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 II: Summary

SEPTEMBER 2011

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

GED
JR
11-168

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 II: Summary

SEPTEMBER 2011

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

THE STUDY ON IMPROVEMENT OF WATER ENVIRONMENT IN VIENTIANE CITY

COMPOSITION OF FINAL REPORT

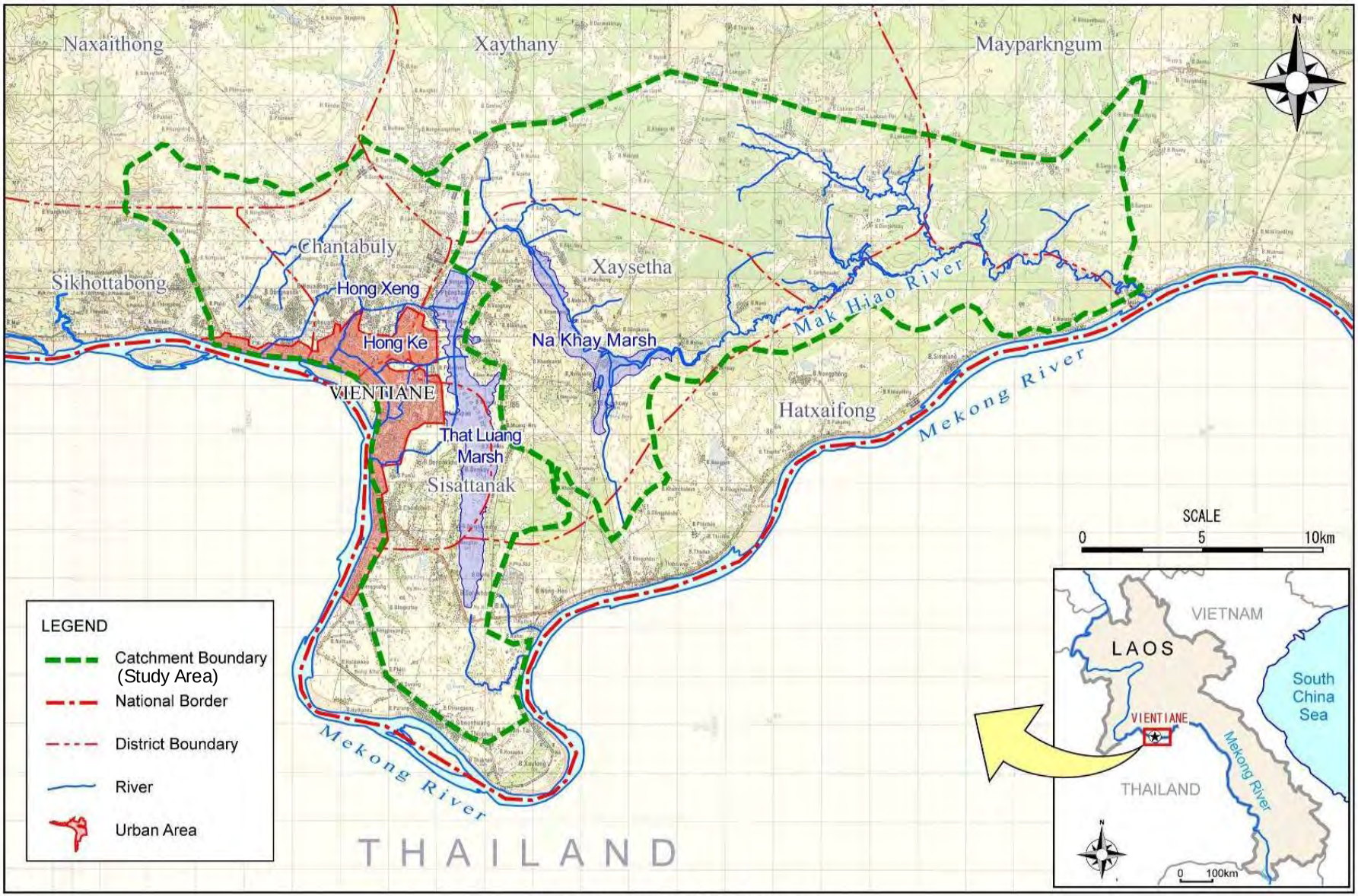
Volume I	**:**	**Main Report**
Volume II	**:**	**Summary**
Volume III	**:**	**Data Book**

Currency Exchange Rate 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 3 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

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

In view of the present condition of the drainage network in Vientiane, the Government of Japan, through the Japan International Cooperation Agency (JICA), dispatched a study team in the middle of January 2009 to formulate the master plan of improvement of water environment in Vientiane. The Study includes the formulation of improvement measures against the worsening hygienic environment and of environmental conservation measures for the Mak Hiao River watercourse.

The specific objectives of the Study are as recapitulated below:

(1) Considering the existing conditions of water environmental management in the Study Area, a Master Plan for water environment management in Vientiane shall be formulated in order to improve the hygienic environment and to conserve the natural purification function of the entire Mak Hiao River basin, and

(2) The knowledge and technologies in formulation of water environment management plan shall be transferred to Lao counterparts through the implementation of the Study.

The ultimate plan of the Study is to apply the above-mentioned Master Plan in urban development projects in Vientiane 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. The following table shows the area and population of the Study Area, including projections for 2020.

Area and Population of the Study Area

Item	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 %)

Note unit: 1,000 for each population value
Figures in parentheses in the column of study area show percentiles to those of Vientiane, while figures in them in the column of major drainage area show percentiles to those of study area.
Source: Preparatory Survey on Industrial Zone Development in the Lao People's Democratic Republic, Progress Report, 2009, JICA, and Study Team

The Study Period is thirty (30) months from January 2009 to June 2011.

3. Major Issues on Water Environment in Vientiane

Various issues related to water environment were discovered in the course of the Study and their clarification and solution are crucial for the smooth preparation of improvement strategy and the Master Plan of Water Environmental Improvement. Based on the survey results and future projections, improvement issues on the water environment are as categorized into technical and institutional areas.

Water Environment in the Study Area

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

The surface water along the urban drainage canals has been deteriorating mainly due to domestic organic pollutants. Furthermore, the situation would much worsen in future according to the simulation results. Among the urban drainage canals, water quality in Hong Thong and Hong Pasak, which receive wastewater discharged from the urban center of Vientiane, is the most seriously deteriorated. The BOD concentrations are 20 to 30 mg/l at present. Projected are more worsened BOD concentrations exceeding 30 mg/l, for the entire stretch of the urban drainage system covering Hong Ke and Hong Xeng.

(2) Aquatic Life in Urban Drainage Canals

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

Various fishes go upstream through these canals in the rainy season, and people enjoy fishing and catching fishes using a net, being not so much popular as in previous time. Conservation of the still existing rich water environment for future generations and the improvement of water environment for fishes to make their habitat even in the dry season could be an urgent issue.

(3) Sanitary Conditions in Community and Household Level

In order to clarify the actual sanitary condition in individual houses of Vientiane, the pre-feasibility study was conducted in 2010 under the study for the Master Plan. Simultaneously, rapid assessment was also conducted on the basis of the WSP (Water and Sanitation Program) of 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. The results, however, also show that the maintenance work of desludging of septage is not properly and periodically done. In addition, the facilities receive only night soils so that domestic wastewater is being discharged without any treatment, the major source of water contamination in canals.

One CBS (Community-Based Sanitation) was constructed in an urban village as the pilot project in the master plan study. The pilot project and the pre-feasibility study in the urban area of Vientiane did not find any possibility of further expansion of CBS facilities due to the high installation rate of individual sanitary facilities and the difficulty of securing land for the installation of CBS.

Institutional and Legal Issues in Water Environment Management

(1) Weakness of Institutional Management on Environment

The capacity of institutions is not sufficient for proper management not only on water environment but also on the entire environment. This might be due to the shortage of experienced and skilled staff in the central government as well as the local governments, and budgetary constraint on governmental services regarding water quality monitoring and drainage maintenance. Furthermore, unless the capacity on water quality testing is strengthened in WERI-WREA, WERI would lose its reputation as the center of environmental management in Lao PDR.

(2) Development Needs for Regulations and Guidelines

International donors such as SIDA and ADB have been providing assistance for the improvement and establishment of environmental legal systems, such as basic laws and important bylaws. However, additional administrative instructions and guidelines shall be prepared for the smooth implementation and effective regulation of improvements based on these laws.

(3) Necessity of Practical Water Quality Standard

The existing standards on 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 on water quality in other countries are normally designated in accordance with the usage of water. If such standards are adopted, various realistic and practical approaches could be applied for improvement.

(4) Strengthening/Establishing Implementing/Coordinating Agencies to Integrate the Functions/Responsibilities of 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 integrated agency/organization to coordinate them in focusing their activities on clear and concrete directions. This kind of organization or network is indispensable for comprehensive approach, since wastewater management is reflected from socio-economic conditions and is complicated.

(5) Disclosure and Dissemination of Information for Awareness Enhancement of Residents

To solve problems caused by the general public such as water quality deterioration by domestic wastewater, the awareness of residents is very important. Therefore, the disclosure of environmental information is the key to dissemination and public awareness on environment. Presently, however, there is no such organization or institution that can disclose enough information which people can easily access. Low awareness of people will thus become an obstacle to appropriate and timely actions by the authorities concerned.

4. Master Plan of Water Environmental Management

Future development scenarios describe how the water environment changes in the target year 2020 based on the projected rapid urban development. To cope with the water quality deterioration, alternatives include cases of environmental deterioration without action, of conventional sewage treatment approaches, and of realistic wastewater treatment measures, for the selection of optimum strategy. The optimum strategy shall be selected through such

comparative study, considering compliance with the future socioeconomic development of Vientiane.

The Master Plan has been formulated based on the above-mentioned strategy whose components are: (1) structural water improvement plan; (2) institutional and legal improvement plan; and (3) environmental education/hygiene education promotion plan.

Structural Water Improvement Plan

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

The Master Plan proposes comprehensive countermeasures in accordance with the causes of pollution and the applicability of these countermeasures. These are mainly: (1) administrative instructions to control the discharge of 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 banks of Nong Chanh against the highly polluted water of Hong Thong.

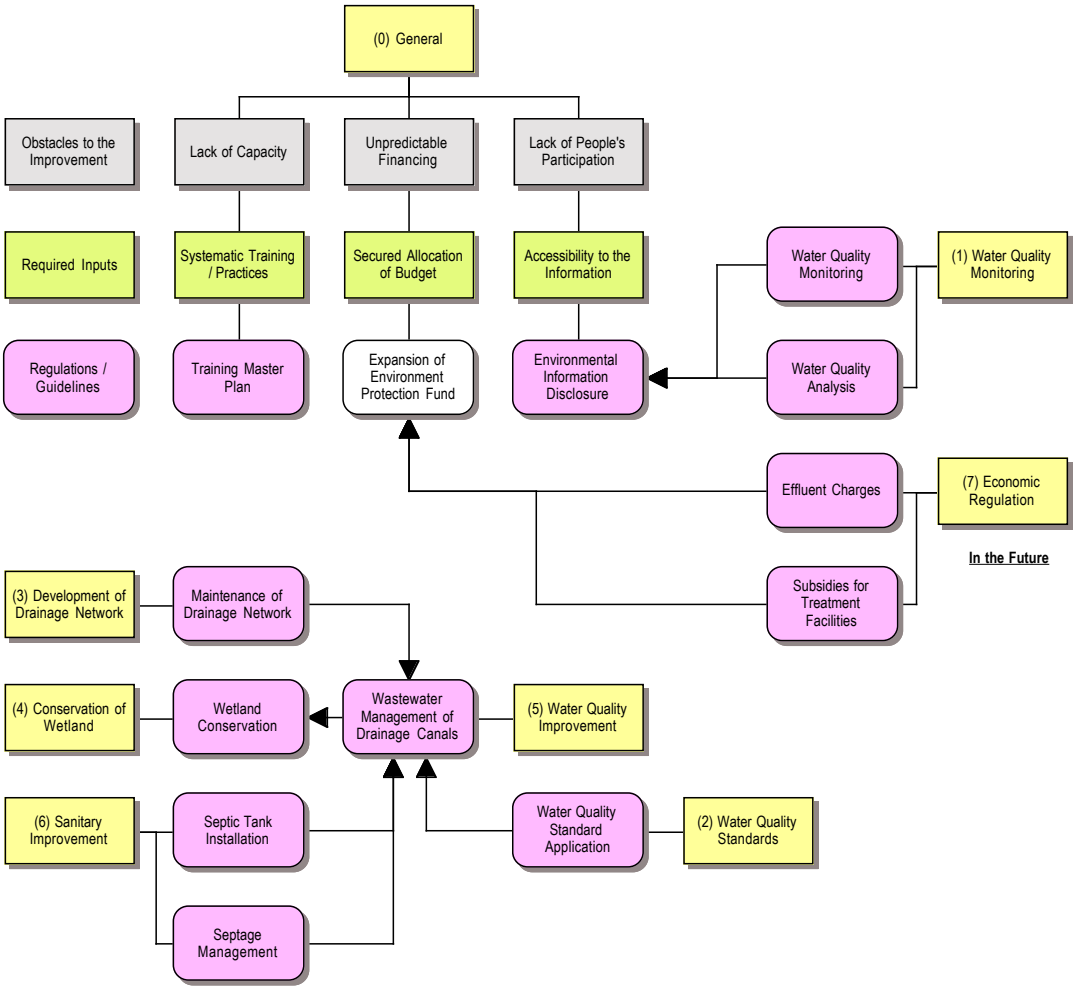
Structural Water Quality Improvement Components

Mak Hiao River Basin		Alternatives in Time Frame	
Divided Areas	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 retarding	Canal improvement for increased draining 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 for rebuilding or newly building	(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 for rebuilding or newly building
	Rural-type aggregated community	Installation of septic tank at the time for rebuilding or newly building	Installation of combined individual sewer system at the time for rebuilding or newly building
	Drainage canal	Construction of decentralized treatment facilities: (1) Construction of simple wastewater treatment plants collecting wastewater by local interceptors (2) Construction of in-stream contact aeration facilities (3) 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 Development	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 the developing areas or inside the 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 for rebuilding or newly building	Installation of combined individual sewer system at the time for rebuilding or newly building
	Rural villages	Wastewater Management	
		Installation of septic tank at the time for rebuilding or newly building	Installation of combined individual sewer system at the time for rebuilding or newly building

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 the various laws and bylaws established.

In the Master Plan, draft guidelines are proposed focusing on drainage management and sanitary improvement.



Relation among Regulations/Guidelines

Environmental/Hygiene Education Promotion Plan

Actions only by administrative bodies are not enough for preventing the deterioration of water quality of water discharged from Vientiane that cause irreversible destruction to the environment. Thus, the Environmental/Hygiene Education Promotion Plan aims to make residents (community people and children) able to take part in water environmental conservation by cooperating with the administrative bodies, through the enhancement of awareness on environmental conservation by environmental education.

Targeting pupils in primary schools and general residents in communities, environmental education activities has been made in parallel with the pilot project of constructing the

community/school based sanitation (CBS and SBS) facilities. Based on the experiences in conducting the above pilot projects, the expansion of activities in environmental education including training trainers is proposed in the Master Plan.

Activity Promotion Roadmap of Environmental Education

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

5. Recommendations

Clarified in the study period of 30 months were various points and issues, most of them incorporated in the Master Plan as issues to be solved or improved. Urbanization in Vientiane has been progressing rapidly and the natural environment of urban areas has been deteriorating accordingly. Fortunately, however, the natural environment in Vientiane is still remains remediable, but it is urgent to conserve them and to restore the lost ones at the earliest opportunity. The points and issues considered in this report are as summarized below, together with recommendations for future improvement of the 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 environmental improvement shall integrate manmade treatment facilities and the natural purification function of marshes, ponds and river courses as natural assets given to Vientiane communities from the physical improvement viewpoint. In this regard, the first step of improvement works through information/educational campaigns and publicity shall be started as early as possible to enhance the understanding of communities on the importance of conserving the precious environment. This process could easily link to the enhancement of people's awareness on environmental improvement.

(2) Prevention of Concrete Covering of Drainage Canals

Hong Thong receives wastewater and rainwater from the most congested areas of Vientiane, similar to Hong Pasak. It joins Hong Khoua Khao near the Nong Chanh Marsh, and then changes its name to Hong Ke. In the present circumstances, concrete slabs cover almost all stretches of Hong Thong. Although concrete covering is one of the alternatives to make people look away from the offensive odor and deteriorated scenery of the worsened water quality, difficulties on improving the water environment will come out due to the invisibility of existing conditions of water quality as well as the inability of conducting improvement works and of monitoring their effects. Conducting the possible improvement measures for water environment in a

~~–~~step-by-step" manner is thus recommended rather than removing the deteriorated environment from the urban residents' eye.

(3) Conservation of Marshes/Wetlands

Wastewater discharged from the urban areas flows down through the drainage system to the That Luang Marsh. The Mak Hiao River receives the surface water from the marsh, runs through the Na Khay Marsh and various pond 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 tail water, the BOD concentration of 30 mg/l could appear at the river mouth of the Mak Hiao even in year 2020, which could still be regarded as good water quality.

Rapid urbanization, however, has been progressing in/around the That Luang Marsh, so that the marsh areas and their functions should be conserved from the urbanization of Vientiane. Furthermore, the remaining marshes in the urban areas, such as Nong Chanh, Nong Ping, Nong Bo and Nong Tha, shall be conserved as well. Unless such conservation measures are implemented, similar urbanization processes, in which various wide mashes that existed in the past have been reclaimed into urban areas, would occur in the remaining marshes mentioned above.

(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. The strengthening of administrative guidance by the responsible agency(s) is necessary to solve such issues.

The enterprises have to follow the effluent standards through the installation of proper devices for wastewater treatment, in line with the administrative guidance. To attain the situation of clean water quality, efforts by various stakeholders, such as communities and government organizations, are indispensable. Thus through these well-functioning efforts, the related governments could gain high reliability to these communities.

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

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

The City Government of Vientiane as administrator of the drainage canal system should conduct maintenance work in the drainage system without any donors' technical and financial support. The management work shall consists of (a) dredging of accumulated sediment at the bottom of canals, if necessary; (b) proper management of vegetation in the canals based on site monitoring, giving due consideration to their natural purification functions; and (c) clarification and resolution of encountered issues based on periodical water quality monitoring in cooperation with WREA.

TABLE OF CONTENTS

Location Map
Summary
Table of Contents ..... **i**
List of Tables ..... **iii**
List of Figures ..... **iv**
List of Photos ..... **v**
Abbreviations ..... **vii**

Chapter 1. Introduction **1-1**

1.1 Background 1-1
1.2 Objectives 1-1
1.3 Study Area 1-1
1.4 Work Schedule 1-2
1.5 Work System 1-2
1.6 Reporting 1-3

Chapter 2. Basic Conditions of the Study Area **2-1**

2.1 Socio-Economic Condition 2-1
2.1.1 Socio-Economic Condition of Lao PDR 2-1
2.1.2 Socio-Economic Condition of the Study Area 2-2
2.2 Regulations and Institutions 2-6
2.2.1 Laws/Regulations on Water Environment 2-6
2.2.2 Organizations/Institutions Related to Water Environment 2-11
2.3 Environmental Education 2-16
2.3.1 Environmental Education in Existing Related Projects 2-16
2.3.2 Community and Education System of Vientiane 2-17
2.4 Hydrology 2-22
2.4.1 Natural Conditions 2-22
2.4.2 Storm Runoff Analysis 2-27
2.4.3 Low Flow Analysis 2-29
2.5 Drainage Network 2-32
2.5.1 Review of Previous Studies and Projects 2-32
2.5.2 Drainage System 2-34
2.6 Water Quality 2-39
2.6.1 Methodology of Water Quality Monitoring 2-39
2.6.2 Monitoring Results 2-43
2.6.3 Industrial Wastewater 2-47
2.6.4 Water Quality Modeling 2-48
2.7 Aquatic Biology 2-50
2.7.1 Survey Objectives and Methodology 2-50
2.7.2 Relation between Water Quality and Aquatic Species 2-51
2.7.3 Developing Biological Indicator 2-56
2.7.4 Target of Water Quality Improvement for Aquatic Organisms 2-59
2.8 Water Purification Effects of Water Plants in Drainage Canals 2-61
2.8.1 Background and Objectives 2-61
2.8.2 Outdoor Experiments and Findings on Water Purification 2-61
2.8.3 Water Quality Improvement Using Water Spinach 2-63

Chapter 3. Pilot Project 3-1

3.1 Community and School Based Sanitation 3-1
3.1.1 Background 3-1
3.1.2 Project Site Selection 3-1
3.1.3 Objectives and Beneficiaries 3-4
3.1.4 Designing of CBS and SBS 3-4
3.1.5 Management Structure for CBS and SBS 3-7
3.1.6 Operation and Maintenance 3-7
3.1.7 Evaluation of Functions of CBS and SBS 3-7
3.2 Water Environment and Hygiene Education 3-9
3.2.1 General 3-9
3.2.2 Development and Dissemination of Side Reader 3-11
3.2.3 TOT Workshop at Project Site 3-12
3.3 Lessons Learnt through the Pilot Project 3-16

Chapter 4. Draft Master Plan of Water Environmental Management 4-1

4.1 Planning Considerations 4-2
4.1.1 Framework Setting in the Target Year 2020 4-2
4.1.2 Projection of Water Quality at the Target Year (2020) 4-3
4.1.3 Present and Future Issues for Improvement 4-5
4.2 Strategy on Water Environment Improvement 4-8
4.2.1 Goal and Objectives 4-8
4.2.2 Overall Targets on Water Quality 4-8
4.2.3 Needs of Comprehensive Approach 4-11
4.3 Alternative Study on Structural Measures for Water Improvement 4-12
4.3.1 Alternative Structural Measures 4-12
4.3.2 Combination of Structural Alternatives 4-13
4.3.3 Comparative Study on Alternatives through Water Quality Simulation 4-14
4.3.4 Comparative Study Results 4-17
4.4 Master Plan for Water Environment Management 4-20
4.4.1 Master Plan Structure 4-20
4.4.2 Structural Water Environment Improvement Plan 4-20
4.4.3 Institutional and Legal Improvement Plan 4-29
4.4.4 Water Environment and Hygiene Education Promotion Plan 4-38
4.4.5 Action Plan 4-41

Chapter 5. Pre-feasibility Study 5-1

5.1 Background, Study Objectives and Selection of Study Area 5-1
5.1.1 Background and Study Objectives 5-1
5.1.2 Selection of Study Area 5-1
5.2 Sanitary Conditions in the Priority Area 5-2
5.2.1 Sampling Data 5-2
5.2.2 Sanitary Conditions 5-3
5.3 Possibilities of Improvement on Water Environment 5-3
5.3.1 Preliminary Design 5-3
5.3.2 Water Quality Improvement Effects 5-5
5.3.3 Cost Estimate 5-6

Chapter 6. Recommendations 6-1

LIST OF TABLES

Table 1.1 Reports on the Study 1-3
Table 2.1 Sixth Plan vs. Fifth Plan Targets/Achievements 2-1
Table 2.2 Population Projections for Lao PDR (2005-2020) 2-2
Table 2.3 Projections of GDP Growth Rate in Lao PDR (Industrial Zone Survey, 2009) 2-2
Table 2.4 Population Projection for the Study Area in 2020 2-3
Table 2.5 GRDP Estimation for Vientiane until 2020 2-3
Table 2.6 Outline of New Development Plans in the Study Area 2-4
Table 2.7 Present Authorized Surface Water Quality Standard 2-8
Table 2.8 Authorized Wastewater Discharge Standard for Factories in General, Lao PDR 2-9
Table 2.9 Authorized Standards of Wastewater Discharge in Urban Area, Lao PDR 2-9
Table 2.10 Building Categorization 2-10
Table 2.11 Main Responsibilities and Number of Personnel of DOE 2-11
Table 2.12 Main Responsibility and Number of Personnel of Public Works and Transport Institute, MPWT 2-12
Table 2.13 Basic Data at Meteorological Stations 2-22
Table 2.14 Basic Statistics of Rainfall Data 2-23
Table 2.15 Standard Runoff Coefficient 2-27
Table 2.16 Parameters of Rainfall Intensity Formula 2-27
Table 2.17 Flow Regime Simulation Conditions 2-29
Table 2.18 Simulated Flow Regime 2-31
Table 2.19 Objective Drainage Channels of VIUDP 2-33
Table 2.20 Objective Drainage Channels of VUISP 2-33
Table 2.21 Principal Features of Drainage System in the Urban Area of Vientiane 2-37
Table 2.22 Drainage Gates of the Mak Hiao River 2-37
Table 2.23 Number of Periodical Monitoring Points 2-39
Table 2.24 Location of Periodical Monitoring Points 2-39
Table 2.25 Frequency of the Periodical Monitoring of Drainage Channels 2-41
Table 2.26 Water Quality Parameters for Periodical Monitoring 2-41
Table 2.27 Number of Points for Simultaneous Longitudinal Monitoring 2-41
Table 2.28 Location of Simultaneous Longitudinal Monitoring 2-42
Table 2.29 Frequency of Longitudinal Monitoring 2-43
Table 2.30 Water Quality Parameters for Simultaneous Longitudinal Monitoring 2-43
Table 2.31 Survey Results of Existing Factories in the Study Area 2-47
Table 2.32 Pollution Load Generation and Runoff (2009) 2-49
Table 2.33 Biological Survey Point 2-50
Table 2.34 Overall Frequency of the Biological Survey 2-51
Table 2.35 Range of Water Quality and Indicative Species 2-57
Table 2.36 Biological Indicator for Stream Water Quality 2-58
Table 3.1 Integrated Selection of Candidate Sites for Joint Pilot Project 3-2
Table 3.2 Beneficiaries of CBS and SBS 3-4
Table 3.3 Participatory Approaches for CBS and SBS 3-4
Table 3.4 Design Conditions for CBS and SBS 3-5
Table 3.5 Results of Water Quality Test 3-8
Table 3.6 Joint Activities and Meetings with LIRE-BORDA in Phase II 3-10
Table 3.7 Table of Contents of Developed Side Reader 3-11
Table 3.8 Dissemination of Side Reader to Relating Agencies 3-12
Table 3.9 Program of School TOT Workshop 3-13
Table 3.10 Program of Community TOT Workshop 3-13
Table 4.1 Population Projection in Vientiane 4-2

Table 4.2 Estimated GRDP in Vientiane 4-2
Table 4.3 Estimated Per Capita GRDP in Vientiane 4-3
Table 4.4 Pollution Load Generation by Category (2009 and 2020) 4-3
Table 4.5 Pollution Load Generation by Basin (2020) 4-4
Table 4.6 Pollution Load Generation by Basin and Category (2020) 4-4
Table 4.7 Surface Water Quality Standards for Fishery in the Asian Countries 4-9
Table 4.8 Planning Water Quality Targets 4-11
Table 4.9 Possible Alternative Structural Measures 4-15
Table 4.10 Comparative Study Results 4-17
Table 4.11 Cost Estimation for Alternative Treatment Systems 4-18
Table 4.12 Comparative Evaluation of Alternative Treatment Systems 4-18
Table 4.13 Structural Water Quality Improvement Components 4-21
Table 4.14 Responsible Body and Major Issues on Structural Measures 4-23
Table 4.15 Short- and Mid-term Stepwise Plan on Structural Water Improvement of Drainage Network 4-29
Table 4.16 Work and Budgetary Allocation on the Structural Water Improvement 4-29
Table 4.17 Menu of Development Regulations/Guidelines to be Considered 4-31
Table 4.18 Existing Laws/Regulations on Wastewater 4-32
Table 4.19 Proposed Domestic Wastewater Management Framework 4-34
Table 4.20 Implementing Schedule 4-38
Table 4.21 Activity Promotion Roadmap of Environmental Education (Summary) 4-39
Table 4.22 Activity Promotion Roadmap of Environmental Education 4-40
Table 4.23 Water Environmental Management Action Plan 4-41
Table 5.1 Sub-Drainage Basin and Population in Hong Pasak Drainage Basin 5-2
Table 5.2 Sampling Data from the Upper and Middle Reaches of Hong Pasak 5-3
Table 5.3 Design Conditions for WTP 5-5
Table 5.4 Cost Estimate for Wastewater Treatment System in the Pre-F/S Area 5-6

LIST OF FIGURES

Fig. 1.1 Overall Study Schedule 1-2
Fig. 2.1 Location Map of Four (4) New Development Areas 2-4
Fig. 2.2 Location of City Walls Built by the Lanexang Kingdom 2-5
Fig. 2.3 Organizational Chart of District Office 2-18
Fig. 2.4 Organizational Chart of Village Office 2-19
Fig. 2.5 Organizational Chart of Department of Education, Vientiane 2-20
Fig. 2.6 Organizational Chart of District Educational Office 2-20
Fig. 2.7 Locations of Meteorological Station 2-22
Fig. 2.8 Distribution of Monthly Rainfall 2-23
Fig. 2.9 Monthly Evaporation and Temperature (Vientiane) 2-23
Fig. 2.10 Land Use (year 2000) 2-24
Fig. 2.11 Land Use Ratio (2000) 2-25
Fig. 2.12 Mak Hiao River Basin (Near Future Condition) 2-26
Fig. 2.13 Result of Storm Runoff Analysis 2-28
Fig. 2.14 Results of Calibration (MP1 and MP2) 2-30
Fig. 2.15 Rainfall and Water Level of Mekong River in August 2008 2-35
Fig. 2.16 Drainage System in the Urban Area of Vientiane 2-36
Fig. 2.17 Location of Periodical Monitoring Points (Entire Basin) 2-40
Fig. 2.18 Location of Periodical Monitoring Points (Urban Center) 2-40
Fig. 2.19 Location of Simultaneous Longitudinal Monitoring 2-42
Fig. 2.20 Schematic Diagram of BOD in Periodical Monitoring (July 2010) 2-44
Fig. 2.21 Schematic Diagram of BOD in Periodical Monitoring (November 2010) 2-44
Fig. 2.22 Schematic Diagram of BOD in Longitudinal Monitoring (November 2010) 2-46

Fig. 2.23 Relations of Observed and Estimated Stream Flow....2-48
Fig. 2.24 Relations of Observed to Estimated BOD....2-48
Fig. 2.25 Pollution Load Generation and Runoff in 2009....2-49
Fig. 2.26 Location of Biological Survey Points....2-51
Fig. 2.27 Water Quality Classification of the Mak Hiao River Basin....2-52
Fig. 2.28 Seasonal Changes of Observed Water Quality....2-53
Fig. 2.29 Seasonal Changes of Average BOD in the Urban Drainage....2-53
Fig. 2.30 Total Number of Fish Species Observed during the Eight Surveys....2-54
Fig. 2.31 Number of Fish Species except Pollution Tolerant Species (Guppy and Mosquitofish) in the Urban Area....2-54
Fig. 2.32 Relationships between BOD and Number of Fish Species except Pollution Tolerant Species in the Urban Area....2-54
Fig. 2.33 Number of Individuals and Wet Weight of Collected Benthic Invertebrates....2-55
Fig. 2.34 Categorization of Aquatic Plant Living Style....2-56
Fig. 2.35 Number of Plant Species Categorized by Living Styles....2-56
Fig. 2.36 Observed BOD and Target Water Quality in the Urban Drainages....2-60
Fig. 2.37 Target of Water Quality Improvement of the Mak Hiao River Basin....2-60
Fig. 2.38 Areas for Outdoor Experiment....2-62
Fig. 2.39 Schematic Mechanism of Water Purification by Water Spinach....2-64
Fig. 2.40 Number of Fishes in Accordance with Bank Type....2-64
Fig. 3.1 Location of Two Selected Pilot Project Sites....3-3
Fig. 3.2 Layout of CBS Sewer Network Plan....3-5
Fig. 3.3 Layout of SBS Sewer Network Plan....3-6
Fig. 3.4 Structural Design of SBS for Khoualuang Primary School....3-6
Fig. 4.1 Projection of Water Quality Change from 2009 toward 2020....4-5
Fig. 4.2 Total Number of Fish Species Observed in the Eight Surveys from 2009 to 2010....4-9
Fig. 4.3 Schematic Diagram of Water Quality Classification along the Mak Hiao River System....4-10
Fig. 4.4 Relationship between Water Quality Classification from Aquatic Biology Survey and Monitored Water Quality....4-10
Fig. 4.5 Comparison of Projected BODs of the Alternatives....4-17
Fig. 4.6 Projected BOD at Present, with No-Action in Future and with Optimum Plan in Future....4-19
Fig. 4.7 Interaction among Three Master Plan Components....4-20
Fig. 4.8 Mid- and Long-Term Interaction among Three Master Plan Components....4-26
Fig. 4.9 Artificial Wetland Concepts proposed by the WWF....4-27
Fig. 4.10 Relation among the Regulations/Guidelines....4-30
Fig. 5.1 Hong Pasak Drainage Basin....5-2
Fig. 5.2 Locations of WTP and Interceptor....5-4
Fig. 5.3 Typical Cross Section of WTP (Anaerobic Treatment Plant)....5-5
Fig. 5.4 BOD Estimated With/Without Project....5-5
Fig. 5.5 Plan and Typical Cross Section of WTP (T1)....5-7
Fig. 5.6 Plan and Typical Cross Section of WTP (T5)....5-8

LIST OF PHOTOS

Photo 2.1 Supplementary Readings by WREA-SIDA Project....2-16
Photo 2.2 Mekong River Integrated Management Project....2-34
Photo 2.3 August 2008 Flood....2-36
Photo 2.4 Drainage Gates of the Mak Hiao River....2-37
Photo 2.5 Imaged Quantitative Analysis in Outdoor Experiment....2-62
Photo 2.6 Condition of Roots of Water Spinach....2-63

Photo 2.7 Snails and Dragonfly in Canal....2-65
Photo 3.1 Wastewater Sampled from CBS/SBS on 25 May 2011 3-8
Photo 3.2 Scenes of School TOT Workshop (Khoualuang Primary School)....3-14
Photo 3.3 Scenes of Community TOT Workshop (Unit 11-13, Thongkhankham Village).3-15

SCOPE OF WORK AND MINUTES OF MEETINGS

ABBREVIATIONS AND ACRONYMS

Organizations

ADB	:	Asian Development Bank
BORDA	:	Bremen Overseas Research and Development Association
CIDA	:	Canada International Development Agency
DANIDA	:	Danish International Development Assistance
DPRA	:	Development Project Responsible Agency
EDCF	:	Economic Development Cooperation Fund
EU	:	European Union
IEC	:	International Electro-technical 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
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
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
VC	:	Vientiane City
DI	:	Department of Industry
DOE	:	Department of Education
DOH	:	Department of Health
DPWT	:	Department of Public Works and Transport
WREO	:	Water Resources and Environmental Office
VEU	:	Village Environment Unit
VUDAA	:	Vientiane Urban Development Administration Agency
WB	:	The World Bank
WHO	:	World Health Organization
WREA	:	Water Resource Environment Agency
DMH	:	Department of Meteorology and Hydrology

DOE	:	Department of Environment
EQMHCC	:	Environmental Quality Monitoring and Hazardous Chemical Center
WERI	:	Water Resources and Environment Research Institute
WTO	:	World Trade Organization
WWF	:	Worldwide Fund for Nature

Programs and Projects

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

Technical Terms

BOD	:	Biochemical 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
SRTM	:	Shuttle Radar Topography Mission
SS	:	Suspended Solid
STP	:	Sewage Treatment Plant
TDS	:	Total Dissolved Solids
TSS	:	Total Suspended Solids
TKN	:	Total Kjeldahl Nitrogen
WTP	:	Wastewater Treatment Plant

Others

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
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
PM	:	Prime Minister
SEA	:	South East Asia
SLSC	:	Sub-Least Square Criterion
TCP	:	Teachers-Children-Parents
TOT	:	Training of Trainers
U/S, u/s	:	Upstream
WQMNS	:	Water Quality Monitoring Network System

CHAPTER 1. INTRODUCTION

1.1 Background

Vientiane, the capital of the Lao People's Democratic Republic (Lao PDR), has the population of about 0.7 million in 2005. The drainage facilities installed mainly with aid from the Asian Development Bank (ADB) have been improved to a certain extent in accordance with the findings of the "**Feasibility Study on Improvement of Drainage System in Vientiane (JICA; 1989)**." However, the water quality of surface water and the remaining marshes has been getting worse and water quantity has been increasing due to inflow of domestic wastewater from urban areas as a result of improved living standards, rapid economic growth, and population increase. The urbanization trend will continue in parallel with large-scale infrastructural development projects like the industrial park, the facilities for the South East Asian Games (SEA Games), urban development projects and so on.

In view the present condition of the drainage system network in Vientiane, the Government of Lao PDR had requested development assistance from the Government of Japan. This project called as **"The Study on Improvement of Water Environment in Vientiane City"** (hereinafter, "**the Study**") was thus initiated by the Government of Japan, in December 2007, to formulate the Master Plan of Improvement of the Water Environment in Vientiane, which includes countermeasures for the worsening hygienic environment, as well as the formulation of environmental conservation measures for the That Luang Marsh, which plays a very important role in the natural purification of rivers.

1.2 Objectives

The objectives of the study are as recapitulated below:

(1) Considering the existing conditions of water environment in the study area, a master plan for water environment management shall be formulated in order to improve the hygienic environment and to conserve the natural purification function of the Mak Hiao River basin, and

(2) The knowledge and technologies in formulation of water environment management plan shall be transferred to Lao counterparts through the implementation of the study.

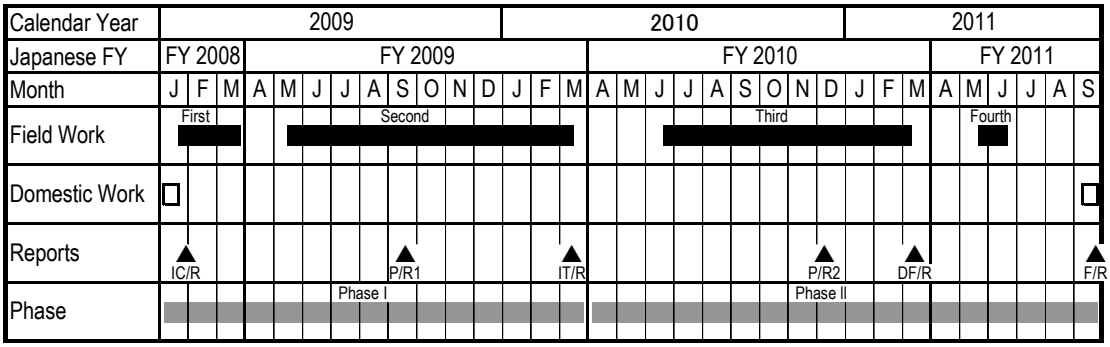
The ultimate plan of the Study is to utilize the above-mentioned Master Plan for urban development projects in Vientiane so as to ensure the sanitary condition and health of its communities.

1.3 Study Area

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

1.4 Work Schedule

The Study is to be carried out in accordance with the schedule shown in **Fig. 1.1**. The study period is thirty (30) months. Various reports are to be submitted periodically, as shown in the schedule.



(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. 1.1 Overall Study Schedule

1.5 Work System

A steering committee is to be established to coordinate the activities of all relevant authorities in water environmental management with PTI as the Secretariat. Summarized below are the objectives, activities, Committee Members, etc., of the Steering Committee.

Objectives	To give support and advice necessary for the Study; To advise on the basic direction of the Study To coordinate the role of organizations relevant to the Study
Activities	To confirm the direction of the study To provide consultation and approval of various reports submitted by the JICA Study Team To evaluate the technology transfer services
Committee Members	Ministry of Public Works and Transport (MPWT); Vientiane City Government; 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 of Vientiane; Education Department of Vientiane
Frequency of Steering Committee Meetings	Three (3) times in Phase I; Three (3) times in Phase II; (A steering committee meeting is to be held after submission of each report.)
Secretariat	Public Works and Transport Institute (PTI)
Venue of Meetings	Ministry of Public Works and Transport (MPWT)
Cost	To be shared among the participating members
Roles of Secretariat	To prepare agenda and schedule of meetings, and contact participants; To prepare meeting materials and manage the meetings; To explain the study and prepare minutes of meetings
Roles of JICA Study Team	To provide support on the preparation of agenda and handouts; To support the explanation of the Study and the minutes

1.6 Reporting

The JICA Study Team is to prepare and submit the reports listed in **Table 1.1** to the Government of Lao PDR, in both hard and digital copies**.**

Table 1.1 Reports on the Study

Reports to be Submitted	Schedule for Submission	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 CONDITIONS OF THE STUDY AREA

2.1 Socio-Economic Condition

2.1.1 Socio-Economic Condition of Lao PDR

(1) National Socio-Economic Development Plan

The currently existing National Development Plan is the Sixth Five-Year National Socio-Economic Development Plan which covers the year 2006 to 2010. Its goals are as follows:

- To accelerate economic growth and improve the people's quality of life;
- To further build the market economy with a socialist orientation, and continue to enlarge and develop effective external economic relations;
- To create breakthrough changes in education and training in terms of quality and quantity;
- To develop culture and society in synchrony with economic growth;
- To continue poverty reduction, creating jobs, and eliminating social evils;
- To continue strengthening the socio-economic infrastructure as fundamentals for the socio-economic development; and
- To maintain political stability and social security.

In order to achieve the goals of the Sixth National Development Plan, targets have been set, as shown below where the targets and achievements of the Fifth Five-Year Plan (2001-2005) are compared.

Table 2.1 Sixth Plan vs. Fifth Plan Targets/Achievements

Items	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 percentage of GDP	5%	6%	9.4%
Inflation rate	6-6.5%	<10%	9.6%
Budge deficit as percentage of GDP	6.07% (5 yr average)	6%	7.4%
GDP per capita (2005)	USD700-750	USD500-550	USD491
Total population (2005)	6.17 million (2010)	5.9 million	5.61 million (2005)
Population growth rate	1.91% (5 yr average)	—	2.0% (5 yr average)
Proportion of poor households (2005)	<15%	20-25%	28.7%
Primary school enrolment (2005)	90.6%	86%	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

(2) Population

It has been agreed that, for JICA study projects presently implemented for Lao PDR and/or Vientiane, socio-economic macro data including population forecasts and GDP growth rate should take into account those employed in the "Preparatory Survey on Industrial Zone Development in the Lao PDR". The Preparatory Survey has the population projections shown below.

Table 2.2 Population Projections for Lao PDR (2005-2020)

	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

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

(3) GDP

As stated above, the forecast on GDP growth has to take into account the results of the Industrial Zone Survey. The Industrial Zone Survey had projected the GDP growth rates shown below.

Table 2.3 Projections of GDP Growth Rate in Lao PDR (Industrial Zone Survey, 2009)

	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

2.1.2 Socio-Economic Condition of the Study Area

(1) Population in the Study Area

The population projection for the year 2020 was made as follows. At first, the population of the Study Area in 2005 is calculated together with that of Vientiane (see, Population and Housing Census 2005). Then, the population for the succeeding years until 2020 is increased and/or decreased for each village at the same annual average rates between 1995 and 2005. When the projection of the Industrial Zone Survey is considered, the population in the Study Area is adjusted at the ratio of the two projections for Vientiane in the same year in order to coincide with that of the Industrial Zone Survey.

The results of the population projection are as summarized in the following table.

Table 2.4 Population Projection for 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

[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 the population of the 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

(2) GRDP of Vientiane

The estimation of GRDP of Vientiane is referred to that of the Industrial Zone Survey in 2009. The Industrial Zone Survey carried out the GRDP estimation, as shown below.

Table 2.5 GRDP Estimation for Vientiane until 2020

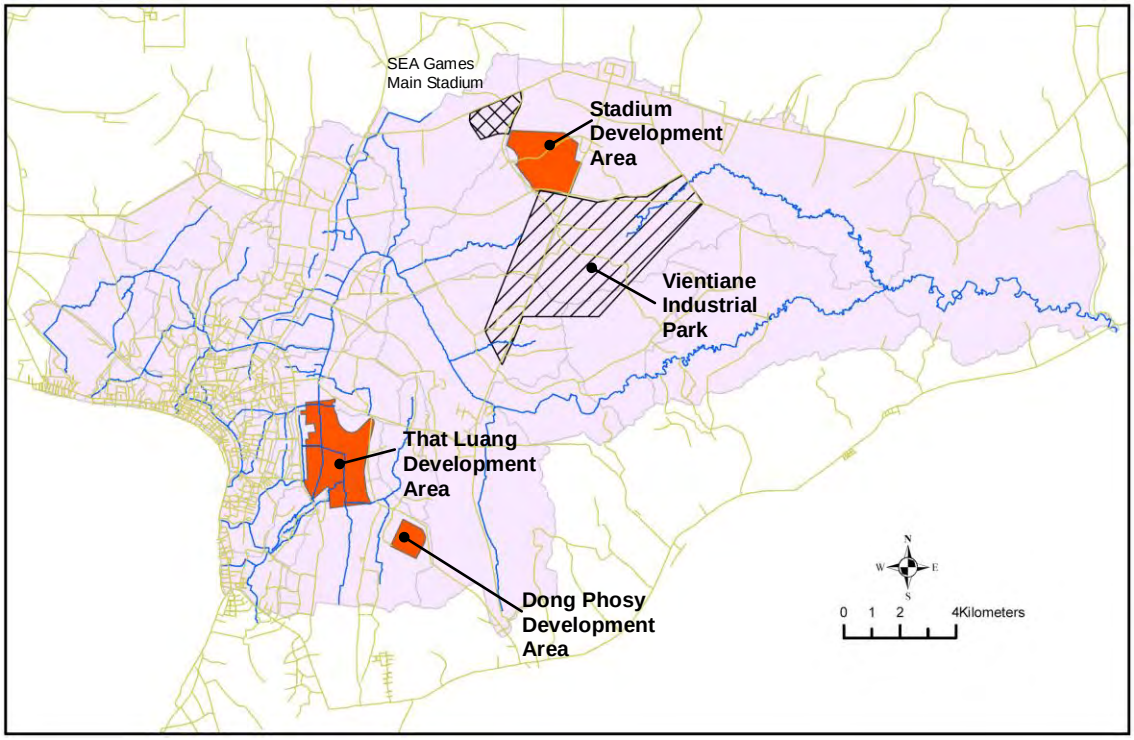
(Unit: constant in 2008 price, billion KIP)

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

[1)] Since the Industrial Zone Survey presented only the data in 2015 and 2025, the data in 2020 was calculated in the Study 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

(3) Development Plan in the Study Area

In the Study Area, a new development plan for four (4) areas (That Luang Development area, Dong Phosy Development Area, Stadium Development Area and Vientiane Industrial Park), is being formulated. The locations of these areas are as shown in the following figure.



Source: PTI and JICA Study Team

Fig. 2.1 Location Map of Four (4) New Development Areas

During the Study, land-use plans were being formulated as shown in the following table, but the population projection was not available or under preparation. The plan for the Vientiane Industrial Park has been prepared under JICA's "Preparatory Study on Industrial Zone Development in the Lao People's Democratic Republic."

Table 2.6 Outline of New Development Plans in the Study Area

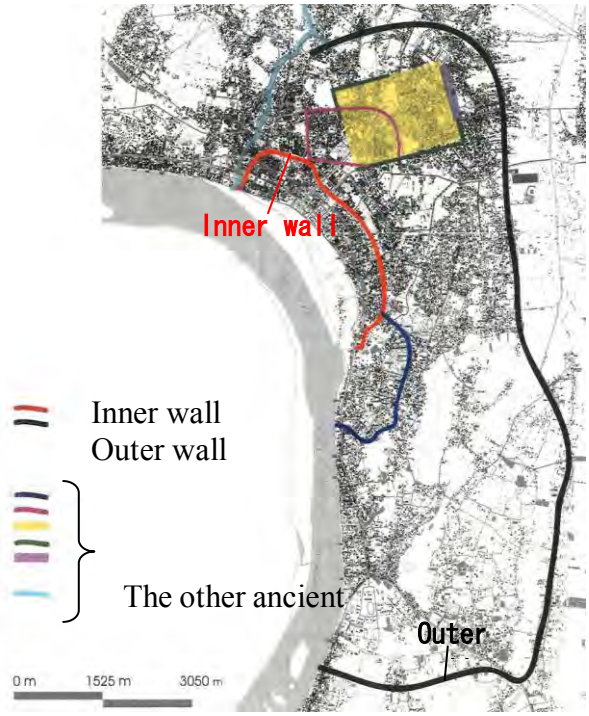
	Area	Area (ha)					
		Total	Residential	Industrial	Public facilities	Untrans-ferable	Others
1	That Luang Dev't. Area	670.0	230.2	-	71.1	368.1	0.6
2	Dong Phosy Dev't. Area	100.0	41.1	-	4.1	54.8	0.0
3	Stadium Dev't. Area	430.0	129.9	58.7	58.2	150.9	32.3
4	Vientiane Industrial Park	2,000.0	286.0	1,540.0	-	-	174.0[1)]
	Total	3,200.0	687.2	1,598.7	133.4	573.8	206.9

[1)] Commercial, Amenity and Logistics Area
Source: PTI and JICA Study Team

(4) Cultural Heritage in the Study Area

The history of the capital city of Vientiane began in the sixteenth century, when the Lanexang Kingdom moved the capital from Luang Prabang to Vientiane. The Kingdom built a city wall (inner wall) around the area facing the Mekong River and settled inside the wall; therefore, the area inside 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 had collapsed because it was made of earth.

Regarding the outside of the city wall, only some information related to the historical heritage has been obtained although some "*stupas*" have been discovered at the east and south of That Luang Marsh. In case heritages are found during construction, they must be dealt 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. 2.2 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 formulated in 2004 with assistance from SIDA. To realize environmental management, this strategy has the following objectives:

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

(2) Environmental Protection Law (EPL)

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

(3) Decree of Environmental Impact Assessment

The amended Decree on Environment Impact Assessment (No. 112/PM.) was approved by the Prime Minister in March 2010. All public and private investment projects, both domestic and foreign, which are operated in Lao PDR have to follow the process to minimize impacts against sustainable development.

In accordance with the screening criteria set under the Minister's Order No. 697/PM.WREA issued in March 2010, the requirement for 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.

(4) Regulation on Wastewater Discharge from Industrial Processing Factories

This regulation was issued by the Minister of Industry and Handicraft (presently, Ministry of Industry and Commerce) in 2005. If a factory environmental inspector finds any factory discharging wastewater or any other waste into any public area, which is harmful or has a negative impact on ecology and people's health, living things or any property, the inspector notifies factory owner of the violation and cancel the certificate of wastewater discharge of the factory. The Director of Industry Department of the Ministry or Province can suspend or terminate the wastewater discharge activity of any factory that violates this regulation until the factory has improved its wastewater treatment system to comply with the standards.

(5) Water Supply Law

The Water Supply Law was approved by the National Assembly in November 2009, but almost all of the stipulations are on water supply services. Sanitation and sewerage matters are planned to be stipulated by decrees which will be prepared. Since the law was approved, the revision work of Water Resources Law was initiated by WREA with assistance from ADB. The final draft of the framework for the new water resources policy was published in May 2009.

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

This decree was issued with assistance from SIDA in 2005, and implemented by WREA. In case that affected people (AP) 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 land for land, which means that compensation should guarantee at least the same living and business conditions.
- Those who do not have any legal land use certificate are assured that they will not be pushed aside 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 months to one year after completion of the implementation of resettlement.

(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 consultations with the related organizations mentioned below were made regarding these water quality standards, they were basically established by WREA.

The revision work on the Environmental Standards in Lao PDR, not only for water quality but also air quality as well as noise was started in 1999 by the Technical Working Group (TWG) whose 37 members come from 13 related agencies. A Technical Consultation Workshop was held in December 2008 for the TWG members. A National Consultation Workshop followed in April 2009, inviting 170 people including central and provincial government agencies. Concerning the surface water standards, it was agreed to employ the same standard adopted by the MRC countries in May 2009. Finally, the revised Standards were issued on December 7, 2009 as the "Present Authorized Environmental Standards."

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 2.7 Present Authorized Surface Water Quality Standard

No.	Parameter	Unit	Standard Value
1	Color, Odor, Taste	-	Natural Level
2	Temperature	°C	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	µg/l	1.0
26	α BHC	µg/l	0.02
27	Dieldrine	µg/l	0.1
28	Aldrin	µg/l	0.1
29	Heptachlor & Heptachlor epoxide	µg/l	0.2
30	Endrin	µg/l	ND

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

This surface water standard is so strict that it is very difficult to satisfy it for the rivers in Vientiane, considering the present situations. For example, the BOD_5 standard value (1.5 mg/l) is usually observed only in mountain streams in rural areas. A more realistic and reasonable value for BOD_5 was thus examined and employed in the Master Plan of the Study.

The following table shows the "Authorized Wastewater Discharge Standard for Factories in General" being enforced at present.

Table 2.8 Authorized Wastewater Discharge Standard for Factories in General, 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	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 following table shows the Authorized Standards of Wastewater Discharge in Urban Area being enforced at present.

Table 2.9 Authorized Standards of Wastewater Discharge in Urban Area, Lao PDR

No.	Parameter	Unit	Permissible Values				
			A	B	C	D	E
1	BOD_5	mg/l	20	30	50	60	200
2	Suspended Solids	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	°C	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 PDR, December 7, 2009, Prime Minister's Office and WREA in Lao PDR.

Table 2.10 Building Categorization

No.	Building Type	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
Building Usage			
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
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 applied to the Study, the definition of the drainage canal in the Study Area is not clear; therefore, wastewater management in the canals might be ineffective. On the other hand, water quality in the canals is getting worse mainly due to untreated or insufficient treated wastewater from the houses, factories, and farmlands.

2.2.2 Organizations/Institutions Related to Water Environment

(1) National Environment Committee (NEC)

The National Environment Committee was established in 2002, where the chairman is 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. Its responsibility is to coordinate the plans, management and monitoring on environment at the national level.

(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 (WREI). Among them, DOE promotes the formulation of environmental laws, especially standards. Present organization structures of WREA and DOE, which was officially approved in March 16, 2009, are shown below.

Detailed organization, responsibility and number of personnel of DOE are summarized in the following table. The actual number of full time staff of the Water Pollution Control Unit is only three. It is actually a severe shortage of human resources for water environmental management in Lao PDR.

Table 2.11 Main Responsibilities and Number of Personnel of DOE

Division/Office	Main Responsibility	Fulltime 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

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

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

- To control water quality (river water, groundwater, wastewater);
- To conduct research on 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.

REA Lab has a total of 11 personnel and all of them are holders of a Bachelor's degree. The Water Quality Monitoring Unit has only 3 members. They face a lot of problems on monitoring practices because their capacity is underdeveloped. Furthermore, the Lab is developing/updating the quality assurance/quality control (QA/QC) system and Standard Operation Procedures (SOPs) aiming to obtain an ISO/IEC 10725 certificate.

(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.

(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 of study and evaluation services on urban planning as well as training on environmental management. Detailed organization, responsibility and number of personnel are summarized in the following table.

Table 2.12 Main Responsibility and Number of Personnel of Public Works and Transport Institute, MPWT

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

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

Water resources and environmental offices (WREOs) are provincial and Vientiane's (the same level as Province) counterpart of the WREA.

The WREO of Vientiane has three units; namely, Administration Unit, Water Resources Unit, and Environment Unit. There is one Director and two Deputy Directors, and each unit has 5 staff members. The WREO of Vientiane is under the Office of the Governor of Vientiane.

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

The total number of district staff members in 9 districts is 12; at least one staff member is located in each district office for all tasks including all kinds of environmental quality and water resources.

WREO makes no initiative for coordination with other related organizations when a law/regulation is prepared. 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 on Vientiane was established in 1997 and similar offices were established in the other four provinces which are relatively developed in economy for the promotion of local administration. VUDAA includes 189 villages belonging to 4 districts; namely, Chanthabuly, Sikhottabong, Xaysetha and Sisattanak. Under the control of the Office of the Governor of Vientiane, it offers various administrative services, management, formulation and implementation of urban plans, which are included in the urban master plan of PTI.

Two items closely related to water environment are as described below.

[Sanitary Toilet]

Control of desludging companies is made by VUDAA and DPWT 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 Department of Industry and Commerce. No clear responsibility for sanitary toilet management is stipulated between VUDAA and DPWT.

There is a pond for the night soil damping. It is located in the new damping site at Na Pa Souk Village, which is 32 km from the center of Vientiane. Its size is 200m x 200m without a treatment facility. It was formally dumped in the EU Pond but it was moved to the new site as many claims of odor were presented.

[Solid Waste]

One unit of VUDAA and five units of private companies are providing solid waste collection services using a total of 45 collection vehicles. A VUDAA unit covers 32,345 households and that of 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 collection service. There is a regulation on the solid waste collection service and licensing system.

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

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

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

DPWT is vested with the responsibility for administrative works that are not in VUDAA's jurisdiction, which includes the remaining 391 villages of Vientiane. Its responsibility includes the following items:

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

The new Housing, Urban Planning and Environment Unit in DPWT also work on environment and water resources. The number staff is 4. Its detailed responsibility on environmental affairs is yet to be stipulated by a decree.

(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 offices, the Industrial Environment Division closely relates to water environment. The Industrial Environment Division has 6 units and 6 staff members in total. Staff members are industrial wastewater inspectors and not one of them is assigned to a particular unit. The Ministry's Department of Industry is responsible for the large-scale and some medium-scale ones which have problems. The Provincial Department of Industry and Commerce is responsible for medium-scale ones and small-scale ones. No regular meeting is held with WREA, but when an environmental problem pops out, the two agencies work together.

Factories having no problem are inspected 2 times a year while factories with problems undergo inspection every month. When an inspector conducts an inspection for a factory, staffs of the Provincial DI, Provincial WREO, District Office of Industry and Commerce, Head of Village and factory go with the inspector. Wastewater samples are sent to the laboratory of WREI or the Ministry of Irrigation and the wastewater analysis report is provided to the factory together with the comments of DI.

Since large-scale factories are required to submit an environmental management plan (EMP) according to the Decree on EIA for Industrial Sector, the inspection is 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 discharged from factories. It has 10 staff members. It also issues a business certificate for factories.

In Vientiane, there are 2,060 factories, which are middle to small-scale ones controlled by Vientiane. Industrial wastewater inspection is held at the same time as the business inspection, which is once in 1 to 3 years when the factory's business certificate is renewed. Only for such factories that discharge wastewater as indicated in the application for business certificate that inspection is held 2 to 3 times a month.

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.

The Industry and Handicraft Division has meetings with all departments of Vientiane every week and meetings with DI of the Ministry every week; however, it does hold regular meetings 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 on water supply and sanitation for rural areas, as well as hygiene education and dissemination in both urban and rural areas.

A final draft of water resources policy and action plan was prepared by WREA in October 2010 and waiting for the approval of the Prime Minister.

[DOH]

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

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

The number of staff of the section is five. In case that more manpower is required, it is assisted by the other sections.

(11) Environmental Protection Fund (EPF)

The Environmental Protection Fund (EPF) was established in 2005 as an autonomous financial 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 and the ADB Loan consisting of 4 million US dollars and 5.8 million US dollars respectively. In the last 5 years, 5.5 million US dollars have been spent; namely, 3.5 million US dollars and 2.0 million US dollars for projects and administration cost respectively. Three million US dollars is to be added to the Fund in three years by the World Bank.

The EPF provides financial support by means of non-refundable grants, preferential loans, interest rate subsidies, or a combination of these. 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 industries council, 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, managing the Financial and Administrative Unit, Sub-Project Operations Unit, Public Information Unit and the Monitoring and Evaluation Unit.

2.3 Environmental Education

2.3.1 Environmental Education in Existing Related Projects

(1) Guidelines for Urban Environmental Management in Lao PDR (PTI - Quebec/Canada, 1998 -2001)

This TOT (training of trainers) project on environmental education for MPWT staff was conducted for four years by PTI with the assistance of Quebec Province, Canada. The themes were (a) general environmental management; (b) water environment preservation; (c) solid waste management; and (d) environmental regulation.

(2) Strengthening of Environmental Management Project, Phase II (WREA-SIDA, 2005-2010)

This project is a comprehensive capacity development (CD) of WREA on environment as a whole with the support of SIDA. The Phase I (2001-2005) and Phase II (2005-2010) of the project have been already completed.

The environmental education and awareness (EEA) component of Phase II was implemented by the Environment Promotion Division, Department of Environment, WREA based on the ―National Strategy on Environment Education and Awareness to the years 2020 and Action Plan for the years 2006-2010" issued by STEA (predecessor of WREA) in 2004. Various EEA activities were implemented with the cooperation of many line agencies such as the National Research Institute for Educational Science (NRIES), Department of General Education of the Ministry of Education, and National Media Department.

The developed EEA deliverables were as follows:

- Side readers on ―climate change", ―solid waste management" and ―trash separation" for primary school pupils and adults (200 -2009) (refer to **Photo 2.1**)
- A publication on the training approach and training guideline for EEA (2009)
- Enlightenment posters, pamphlets and stickers such as ―climate change" and ―solid waste management" (printed in 2007)
- Original songbook and CDs of world environment day concert (June 5, 2007) (supported by SIDA, UNDP, WB, WWF and IUCN)

Photo 2.1 Supplementary Readings by WREA-SIDA Project

(3) That Luang Marsh Project (WREO-WWF, 2007-2009)

The Science, Technology and Environment Agency (the former organization of WREA) and WWF implemented the "That Luang Marsh Project" from 2007 to 2009 and created artificial wetlands as structural measures for water quality improvement at the following five sites in Vientiane. The agency is scheduled to carry out the Phase 2 of this project thereafter with the concept to create more large-sized artificial wetlands.

- None Khor Primary School, None Khor Village, Xaysetha District
- Resident in None Khor Village, Xaysetha District
- Small canal connecting Hong Xeng in Viengchalearn Village, Xaysetha District
- Nong Hai Village, Hatxaifong District
- Canal around Beer Lao Factory, Hatxaifong District

(4) Sanitary Model Village Project (Department of Health, Vientiane, 2003 -)

The Department of Health of Vientiane (DOH) has been conducting the "Sanitary Model Village Project" as sanitary education activity since 2003. The activity is being conducted in cooperation with the related city departments through discussions at the Committee of Urban and Rural Area Development of Vientiane.

The activity targets all of the villages in Vientiane and includes vaccination, wastewater disposal, public health and solid waste disposal. Staffs of the nine district health offices of DOH implement the activities in the villages under their jurisdiction as lecturers.

The educational activities were 80% completed in 2010. The staffs of nine district health offices evaluate the achievement of each village by a common evaluation sheet and gives award to villages that attain excellent achievement.

(5) Green School Project (Department of Education, Vientiane, 2006-)

The Department of Education (DOE) of Vientiane has been carrying out the "Green School Project" which performs tree-planting as environmental beautification of school grounds since 2006 based on city policy. Many primary, junior high and senior high schools (107 schools: 86 public and 21 private schools) selected have been conducting the activity. DOE evaluates the result in each school in three steps, and had commended top nine schools (3 primary schools, 3 junior high schools and 3 senior high schools) which obtained excellent results.

2.3.2 Community and Education System of Vientiane

(1) Community Structure in Vientiane

Vientiane consists of nine districts and 491 villages ("Ban" in Laotian) as the minimum administration unit under the Districts. A village is also an aggregate of several hamlets ("Ngoi" in Laotian).

The merger of villages is advancing in Vientiane at present according to the policy of the Lao Government. Especially, in Chanthaboury District covering the urban central area, the village number decreased from 39 to 32 by the merger in June 2009.

A typical organization of a district office is shown in **Fig. 2.3**.

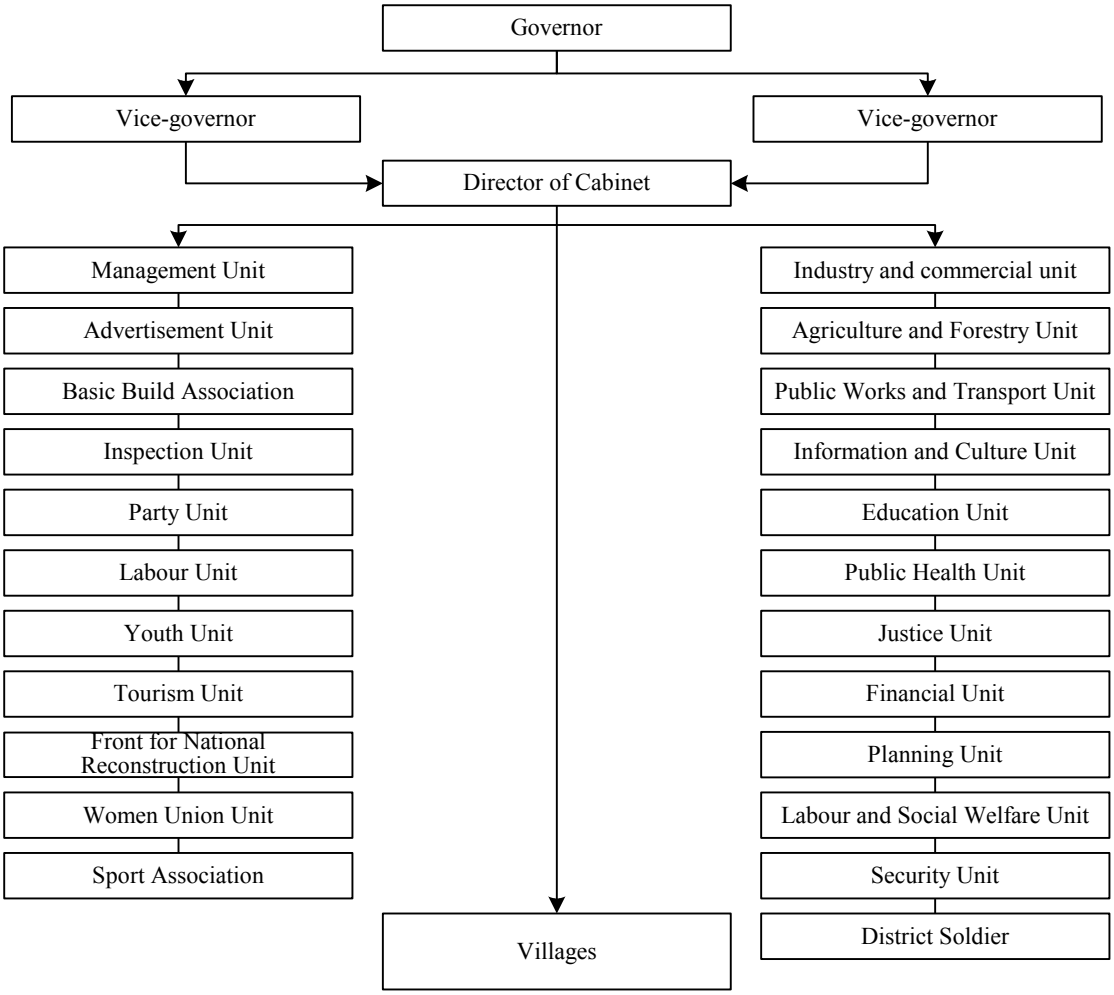


Fig. 2.3 Organizational Chart of District Office

A village (*ban*) organization mainly consists of a village chief, two deputy chiefs, security committee, economic committee, and social and culture committee with several units belonging. In addition, there are village level units of mass organizations such as Lao Women's Union, Lao Youth Organization and Lao Front for National Reconstruction. This basic structure is almost the same at all the villages in Lao PDR. Typical organization of a village office is shown in **Fig. 2.4**.

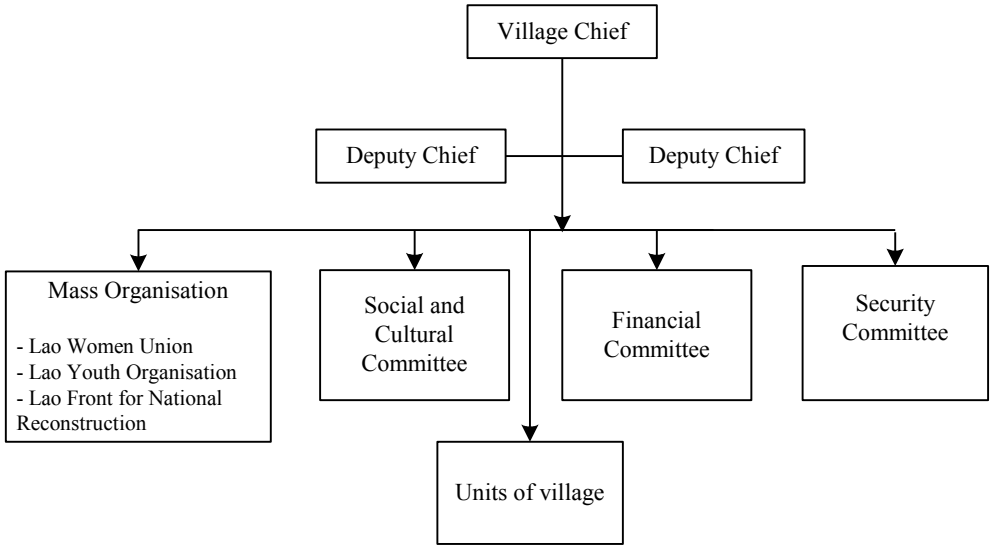


Fig. 2.4 Organizational Chart of Village Office

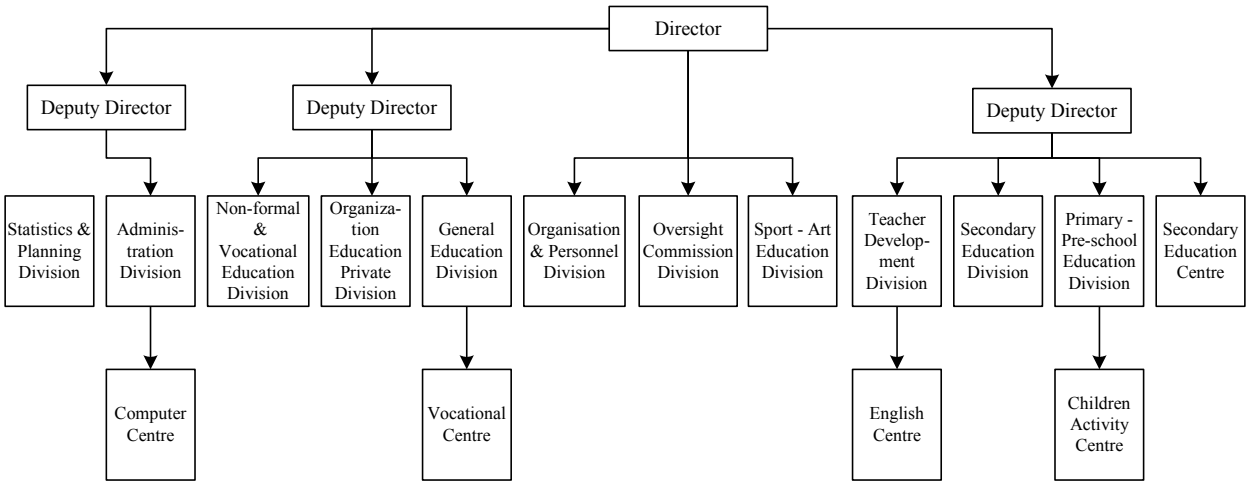
In four urban center districts, some villages have the village environment unit (VEU) organized by WREO. In Lao PDR, the basic composition of one community (village) is one village office, one primary school and one temple. Junior high school and high school are not fundamental compositions of a community (village) as compared with primary school, since not so many schools are distributed unevenly and they are not compulsory education.

(2) Educational Situation in Vientiane

In Lao PDR, primary school education (compulsory education: 5 grades), junior high school (4 grades), and high school (3 grades) is the fundamental public education. Junior high school was changed from 3 to 4 grades in 2010. Although the Ministry of Education formulates the whole education policy, actual school management is divided into the following jurisdiction in Vientiane:

- University and vocational schools: Ministry of Education
- Secondary (Junior High & High) schools: Department of Education, Vientiane (DOE)
- Kindergarten, primary & secondary schools: District Educational Office, DOE

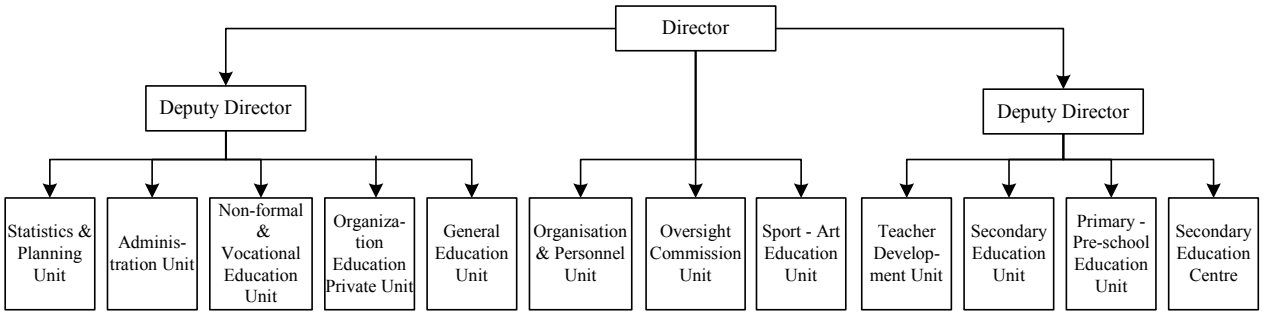
The organizational chart of the Department of Education, Vientiane (MOE) is as shown in **Fig. 2.5**.



Source: Department of Education, Vientiane

Fig. 2.5 Organizational Chart of Department of Education, Vientiane

The organizational chart of the District Educational Office is as shown in **Fig. 2.6**. There are nine district offices under DOE in Vientiane.



Source: Department of Education, Vientiane

Fig. 2.6 Organizational Chart of District Educational Office

(3) Outline of Primary Schools

In Lao PDR, one public primary school is established in one village (Ban), in principle. In Vientiane, the total number of villages is 491 and the total number of public primary schools is 399 (of which 353 are complete schools with 4-5 grades) in 2010. In some urban villages in Vientiane occupied mostly by commerce, industry or administration institutions, there is no primary school.

The curriculum of primary schools consists of seven regular subjects (80%) and extracurricular activities (20%). The regular subjects are Laotian, mathematics, our surroundings (including history, natural science, morals, etc.), art, music, gymnastics and craft work. The extracurricular activities are equivalent to the "Integrated Study Period" in Japan. The 1st term is from September 1 to January 31, and the 2nd term is from February 1 to May 30. School holiday is three months from June to August.

(4) Relationship between Residents and Primary School in Village

The partnership between a primary school and residents in a village is very strong through the PPA (Pupils' Parents Association) and the village office. Many village meetings are held in the primary school or temple. Since the budget of the District Educational Office has been tight, the maintenance of primary school facilities is substantially conducted by the village office. The primary school head submits the purchase/repair budget plan of required equipment to the village office, and the residents are to pay the expense after the village office has approved the plan.

2.4 Hydrology

2.4.1 Natural Conditions

(1) Rainfall

There are two meteorological stations near the Study Area which observe daily rainfall. **Table** 2.13 shows their locations and observation periods, and **Fig. 2.7** show their location on the map. Furthermore, **Table 2.14** summarizes the basic rainfall data collected at both stations, and **Fig. 2.8** present their monthly rainfall distribution.

Table 2.13 Basic Data at Meteorological Stations

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

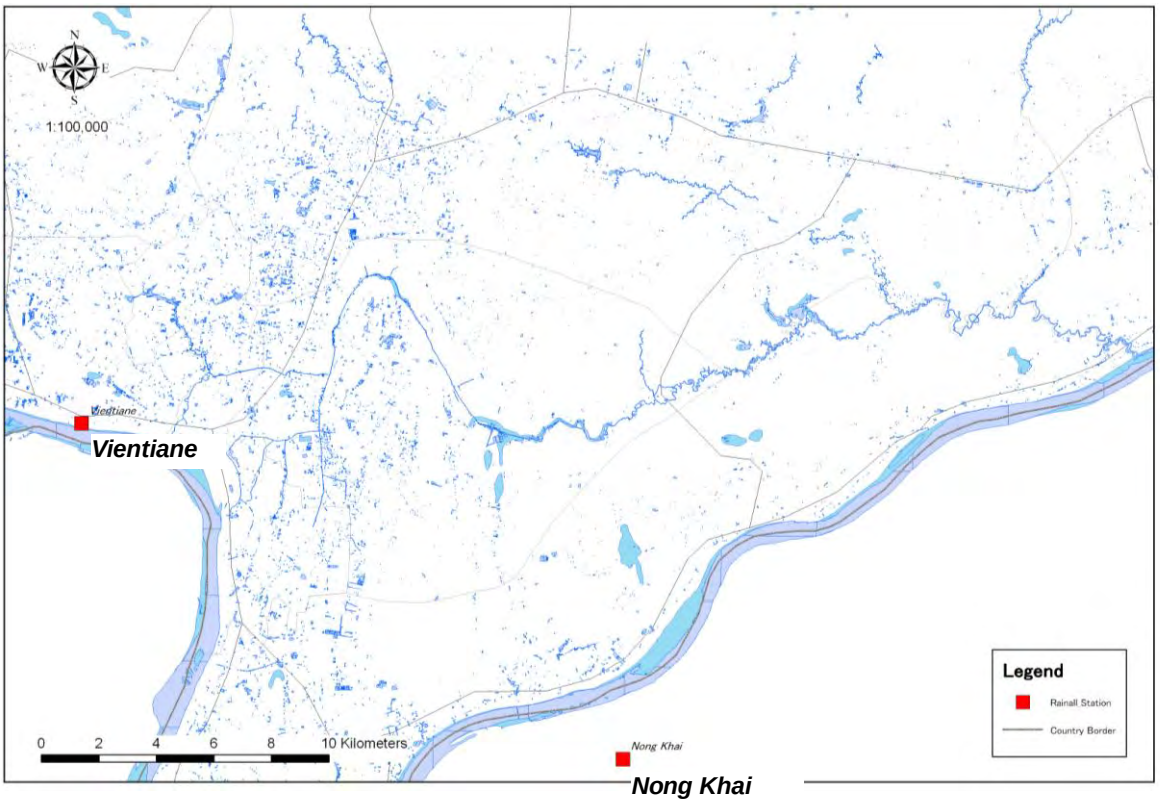


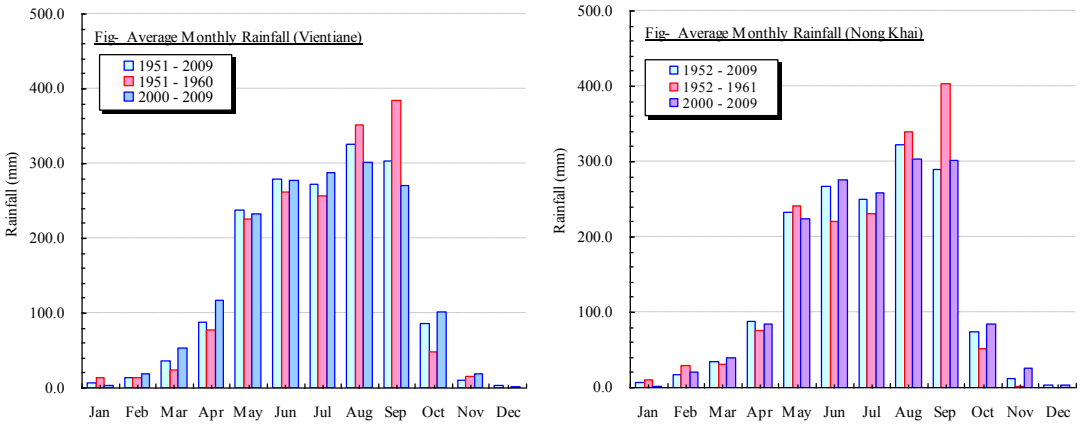
Fig. 2.7 Locations of Meteorological Station

Table 2.14 Basic Statistics of Rainfall Data

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: 59 samples (years) in Vientiane, 58 samples (years) in Nong Khai
Source: MRC and DMH

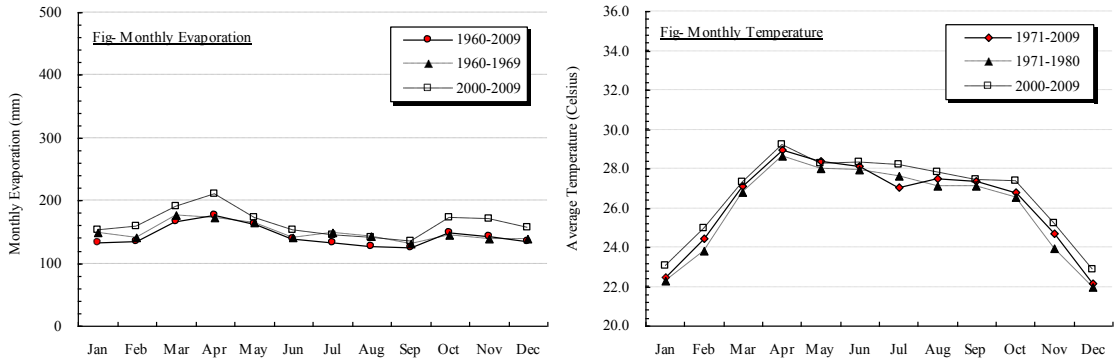


Source: MRC and DMH

Fig. 2.8 Distribution of Monthly Rainfall

(2) Evaporation and Temperature

As shown in **Fig. 2.9**, monthly average temperature in the last decade was obviously much higher than the 1970's. It seems that this is caused by rapid urbanization. Comparing temperature and evaporation, there is an apparent co-relation between them; however, the co-relation between temperature and rainfall is not clear.



Source: MRC and DMH

Fig. 2.9 Monthly Evaporation and Temperature (Vientiane)

(3) Land Use

The land use map in 2000 that was prepared by the National Geographic Department in Lao PDR is shown in **Fig. 2.10** and the land use ratio is shown in **Fig. 2.11**. The urban area extends in the upper part of the Mak Hiao River, while paddy fields and forest extend in the middle/lower river

basin. Compared with the land use map and a satellite imagery taken in 1990, a built-up area has developed and expanded to the marsh/paddy fields.

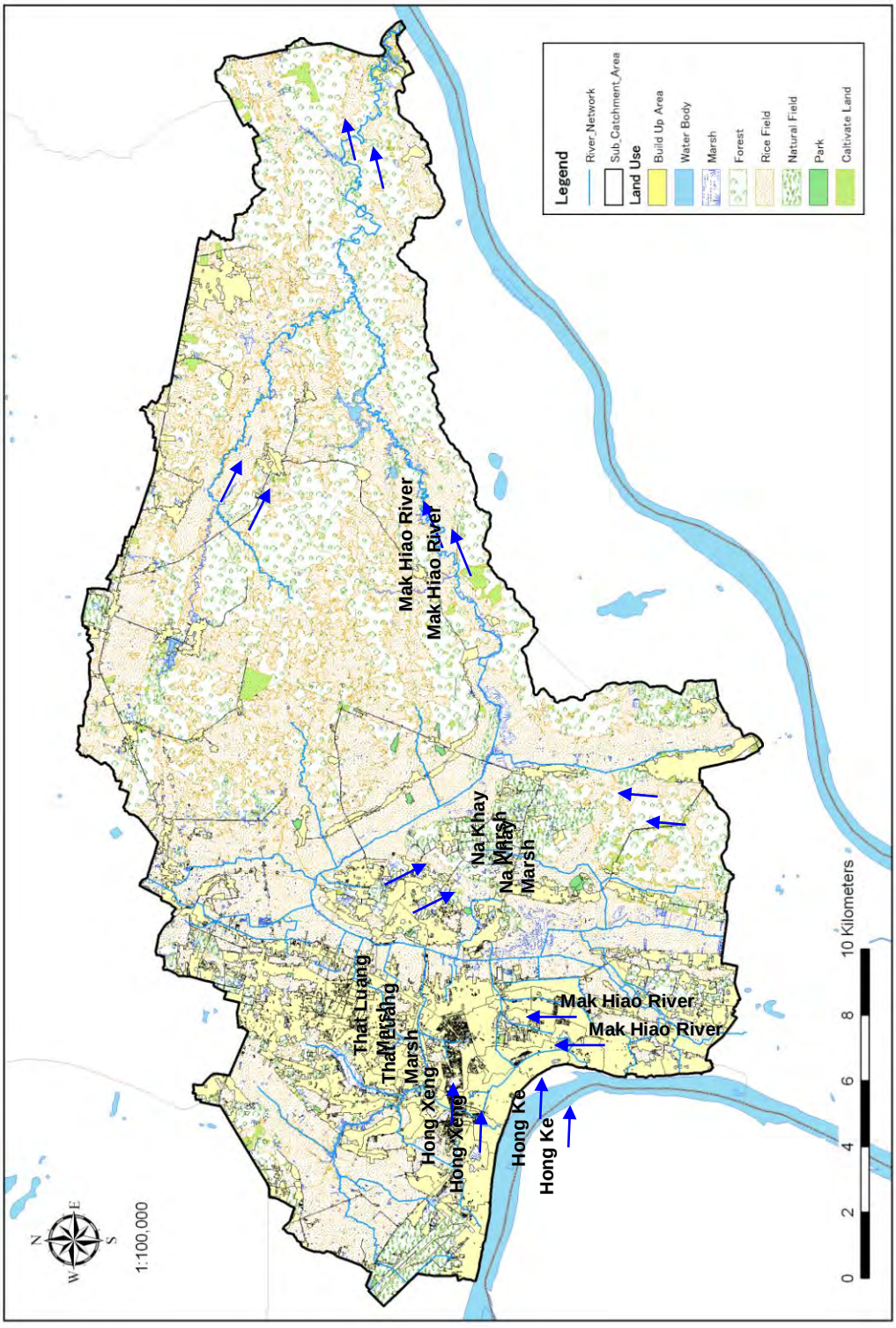
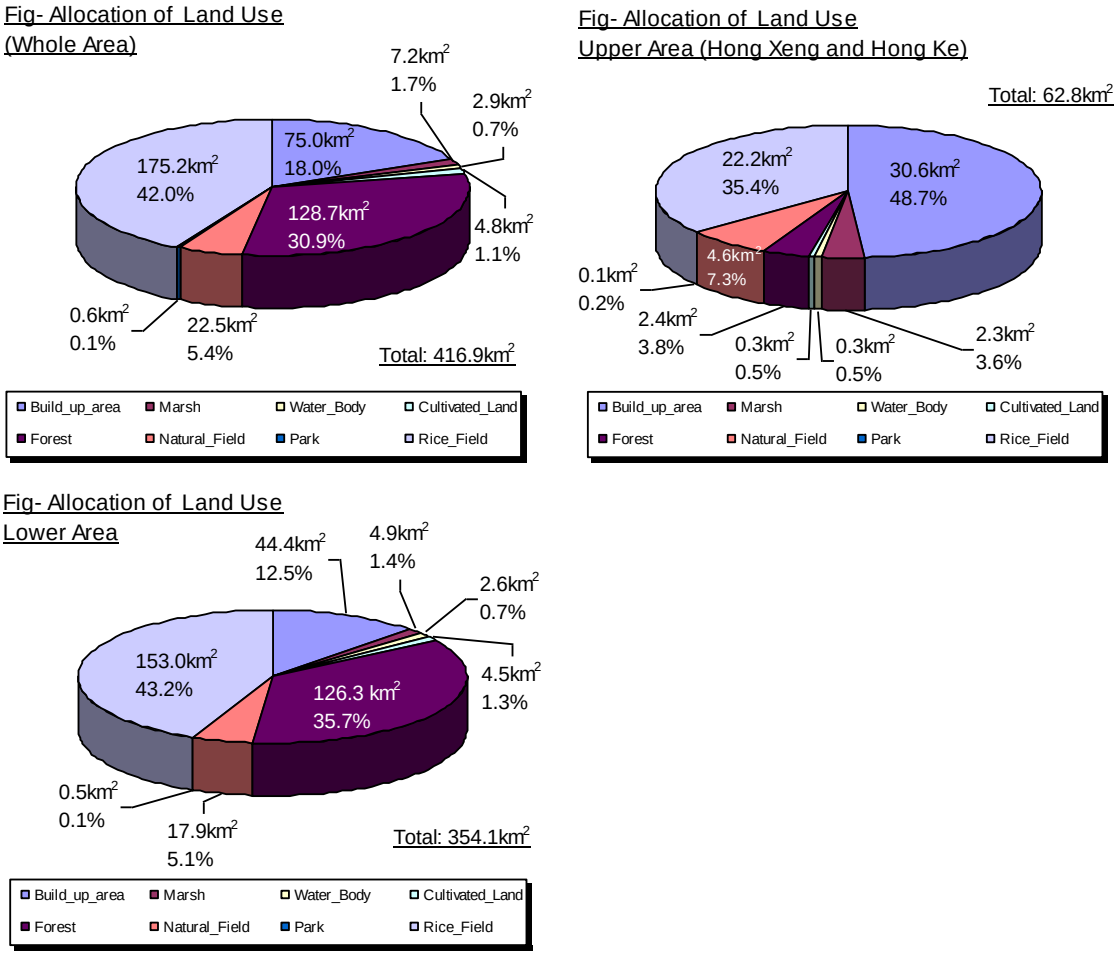


Fig. 2.10 Land Use (year 2000)

National Geographic Department



National Geographic Department

Fig. 2.11 Land Use Ratio (2000)

(4) Catchment Area

The drainage sub-catchment will change in accordance with the progress of drainage improvement works, particularly, in urban areas, so that drainage division in the near future is as shown in **Fig. 2.12**. Total number of sub-catchment area is 59 and total areas of sub-catchments are around 413 km^2.

(5) Water Level

Water level has never been continuously observed in the study area for the Mak Hiao river basin.

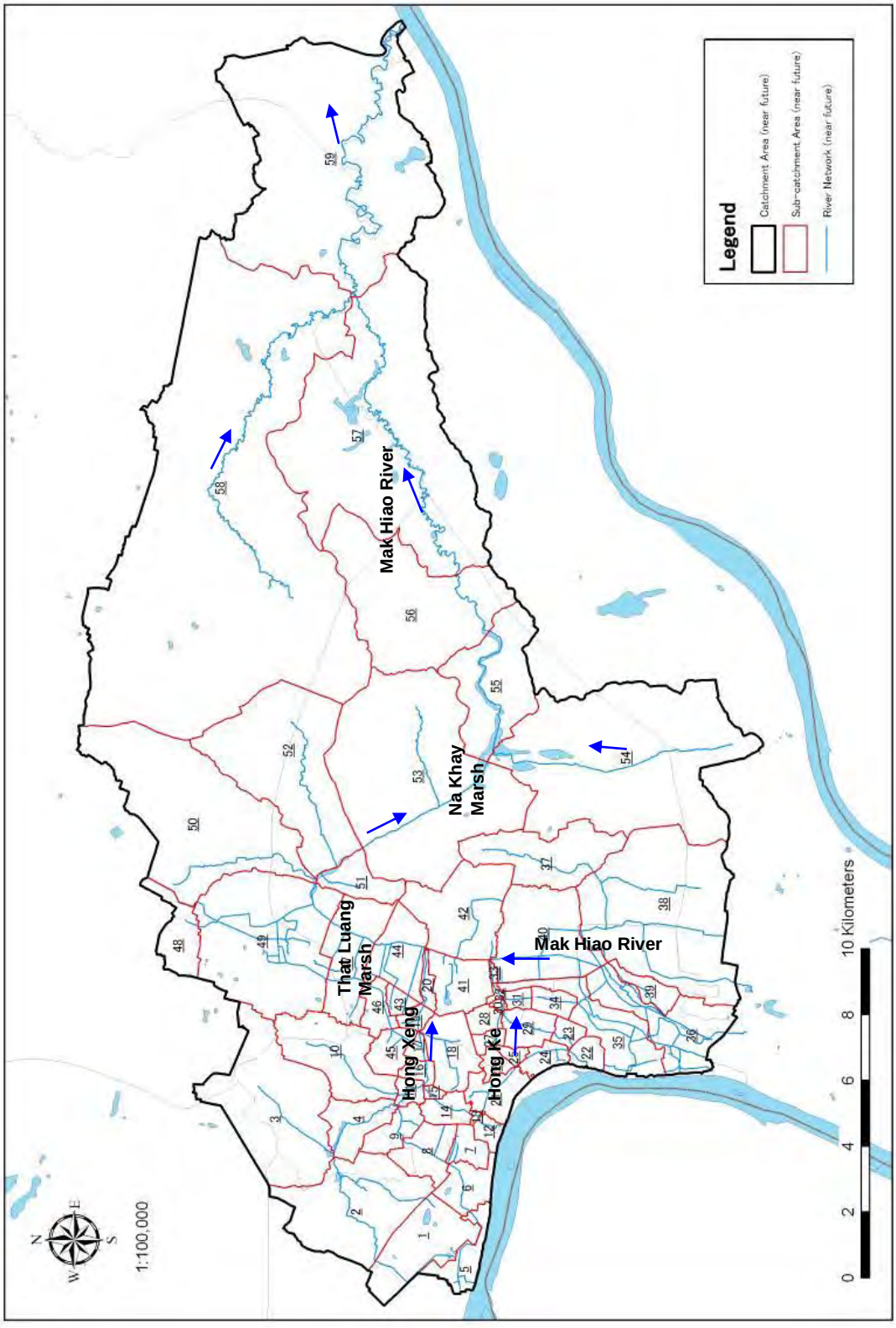


Fig. 2.12 Mak Hiao River Basin (Near Future Condition)

2.4.2 Storm Runoff Analysis

In order to evaluate storm water draining levels of the Hong Xeng and Hong Ke canal systems improved under the ADB project, runoff analysis was conducted by using the rational formula which is suitable for a small sub-catchment.

(1) Rational Formula

Storm runoff of peak discharges shall be computed using a rational formula at evaluation points.

(2) Runoff Coefficient

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

Table 2.15 Standard Runoff Coefficient

Standard Runoff Coefficient						
Dense Urban	Sparse Urban	Field	Paddy Field	Mountai n	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

(3) Rainfall Intensity

In the study, the existing rainfall intensity curve developed in 1990 was not updated because latest hourly data were not available. A comparison between the old data and the latest daily probable rainfall suggests that it is necessary to revise the short-term probable rainfall because the latest rainfall intensity is stronger by approximately 3%. Therefore, the existing rainfall intensity curve was modified by multiplying a 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 2.16 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

(4) Computed Storm Runoff

The runoff peaks calculated by rational formula at main points are shown in **Fig. 2.13**. Compared with the results computed in the feasibility study in 1990, most of the values are larger. The reasons are as follows:

- Rainfall intensity is higher than the one in the previous study because latest rainfall was considered.
- In the previous study, storage effects of small marsh and pond in catchment area were considered. However, no marsh and pond exist to retain rainfall and storm runoff from the present land use conditions.

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	-			

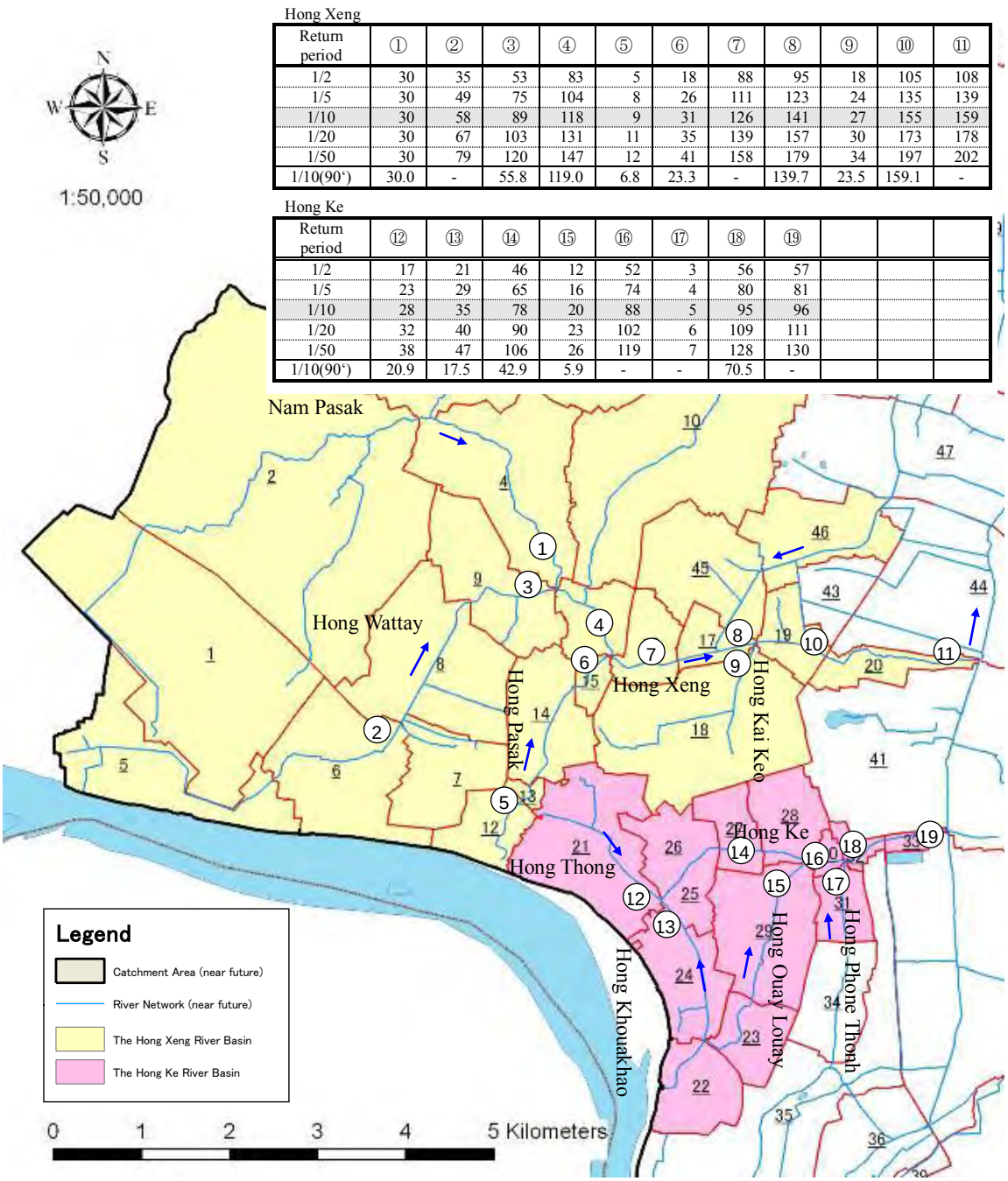


Fig. 2.13 Result of Storm Runoff Analysis

2.4.3 Low Flow Analysis

(1) Outline of the Analysis

Low flow discharges at water sampling points were measured in the course of water quality sampling. Low flow analysis using tank model method was established in order to evaluate water volume in dry season, and thus to supplement the observed data. Tank model is one of the non-linear runoff 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).

Domestic wastewater discharge from each sub-catchment, which is estimated by population, is considered one of major flow components in low flow since domestic wastewater is dominant water source in the dry season. Domestic wastewater discharge could be 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 could be modeled in a similar tank model since land topography is gentle and there is high possibility of retaining and/or retarding water according to topographical features.

Tank model parameters were calibrated by using discharges observed in 2009. The typical calibration results at the downstream ends of Hong Xeng and Hong Ke are shown in **Fig. 2.14**. According to the calibration results, it can be said that the results are acceptable 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. However, since accuracy of the reproduced values in rainy season is not so high, periodical review of model parameters should be made when observed data have accumulated.

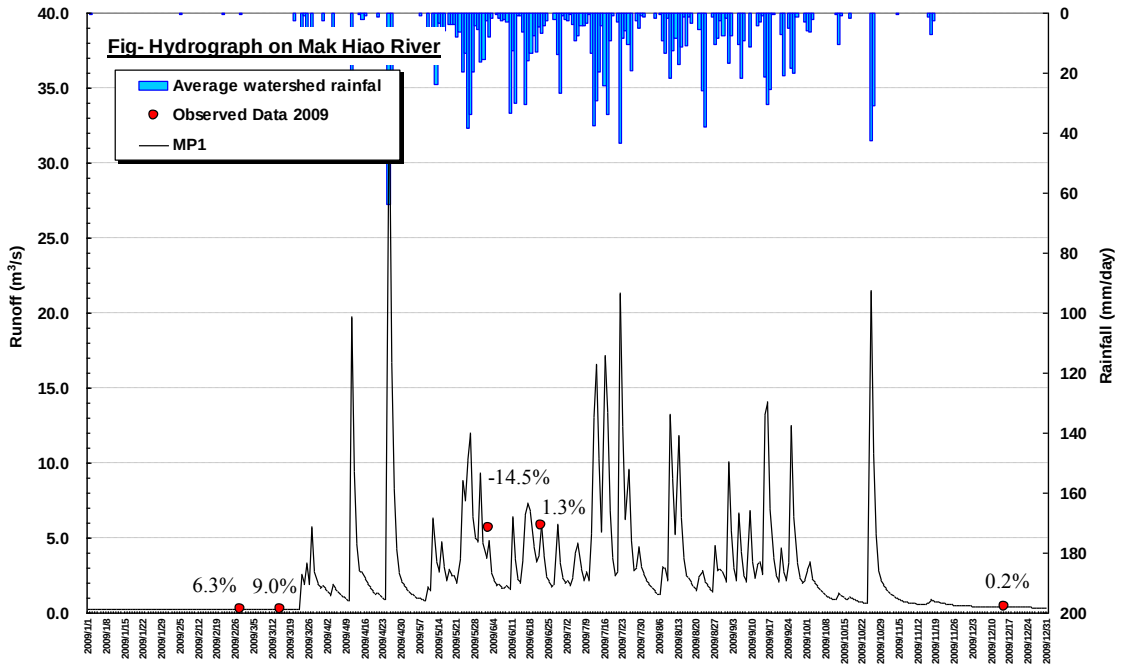
(2) Estimation of Flow Regime

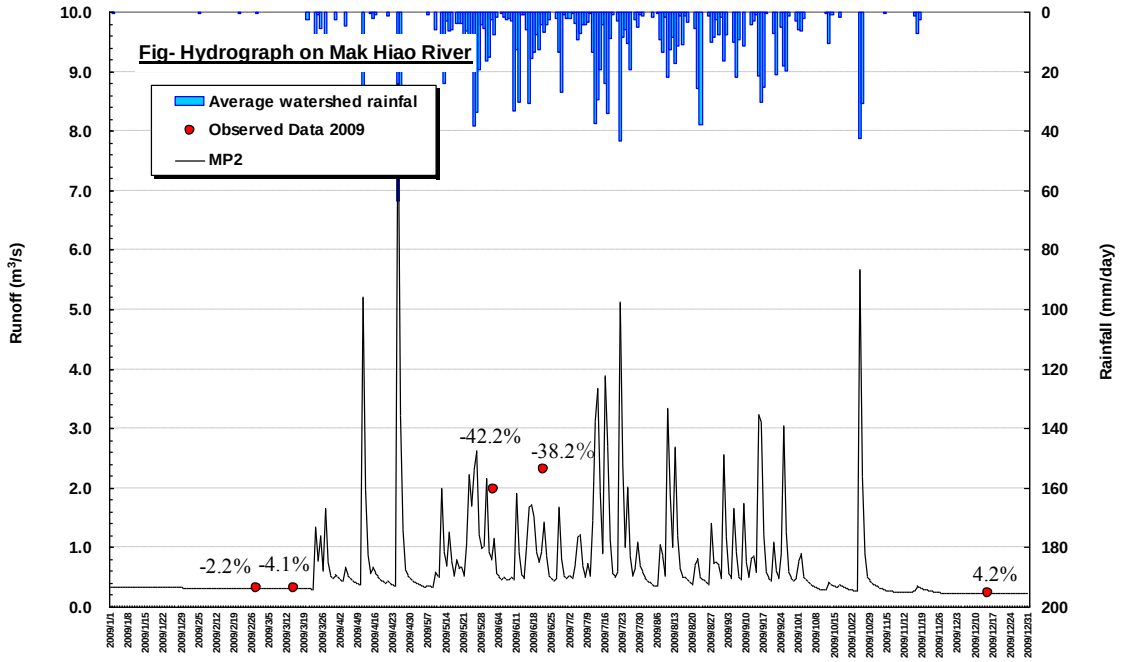
In the Study, BOD (Biochemical Oxygen Demand) is employed as indicator for evaluating water quality in the target area. For adequate water quality analysis, reasonable stream flow in the target year 2020 should be estimated. Here, the "Guidelines for Comprehensive Basin-wide Planning of Sewerage Systems (Japan, 2008)," 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 should be employed for the analysis. In the Study, annual flow regime was calculated under the following condition.

Table 2.17 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 computation result of flow regime is shown in **Table** 2.18.





* Values described on the hydro graph are errors between observed value and estimated one.
Note: MP1 and MP2 are located at the downstream ends of Hong Xeng and Hong Ke, respectively.

Fig. 2.14 Results of Calibration (MP1 and MP2)

Table 2.18 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	8.532
	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

Note: Coefficient of flow regime = Maximum discharge/Minimum discharge

2.5 Drainage Network

2.5.1 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 been improved. These studies and projects are as described below.

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

The feasibility study was conducted in 1990 under JICA. The 10-year return period flood was applied as the protection level, based on the assessment by a B/C index. After formulating the basic plan through alternative case studies, the following projects were selected as 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; and
- Lateral canals in the area enclosed by Hong Xeng.

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

JICA conducted the above survey in 2001 to 2002. The survey area for the inundation conditions covers the urbanized area of 27 km^2 of Vientiane.

(3) Rehabilitation Project of Sihom Area

Upstream of Hong Pasak (L=1.5 km) was improved by MCTPC (presently, MPWT) in the "Rehabilitation Project of Sihom Area". The implementation period was from October 1991 to October 1997 and the total project cost was 5.5 million US dollars. The project aimed at the following items:

- To improve the living conditions for the population of the Sihom area;
- To improve the sanitation and storm water drainage in the catchment area along the entire stretch of Hong Pasak; and
- To strengthen the institutional and technical capacity of related government agencies.

(4) Vientiane Integrated Urban Development Project (VIUDP)

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 with financial assistance from ADB.

Some primary and associated secondary drainage channels were improved under this project. Objective drainage channels planned to be improved in the project are shown in **Table** 2.19. 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 VIUDP, July 2002".

Table 2.19 Objective Drainage Channels of VIUDP

Drainage channel	Length (km)
Hong Ke	3.40 km
Hong Thong	1.75 km
Hong Khoua Khao	2.55 km
Hong Ouay Louay	1.80 km
Hong Phone Thanh	0.95 km
Hong Kai Keo	1.36 km
Hong Thong Sang Nang	1.31 km
Hong Pasak (Downstream)	1.68 km
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 implemented from 2002 to 2006, and VUDAA was the implementing agency.

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. Under this project, some drainage channels shown in **Table** 2.20 were improved.

Table 2.20 Objective Drainage Channels of VUISP

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

Source: ADB

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

The project was conducted from 2005 to 2007 with funds from JICA to achieve safe and smooth traffic of No. 1 road in a stretch of 28.9 km from Sikhai Junction near the Wattay Airport to Thanaleng near the friendship bridge by improvement of the road and drainage. The implementing agency was the Department of Road (DOR), MCTPC (presently, MPWT).

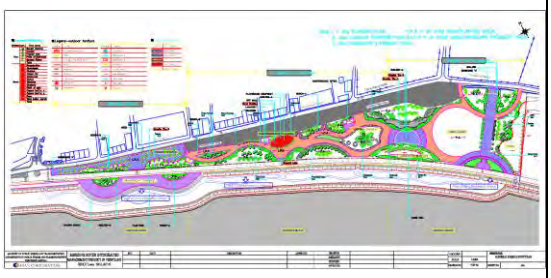
(7) Construction of Drainage System and T2 Road Improvement Project

The downstream stretch of Hong Wattay was improved for 2.9 km under the project funded by the Kingdom of Thailand. VUDAA was the implementation agency. The project was implemented from August 28, 2006 to February 28, 2008.

(8) Mekong River Integrated Management Project (Ongoing)

This project was started in 2009 and it is scheduled to be completed by 2013. It is funded by the Economic Development Cooperation Fund (EDCF) of Korea and is being implemented by DPWT. Construction cost is about USD 30 million.

In order to mitigate flood hazard and prevent riverbank erosion along the Mekong River in the Vientiane area, the project is composed of the construction of dike and bank protection works for 12.2 km from Kaoliao to KM3. The dike and bank protection works are designed against a 100-year return period flood corresponding to 26,500 m^3/s of peak discharge. In response to the need for an affluent riparian environment for tourism and recreation, a riverside park (Chao Anouvong Park) is to be developed in an area of 16 ha. (see **Photo 2.2**)



Riverside park

Siboungeuang (L=120 m)

Wattaygnay Tha (L=230 m)

Sithanh Neua (under construction)

Photo 2.2 Mekong River Integrated Management Project

2.5.2 Drainage System

The drainage network in Vientiane consists mainly of the Hong Xeng and Hong Ke systems. Various projects have improved these systems as mentioned in the preceding section. These projects have improved urban drainage conditions drastically.

(1) Past Major Floods

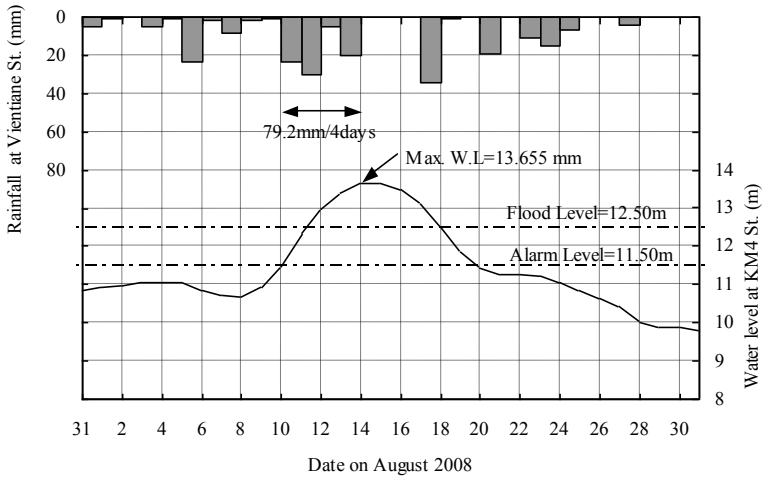
Vientiane is situated on an alluvial plain formed by the deposition process of the Mekong River. Therefore, Vientiane suffers from damages by Mekong floods or heavy local rainfall. The following two floods were the major flooding events that caused damage to Vientiane.

September 1966 Flood

In 1966, tropical storm Phyllis brought enormous flood damage to the Mekong river basin. The water level at Vientiane exceeded the alarm level of 11.5 m for 19 consecutive days from August 28 to September 15, 1966. The maximum water level of 12.71 m was recorded on September 4 and it is higher than the flood level of 12.5 m. Historically, this event was the highest flood at Vientiane. Due to overflow from the Mekong, most of the areas below El. 170 m including the Wattay Airport were submerged.

August 2008 Flood

Tropical storm Kammuri struck southern China and northern Vietnam, and moved into northern Lao PDR in August 2008. It brought heavy rainfall in the Mekong river basin. The water level of the Mekong had risen due to heavy rainfall in the upper basin. The water level at KM4 station in Vientiane exceeded the alarm level (11.50 m) on August 11 and flood level (12.50 m) on August 12 as shown in **Fig. 2.15**, and finally reached 13.655 m at peak, the highest flood level since 1913. Historically, the peak water level was 1 m higher than the highest record of 12.71 m in the 1966 Flood.



Source: DMH

Fig. 2.15 Rainfall and Water Level of Mekong River in August 2008

The flood damage in Vientiane was reported in the "Damage & Recovery Report in 2008" prepared by Vientiane. Severe overtopping from the Mekong River did not occur in the urban area because the dike was heightened by 1.5 m after the 1966 Flood, and sandbags were piled up along the riverbank for about 17 km from Kaoliao to Chinaimo as an emergency flood fighting activity. Local inundations, however, occurred due to seepage through the dike or sandbags. The suburban areas of Sikhottabong and Hadxaifong districts were widely submerged, due to overflow from the bank (see **Photo 2.3**) and some stretches of the riverbank were eroded.

Inundated area in the suburban area of Vientiane

Source: MPWT

Photo 2.3 August 2008 Flood

(2) Drainage Channels

The Vientiane urban area is covered by (a) the 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) the 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. Total catchment areas of Hong Xeng and Hong Ke systems are 56.57 km^2 and 9.54 km^2, respectively.

Fig. 2.16 shows a schematic diagram of a drainage system, and **Table** 2.21 summarizes the principal features.

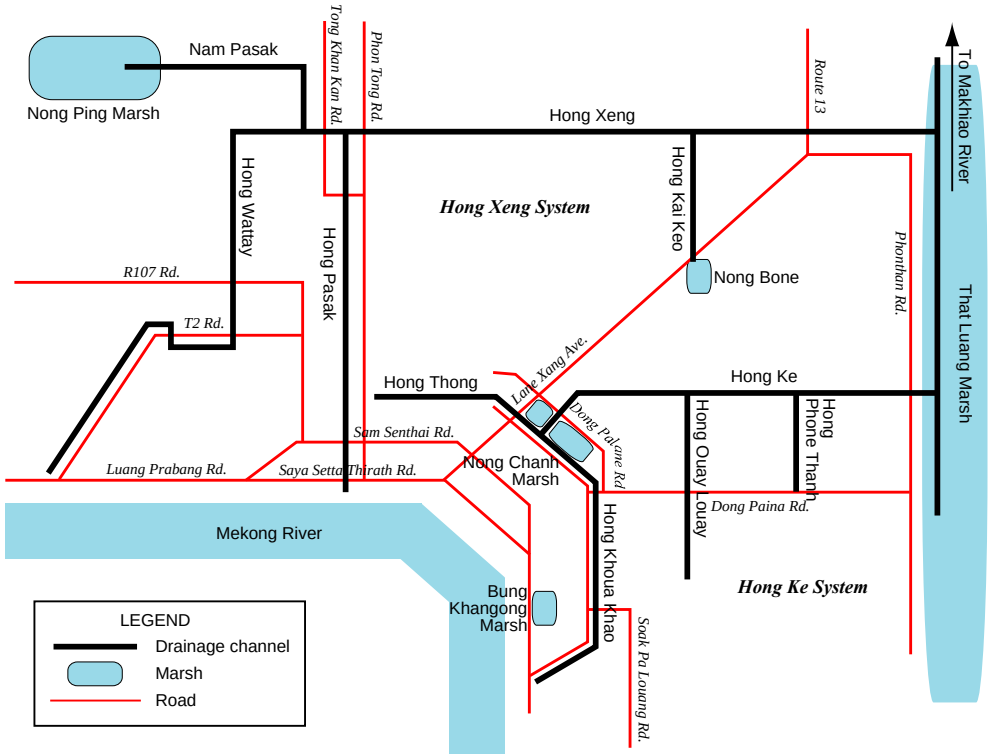


Fig. 2.16 Drainage System in the Urban Area of Vientiane

Table 2.21 Principal Features of Drainage System in the Urban Area of Vientiane

Drainage Channel	Catchment Area (km^2)	Channel Length (km)	Improvement Period (year)	Remarks
Hong Xeng System				
Hong Xeng	56.57	4.01	2006 to 2009	
Hong Kai Keo	3.09	1.36	2000	
Hong Pasak	2.24	3.20	1995 and 2000	
Hong Wattay	9.28	4.20	2005 to 2006	Former irrigation canal constructed in 1985
Hong Ke System				
Hong Ke	9.54	3.65	2001	
Hong Phone Tanh	0.48	0.95	2001	
Hong Ouay Louay	1.66	1.80	2001	
Hong Khoua Khao	2.60	2.56	2001	
Hong Thong	2.09	1.79	2001	Concrete-covered for a length of 1.47 km

(3) Drainage Gate

The lower stretch of the Mak Hiao River has two drainage gates at the confluence with the Mekong River (**Photo 2.4**). The Irrigation Sector of the Department of Agriculture and Forestry of Vientiane is responsible for the maintenance of these gates.

Mak Hiao Main River

Mak Hiao Branch River

Photo 2.4 Drainage Gates of the Mak Hiao River

In the rainy season, the upstream gate is opened to drain floodwaters of the Mak Hiao River to the Mekong. If the water level of Mekong is higher than that of the Mak Hiao River, the downstream gate is closed to prevent backwater from the Mekong. In the dry season, the storage of water in the Mak Hiao River is made possible by closing the upstream gate. **Table** 2.22 shows the types of gate ar Mak Hiao.

Table 2.22 Drainage Gates of the 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

(4) Maintenance of Drainage Channels

VUDAA is responsible for the maintenance of drainage channels in the urban area of Vientiane. Since VUDAA does not have any machine and equipment for maintenance work, it puts the works out to private companies by special appointment contracts following a regulation of the

Ministry of Finance stipulated under the Decree on bidding of procurement construction, maintenance and services from government's budget, No. 03/pm, 09/01/2004. The contractors conduct maintenance work by using a backhoe, light-bulldozer, truck and manual labor.

VUDAA has a maintenance plan to clean the drainage channels twice a year, but they actually do it once a year due to lack of funds. VUDAA personnel cut grasses and dredge up sediment and sludge accumulated in the channels usually before or during the rainy season.

2.6 Water Quality

Water quality monitoring has been carried out with the following objectives: (1) to understand the current water quality conditions around the Mak Hiao river basin; and (2) to conduct water quality modeling for the evaluation of pollution load runoff and the natural purification functions in the basin.

The water quality monitoring surveys consist of (1) Periodical Monitoring; and (2) Longitudinal Simultaneous Monitoring, to monitor the longitudinal changes in water quality for the evaluation of natural purification functions.

2.6.1 Methodology of Water Quality Monitoring

(1) Periodical Monitoring

The monitoring points were selected along the mainstream of the Mak Hiao River, Hong Ke and Hong Xeng. The selected monitoring points consist of six main monitoring points and nine sub-monitoring points, totaling fifteen points as shown in **Table** 2.23**, Fig. 2.17** and **Fig. 2.18**.

Table 2.23 Number of Periodical Monitoring Points

Symbol	Classification	Number of points
MP	Main monitoring points	6
SP	Sub monitoring points	9
	Total	15

Details about the location and monitoring purpose for the fifteen points are tabulated in **Table** 2.24. Of the fifteen points, MP1, MP2, MP3, SP3, SP6, SP7, SP8 and SP9 (8 points in total) are located at the same positions as those established by WERI-WREA.

Table 2.24 Location of Periodical Monitoring Points

No.	Monitoring Point	Monitoring Purpose
MP 1	Downstream end of Hong Xeng	To check water quality at major channel
MP 2	Downstream end of Hong Ke	Ditto
MP 3	Upstream end of That Luang Marsh	Ditto
MP 4	Upstream end of Na Khay Marsh	To measure natural purification function of the marsh
MP 5	Downstream end of Na Khay Marsh	Ditto
MP 6	Confluence of the Mekong River and Mak Hiao River	To measure natural purification function of the river
SP 1	Downstream end of Hong Wattay	To check water quality at tributaries of Hong Xeng
SP 2	Downstream end of Nam Pasak	To check water quality at tributaries which drain suburban and/or rural areas
SP 3	Downstream end of Hong Pasak	To check water quality at tributaries of Hong Xeng
SP 4	Downstream end of Hong Thong	To check water quality at tributaries of Hong Ke
SP 5	Downstream end of Hong Khoua Khao	Ditto
SP 6	Downstream end of Hong Kai Keo	Ditto
SP 7	Midstream of Hong Ke	To check water quality at major channel
SP 8	Downstream end of Hong Ouay Louay	To check water quality at tributaries of Hong Ke
SP 9	Downstream end of That Luang Marsh	To measure natural purification function of the marsh

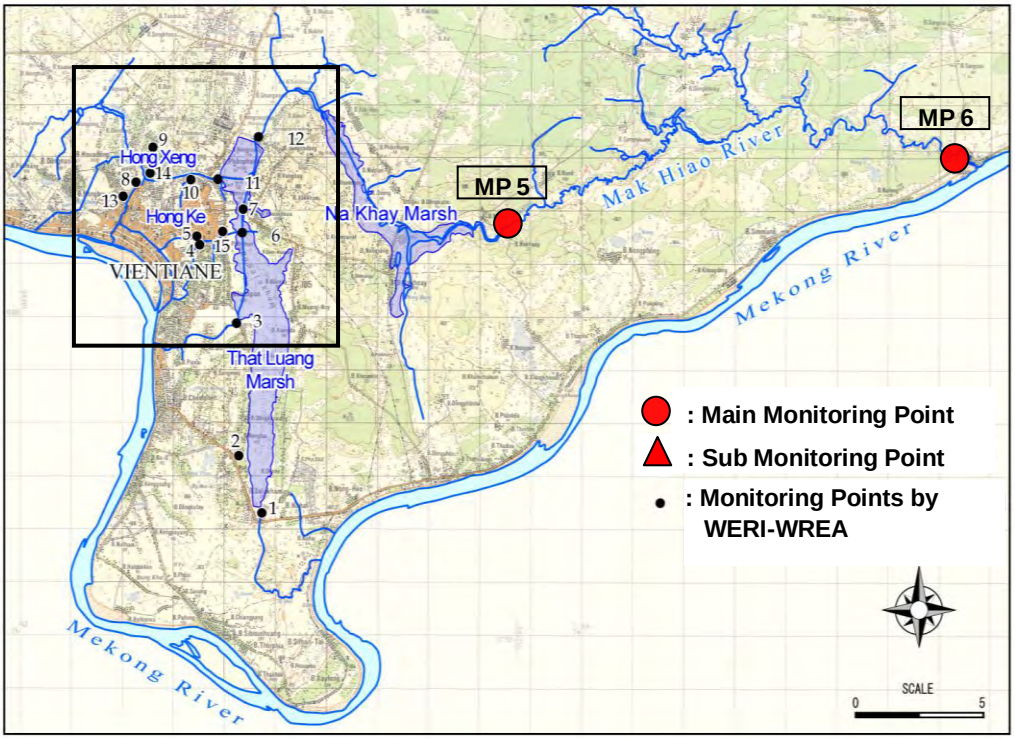


Fig. 2.17 Location of Periodical Monitoring Points (Entire Basin)

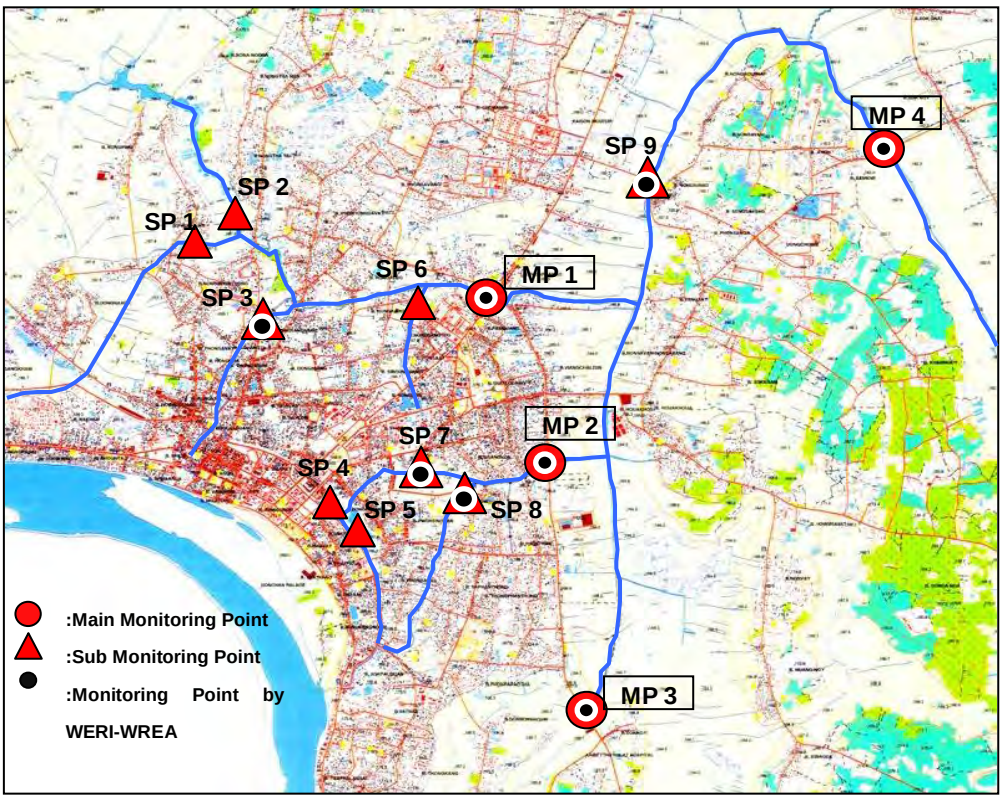


Fig. 2.18 Location of Periodical Monitoring Points (Urban Center)

The periodical monitoring was planned to be conducted 8 times throughout the study period; i.e., 6 in the dry season and 2 in the rainy season, as shown in **Table** 2.25.

Table 2.25 Frequency of the Periodical Monitoring of Drainage Channels

Month / Year	Dry Season				Rainy Season						Dry Season	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009		X	X			X					X	X
2010		X				X						X

In principle, water quality was analyzed by utilizing portable equipment. However, BOD, SS, total/fecal coliform, heavy metals (6 items) and pesticides (3 items) were analyzed by a reliable laboratory in Thailand. Water quality parameters monitored are as shown in the table below.

Table 2.26 Water Quality Parameters for Periodical Monitoring

Group	Parameters	Remarks	Group	Parameters	Remarks
I: Stream Flow	depth and width of flow, velocity	15 points (SP & MP)	IV: Organic Pollutant	COD_{Mn}, BOD, SS, total coliform, fecal coliform	15 points
II: Field Observation	odor, color, air temperature		V: Heavy Metals	Cadmium (Cd), Mercury (Hg), Selenium (Se), Lead (Pb), Arsenic (As), Hexavalent Chromium (Cr^{6+})	6 points (MP only)
III: Basic Items	pH, EC, turbidity, DO, water temperature, TDS, ORP, NH_3-N, NO_2-N, NO_3-N, PO_4-P, hardness, sulfide, acidity, alkalinity, Zn, Fe, Mn		VI: Pesticides	Simazine, Thiram, Thiobencarb	

(2) Simultaneous Longitudinal Monitoring

In addition to the periodical monitoring mentioned above, simultaneous longitudinal monitoring were carried out from June 2009 until November 2010 to evaluate the longitudinal changes in water quality and natural purification functions of Hong Ke and Hong Xeng and their tributaries.

Monitoring points are twenty-three in total, as shown in **Table** 2.27 and **Fig. 2.19.** Details of location are as shown in **Table** 2.28

Table 2.27 Number of Points for Simultaneous Longitudinal Monitoring

Symbol	Classification	Number of Points
LA	Hong Ke and its tributaries	9
LB	Hong Xeng and its tributaries	14
	Total	23

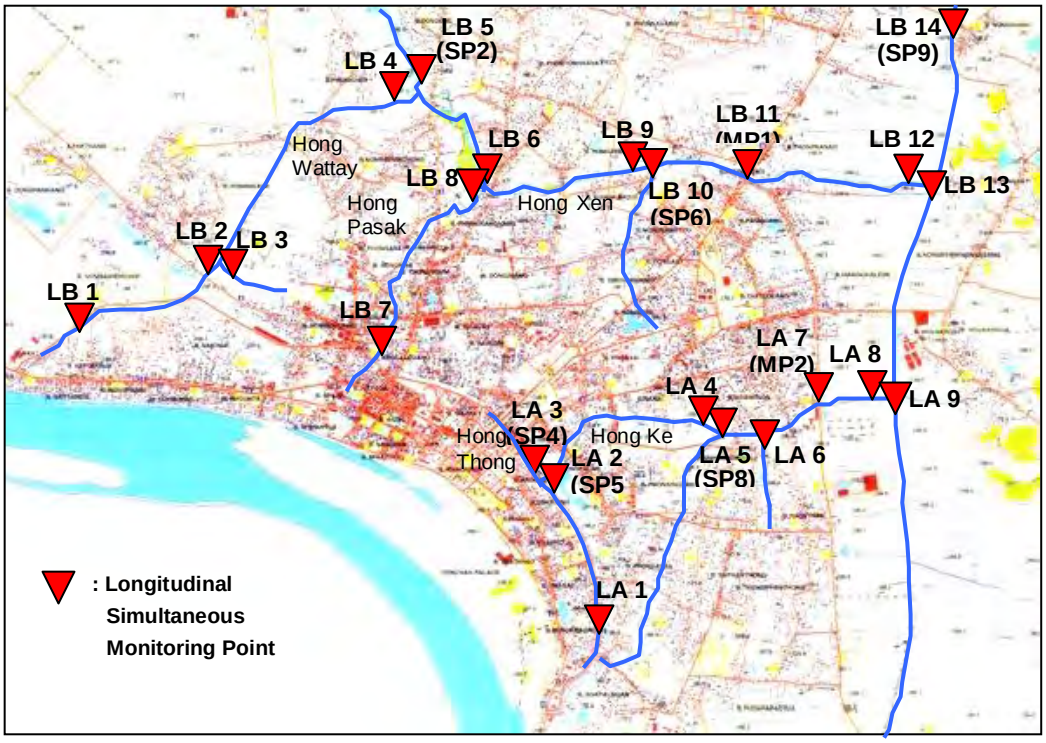


Fig. 2.19 Location of Simultaneous Longitudinal Monitoring

Table 2.28 Location of Simultaneous Longitudinal Monitoring

No.	Monitoring Point	Remarks
LA 1	Upstream end of Hong Khoua Khao	
LA 2	Downstream end of Hong Khoua Khao	Same location as SP5
LA 3	Downstream end of Hong Thong	Same location as SP4
LA 4	Confluence of Hong Ouay Louay and Hong Ke	
LA 5	Downstream end of Hong Ouay Louay	Same location as SP8
LA 6	Downstream end of Hong Phone Thanh	
LA 7	Downstream of Hong Ke (Hong Ke Bridge)	Same location as MP2
LA 8	Downstream end of Hong Ke (at the confluence with That Luang Marsh)	
LA 9	That Luang Marsh at downstream end of Hong Ke	
LB 1	Upstream end of Hong Wattay	
LB 2	Confluence of a tributary of Hong Wattay	
LB 3	Downstream end of a tributary of Hong Wattayl	
LB 4	Confluence of Nam Pasak and Hong Wattay	
LB 5	Downstream end of Nam Pasak	Same location as SP2
LB 6	Confluence of Hong Pasak and Hong Xeng	
LB 7	Upstream end of Hong Pasak	
LB 8	Downstream end of Hong Pasak	
LB 9	Confluence of Hong Kai Keo and Hong Xeng	
LB 10	Downstream end of Hong Kai Keo	Same location as SP6
LB 11	Downstream of Hong Xeng (Hong Xeng Bridge)	Same location as MP1
LB 12	Downstream end of Hong Xeng (at the confluence with That Luang Marsh)	
LB 13	That Luang Marsh at downstream end of Hong Xeng	
LB 14	Downstream end of That Luang Marsh	Same location as SP9

The simultaneous longitudinal monitoring had been conducted three times in the study period; namely, two times in the dry season (November) and once in the rainy season (June), as shown in **Table** 2.29.

Table 2.29 Frequency of Longitudinal Monitoring

Month / Year	Dry season				Rainy season						Dry season	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009						X					X	
2010											X	

In principle, water quality was analyzed by utilizing portable equipment. However, BOD and SS were analyzed by a reliable laboratory in Thailand. Water quality parameters monitored are shown in the table below.

Table 2.30 Water Quality Parameters for Simultaneous Longitudinal Monitoring

Group	Parameters	Remarks	Group	Parameters	Remarks
I: Stream Flow	depth and width of flow, velocity			water temperature, TDS, ORP, NH_3-N, NO_2-N, NO_3-N, PO_4-P	
II: Field Observation	odor, color, air temperature		IV: Organic Pollutant	COD_{Mn}, BOD, SS, total coliform, fecal coliform	
III: Basic Items	pH, EC, turbidity, DO				

2.6.2 Monitoring Results

(1) Periodical Monitoring

(a) Stream Flow

In the small catchments of which drainage area is less than 8 km^2, the observed stream flow of the rainy season (in June and July) ranges from 1 to 5 times of the dry season flow (in February, March, November and December). On the other hand, in the large catchments of which drainage area is larger than 8 km^2, the observed stream flow of the rainy season ranges from 5 to 45 times of the dry season flow. Since monitoring activities were not conducted under rainy weather, storm water in the small catchments already subsided during the monitoring period. On the other hand, the storm water in the large catchment accumulated towards the downstream stretch even during the monitoring period. Therefore, the above-mentioned differences appear in accordance with the scale of catchment.

(b) BOD and SS

In the middle and downstream of Hong Ke and Hong Xeng, BOD gradually increased in the early dry season (November and December), compared with those in the rainy season (June and July). On the other hand, at MP5 and MP6, which are located at the downstream end of the Mak Hiao River, BOD ranging from less than 2.0 mg/l to 3.1 mg/l has been continuously recorded without significant seasonal changes.

Typical seasonal distributions of monitored BOD are presented in **Fig. 2.20** for the rainy season and **Fig. 2.21** for the dry season. The highest BOD of 32.6 mg/l was observed in November 2010 at the downstream end of Hong Pasak (SP3). In general, all the results of BOD remained below about 30 mg/l at maximum.

As for SS, at the Hong Ke and Hong Xeng and their tributaries, the observed values ranged from about 10 to 50 mg/l. In contrast, the observed values ranged from 40 to 100 mg/l along the Mak Hiao mainstream (MP4, 5 and 6). The source of these high values may be soil particles coming from bare lands and fields in the catchment.

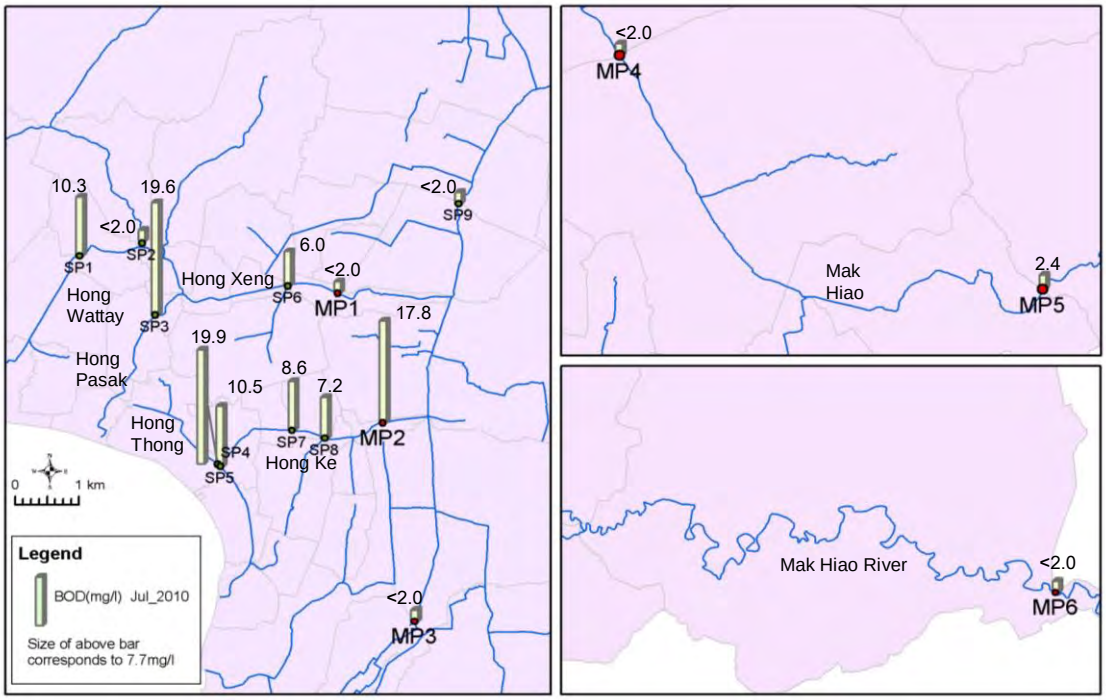


Fig. 2.20 Schematic Diagram of BOD in Periodical Monitoring (July 2010)

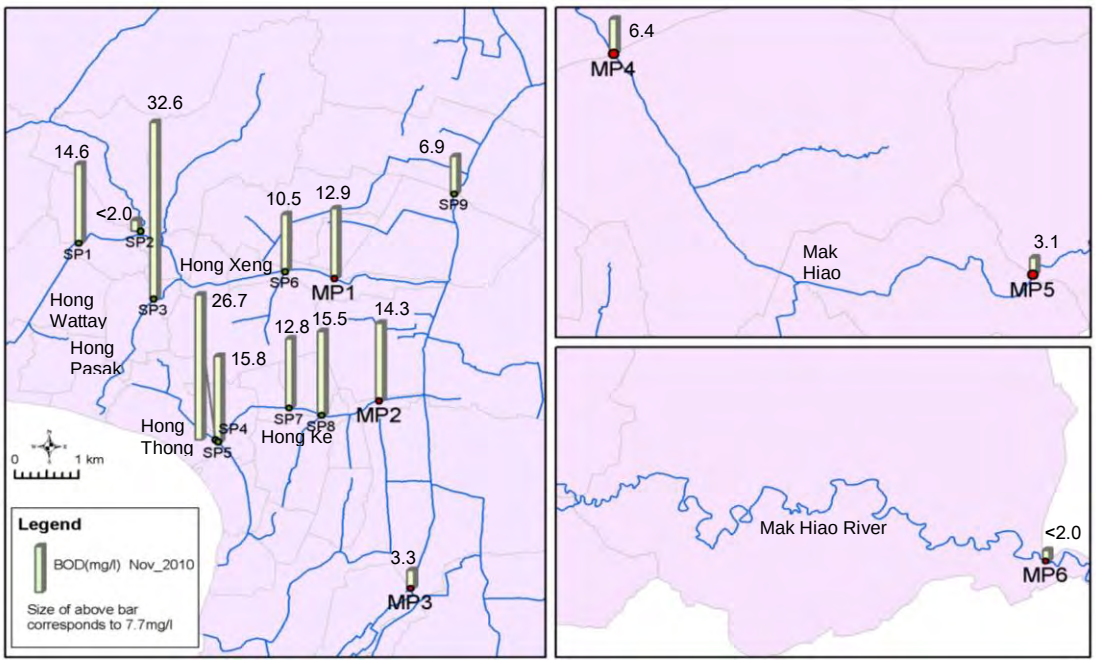


Fig. 2.21 Schematic Diagram of BOD in Periodical Monitoring (November 2010)

(c) Total and Fecal Coliform

The number of 100,000 MPN/100 ml or more of total/fecal coliform was detected in the downstream ends and tributaries of Hong Ke and Hong Xeng (SP3, SP4, SP6, SP7 and

MP2) even in the rainy season. This fact means that the stream flow is dominated by domestic and commercial wastewater.

During the monitoring surveys from November 2009, only MP5 and MP6 in the downstream of the Mak Hiao sometimes met with the standard of surface water quality in Lao PDR (less than 5,000 MPN/100 ml of total coliform and less than 1,000 MPN/100 ml of fecal coliform).

(d) Nitrogen and Phosphorus

NH_3-N observed in the up- and middle reaches of Hong Ke and Hong Xeng as well as their tributaries, ranging approximately from 5 to 10 mg/l, were higher than those of less than 5 mg/l observed in the lower reaches of Hong Ke and Hong Xeng as well as the Mak Hiao River.

Unlike NH_3-N, NO_3-N was less than 1.0 mg/l even at the monitoring points that observed high NH_3-N, and their variations between the monitoring points were not significant. This is because the time of flowing down from the source to the monitoring points in the tributaries of Hong Ke and Hong Xeng is not enough for nitrification. Meanwhile, lower values of NO_3-N in the Mak Hiao River are mainly due to dilution effects.

Regarding phosphorus (PO_4-P), the concentration of less than 1.0 mg/l was normally observed at most of the stations.

(e) Heavy Metals and Pesticides

Cadmium (Cd), Selenium (Se) and Hexavalent Chromium (Cr^{6+}) were not detected in all the monitoring surveys. Other metals [Mercury (Hg), Lead (Pb), Arsenic (As)] were occasionally detected, but the concentrations were very low and within the surface water quality standard in Lao PDR.

As for pesticides, three parameters of pesticides (Simazine, Thiram and Thiobencarb) were below the detection limit. Therefore, the monitoring of pesticides had been cancelled since the monitoring in June 2010.

(2) Simultaneous Longitudinal Monitoring

Since June 2009, simultaneous longitudinal monitoring had been conducted three times (June and November 2009, and November 2010). The following items summarize the monitoring results.

(a) BOD

In general, high BOD concentration was observed at the monitoring points LB7 (upper reaches of Hong Pasak), LA3 (downstream end of Hong Thong) and LA8 (downstream end of Hong Ke), which are located at the tributaries or downstream end of Hong Ke. Furthermore, wastewater effluents from the slaughterhouses directly influenced the highest BOD concentration of more than 200 mg/l at LB3. On the other hand, BOD was not so high at the Mak Hiao River such as LB13 mainly due to dilution effects. **Fig. 2.22** presents these typical situations as describing the dry season condition in 2010.

(b) DO

In general, the channels where high DO values were observed show similar characteristics such as shallow water depth (about less than 10 cm) and overgrowth of vegetation. Considering such conditions, the high DO seemed to result partly from

surface aeration due to shallow water depth, and partly from oxygen supply brought about by the photosynthetic process in algae. On the other hand, at the monitoring points where high BOD was observed, low DO was observed as a whole.

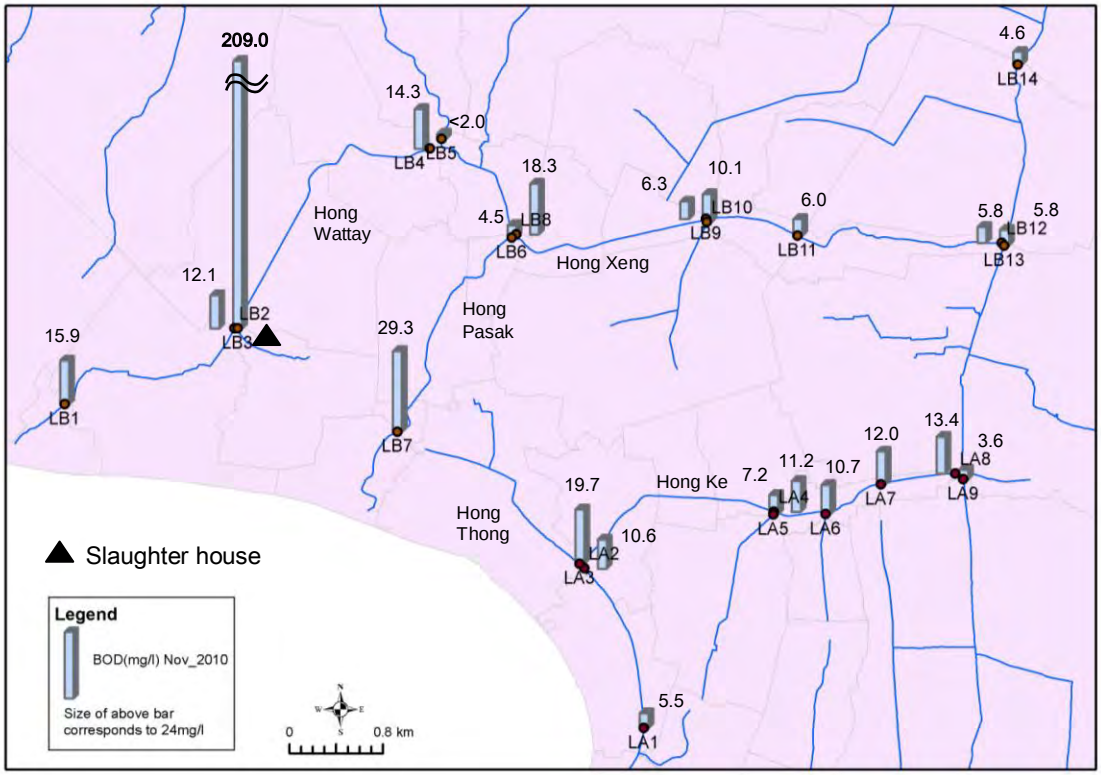


Fig. 2.22 Schematic Diagram of BOD in Longitudinal Monitoring (November 2010)

(3) Summary of Monitoring Results and Recommendation

Periodical and simultaneous longitudinal monitoring results are summarized, and a recommendation is given below.

- Judging from the coliform number observed at the monitoring points located along the mainstream or tributaries of Hong Ke and Hong Xeng, domestic and commercial wastewater may be dominant in the stream flow. High concentrations of BOD were not found in the stream flow, and BOD ranged from about 10 mg/l to 35 mg/l even in the dry season. On the other hand, at monitoring points along the Mak Hiao mainstream, observed BOD concentrations ranged from about 2 to 3 mg/l without significant seasonal variations.
- At the monitoring points along the mainstream or tributaries of Hong Ke and Hong Xeng, concentrations of NH_3-N were high, but the concentrations considerably lowered at monitoring points along the Mak Hiao mainstream in a similar manner as BOD.
- In general, NO_3-N was below 1.0 mg/l at most of the monitoring points and thus variations between the monitoring points were not significant.
- Except for some data, the range of observed PO_4-P concentrations was less than 1.0 mg/l.
- All the Heavy metals (six parameters) and pesticides (three parameters) were either undetected or negligible.
- At monitoring point LB3 where highly polluted wastewater is discharged from small-scale enterprises (slaughterhouse), it is recommended that treatment facilities with screens should be installed to control effluents.

2.6.3 Industrial Wastewater

WERI-WREA, Ministry of Industry and Commerce as well as the Department of Industry and Commerce, Vientiane, understand the importance of monitoring and inspecting industrial wastewater. Due to limitation of budget and human resources, however, such activities have never been conducted properly. Accordingly, very limited data on industrial wastewater are available.

WERI-WREA, Ministry of Industry and Commerce as well as the Department of Industry and Commerce, Vientiane, keep an inventory of factories. They understand the importance of monitoring and inspecting industrial wastewater, but due to limitation of budget and human resources, such activities are not conducted properly. Accordingly very little data on industrial wastewater is available.

Table 2.31 shows the survey results on the existing factories, including whether or not the factories affect the water quality of the Mak Hiao River and its tributaries. So far, the factories do not have a strong impact on the water environment of the Mak Hiao river basin or some of them are located out of the basin. At present industrial development has progressed centering on the industrial zone in the middle part of the basin, so that the appearance of water quality issues due to industrial effluent is to be anticipated in this area in future.

Table 2.31 Survey Results of Existing Factories in the Study Area

No.	Name of Factories	Existing Condition of the Factories
1	Beer Lao	Beer Lao is a large-scale factory located at the southern edge of That Luang marsh and producing beverages such as beer and drinking water. Wastewater generated is treated in its own treatment plant using a combination of anaerobic and aerobic process with the capacity of 3,500 m^3/day. The treated water is then discharged to the open channel next to the factory. The channel drains the water directly to the Mekong throughout the year, which means the treated water will not affect the water quality of Mak Hiao river basin.
2	Paper factory	Located in the north of 1.5 km from Beer Lao, the factory discharges white colored wastewater. However, the wastewater is scarce in quantity and this factory is out of the catchment area of Mak Hiao River.
3	Slaughterhouse located in Dondou Village	This slaughterhouse is located in Dondou Village in the west of That Luang Marsh. A pit for stocking the residues arising from the slaughter process is installed. However, wastewater is not observed and the factory is found to be out of the catchment area of Mak Hiao River.
4	Slaughterhouse located in Nongdouang Village	The factory is located at the upstream of the monitoring point LB3 and discharges considerably polluted wastewater. According to the monitoring result, the impact of wastewater seems to be limited, but pollution load discharged from the slaughterhouse is considered in water quality modeling.
5	Noodle factory	This factory is located in Nongsanokham Village in the east of Wattay International Airport, but the factory is small in scale and wastewater discharged can be negligible.
6	Garment factory located in Nakham Village	This factory is located in Nakham Village in the east of Wattay International Airport, but the factory is small in scale and wastewater discharged can be negligible.
7	Garment factory located in Donparlap Village	This factory is located in Donparlap Village, the neighboring area of monitoring point SP3. Small amount of wastewater seems to be discharged to the marsh nearby, but the connection of the marsh and the public water body (Hong Pasak) is not clearly identified.
8	Existing factories located at Vientiane Industrial Park	Around 17 factories are located in the Vientiane Industrial Park. The categories of the factories are steel mill, wood products, silicon and so on. Wastewater discharged by the factories is found to be negligible.
9	Others	Other factories such as tannery, which are discharging toxic and/or heavily polluted wastewater, are not located in the Study Area.

2.6.4 Water Quality Modeling

To evaluate and improve the water environment in Vientiane for the target year, water quality modeling for evaluating pollution load runoff was conducted considering the changes in living standard of people as well as socioeconomic, meteorological and hydrological conditions.

(1) Target Water Quality Parameter and Stream Flow

BOD is set as the target water quality parameter, and low flow is set as the target stream flow in the water quality modeling. To calculate BOD concentration, annual average low flow (75% flow, Q75) is utilized based on the "Guidelines for Comprehensive Basin-wide Planning of Sewerage Systems, The Japan Sewerage Works Association."

(2) Pollution Load to be Considered

Pollution loads considered in the water quality modeling are a) domestic wastewater, b) commercial wastewater, c) industrial wastewater, d) livestock, and e) non-point load from the fields.

(3) Model Calibration

Calibration of stream flow is conducted focusing on the monitoring result of December 2010 for eliminating the storm water effects. In the dry season, stream flow is dominated by wastewater originating from the water supply by pipe network or wells. Furthermore, most of the water is used in the daytime. Therefore, a peak factor is introduced to match the actual condition of water use. **Fig. 2.23** shows relations between observed and estimated stream flow at the monitoring points in good agreement.

BOD is also calibrated using the monitoring results in December as well as setting-up of runoff coefficient and self-purification coefficient, which were referred to relevant data and the present situations. As shown in **Fig. 2.24**, relationship between observed BOD and estimated one is satisfactory. Thus, the water quality model constructed in the study could be suitable for estimating the future water quality.

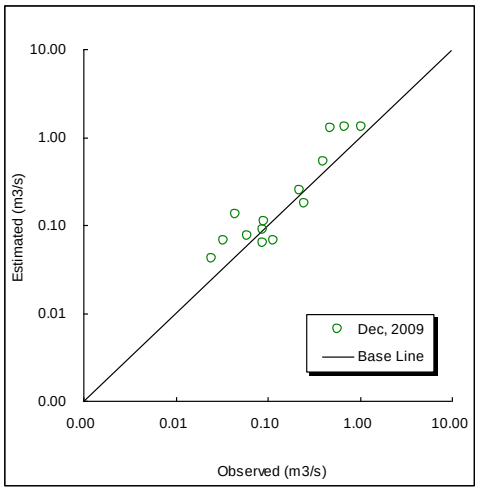


Fig. 2.23 Relations of Observed and Estimated Stream Flow

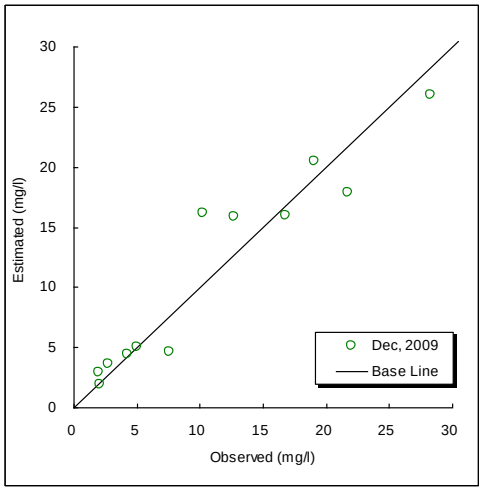


Fig. 2.24 Relations of Observed to Estimated BOD

(4) Pollution Load Generation and Runoff in 2009

Table 2.32 and **Fig. 2.25** shows pollution load generation and runoff in 2009 computed by applying the water quality model. Total pollution load generation is 31,485 kg/day. The pollution load is discharged to the river/drainage channel after it is treated in the septic tank, or without treatment. Due to low runoff coefficient, only 2,579 kg/day or 8.2% of the total reaches the river/drainage channel. Pollution load at the downstream end of the Mak Hiao River was computed at 220 kg/day or 8.5% of the load reaching the river/drainage channel. It resulted from the natural purification function in the Mak Hiao River due to low velocity (less than 0.1 to 0.2 m/s) as well as the long distance of about 30 km from the source areas in central Vientiane.

Table 2.32 Pollution Load Generation and Runoff (2009)

	Pollution Source	Pollution Load (kg/day)			Percentage (%)		
		Generated	Reach the River	D/S end of Mak Hiao River	Generated	Reach the River	D/S end of Mak Hiao River
1	Domestic	16,326	1,437	70	100.0	8.8	0.4
2	Commercial	2,441	221	8	100.0	9.1	0.3
3	Industrial	300	300	4	100.0	100.0	1.2
4	Livestock	12,107	605	131	100.0	5.0	1.1
5	Non-point	309	15	3	100.0	5.0	1.0
	Total	31,485	2,579	217	100.0	8.2	0.7

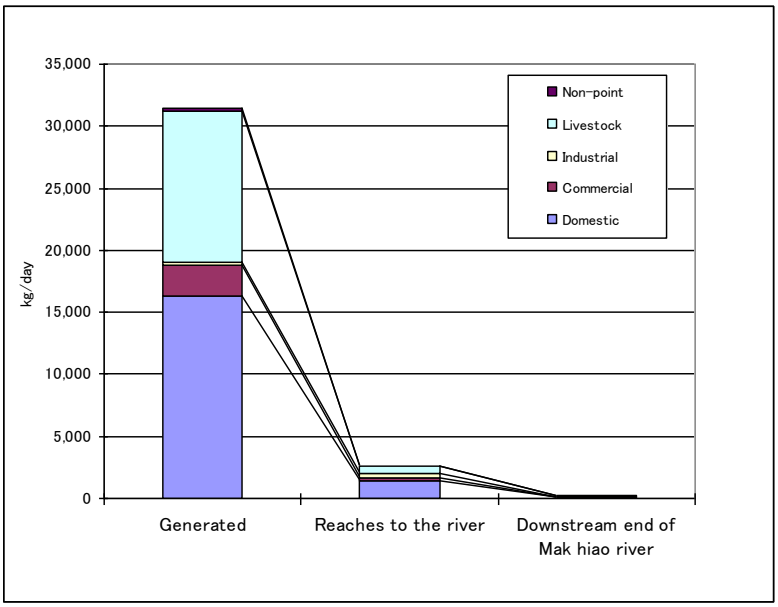


Fig. 2.25 Pollution Load Generation and Runoff in 2009

2.7 Aquatic Biology

2.7.1 Survey Objectives and Methodology

(1) Objectives

In general, aquatic species composition differs depending on water quality at the site; therefore, aquatic species are used as indicators to evaluate water quality.

The biological survey aims to comprehend current biological conditions in the Mak Hiao river basin by conducting field survey and to develop biological indicators by analyzing the relationship between species and water quality. The developed biological indicators are expected to be utilized for supplementing water-quality monitoring and understanding water environment from ecological viewpoints.

(2) Methodology

Fourteen survey points in the Mak Hiao river basin were selected, as shown in **Table** 2.33 and **Fig. 2.26**. The regular survey points, B1-B9, were selected to be the same location as the water quality monitoring points to analyze the relationship between species and water quality. The additional survey points, B10-B14, were set in the marsh area, upper reaches of the Mak Hiao River, to comprehend natural biological condition without influence of wastewater from the city.

Table 2.33 Biological Survey Point

Classification	Biological Survey Points	Correspondent Water Quality Monitoring Points	Location
Regular Survey Points	B1	SP2	Downstream end of Nam Pasak (Upstream of Hong Xeng)
	B2	SP3	Downstream end of Hong Pasak
	B3	SP6	Downstream end of Hong Kai Keo
	B4	SP7	Midstream of Hong Ke
	B5	MP3	Mak Hiao River
	B6	SP9	Mak Hiao River
	B7	MP4	Mak Hiao River
	B8	MP5	Mak Hiao River
	B9	MP6	Mak Hiao River
Additional Survey Points	B10	-	That Luang Marsh
	B11	-	That Luang Marsh
	B12	-	That Luang Marsh
	B13	-	That Luang Marsh
	B14	-	Upstream marsh of Nam Pasak

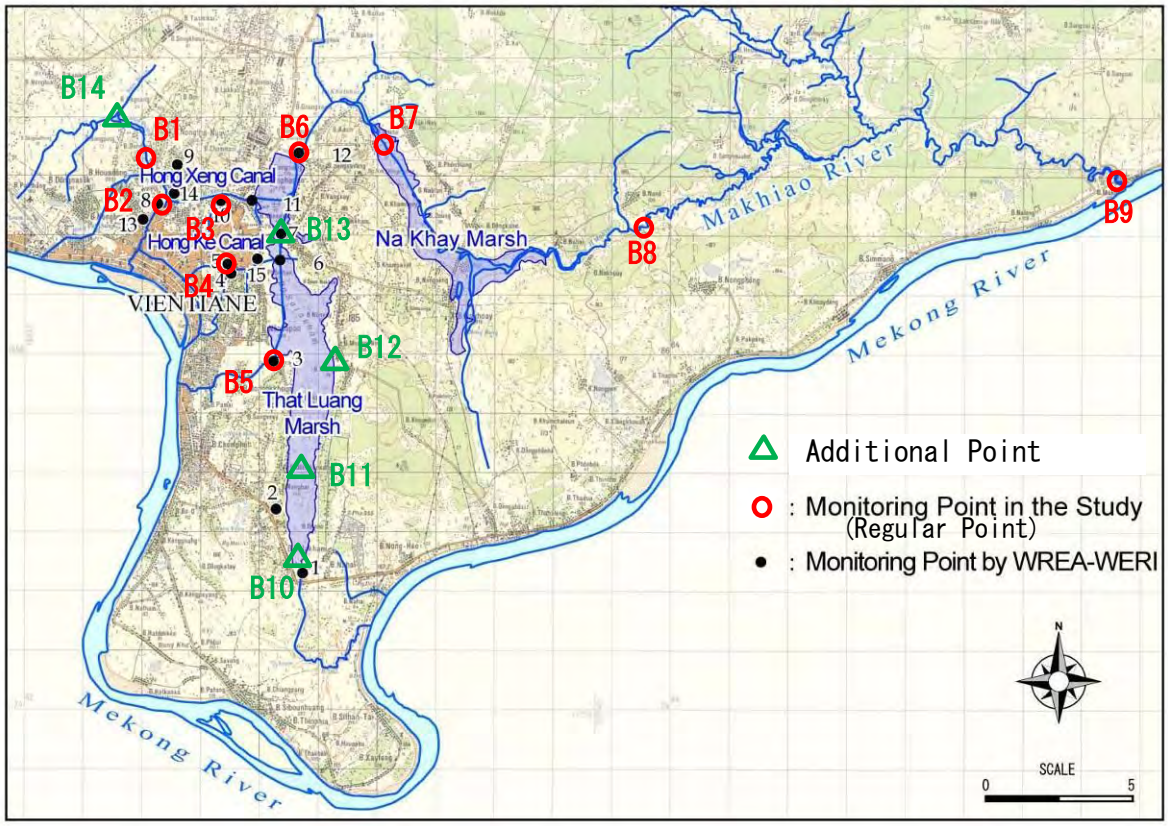


Fig. 2.26 Location of Biological Survey Points

Table 2.34 presents the overall frequency of field survey. The regular survey sites were explored every time, while the additional sites were once in each season; rainy and dry season.

Table 2.34 Overall Frequency of the Biological Survey

Month / Year	Dry Season				Rainy Season						Dry Season	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009		X	X				XX					X
2010	X	XX						X			X	

Note: X: regular survey points only; XX: both regular and additional survey points

2.7.2 Relation between Water Quality and Aquatic Species

(1) Water Quality Classification

In order to understand the biological conditions in accordance with water quality, water quality at each survey point was overviewed based on the water quality survey results. **Fig. 2.27** shows a schematic diagram of water quality classification of the Mak Hiao river basin, which consists of five classes from "very good" to "very bad." **Fig. 2.28** depicts actual water quality survey results at each biological survey point.

(a) Urban area (B2, B3 and B4): Very Bad

Water quality in the urban area (urban drainage), where B2, B3 and B4 are located, is highly polluted especially in the dry season. Observed BOD at each point in the dry season far exceeds 10 mg/l (see **Fig. 2.28**), and the average at 9 water quality survey points in the urban drainage reached 20 mg/l (see **Fig. 2.29**). Therefore, the water quality

is classified as "very bad" water quality. On the other hand, the BOD and nitrogen (NH_3-N) concentrations improved in the rainy season.

(b) Middle to Downstream of the Mak Hiao River (B6, B7, B8 and B9): Bad→Fair→ Good→Very Good

The points in the Mak Hiao River (B6, B7, B8 and B9) show relatively lower BOD compared with the urban area, below 8 mg/l throughout the year. Especially, the water quality changes to better and better conditions toward downstream (the classification changes as "bad→ fair→ good"), and finally BOD reaches less than 3 mg/l at B9 of the river mouth (classified as "very good" water quality).

(c) Upstream of the Urban Area (B1, B5): good

In the upstream of the urban area, where B1 and B5 are located, the water quality is also in good condition because it is not affected by the wastewater from the urban areas. The BOD and nitrogen (NH_3-N) concentrations are almost in the same level as the lower reaches of the Mak Hiao River.

(d) Additional Survey Points (B10-B14)

Since no water quality survey has been conducted at the additional survey points (B10-B14) which include the That Luang Marsh. NH_3-N was examined in the rainy season (August, 2010) and the dry season (November, 2010) and found that water quality was in good condition with low level of NH_3-N concentration.

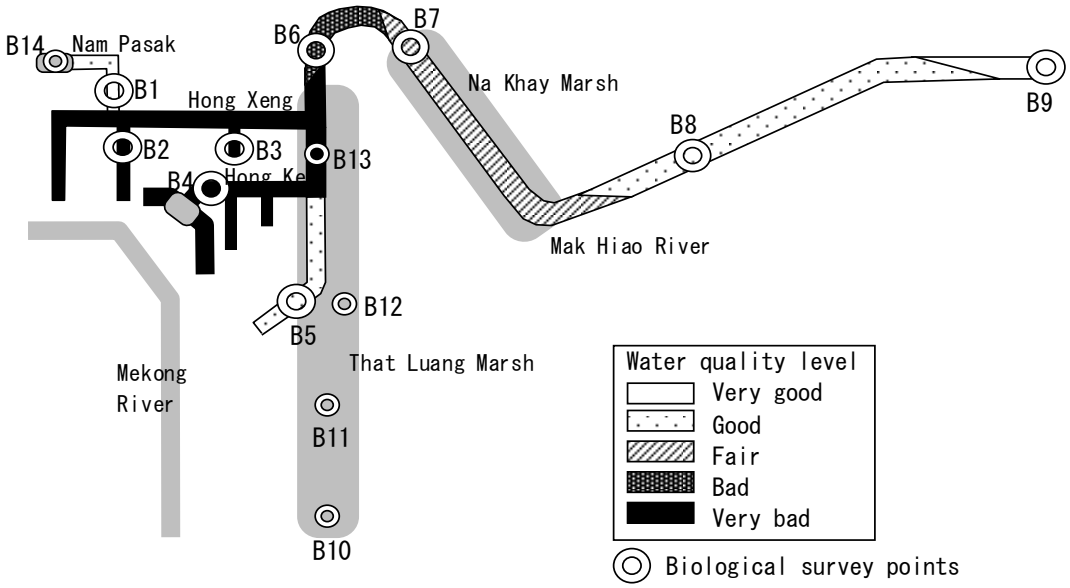


Fig. 2.27 Water Quality Classification of the Mak Hiao River Basin

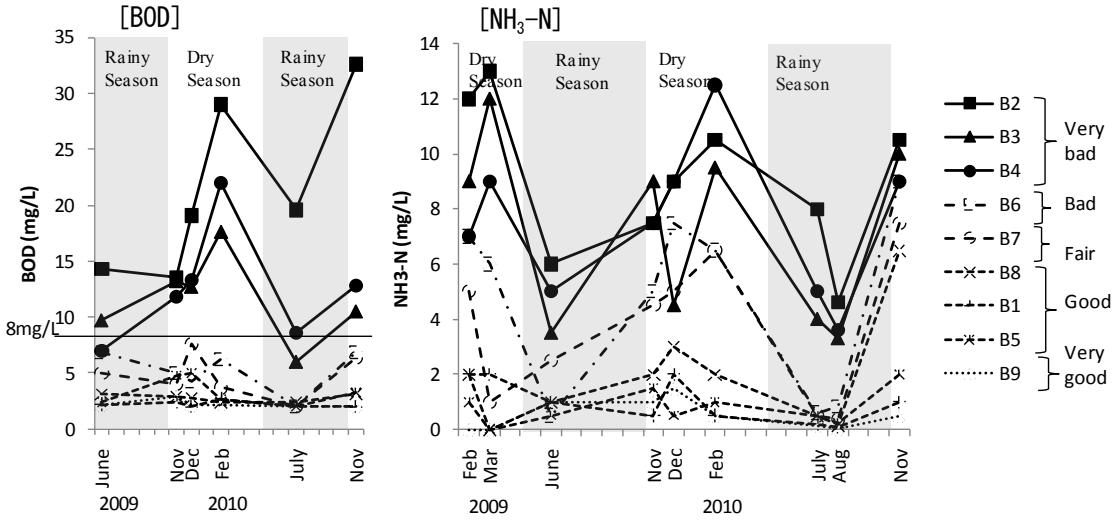


Fig. 2.28 Seasonal Changes of Observed Water Quality

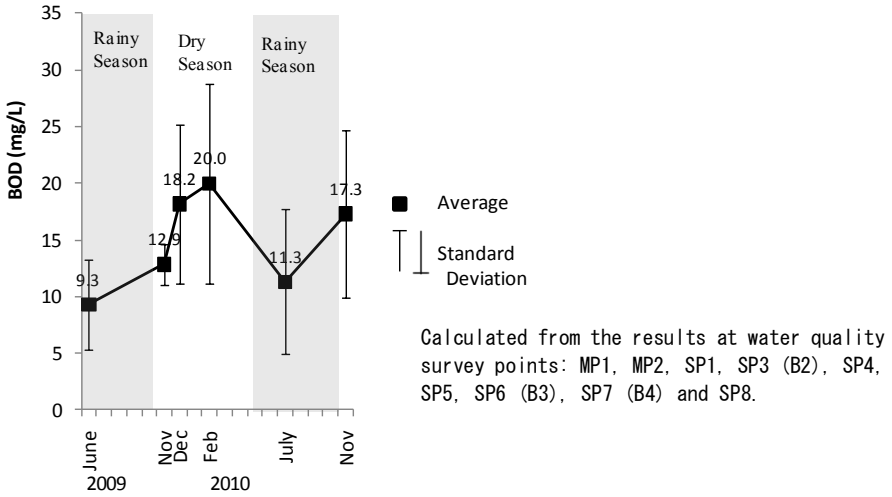
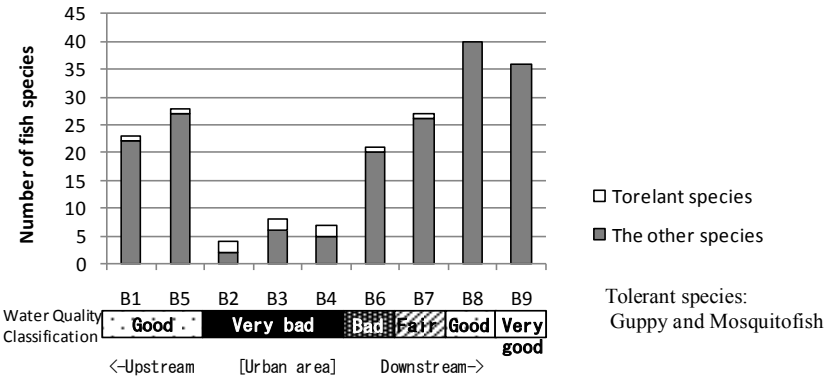


Fig. 2.29 Seasonal Changes of Average BOD in the Urban Drainage

(2) Fish

Fig. 2.30 shows the total number of fish species observed at each survey point during the 8 surveys. In the urban area (B2-B4) with "very bad" water quality, the number of fish species was obviously smaller than the other sites. Furthermore, pollution tolerant species accounts for a larger portion of the total number of species in this area compared with the other sites.

The number of species except pollution tolerant species (**Fig. 2.31**) tends to increase in the rainy season in the urban area. These facts indicate that the habitat conditions in the urban area are briefly improved and enable fish to come into and inhabit in the area due to stream flow increase and brief improvement of water quality brought by dilution. In addition, the relationship between BOD and the number of fish species except tolerant species (**Fig. 2.32**) shows that more fish species live in the sites with low BOD.



Surey frequency: Eight times excepting B9. B9 is seven times since it was not explored in July 2009 due to high water level.

Fig. 2.30 Total Number of Fish Species Observed during the Eight Surveys

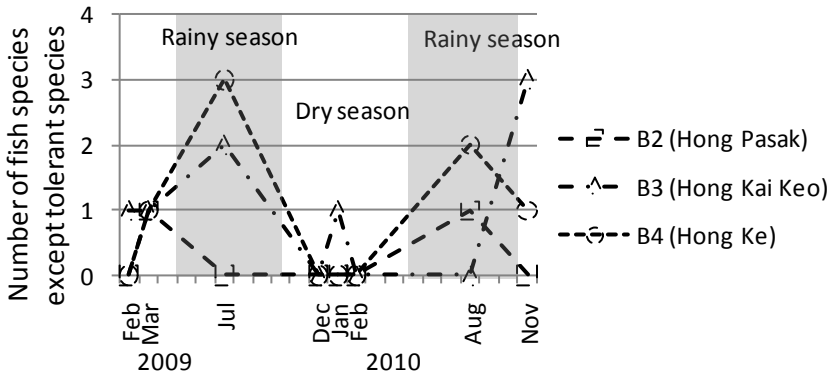


Fig. 2.31 Number of Fish Species except Pollution Tolerant Species (Guppy and Mosquitofish) in the Urban Area

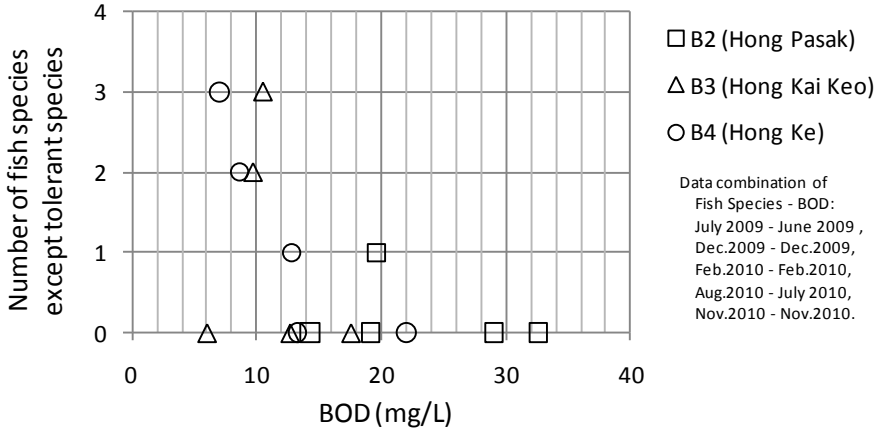
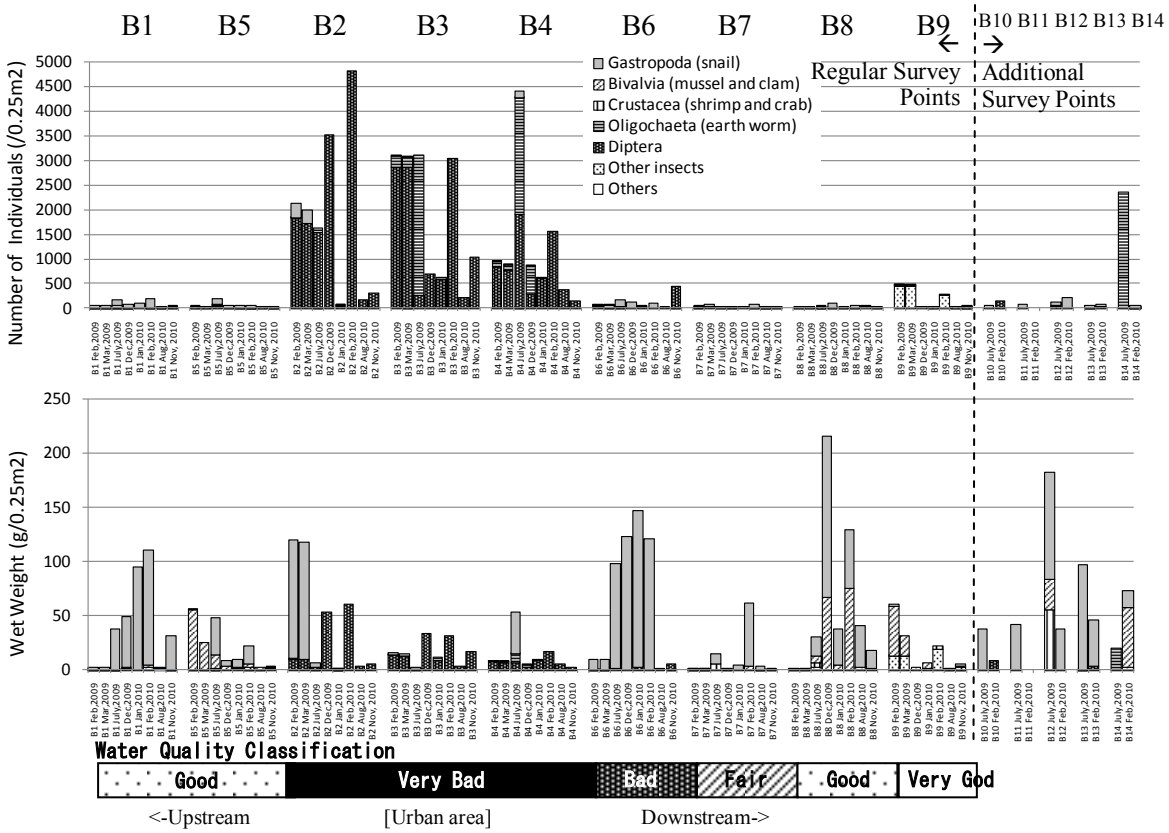


Fig. 2.32 Relationships between BOD and Number of Fish Species except Pollution Tolerant Species in the Urban Area

(3) Benthic Invertebrates

The individual number and wet weight of collected benthic invertebrates are illustrated in **Fig. 2.33**. Different benthic invertebrate species were found in accordance with the water quality condition at the survey points.

In "very bad" water quality area (B2-B4), large number of diptera larvae (blood worm, mosquito and moth fly) and oligochaeta (aquatic earth worm) were collected. In terms of wet weight, gastropoda (snail) and bivalvia (mussel and clam) dominated at many sites. Bivalvia tends to concentrate in "good" and "very good" water quality, while gastropoda is deemed to distribute in wide a range of the water quality. Furthermore, caddis fly (categorized into other insects) dominates in B9 with "very good" water quality.

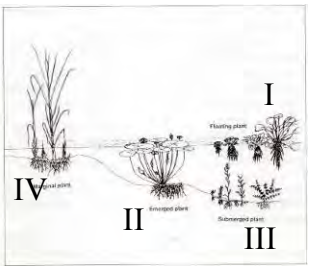


Note 1) Additional survey points were explored only in July and February, 2010.
2) B9 was not explored in July 2010 due to high water level.

Fig. 2.33 Number of Individuals and Wet Weight of Collected Benthic Invertebrates

(4) Plants

Plant species do not directly relate to water quality classification; lots of species are found even in the "very bad" water quality area. In general, aquatic plant species are categorized into four groups in accordance with their living styles: floating species, emerged species, submerged species and marginal species (**Fig. 2.34**). Adding terrestrial species as the fifth group, the observed species at each regular survey point are categorized and the number of species is summarized in **Fig. 2.35**. Excepting the terrestrial species, lots of aquatic species are observed in the urban area indicating richness of the aquatic flora in the urban drainages. Aquatic plants provide habitat to fish and other aquatic organisms since the organisms inhabit among the roots and leaves of plants. Therefore, the richness of aquatic plants may indicate that various fish and the other organisms inhabit if the water quality is improved.



Category I: Floating species
Category II: Emerged species
Category III: Submerged species
Category IV: Marginal species

Fig. 2.34 Categorization of Aquatic Plant Living Style

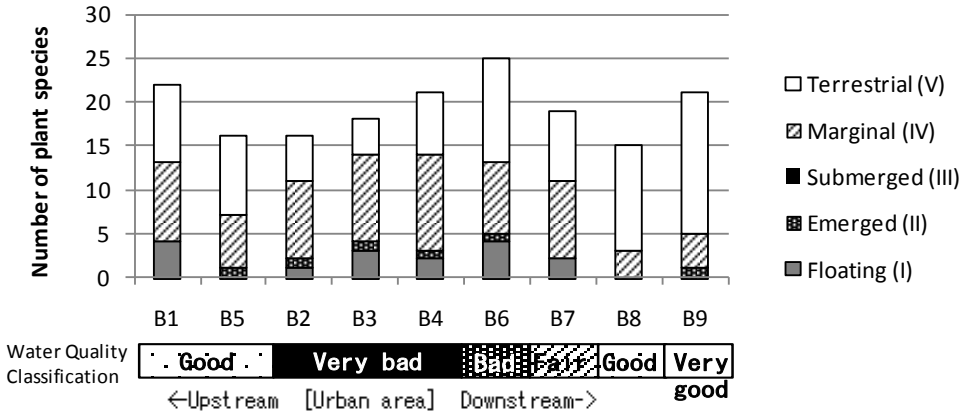


Fig. 2.35 Number of Plant Species Categorized by Living Styles

2.7.3 Developing Biological Indicator

The survey results show that the each species of fish and benthic invertebrates distribute in accordance with the water quality; for example, some species are mainly found in "good" or "very good" quality water, while others concentrate in "very bad" water quality area. The selected biological indicators are categorized into six groups; three of them are fish (F-I, F-II and F-III) and the other three are benthic invertebrates (B-I, B-II and B-III). The range of water quality indicated by each group is shown in **Table** 2.35. Furthermore, **Table** 2.36 presents the relationship between pictures of indicative species and their suitable water quality and general conditions.

In the most polluted urban area with "very bad" quality water, almost only pollution tolerant species (F-I and B-I) are found, and it is deemed to be difficult for the other species to inhabit there. Species categorized into F-I, guppy and mosquito fish, tend to concentrate in the polluted area although they are capable to live in the better quality water. B-I consists of bloodworm, mosquito and moth fly larvae, which are generally uncomfortable species for human life.

The water quality areas categorized into "bad to fair" indicate the other fish species are typical except guppy and mosquito fish (F-II). Some of them are beneficial for fishery; loach, climbing perch and tilapia. In this area, there are no specified benthic invertebrates to indicate the water quality although a lot of kind of snails can be observed (Snails can live in wide range of water quality).

In the "good" and "very good" quality water, the number of beneficial fish species for fishery is increased; freshwater garfish, leaf fish, catfish and eel are included in the indicator species (F-III). In addition, valuable benthic invertebrates such as mussel, clam and dragonfly larvae are found in

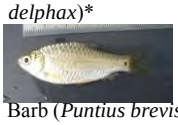
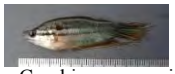
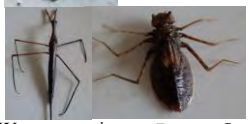
–good" quality water (B-II). In –very good" quality water, another mussel and caddis fly indicate the condition (B-III).

Table 2.35 Range of Water Quality and Indicative Species

	Water Quality Level	**Very Bad**	**Bad**	**Fair**	**Good**	**Very Good**
	BOD	more than 10 mg/l*	4-8 mg/l	4-8 mg/l	2-5 mg/l	2-3 mg/l
	NH3-N	more than 3 mg/l	1-9 mg/l	1-8 mg/l	less than 3 mg/l	less than 2 mg/l
	DO		Low			
Group	Survey points	B2, B3, B4	B6	B7	B1, B5, B8	B9
Fish	F-**I**	←	– – –	– – –	– – →	
	F-**II**		←	←	→	– – →
	F-**III**				←	→
Benthic invertebrates	B-**I**	←				
	B-**II**				←	
	B-**III**					←

* Dry season

Table 2.36 Biological Indicator for Stream Water Quality

Water Quality	General Condition	Indicator Species
Very Bad	 BOD >10mg/l, NH_3-N>3mg/l Smelly black colored mud with rubbish.	**[F-I]**  Guppy Mosquito fish  Guppy and Mosquito fish  Bloodworm (*Chironomus tentans*) Mosquito **[B-I]**  Bloodworm (*Procladius* sp.)  Moth fly (*Psychoda alternate*)*
Bad to Fair	 BOD 4-8mg/l, NH_3-N 1-9mg/l Turbid yellowish water. A little muddy sediment.	**[F-II]**  Loach (*Acanthopsoides delphax*)*  Barb (*Puntius brevis*)  Croaking gourami  Mekong flying barb  Climbing perch  Nile tilapia  Rasbora *(Rasbora rubrodorsalis)*
Good	 BOD 2-5mg/l, NH_3-N <3mg/l Turbid water without pollution. Riverbed consists of clean soil.	**[B-II]**  Mussel (*Ensidens ingallsianus*)  Clam (*Corbicula* sp.)  Water scorpion (*Cercotmetus* sp.) Dragonfly (*Epicordulia* sp.) **[F-III]**  Catfish (*Mystus atrifasciatus*)  Catfish (*Mystus mysticenus*)  Malayan leaffish  Freshwater garfish  Butter catfish  Peacock eel
Very Good	 **BOD 2-3mg/l, NH3-N <2mg/l** **Water flows washing the riverbed which consists of gravels.**	**[B-III]**  Mussel (*Anodonta cygnea*)  Caddis fly (*Macrostemum* sp.)  Caddis fly (*Cheumatopsych peltiti*.)

Source of photo with *
Moth fly (*Psychoda alternate*): http://hydrobiology-bg.com/ and http://entoplp.okstate.edu/ddd/insects/mothfly.htm
Loach (*Acanthopsoides delphax*): http://www.fishbase.org/

2.7.4 Target of Water Quality Improvement for Aquatic Organisms

Based on the aquatic biological conditions clarified through the survey, the improvement target of water quality in the Mak Hiao river basin is as deliberated below.

(1) Urban Area (Urban Drainage): Target BOD < 8-12 mg/l

In Hong Xeng, Hong Ke and the other urban drainages connecting to these two canals, aquatic biological condition is very poor due to water pollution. Only limited fish species with pollution tolerance and uncomfortable invertebrates such as bloodworm and mosquito larvae manage to inhabit. On the other hand, various species can be observed at the upstream and the downstream of the urban area. Therefore, if the water quality in the urban area is improved to a similar level as those stretches, the migratory species such as fish will be able to migrate in the entire stretch and the biological productivity of the river basin will be increased. The highest observed BOD in the upstream and downstream stretches is 8 mg/l, as illustrated in **Fig. 2.36**. Therefore, 8 mg/l is proposed as the desirable target of water quality improvement in the urban drainages.

The actual BOD in the urban drainages, however, is showing a considerably polluted condition, especially in the dry season, since the average BOD of the nine water quality survey points reaches 20 mg/l. Therefore, an immediate target is required because it is deemed to be difficult to achieve the desirable target of 8 mg/l directly.

It has been observed that BOD in the urban drainages becomes lower in the rainy season due to dilution, and it enables fish without pollution tolerance to come into and inhabit in the drainages temporarily. Based on this fact, the immediate target of BOD is proposed to be the same level as in the rainy season. Since the average BOD observed during each of the two surveys in the rainy season was below 12 mg/l, BOD 12 mg/l is proposed as the immediate target (see **Fig. 2.36**).

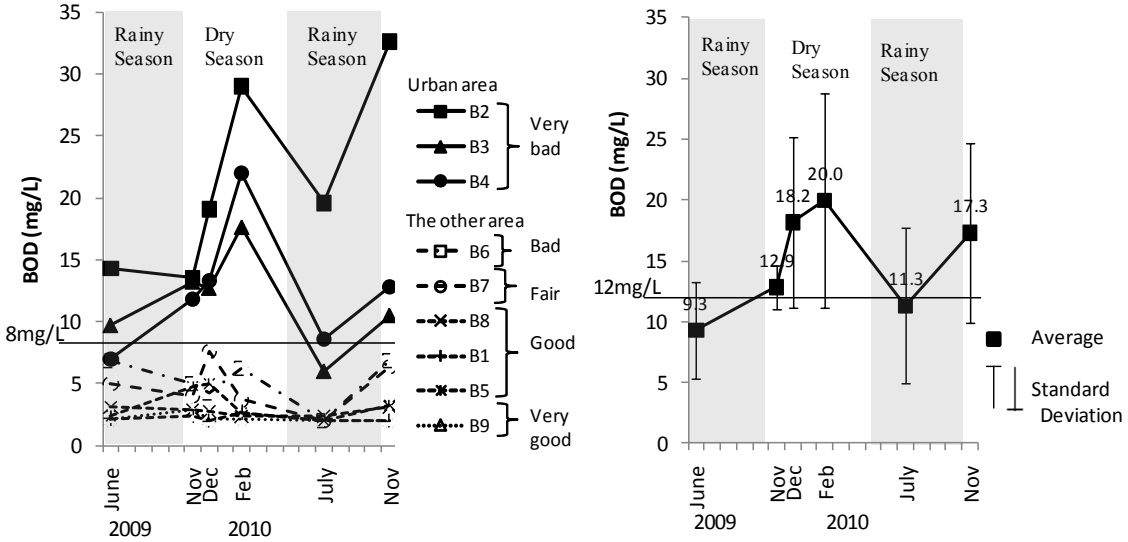
(2) Middle Stretch of the Mak Hiao River including the That Luang Marsh: Target BOD < 8 mg/l

Water quality in the Mak Hiao River including the That Luang Marsh is still in inhabitable condition for the species without pollution tolerance, except for the areas around the confluences with Hong Xeng and Hong Ke. The current BOD in most areas is 8 mg/l at the highest. However, in the downstream of the urban area (B6), the habitat condition is not sufficient, as shown by the accumulated sludge and low level of DO. If the pollutant load from the urban area will continue or increase, the habitat condition in this area will be worse and only limited species may be able to inhabit as in the urban area. Therefore, it is recommended that the condition should be monitored carefully to keep the current water quality below BOD 8 mg/l.

(3) Down-most Stretch of the Mak Hiao River (Near Rivermouth): Target BOD < 5 mg/l

Water quality near the river mouth of the Mak Hiao River is in good condition throughout the year showing low BOD below 5 mg/l. Various species have been observed including beneficial species for fishery. Any indication toward deterioration has never been identified so far. Therefore, it is desirable that the current condition could be maintained continuously.

Fig. 2.37 presents the suitable target of water quality.



a. Observed BOD at the Biological Survey Points and the Desirable Target (8mg/L)

b. Observed BOD at the Nine Water Quality Survey Points in the Urban Drainages and the Immediate Target (12mg/L)

Fig. 2.36 Observed BOD and Target Water Quality in the Urban Drainages

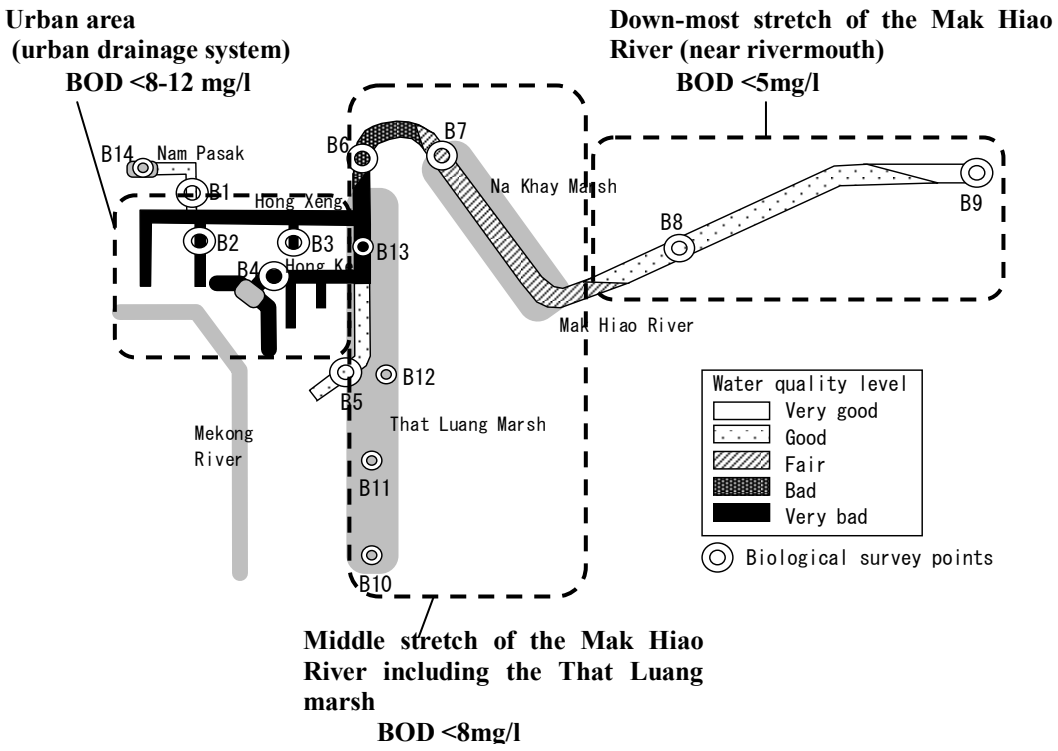


Fig. 2.37 Target of Water Quality Improvement of the Mak Hiao River Basin

2.8 Water Purification Effects of Water Plants in Drainage Canals

2.8.1 Background and Objectives

It has been confirmed that the canals in Vientiane suffer from some water pollution accompanying bad odor, sludge sedimentation, and the others, mainly due to the direct discharge of domestic wastewater. This situation could be improved by installing some wastewater treatment facilities including sanitation improvement measures such as Community-Based Sanitation (CBS) system at suitable sites.

Sediment on the riverbed can provide the base ground for plants to grow in the canals as can be seen in some water surface areas of the canals covered with natural vegetation, including wild water spinach (*Ipomoea aquatica Forsk*). It has been reported that natural vegetation has water purification effects in water bodies in many countries. Thus, it would be valuable to verify any effect of natural vegetation in an existing canal, as an experimental approach to the establishment of a suitable water environmental improvement in the city.

In general, natural vegetation has the following water purification effects in water bodies: (1) decrease of Suspended Solids (SS) through acceleration of sedimentation and filtering effect; (2) absorption of nutrients [phosphorus (P), nitrogen (N)]; and (3) decomposition of organic substances by adhering microorganisms. However, there are few cases to conduct verification for any water purification effect by water spinach quantitatively in existing canals. Thus, field survey and experiments were conducted to understand the following items, even only in preliminary stage:

- Water purification effects by wild plants, mainly wild water spinach in some sections in the canal
- Water purification mechanism by wild plants, mainly wild water spinach

2.8.2 Outdoor Experiments and Findings on Water Purification

(1) Experimental Approach

Outdoor experiments were conducted from 2 to 6 August 2010. The experiment sites were selected based on the present water quality and vegetation conditions in the canal. Two experiment sites were selected in the lower reaches of the Hong Pasak (see **Fig. 2.38**).

The experiment sites selected require the following conditions:

- Wild water spinaches are broadly grown in or on surface water along the canal;
- There are few inflows from drainage system; and
- The site is located in some straight alignment, where no morphological effect to water purification might be caused.

The water quality such as SS values in the upstream and downstream ends was measured before cutting the natural vegetation including water spinach and after cutting the natural vegetation in each case. **Photo 2.5** presents the images of the analyzing method for SS. As the additional measurements, depth and velocity were measured to calculate the flow discharge.

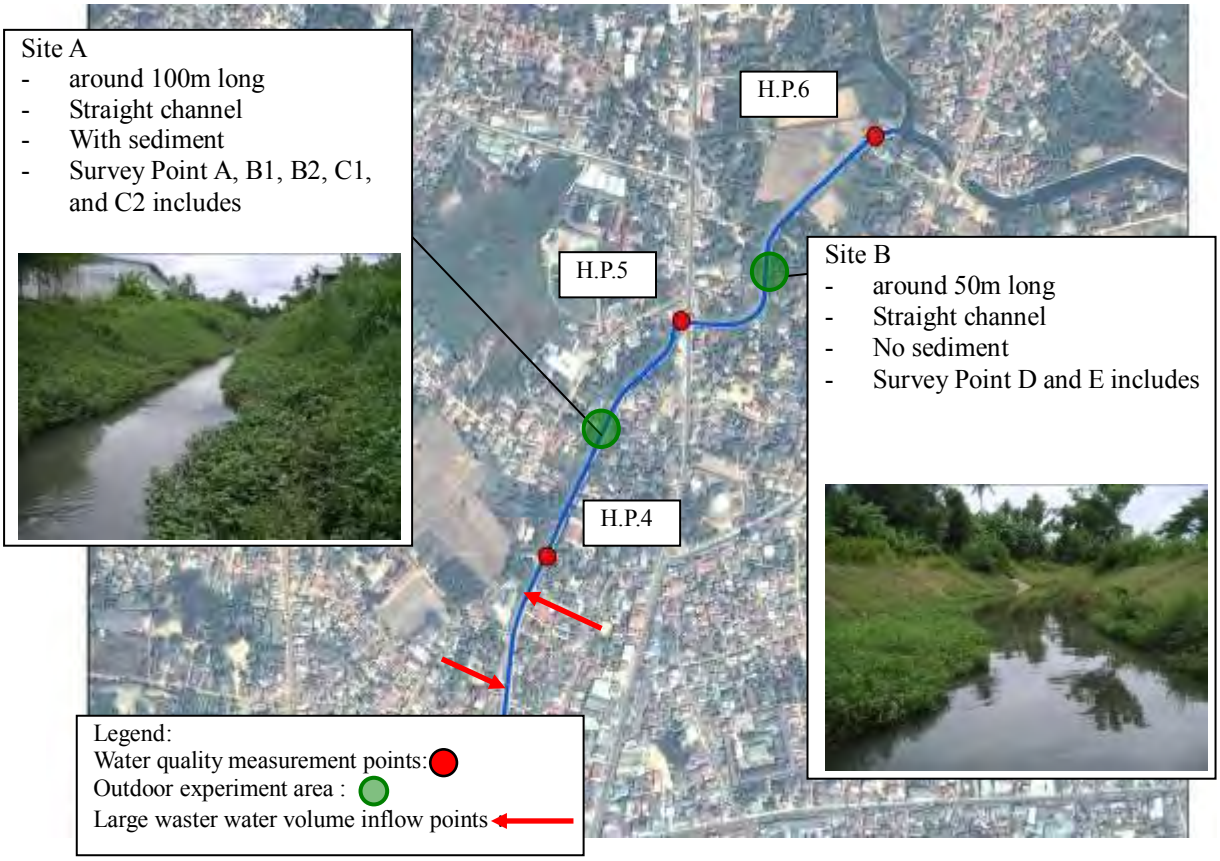


Fig. 2.38 Areas for Outdoor Experiment

Photo 2.5 Imaged Quantitative Analysis in Outdoor Experiment

(2) Water Purification Mechanism by Water Spinach

Based on the results of the outdoor experiments and related observations, the mechanism of water purification by water spinach could be summarized as below.

(a) Reduction of SS

The following reduction process of SS was found through the outdoor experiments:

(i) The vegetation reduces velocity of stream flow through the stalks and roots thickly growing in the water.

(ii) SS concentration decreases through filtration and sedimentation effects of the stalks and roots.
(iii) The stalks and roots of water plants can cultivate a layer of microorganisms on them, called microbial bio-film, and it could contribute to trapping SS.

Photo 2.6 shows the difference in the color of roots of water spinach; brown in the canal and white in the indoor tub. This difference in color may suggest SS was trapped in the canal by the roots.

(b) Reduction of Inorganic N

The amount of absorption of inorganic N by plants in the canal was quite few applying the result of indoor experiment. Therefore, the reduction of inorganic N could be consistent with the reduction of organic matters of SS and it leads to the reduction of BOD value as well.

(c) Reduction of BOD

Reduction of BOD would occur mainly through filtration and sedimentation of organic matters of SS.

Roots of water spinach (outdoor)

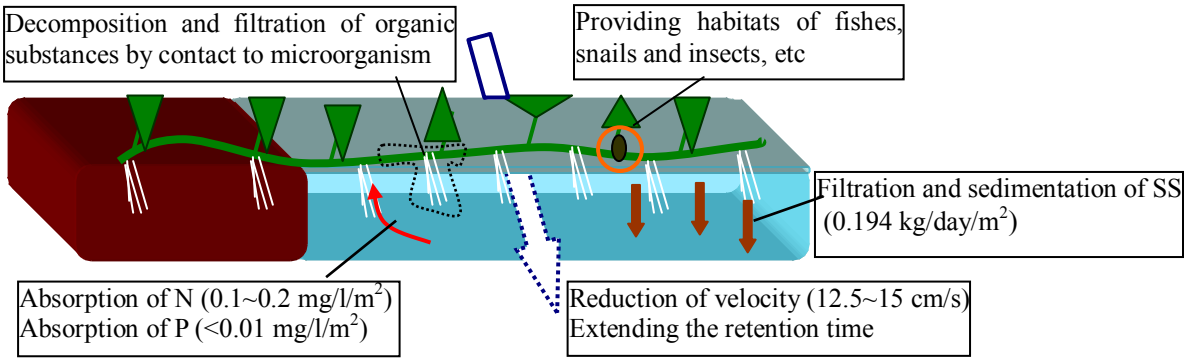
Roots of water spinach (indoor)

Photo 2.6 Condition of Roots of Water Spinach

2.8.3 Water Quality Improvement Using Water Spinach

(1) Water Purification Mechanism of Water Spinach

In due consideration of the experimental examination, water purification functions of water spinach could improve water quality in the canal to some extent. **Fig. 2.39** illustrates a schematic mechanism of water purification based on the experiments in Hong Pasak. Water purification effects by water spinach occurs mainly through reduction of SS including suspended organic matters which leads to the reduction of the BOD and N in the thickly growing area of the water plants in Hong Pasak.



Note: The reduction rates are based on the survey results

Fig. 2.39 Schematic Mechanism of Water Purification by Water Spinach

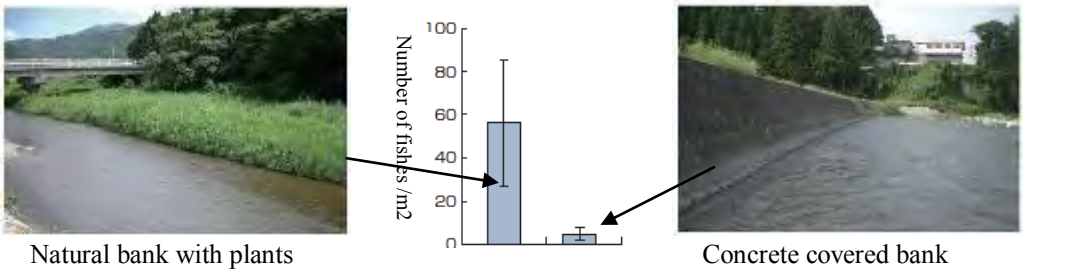
(2) Suitability of Water Spinach for Water Purifying Measures

According to the relevant findings and hearings with a botanical specialist in the National University of Lao PDR, water spinach could be suitable as a plant for the vegetative water purification measure in the drainage canals for the following reasons:

- There are few seasonal fluctuations of purification effects by water spinach, since water spinach grows throughout the year without defoliation. On the other hand, water spinach does not grow so much in the dry season due to scarce rainfall.
- Water spinach is applicable to fluctuations of water volume between the dry season and the rainy season, since water spinach grow floating stalks and leaves on a water surface. On the other hand, other types of plants such as sessile joy weed, which grow with roots in the ground, would be flooded in the rainy season and finally wither.
- Water spinach in the drainage canals is utilized for feed of swine. Therefore, water spinach is a usable plant.

(3) Effects of Water Plants on Habitats of Aquatic Organisms

Water plants can contribute to providing habitat for aquatic organisms. As an experimental result, **Fig. 2.40** shows the number of fishes in accordance with the bank type. This investigation result clearly indicates that water plants can provide important habitat for fishes.



Natural bank with plants

Concrete covered bank

Cited from ARRC activity report 2004

Fig. 2.40 Number of Fishes in Accordance with Bank Type

Many snails stick to the water spinach, and several species of dragonfly fly and rest among the water plant areas in the canal. Thus, water spinach can contribute to providing habitats for fishes, snails and some species of insects (see **Photo 2.7**).

	
Snails stick to the roots and stalks	A species of dragonfly flies in the canal

Photo 2.7 Snails and Dragonfly in Canal