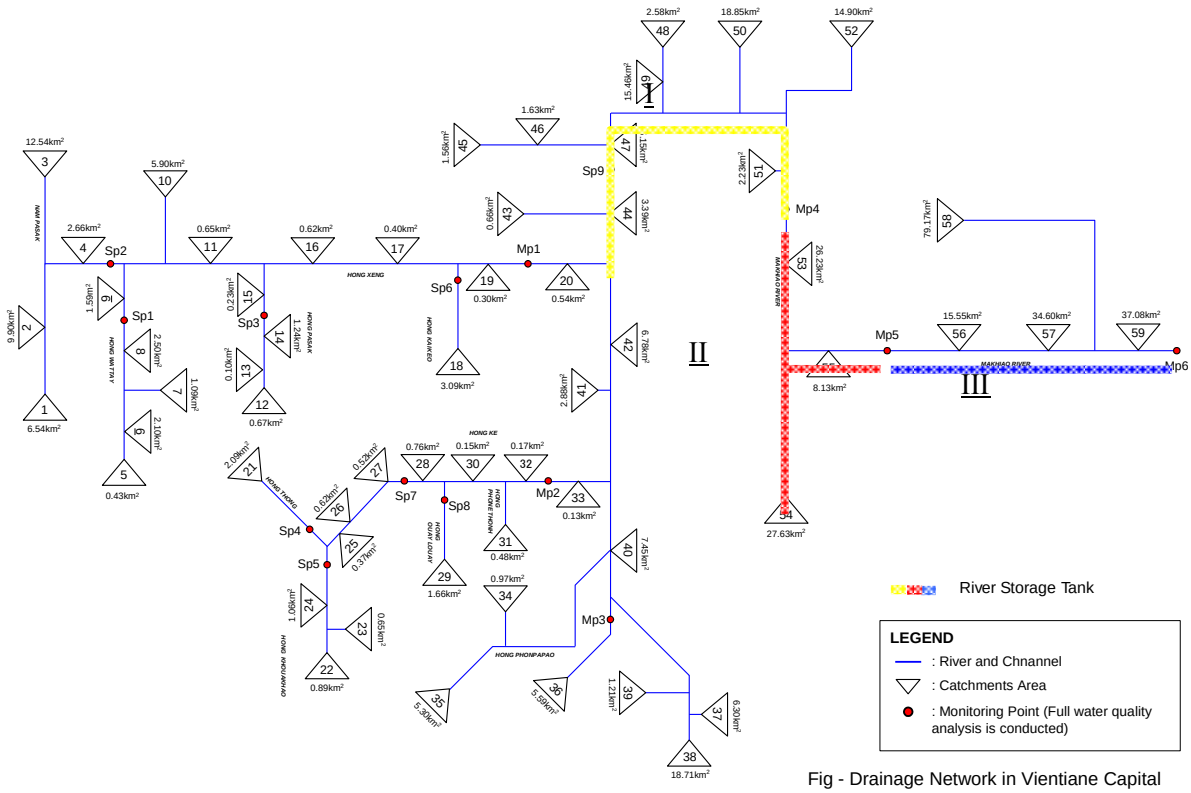


Fig - Drainage Network in Vientiane Capital

Fig. 2.3.18 River Network (Existing Condition)

(b) Parameters

For calculating a lower water discharge in the Mak Hiao River appropriately, model parameter calibration was conducted based on standard values shown in **Table 2.3.6**. Since four or five discharge measurements were conducted in 2009, the model parameters were modified for describing the observed value in 2009. In the study, four basic parameters of land use, namely, built-up area, paddy field, natural field and forest, were established and the model parameter at each sub-catchment was set up by the weighted mean of basic parameters.

Table 2.3.8 Range of Standard Parameters of Tank Model

Upper Tank						
a	H_a	b	H_b	Z	H_z	$H_{initial}$
0.1-0.2	10-20	0.2-0.5	20-50	0.1-0.3	-	-
Middle Tank (1)						
a	H_a	b	Hb	Z	H_z	$H_{initial}$
0.05-0.15	0-15	-	-	0.06-0.12	-	-
Middle Tank (2)						
a	H_a	b	H_b	Z	H_z	$H_{initial}$
0.02-0.05	-	-	-	0.02-0.04	-	-
Lower Tank						
a	H_a	b	H_b	z	H_z	$H_{initial}$
0.001-0.004	-	-	-	-	-	Trial and Error

**Parameter column filled in "-" is NOT used for calculation*

Sources: *Suimon-gaku Kouza Ryushutsu Kaiseki-hou* (Japanese), 1972. Masami, Sugawara, and *Suimon-gaku Kouza Bekkan Zoku Ryushutsu Kaiseki-hou* (Japanese), 1979. Masami, Sugawara

Parameter calibration was conducted for six main evaluation points of water quality. The results of calibration are shown in **Fig. 2.3.19** to **Fig. 2.3.21** and the final parameter used for calibration is shown in **Table 2.3.7** and **Table 2.3.8**.

Based on the calibration results, it can be said that the final parameter is suitable for describing the observed flow in 2009 practically because the usual error of flow measurement is 10% to 20% and observed values in dry season were reproduced well.

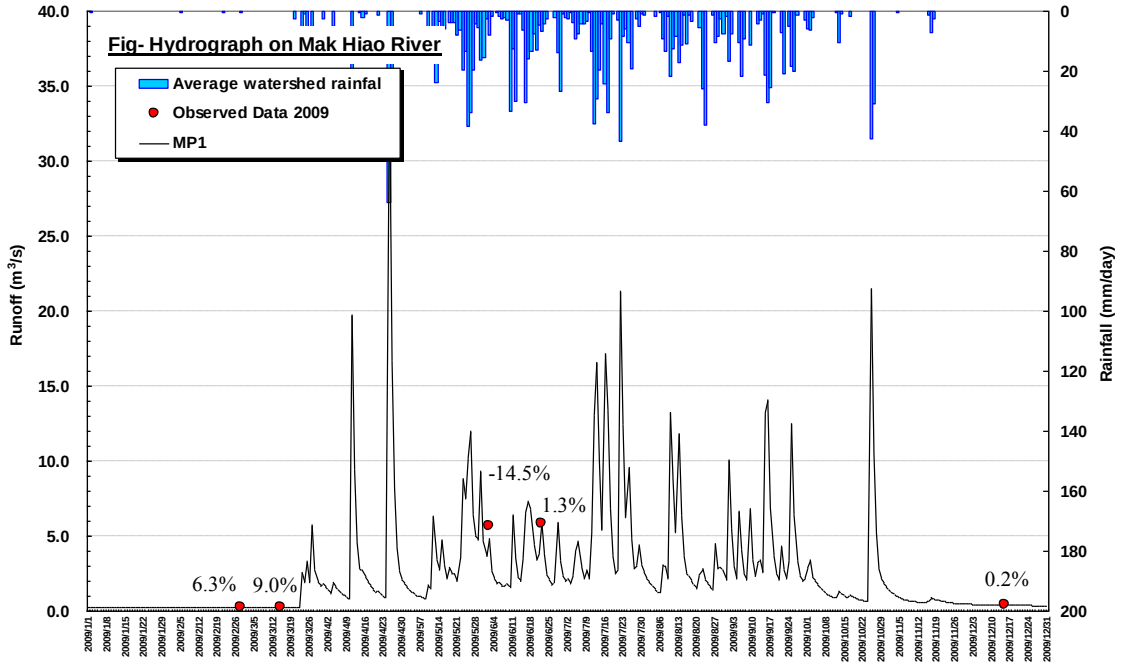
Table 2.3.9 Final Values of Model Parameter

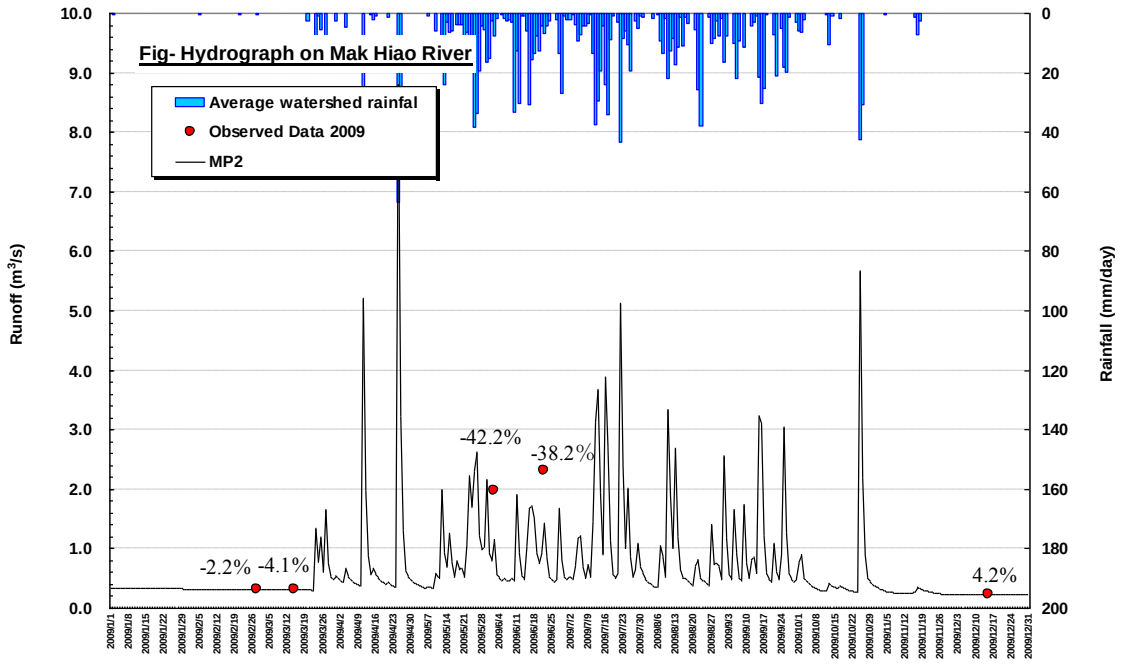
	Parameter	Land Use			
		Built up Area	Paddy field	Natural Field	Forest
Upper tank	a	0.2	0.1	0.15	0.1
	H_a	10	20	15	20
	b	0.5	0.2	0.35	0.2
	H_b	20	50	35	50
	z	0.01	0.01	0.16	0.3
	H_z	0	0	0	0
	$H_{initial}$	-	-	-	-
Middle tank (1)	a	0.05	0.05	0.05	0.05
	H_a	0	0	0	0
	b	-	-	-	-
	H_b	-	-	-	-
	z	0.06	0.06	0.06	0.06
	H_z	0	0	0	0
	$H_{initial}$	-	-	-	-
Middle tank (2)	a	0.02	0.02	0.02	0.02
	H_a	0	0	0	0
	b	-	-	-	-
	H_b	-	-	-	-
	z	0.02	0.02	0.02	0.02
	H_z	0	0	0	0
	$H_{initial}$	-	-	-	-
Lower tank	a	0.001	0.001	0.001	0.001
	H_a	-	-	-	-
	b	-	-	-	-
	H_b	-	-	-	-
	z	-	-	-	-
	H_z	-	-	-	-
	$H_{initial}$	It is necessary to conduct trial in order to identify initial base flow each year			

**Parameter column filled in "-" is NOT used for calculation*
Parameter column painted gray color is out of standard values

Table 2.3.10 Final Values of River Storage Tank

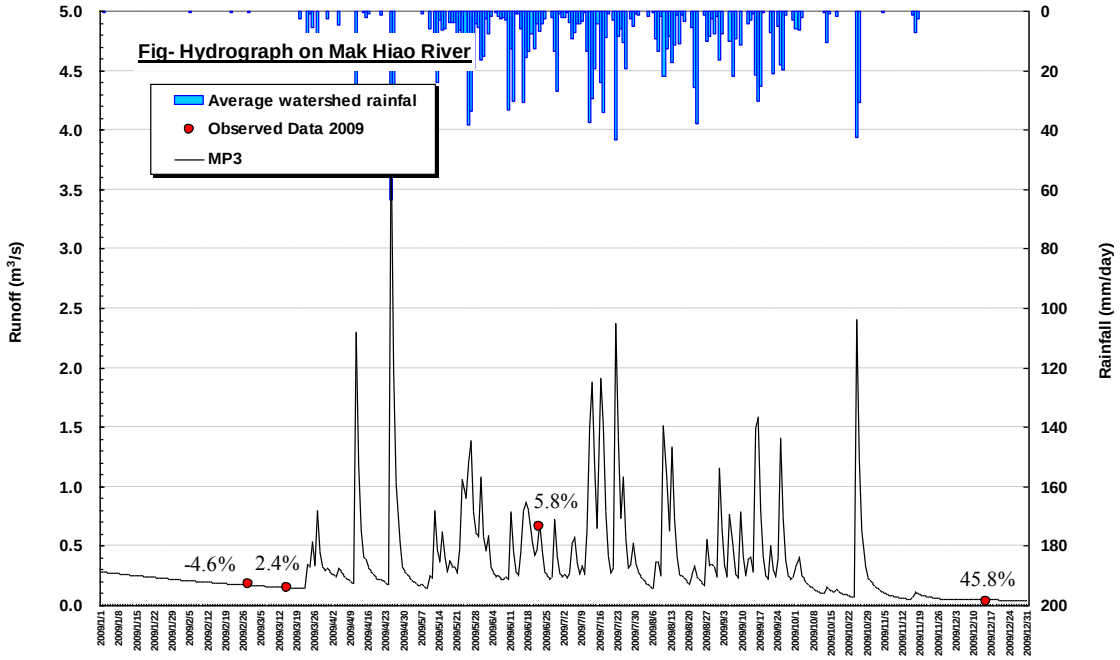
Parameter	River Storage Tank			Remarks
	I	II	III	
$V_{initial}$	100,000	100,000	100,000	Initial storage volume (m^3)
V_{max}	2,000,000	1,000,000	1,500,000	Maximum storage volume (m^3)
a	0.06	0.08	0.09	Runoff coefficient in low water
b	0.50	0.60	0.60	Runoff coefficient in high water

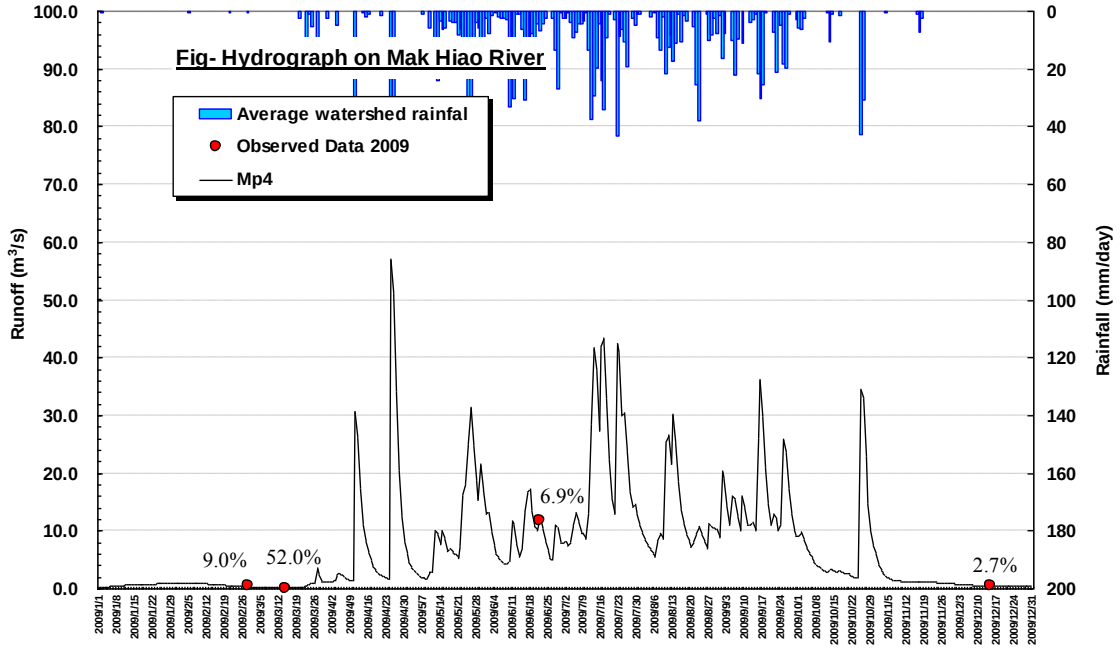




** Values described on the hydrograph is error between observed value and estimated one*

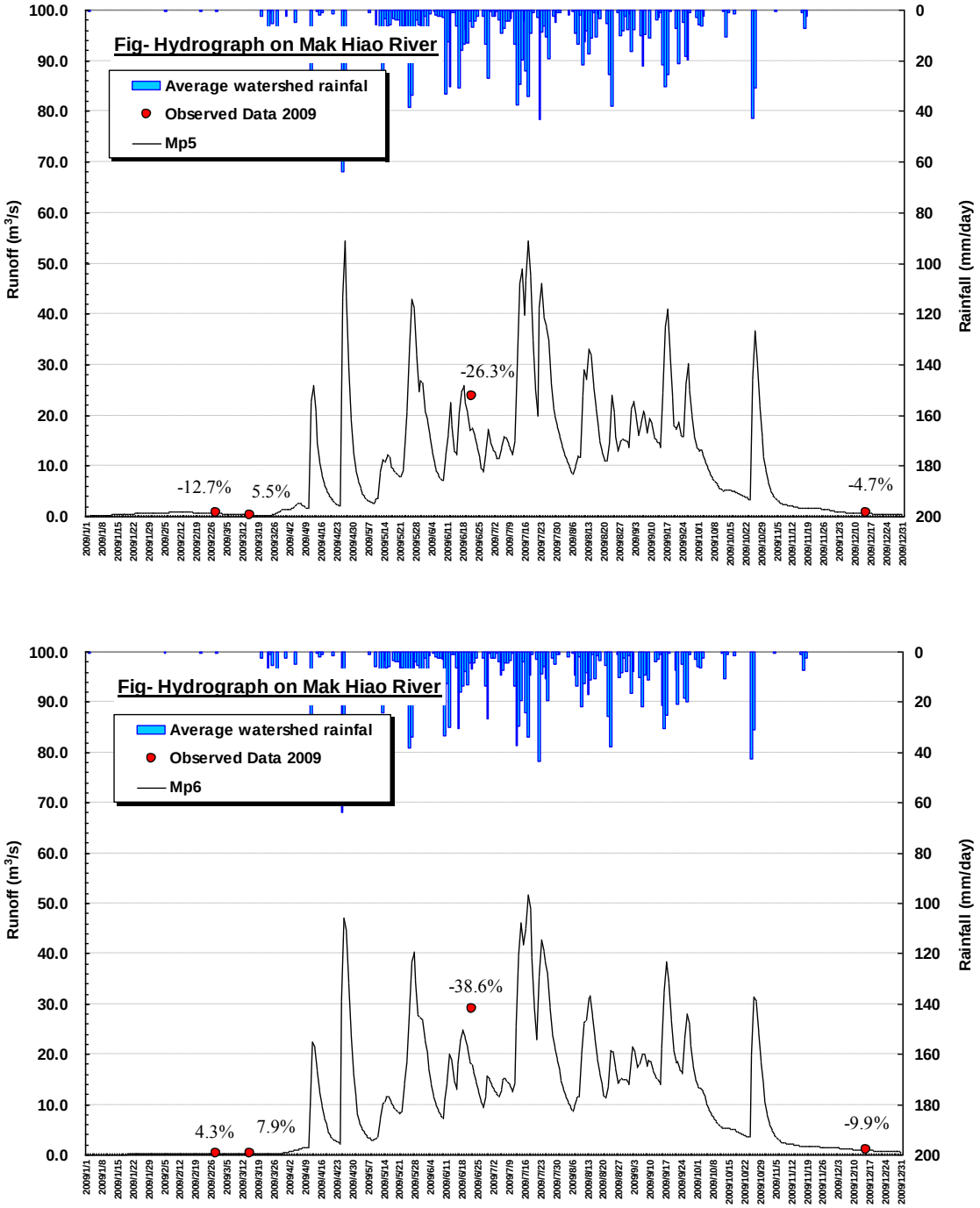
Fig. 2.3.19 Results of Calibration (MP1 and MP2)





** Values described on the hydrograph is error between observed value and estimated one*

Fig. 2.3.20 Results of Calibration (MP3 and MP4)



** Values described on the hydrograph is error between observed value and estimated one*

Fig. 2.3.21 Results of Calibration (MP5 and MP6)

(3) Estimation of Flow Regime

In the study, BOD (Biochemical Oxygen Demand) is employed as indicator for evaluating water quality in the target area. For adequate water quality analysis, the reasonable water volume in the target year 2020 should be estimated.

Here, according to *the Guideline for Comprehensive Basin-wide Planning of Sewerage Systems (Japan, 2008)*, flow regime for water quality analysis was calculated. The Guideline recommends that low water discharge identified as the 275th largest discharge in a year should be used and the average of values observed/calculated over the past decade be employed for analysis. In the study, annual flow regime was calculated with the following conditions.

Table 2.3.11 Flow Regime Simulation Conditions

Items	Conditions
Period	10 years from 2000 to 2009
Lower water discharge	275th largest flow in a year (75% flow)
Model	Tank model with river storage tank
Status	Existing and near future condition considering increase in population (domestic discharge) and improvement by the drainage work.

The results of flow regime calculation are shown in **Table 2.3.12**.

Table 2.3.12 Simulated Flow Regime

Unit: m^3/s

Status	Flow Regime in Percentile of Exceedance	Evaluation Point					
		MP1	MP2	MP3	MP4	MP5	MP6
Existing (2009)	Maximum Flow (1st day)	35.548	8.170	3.973	74.510	79.392	106.957
	26 % Flow (95th day)	2.984	0.681	0.387	11.325	16.119	25.030
	49 % Flow (185th day)	1.248	0.381	0.197	2.924	4.737	8.537
	75 % Flow (275th day)	0.372	0.255	0.098	0.854	1.182	1.459
	97 % Flow (355th day)	0.264	0.249	0.093	0.278	0.507	0.375
	Minimum Flow (365th day)	0.259	0.249	0.093	0.230	0.408	0.341
	Coefficient of flow regime	137	33	43	324	195	314
Near future (2020)	Maximum Flow (1st day)	40.793	8.198	4.546	79.477	82.921	110.111
	26 % Flow (95th day)	3.277	0.683	0.426	11.594	16.804	25.791
	49 % Flow (185th day)	1.419	0.383	0.226	3.314	5.486	9.184
	75 % Flow (275th day)	0.533	0.257	0.126	1.056	1.830	1.705
	97 % Flow (355th day)	0.430	0.252	0.121	0.368	0.762	0.537
	Minimum Flow (365th day)	0.426	0.252	0.121	0.312	0.670	0.465
	Coefficient of flow regime	96	33	38	255	124	237

* Coefficient of flow regime = Maximum discharge/Minimum discharge

2.4 Drainage Network

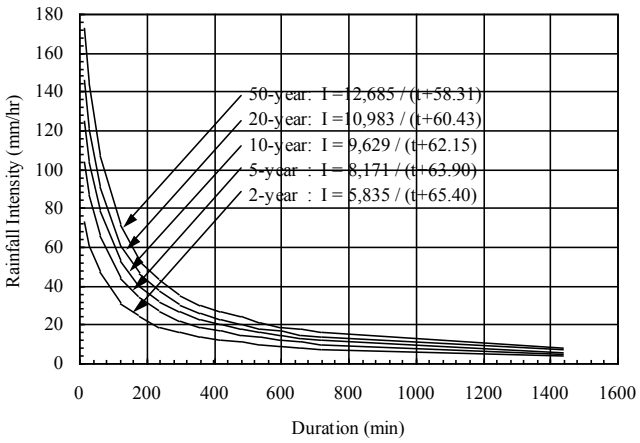
2.4.1 Review of Previous Studies and Projects

Various studies and projects regarding drainage have been made previously in Vientiane. Owing to the implementation of such improvement works, flood control and drainage situations in Vientiane have improved. These studies and projects are outlined hereunder.

(1) Feasibility Study on Improvement of Drainage System in Vientiane

JICA carried out the "Feasibility Study on Improvement of Drainage System in Vientiane" in 1990. The objectives of the Study were (i) to formulate a basic plan for storm water drainage system improvement in the study area of 56.2 km^2 in the urbanized part of Vientiane and to identify the priority project; and (ii) to conduct a Feasibility Study on the identified priority project. The target year for the basic plan was set at the year of 2020.

Based on the probable rainfall estimates, the rainfall intensity duration curve was produced applying the Talbot's formula as shown in **Fig. 2.4.1**. This rainfall intensity duration curve has been widely applied to estimate design discharge for other drainage projects.

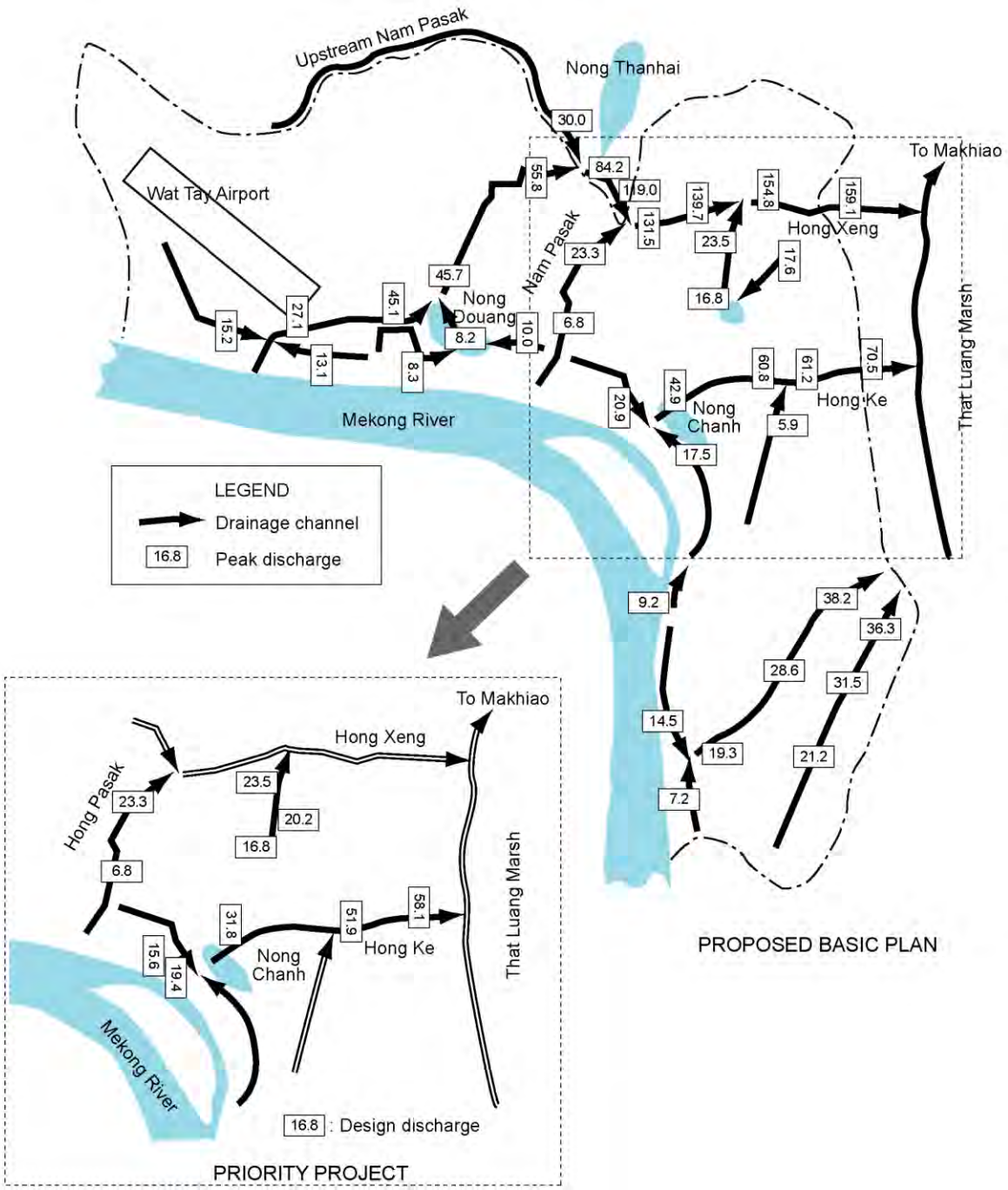


Source: Feasibility Study on Improvement of Drainage System in Vientiane, 1990. JICA

Fig. 2.4.1 Rainfall Intensity Duration Curve

The 10-year return period was applied to the protection level of the Basic Plan based on the assessment by a B/C index. The design hyetograph was constructed with 10-year return period, using recorded hourly rainfall on June 1, 1987. After studying alternative plans, the Basic Plan was decided as illustrated in **Fig. 2.4.2**. Among the Basic Plan, the following projects were selected as priority projects. **Fig. 2.4.2** illustrates the priority projects.

- Hong Ke system: Hong Ke, Hong Thong, Hong Khoua Khao, and Nong Chanh marsh
- Hong Pasak with 5 shortcut channels
- Hong Kai Keo with Nong Bone marsh
- Lateral canals in the area enclosed by Hong Xeng



Source: Feasibility Study on Improvement of Drainage System in Vientiane, 1990. JICA

Fig. 2.4.2 Proposed Basic Plan and Priority Projects

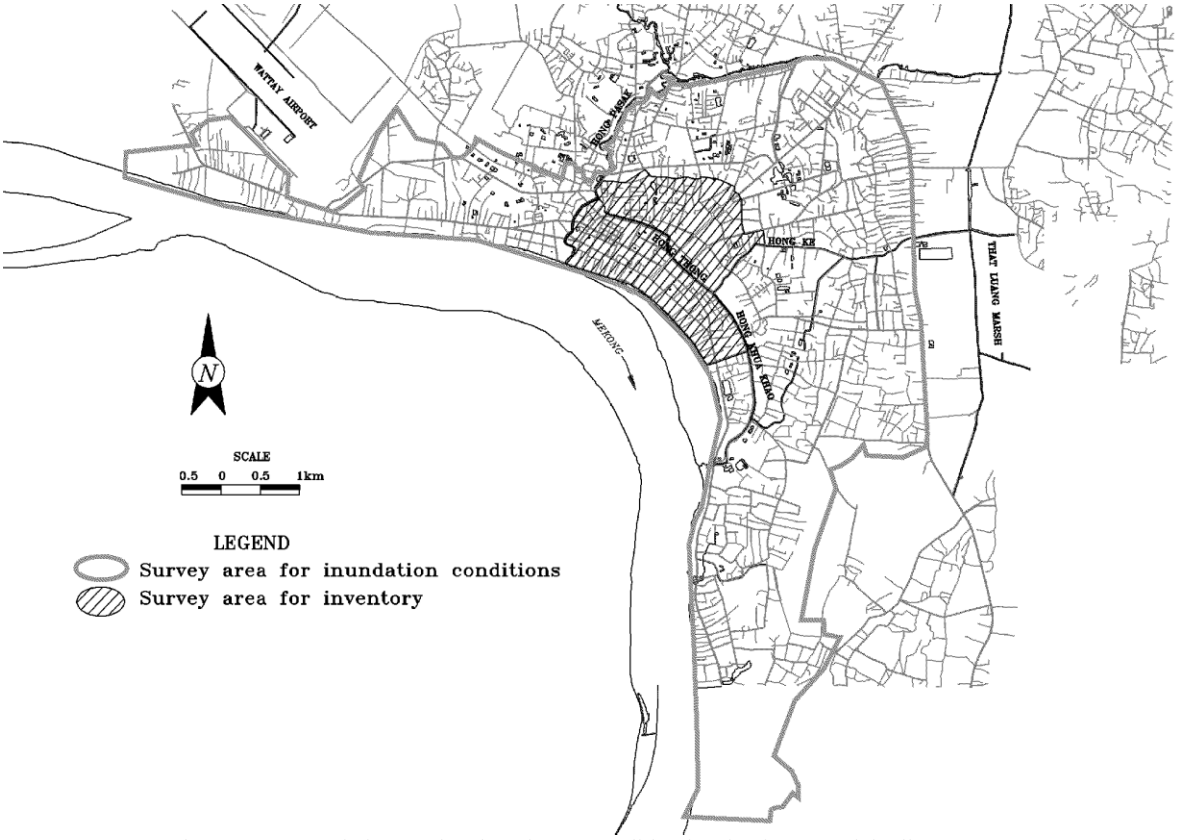
(2) The Survey on Existing Road and Drainage Condition in Vientiane Municipality

JICA conducted "The Survey on Existing road and Drainage Condition in Vientiane Municipality" in 2001 to 2002 in order to achieve the following:

- To ascertain the present conditions of existing drainage laterals;

- To establish a database of drainage laterals that can be used as guide in the operation, maintenance, rehabilitation and/or improvement of these facilities; and
- To analyze problems in the laterals of the drainage system of Vientiane

The survey area for the inundation conditions covers the urbanized area of 27 km^2 of Vientiane. The survey area for inventory of manholes and drainage laterals for database is limited to the core area of Vientiane of 3.3 km^2 as shown in **Fig. 2.4.3**.



Source: The Survey on Existing road and Drainage Condition in Vientiane Municipality, 2002. JICA

Fig. 2.4.3 Study Area of "The Survey on Existing Road and Drainage Condition"

(3) Rehabilitation of Sihom Area Project

Upstream of Hong Pasak (L=1.5 km) was improved by MCTPC (existing MPWT) in the "Rehabilitation of Sihom Area Project". The project period was from October 1991 to October 1997 and the project cost was totally USD5.5 million. The project objectives are the following:

- To improve the living conditions for the population of the Sihom area through its rehabilitation and upgrading;
- To improve the sanitation and storm water drainage in the catchment area along the Hong Pasak between the Mekong and the junction with the Hong Xeng stream; and
- To strengthen the institutional and technical capacity of the Ministry of Communication, Post, Transport and Construction (MCTPC) and the Institute for Technical Studies (ITSUP)

(4) Vientiane Integrated Urban Development Project (VIUDP)

In order to improve the urban environment and develop the urban sector's institutional capacities by rehabilitating and upgrading urban infrastructure and services, the "Vientiane Integrated Urban

Development Project (VIUDP)" was carried out from 1996 to 2001 under the financial assistance of ADB. The project consisted of the following parts:

- Part A: Environment Improvements (drainage/solid waste management/sanitation)
- Part B: Road Infrastructure Upgrading
- Part C: Social Action Program
- Part D: Implementation Assistance and Institutional Strengthening Consulting Services

Some primary and associated secondary drainage channels were improved in Part A among the above components. Objective drainage channels planned to be improved in the project are shown in **Table 2.4.1**. The construction of a proposed retarding basin at Nong Chanh was canceled because Nong Chanh retarding basin was determined to be ineffective according to the "Project Completion Report on the Vientiane Integrated Urban Development Project, July 2002."

Table 2.4.1 Objective Drainage Channels of VIUDP

Drainage channel	Length (km)
Hong Ke	3.40
Hong Thong	1.75
Hong Khoua Khao	2.55
Hong Ouay Louay	1.80
Hong Phone Thanh	0.95
Hong Kai Keo	1.36
Hong Thong Sang Nang	1.31
Hong Pasak (Downstream)	1.68
Lateral & secondary drains	-

Source: ADB

(5) Vientiane Urban Infrastructure and Service Project (VUISP)

In 2001, ADB and the Government of Lao PDR signed the loan agreement for the "Vientiane Urban Infrastructure and Service Project." Project period was from 2002 to 2006. VUDAA was the implementing agency for the project.

The project aimed to improve the quality of life and to enhance productivity and economic growth in the Vientiane urban area. The project area covered the four urban districts of Saysetha, Sisathanak, Chanthabouly, and Sikhottabong, including 50 villages. The project consisted of the following parts:

- Part A: Citywide Infrastructure and Environmental Improvements
- Part B: Village Area Improvements
- Part C: Capacity Building and Project Implementation Support

Part A was to provide critical missing links in the primary and secondary road and drainage networks, along with improvements in solid waste and traffic management. In this Part A, some drainage channels shown in **Table 2.4.2** were improved.

Table 2.4.2 Objective Drainage Channels of VUISP

Drainage channel	Length (km)
Hong Xeng	4.19
Hong Wattay (Upstream)	1.65
Hong Khaonhot-Simeung-Phapho	0.95
Hong Khoualouang	0.16
Hong Souanmon-Chimcheng-Khotninh	1.65
Hong Phonpapao	2.45
Hong Thongsangnang	0.50
Hong Ouaylouay	0.99
Hong Sisavath Kang	0.58
Hong Hongkha Tai	0.78

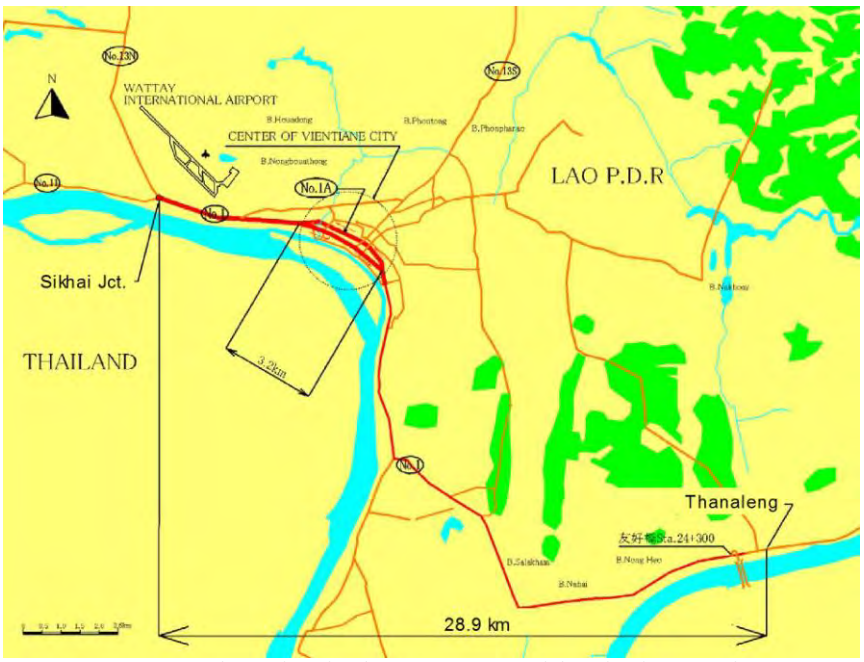
Source: ADB

(6) The Project for the Improvement of the Vientiane Road No. 1

"The Project for the Improvement of the Vientiane Road No. 1" was conducted from 2005 to 2007 with funds from JICA. The objective of the project was to achieve safe and smooth traffic on Road No. 1 by improvement works on the road and drainage from the Sikhai Junction near Wattay Airport to Thanaleng near the friendship bridge. Location map of the project is shown in **Fig. 2.4.4**. The implementing agency was the Department of Road (DOR), MCTPC (existing MPWT).

Road drainage was improved for the following stretches:

- Sikhai Jct. - Laksong Jct. : 3.9 km
- Laksong Jct. - Thatkao Jct. : 6.5 km
- Thatkao Jct.- Chinaimo Jct. : 5.1 km
- Chinaimo Jct. - Thanaleng : 13.4 km



Source: The Project for the Improvement of the Vientiane Road No. 1, 2007. JICA

Fig. 2.4.4 Location Map of the Project for Improvement of Vientiane Road No. 1

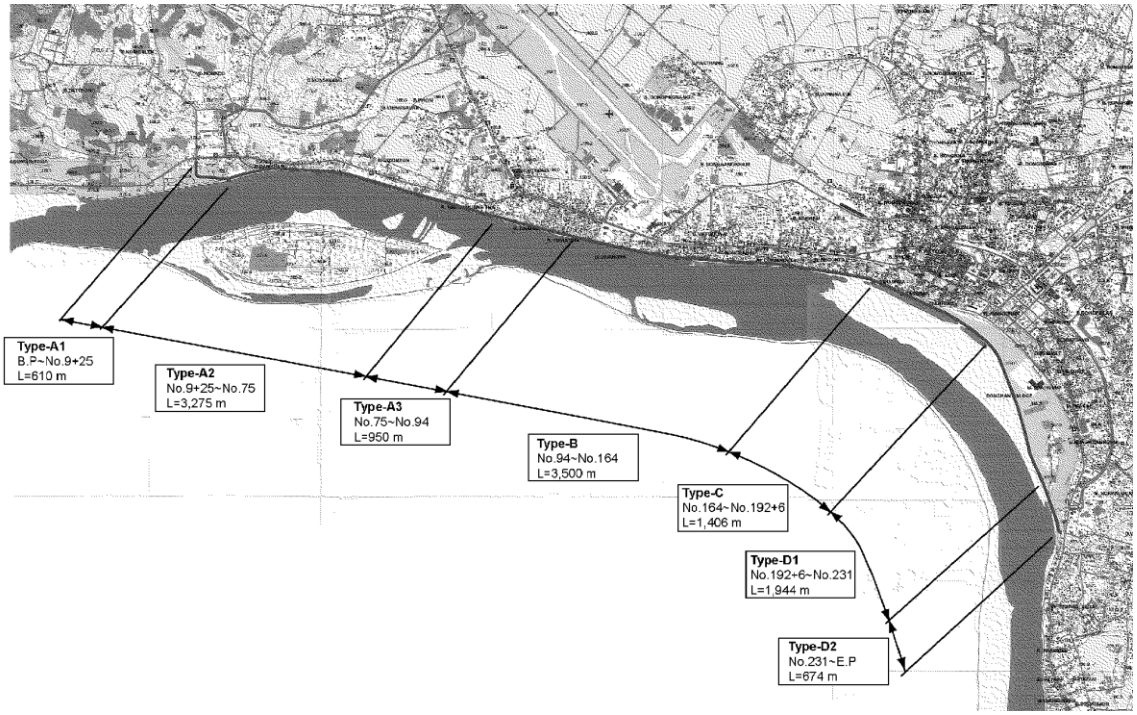
(7) The Construction of Drainage System and T2 Road Improvement Project

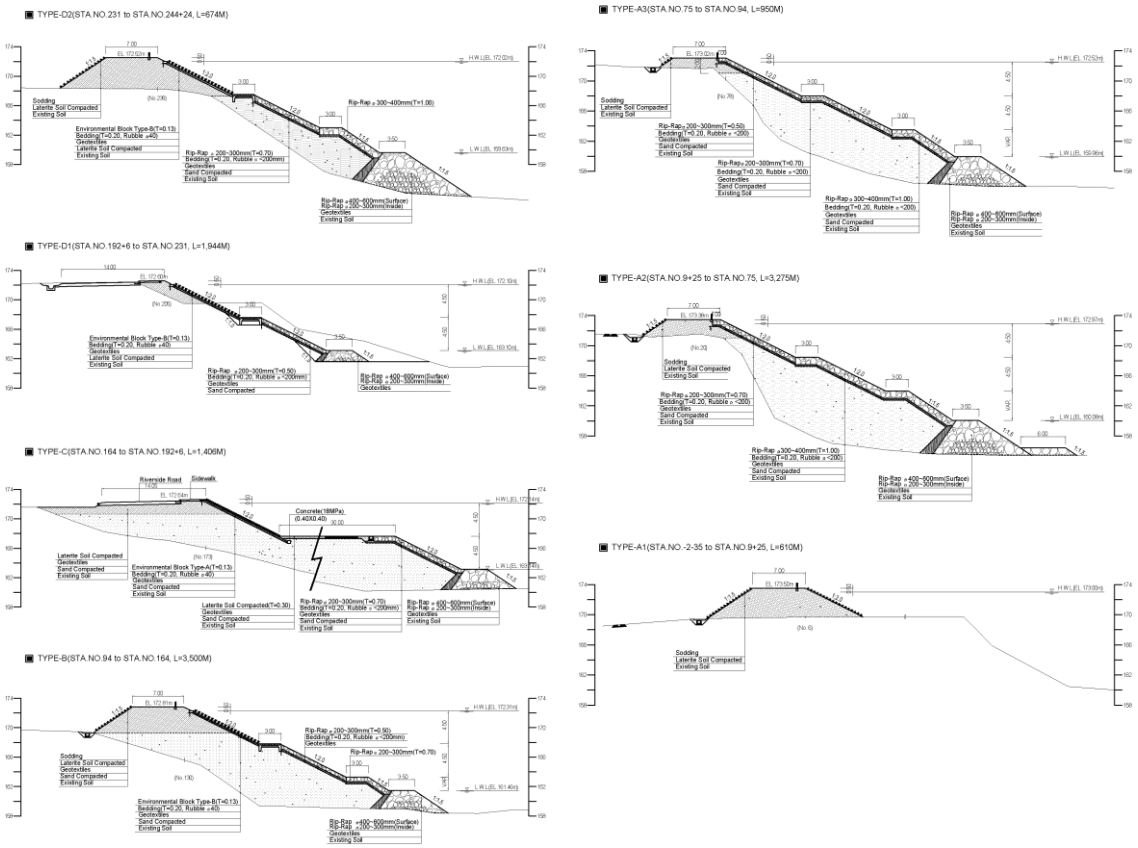
Downstream of Hong Wattay, 2.9 km was improved in "The Construction Drainage System and T2 Road Improvement Project" funded by the Kingdom of Thailand. VUDAA was the implementing agency and TEAM Consulting and Management Co., Ltd., Bangkok, Thailand in association with STS Consultant Co., Ltd., Vientiane, Lao PDR, provided the consulting services. The project was implemented from August 28, 2006 to February 28, 2008.

(8) Mekong River Integrated Management Project (Ongoing)

The "Mekong River Integrated Management Project" was started in 2009 and it will be completed by 2013. It is funded by the Economic Development Cooperation Fund (EDCF), Korea, and implemented by DPWT. Construction cost is USD30,855,000.

- In order to mitigate flood hazards and prevent riverbank erosion in Mekong River at the Vientiane area, the project comprises the construction of dike and bank protection of 12.2 km from Kaoliao to KM3. Dike and bank protection works are designed for a 100-year probable discharge, i.e., 26,500 m3/s. (**Fig .4.5, Photo 2.4.1**)
- Riverside road of 2.7 km on the top of dike including connection roads is planned. The road will be surfaced with bituminous pavement.
- In response to the need of affluent riparian environment as tourism resources and recreation, riverside park (Chao Anouvong Park) is planned. The park is to be developed on a 16 ha area. (**Photo 2.4.1**)





Source: Mekong River Integrated Management Project, Economic Development Cooperation Fund (EDCF), Korea

Fig. 2.4.5 Outline of Mekong River Integrated Management Project

Riverside Park

Siboungeuang (L=120 m)

Wattaygnay Tha (L=230 m)

Sithanh Neua (under construction)

Photo 2.4.1 Mekong River Integrated Management Project

2.4.2 Drainage System

The drainage system in Vientiane consists of the Hong Xeng system and the Hong Ke system. These systems were improved in the previous projects mentioned in **Subsection 2.4.1**. After completion of the projects, drainage condition in the city had improved dramatically. The drainage system is as described below.

(1) Drainage Condition

(a) Past Major Flood

Vientiane is located on alluvial plain formed by depositional process of Mekong River. Therefore, Vientiane suffers from flood damage by Mekong River or heavy rainfall, occasionally. Major past flood events, which caused damage to Vientiane, are summarized as follows.

<u>September 1966 Flood</u>

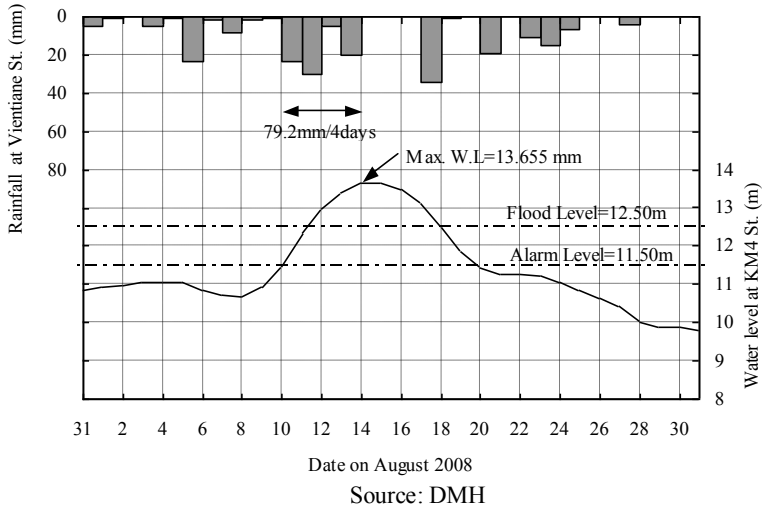
In 1966 tropical storm Phyllis brought huge flood damage to Mekong River basin. At Vientian, the water level exceeded the alarm level (11.5 m) for 19 consecutive days: from August 28 to September 15, 1996. The maximum water level of 12.71 m was recorded on September 4 and it was higher than the flood level (12.5 m). It was the highest flood ever recorded in the basin and due to the overflow from Mekong River, most of the areas below El. 170 m, including Wattay Airport, were submerged.

May 1988 Flood

On May 14, 1988, heavy rainfall happened in Vientiane. Daily rainfall of 162 mm was recorded at the Vientiane Station, which was more than the 10-year probable rainfall (150.6 mm). Roads, houses, temples and paddy field were inundated and damaged in many places. Inundation depth was 60 cm on the average.

August 2008 Flood

Tropical storm Kammuri struck southern China and northern Viet Nam and moved into northern Lao PDR bringing heavy rainfall in Mekong River basin on August 2008. Water level of Mekong River had risen due to heavy rainfall in the upstream basin. Water level of KM4 station in Vientiane exceeded the alarm level (11.50 m) on August 11 and the flood level (12.50 m) on August 12 as shown in **Fig. 2.4.6**, and finally reached up to 13.655 m at peak, the highest level since 1913. The peak water level was 1 m higher than the maximum level (12.71 m) recorded in 1966.



Source: DMH

Fig. 2.4.6 Rainfall and Water Level of Mekong River in August 2008

Flood damage in Vientiane was reported in "Damage & Recovery Report in 2008" prepared by Vientiane. Severe overtopping from Mekong River did not occur in the urban area because the dike was heightened after the 1966 flood and sandbags were piled up along the Mekong River for about 17 km from Kaoliao to Chinaimo as a flood fighting activity (**Photo 2.4.2**: left). However, it was confirmed that local inundations occurred due to seepage through the dike or sandbags. Suburban areas of Sikhottabong and Hadxaifong districts were widely submerged, due to overflow from the Mekong River (**Photo 2.4.2**: right) and some riverine lands were eroded.

Rainfall in Vientiane was recorded at 79.2 mm for 4 days between the 11th and 14th day of August 2008 as shown in **Fig. 2.4.6**. This rainfall amount was not so much compared with the rainfall in June and July, and severe inland water inundation did not happen in the urban area.

Sandbags along the Mekong River in urban area

Inundated area in suburban area

Source: MPWT

Photo 2.4.2 August 2008 Flood

(b) Current Situation of Drainage

A total of 175 flood prone areas were identified in the urban area by the previous study, "The Survey on Existing Road and Drainage Condition in Vientiane Municipality." In these flood prone areas, flooding occurred more than 5 times a year. However, inundation along the drainage channels never occurred since the VIUDP and VUISP were completed. It can be said that the current situation of drainage became much better than before.

However, sediment has accumulated in the drainage channels. This might worsen the drainage condition by decreasing the flood flow area. The study team conducted a survey to grasp the sediment volume in May and June 2009. The survey result is shown in **Fig. 2.4.7**. Hong Xeng, Hong Ke and Hong Wattay store a lot of sediment, but the sediment volumes per unit riverbed area between drainage channels are not so different.

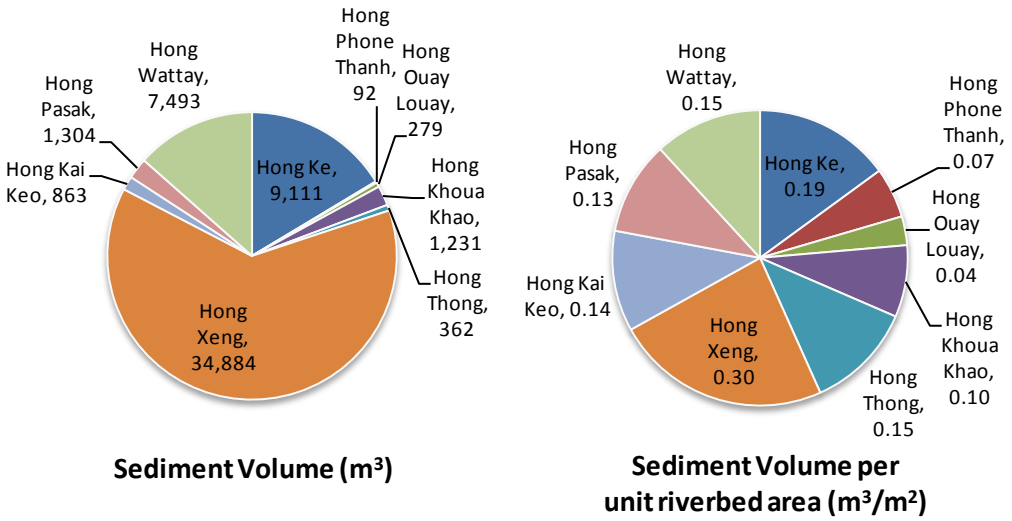


Fig. 2.4.7 Sediment Volume in Drainage Channels

(2) Drainage Channels

The Vientiane urban area is covered by (a) Hong Xeng system, which consists of Hong Xeng and its tributaries, i.e., Hong Kai Keo, Hong Pasak, Hong Wattay and Nam Pasak; and (b) Hong Ke system, which consists of Hong Ke and its tributaries, i.e., Hong Phone Thanh, Hong Ouay Louay, Hong Thong and Hong Khoua Khao, as shown in **Fig. 2.4.8**. Total catchment areas of the Hong Xeng and Hong Ke systems are 56.57 km^2 and 9.54 km^2, respectively.

These channels were improved in the various projects mentioned in **Subsection 2.4.1**, as summarized in **Table 2.4.3**. Existing channel characteristics for drainage channels were studied based on the drawings for the above projects and supplemental survey result conducted in this study, and described below.

Table 2.4.3 Drainage Channels of Hong Xeng and Hong Ke Systems

Channel	Stretch	Organization	Completion Year	Project
Hong Xeng System				
Hong Xeng	D/S 1.5 km	VUDAA	2009	
	4.2 km	VUDAA	2006	VUISP [1)]
Hong Kai Keo	1.3 km	VUDAA		VIUDP [2)]
Hong Pasak	D/S 1.7 km	VUDAA	2000	VIUDP
	U/S 1.5 km	MCTPC	1995	Rehabilitation of Sihom Area Project
Hong Wattay	D/S 2.7 km	VUDAA	2005	Drainage System and T2 Road Improvement Project
	U/S 2.3 km	VUDAA	2006	VUISP
Hong Ke System				
Hong Ke	3.4 km	VUDAA	2001	VIUDP
Hong Phone Thanh	0.95 km	VUDAA		VIUDP
Hong Ouay Louay	1.8 km	VUDAA		VIUDP
Hong Khoua Khao	2.55 km	VUDAA	2001	VIUDP
Hong Thong	1.75 km	VUDAA	2001	VIUDP

Note: 1) VUISP: Vientiane Urban Infrastructure and Service Project
2) VIUDP: Vientiane Integrated Urban Development Project
Source: VUDAA

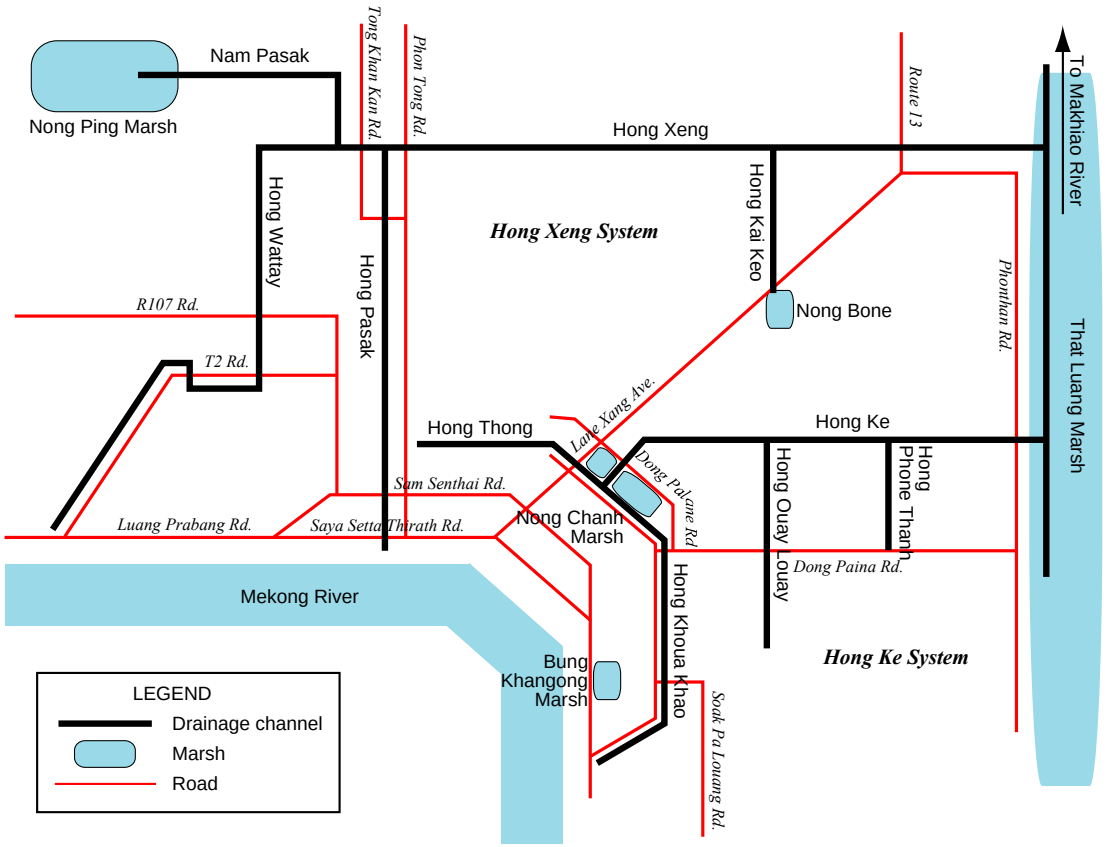


Fig. 2.4.8 Drainage System in the Urban Area of Vientiane

Based on the drawings of previous projects, the existing channel features of the above 9 drainage channels are as summarized below. The longitudinal profile, channel width and carrying capacity of each channel are illustrated also in **Fig. 3.1.2** to **Fig. 3.1.10** of the **Data Book**.

Longitudinal Profile: Riverbank, riverbed and riverbed slope are illustrated in longitudinal profile. Sediment depths measured in this study are also shown in the profile.

River Width: Typical cross sections are made for each segment, which have similar riverbed slope, bank height, cross sectional shape and width, based on the drawings. Then width of riverbank and riverbed are summarized using the typical cross-section. Drawings of cross-section for upstream of Hong Pasak (1,360 m), upstream of Hong Ke (150 m), downstream of Hong Khoua Khao (250 m), and downstream of Hong Thong (400 m) were not available; therefore, the study team measured the dimensions and obtained their cross sectional shapes.

Carrying Capacity: Carrying capacity is calculated by the uniform flow model of Manning's Formula as described below. Channel condition is considered in two situations for calculation. One is the as-built channel based on drawings and the other is the existing channel with accumulated sediment.

$$Q = \frac{1}{n} \times A \times R^{\frac{2}{3}} \times I^{\frac{1}{2}}$$

where, Q : Discharge capacity (m^3/sec)
n : Coefficient of roughness
- Concrete lining on banks and riverbed: n = 0.016
- Concrete lining on banks: n = 0.025

- No lining: n = 0.030

(Source: Japan River Association (Ed.), "Technical Criteria for River Works: Practical Guide for Study" and others

A : Flow area (m^2)
Typical cross-sections are used for calculation. Water depth for carrying capacity is decided to be [0.8 x (river bank height)] according to Japanese guideline.
R : Hydraulic radius (m)
I : Riverbed slope

Hong Xeng

Hong Xeng is a main stream of Hong Xeng system. Catchment area is 56.57 km^2 and channel length is 4.01 km. It flows from the confluence of Nam Pasak and Hong Wattay at St. 4+006 and it joins Hong Pasak at St. 2+875 and Hong Kai Keo at St. 1+158.

The riverbank is protected with concrete lining from Sta. 0+000, which is located at 320 m downstream from the bridge on Route 13 to the end of the upstream. This stretch was improved in the "VUISP". For the downstream stretch between Sta. 0+000 and the confluence with the canal in That Luang Marsh, Hong Xeng was widened by the VUDAA in 2009 and the removed materials were placed on both banks (height: about 1 m).

For the downstream from Sta. 0+000, the carrying capacity is very low because the ground level is relatively low as shown in **Fig. 3.1.2** of the **Data Book**. The area along this stretch is wasted land or paddy field, which was originally a portion of That Luang Marsh.

The carrying capacity of all stretches is less than a 2-year probable discharge even if the channel is as-built without sediment. On the other hand, the carrying capacity of the tributaries of Hong Xeng, namely, Hong Kai Keo and Hong Pasak, are higher than a 2-year probable discharge. This means that if a 2-year probable rainfall occurs, 2-year probable discharges will flow through the tributaries safely and bring flood damage along Hong Xeng by channel overflow.

After VUISP, rainfall of over the 2-year probability (104.0 mm/day) occurred on July 30, 2006 (154.0 mm/day) and October 09, 2006 (160.1 mm/day), but overflow from Hong Xeng did not happen though the carrying capacity is less than half of a 2-year probable discharge. The reason is as explained below.

In the Hong Xeng basin, there are a lot of marshes and ponds with a total area of 225 ha according to satellite image. If they store runoff water to a depth of 0.5 m above normal water surface during heavy rain, the total storage volume would be $1{,}125 \times 10^3 m^3$. On the other hand, the 2-year probable hydrograph at the MP1 point of Hong Xeng was figured out by the synthetic rational formula as shown in **Fig. 2.4.9** (Left). When the water bodies cut the above stored volume from the hydrograph, the peak discharge would be reduced from 90 m^3/s to 42 m^3/s as shown in **Fig. 2.4.9** (Right). Bankfull discharge at the MP1 point of Hong Xeng is 42.3 m^3/s and is less than the peak discharge after storage. Hence, it can be presumed that Hong Xeng has the capacity to flow a 2-year probable flood without channel overflow through its basin's retarding function.

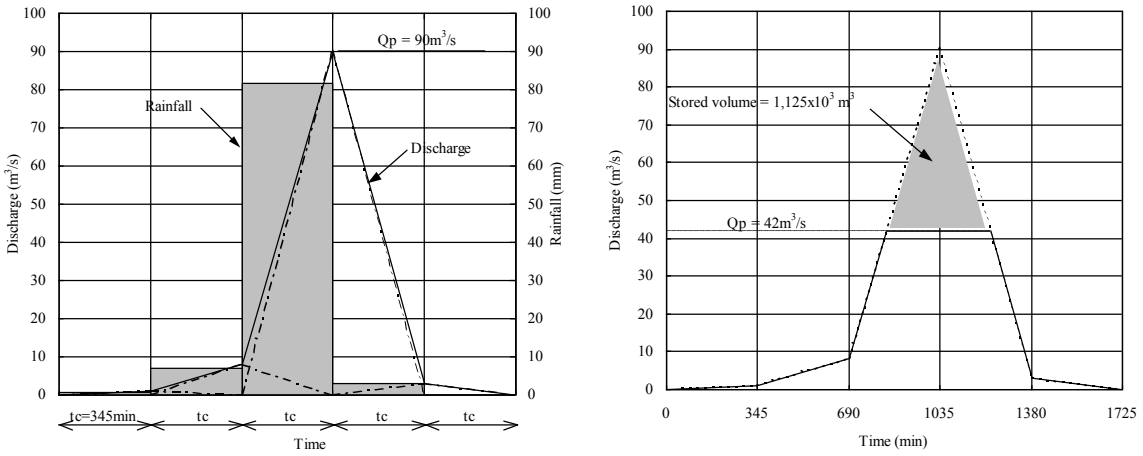


Fig. 2.4.9 Hydrograph at R13 Bridge of Hong Xeng

Hong Kai Keo

Hong Kai Keo flows into Hong Xeng from the right bank at 900 m upstream from the Route 13 Bridge. The catchment area is 3.09 km^2, the length is 1.36 km and the width is 11-13 m. Both banks and riverbed are protected with concrete. The riverbed slope is 1/2,500. The carrying capacity of the as-built channel is 25 m^3/s to 17 m^3/s but that of the existing channel is 25 m^3/s to 9 m^3/s due to accumulated sediment in the upstream. The characteristics of Hong Kai Keo are shown in **Fig. 3.1.3** of the **Data Book**. The end of upstream reach is connected to the Nong Bon Marsh. In the Hong Kai Keo catchment area, there are the following 4 marshes:

- Thong Sang Nang marsh 2.66 ha
- Phosaat marsh 2.07 ha
- Nong Bon marsh 1.99 ha
- Naxay marsh 0.81 ha

Hong Pasak

Hong Pasak drains the urban area. It has a catchment area is 2.24 km^2 and 1.5 km of the upstream reach and 1.7 km of the downstream were improved in the "Rehabilitation of Sihom Area Project (1995)" and the "VIUDP (2000)" respectively. Some shortcut channels were constructed at the meandering reaches in the latter project. Both banks and channel bed are surfaced with concrete.

The channel characteristics are shown in **Fig. 3.1.4** of the **Data Book**. Drawings for the "Rehabilitation of Sihom Area Project" were not available for the study. Therefore, regarding the upstream reach without drawings, the study team assumed that the riverbed was extended with the same riverbed slope (1/2,500) as the downstream reach and thus the cross section profile was made by measurement. The existing carrying capacity is about 60% of that of the as-built channel due to accumulated sediment.

Hong Wattay

Hong Wattay was constructed originally as an irrigation canal in 1985. After that it was improved into a drainage canal, i.e., 2.7 km of downstream in "The Construction of Drainage System and T2 Road Improvement Project (2005)" and 2.3 km of the upstream in the "VUISP (2006)".

The catchment area is 9.28 km^2 and the length is 4.2 km. Banks and the riverbed are protected with concrete lining. Riverbed slope is 1/4,760 to 1/5,000 for the downstream reach lying in apaddy field and 1/2,000 to 1/3,230 for the upstream lying in a natural levee. The existing carrying capacity is 25 m^3/s to 7 m^3/s, while the carrying capacity of the as-built channel is 43 m^3/s

to 12 m^3/s. The carrying capacity of all stretches of both conditions are less than a 2-year probable discharge as shown in **Fig. 3.1.5** of the **Data Book**.

Hong Ke

Hong Ke is a main stream of the Hong Ke drainage system. The catchment area is 9.54 km^2 and channel length is 3.65 km. Hone Ke flows from the confluence of Hong Khoua Khao and Hong Thong near the Nong Chanh Marsh, and it joins Hong Ouay Louay at Sta. 1+683 km and Hong Phone Thanh at Sta. 1+250 km. Finally, it drains into the That Luang Marsh.

In 1983 Hong Ke was widened and deepened in order to increase the flow area. After that, Hong Ke was improved in "VIUDP (2001)". In this project, the construction of a proposed retarding basin at the Nong Chanh Marsh was determined to be ineffective and, therefore, canceled. Bank protection works are installed at the downstream from the Phonthan road-bridge and bank and riverbed protection works are installed at the upstream from the bridge. Channel characteristics are as summarized below and shown in **Fig. 3.1.6** of the **Data Book**. For the upstream from the Phonthan road bridge, accumulated sediment causes the carrying capacity to decrease.

Stretch	Riverbed Slope	River Width	Ex. Carrying Capacity
Sta. 0+000 – Sta. 0+730	1/3,330	39.4 m	66 m^3/s
Sta. 0+730 – Sta. 3+650	1/2,500	20.6 – 16.0 m	38 – 24 m^3/s

Hong Phone Thanh

Hong Phone Thanh has a catchment area of 0.48 km^2 and a length of 0.95 km. The channel was improved with bank and riverbed protection works in "VIUDP." Steep (1/105 to 1/192) and gradual (1/1,110) riverbed slopes appear alternately. The carrying capacity of the as-built channel is very high and its safety level is over 30-year return period, but the current safety level of the middle and upper reaches is 3.8 to 6.7-year return period due to accumulated sediment in the channel as shown in **Fig. 3.1.7** of the **Data Book**.

Hong Ouay Louay

Hong Ouay Louay with 1.66 km^2 of catchment area flows in a residential area. The channel is protected with concrete lining on the riverbanks and riverbed totaling 1.80 km. Riverbed slope is 1/1,950 to 1/2,500 except around Section 1+300 where the slope is 1/96. In the middle reach, the existing carrying capacity is half of that of the as-built channel because sediment has accumulated in the reach. The downstream and upstream reaches have no sediment. These channel characteristics are shown in **Fig. 3.1.8** of the **Data Book**.

Hong Khoua Khao

Hong Khoua Khao was constructed by France in 1945. The existing channel was improved in "VIUDP (2001)". Before "VIUDP," Hong Khoua Khao had 2 flow directions. One flowed from Sta. 1+800 to Hong Ke and the other flowed from Sta. 1+800 to Mekong River. Then, in the "VIUDP" the confluence of Mekong River was closed and the riverbed slope was fixed to flow from the closing point to Hong Ke.

The catchment area is 2.60 km^2 and the length is 2.56 km. Riverbanks and the riverbed are covered with concrete. Carrying capacity of the as-built channel is 26 m^3/s to 12 m^3/s, whereas that of the existing channel is 16 m^3/s to 7 m^3/s due to sediment which accumulated in the channel at an average depth of 10 cm. These channel characteristics are shown in **Fig. 3.1.9** of the **Data Book**.

Hong Thong

Hong Thong was constructed by France in 1945. Then, the downstream 320 m section was improved as an open channel and the upstream 1,470 m section as a box culvert in the "VIUDP." Since the drawings of the project is different from the existing channel condition (e.g., length of open channel, cross section shape, etc.), the study team measured the dimensions of the cross-section and prepared a typical cross section using the riverbed elevation shown in the drawings. Channel characteristics of Hong Thong are shown in **Fig. 3.1.10** of the **Data Book**. This channel originally had enough carrying capacity, which is equivalent to about 10-year return period flood. However, sediment in the channel has decreased the carrying capacity to one-third of the original capacity.

(3) Drainage Gate

Mak Hiao River has 2 drainage gates at the confluence of Mekong River **(Photo 2.4.3)**. The Irrigation Sector of the Department of Agriculture and Forestry, Vientiane, is responsible for maintenance of these gates. However, the related reports and drawings were not available for the study because they have been missing since the office moved to another location.

Mak Hiao Main River

Mak Hiao Branch River

Photo 2.4.3 Mak Hiao River Gates

Gates were installed on upstream and downstream sides at each site. The gate types are shown in **Table 2.4.4**. During the rainy season, the upstream gate is opened and drain Mak Hiao River flood to Mekong River. If water level of Mekong River is higher than that of Mak Hiao River, the downstream gate prevents backward flow from Mekong River. During the dry season, water is able to be stored in Mak Hiao River by closing the upstream gate. Drainage gates of Mak Hiao River were installed as shown in **Fig. 2.4.19**.

Table 2.4.4 Drainage Gate of Mak Hiao River

Channel	Completion Year	Gate Type
Mak Hiao Main River	1976	Upstream: Sluice gate Downstream: Flap gate
Mak Hiao Branch River	1995	Upstream: Stop log Downstream: Flap gate

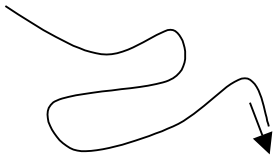
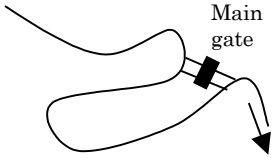
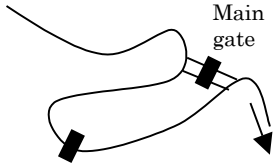
1 (before 1976)	2 (from 1976 to 1995)	3 (from 1995 onward)
Makhiao River  To Mekong River	Makhiao River Main river gate  To Mekong River	Makhiao River Main river gate  Branch river gate To Mekong River
There was no gate before 1976.	Short cut channel was excavated to drain floodwater quickly and a gate was constructed for backflow prevention in 1976.	A new gate was installed at a branch river in 1995 to prevent backflow from Mekong River.

Fig. 2.4.10 Installation of Mak Hiao River Gates

(4) Lateral Drainage Plan

VUDAA has a plan to improve the lateral drainage channels connected to the Hong Xeng System, Hong Ke System or That Luang Marsh directly in Chanthabouly, Sikhottabong, Saysetha and Sisathanak districts. VUDAA had already submitted a proposal for the study to MPWT and is waiting for its approval. The plan is to rehabilitate the former irrigation channels into drainage channels and to improve the existing drainage channels. When rehabilitation and improvement of these channels are completed, the northern and southern parts of the urban area will become much safer from inundation. **Fig. 2.4.20** illustrates the objective channel improvement works.

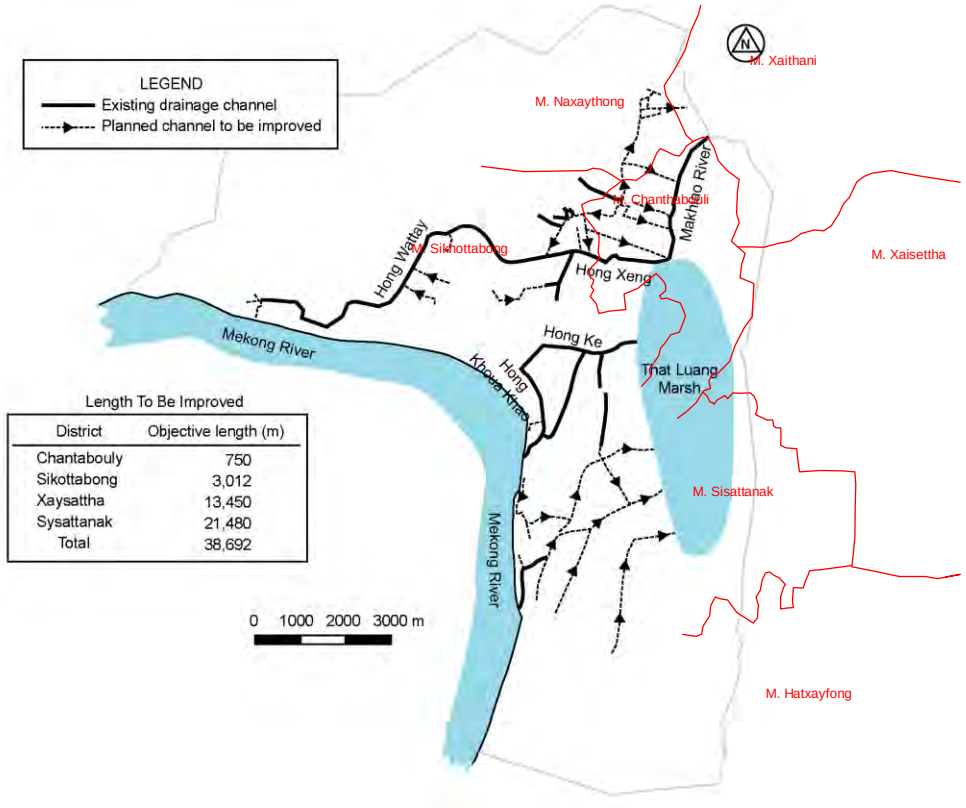


Fig. 2.4.11 General Layout of Lateral Drainage Plan

2.4.3 Maintenance of Drainage Channels

VUDAA is responsible for the maintenance of drainage channels in the urban area. VUDAA does not have any machine and equipment for maintenance works and put the works out to a private company by a special appointment contract following the regulation of the Ministry of Finance (―Decree on bidding of procurement construction, maintenance and services from government's budget, No. 03/pm, 09/01/2004"), that bidding is not required if contract amount is under KIP 50 million. The contractor conducts maintenance works by using a backhoe, light-bulldozer, truck and manpower. Villages along the drainage channels are not involved in the maintenance/cleaning activities.

VUDAA has a maintenance plan to clean the drainage channels twice a year, but cleaning is actually done once a year due to lack of funds. Grasses are cut and sediment in the channels is dredged up usually before the rainy season and during the rainy season supplementarily. The maintenance plan requires the sediment and grass removed from the channels to be conveyed to the dumping site about 32 km from Vientiane, but this is actually not carried out because people living near the hannels take them for landfill or farmland material.

VUDAA has a budget of 300 to 350 million KIP a year for the maintenance of drainage channels as shown in **Table 2.4.5**. This amount is allocated from the ―Road Maintenance Foundation of MPWT" and Vientiane. Maintenance work consists of dredging and transportation. Costs of these works are as follows.

- Dredging (drainage channels): KIP 25,945/m3
- Dredging (manhole): KIP 50,000/site
- Dredging (side ditch): KIP 20,000/m
- Transportation (Vientiane to Ban, 32 KM): KIP 500,000/truck (1 truck contains 4 m3)

Table 2.4.5 Budget for Maintenance of Drainage Channels

Year	Budget (KIP)
2007 - 2008	292,000,000
2008 - 2009	370,000,000
2009 - 2010	366,000,000

Source: VUDAA

Based on the results of the field survey conducted by the study team, the projected sludge volume accumulated in the channels of Hong Ke and Hong Xeng is 55,619 m^3 in total. Cost for removing all the sediment has been calculated based on the above unit costs. It amounts to KIP 8,398 million and covers more than two decades of budget as shown in **Table 2.4.6**.

Table 2.4.6 Sediment Volume and Maintenance Cost

Channel	Sediment Volume (m^3)
Hong Xeng	9,111
Hong Kai Keo	92
Hong Pasak	279
Hong Wattay	1,231
Hong Ke	362
Hong Phone Thanh	34,884
Hong Ouay Louay	863
Hong Khoua Khao	1,304
Hong Thong	7,493
Total	55,619

Work Item	Unit Cost (Kip/m^3)	Sediment Volume (m^3)	Cost (Kip million)
Dredging	26,000	55,619	1,446
Transportation	125,000	55,619	6,952
Total			8,398

8,398 (mil. Kip) / 350 (mil. Kip/year) = 24 (years)