JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

DEPARTMENT OF PUBLIC WORKS AND TRANSPORT
PHNOM PENH CAPITAL CITY
KINGDOM OF CAMBODIA

THE STUDY ON DRAINAGE AND SEWERAGE IMPROVEMENT PROJECT IN PHNOM PENH METROPOLITAN AREA

FINAL REPORT

VOLUME I
SUMMARY

DECEMBER 2016

CTI ENGINEERING INTERNATIONAL CO., LTD.
NIPPON KOEI CO., LTD.
KITAKYUSHU WATER SERVICE CO., LTD.

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COMPOSITION OF FINAL REPORT

VOLUME I: SUMMARY

VOLUME II: MAIN REPORT

VOLUME III: ANNEX

Currency Exchange Rates used in this Report

[Master Plan Stage]

USD	1.00	= Riel	3,988	= JPY	119.64
Riel	1.00	= USD	0.00025	= JPY	0.030
JPY	1.00	= USD	0.0084	= Riel	33.3

(As of 1st April 2015)

[Pre-Feasibility Study Stage]

USD	1.00	= Riel	4,033	= JPY	122.85
Riel	1.00	= USD	0.00025	= JPY	0.030
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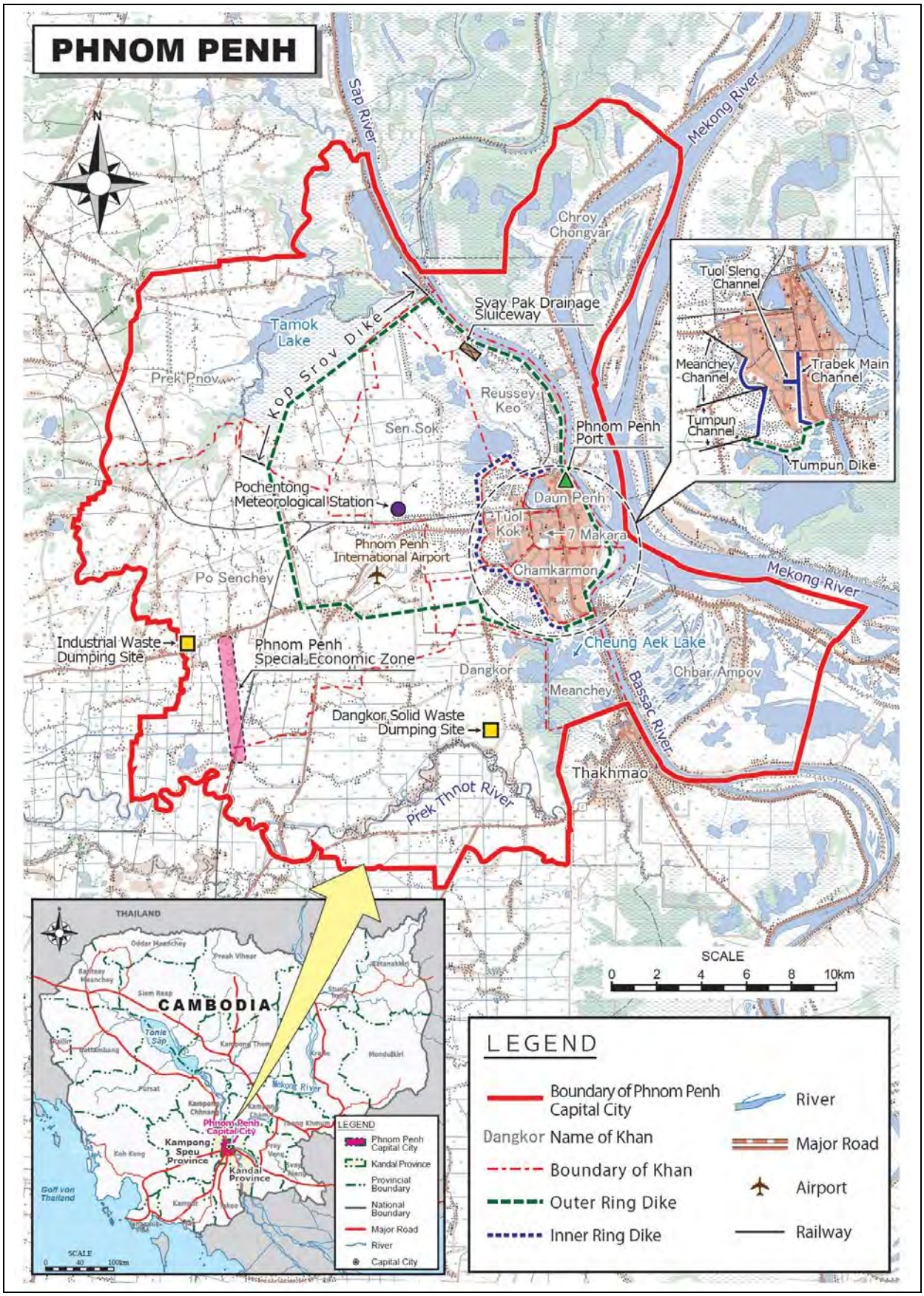


LOCATION MAP

	
Cheung Aek Lake	Discharged Water from Kop Srov Pumping Station
	
Trabek Channel	Tamok Lake
	
Wastewater Treatment Facilities in Dye House	Wastewater Treatment Facilities in Aeon Mall
	
Water Quality Monitoring at Prek Thnot River	Septic Tank (Under Construction)
	
Septage Vacuum Truck	Candidate Site of Cheung Aek STP

PHOTOGRAPHS (1/2)

	
Inundation in Wat Phnom Northern Area	Inundation in Trabek Channel
	
House near Trabek Pumping Station (In inundation)	House near Trabek Pumping Station (No Inundation)
	
Existing Drainage Channel (1/2)	Existing Drainage Channel (2/2)
	
Existing Pumping Station (Kop Srov Pumping Station)	Existing Pumping Station (Tuol Sampeo Pumping Station)
	
Box Culvert in Development Area (Under Construction)	Pipe Cleaning by DSD

PHOTOGRAPHS (2/2)

Outline of Master Plan and Pre-Feasibility Study

Item	Contents
Sewage Management (M/P)	
Target year	2035
Planning strategy	PPCC is subdivided into three areas (Cheung Aek, Tamok and Other areas) and applicability of on-site and off-site treatment for the target year 2035, is evaluated.
Planning frame	Cheung Aek area: Population of 1,093,155 in the planning area of 4,701.9 ha. Tamok area: Population of 481,423 in the planning area of 6,019.2 ha. Other area: Population of 1,292,522 (Total Population of 2,867,100-1,093,155-481,423)
Treatment system	Cheung Aek area: Off-site treatment with combined system is applied. A STP is proposed with capacity of 282,000 m^3/day. Conventional Activated Sludge Process (CASP) is applied for the STP. Tamok area: On-site treatment (Johkasou) is applied. Other area: Installation of septic tank, which is most popular sanitary device in PPCC, is recommended especially in households in which no toilet or pit latrine is equipped.
Legal and institutional set-up	Sewerage and Drainage Advancement Office under the director of DPWT/PPCC is proposed in the M/P, with the approach of "Start small and grow big". After the establishment of the Advancement Office, phased implementation plan for establishing independent sewage implementing body, in parallel with human resource development, is proposed.
Phased implementation schedule	Phased implementation schedule is proposed up to year 2040 to equalize volume of projects implemented in each period, as follows. Cheung Aek area: Phased implementation, consisting of (i) Preparatory Project, (II) Phase 1 Project, (iii) Phase 2 Project and (iv) Phase 3 Project, is proposed. Tamok area: Installation of Johkasou is commenced in Medium-term and ended in 2040, the last year of Long-term period, to equalize number of installation of Johkasou.
Project cost and O&M cost	Project cost: 1,025 million USD Breakdown is as follows. Construction cost in Cheung Aek area : 450.1 million USD Construction cost in Tamok area : 396.2 million USD Administration cost and so on : 178.7 million USD O&M cost: 30.692 million USD/year Breakdown is as follows. Cheung Aek area : 14.895 million USD Tamok area : 15.797 million USD
Financial and economic evaluation	Financial evaluation: Sewerage charge, which is equivalent of 75% of water tariff, will be required in the ultimate stage of implementation of Cheung Aek and Tamok area to cover O&M cost. Economic evaluation: EIRR is estimated at 26.31% in the combination of treatment of Cheung Aek and Tamok area.
Environmental and social considerations	Significant environmental and social impacts such as resettlement are not anticipated because proposed sewerage facilities in the M/P are installed in vacant public land or under public roads. Negative impacts such as traffic interruption, noise, dust and vibration would be unavoidable during the construction stage. However, the impacts could be minimized by introducing counter measures such as setting up diversion road, sprinkling water and selecting low-noise and/or low-vibration type construction equipment as far as practicable.
Sewage Management (Pre-F/S)	
Pre-F/S	Pre-F/S is conducted targeting "Preparatory Project", consisting of construction of a part of STP in Cheung Aek treatment area with capacity of 5,000 m^3/day and sewer pipe of about 1,300 m. Project cost of the Project is estimated at 24.05 million USD and O&M cost is estimated at 0.41 million USD/year.

Item	Contents
Drainage Management (MP)	
Target year	2035
Planning strategy	PPCC is subdivided into 25 catchment areas and structural measures, consisting of drainage channels, pumping stations and regulation ponds, are proposed considering topographical conditions as well as availability of existing drainage facilities.
Planning frame	Planning area in the M/P is 621.73 km^2 in total. Drainage facilities in the M/P are designed with return period of 5 years. Rainfall intensity of 5-year return period is 63.2 mm/ha or 112.3 mm/day.
Proposed drainage facilities	Proposed drainage facilities are construction of (i) Drainage channel of 123 km, (ii) Pumping stations in 6 locations and (iii) Regulation pond in 5 locations.
Legal and institutional set-up	Institutional and implementation framework in drainage management is already established to some extent through implementation of drainage improvement projects such as "The Project for Flood Protection and Drainage Improvement Project in Phnom Penh Capital City (Phase 1, 2 and 3)". However, strengthening of institutional framework is proposed because the present framework is insufficient to smoothly implement a number of drainage projects proposed in the M/P, corresponding to rapid urbanization.
Phased implementation schedule	Based on the EIRR, 25 drainage areas are categorized into 4 groups by priority. Of the 25 drainage areas, improvement works of drainage areas in 1st prioritized group are implemented in the Project for Flood Protection and Drainage Improvement Project in Phnom Penh Capital City (Phase 4). Of the 2nd prioritized group, Pochentong East Drainage Area (No. 9 Drainage Area) is studied in the Pre-F/S. Other drainage areas are implemented after implementation of Pochentong East Drainage Area.
Project cost and O&M cost	Project cost: 662.2 million USD Breakdown is as follows. Construction cost : 506.5 million USD Administration cost and so on: 155.7 million USD O&M cost: 5.501 million USD/year
Financial and economic evaluation	Financial evaluation: Not implemented in the M/P due to the reason that cost for drainage management should be borne by PPCC. Economic evaluation: EIRR is estimated at 12.6%.
Environmental and social considerations	About 900 households are to be resettled in the implementation of the proposed projects in the M/P, so detailed survey in the implementation stage will therefore be required to minimize the resettlement. Negative impacts such as traffic interruption, noise, dust and vibration would be unavoidable during the construction stage. However, the impacts could be minimized by introducing countermeasures such as setting up diversion road, sprinkling water and selecting low-noise and/or low-vibration type construction equipment as far as practicable.
Drainage Management (Pre-F/S)	
Pre-F/S	Pre-F/S is conducted targeting "Pochentong East Drainage Area (No. 9 Drainage Area), consisting of construction of: (i) Box Culvert of 5,220 m, (ii) Inlet channel of 480 m, (iii) Pumping Station of 1 location (Capacity of 40 m^3/s), (iv) Regulation pond of 1 location, as well as (v) Rehabilitation of drainage channel of 2,660 m. Project cost is estimated at 93.01 million USD and O&M cost is estimated at 1.23 million USD/year. EIRR is estimated at 12.7%.

Location Map
Photographs
Outline of Master Plan and Pre-Feasibility Study

TABLE OF CONTENTS

Table of Contents ..... **i**
List of Tables ..... **vi**
List of Figures ..... **ix**
Abbreviations ..... **xi**

Chapter 1 Introduction **1-1**
1.1 Background 1-1
1.2 Study Objectives 1-1
1.3 Study Area 1-2
1.4 Study Schedule 1-2

Chapter 2 Basic Study **2-1**
2.1 Natural Condition 2-1
2.1.1 Land Use 2-1
2.1.2 Meteorology and Hydrology 2-2
2.1.3 Runoff and Inundation Analysis for Drainage Improvement Plan 2-3
2.2 Socioeconomic Situation 2-5
2.2.1 Socioeconomic Situation 2-5
2.2.2 Population Dynamics in PPCC 2-6
2.3 National Plans and Relevant Plans 2-9
2.3.1 Urban Planning and Development Planning 2-9
2.3.2 Water Supply Plan 2-10
2.4 Status of Existing Facilities 2-11
2.4.1 Sewage Facilities 2-11
2.4.2 Drainage Facilities 2-12
2.4.3 Sludge Management Facilities 2-15
2.4.4 Flood Protection 2-15
2.5 Water Quality 2-16
2.5.1 Water Quality and Effluent Standard 2-16
2.5.2 Water Monitoring and Analysis in the Study 2-18
2.6 Current Status of Organizations and the System 2-21
2.6.1 Related Laws and Regulations 2-21
2.6.2 Organizations Concerned 2-23

2.6.3 Budget and Financial Situation 2-27
2.7 Environmental and Social Consideration 2-31
2.7.1 EIA Process in Cambodia 2-31
2.7.2 Legislation and Legal Procedures for Resettlement and Land Acquisition for Development 2-32

Chapter 3 Strategy for Formulation of Sewage Management Master Plan 3-1
3.1 Summary of Issues 3-1
3.2 Planning Frame 3-4
3.2.1 Target Year 3-4
3.2.2 Planning Frame 3-4
3.2.3 Strategy for Phased Schedule 3-7
3.3 Planning Conditions for Off-Site Treatment Area 3-7
3.3.1 Projection of Water Use 3-7
3.3.2 Water Quality for Designing 3-9
3.3.3 Structural Measures 3-10
3.4 Planning Conditions of On-site Treatment 3-12
3.4.1 Projection of Water Use 3-12
3.4.2 Pollution Load per Capita 3-12
3.4.3 Structural Measures 3-12
3.5 Effects of Environmental Improvement by the Proposed Plan 3-12
3.6 Other Considerations 3-13
3.6.1 Non-Structural Measures 3-13
3.6.2 Land Expropriation 3-13
3.6.3 Environmental and Social Considerations 3-13

Chapter 4 Sewage Management Master Plan 4-1
4.1 Sewage Management Master Plan 4-1
4.1.1 Cheung Aek Treatment Area 4-1
4.1.2 Tamok Treatment Area 4-8
4.1.3 Other Area 4-17
4.1.4 Summary of Application of On-site and Off-site Treatment System 4-17
4.2 Facilities Plan 4-19
4.2.1 Sewer Network Plan in Cheung Aek Treatment Area 4-19
4.2.2 Sewage Treatment Plan Facilities Plan in Cheung Aek Treatment Area 4-22
4.2.3 On-site Treatment Plan in Tamok Area 4-22
4.2.4 Sludge Disposal Plan 4-24
4.3 Operation and Maintenance Plan 4-25
4.3.1 Sewer Network 4-25
4.3.2 Sewage Treatment Plant and Sludge Disposal Site 4-25

4.3.3 On-site Treatment Facilities 4-26
4.4 Review of Organization and Legal Framework of Sewage Management 4-27
4.4.1 Review for Proposal of a New Organization to Implement the Sewer Network Service 4-27
4.4.2 Review of Legal Framework 4-31
4.4.3 Financial Review 4-34
4.5 Implementation Plan 4-35
4.5.1 Short-term 4-35
4.5.2 Medium-Term and Long-Term 4-36
4.6 Cost Estimate 4-40
4.6.1 Construction Cost (Project Cost) 4-40
4.6.2 Operation and Maintenance Cost 4-42
4.7 Financial Analysis 4-42
4.7.1 Cheung Aek System 4-42
4.7.2 Tamok System 4-45
4.7.3 Financing of Sewerage Systems 4-45
4.8 Economic Analysis 4-48
4.8.1 Preconditions for Economic Analysis 4-48
4.8.2 Cheung Aek System EIRR 4-48
4.8.3 Tamok System EIRR 4-50
4.9 Selection of Priority Projects for Pre-F/S 4-51

Chapter 5 Strategy for Formulation of Drainage Management Master Plan 5-1
5.1 Summary of Issues 5-1
5.2 Planning Frame 5-2
5.2.1 Target Year 5-2
5.2.2 Planning Scale 5-2
5.2.3 Drainage Area for Master Plan 5-2
5.2.4 Drainage Management Plan per Drainage Area 5-3
5.3 Design Criteria 5-4
5.3.1 Rainfall 5-4
5.3.2 Catchment Area, Run-off and Inundation Analysis 5-5

Chapter 6 Drainage Management Master Plan 6-1
6.1 Improvement Plan for Stormwater Drainage Management 6-1
6.1.1 Improvement Plan for Each Drainage Area 6-1
6.1.2 Alternative Study on Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8) 6-11
6.1.3 Alternative Study on Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13) 6-11

6.2 Drainage Facilities Plan 6-12
6.2.1 General Layout of Drainage Management Plan 6-12
6.2.2 Run-off Analysis 6-13
6.2.3 Planning of Drainage Channels and Pipes 6-16
6.2.4 Planning of Pumping Stations 6-24
6.3 Maintenance Plan 6-25
6.3.1 Drainage Channels and Pipes 6-25
6.3.2 Pumping Station and Regulation Pond 6-25
6.4 Review of Organization and Legal Framework of Drainage Management 6-26
6.4.1 Review of Organization 6-26
6.4.2 Review of Legal Framework 6-27
6.5 Phased Implementation Plan 6-27
6.6 Cost Estimate 6-30
6.6.1 Construction Cost (Project Cost) 6-30
6.6.2 Operation and Maintenance Cost 6-33
6.7 Economic Analysis 6-34
6.7.1 Preconditions for Economic Analysis 6-34
6.7.2 EIRR 6-35
6.8 Selection of Priority Project for Pre-Feasibility Study 6-36

Chapter 7 Environmental and Social Consideration of Master Plan 7-1
7.1 Consideration at the Master Plan Formulation 7-1
7.2 Alternative Comparison 7-1

Chapter 8 Pre-Feasibility Study on Priority Project of Sewage Management 8-1
8.1 Components of Priority Project 8-1
8.2 Preliminary Design of Sewer Line 8-1
8.2.1 Design Flow 8-1
8.2.2 Study on Sewage Interception and Conveyance 8-1
8.3 Preliminary Design of Sewage Treatment Plant 8-4
8.3.1 Construction Site 8-4
8.3.2 Treatment Facilities 8-4
8.4 Implementation Framework 8-9
8.5 Cost Estimate 8-9
8.6 Implementation Schedule 8-10
8.7 Financial Analysis 8-10
8.8 Economic Analysis 8-10
8.9 Project Evaluation 8-11

Chapter 9 Pre-Feasibility Study on Priority Project of Drainage Management 9-1
9.1 Components of Priority Project 9-1
9.2 Framework of Implementation 9-2
9.3 Cost Estimation 9-2
9.4 Implementation Schedule 9-3
9.5 Economic Analysis 9-3
9.6 Project Evaluation 9-4

Chapter 10 Environmental and Social Consideration of Pre-Feasibility Study 10-1
10.1 Impact Assessment for the Pre-Feasibility Study 10-1
10.1.1 Impact Assessment for Preparatory Project in Sewage Management 10-1
10.1.2 Impact Assessment for Priority Project in Drainage Management 10-3

Chapter 11 Conclusion and Recommendation 11-1
11.1 Conclusion 11-1
11.1.1 Sewage Management 11-1
11.1.2 Drainage Management 11-1
11.2 Recommendation 11-2
11.2.1 Sewage Management 11-2
11.2.2 Drainage Management 11-2

LIST OF TABLES

Table 2.1.1 Probable Rainfall 2-5
Table 2.2.1 National Accounts of Cambodia 2-5
Table 2.2.2 Household Income Composition, Average per Month in Cambodia 2-6
Table 2.2.3 Household Income Composition, Average per Month in Phnom Penh 2-6
Table 2.2.4 Population and Number of Households 2-7
Table 2.2.5 Population Projection by JICA Project 2-8
Table 2.3.1 Water Supply of PPWSA 2-10
Table 2.4.1 Current Condition of Sewerage Facilities in PPCC 2-11
Table 2.4.2 Total Length of Drainage Pipes and Number of Manholes 2-12
Table 2.4.3 Total Length of Open Channels Managed by DPWT 2-13
Table 2.4.4 List of Pumping Stations Managed by DPWT 2-14
Table 2.5.1 Water Quality Standard for Bio-Diversity Conservation 2-16
Table 2.5.2 Effluent Standard for Public Water Areas or Sewer 2-17
Table 2.5.3 Monitoring Points and Parameters in the Study 2-18
Table 2.5.4 Minimum, Maximum and Average Values at Monitoring Points in the Study 2-19
Table 2.6.1 Number of DPWT Staff Members 2-26
Table 2.6.2 Cambodia State Budget Revenue 2-28
Table 2.6.3 Cambodia State Budget Expenditure 2-28
Table 2.6.4 DPWT's Budget 2-29
Table 2.6.5 Expenditures of DSD 2-29
Table 2.6.6 Drainage related Expenditures of PPCC 2-30
Table 2.6.7 Drainage and Sewerage Cost transferred from PPWSA to PPCC 2-30
Table 3.1.1 Current Conditions and Issues Related to Sewage Management in PPCC and Countermeasures (1/2) 3-1
Table 3.1.2 Current Conditions and Issues related to Sewage Management in PPCC and Countermeasures (2/2) 3-2
Table 3.2.1 Candidate Sites for Construction of Sewage Treatment Plant 3-4
Table 3.2.2 Current Condition of Sewage Management in Large-Scale Development Area 3-7
Table 3.3.1 Ratio of Domestic and Other Usage in Neighbouring Countries 3-8
Table 3.3.2 Sewage Generation per Capita (Off-Site Treatment Area) 3-9
Table 3.3.3 Upper Limits of Design Effluent Water Quality for STP 3-10
Table 3.3.4 Off-site Treatment Methods Evaluated 3-11
Table 3.4.1 Sewage Generation per Capita (On-site Treatment Area) 3-12
Table 4.1.1 Outline of Cheung Aek Treatment Area 4-1
Table 4.1.2 Design Inflow to Cheung Aek STP 4-2
Table 4.1.3 Design Water Quality of Cheung Aek STP 4-2
Table 4.1.4 Comparison of Wastewater Treatment Method applied to Cheung Aek STP (1/2) 4-4
Table 4.1.5 Comparison of Wastewater Treatment Method applied to Cheung Aek STP (2/2) 4-5
Table 4.1.6 Outline of Tamok Treatment Area 4-9
Table 4.1.7 Design Inflow to Tamok STP 4-9

Table 4.1.8 Design Water Quality of Cheung Aek STP 4-9
Table 4.1.9 Comparison of Wastewater Treatment Method applied to Tamok STP (1/2)....4-10
Table 4.1.10 Comparison of Wastewater Treatment Method applied to Tamok STP (2/2)....4-11
Table 4.1.11 Outline of On-site Treatment System applied to Tamok Treatment Area 4-13
Table 4.1.12 Image of Application of Treatment (Tamok: Off-site) 4-14
Table 4.1.13 Image of Application of Treatment (Tamok: On-site) 4-15
Table 4.1.14 O&M Cost per Capita per Month....4-16
Table 4.1.15 Summary of Application of On-site and Off-site Treatment 4-17
Table 4.1.16 Conditions for Evaluation of Pollution Load Reduction....4-18
Table 4.2.1 Covered Area and Population of Cheung Aek Treatment Area....4-19
Table 4.2.2 Summary of Sewer Network Facilities in Cheung Aek Treatment Area 4-22
Table 4.2.3 Overview of STP....4-22
Table 4.3.1 O&M Items in STP 4-26
Table 4.4.1 Policy for Staged Streamlining of Organizations that Implement the Project 4-29
Table 4.4.2 Division Offices to implement Projects and their Work 4-30
Table 4.4.3 Summary of Discussions and Proposals on Organization and Legal System 4-33
Table 4.5.1 Overview of Trabek and Tumpun System 4-35
Table 4.5.2 Phased Implementation Schedule (Sewage Management)....4-38
Table 4.5.3 Phased Implementation Plan for Construction Works 4-39
Table 4.6.1 Project Cost for Sewerage Management 4-40
Table 4.6.2 Disbursement Schedule of Project Cost for Sewerage Management 4-41
Table 4.6.3 Annual Operation and Maintenance Cost for Sewerage Management 4-42
Table 4.7.1 Operational Profit or Loss Excluding Depreciation (Imposing Charges only on Cheung Aek Area) 4-43
Table 4.7.2 Cash Flow of Sewerage Project (Sewerage Use Fee of 60% to Water Use Fee Case) 4-44
Table 4.7.3 Profit or Loss Including Tamok (10% to 75% of Water Use Revenue)....4-46
Table 4.7.4 Cash Flow Including Tamok....4-47
Table 4.8.1 Cheung Aek System EIRR (Final Users)....4-49
Table 4.8.2 Both Systems EIRR (Final Users)....4-50
Table 4.9.1 Components of Preparatory Project (Priority Project) 4-51
Table 5.2.1 List of Drainage Areas 5-2
Table 5.2.2 List of Alternatives (Tentative)....5-3
Table 5.3.1 Design Rainfall 5-4
Table 5.3.2 Outline of Two-Dimensional Unsteady Flow Model (MIKE 21) 5-5
Table 5.3.3 Run-off Coefficient by Land Use....5-8
Table 5.3.4 Overall Run-off Coefficient 5-8
Table 5.3.5 Outline of Inundation Analysis Model....5-9
Table 6.2.1 Run-off Analysis (1/2) 6-14
Table 6.2.2 Run-off Analysis (2/2) 6-15
Table 6.2.3 Summary of Proposed Drainage Channels and Pipes 6-16
Table 6.2.4 Summary of River Channel Analysis Model 6-24
Table 6.2.5 Summary of Capacity of Pumping Station....6-24
Table 6.2.6 Summary of Regulation Pond 6-24

Table 6.3.1 Items of Maintenance for Drainage Channels and Pipes 6-25
Table 6.3.2 Items of Maintenance for Pumping Station and Regulation Pond 6-25
Table 6.5.1 Priority of Implementation for Each Drainage Area 6-28
Table 6.5.2 Phased Implementation Plan 6-29
Table 6.6.1 Summary of Cost Estimate 6-30
Table 6.6.2 Cost Disbursement Schedule (Drainage Management 1/2) 6-31
Table 6.6.3 Cost Disbursement Schedule (Drainage Management 2/2) 6-32
Table 6.6.4 Summary of O&M Cost 6-33
Table 6.7.1 Average House Damages per Household in Three Districts 6-34
Table 6.7.2 Average House Damage per Household in Phnom Penh 6-34
Table 6.7.3 Production Loss Recovery in Phnom Penh 6-35
Table 6.7.4 EIRR of Drainage Management Projects 6-35
Table 6.8.1 Priority Project for Pre-Feasibility Study 6-36
Table 7.2.1 Comparison of Alternatives of Sewage Management M/P (April 2015) 7-1
Table 7.2.2 Comparison of Alternatives of Drainage Management M/P (April 2015) 7-2
Table 8.1.1 Component of Priority Project (Preparatory Project) in Sewage Management 8-1
Table 8.1.2 Design Flow 8-1
Table 8.3.1 Specification of Treatment Facilities (Preparatory Project) 8-5
Table 8.3.2 Specification of Treatment Facilities (Ultimate Stage) 8-5
Table 8.5.1 Project Cost (Preparatory Project) 8-9
Table 8.5.2 Summary of O&M Cost (Preparatory Project) 8-10
Table 9.1.1 Components in Pochentong East Drainage Area 9-1
Table 9.3.1 Project Cost 9-2
Table 9.3.2 Summary of O&M Cost 9-3
Table 10.1.1 Preliminary Scoping for Preparatory Project in Sewage Management (December 2015) 10-1
Table 10.1.2 Preliminary Scoping for Priority Project in Drainage Management (December 2015) 10-4

LIST OF FIGURES

Fig. 1.4.1 Overall Study Schedule 1-2
Fig. 2.1.1 Land Use of PPCC in 2035 2-1
Fig. 2.1.2 Inland Flooding Area 2-3
Fig. 2.1.3 Rainfall Intensity and Probable Rainfall 2-4
Fig. 2.1.4 Annual Rainfall (1981 to 2013) 2-4
Fig. 2.1.5 Maximum Daily Rainfall (1981 to 2013) 2-4
Fig. 2.2.1 Administrative Area in PPCC (Old/New) 2-7
Fig. 2.2.2 Population Projection by JICA Project 2-8
Fig. 2.3.1 Strategy for Sewage/Drainage Sector in White Book 2-10
Fig. 2.3.2 Water Consumption per Capita per Day 2-11
Fig. 2.4.1 Drainage Pipe Location Map from Database 2-13
Fig. 2.4.2 Location Map of Channels and Pumping Stations Managed by DPWT 2-15
Fig. 2.4.3 Variation of Annual Maximum Water Level in Sap River 2-16
Fig. 2.5.1 Location Map for Water Sampling Survey 2-19
Fig. 2.6.1 Organizational Chart of MPWT 2-23
Fig. 2.6.2 Organizational Chart of Department of Sub-National Urban Infrastructure and Engineering 2-24
Fig. 2.6.3 Organizational Chart of PPCC 2-24
Fig. 2.6.4 Organizational Chart of DPWT 2-25
Fig. 2.6.5 Organizational Chart of Drainage and Sewerage Division (DSD) 2-26
Fig. 2.6.6 Drainage and Sewerage Related Cost Resource Fund Flow in Phnom Penh 2-31
Fig. 2.7.1 Flowchart of the IEIA/EIA Process for National Level Projects 2-31
Fig. 2.7.2 Flowchart of Land Acquisition 2-33
Fig. 2.7.3 Workflow of Resettlement Process 2-34
Fig. 3.2.1 Location of Candidate Sites for Construction of Sewage Treatment Plant 3-5
Fig. 3.2.2 Target Area for Selection of Off-site Treatment Area 3-6
Fig. 3.3.1 Water Use Projection per Capita per Day for the Target Year 2035 3-8
Fig. 4.1.1 Comparison of Land Requirement of Lagoon and CASP 4-3
Fig. 4.1.2 Layout Plan of Cheung Aek STP 4-6
Fig. 4.1.3 Transition of Sewerage Fee to cover Cost of Cheung Aek Treatment Area 4-7
Fig. 4.1.4 Alternative Study on Tamok Treatment Area 4-8
Fig. 4.1.5 Layout Plan of Tamok STP 4-12
Fig. 4.1.6 Transition of Sewerage Fee to cover Costs for Cheung Aek and Tamok Treatment Area (Tamok Treatment Area: Off-site) 4-15
Fig. 4.1.7 Transition of Sewerage Fee to cover Cost of Cheung Aek and Tamok Treatment Area (Tamok Treatment Area: On-site) 4-16
Fig. 4.1.8 Reduction of Pollution Load 4-18
Fig. 4.2.1 Sewer Network Plan in Cheung Aek Treatment Area 4-21
Fig. 4.2.2 Image of Johkasou (for 5 persons) 4-23
Fig. 4.2.3 Image of Johkasou (for 300 persons) 4-23
Fig. 4.2.4 Image of Community-Based Sewage Treatment applying Johkasou 4-24

Fig. 4.2.5 Treatment Facilities for Septage and Johkasou Sludge 4-24
Fig. 4.3.1 Flowchart of O&M in STP 4-26
Fig. 4.4.1 Organizational Chart based on the Proposed Organization 1 4-29
Fig. 4.4.2 Example of Management Organization in STP 4-31
Fig. 4.4.3 Concept of the New Organization established in MPWT of Sewerage and Drainage Management 4-32
Fig. 4.5.1 Trabek and Tumpun System in Cheung Aek Treatment Area 4-36
Fig. 4.9.1 Location Map of Preparatory Project (Priority Project) 4-51
Fig. 5.2.1 Map of Drainage Areas 5-3
Fig. 5.3.1 Procedure of Establishment of Hydrological and Hydraulic Model 5-5
Fig. 5.3.2 Ground Elevation of Phnom Penh Metropolitan Area 5-6
Fig. 5.3.3 Catchment Area and Present Inundation Area (Analysis based on Rainfall on 26 September 2012) 5-7
Fig. 5.3.4 Image of Inundation Analysis 5-10
Fig. 6.2.1 General Layout of Proposed Drainage Management Plan 6-13
Fig. 6.2.2 General Map of Drainage Improvement (1/7) (Boeung Thom/PPSEZ/NR. 3 West Drainage Areas) 6-17
Fig. 6.2.3 General Map of Drainage Improvement (2/7) (Krang Pongro/Pratek Lang Channel/Tuol Pongro Drainage Areas) 6-18
Fig. 6.2.4 General Map of Drainage Improvement (3/7) (Preaek Thloeng/Chbar Ampov Middle/Cheung Aek Lake Drainage Areas) 6-19
Fig. 6.2.5 General Map of Drainage Improvement (4/7) (Pochentong East Drainage Area) 6-20
Fig. 6.2.6 General Map of Drainage Improvement (5/7) (Tamok East/Hanoi West Drainage Areas) 6-21
Fig. 6.2.7 General Map of Drainage Improvement (6/7) (Poung Peay/O'veng/Satellite City/Chroy Changvar/City Core North Area Drainage Areas) 6-22
Fig. 6.2.8 General Map of Drainage Improvement (7/7) (Preaek Moat Kandol Drainage Area) 6-23
Fig. 6.4.1 Proposal to divide DSD Technical Section 6-26
Fig. 8.2.1 Plan and Profile of Sewer Line in the Preparatory Project 8-3
Fig. 8.3.1 Proposed STP Site in Cheung Aek Lake 8-4
Fig. 8.3.2 Processing Flow of STP 8-4
Fig. 8.3.3 General Layout Plan of STP in the Preparatory Project 8-6
Fig. 8.3.4 General Layout Plan of Wastewater Treatment Facilities in the Preparatory Project 8-7
Fig. 8.3.5 Transition of STP from Preparatory Project Stage to Ultimate Stage 8-8
Fig. 8.4.1 Implementation Framework for Preparatory Project 8-9
Fig. 8.6.1 Implementation Schedule for Preparatory Project 8-10
Fig. 9.1.1 Location of Pochentong East Drainage Area 9-1
Fig. 9.1.2 Location of Components in Pochentong East Drainage Area 9-2
Fig. 9.4.1 Implementation Schedule 9-3

ABBREVIATIONS

1. Organizations/Programs/Projects

ADB	Asian Development Bank
AFD	Agence Française de Développement
CDS	City Development Strategy
DPWT	Department of Public Works and Transport
DHI	Danish Hydraulic Institute
DOE	Department of Environment
DOP	Department of Planning
DSD	Drainage and Sewerage Division
GDCE	General Department of Customs and Excise
GDT	General Department of Taxation
GOJ	Government of Japan
ICHARM	International Centre for Water Hazard and Risk Management
IRC	Inter-Ministerial Resettlement Committee
JICA	Japan International Cooperation Agency
KOICA	Korea International Cooperation Agency
MEF	Ministry of Economy and Finance
MIH	Ministry of Industry and Handicrafts
MLMUPC	Ministry of Land Management, Urban Planning and Construction
MOE	Ministry of Environment
MOI	Ministry of Interior
MOP	Ministry of Planning
MOWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
NSDP	National Strategic Development Plan
PIU	Project Implementation Unit
PISC	Project Implementation Support Consultant
PMU	Project Management Unit
PPCC	Phnom Penh Capital City
PPSEZ	Phnom Penh Special Economic Zone
PPUTMP	Phnom Penh Urban Transport Mater Plan
PPWSA	Phnom Penh Water Supply Authority
RGC	Royal Government of Cambodia
WHO	World Health Organization
WMD	Waste Management Division

2. Technical Terms

BOD	Biochemical Oxygen Demand
CASP	Conventional Activated Sludge Process
CCTV	Closed-circuit Television
COD	Chemical Oxygen Demand
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
GDP	Gross Domestic Product
IEIA	Initial Environmental Impact Assessment
MPN	Most Probable Number
OD	Oxidation Ditch
pH	Potential Hydrogen
PTF	Pre-treated Trickling Filtration
TF	Trickling Filter
T-N	Total Nitrogen

T-P	Total Phosphorus
TSS	Total Suspended Solid
SBR	Sequential Batch Reactor
SEA	Strategic Environmental Assessment
SLSC	Standard Least Square Criterion
SRTM	Shuttle Radar Topography Mission

3. Others

EIRR	Economic Internal Rate of Return
F.C.	Foreign Currency
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
HH Income	Household Income
HRD	Human Resource Development
l/c/d	Litre per capita per day
L.C.	Local Currency
M/P	Master Plan
O&M	Operation and Maintenance
OJT	On-the-Job Training
PAP	Project Affected Peoples
Pop.	Population
PV	Present Value
RAP	Resettlement Action Plan
RCS	Replacement Cost Study
R/D	Record of Discussions
SEZ	Special Economic Zone
STP	Sewage Treatment Plant
USD	United States Dollars

CHAPTER 1 INTRODUCTION

1.1 Background

Since 2008 the administrative area of Phnom Penh Capital City (hereinafter referred to as "PPCC") has been expanding and reached up to 678.46 km^2 in 2011. PPCC's population has been also increasing from about 1.0 million in 1998 to 1.5 million in 2010. The city is often threatened by floods from the Mekong River due to the insufficient safety from the flood dikes.

Urban drainage facilities are not also functioning well. The facilities were constructed from the beginning of 1960's and thus superannuated. Poor maintenance during the civil war in the 1970's has worsened the situation. As a result, the city habitually suffers from inundation by local rainfall, especially, in the rainy season.

The Japan International Cooperation Agency (hereinafter referred to as "JICA"), in response to the request from the Royal Government of Cambodia (hereinafter referred to as "RGC"), conducted "The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh" in 1999. Based on the Master Plan formulated in that study, the Government of Japan (hereinafter referred to as "GOJ") conducted grant aid projects (Phase I, II and III) for the purpose of strengthening the drainage capacity in the city area and to protect the city from flooding. In spite of these efforts, drainage problems are still generated in areas other than the areas of Phase I, II and III, due to the rapid urbanization and changes in land use.

As for sewage management in PPCC, only human excreta are held on plot in septic tanks. On the other hand, overflow effluent from the septic tanks as well as domestic wastewater, flows directly to the drainage pipes or open channels and runs into the ponds/swamps located in the downstream of the watersheds, in which wastewater is purified by the natural purification function to some extent.

However, the ponds/swamps have been invaded by houses, factories and other activities, and they no longer demonstrate their natural purification functions. Since the amount of wastewater increased due to the population growth and city development, the ponds and swamps have become black and smell terribly. As a result, outbreak of insects and waterborne diseases are anticipated, and the water quality of Mekong River, Sap River and Bassac River, which are the final disposal bodies of wastewater from the city, are also polluted[1].

Taking the above conditions into consideration, revision of the Master Plan (hereinafter referred to as M/P) on urban drainage improvement as well as consideration of wastewater treatment is necessary. Thus, the RGC requested assistance from the GOJ. In response to the official request, the GOJ decided to conduct the "The Study on Drainage and Sewerage Improvement Project in Phnom Penh Metropolitan Area". Accordingly, JICA, which is the official agency responsible for the implementation of technical cooperation programs of the GOJ, dispatched its Detailed Planning Survey Team to Cambodia from March to April, 2014 and the Record of Discussions (R/D) was finalized in May 2014.

1.2 Study Objectives

The objectives of the Study are:

(1) To formulate the M/P of drainage and sewerage improvement in PPCC;

---

[1] Annual average of TSS and conductivity increased by more than 25% and 30% based on the monitoring results at 10 monitoring points in PPCC provided by MOE (1999 to 2004 and 2007 to 2013). In addition, TSS of Mekong River became 1.5 times and conductivity of Sap and Bassac River increased by more than 25%. These data indicate progress of contamination in the rivers.

(2) To conduct a Pre-Feasibility Study on priority projects selected in the M/P;

(3) To develop planning capacity of drainage and sewerage improvement; and

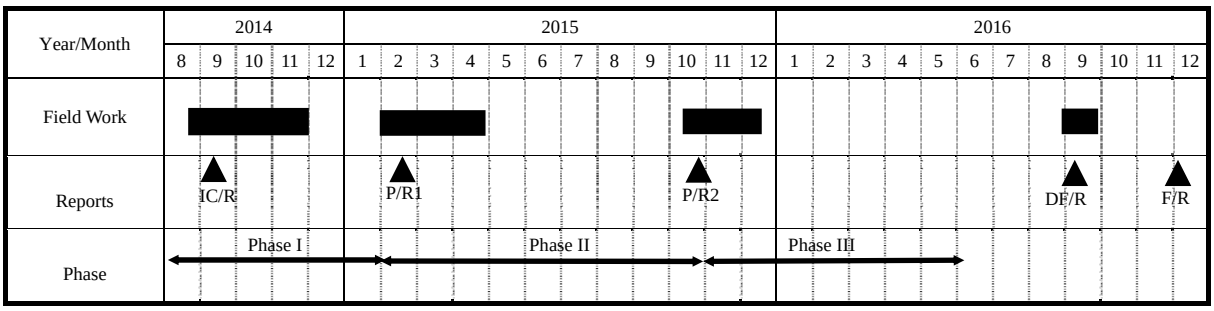
(4) To transfer relevant skills and technologies to personnel concerned in Cambodia in the course of the Study.

1.3 Study Area

The Study Area covers the entire area of PPCC.

1.4 Study Schedule

The Study is to be carried out in accordance with the schedule shown in **Fig. 1.4.1**. The study period is about twenty-two (22) months. Various reports are to be submitted periodically as shown in the schedule.



Legend: IC/R: Inception Report; P/R1: Progress Report I; P/R2: Progress Report II;
DF/R: Draft Final Report; F/R: Final Report
Phase I : Collection and analysis of basic information on sewerage and drainage improvement
Phase II : Formulation of M/P
Phase III : Pre-Feasibility Study on the priority projects
Source: JICA Study Team

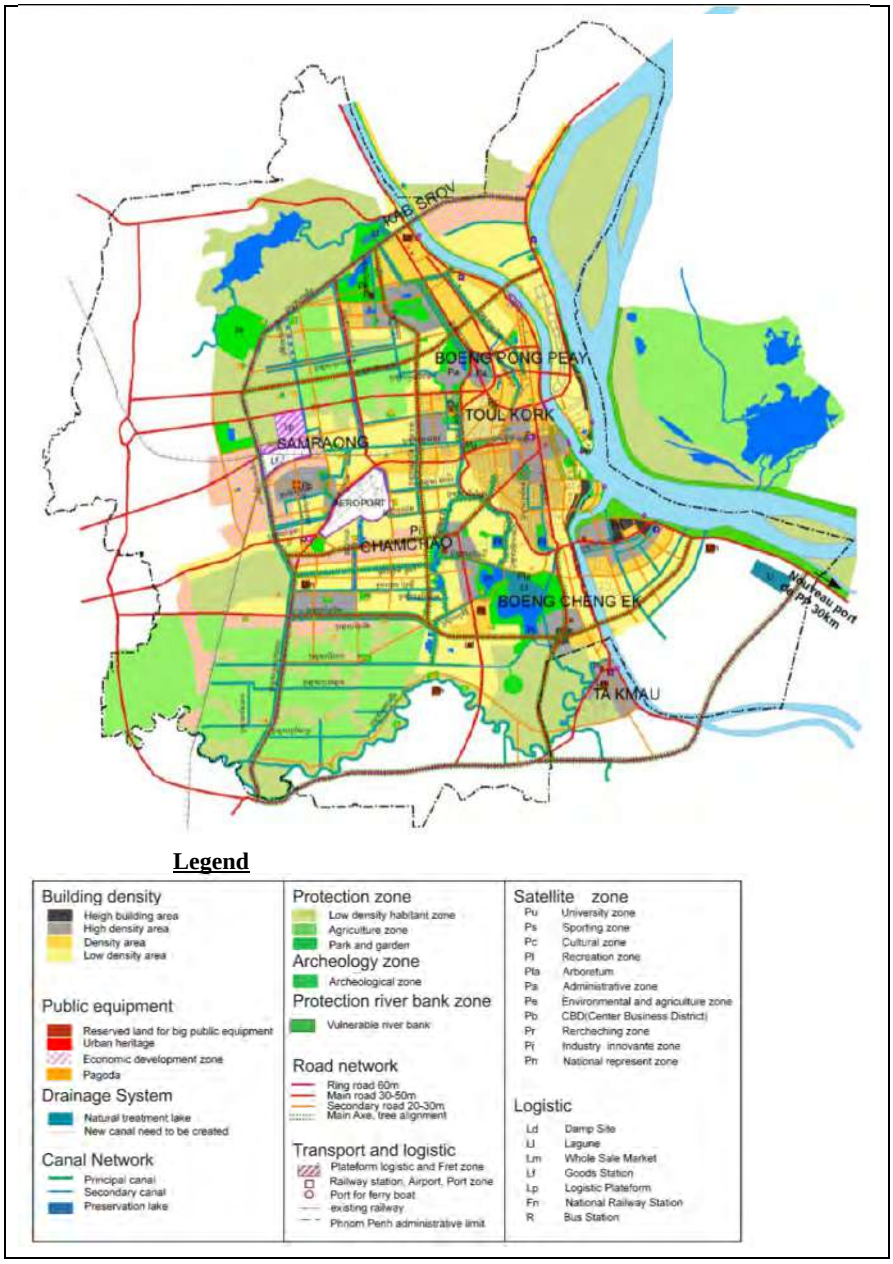
Fig. 1.4.1 Overall Study Schedule

CHAPTER 2 BASIC STUDY

2.1 Natural Condition

2.1.1 Land Use

As the urban development Master Plan of PPCC, the "White Book on Development and Planning of Phnom Penh" was issued in October 2007 (hereinafter referred to as "White Book"). In the White Book, the land use plan for the target year 2035 (**Fig. 2.1.1**) was formulated based on land use in 2004. The land use plan is in the process of approval with the issuance of a sub-decree, followed by the approval in the committee for land management and urban planning for the capital, which was established in accordance with a Royal Decree.



Source: White Book on Development and Planning of Phnom Penh, PPCC

Fig. 2.1.1 Land Use of PPCC in 2035

2.1.2 Meteorology and Hydrology

(1) Climate of Cambodia

Cambodia is part of a tropical monsoon climate and average total annual rainfall from 1981 to 2013 (33 years) is 1,428.5 mm/year. However, large variation can be seen in annual rainfall from 1,095.4 mm/year (1992) to 2,147.3 mm/year (2000). The dry season is from December to April and 80% or more of the annual precipitation are concentrated in the rainy season (May to November).

(2) Meteorology

According to the observed data from 1985 to 2013 at Pochentong Station, the averages of monthly maximum and minimum temperature are 35.3 and 21.8 degrees Celsius in Phnom Penh Capital City. The temperature is as a whole higher in March to May and the difference of maximum and minimum is about 20 degrees Celsius. The annual average of humidity is 77%, ranging from 70% to 80% and secular change is not observed.

(3) Rainfall

PPCC belongs to the tropical monsoon climate. The annual average rainfall in 2004 to 2013 is 1,487.2 mm/year and large variation can be seen in annual rainfall from 1,170.9 mm/year (2006) to 1,938.7 mm/year (2008).

(4) River Water Level

The highest water level of Bassac River and Sap River is generally recorded during August to October. The highest water level of Bassac River is 9.84 m (2011) and lowest level is 7.47 m (2010). On the other hand, water level during March to May is very low (1.2 m). The difference of water level between the dry season and the rainy season is about 8 m. According to the interview survey with MOWRAM (Ministry of Water Resources and Meteorology), water level is not observed during the dry season (December to April) because of backwater from the river month of Mekong River. The daily water level fluctuation is about 0.3 m to 0.5 m.

(5) River Discharge

According to the interview with MOWRAM, river discharge of the Upper Mekong River is 32,000 m^3/s and maximum river discharges to Sap River and Bassac River are about 8,000 m^3/s and 1,500 m^3/s respectively. Peak discharge of Mekong River is recorded in June to October and the backflow from Mekong River to Sap River occur in this season.

(6) Inundation Area

(a) Inundation Area of Inland Flooding

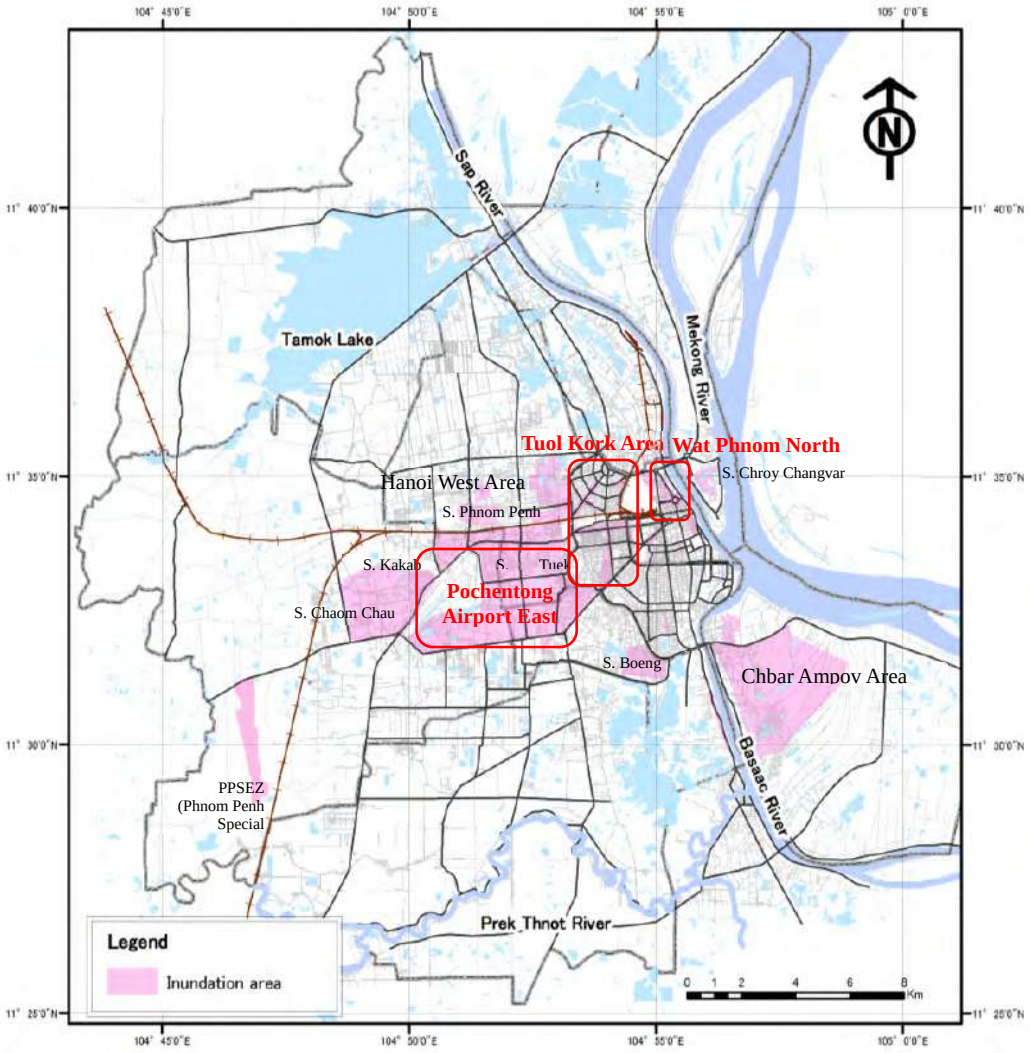
Fig. 2.1.2 shows the inundation-prone area of inland flooding[2], which was grasped through interview with DPWT staff, DSD staff, public works office of each Khan, and social survey. It is reported that inundation occurs several times in the rainy season every year in these areas.

In the city center (inside of the inner ring dike), damage of inland flooding has been decreasing in many parts of the area with the upgrading of drainage pipe network and drainage channel, rehabilitation of existing pumping stations and construction of new pumping station. On the other hand, drainage improvement in the area on the northern side of Wat Phnom (eastern half of Sangkat Srah Chak) and most parts of Tuol Kok District have lagged behind other area.

[2] Inland flooding: Inundation in urbanized area due to rainfall exceeds capacity of drainage facilities

Inundation in these areas still occur several times a year in the rainy season

In the newly urbanised area located at Western Phnom Penh, especially in the Pochentong East Area, not enough drainage facilities have been installed, and as a result, inland flooding damage frequently occurs even in short-time duration rainfall in the rainy season.



Note S: Sangkat
Source: JICA Study Team

Fig. 2.1.2 Inland Flooding Area

2.1.3 Runoff and Inundation Analysis for Drainage Improvement Plan

(1) Rainfall Analysis

Rainfall intensity was estimated using short-time duration rainfall data observed from 1980 to 1997 at Pochentong Station in the previous JICA study, “The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh, 1999”. The rainfall intensity estimated in the Master Plan in 1999 is shown in **Fig. 2.1.3**.

Hourly Rainfall (Pochentong meteorological station)

Return Period (year)	Hourly Rainfall (mm/h)	Daily Rainfall (mm/day)
2	44.8	87.8
5	63.2	112.3
10	75.4	128.4

Horner Type[3] was selected as rainfall intensity formula type. Rainfall intensity formula is shown as follows;

$I=2{,}566.07\times(T+25.48)^{-0.93}$ (Design scale of sewer system, 2-year return period)

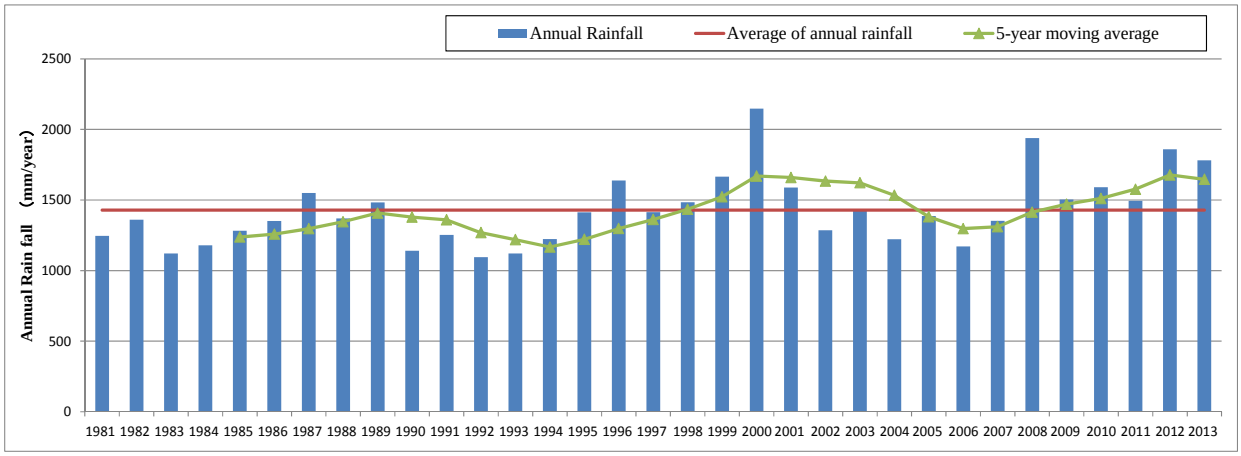
$I=5{,}009.12\times(T+31.38)^{-0.98}$ (Design scale of infrastructure, 5-year[4] return period)

where, I：Rainfall intensity (mm/hr), T：Rainfall Duration (min)

Source: The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh, JICA, 1999

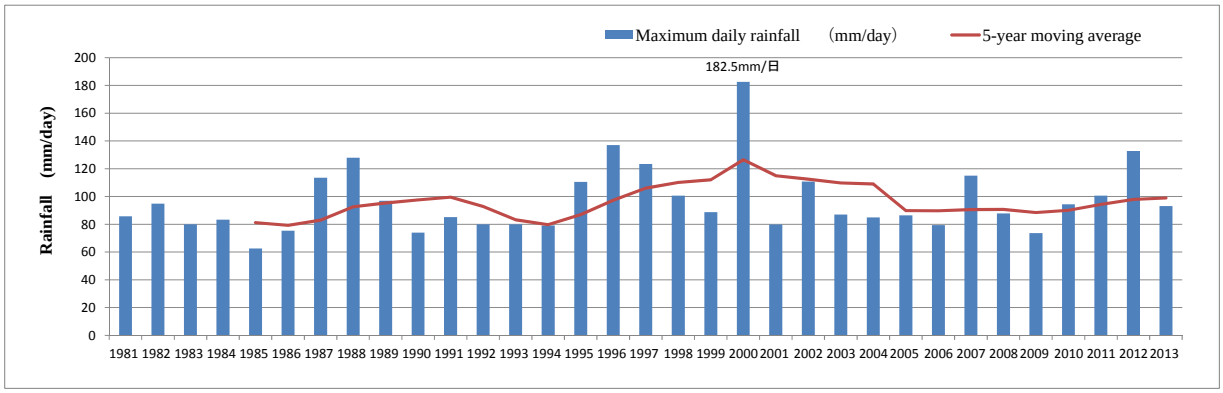
Fig. 2.1.3 Rainfall Intensity and Probable Rainfall

Review of rainfall intensity and model hyetograph using recent rainfall data is needed because 15 years has passed after the last estimation in 1999, using the data in **Figs. 2.1.4** and **2.1.5**.



Source: MOWRAM (Ministry of Water Resources and Meteorology)

Fig. 2.1.4 Annual Rainfall (1981 to 2013)



Source: MOWRAM (Ministry of Water Resources and Meteorology)

Fig. 2.1.5 Maximum Daily Rainfall (1981 to 2013)

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[3] In the Master Plan in 1999, actual rainfall data were analyzed by employing rainfall intensity formulae such as Talbot Type, Sherman Type, Kuno and Ishiguro Type, and Cleveland Type, which are commonly employed in Japan, as well as Horner Type, which is commonly employed in Asian countries such as the Philippines and Taiwan. Thus rainfall intensity was established using Horner Type, which showed minimum error.

[4] Pumping stations, regulation ponds and main channel drains area with approximately more than 1 km^2 of catchment area.

(a) Evaluation of Probable Rainfall

A probable rainfall analysis was performed using the daily rainfall data, condition and probability distribution model shown below. As a result, "Extreme Value Distribution" model was selected. The reference SLSC value of the selected model is less than 0.04. Probable rainfall is summarised in **Table 2.1.1**.

Table 2.1.1 Probable Rainfall

Return Period	Daily Rainfall (mm)		Balance
	(1) Study of 1999 Note1	(2) This Study Note2	(1)-(2)
2	87.8	90.1	+2.3
5	112.3	109.6	-2.7
10	128.4	125.4	-3.0
30	152.9	154.5	+1.6
50	164.0	170.3	+6.3

Note 1: Estimated using observed rainfall data from 1981 to 1997
Note 2: Estimated using observed rainfall data from 1981 to 2013
Source: JICA Study Team

(b) Review of Rainfall Intensity

A large difference is not observed from the probability rainfall analysis result compared to the previous study (1999) of 2-year and 5-year return periods for drainage facilities plan. Therefore, rainfall intensity in the previous Master Plan (1999) is employed for the drainage improvement plan in the Study.

2.2 Socioeconomic Situation

2.2.1 Socioeconomic Situation

(1) Gross Domestic Product (GDP)

GDP and related economic statistics data in Cambodia are shown in **Table 2.2.1** to display the national economic development state.

Table 2.2.1 National Accounts of Cambodia

Year	2000	2001	2002	2003	2004	2005	2006
GDP (Billion Riel)	14,083	15,633	16,781	18,536	21,438	25,754	29,849
GDP Growth Rate	5.3%	11.0%	7.3%	10.5%	15.7%	20.1%	15.9%
GDP per capita (USD)	295	319	340	367	417	487	558
GDP per capita Growth Rate	3.2%	8.2%	6.5%	8.0%	13.5%	16.9%	14.6%
GDP (Constant Price)	14,175	15,320	16,232	17,613	19,434	22,009	24,380
GDP (Constant Price) Growth Rate	10.7%	7.4%	6.6%	8.5%	10.3%	13.3%	10.8%

Year	2007	2008	2009	2010	2011	2012	
GDP (Billion Riel)	35,042	41,968	43,057	47,048	52,069	56,617	
GDP Growth Rate	17.4%	19.8%	2.6%	9.3%	10.7%	8.7%	
GDP per capita (USD)	656	760	753	830	911	971	
GDP per capita Growth Rate	17.6%	15.8%	-0.9%	10.2%	9.9%	6.6%	
GDP (Constant Price)	26,870	28,668	28,692	30,406	32,553	34,916	
GDP (Constant Price) Growth Rate	10.2%	6.7%	0.1%	6.0%	7.1%	7.3%	

Note: The top GDP is in current price or market price different from constant price below.
Source: National Institute of Statistics (http://www.nis.gov.kh/nis/NA/NA2012.html)

(2) Household Income

The National Institute of Statistics, Ministry of Planning, publishes socio-economic research results every year. The household income is shown in **Table 2.2.2**. Total income and disposable income in total Cambodia increased from 2009 to 2013 except in 2011. In 2011, self-employment income, in particular, non-agriculture decreased so that total and disposable incomes decreased. However, total and dispensable incomes in Phnom Penh decreased in not only 2011 but also 2010, as shown in **Table 2.2.3**.

Table 2.2.2 Household Income Composition, Average per Month in Cambodia

Source of income	Value in thousand Riels				
	2009	2010	2011*	2012*	2013*
Cambodia					
Primary income	727	877	862	984	1,183
Wage and Salary	241	292	340	403	505
Self-employment Income	482	582	520	576	675
Agriculture	162	205	209	229	195
Non Agriculture	250	290	224	249	369
Owner occupied house	70	88	86	98	111
Property income	4	3	2	5	3
Total transfers received	19	24	26	35	53
Total Income	**747**	**901**	**888**	**1,019**	**1,236**
Total transfers paid	11	24	17	5	95
Disposable Income	**736**	**877**	**871**	**1,014**	**1,141**

Note: * Preliminary results
Source: National Institute of Statistics
(http://www.nis.gov.kh/index.php/en/find-statistic/social-statistics/cses/cses-tables.html)

Table 2.2.3 Household Income Composition, Average per Month in Phnom Penh

Source of income	Value in thousand Riels				
	2009	2010	2011*	2012*	2013*
Phnom Penh					
Primary income	1,986	1,940	1,770	1,847	2,478
Wage and Salary	765	910	991	930	1,135
Self-employment Income	1,203	1,023	769	909	1,326
Agriculture	22	20	8	22	11
Non Agriculture	878	650	423	560	935
Owner occupied house			338	327	381
Property income	17	7	10	8	17
Total transfers received	54	47	50	40	38
Total Income	**2,039**	**1,987**	**1,819**	**1,886**	**2,517**
Total transfers paid	24	44	26	17	138
Disposable Income	**2,016**	**1,944**	**1,793**	**1,870**	**2,378**

Note: * Preliminary results
Source: National Institute of Statistics
(http://www.nis.gov.kh/index.php/en/find-statistic/social-statistics/cses/cses-tables.html)

2.2.2 Population Dynamics in PPCC

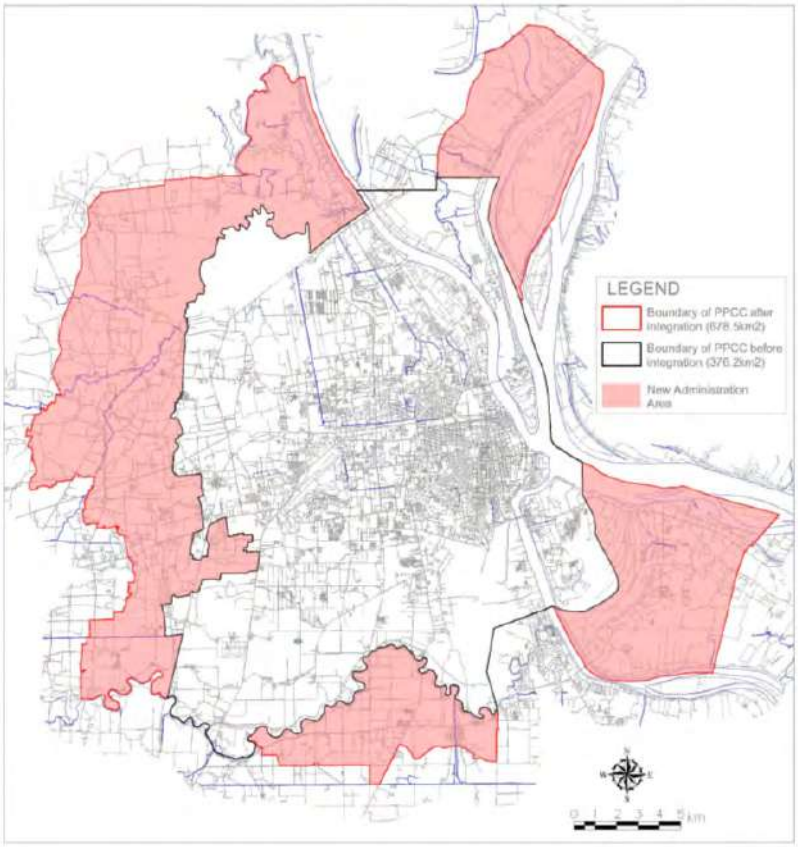
(1) Population and Number of Households

According to the 1998 and 2008 census, the population of PPCC increased to 1,327,615 in 2008 from 999,804 in 1998. Additionally, due to the expansion of the jurisdiction area in 2010, its population became 1,501,725. The population became about 1.5 times of 1998's. Population and the number of households in 1998 and 2008 are shown in **Table 2.2.4**. New Administrative Area in **Table 2.2.4** is shown in red hatched area in **Fig. 2.2.1**.

Table 2.2.4 Population and Number of Households

	1998	2008
Population		
Old Administrative Area	999,804	1,327,615
Urban Area	570,155	1,242,992
Rural Area	429,649	84,623
New Administrative Area	-	174,110
Total	999,804	1,501,725
Household		
Old Administrative Area	173,678	260,468
Urban Area	97,296	242,974
Rural Area	76,382	17,494
New Administrative Area	-	34,890
Total	173,678	295,358
Average Number of Persons in Household		
Old Administrative Area	5.76	5.10
Urban Area	5.86	5.12
Rural Area	5.63	4.84
New Administrative Area	-	4.99
Total	5.76	5.08

Note: Urban Area: (The Sum of Sangkat which satisfies the following 3 conditions. Population Density; More than 200 people/km^2, Proportion of farmers of adult men; Less than 50%, Total Population; More than 2,000)
Source: Overview of Urban Development in Phnom Penh Capital City, 2011



Source: JICA Study Team

Fig. 2.2.1 Administrative Area in PPCC (Old/New)

(2) Population Projection

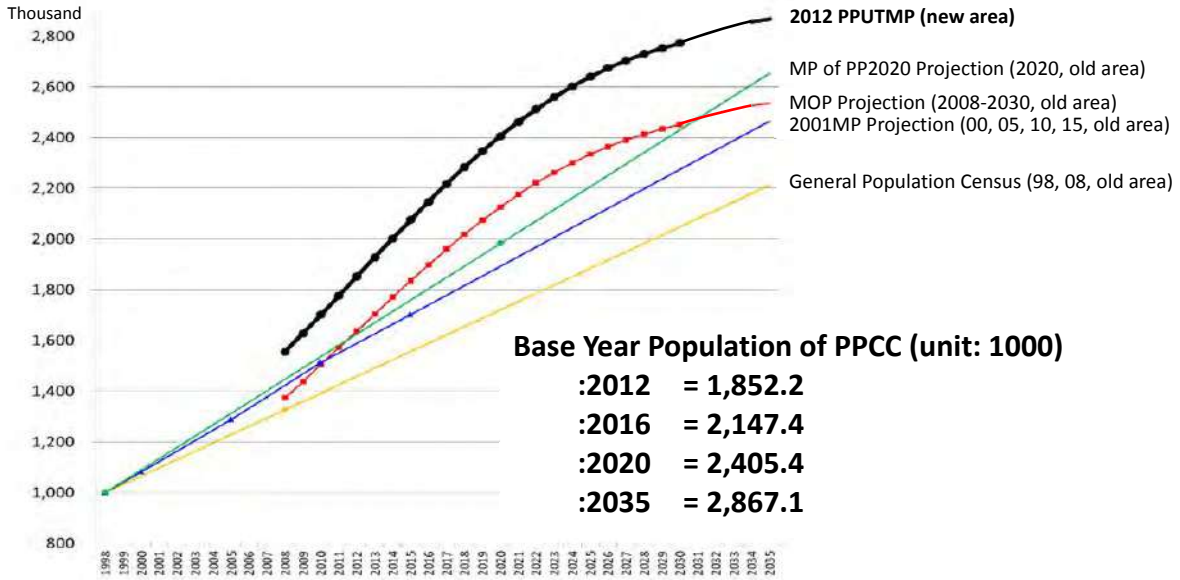
Population up to 2035 has been projected based on the population in base year of 2012, with the reference of census of 1998, 2008, and report of population projection up to 2030, in the "Project for Comprehensive Urban Transport Planning in Phnom Penh Capital City" implemented by

JICA, as shown in **Table 2.2.5** and **Fig. 2.2.2**[5]**.** According to this projection, the population of 2035 will be 2,867,100 people. Sewerage and drainage improvement plans for year 2035 will be formulated, using this population projection in this Study.

Table 2.2.5 Population Projection by JICA Project

Name of Khan		1998	2008	2012	2016	2020	2035
01	Chamkarmon	187,082	182,004	184,200	196,500	200,900	240,400
02	Daun Penh	131,913	126,550	119,500	123,300	126,700	138,200
03	7 Makara	96,192	91,895	93,300	95,100	96,600	102,700
04	Tuol Kok	154,968	171,200	186,100	187,900	185,100	181,100
01-04 Sub-total		**570,155**	**571,649**	**583,100**	**602,800**	**609,300**	**662,400**
05	Dangkor	48,921	73,287	96,100	128,500	148,900	183,700
06	Po Senchey	73,414	159,455	234,900	269,300	321,600	349,500
07	Meanchey	97,190	194,636	282,700	349,100	403,300	490,800
08	Chbar Ampov	108,796	133,165	160,500	194,300	210,100	251,500
09	Reussey Keo	76,473	115,740	152,600	178,800	204,300	251,300
10	Chroy Changvar	53,231	68,708	84,000	102,900	126,700	155,500
11	Sen Sok	70,676	137,772	198,600	237,000	296,700	392,500
12	Prek Pnov	34,574	47,313	59,700	84,700	84,500	129,900
05-12 Sub-total		**563,275**	**930,076**	**1,269,100**	**1,544,600**	**1,796,100**	**2,204,700**
Total Population		**1,133,430**	**1,501,725**	**1,852,200**	**2,147,400**	**2,405,400**	**2,867,100**

* The population is corrected based on new administrative area in PPCC (678.5 km^2)
Source: JICA, "Project for Comprehensive Urban Transport Planning in Phnom Penh Capital City"



Source: JICA, "Project for Comprehensive Urban Transport Planning in Phnom Penh Capital City"

Fig. 2.2.2 Population Projection by JICA Project

[5] "Old Area" in this figure represents the white hatching area, and "New Area" represents the area covering both white and red hatching area, as shown in **Fig. 2.2.1**.

2.3 National Plans and Relevant Plans

2.3.1 Urban Planning and Development Planning

(1) National Strategic Development Plan (NSDP)

The RGC places top priority on establishing good governance (Fighting Corruption, Legal and Judicial Reforms, Public Administration Reform, Reform of Armed Forces) for national strategy that becomes the foundation of the national development plan. The RGC also set up "Rectangular Strategy", listing the most important issues: "1. Promotion of Agriculture Sector"; "2. Development of Physical Infrastructure"; "3. Private Sector Development and Employment"; and "4. Capacity Building and Human Resources Development".

The RGC announced NSDP 2009-2013 as a development plan based on rectangular strategy in June 2010. In this NSDP 2009-2013, installation and maintenance of sewage/drainage facilities is ranked as priorities in the large cities located along national highway including Phnom Penh. In the latest NSDP 2014-2018, that is also ranked as priorities.

(2) Wastewater Management Plan

MPWT prepares the Wastewater Management Plan, which consists of completed and ongoing plans in wastewater management in major cities of Cambodia. However, this plan is not compiled as documentary records.

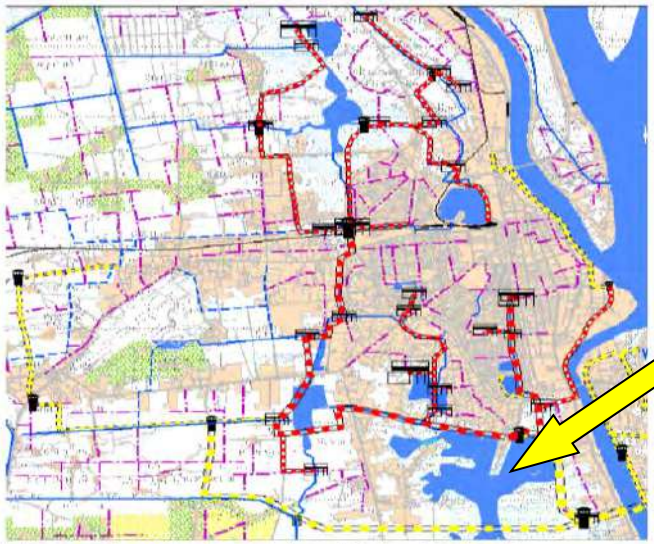
(3) City Development Strategy (CDS)

PPCC formulated CDS for the target year 2015 based on NSDP in 2005. In order to develop Phnom Penh and to improve civic life, CDS has listed the following five key visions: (1) Land use and housing; (2) Environment and natural resources; (3) Infrastructure and transportation; (4) Social services; and (5) Economic development. Under these 5 visions, there are goals such as "Prevention of water pollution", "Promotion of sewage treatment" and "Improvement of drainage system". Under the key visions, "Prevention of Water Pollution" and "Promotion of Wastewater Treatment" are listed under Vision (2) and "Drainage Improvement" is listed under Vision (3).

(4) White Book on Development and Planning of Phnom Penh

PPCC with the support of the French government and the City of Paris formulated the White Book for target year 2020 on the basis of CDS in 2007. Then, PPCC revised it by expanding the target year to 2035. It was approved by the committee for land management and urban planning for the capital and was finally approved by sub-decree, dated on 23rd December 2015..

The White Book suggests plans such as "Development of suburbs and expansion of the capital area to prevent the overconcentration of PPCC", "Promotion of public-private partnerships in the housing and land development" and "Establishment of identity as an aesthetic and environmental city". The Book also shows the strategy for development policy of sewage/drainage sector as shown in **Fig. 2.3.1,** suggesting construction of a new sewage treatment plant at Cheung Aek Lake with lagoon system.



Combined pipe network (Red shows main line)

Location of sewage treatment plant (Cheung Aek Lake)

Source: White Book on Development and Planning of Phnom Penh

Fig. 2.3.1 Strategy for Sewage/Drainage Sector in White Book

2.3.2 Water Supply Plan

(1) Current Condition of Water Supply

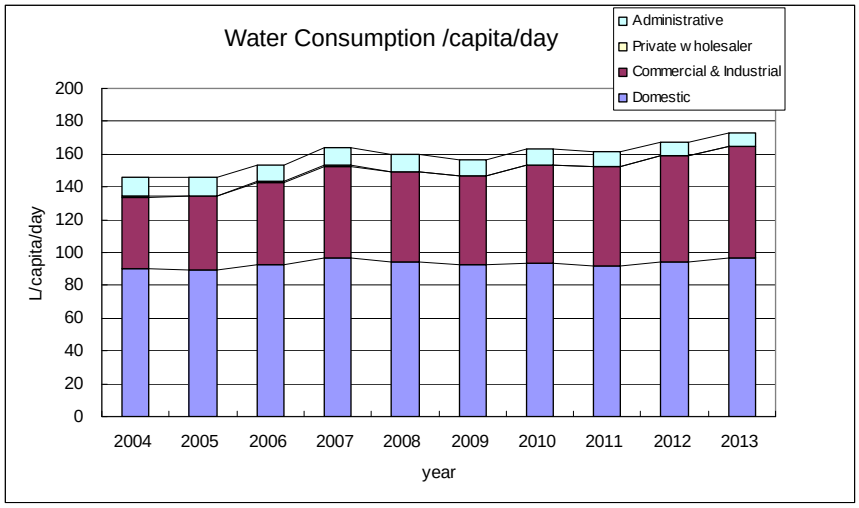
Water Supply in Phnom Penh is operated and maintained by the Phnom Penh Water Supply Authority (PPWSA). Current condition (2004-2013) of water supply by PPWSA is shown in **Table 2.3.1**. It shows that supplied population and water supply amount has increased due to rapid urbanization. Water consumption per capita per day is shown in **Fig. 2.3.2**. The growth rate in annual average is about 2.0%. On the other hand, non-revenue water rate has been stable at 6.0-8.0% in the last 10 years. Ratio of domestic and non-domestic water supply is 6:4.

Table 2.3.1 Water Supply of PPWSA

Item	Unit	2004	2005	2006	2007	2008
Supplied population (Ave.)	Thousand	917.7	1,055.5	1,166.8	1,246.5	1,372.9
Authorized consumption (Ave.)						
(1) Domestic	Thousand m^3/day	83.0	94.5	107.9	121.0	129.6
(2) Commercial/Industry	Thousand m^3/day	39.8	47.4	58.5	69.5	75.0
(3) Water distributor	Thousand m^3/day	0.2	0.3	0.6	0.6	0.6
(4) Government office	Thousand m^3/day	10.6	11.7	12.2	12.9	13.7
(5) Total	Thousand m^3/day	133.5	153.9	179.2	204.0	218.9
Ratio of Domestic consumption out of total (=(1)/(5))		0.62	0.61	0.60	0.59	0.59
Water consumption per capita per day (Ave.)						
(1) Domestic	L/capita/day	90.4	89.5	92.5	97.1	94.4
(2) Commercial/Industry	L/capita/day	43.4	44.9	50.1	55.8	54.6
(3) Water distributor	L/capita/day	0.2	0.3	0.5	0.5	0.4
(4) Government office	L/capita/day	11.6	11.1	10.5	10.3	10.0
(5) Total	L/capita/day	145.5	145.8	153.6	163.7	159.4
Non-revenue water rate (Ave.)	%	14.1	9.2	7.4	6.2	6.2

Item	Unit	2009	2010	2011	2012	2013
Supplied population (Ave.)	Thousand	1,483.2	1,579.6	1,695.1	1,812.6	1,955.7
Authorized consumption (Ave.)						
(1) Domestic	Thousand m^3/day	137.7	148.2	155.9	171.6	189.0
(2) Commercial/Industry	Thousand m^3/day	79.8	93.4	102.4	116.3	132.5
(3) Water distributor	Thousand m^3/day	0.4	0.3	0.2	0.2	0.1
(4) Government office	Thousand m^3/day	14.3	16.2	14.9	15.5	17.1
(5) Total	Thousand m^3/day	232.2	258.1	273.3	303.6	338.7
Ratio of Domestic consumption out of total (=(1)/(5))		0.59	0.57	0.57	0.57	0.56
Water consumption per capita per day (Ave.)						
(1) Domestic	L/capita/day	92.8	93.8	92.0	94.7	96.6
(2) Commercial/Industry	L/capita/day	53.8	59.1	60.4	64.2	67.8
(3) Water distributor	L/capita/day	0.3	0.2	0.1	0.1	0.1
(4) Government office	L/capita/day	9.6	10.3	8.8	8.6	8.7
(5) Total	L/capita/day	156.6	163.4	161.2	167.5	173.2
Non-revenue water rate (Ave.)	%	5.9	5.8	6.7	6.6	7.7

Source: PPWSA



Source: JICA Study Team

Fig. 2.3.2 Water Consumption per Capita per Day

2.4 Status of Existing Facilities

2.4.1 Sewage Facilities

(1) Current Conditions and Challenges

There is no sewage treatment plant in Phnom Penh. **Table 2.4.1** shows the current condition of sanitary facilities such as septic tanks. According to **Table 2.4.1**, 71.8% of households have toilet facilities and connects to drainage facilities and 19.7% of the households have independent septic tanks.

Table 2.4.1 Current Condition of Sewerage Facilities in PPCC

Total No. of Households	Installation of toilet in household (%)		Type of toilets in household (%)			
	NO	YES	Connecting to drainage facilities[6]	Septic Tank	Pit Latrine	Others
352,702	7.1	92.9	71.8	19.7	1.3	-

Source: Cambodia Inter-Census Population Survey, 2013

[6] According to DPWT/PPCC, 'Connecting to drainage facilities' means the house which has a septic tank, and it discharges supernatant water from the septic tank and gray water to the drainage pipe.

2.4.2 Drainage Facilities

(1) Condition of Existing Drainage Facilities

Drainage facilities are constructed by DPWT and local authorities, such as Khan and Sangkat. After construction, the drainage facilities are operated and maintained by DPWT. DPWT records the total length of drainage pipes by diameter and number of manholes by size since 1994. Cumulative length of drainage pipe and number of manholes constructed in 2006-2013 are shown in **Table 2.4.2**.

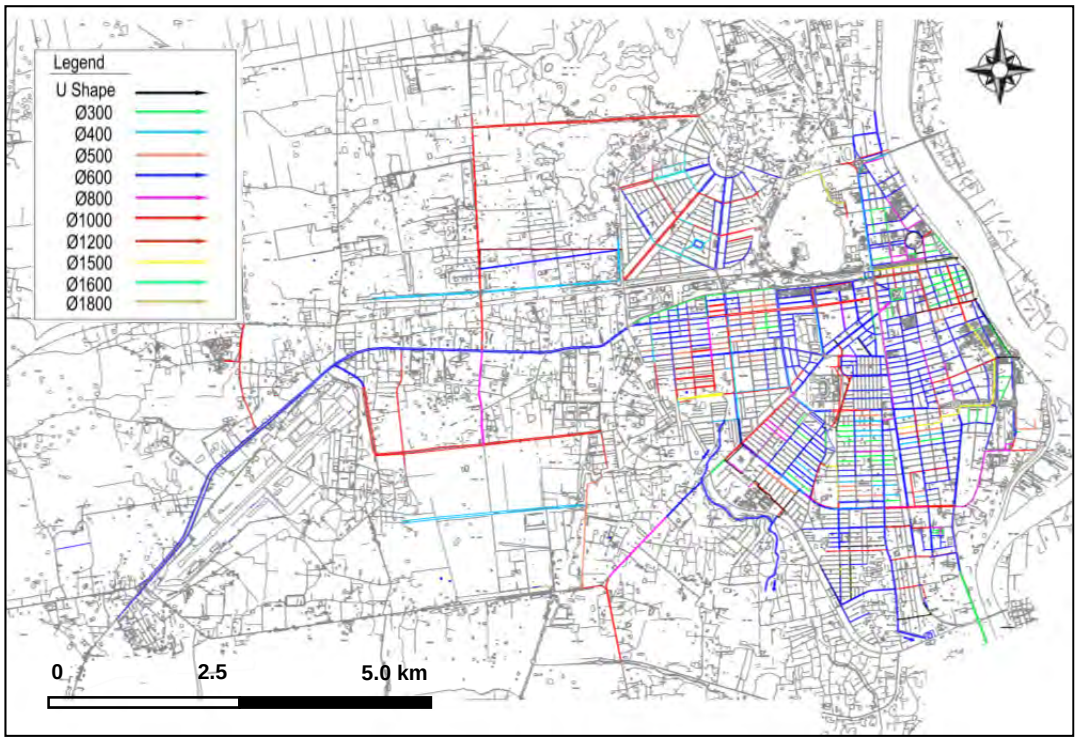
Table 2.4.2 Total Length of Drainage Pipes and Number of Manholes

Drainage Pipes (m)								
Pipe size	2006	2007	2008	2009	2010	2011	2012	2013
Ø200cm								
Ø180cm					301	301	301	301
Ø160cm	85	85	85	85	85	85	85	85
Ø150cm	8,331	9,631	10,847	13,918	17,966	17,966	18,752	19,782
Ø120cm	775	17,820	17,820	17,820	18,187	18,187	18,187	18,187
Ø100cm	42,837	57,962	65,620	81,250	82,110	82,417	84,325	87,876
Ø80cm	26,675	41,712	46,317	50,601	50,939	51,452	51,452	52,125
Ø60cm	124,106	142,125	147,297	157,628	158,068	160,173	160,545	162,049
Ø50cm	51,753	59,873	64,488	64,488	66,237	66,237	66,237	66,237
Ø40cm	13,815	18,942	22,049	22,049	22,105	22,105	22,105	22,105
Ø30cm	33,883	42,902	46,115	46,755	46,755	47,173	47,536	48,412
U-drain					320	320	320	320
Total (m)	302,260	391,052	420,638	454,594	463,073	466,416	469,845	477,479
Manholes								
Size	2006	2007	2008	2009	2010	2011	2012	2013
$Rg_{200x130}$					45	45	61	127
$Rg_{130x130}$	1,993	3,420	3,701	4,510	4,530	4,558	4,617	4,785
$Rg_{110x110}$	1,395	1,669	1,823	2,025	2,025	2,025	2,025	2,052
Rg_{90x90}	5,171	8,080	8,545	9,120	9,142	9,233	9,266	9,354
Rg_{70x70}	6,629	9,103	9,334	16,662	16,682	16,822	16,895	17,104
Total	15,188	22,272	23,403	32,317	32,424	32,683	32,864	33,422

Source: DPWT/PPCC

DPWT is in the process of establishing the database[7] of drainage pipes at present. **Fig. 2.4.1** shows the location map derived from the database. However, there are still many drainage pipes in the capital city that have not been recorded in this database yet. Further survey about drainage pipe network is necessary.

[7] The database is established in the soft component of the Japan's Grant Aid Project, "The Project for Flood Protection and Drainage Improvement in the Phnom Penh Capital City (Phase III)".



Source: DPWT/PPCC

Fig. 2.4.1 Drainage Pipe Location Map from Database

Details of open channels and pumping stations managed by DPWT as of September 2014, are shown in **Table 2.4.3** and **Table 2.4.4**. Total length of channel is about 55 kilometres and number of pumping stations is 12.

Table 2.4.3 Total Length of Open Channels Managed by DPWT

No.	Name	Total length (m)	Improved Length (m)	Canal Type
1	Boeng Trabek Upper Canal	2,410	2,410	Reinforced Concrete Canal
2	Boeng Trabek Downstream Canal	850	0	Earth Canal
3	Boeng Tumpun Canal	3,710	3,710	Improved Earth Canal
4	Stoeng Mean Chey Canal	1,900	0	Earth Canal
5	East & West Tuol Sen Canals	1,118	1,118	Improved to Reinforced Concrete Canal
6	Boeng Salang canal	1,260	887	Improved Earth Canal (887m)
7	Canal Baraing (France)	3,700		Earth Canal
8	Canal Lou Pram	1,700		Earth Canal
9	Tuol Poung Ror Canal (South Prey Pring)	7,500		Earth Canal
10	Prey Spoeu Canal	7,000		Earth Canal
11	O Akuch Canal	4,200		Earth Canal
12	598 Canal	1,850		Earth Canal
13	Tuol Sampoeuv Canal (Philippines Canal)	5,000		Earth Canal
14	Kop Srov Canal	4,700		Earth Canal
15	Bak Touk Canal	3,800		Earth Canal
16	O Veng Canal	4,150		Earth Canal
	Total	**54,848**	**8,125**	
	Improved to Reinforced Concrete Canal	**3,528**		
	Improved in Earth Canal	**4,597**		
	Normal Earth Canal	**46,723**		

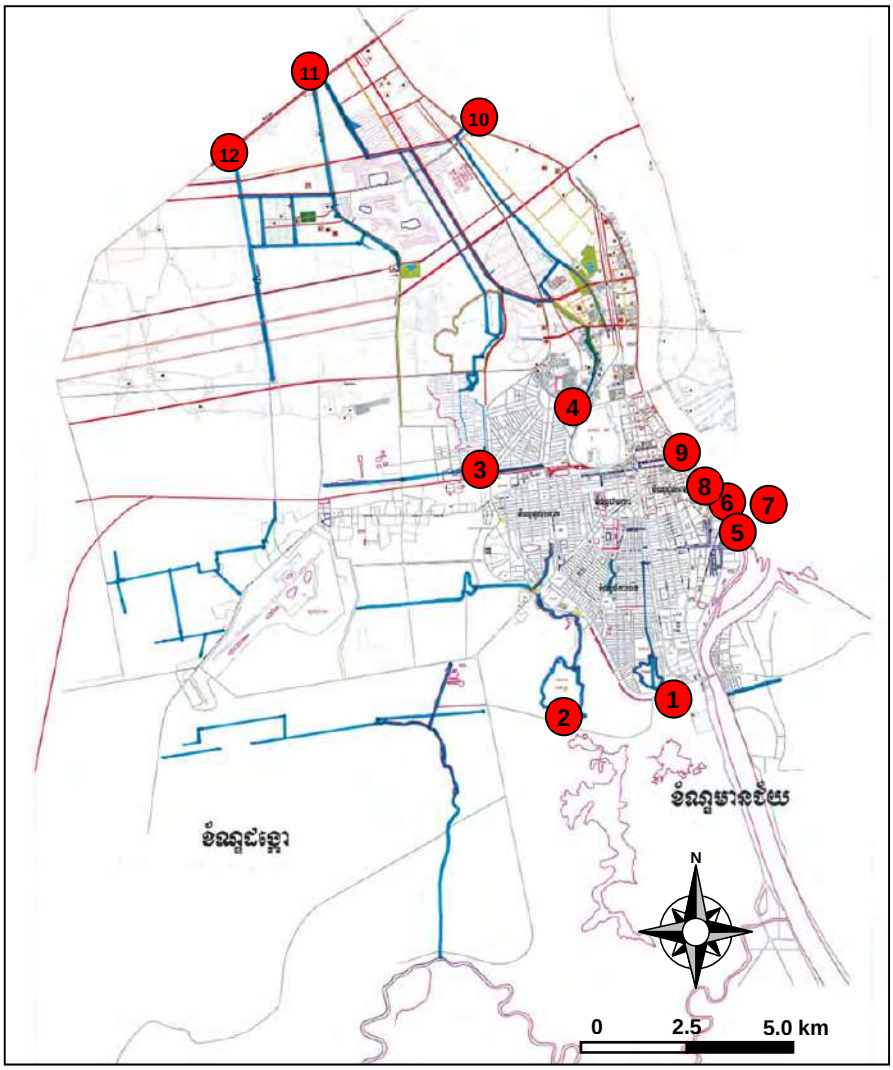
Source: DPWT/PPCC

Table 2.4.4 List of Pumping Stations Managed by DPWT

Station Name		Electrical Engine Driven				Diesel Engine Driven				Total Discharge Capacity [m^3/sec.]	Observation (Date of Equipment)
		Nos	Pump type	Power /Unit [kW]	Capacity /Unit [m^3/sec.]	Nos	Pump type	Power /Unit [HP]	Capacity /Unit [m^3/sec.]		
1	Boeng Trabek	8	Horizontal	132	1.0	1 unit of Backup Generator, 1000 KVA				8.0	Operation since 2003 (ADB Loan)
2	Boeng Tumpun	5	Submergible Pump	280	3.0	2 units of Backup Generator, 700 KVA each				15.0	Operation since 2004 (Japan's Grant Aid)
3	Tuol Kork I	2	Vertical shaft	45	0.47	2	Vertical shaft	145	0.69	2.32	Constructed in 1970's
4	Tuol Kork II	1	Vertical shaft	45	0.47	2	Vertical shaft	145	0.69	1.85	Constructed in 1970's
5	Chak Tomuk	2	Pump Gate	45	0.7	1 unit of Backup Generator, 200 KVA				1.4	Operation since 2010 (Japan Grant Aid)
6	Preah Kumlung 1	1	Pump Gate		0.2	-				0.2	Operation since 2004 (Joint Research with Kubota)
7	Preah Kumlung 2	2	Pump Gate	22	0.35	-				0.7	Operation since 2010 (Japan's Grant Aid)
8	Phsar Kandal	2	Pump Gate	45	0.7	1 unit of Backup Generator, 200 KVA				1.4	Operation Since 2010 (Japan's Grant Aid)
9	Phsar Chaas	2	Pump Gate	45	0.7	1 unit of Backup Generator, 200 KVA				1.4	Operation since 2010 (Japan's Grant Aid)
10	Svay Pak Km No.9	4	Submergible Pump	75	0.13	3	Vertical shaft	190	0.38	1.66	Operation since 2006
11	Kop Srov	5	Vertical shaft	400	2.8	-				14.0	Operation since 2010
12	Tuol Sampeo	3	Submergible Pump		0.66	-				1.98	Operation since 2014

Source: DPWT/PPCC

Fig. 2.4.2 shows location of open channels and pumping stations managed by DPWT.



Blue line: location of open channels, Red mark: location of pumping station
(Numbers correspond to **Table 2.4.4**)
Source: DPWT/PPCC, JICA Study Team

Fig. 2.4.2 Location Map of Channels and Pumping Stations Managed by DPWT

2.4.3 Sludge Management Facilities

The Waste Management Division of PPCC is responsible for septage management but there exists no septage disposal site for septage collected by vacuum trucks. Therefore, the septage is disposed into the lagoon in Dangkor solid waste disposal site with charge of 10,000 riel per vacuum truck. However, most of septage collected by vacuum car from the households is illegally dumped in the drainage channels or wetlands.

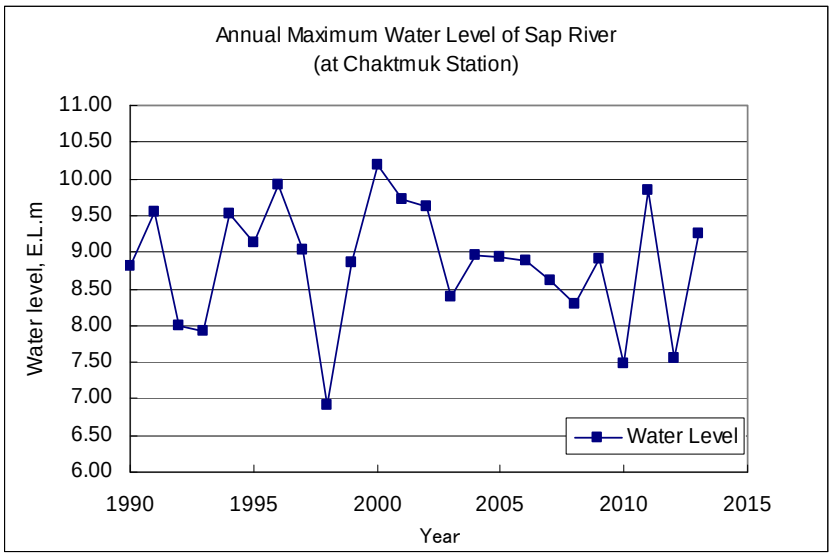
2.4.4 Flood Protection

Urbanized area in Phnom Penh is protected from flooding arising from overflow of Mekong/Sap River by Kop Srov Dike at northern part, Tumpun Dike at southern part and natural levees along the Mekong/Sap River.

When the M/P 1999 study was conducted, Kop Srov Dike formed a part of the northwest administrative boundary of the Municipality of Phnom Penh, connecting National Roads of Routes 4 and 5. Due to expansion of the administrative area of Phnom Penh, the role of Kop Srov Dike has changed into a dike to protect the city from flooding as well as a ring road to bypass the city center

area. Similarly, there are two roles of Tumpun dike, namely, as a dike and a ring road. The crests of the two dikes are paved by asphalt or cement concrete.

Water level of Sap River has been observed since the 1960's, the maximum water level was recorded in 2000. Annual maximum water level recorded between 1993 and 2013 is shown **Fig. 2.4.3**. It is obvious that there is no record which exceeds the maximum water level recorded in 2000 (E.L. 10.18m).



Source: MOWRAM

Fig. 2.4.3 Variation of Annual Maximum Water Level in Sap River

2.5 Water Quality

2.5.1 Water Quality and Effluent Standard

The Sub-Decree on Water Pollution Control, 1999 was enacted on 6th April 1999, aiming to prevent water pollution in Cambodia. This sub-decree defines "Classification of waste and hazard discharge", "Water Quality Standard", "Effluent Standard", "Responsibility of polluter", "Monitoring", "Discharge Permit", "Inspection" and "Penalty", etc.

Water quality standard in public water areas such as river, lakes, reservoirs and coastal water is set for bio-diversity conservation (**Table 2.5.1**). In addition, effluent standard (Effluent standard for pollution sources discharging wastewater to public water areas or sewer) is set as shown in **Table 2.5.2**.

Table 2.5.1 Water Quality Standard for Bio-Diversity Conservation

	No	Parameter	Unit	Standard Value
1. River	1	pH	-	6.5 – 8.5
	2	BOD_5	mg/l	1 – 10
	3	Suspended Solid	mg/l	2.4 – 100
	4	Dissolved Oxygen	mg/l	2.0 – 7.5
	5	Coliform	MPN/100ml	< 5,000
2. Lakes and Reservoirs	1	pH	-	6.5 – 8.5
	2	COD_{Mn}	mg/l	1 – 8
	3	Suspended Solid	mg/l	1 – 15
	4	Dissolved Oxygen	mg/l	2.0 – 7.5
	5	Coliform	MPN/100ml	< 1,000
	6	Total Nitrogen	mg/l	1.0 – 0.6
	7	Total Phosphorus	mg/l	0.005 – 0.05

	No	Parameter	Unit	Standard Value
3. Coastal Water	1	pH	-	7.0 – 8.3
	2	COD_{Mn}	mg/l	2 – 8
	3	Suspended Solid	mg/l	2 – 7.5
	4	Coliform	MPN/100ml	< 1,000
	5	Oil Content	mg/l	0
	6	Total Nitrogen	mg/l	0.2 – 1.0
	7	Total Phosphorus	mg/l	0.02 – 0.09

* Some parameters have 'lower limit' and 'upper limit'. As the result of inquiry to MOE about 'lower limit', setting up of the 'lower limit' (excluding pH) is not correct and those should be revised but the schedule of the revision is not fixed.

Source: Sub-Decree on Water Pollution Control, Annex 4: Water Quality Standard in public water areas for bio-diversity conservation.

Table 2.5.2 Effluent Standard for Public Water Areas or Sewer

No	Parameter	Unit	Standard	
			Protected Public Water Area	Public Water Area and Sewer
1	Temperature	^0C	< 45	< 45
2	pH		6 – 9	5 – 9
3	BOD_5 (5 days at 20℃)	mg/l	< 30	< 80
4	COD_{Cr}	mg/l	< 50	< 100
5	Total Suspended Solids	mg/l	< 60	< 120
6	Total Dissolved Solids	mg/l	< 1,000	< 2,000
7	Grease and Oil	mg/l	< 5.0	< 15
8	Detergents	mg/l	< 5.0	< 15
9	Phenols	mg/l	< 0.1	< 1.2
10	Nitrate (NO_3)	mg/l	< 10	< 20
11	Chlorine (free)	mg/l	< 1.0	< 2.0
12	Chloride (ion)	mg/l	< 500	< 700
13	Sulphate (as SO_4)	mg/l	< 300	< 500
14	Sulphate (as Sulphur)	mg/l	< 0.2	< 1.0
15	Phosphate (PO_4)	mg/l	< 3.0	< 6.0
16	Cyanide (CN)	mg/l	< 0.2	< 1.5
17	Barium (Ba)	mg/l	< 4.0	< 7.0
18	Arsenic (As)	mg/l	< 0.10	< 1.0
19	Tin (Sn)	mg/l	< 2.0	< 8.0
20	Iron (Fe)	mg/l	< 1.0	< 20
21	Boron (B)	mg/l	< 1.0	< 5.0
22	Manganese (Mn)	mg/l	< 1.0	< 5.0
23	Cadmium (Cd)	mg/l	< 0.1	< 0.5
24	Chromium (Cr^{+3})	mg/l	< 0.2	< 1.0
25	Chromium (Cr^{+6})	mg/l	< 0.05	< 0.5
26	Copper (Cu)	mg/l	< 0.2	< 1.0
27	Lead (Pb)	mg/l	< 0.1	< 1.0
28	Mercury (Hg)	mg/l	< 0.002	< 0.05
29	Nickel (Ni)	mg/l	< 0.2	< 1.0
30	Selenium (Se)	mg/l	< 0.05	< 0.5
31	Silver (Ag)	mg/l	< 0.1	< 0.5
32	Zinc (Zn)	mg/l	< 1.0	< 3.0
33	Molybdenum (Mo)	mg/l	< 0.1	< 1.0
34	Ammonia (NH_3)	mg/l	< 5.0	< 7.0
35	DO	mg/l	>2.0	>1.0
36	Polychlorinated Byphenyl	mg/l	<0.003	<0.003
37	Calcium	mg/l	<150	<200
38	Magnesium	mg/l	<150	<200
39	Carbon tetrachloride	mg/l	<3	<3
40	Hexachloro benzene	mg/l	<2	<2
41	DTT (Dithiothreitol)	mg/l	<1.3	<1.3
42	Endrin	mg/l	<0.01	<0.01
43	Dieldrin	mg/l	<0.01	<0.01

No	Parameter	Unit	Standard	
			Protected Public Water Area	Public Water Area and Sewer
44	Aldrin	mg/l	<0.01	<0.01
45	Isodrin	mg/l	<0.01	<0.01
46	Perchloro ethylene	mg/l	<2.4	<2.4
47	Hexachloro butadiene	mg/l	<3	<3
48	Chloroform	mg/l	<1	<1
49	1,2 Dichloro ethylene	mg/l	<2.4	<2.4
50	Trichloro ethylene	mg/l	<1	<1
51	Trichloro benzene	mg/l	<2	<2
52	Hexaxhloro cyclohexene	mg/l	<2	<2

Note: "Protected public water area" is set in this standard. All effluents including those of industries should be subject to the standard of "Public water area and sewer" since the protected area is not yet currently specified.
Source: Sub-Decree on Water Pollution Control, Annex 2: Effluent standard for pollution sources discharging wastewater to public water areas or sewer

2.5.2 Water Monitoring and Analysis in the Study

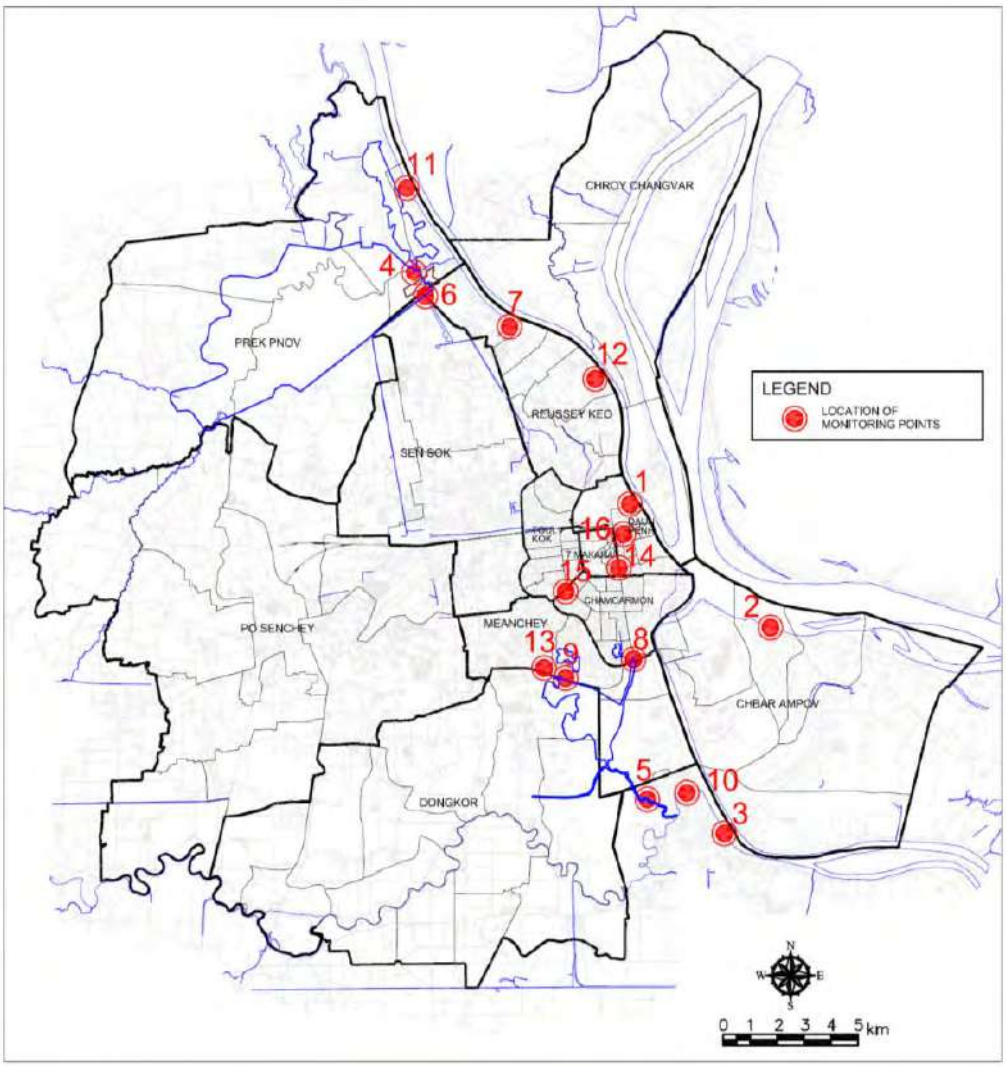
(1) Monitoring Locations and Parameters

Water monitoring and analysis was implemented by JICA Study Team. The survey was independent from MOE's monitoring survey. Locations of monitoring are shown in **Table 2.5.3** and **Fig. 2.5.1**. Sixteen monitoring locations in total include river, lake/swamp, small channel, factory and commercial facilities. Samplings were conducted six times (three times in the dry season and three times in the rainy season).

Table 2.5.3 Monitoring Points and Parameters in the Study

No	Category	Monitoring Point	Parameters	Remarks
1	River	Sap River (Phnom Penh Port)	pH, DO, BOD_5, COD_{Cr}, COD_{Mn}, TSS, T-N, T-P, Total Coliform (9 parameters)	Surface water is taken from the riverside
2		Mekong River (Kien Svay)		
3		Bassac River (Thakhmao)		
4	Lake/swamp	Tamok Lake (Discharge Point)		Water is taken at discharge point of the lake/swamp
5		Cheung Aek Lake (Discharge Point)		
6	Small Channel	Kop Slov Pumping Station	pH, DO, BOD_5, COD_{Cr}, TSS, T-N, T-P, Total Coliform (8 parameters)	Surface water is taken at the middle of channels. The points of factory and commercial facilities are selected in collaboration with DOE/PPCC.
7		Svay Pak Sluiceway		
8		Trabek Pumping Station		
9		Tumpun Pumping Station		
10		Prek Thnot River (Thakhmao Bridge)		<Treatment Facility>
11	Factory	Men Sarun (Noodle Factory)		Septic Tank
12		SKD (Liquor Factory)		Digestion Tank + Lagoon
13		SL (Garment and Washing)		Activated sludge process + Chemical treatment
14	Commercial Facilities	Phnom Penh Tower (Office Building)		Activated sludge process
15		Intercontinental Hotel		Septic tank + Aeration
16		Central Market		Septic tank

Note: COD_{Mn} is monitored at rivers to compare the COD_{Mn} of lake and swamp where it is regulated.
Source: JICA Study Team



Source: JICA Study Team

Fig. 2.5.1 Location Map for Water Sampling Survey

(2) Survey Result

Minimum, maximum and average at each monitoring point are summarized in **Table 2.5.4.**

Table 2.5.4 Minimum, Maximum and Average Values at Monitoring Points in the Study

No.	Location		pH (-)	DO (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD_{Mn} (mg/L)	COD_{Cr} (mg/L)	T-N (mg/L)	T-P (mg/L)	Total Coliform (MPN/100 ml)
1	Sap River	Min	6.17	3.44	72.0	2.79	3.98	22.64	0.09	0.01	1.1E+04
		Max	7.73	5.51	214.0	5.18	8.14	43.12	0.91	0.06	9.3E+05
		Average	6.91	4.47	124.3	4.05	6.04	32.40	0.43	0.04	2.2E+05
2	Mekong River	Min	4.20	4.37	98.0	0.90	2.79	19.60	0.13	0.04	2.9E+03
		Max	7.54	5.82	364.0	3.06	6.20	37.50	1.67	0.28	7.5E+05
		Average	6.41	5.15	179.5	2.04	4.51	27.67	0.54	0.09	1.8E+05
3	Bassac River	Min	5.83	4.18	95.0	0.50	3.05	15.68	0.48	0.05	4.6E+03
		Max	7.40	5.71	332.0	3.75	6.80	27.44	1.67	0.28	2.4E+06
		Average	6.71	4.83	165.2	2.06	4.38	22.30	0.84	0.14	4.4E+05
4	Tamok Lake	Min	6.61	4.72	59.0	2.90	4.31	33.80	0.66	0.12	2.3E+04
		Max	9.16	7.59	102.0	6.44	12.29	62.40	4.86	0.51	2.4E+05
		Average	7.64	6.06	85.8	5.17	9.76	49.43	1.74	0.30	9.8E+04
5	Cheung Aek Lake	Min	6.37	0.64	26.0	3.60	6.95	35.27	1.78	0.31	2.3E+04
		Max	7.38	4.85	164.0	9.69	18.24	74.16	4.76	0.76	7.5E+05

No.	Location		pH (-)	DO (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD_{Mn} (mg/L)	COD_{Cr} (mg/L)	T-N (mg/L)	T-P (mg/L)	Total Coliform (MPN/100 ml)
		Average	6.85	2.06	95.7	7.13	13.11	54.48	3.45	0.53	2.3E+05
6	Kop Slov Pumping Station	Min	6.10	0.13	84.0	10.80	-	36.84	2.23	0.99	1.5E+04
		Max	7.42	6.10	154.0	26.73	-	59.00	6.65	2.17	1.1E+06
		Average	6.92	2.82	106.5	18.05	-	46.00	3.49	1.47	3.2E+05
7	Svay Pak Sluiceway	Min	5.82	0.00	134.0	88.00	-	50.96	3.44	0.36	2.1E+04
		Max	7.23	3.57	640.0	156.62	-	90.16	8.80	2.10	2.4E+07
		Average	6.73	1.59	315.0	121.35	-	74.21	5.75	1.19	4.2E+06
8	Trabek Pumping Station	Min	6.66	0.00	72.0	89.00	-	116.52	2.74	1.17	2.1E+04
		Max	7.06	0.07	740.0	299.85	-	247.61	26.31	4.01	9.3E+06
		Average	6.85	0.03	254.5	243.05	-	195.71	11.13	2.18	1.8E+06
9	Tumpun Pumping Station	Min	6.09	0.00	142.0	112.00	-	92.18	3.32	0.59	2.3E+04
		Max	7.27	0.73	480.0	249.50	-	196.37	21.90	4.95	1.5E+07
		Average	6.79	0.13	237.5	164.09	-	132.06	10.62	2.01	2.7E+06
10	Prek Thnot River	Min	6.18	0.98	170.0	7.38	-	31.32	1.84	0.19	3.5E+03
		Max	7.39	5.10	474.0	20.69	-	48.12	6.96	1.83	9.3E+06
		Average	6.77	3.02	248.5	12.84	-	41.32	4.06	0.77	1.6E+06
11	Men Sarun (Noodle Factory)	Min	4.30	2.60	108.0	36.40	-	48.80	0.75	0.16	2.8E+04
		Max	7.25	6.12	478.0	127.50	-	595.84	4.10	1.04	1.1E+06
		Average	6.15	4.83	218.8	79.70	-	251.24	2.91	0.56	6.1E+05
12	SKD (Liquor Factory)	Min	3.35	1.03	52.0	30.75	-	48.76	0.59	0.14	7.5E+03
		Max	7.32	6.78	98.0	47.06	-	104.16	5.96	1.58	2.4E+05
		Average	6.34	3.09	79.2	39.34	-	71.36	2.33	0.54	1.4E+05
13	SL (Garment and Washing Factory)	Min	6.30	2.60	52.0	36.95	-	70.68	4.87	0.18	1.5E+03
		Max	7.51	6.35	128.0	65.52	-	160.72	14.75	2.18	7.5E+05
		Average	6.96	4.38	80.8	45.17	-	112.29	8.61	0.57	1.9E+05
14	Phnom Penh Tower (Office Building)	Min	5.48	0.00	86.0	15.70	-	49.60	4.08	2.55	2.3E+04
		Max	7.21	3.10	302.0	72.54	-	101.40	10.88	3.63	7.5E+05
		Average	6.63	1.67	201.7	37.37	-	79.90	7.56	3.01	1.7E+05
15	Intercontinental Hotel	Min	5.38	4.70	64.0	21.06	-	58.82	7.92	1.09	2.1E+04
		Max	7.83	5.72	268.0	75.58	-	84.88	26.14	2.96	2.1E+07
		Average	7.03	5.10	149.2	41.41	-	74.37	13.10	2.13	3.6E+06
16	Central Market	Min	4.70	0.00	144.0	135.62	-	202.80	7.21	2.24	2.3E+04
		Max	6.95	0.34	276.0	292.50	-	356.72	22.08	5.81	7.5E+07
		Average	6.17	0.07	190.0	212.91	-	283.35	11.19	3.38	1.3E+07
Standard for Monitoring Point											
	No. 1 to 3		6.5-8.5	>2.0	<100	<10	-	-	-	-	5.0E+03
	No. 4 to 5		6.5-8.5	>2.0	<15	-	<8	-	<1.0	<0.05	1.0E+03
	No. 6 to 16		5.0-9.0	>2.0	<120	<80	-	<100	-	-	-

Source: JICA Study Team

2.6 Current Status of Organizations and the System

2.6.1 Related Laws and Regulations

Cambodian laws consist of the Constitution, Constitutional Law, Kram (Law), Kret (Royal Decree), Anukuret (Sub-Decree), Prakas (Regulation or Declaration), Sarachor (Circular) and other forms (such as Ordinance of the Mayor, Provincial Governor or Bureau Director). The related laws and regulations are as described below.

(1) Sewage and Sludge Management

No law relating to sewerage and drainage management currently exists. Therefore, a "Wastewater Management Law" is being formulated by MPWT as a new law concerning sewerage and drainage management. Formulation work has been ongoing as of February 2015. Although a draft has been written, the work is still in the stage of gathering ideas from neighbouring countries; therefore, completion of the final is still uncertain. This draft consists of 83 articles in 14 chapters. Currently, assistance from UN-HABITAT and UN-ESCAP is being sought.

As stated above, no law has been enacted for wastewater management, except for those relevant to the Ministry of Environment. In order to proceed with the establishment of a sewer system, a law concerning the treatment of wastewater and disposal of sludge needs to be established. To address this issue, a sewerage law as the basic law concerning treatment of wastewater and disposal of sludge needs to be established and aligned with other relevant laws; while relevant local government ordinances and decrees need to be formulated. The sewerage law (or ordinance) to be proposed shall include, for example, definition of terms, business plan, structural standards, discharged water quality, installation of drainage utilities, announcement of commission, obligation of sewer connection, installation of specified facilities, monitoring of discharged water quality and effluent utilities, treatment and disposal of sludge, standards for operation and maintenance, setting sewerage fee and method to collect the charges, support scheme such as reduction or exemption of the charges, procedures for respective notifications, and penalty provisions.

(2) Sewage and Sludge Management in Private Developments

The "Law on Land Management, Urban Planning and Construction (1994)" concerns private development, stipulating provisions related to processes of national or provincial level development planning and land use planning. Local authorities such as PPCC are mandated to formulate a Master Plan for development planning and a land use plan, which must receive national approval.

Sub-Decree No. 86 "Anukret 86 on Construction Permit (ANK/BK)" concerning building permits was formulated on December 19, 1997. ANK/BK applies to all buildings in the absence of a land use plan or approved Master Plan. As the conditions for issuance of a building permit, there are provisions concerning sanitary facilities, connection of sewers and land reclamation (Article 2 of the mentioned law), and provisions concerning drinking water supply and connection of sewers and drains (Article 31 of the mentioned law). In the absence of a sewerage system, there are provisions for obligation to install wastewater treatment facilities such as septic tanks and its standards of facilities (Article 31-3 of the mentioned law). Building permits are issued by the RGC (Council of Ministers). In particular, the buildings in the following list require approval of the National Committee Chairman of the Ministry of Land Management, Urban Planning and Construction (Article 5 of the mentioned law). The member of the National Committee is stipulated in Article 6.2 of the mentioned law.

- Commercial or industrial building whose floor area exceeds 3,000 m^2
- Commercial hotel

- Farmland development not less than 500 ha
- Airport, seaport, railway or carriage storage
- Public or private facility whose floor area exceeds 3,000 m^2 (including such a building whose floor area exceeds 3,000 m^2 after extension)
- Construction in a protected area (environmental, scenic or historical cultural asset)
- Building classified as national heritage
- Building for defence of military facilities

(3) Land Use and Regulations

The "Land Law" regulates land use. The "Land Law" was enacted in 1992 and revised in 2001. This law stipulates rights, form and acquisition of land ownership, and the procedures for land ownership. Although the "Land Law" recognizes legal ownership of land, it does not recognize pre-1980 land ownership rights. However, there are categories of land ownership rights known as ownership rights and a special right to occupy. Depending on the availability of documentary evidence, one may be granted ownership rights or a special right to occupy. Note that land ownership rights are only granted to citizens or organizations having Cambodian nationalities. Incidentally, the 2001 revision of the Land Law clearly listed, in Article 29–31, the conditions for which a special right to occupy is granted.

(4) Environmental and Social Considerations, as well as Land Expropriation

Details of laws concerning environmental and social considerations, as well as land expropriation are mentioned in **Section 2.7**.

(5) Identification of Issues

As stated in **Subsection 2.3.1** (Urban Plan, Development Plan, and Urban Plan), improvements in sewerage and drainage area are identified as the focus of such materials as NSDP, CDS, and the White Book. However, in the absence of a legal framework concerning establishment of the sewer system, the following are identified as the issues concerning the legal framework.

(a) Absence of Legal Framework concerning Sewerage, Effluent and Sludge Management (Sewerage Law)

The sewerage law governing the sewer system is the bible of smooth implementation of M/P of sewage and drainage improvement. Therefore, establishment of the law is essential.

(b) Absence of Guidelines and Standards for Sewerage Management

Specific guidelines and standards related to the sewer system, based on the sewerage law, are required, to stipulate such matters as subsidiary schemes concerning the sewer system, sewer connection from factory/plant, commercial facility or general household, standards concerning the structure of culvert/pipes and treatment plants, standards for regulating water quality and standards for operation and maintenance.

(c) Establishment of the System to promote the Sewerage Management

In order to smoothly implement this project, which is targeting 2035, firstly, the formulation of sewerage and other relevant laws is required. Also, to promote the sewerage improvement, the following system design will be effective: formulation of short-, medium- and long-term plans, followed by approval from central government and then detailing of a "Five-Year Plan for Sewerage Improvement in Phnom Pen Capital City (provisional name)" to be sustainable until the target year.

2.6.2 Organizations Concerned

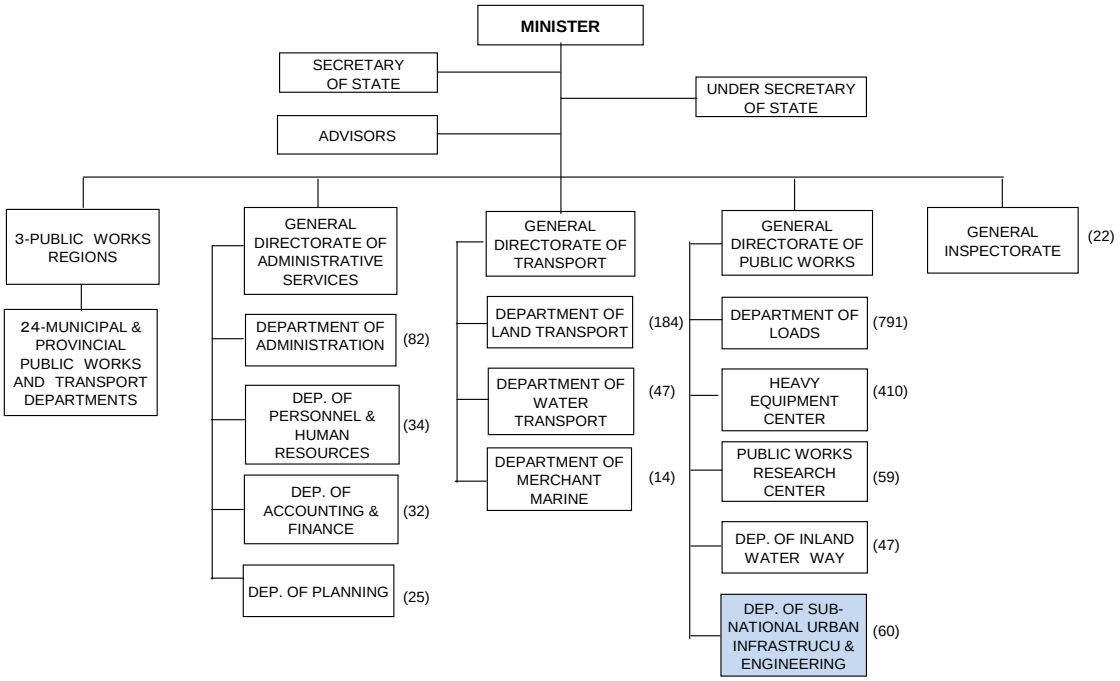
(1) Ministry of Public Works and Transport

The Ministry of Public Works and Transport (MPWT) governs Cambodia's public works and transport such as roads, ports, transport, urban development, sewerage and drainage. MPWT consists of five departments (General Directorate of Administrative Services, General Directorate of Transport, General Directorate of Public Works, General Inspectorate and public works regions).

MPWT has a plan to create two more departments under the General Directorate of Public Works: one is sewerage and drainage department to promote the establishment and improvement of laws and standards, the other is the department in charge of highways. In addition, alongside organizational development at MPWT, organization at the Department of Public Works and Transport (DPWT) will also be strengthened

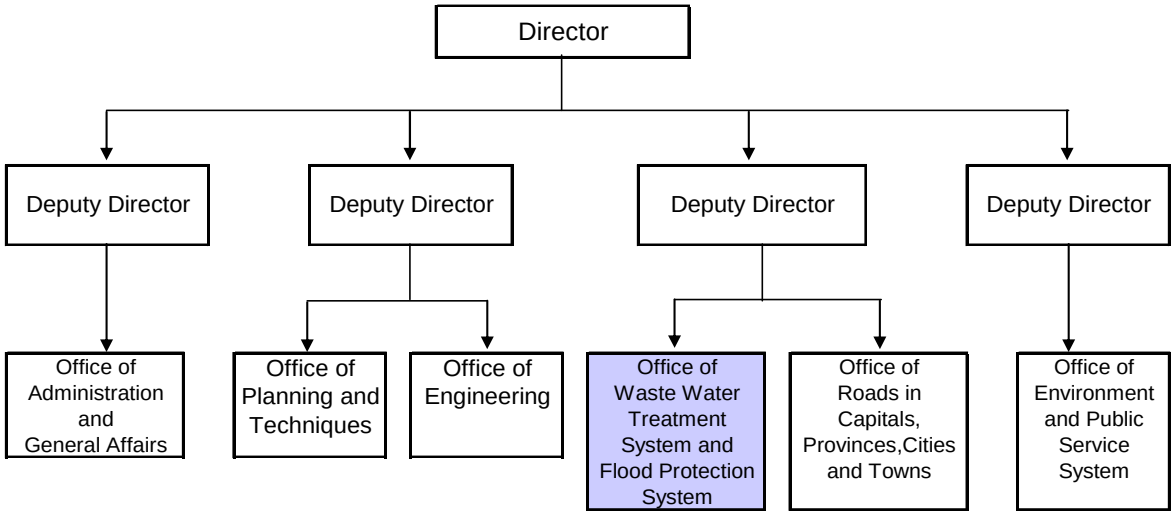
When issues arise during establishment of sewerage system, a steering committee will be established by the ministries and agencies concerned for coordination toward solving the issue. The committee will be convened by the Secretariat at the Ministry of Economics and Finance, with members coming from the concerned ministries and agencies.

The Office of Wastewater Treatment System and Flood Protection System in the Department of Sub-national Urban Infrastructure and Engineering in DPWT is responsible for laws and standards concerning sewerage and drainage. As of February 2014, MPWT has altogether 3,391 staff members, while the Department of Sub-national Urban Infrastructure and Engineering has 60. **Fig. 2.6.1** shows the organization of the MPWT, while **Fig. 2.6.2** shows the organization of the Department of Sub-national Urban Infrastructure and Engineering. Incidentally, at present, the sewerage and drainage services in Cambodia are the responsibilities of the General Department of Public Works and Transport of each province or PPCC.



Source: MPWT

Fig. 2.6.1 Organizational Chart of MPWT

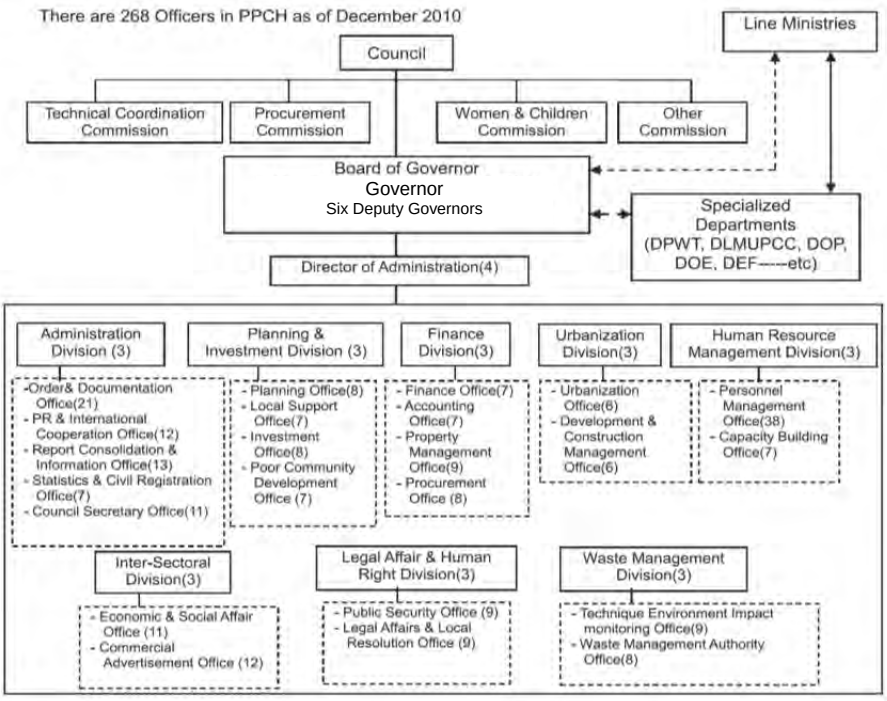


Source: MPWT

Fig. 2.6.2 Organizational Chart of Department of Sub-National Urban Infrastructure and Engineering

(2) Phnom Penh Capital City

As shown in **Fig. 2.6.3**, PPCC consists of an Administration Division, Planning and Investment Division, Finance Division, Urbanization Division, Human Resource Management Division, Inter-Sectoral Division, Law and Human Right Affair Division, and Waste Management Division. As of December 2010, 268 staff members work there. PPCC operates its services in collaboration with respective ministries and departments under ministries. Concerning sewerage services, after approval by the Governor of the Capital City, they will be carried out by the DPWT under direction of and with technical support from MPWT



Source: Overview of Urban Development in Phnom Penh Capital City, 2011

Fig. 2.6.3 Organizational Chart of PPCC

(3) Department of Public Works and Transport

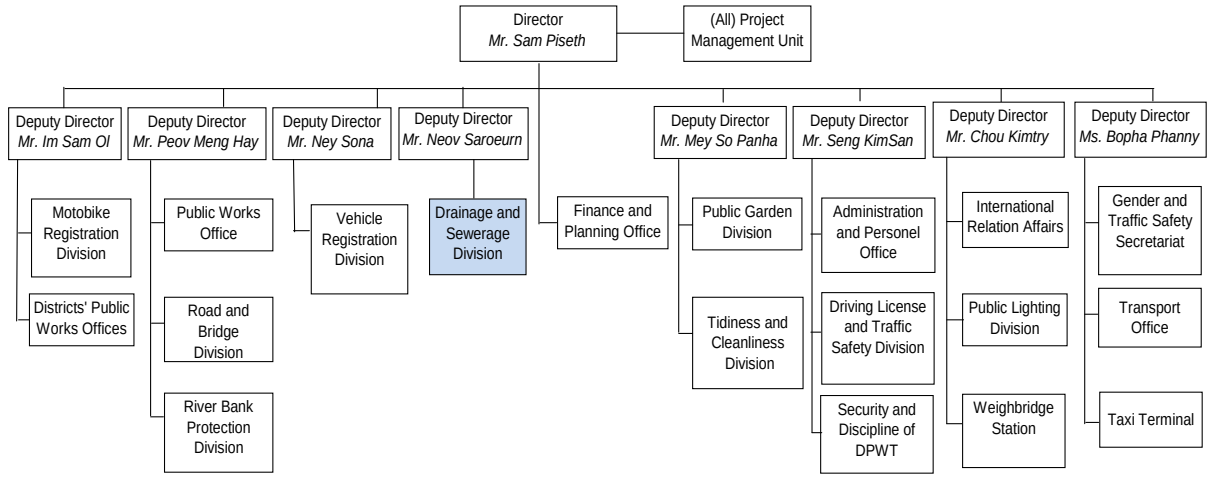
(a) Organizational Structure and Staff Assignment

The Department of Public Works and Transport (DPWT/PPCC) is a branch under MPWT. Under the oversight of PPCC and MPWT, DPWT/PPCC manages public services in Phnom Penh such as roads, ports, transport, urban development, sewerage and drainage, and other services, and is responsible for operation and maintenance of infrastructures. DPWT is one of the counterpart organizations for the Study. In addition, when a project is implemented through international cooperation such as this project, the deputy director responsible for International Relation Affairs and the Public Works Office are also involved.

Among those divisions/offices, the Drainage and Sewerage Division (DSD) is strongly related to the operation and maintenance of sewerage and drainage systems.

DSD consists of four sections and carries out tasks for operation and management of drainage systems in Phnom Penh. DSD has 30 regular employees, assigned to the management of drainage systems, and the management of cleaning equipment, etc. The Technical Section prepares the improvement plans (budgetary requests) for drainage and sewage treatment systems including such works as repairs of drainage pipes, channels and equipment, operation and management of pumping stations, and reports to DPWT. Field works are implemented by contracted employees in this system. Those contracted employees renew their contract annually. Any change in the quantity of works results in the fluctuation of number of contracted employees.

As shown in **Table 2.6.1**, the number of DPWT staff members is 826 as of end of February 2014, including the 193 staff members at DSD. **Fig. 2.6.4** shows the DPWT organizational structure and **Fig. 2.6.5** shows the DSD organizational structure, respectively.



Source: DPWT/PPCC

Fig. 2.6.4 Organizational Chart of DPWT

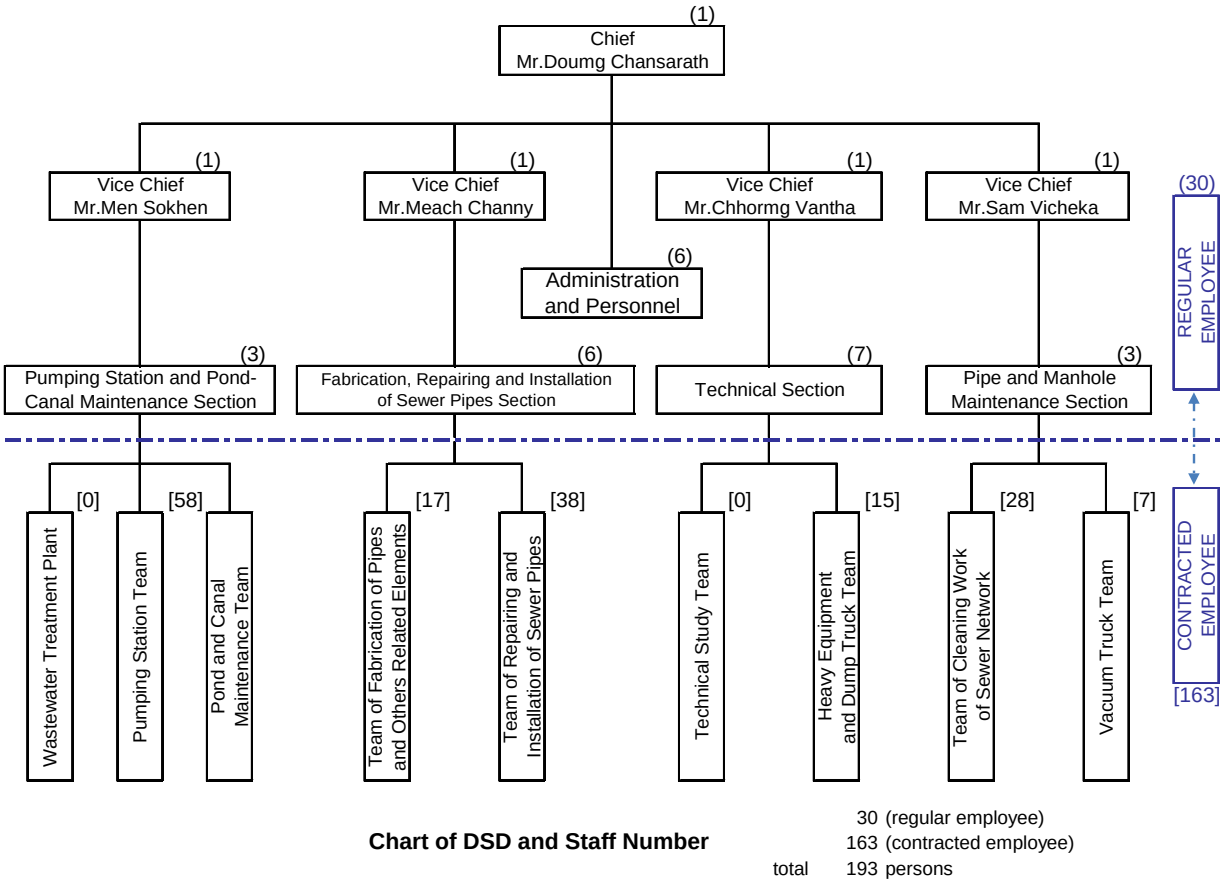


Chart of DSD and Staff Number

30 (regular employee)
163 (contracted employee)
total 193 persons

Source: DPWT/PPCC

Fig. 2.6.5 Organizational Chart of Drainage and Sewerage Division (DSD)

Table 2.6.1 Number of DPWT Staff Members

No.	Section	Regular Employees					Contracted Employees	Total
		Category 1 (Engineer/Other)		Category 2 (Male/Female)		Sub-Total		
		Engr.	Other	Male	Female			
1	Director Board	5	0	4	1	5	-	5
2	Administration and Personnel Office	-	7	5	2	7	2	9
3	Finance and Planning Office	1	11	9	3	12	1	13
4	Public Works Office	19	3	21	1	22	3	25
5	Transport Office	2	18	13	7	20	5	25
6	Road and Bridge Division	6	25	22	9	31	38	69
7	Drainage and Sewerage Division	6	24	19	11	30	163	193
8	Public Lighting Division	-	-	-	-	-	20	20
9	Public Garden Division	4	14	12	6	18	272	290
10	Pound Division	1	7	8	-	8	7	15
11	Flood Control Division	0	1	1	-	1	-	1
12	Solid Waste Management Division	-	-	-	-	-	-	-
13	District Public Works Offices	7	10	14	3	17	-	17
14	Motorbike Registration Division	3	26	23	6	29	14	43
15	Municipal Transport Authority	-	-	-	-	-	-	-
16	Vehicle Registration Division	3	43	25	21	46	12	58
17	Driving License and Traffic Safety Division	7	33	29	11	40	3	43
	Sub Total	64	222	205	81			
	Total		286		286	286	540	826

Note: No. 12 is not shown in the organizational chart. Based on the latest information, staff numbers were reduced to 821, but the section where staff was reduced is unclear.

Source: DPWT/PPCC

(b) Capacity to implement the Service

DPWT/PPCC employs 826 staff members, 64 of which are engineers in regular employment. Out of the 64, the number of engineers working for DSD, who operate and maintain drainage system, is six employees. Although there are drainage pumping stations for flood protection, the absence of sewerage treatment facilities means that they currently lack the capacity for operation and maintenance for sewerage treatment system. Their main works are to clean and to repair the drainage pipes and channels, without maintenance standards, operational manuals or any rules. In order to implement sewerage services including drainage systems, capacity development will be crucial.

(4) Identification of Issues

Issues concerning organizations are as described below.

(a) Improvement of Organizational Framework (departments and personnel) for operation

PPCC does not have any engineer for operation and maintenance of sewage treatment plant since there is no sewage treatment plant at present. Although it depends on how future sewage treatment plants are to be operated, for the time being, PPCC needs to organize departments in charge of sewerage planning, sewage connection and sewerage fee collection. Currently there are 193 staff members involved in drainage and sewerage services. Future staffing will need to be an appropriate number for the operation, taking into consideration the operation form (direct operation, contracted operation or another form of operation). Incidentally, PPWSA has 849 staff members for water supply operations.

(b) Clarification of Allocation of Roles between the Central and Local Organizations

This matter should be discussed with the related parties as the reference of Japanese organization system; MPWT formulates the legal framework and standards, while DPWT develops the technical and construction supervision guidelines, and operation and maintenance manual based on the legislation and standards. For such formulation, it is necessary to consider inviting experts from experienced countries. In addition, there is also an issue of role allocation and staff assignment between regular employees and contracted employees in DPWT.

(c) Necessity to ensure Technical Skill and Personnel for Sewerage Services

Establishing and improving sewerage services require administrative abilities and operation management abilities. Currently, DPWT has staff for maintenance of drainage pipe and channels, but lacks engineers to operate sewerage services. Therefore, it is necessary to have trainings for key-personnel utilizing the Capacity Development Program or overseas training in experienced countries that have good sewerage systems such as Japan. Thereby, technical skill and appropriate personnel are continuously ensured through on-the-job training.

2.6.3 Budget and Financial Situation

(1) State Budget Size

The budget of the Cambodian Government from the viewpoint of revenue is shown in **Table 2.6.2**. The revenues in 2012, 2013 and 2014 are 8,452.0 billion Riels, 8,769.5 billion Riels and 10,517.4 billion Riels, respectively, and increasing year by year. The revenue breakdown shows that tax revenues account for 84.2% in 2014. In the tax revenues, GDCE (General Department of Customs and Excise) revenues are more than half (51.2%). The GDT (General Department of Taxation) revenues follow at 38.7%. Domestic Capital is only 2.2% of the domestic revenue and much less than the Current Revenue accounting for 97.8%.

Table 2.6.2 Cambodia State Budget Revenue

(Unit: Million Riels)

Item	Actual 2012		Estimate 2013		BL 2014	
	Amount	%	Amount	%	Amount	%
Domestic Revenue	8,452,007	100.00%	8,769,480	100.00%	10,517,449	100.00%
Current	8,201,155	97.03%	8,690,464	99.10%	10,284,449	97.78%
-Tax	6,908,490	81.74%	7,487,915	85.39%	8,852,481	84.17%
GDCE	3,651,948	43.21%	3,566,079	40.66%	4,533,500	43.10%
GDT	2,558,859	30.28%	2,993,585	34.14%	3,429,800	32.61%
Other TR	212,440	2.51%	219,525	2.50%	245,321	2.33%
Province	455,243	5.39%	408,727	4.66%	543,860	5.17%
-Non Tax	1,292,665	15.29%	1,202,548	13.71%	1,431,968	13.62%
Domestic Capital	250,852	2.97%	79,015	0.90%	233,000	2.22%

Note: BL means Budget Law; TR means Taxable Resources.
Source: Ministry of Economy and Finance
(http://www.mef.gov.kh/documents/shares/budget/budget-in-brief-2014.pdf)

Next, the budget expenditures are shown in **Table 2.6.3** and those in 2012, 2013 and 2014 are 12,034.7 billion Riel, 12,056.2 billion Riels and 13,595.6 billion Riels, respectively, showing increase. The profit and loss balance is described soon later, but the breakdown of expenditures shows that current expenditure accounts for approximately 60% and capital expenditure accounts for the remaining 40% in 2014. 54.3% of the current expenditure is non-wage and non-salary, and remaining 45.7% is wage and salary.

Table 2.6.3 Cambodia State Budget Expenditure

(Unit: Million Riels)

	Actual 2012		Estimate 2013		BL 2014	
	Amount	%	Amount	%	Amount	%
Current Expenditure	6,677,327	55.48%	7,173,718	59.50%	8,268,703	60.82%
-Wage and Salary	2,598,189	38.91%	3,079,429	42.93%	3,782,870	45.75%
-Non-wage & Salary	4,079,138	61.09%	4,094,289	57.07%	4,485,833	54.25%
Capital Expenditure	5,357,396	44.52%	4,882,500	40.50%	5,326,924	39.18%
Total	12,034,723	100.00%	12,056,218	100.00%	13,595,627	100.00%

Source: Ministry of Economy and Finance (http://www.mef.gov.kh/documents/shares/budget/budget-in-brief-2014.pdf)

(2) Ministry of Public Works and Transport (MPWT)

Revenue in the budget of MPWT in 2014 is 32 billion Riels and, concerning the central administration and total provincial revenues, provincial total is a little more than the central administration, accounting for 56%. Among the total provinces, Phnom Penh revenue is the most. Although it is less than the 23 other provinces total, it accounts for 47.8%. The MPWT does not clarify the budget by each sub-sector (such as road). However, it shows expenditures of materials and external services for road and drainage so that operation and maintenance expenditures can be grasped to some extent. Total expenditure is 307 billion Riels and the ministry's budget is a big loss, which seems to be covered by the Ministry of Economy and Finance. In the expenditures, the central administration's expenditure is much more than those of provinces and accounts for 88.7%. Among the provinces, Phnom Penh's is not so much compared with the revenues and accounts for only 21.6%. In the expenditures, capital expenditures are more and account for 80%. However, this Ministry's budget is only the sum of the MPWTs and there are other capital expenditures in foreign currency such as soft loans, which are managed by the MEF. After the coordination with the MEF, the official budget is finalized.

Among the ordinary expenditures other than capital expenditures, staff expenses (salaries and bonuses, etc.) are the most accounting for 58.6%. Material purchase expenses (19.1%), external service expenses (13.6%) and other service expenses (8.4%) such as PR and social expenses follow. Staff expenses include allowances for family and mutual aid such as condolence, baby delivery and disease support. It is noteworthy that drainage expenditures are not allocated to Phnom Penh. Therefore, the fund for drainage expenses is not prepared by the MPWT, but by the

Phnom Penh Capital government. Staff expenses are allocated to Phnom Penh, that is, the fund goes to DPWT Phnom Penh.

(3) Phnom Penh Capital City Department of Public Works and Transport (DPWT)

The budget of DPWT in Phnom Penh Capital City is shown in **Table 2.6.4**. It is basically increasing although it fluctuates a little. Its breakdown shows that salaries and indemnities and capital expenditure are the most. In 2013, salaries and indemnities are more than capital expenditure, but from 2008 to 2012 and 2014, capital expenditure exceeded salaries and indemnities on the contrary. 100% of the salaries and indemnities come from the MPWT, but operational expenditure and small repairs are burdened by the PPCC's budget. However, the budget for operation and maintenance of the national and main roads come from the MPWT.

Table 2.6.4 DPWT's Budget

(Unit: Million Riels)

Items	2008	2009	2010	2011	2012	2013	2014
Salaries and Indemnities	3,581.80	4,053.35	2,393.47	2,442.53	2,658.43	6,082.53	7,524.95
Operational Expenditure & small repair	300.00	397.03	432.55	470.31	558.40	588.40	943.40
Social & cultural (ceremonies, etc.)	161.20	99.50	206.68	229.73	219.84	274.40	246.60
Capital expenditures	3.627.89	5,334.50	4,173.88	9,746.99	10,509.42	4,771.83	9,896.70
Total	7,670.89	9,884.38	7,206.58	12,889.56	13,946.09	11,717.16	18,611.65

Source: DPWT

Next, the expenditures of DSD (Drainage and Sewerage Division) under the DPWT are shown in **Table 2.6.5**. The total amount increased a lot in 2012, 2013 and 2014. The breakdown shows that drainpipe cleaning decreased, but new drainpipe construction increased recently accounting for 62.8% of the total in 2014.

Table 2.6.5 Expenditures of DSD

(Unit: Million Riels)

Item	2009	2010	2011	2012	2013	2014
Drainpipe cleaning	321.48	438.05	732.98	682.03	496.17	390.09
Drainpipe repair	265.91	297.73	162.02	179.02	248.10	222.50
Pumping station repair	253.67	-	-	171.00	262.00	255.95
Drainage ditch & balancing reservoir cleaning	672.17	-	-	265.74	170.00	882.00
Diesel oil for pumping out to the city (kl)	103.9kl	115.7kl	90.5kl	129.4kl	123.6kl	83.9kl
New construction of drainpipe	526.47	373.30	168.00	747.22	2,525.98	2,959.37
Total	2,039.70	1,109.08	1,063.00	2,045.01	3,702.25	4,709.91

Source: DSD

(4) Phnom Penh Capital City (PPCC)

PPCC's drainage related expenditures are shown in **Table 2.6.6**. The total expenditure decreased from 2009 to 2011, but it increased in 2012 and 2013 and decreased again in 2014. In 2014, the breakdown shows that pumping station electricity expenses, pipe & channel cleaning expenses, and pipe repair and new construction expenses are much (one digit) more than others in order. These expenditures include DSD's expenditures in **Table 2.6.5** above. Namely, it seems that pumping stations are managed by the DSD, but most of the expenditures excluding personnel expenditures are covered by the PPCC. Both PPCC and DSD seem to manage pipes and channels. **Table 2.6.7** shows drainage and sewerage cost transferred from PPWSA to PPCC, The overall sewerage and drainage expenditures burden from the organizational viewpoint is explained later.

Table 2.6.6 Drainage related Expenditures of PPCC

(Unit: Million Riels)

Item	2009	2010	2011	2012	2013	2014
Pumping station electricity expenses	3,610	3,690	3,730	3,868	5,264	4,447
Pumping station fuel expenses	585	690	785	647	619	419
Pipe & channel cleaning expenses	3,670	2,960	3,137	3,970	3,866	4,272
Pipe repair and new construction expenses	2,760	3,050	1,980	3,070	2,774	3,181
Pumping building maintenance expenses	560	470	769	975	362	256
Pumping facility maintenance t expenses	440	758	826	649	450	456
Total	11,625	11,618	11,227	13,260	13,335	13,031

Note: These expenses include DSD's expenditures in **Table 2.6.5**.
Source: PPCC

Table 2.6.7 Drainage and Sewerage Cost transferred from PPWSA to PPCC

(Unit: Million Riels)

Item	2009	2010	2011	2012	2013	2014
Transferred amount (shown by PPCC)	5,158	5,873	6,253	6,500	7,300	7,200
PPWSA's use charge revenues (sales)	85,869	96,024	102,041	114,157	127,446	137,018
Actual ration to sales	6.01%	6.12%	6.13%	5.69%	5.73%	5.25%

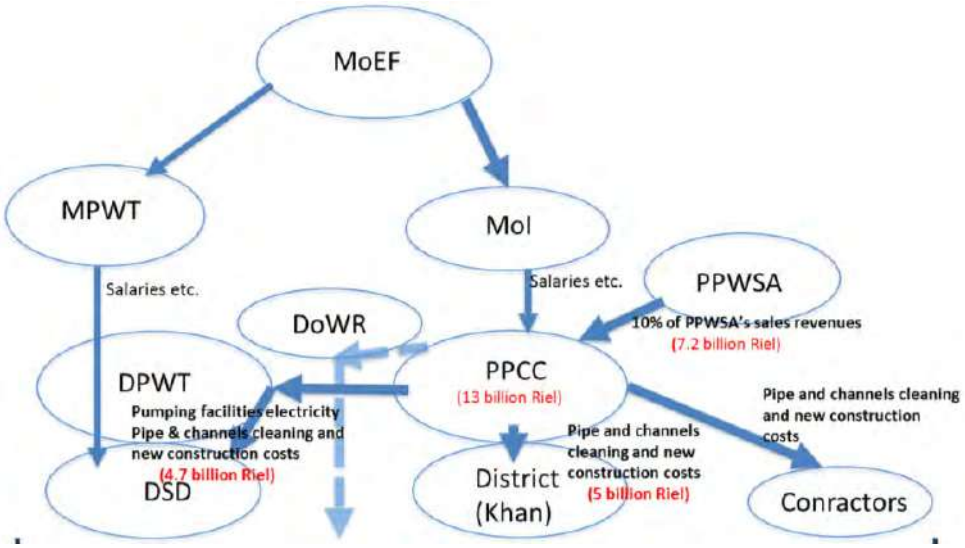
Source: PPWSA

(5) Organizational Burden of Drainage and Sewerage Facilities Cost in Phnom Penh

The budgets of drainage and sewerage related organizations in Phnom Penh were described for each entity above, but it does not show the overview of the whole. Therefore, it is organized here. At first, pumping facilities are managed by the DSD/DPWT and the budget is shown in the above **Table 2.6.5**, but it is included in PPCC's budget, that is, **Table 2.6.6**. The total amount of PPCC is much more than DSD's. Consequently, part of the budget came from DSD or DPWT.

On the other hand, DSD's personnel expenses are included in DPWT budget, **Table 2.6.4**. It means that these costs are burdened by the MPWT. In addition, PPCC's drainage and sewerage related expenses are covered by the 10% of PPWSA sales revenues other than PPCC's own budget resource. Amount from the PPWSA is 7,200 million Riels in 2014 and it accounts for approximately 55.3%, more than a half of PPCC total expenditures, 13,031 million Riels. However, if collection of more than 10% of PPWSA sales revenues is not easy based on the discussion above, it is easily imagined that 10% of water supply sales is very insufficient considering the investment and operation and maintenance costs of new sewage treatment facilities because 10% of sales is not enough for even the present drainage facilities maintenance.

The relationship of present drainage and sewerage related cost resource burdening organizations above can be shown in **Fig. 2.6.6**.



Source: JICA Study Team

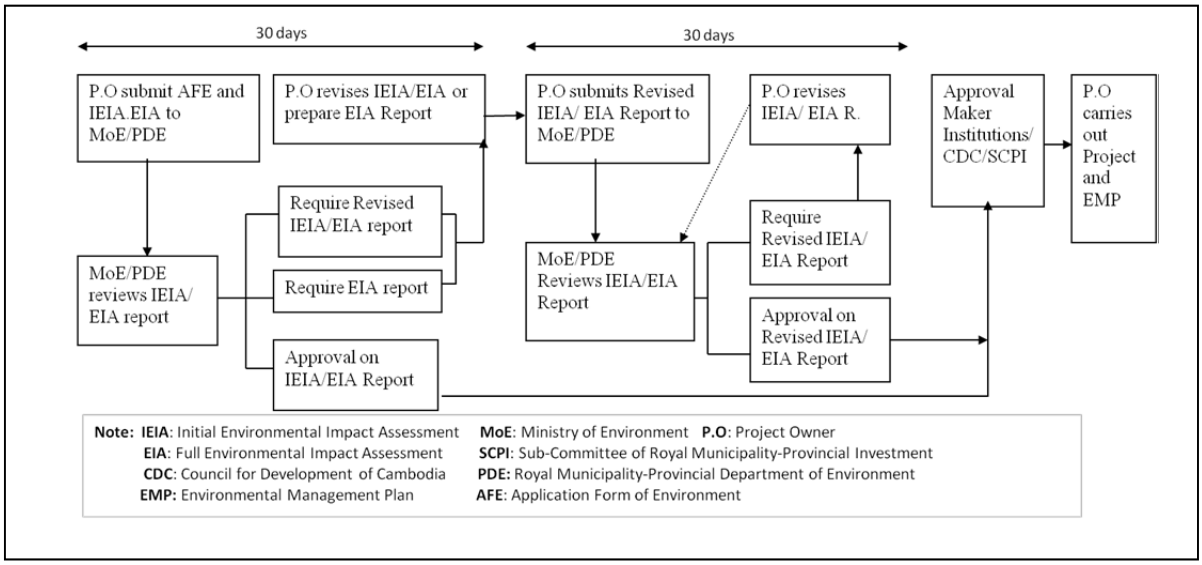
Fig. 2.6.6 Drainage and Sewerage Related Cost Resource Fund Flow in Phnom Penh

2.7 Environmental and Social Consideration

2.7.1 EIA Process in Cambodia

(1) EIA Process in the Country

As shown in the flowchart below (**Fig. 2.7.1**), the project owner firstly submits the Environment Application Form together with his report to the competent authority, which means, the Ministry of Environment (MOE) or the Provincial Department of Environment (DOE). After the authority has reviewed the report, it may require the project owner to revise the report or implement further study as the Environmental Impact Assessment (EIA). Should the environmental study fulfill the requirement of the authority, the report is approved and forwarded to the Council for Development/Sub-Committee of Royal Municipality, Provincial Department of Environment for the approval of project implementation.



Source: Declaration on General Guidelines for Conducting Initial and Full Environmental Impact Assessment Reports

Fig. 2.7.1 Flowchart of the IEIA/EIA Process for National Level Projects

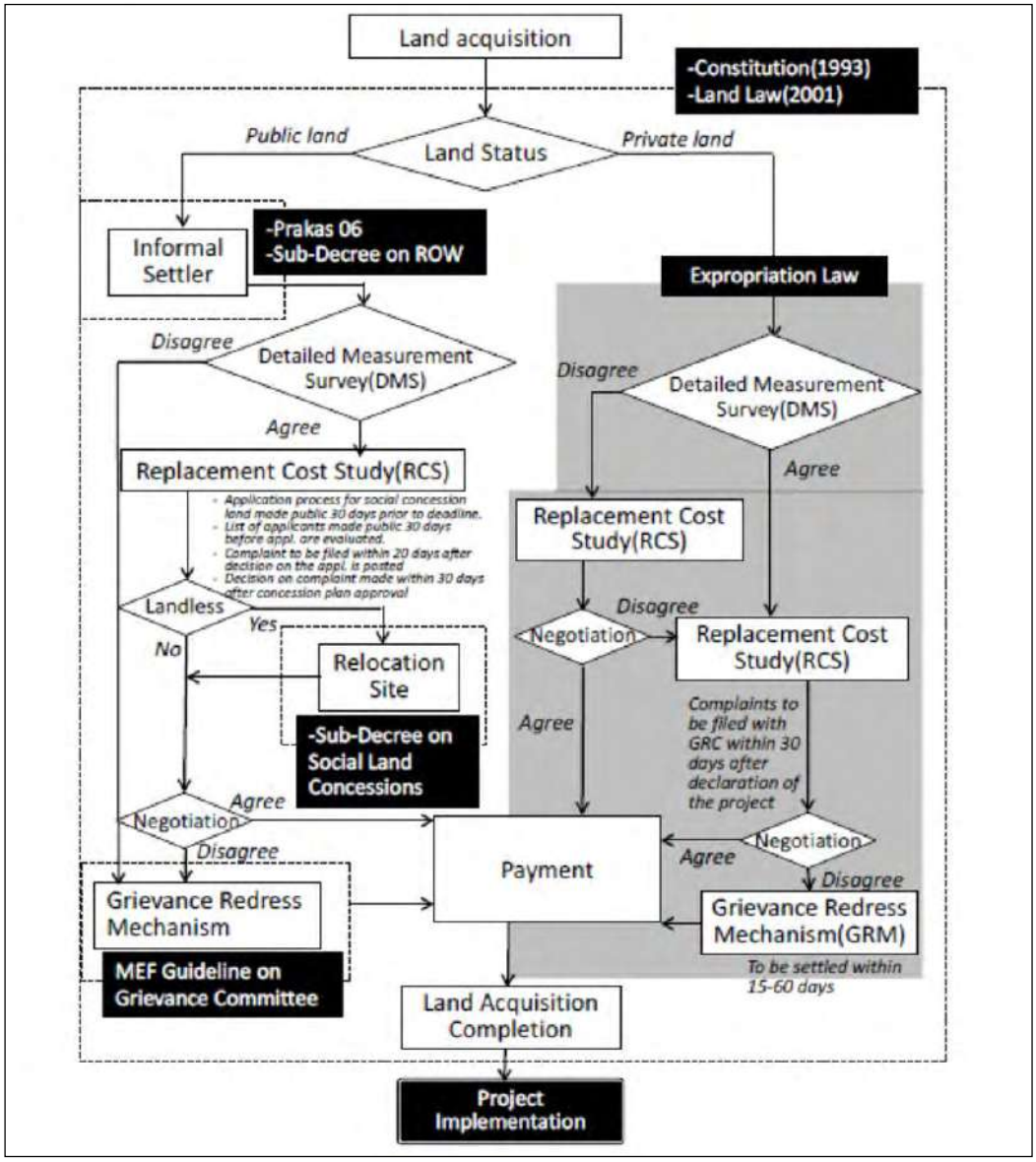
(2) Legislation and Procedures for Environmental Study on Sewerage and Drainage Project Development

Projects, which needs Environmental Assessment required are prescribed in the Annex in the sub-decree, No. 72 ANRK.BK, 1999. This study aims to develop physical countermeasure for the sewerage and drainage issues in PPCC. According to the Sub-decree, the expected activities within the current project may be related to (i) waste processing, burning activities, all sizes; (ii) wastewater treatment plants, all sizes; and (iii) drainage systems, ≧5,000 ha in the Annex.

2.7.2 Legislation and Legal Procedures for Resettlement and Land Acquisition for Development

(1) Procedure of Land Acquisition

Acquisition of private land for the public interest shall be in accordance with the Land Expropriation Law (2010). On the other hand, the acquisition of state land should be in accordance with the Sub-Decree on State Land Management and it may follow the Prakas (Declaration) No. 06, 1999, on measures to crack down on anarchic land grabbing and encroachment if the area is occupied illegally and also Circular No. 2, 2007, if "related to illegal occupation of state land" and Circular No. 3, 2010, if it involves the "settlement of illegal construction on a state land in cities and urban areas". In any case, a survey should be conducted to identify the situation (**Fig. 2.7.2**).

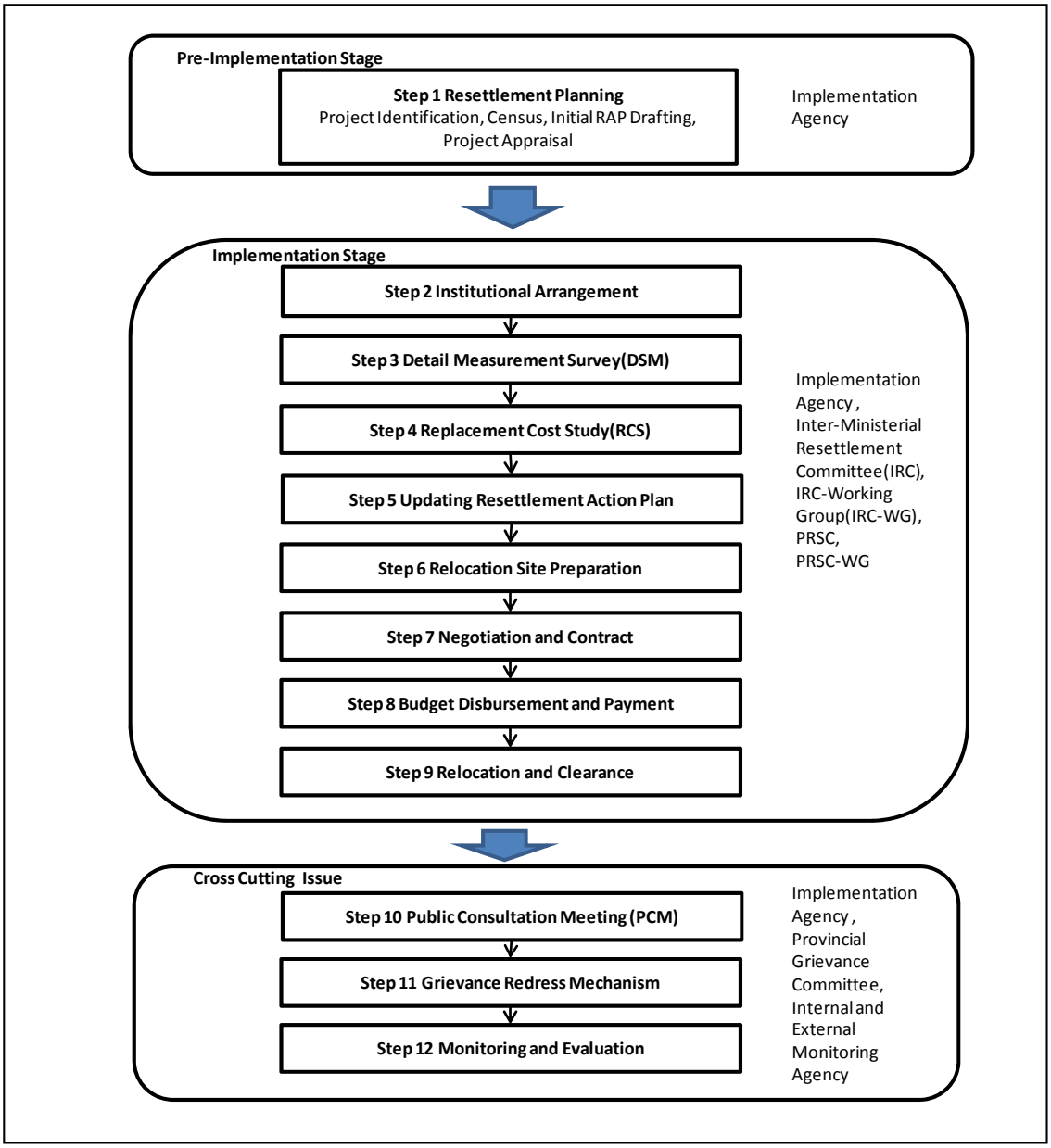


Source: Ministry of Economy and Finance (MEF), 2012, Basic Resettlement Procedure

Fig. 2.7.2 Flowchart of Land Acquisition

(2) Resettlement Framework in the Country

Resettlement framework is explained in the Standard Operating Procedures for All Externally Financed Projects/Programs in Cambodia (2012, Ministry of Economy and Finance), as shown in **Fig. 2.7.3**.



Source: JICA Study Team based on the MEF (2012), Basic Resettlement Procedure

Fig. 2.7.3 Workflow of Resettlement Process

CHAPTER 3 STRATEGY FOR FORMULATION OF SEWAGE MANAGEMENT MASTER PLAN

3.1 Summary of Issues

Current conditions and issues related to sewage management in PPCC, as well as countermeasures to solve the issues, are summarized in **Table 3.1.1** based on the study results discussed in **Chapter 2**.

Table 3.1.1 Current Conditions and Issues Related to Sewage Management in PPCC and Countermeasures (1/2)

Items/current conditions and issues	Countermeasures and roadmap to solve the issues
1. Technical Aspects	
1.1 Deterioration of water quality in Cheung Aek Lake basin	
Cheung Aek Lake basin, located in southern part of Phnom Penh, extremely suffers from water pollution. Results of water monitoring conducted in the Study, reveal the situation as follows: [Water quality of Cheung Aek Lake: • Influent BOD_5 Max. 200-300 mg/L • Effluent COD_{Mn} Max. 18 mg/L (Standard: COD_{Mn} 8 mg/L)	➢ Sewage from the area should be treated, introducing off-site treatment system, considering investible funds of Phnom Penh ［Reasons］ • Existing pipe network covers 100% of the basin and thus it is easy to collect sewage from the basin using the network. • Population density of more than half of the basin is over 300 persons/ha in the target year of 2035, as described later. • The area is located inside of inner dike and sewage generated from the area is not diluted, which is different from condition in Bangkok (In Bangkok, backwater from canal dilute sewage and the efficiency of treatment is affected).
1.2 Lack of Septage Management	
In Phnom Penh, most of people use septic tank as a sanitary facilities and Waste Management Office PPCC, is responsible for septage (sludge from septic tanks) management. PPCC has however no septage disposal site yet.	➢ To secure land in PPCC to dispose septage. ➢ To secure land in PPCC to dispose treated sludge, before sewage treatment plant is in operation. [Reasons] • At present, a lagoon for treating leaching effluent in Dangkor solid waste disposal site temporarily accept septage due to the lack of treatment facilities for septage, but there exists a concern that the lagoon would be overloaded and thus water quality would be deteriorated due to the septage. • Dangkor solid waste disposal site was constructed in 2009 with total area of 31.4 ha. At present, 11 ha of the area is in commission and their lifetime would end in 2018 based on the estimation. In addition, rapid population growth decreases the capacity of the site. Thus, the disposal site would have no room to accept septage and sewage sludge from STP in the future.
2. Organizational and Institutional Aspects	
2.1 Establishment of implementation body responsible for sewage management (department/staff)	
In PPCC, it is not clear if which department is responsible for formulating sewage management plan and implementation plan.	➢ To empower existing department or to establish new department responsible for formulating sewage management plan, implementation plan, establishing framework of sewerage connection and sewage charge collection.
2.2 Determination of scope of works for central and provincial government	
At present, scope of works and allocation for sewage management among central (MPWT) and provincial (DPWT) government are not clear.	➢ To determine scope of work of central (MPWT) and provincial (DPWT) government and then, (i) to provide them budget for and jurisdiction over sewage management, and (ii) to train engineers to implement them.
2.3 Securing technical level and human resources for sewage management	
Engineers for sewage management are insufficient especially in operation of sewage treatment plant.	➢ To cultivate key engineers in the field of sewage management and implementation by inviting experienced engineers from other countries or dispatching engineers to the countries. ➢ To continuously train engineers by the key engineers mentioned above, through On-the-Job Training (OJT)
2.4 Insufficient managing and monitoring of industrial wastewater	
It is not enough to manage installation of treatment plants and monitor whether industrial wastewater meets discharge	➢ To increase budget for monitoring and to centralize authorities over regulating factories. ➢ To share strategies for regulating and monitoring factories and to

Items/current conditions and issues	Countermeasures and roadmap to solve the issues
standard by MIH, which is responsible for managing industrial wastewater.	formulate activities plan with MOE.
2.5 Lack of guideline for sewage management in large-scale development area	
Large-scale development area has expanded in recent years. However, guideline for sewage management is not available in PPCC and thus developers install their treatment plant in accordance with their own strategy.	To establish guideline for sewage management in large-scale development area
3. Financial Aspects	
3.1 Insufficient fund	
DPWT, PPCC has insufficient budget for implementing sewage management projects. In addition, central government has insufficient budget allocation for sewage management.	➢ To secure funds by soft loan. ➢ To establish autonomous or semi-autonomous authority to implement projects and collect sewerage fee from users.
3.2 Establishment of autonomous sewerage authority	
To allocate burden for sewage and drainage management between the authorities concerned Ratio of allocated burden for sewage and drainage management will be a big issue for authorities concerned in particular in construction and O&M of combined sewer system.	➢ It is essential to allocate initial and running cost between PPCC and autonomous sewerage authority in order not to threaten operation of the autonomous sewerage authority.
Sewerage fee collection system Existing sewerage management bodies in Sihanoukville and Siem Reap have been collecting sewerage fee, targeting large commercial facilities such as hotels and restaurants but they face difficulties in collecting enough charges covering O&M cost of sewerage facilities.	➢ To study on set up of sewerage fee system, sewerage fee collection system to widely collect the charges, especially from wealthy and ordinary households, which dominate in number in PPCC. ➢ To study alternative to include sewerage fee in some tax charges.
3.3 Collaboration with PPWSA	
PPWSA distributes 10% of water charge to PPCC for sewage and drainage management. The amount of 10% accounts for about 7,300 million Riel annually but the amount would be insufficient to cover sewage treatment.	➢ In case of PPWSA is responsible for sewerage management together with water supply, elaborate coordination will be required between MIH and MPWT, which have jurisdiction over water supply and sewage management, respectively. ➢ A listed company, PPWSA might be reluctant to incorporate sewage management, which might be unprofitable. The following schemes should be considered: • To set up policy that the Government shoulder the soft loan covering construction cost; • To turn off water supply service to users who do not pay for sewerage fee; and • To establish cost-effective sewerage fee collection system in collaboration with sewerage management body.

Source: JICA Study Team

Further, the envisaged bodies to implement countermeasures, as well as needs of assistance from donors and priorities for the countermeasures listed in **Table 3.1.1**, are summarized in **Table 3.1.2**.

Table 3.1.2 Current Conditions and Issues related to Sewage Management in PPCC and Countermeasures (2/2)

Items/current conditions and issues	Implementing body	Requirements of assistance from the donors	Priority
1. Technical Aspects			
1.1 Deterioration of water quality in Cheung Aek Lake basin	DPWT	➢ Assistance from the donors is indispensable, because PPCC has limited experience of sewage management, especially in planning and construction of sewage	[1st Priority] Reason: it is urgent to improve the area generating most of the pollution load and deteriorating water environment in and around Phnom Penh.

Items/current conditions and issues	Implementing body	Requirements of assistance from the donors	Priority
		treatment plant.	
1.2 Lack of septage management	Waste Management Division /DPWT /DOE	➢ Procedure to secure and purchase disposal site is taken care of by the government with own fund. ➢ Fund from donors might be required to construct facilities in the disposal site.	[1st Priority] Reason: It is urgent to secure septage disposal site because most people in Phnom Penh currently use septic tank as major sanitary facility.
2. Organizational and Institutional Aspects			
2.1 Establishment of implementation body responsible for sewage management (department/staff)	DPWT	➢ Implemented with own fund	[1st Priority] Reason: It is essential to smoothly commence sewage treatment in PPCC.
2.2 Determination of scope of work for central and provincial government	MPWT/DPWT	➢ Ditto	[2nd Priority] Reason: Step-by-step implementation will be required with coordination among the agencies concerned.
2.3 Securing technical level and human resources for sewage management	MPWT/DPWT	➢ Implemented by combination of assistance from donors and own fund	[1st Priority] Reason: It is essential to smoothly commence sewage treatment in PPCC.
2.4 Insufficient management and monitoring of industrial wastewater	MIH/MOE/DOE	➢ Implemented with own fund	[2nd Priority] Reason: Step-by-step implementation will be required with coordination among the agencies concerned.
2.5 Lack of guideline for sewage management in large-scale development area	Urbanization Division/DPWT	➢ Ditto	[2nd Priority] Reason: Step-by-step implementation will be required with coordination among the agencies concerned in PPCC.
3. Financial Aspects			
3.1 Insufficient fund	MEF/MPWT/ PPCC	➢ Soft loan is to be secured from donors. ➢ It is desirable to establish sewerage management authority with own fund but it is acceptable to receive support from donors in terms of coordination and introduction of good approach.	[1st Priority] Reason: It is essential to smoothly commence sewage treatment in PPCC.
3.2 Establishment of autonomous sewerage authority	PPCC/MPWT/MIH /DPWT	➢ Ditto	[1st Priority] Reason: Ditto
3.3 Collaboration with PPWSA	PPCC/MPWT/MIH /DPWT /PPWSA	➢ Ditto	[1st Priority] Reason: Ditto

Source: JICA Study Team

3.2 Planning Frame

Facilities design, legal and institutional setup plan, as well as human resource development plan, are required for sewage management. For facilities design, the following planning frame is set up.

3.2.1 Target Year

Target year of the Study is the year 2035, as with the "Project for Comprehensive Urban Transport Planning in Phnom Penh Capital City" and "White Book on Development and Planning of Phnom Penh".

3.2.2 Planning Frame

(1) Setting-up of Off-site and On-site[8] Treatment Area

(a) Approach

The Sewage Management Plan is formulated as the combination of on- and off-site treatment, considering development status, topological feature and availability of existing drainage (combined sewer) network in the target area. Off-site treatment area is determined in consideration of analysis of relevant plans/projects, development status, population density and availability of existing combined sewer network, financial analysis, as well as acceptable financial burden to PPCC. As for on-site treatment area, installation of pit latrine is proposed for households without toilet and study on introduction of septic tank or decentralized treatment system are carried out for households in which pit latrine or septic tank is installed.

(b) Candidate Sites for Construction of Sewage Treatment Plant

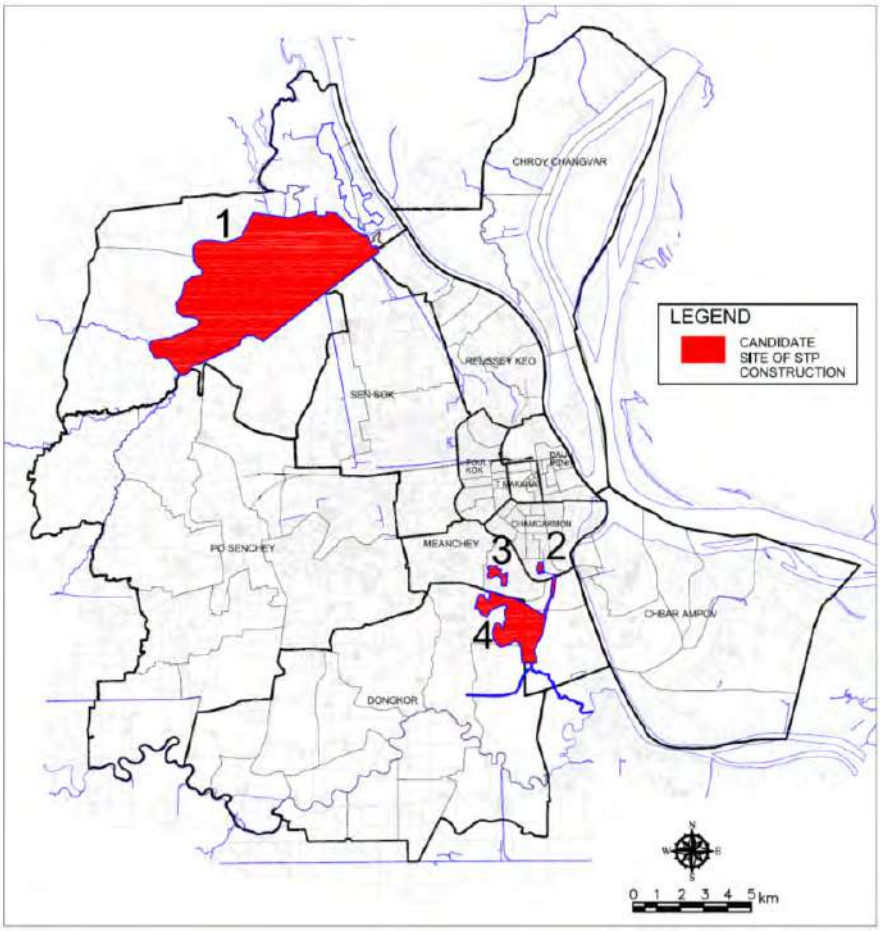
In the consultation with PPCC, four candidate sites for construction of sewage treatment plant in off-site area are proposed, as shown in **Table 3.2.1** and **Fig. 3.2.1**. Of the four sites, Tamok Lake and Cheung Aek Lake are studied because the two lakes have a defined line of control.

Table 3.2.1 Candidate Sites for Construction of Sewage Treatment Plant

No.	Name	Area (ha)	Depth (m)		Owner/Administrator	Remarks
			Dry Season	Rainy Season		
1	Tamok Lake	3,270	3.0-4.5	2-3 m plus that of dry season, at maximum	Owner: PPCC Administrator: PPCC/ MOWRAM	
2	Trabek Lake	Unknown	1.0-2.0	Same as that of dry season	Owner: PPCC Administrator: PPCC	Definite boundary is not defined in laws such as Sub-Decree
3	Tumpun Lake	Unknown	1.0-2.0	Ditto	Owner: PPCC Administrator: PPCC	Ditto
4	Cheung Aek Lake	520	2.0-3.0	2-3 m plus that of dry season, at maximum	Owner: PPCC Administrator: PPCC/ MOWRAM	

Source: JICA Study Team

[8] In the M/P, off-site treatment is defined as the sewage treatment system consisting of sewer network and sewage treatment plant. On the other hand, on-site treatment is defined as sewage treatment system consisting of individual facilities such as septic tank and Johkasou or decentralized system such as community plant.



Source: JICA Study Team

Fig. 3.2.1 Location of Candidate Sites for Construction of Sewage Treatment Plant

(2) Preliminary Study on Setting-up of Off-site Treatment Area

In Phnom Penh, Tamok Lake and Cheung Aek basins are fully urbanized and densely populated, considering planning population and population density for the target year 2035 in "Project for Comprehensive Urban Transport Planning in Phnom Penh Capital City", JICA.

Population density suitable for introducing off-site treatment in general ranges from more than 250 to 300 persons/ha[9]. In light of the population density, Cheung Aek basin can obviously be included in the area suitable for introducing off-site treatment. On the other hand, Tamok Lake basin would somewhat be premature to introduce off-site treatment. The following approach is therefore employed to evaluate the applicability of on- and off-site treatment.

(a) Catchment Area of Cheung Aek Lake

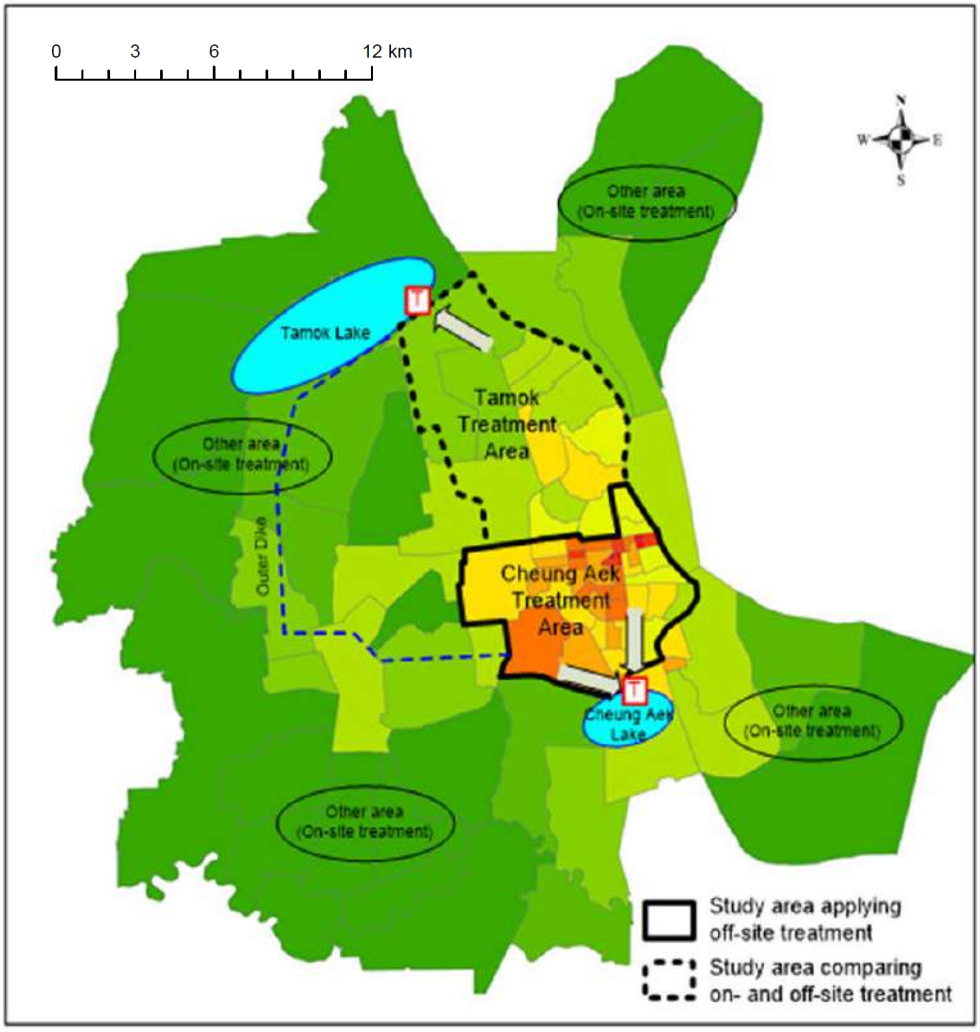
A study on application of off-site treatment is carried out for the catchment area of Cheung Aek Lake basin, targeting the area as shown in **Fig. 3.2.2**. Name of the off-site area is "Cheung Aek Treatment Area". Based on the preliminary study, the treatment area is estimated to be 41 km^2 and present (year 2014) and future population (year 2035) in the area is 720 and 1,070 thousand.

[9] Source: Guideline for Cost-Effective Sewerage System in Developing Countries (August 2004), Infrastructure Development Institute- Japan

(b) Catchment Area of Tamok Lake

Alternative study on selection of on- and off-site treatment is carried out. Boundary of off-site treatment area for the alternative study is as shown in **Fig. 3.2.2**.

Moreover, some studies are conducted on septage disposal site, which is not yet secured by Phnom Penh, how to collect and transport the septage to the site and division of roles of the departments concerned.



Source: JICA Study Team

Fig. 3.2.2 Target Area for Selection of Off-site Treatment Area

(3) Sewage Management in Large-scale Development Area

Present condition of sewage management in large-scale development area is summarized in the following table. In principle, the developer is responsible for establishing its sewage treatment system in the site, and operates and maintains them to treat sewage from the development area.

Table 3.2.2 Current Condition of Sewage Management in Large-Scale Development Area

No.	Name	Area (ha)	Type of Use(Note 1)	Combined /Separate	Sewage Treatment System
1	Boueng Kok	133	Commercial and Office, Residential (40,000)	Combined	Individual house: Septic tank Buildings: Any type of treatment plant)
2	Diamond City	80	Commercial and Office, Residential (5,000)	Combined	Lagoon
3	Camko City	119	Residential (10,000)	Separate	Activated Sludge Process
4	Grand Phnom Penh	233	Commercial and Office, Residential (12,000)	Combined	Bio-Filter (Septic tank, product of Thailand)
5	Chroy Changvar	13	Commercial	Combined	Unknown
6	Satellite City	380	Commercial and Office, Residential (40,000)	Combined	Unknown
7	Pratinum City	140	Residential (8,000)	Combined	Two-stage septic tank (individual and downstream end of the area)
8	ING City	2,572	Residential (300,000)	Separate	Activated Sludge Process
9	BTP	10	Residential (1,000)	Combined	Two-stage septic tank (individual and downstream end of the area)

Note 1: Values in parentheses show planning population
Source: JICA Study Team

(4) Management of Industrial Wastewater

Owners of factories are responsible for installing sewage treatment plant and discharge treated wastewater to sewer or directly to public water bodies to meet effluent standard.

(5) Sewage Generation per Capita

Sewage generation and pollution load per capita for the formulation of Master Plan are detailed in **Section 3.3**.

3.2.3 Strategy for Phased Schedule

Proposed components in the M/P are scheduled in three phases; namely, Short-Term (present to year 2020), Medium-Term (year 2021 to 2030) and Long-Term (after year 2031). The proposed component includes structural and non-structural measures.

3.3 Planning Conditions for Off-Site Treatment Area

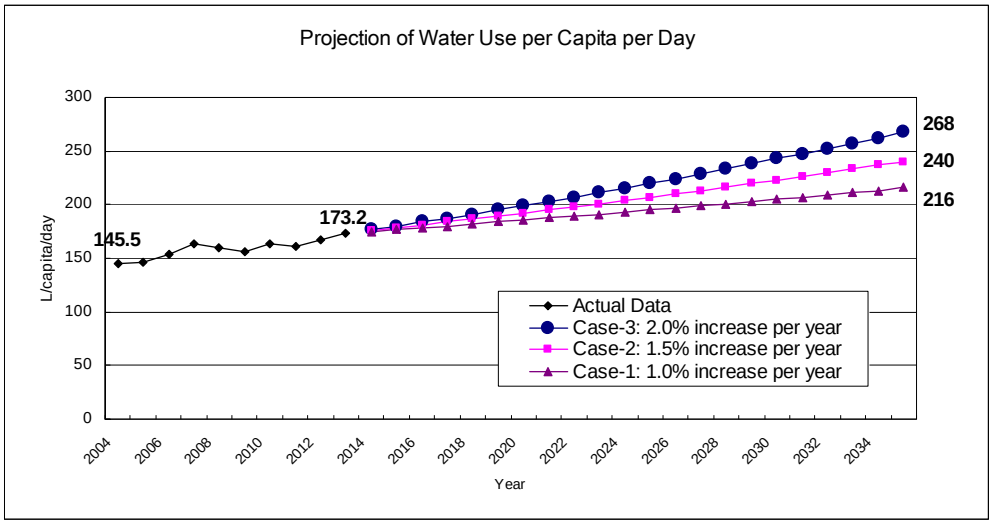
3.3.1 Projection of Water Use

(1) Projection of Water Use

As discussed in **Subsection 2.3.2**, water use per capita per day in Phnom Penh increases at the rate of about 2.0% each year. On the other hand, PPWSA predicts water use in Phnom Penh only up to 2020 with value of 145 L/capita/day, which is already lower than that of present. Water use for the target year is therefore projected in the Study, with the following cases; namely, increasing rate of 1.0%, 1.5% and 2.0%.

Case-1: Growth rate 1.0%:	Current growth rate (2.0%) cuts by half (1.0%) due to such reasons as enhancement of water-saving awareness.
Case-2: Growth rate 1.5%:	Medium growth rate of Case-1 and Case-3; namely, 1.5% is assumed.
Case-3: Growth rate 2.0% :	Current growth rate of 2.0 is maintained up to 2035.

As shown in **Fig. 3.3.1**, result of Case-3 shows about 270 L/capita/day water use in 2035, which is close to Japan's (289 L/capita/day, domestic and commercial water use in 2011) and thus deems to be slightly excessive. On the other hand, sharp drop of increase by applying 1.0% growth rate might be unreasonable. Thus 240 L/capita/day in 2035, applying medium growth rate of 1.5%, is employed in the M/P to project sewage generation.



Source: JICA Study Team

Fig. 3.3.1 Water Use Projection per Capita per Day for the Target Year 2035

(2) Ratio of Domestic and Other Usage

Ratio of domestic and other usage is set at 60 to 40, in consideration of actual data in **Table 2.3.1** and those of neighbouring countries in **Table 3.3.1**.

Table 3.3.1 Ratio of Domestic and Other Usage in Neighbouring Countries

	Ho Chi Minh	Jakarta	Kuala Lumpur	Manila	Osaka	Seoul	Shanghai	Bangkok
Year	2001	2001	2001	2001	2001	2001	2001	2009
Domestic water use	73	59	53	61	54	71	64	52
Non-domestic water use	27	41	47	39	46	29	36	48

Source: Preparatory Survey Report on the Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City in the Republic of the Union of Myanmar, 2014, JICA

(3) Ratio of Daily Average, Daily Maximum and Hourly Maximum

Ratio of daily average and daily maximum is set at 1.0:1.1 based on actual data of PPWSA. Ratio of daily maximum and hourly maximum is set at 1.0:1.5, also based on actual data provided by PPWSA. Daily maximum is employed to design sewage treatment plant and hourly maximum is employed to design pipe network and pumping stations.

(4) Sewage Generation Ratio

Sewage generation ratio of 85%, intermediate value of 80% and 90% is applied with reference to WHO's guideline, "A Guideline to the Development of On-site Sanitation" and typical values ranging from 80 to 90% employed in the neighbouring countries.

(5) Ratio of Commercial and Industrial Use

PPWSA has no data related to ratio of commercial and industrial use. However, about 90% of commercial and industrial users execute contracts with PPWSA to be supplied by water tap of 15 mm in diameter. According to PPWSA, a contractant supplied by 15 mm pipe uses not more

than 50 m^3/day. In general, amount of use not more than 50 m^3/day, can be regarded as commercial use. As a result, 90% of total commercial and industrial use is regarded as commercial, while the remaining 10% is regarded as industrial use.

(6) Ground Water Infiltration

Actual data of groundwater infiltration is not available in Phnom Penh. On the other hand, in the capital cities of neighbouring countries, unit groundwater infiltration of 10 m^3/ha/day is applied to Bangkok and Yangon, while 7.5 m^3/ha/day is applied to Manila. In the Study, 7.5 m^3/ha/day is applied to estimate groundwater infiltration considering that the 10 m^3/ha/day applied to Bangkok includes incremental water from canal. However, upper limits of 15% of dairy maximum is set up in the M/P, referring to intermediate value of groundwater infiltration, ranging from 10 to 20% of daily maximum of domestic and commercial use in accordance with the "Guideline for Sewerage Facilities Planning and Designing in Japan", Japan Sewage Works Association.

(7) Sewage Generation per Capita

Sewage generation per capita is computed based on the amount of water use, as summarised in **Table 3.3.2**.

Table 3.3.2 Sewage Generation per Capita (Off-Site Treatment Area)

	Amount of Water Use (L/capita/day)				Generation Ratio (%)	Generation per Capita (L/capita/day)
	Domestic	Commercial	Industrial	Total		
Daily average	150	80	10	240	85	**205**
Daily maximum	160	95	10	265	85	**225**
Hourly maximum	240	140	20	400	85	**340**

Source: JICA Study Team

3.3.2 Water Quality for Designing

(1) Target Parameters

Sewage treatment plant, which is a key component of the off-site treatment system, is designed targeting removal of BOD, TSS and total coliform, since the treatment plant will not discharge the treated water to closed water.

(2) Pollution Load per Capita

(a) BOD

Influent BOD concentration of sewage treatment plant is computed, employing 45 g/capita/day, which is maximum of typical BOD load per capita ranging from 40 to 45 g/capita/day applied in developing countries located in the tropical region, considering relatively high BOD in six times of water quality monitoring results in the Study, recorded at Trabek Pumping Station, which receives extensive amount of sewage in PPCC. The 45 g/capita/day includes domestic and commercial pollution load.

Industrial wastewater can be discharged to sewer under the condition that the owner of the industrial facilities installs pre-treatment plant to meet BOD effluent standard of 80 mg/l as indicated in **Table 2.5.2**.

(b) TSS

TSS load is set up considering average ratio of BOD to TSS (BOD:TSS=1.0:1.05), which is typical value of quality monitoring conducted in the Study at Trabek Pumping Station.

(3) Design Effluent Water Quality for STP

Upper limits of design effluent water quality for STP are summarized in **Table 3.3.3,** including those of Cambodia and the neighbouring countries of Thailand, Vietnam and Myanmar. Of the limits, neighbouring countries' are definitely typical for effluent standard of STP targeting removal of BOD and TSS. On the other hand, standard of "Public Water Area and Sewer", namely, BOD=80 mg/L and TSS=120 mg/L, are to be applied to Phnom Penh because Phnom Penh has no "Protected Public Water Area". However, those upper limits for Phnom Penh seem to be relatively lax and suitable only for primary treatment, compared to those of the neighbouring countries.

Treatment methods studied in the M/P will be able to treat water to BOD concentration of 30 to 40 mg/L as a whole. Therefore, same level of effluent water quality for "Protected Public Water Area", which exceeds standard of "Public Water Area and Sewer", is applied to design STP proposed in the M/P in consideration of: (i) to optimize facilities' performance, (ii) to be consistent to the trend of standard of secondary treatment in the neighbouring countries and (iii) to effectively reduce pollution load in order to preserve water quality of public water bodies.

Table 3.3.3 Upper Limits of Design Effluent Water Quality for STP

	Cambodia		Thailand		Vietnam	Myanmar
	Protected Public Water Area	Public Water Area and Sewer	National Level	Bangkok	National Level	Yangon City[3)]
BOD (mg/L)	< 30	< 80	< 20[1)]	< 20	10～30	< 20
TSS (mg/L)	< 60	< 120	< 30[2)]	< 30	10～30	< 30

Note 1) Filtered sample shall be monitored for Lagoon
Note 2) 50 mg/L shall be applied to Lagoon
Note 3) National Standard is not available in Myanmar
Source: Sub-Decree on Water Pollution Control, Annex 2, Effluent standard for pollution sources discharging wastewater to public water areas or sewer.
Vietnam: Discharge StandardTCVN7222:2002
Preparatory Survey for Bangkok Wastewater Treatment Project in Thailand, Final Report, 2011, JICA
Preparatory Survey Report on the Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City in the Republic of the Union of Myanmar, 2014, JICA

3.3.3 Structural Measures

(1) Collection System

Cheung Aek Treatment Area will adopt combined system, considering 100% of service ratio[10] of the existing drainage pipe network, in combination with the installation of interceptor in downstream of Trabek and Tumpun open channels. On the other hand, an alternative study of on- and off-site treatment is conducted for Tamok Treatment Area. As for off-site treatment in Tamok Treatment Area, separate system is studied, considering low installation rate of drainage piles in the area.

(2) Wastewater Treatment Method

The following wastewater treatment methods are to be studied and their applicability to Phnom Penh are evaluated. As discussed later, estimated sewage of Cheung Aek and Tamok in 2035 exceeds more than 100 thousand m^3/day, and thus aerated lagoon is not applicable to such amount of sewage. Therefore, aerated lagoon is not evaluated in the M/P.

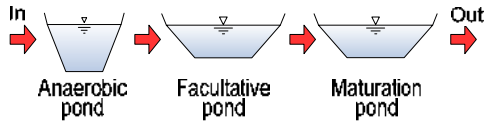
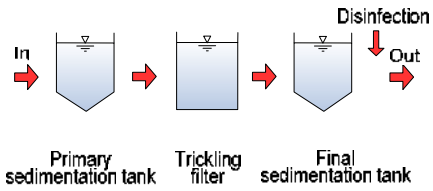
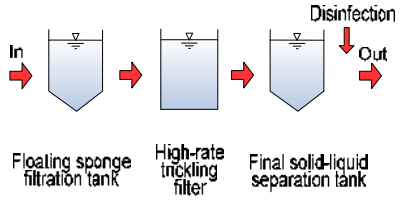
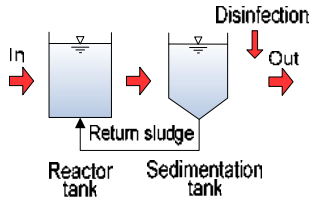
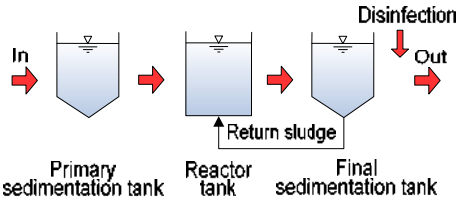
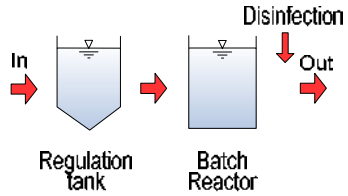
- Lagoon
- Aerated Lagoon
- Tricking Filter
- Oxidation Ditch (OD)

[10] Covering ratio of 100% was obtained by the site survey conducted in the Study.

- Conventional Activated Sludge Process (CASP)
- Sequential Batch Reactor (SBR)

On the other hand, Pre-treated Trickling Filtration (PTF), which has been recently developed in Japan as an upgraded technology of traditional Trickling Filter system, is included in the evaluation. As a result, six wastewater treatment methods are evaluated as summarized in **Table 3.3.4**.

Table 3.3.4 Off-site Treatment Methods Evaluated

Method	Typical Flow Sheet	Salient Features
Lagoon		• Wastewater is treated without machinery. Oxygen is introduced into the lagoon by photonic synthesis and thus wastewater is purified. • Among the four methods, O&M is the easiest and unit cost for treatment is the lowest. On the other hand, land requirement is the largest.
Trickling Filter (TF)		• Wastewater is treated by sprinkling them to filter bed in the trickling filter. • Energy consumption is much smaller than treatment methods using blower. • Land requirement is larger than that of CASP. • It is difficult to control offensive odor and generation of flies from filter bed.
Pre-treated Trickling Filtration (PTF)		• This is new Japanese technology upgrading trickling filter by introducing new media to save processing time and space. • Filter bed can be easily washable and thus prevent offensive odor and generation of flies from filter bed. • Land requirement is smaller than CASP.
Oxidation ditch (OD)		• Endless channel is employed for wastewater circulation. Equipment is simplified and easier O&M is achieved compared with activated sludge process. • Land requirement is smaller than that of aerated lagoon, while bigger than that of activated sludge process.
Conventional Activated sludge process (CASP)		• Among the four methods, the highest efficiency in pollution load reduction and the smallest land requirement is achieved. • On the other hand, machinery equipment is large in number and unit cost of treatment is the highest. Further sophisticated technique is required.
Sequential Batch Reactor (SBR)		• All the processes of (i) feeding/mixing, (ii) aeration, (iii) sedimentation and (iv) decant, are executed in batch reactor. • Land requirement is smaller than that of CASP since primary and final sedimentation tanks are not required. • Skilled techniques are required to control the batch reactor, in particular sludge sedimentation and withdrawal.

Source: JICA Study Team

(3) Sludge Treatment Method

Typical sludge treatment configuration, consisting of thickener, digester and dewatering equipment, is studied, considering effects of sufficient volume reduction and stabilization, as well

as cost performance and easiness of O&M. In addition, re-use of treated sludge is considered, if enough demands are expected around the STP.

3.4 Planning Conditions of On-site Treatment

3.4.1 Projection of Water Use

Amount of water use (175 L/capita/day), which is rounded up actual amount of 173.2 L/capita/day in PPWSA in 2014, is employed for amount of water use in target year 2035, under the assumption that urbanization in on-site treatment area delays compared to that in off-site treatment area. The 175 L/capita/day is equivalent to about 70% of 240 L/capita/day, the amount in off-site treatment area, and same amount in 2014 of Dangkor District, which is located in suburban area.

Sewage amount in on-site treatment is estimated, adopting generation ratio of 80%, which is lower limit of typical range (80 to 90%), under the assumption that the amount of water used in the garden increases and thus the water will not reach to sewer pipe, in comparison with that in off-site treatment area. Same ratio of daily average and maximum as well as hourly maximum in off-site area, is employed in estimating those in on-site area. Consequently, sewage generation is projected as summarized in **Table 3.4.1**.

Table 3.4.1 Sewage Generation per Capita (On-site Treatment Area)

	Amount of Water Use (L/capita/day)				Generation Ratio (%)	Generation per Capita (L/capita/day)
	Domestic	Commercial	Industrial	Total		
Daily average	105	65	5	175	80	**140**
Daily maximum	160	95	5	195	80	**160**
Hourly maximum	240	140	10	295	80	**240**

Source: JICA Study Team

3.4.2 Pollution Load per Capita

As with amount of water use, pollution load will be estimated at 70% of off-site's considering delay in urbanization and improvement of living standard, compared to those of off-site area.

3.4.3 Structural Measures

Alternative study will be conducted on (i) promotion of septic tanks or pit latrines which are commonly utilised as sanitary facilities and (ii) introduction of other on-site treatment facilities such as Johkasou and community plants.

3.5 Effects of Environmental Improvement by the Proposed Plan

(1) Effect on Pollution Load Reduction of Implementation of Proposed Sewage Management Plan

Effect on pollution reduction with and without projects proposed in the M/P implementation, will be quantitatively evaluated.

(2) Others

Other than the effects on pollution reduction, such side effects as elimination of waterborne disease will be evaluated.

3.6 Other Considerations

3.6.1 Non-Structural Measures

Implementation bodies and institutional set-up are proposed for smooth implementation of initial attempt of off-site treatment in PPCC. Also, measures to strengthen existing institutions, develop human resources, secure budget and set legal framework, are proposed for facilitating on-site treatment such as septic tank.

3.6.2 Land Expropriation

Sewerage facilities consist of pipe network, pumping station and sewage treatment plant. Of the facilities, pipes are in principle proposed to be laid under public roads. Pumping stations and sewage treatment plant are in principle proposed in the public land to avoid land expropriation of public land as much as possible. In public area, the facilities will not be proposed to occupy area in which illegal residents are living, unless absolutely necessary. Compensation will be proposed, if the occupation in the area is necessary.

3.6.3 Environmental and Social Considerations

Environmental and social impacts of all the proposed on- and off-site facilities are to be minimized in pre-construction, construction and operation stages. Resettlement is in particular to be avoided as much as possible in the site selection of facilities designing.

CHAPTER 4 SEWAGE MANAGEMENT MASTER PLAN

4.1 Sewage Management Master Plan

As discussed in the previous chapter, the applicability of on- and off-site treatment is evaluated by dividing PPCC into three areas, namely, (i) Cheung Aek Treatment Area, in which off-site treatment is applicable, (ii) Tamok Treatment Area, in which alternative study of on- and off-site treatment is conducted, and (iii) Other Area, in which on-site treatment is applicable.

4.1.1 Cheung Aek Treatment Area

As discussed in **Subsection 3.2.2**, Cheung Aek Treatment Area is evaluated applying off-site treatment, with the following assumptions.

- Sewage collection system: Combined system (including interceptor)
- Sewage treatment methods: 6 methods are evaluated

(1) Sewage Collection System

As shown in **Table 4.1.1**, evaluation result shows that treatment area amounts to 4,701.9 ha with population of 1,093 thousand. Total length of trunk sewer[11] is 34.1 km (diameter from φ250 mm to φ2,200 mm), with estimated construction cost of 130.7 million USD, as shown in **Table 4.1.4**. Branch sewer is not required because combined system, which utilizes existing pipe network, is adopted in this treatment area. On the other hand, no relay pumping station will be required.

Table 4.1.1 Outline of Cheung Aek Treatment Area

Item	Contents
Area (ha)	4,701.9
Population (year 2035)	1,093,155
Sewage collection system	Combined system
Trunk sewer (km)	34.1 (φ250 mm-φ2,200 mm)
Requirement of installing branch sewer	Not required
Pumping station	Not required
Construction cost of sewer network	See **Tables 4.1.4** and **4.1.5**

Source: JICA Study Team

(2) Sewage Treatment Plant

Based on the population in **Table 4.1.1** and sewage generation per capita discussed in **Chapter 3**, design inflow to STP and pollution load are projected as shown in **Tables 4.1.2** and **4.1.3.** Evaluation results of 6 treatment methods are summarized **in Tables 4.1.4 and 4.1.5**, with layout plan of STP in Cheung Aek Lake as illustrated in **Fig. 4.1.2**.

[11] Trunk sewer includes (i) Trunk Sewer: Sewer connected to STP, and (ii) Main Sewer: Sewer connected to the trunk sewer or covers whole area of its sewer district.

Table 4.1.2 Design Inflow to Cheung Aek STP

	Sewage (m^3/day)	Groundwater (m^3/day)	Total (m^3/day)	Design inflow (m^3/day)
Daily average	224,097	35,264	259,361	260,000
Daily maximum	245,960	35,264	281,224	282,000
Hourly maximum	371,673	35,264	406,937	407,000

Note) (Groundwater Estimate 1)= 4,701.9 ha×7.5 m^3/day/ha=35,264 m^3/day…..(1)
(Groundwater Estimate 2)=Population×(160+95)L/capita/day×0.85×15%=35,541 m^3/day.....(2)
The results shows that (1)<(2). Therefore, (Groundwater estimate 1) is adopted.
Source: JICA Study Team

Table 4.1.3 Design Water Quality of Cheung Aek STP

	Daily average inflow (m^3/day)	Concentration calculated (mg/L)	Design water quality (mg/L)	Remarks
BOD	260,000	192	195	Total BOD load: 49,935 kg/day Of which domestic and commercial: 49,192 kg/day Industrial: 743 kg/day
TSS	260,000	202	205	BOD×1.05

Note: (Domestic and commercial BOD load)=(Population)×45 g/capita/day×10^{-3}
(Industrial BOD load)=(Population)×8.5 L/capita/day (amount of water use)×80 mg/L×10^{-6}
Source: JICA Study Team

Study result on STP is enumerated below.

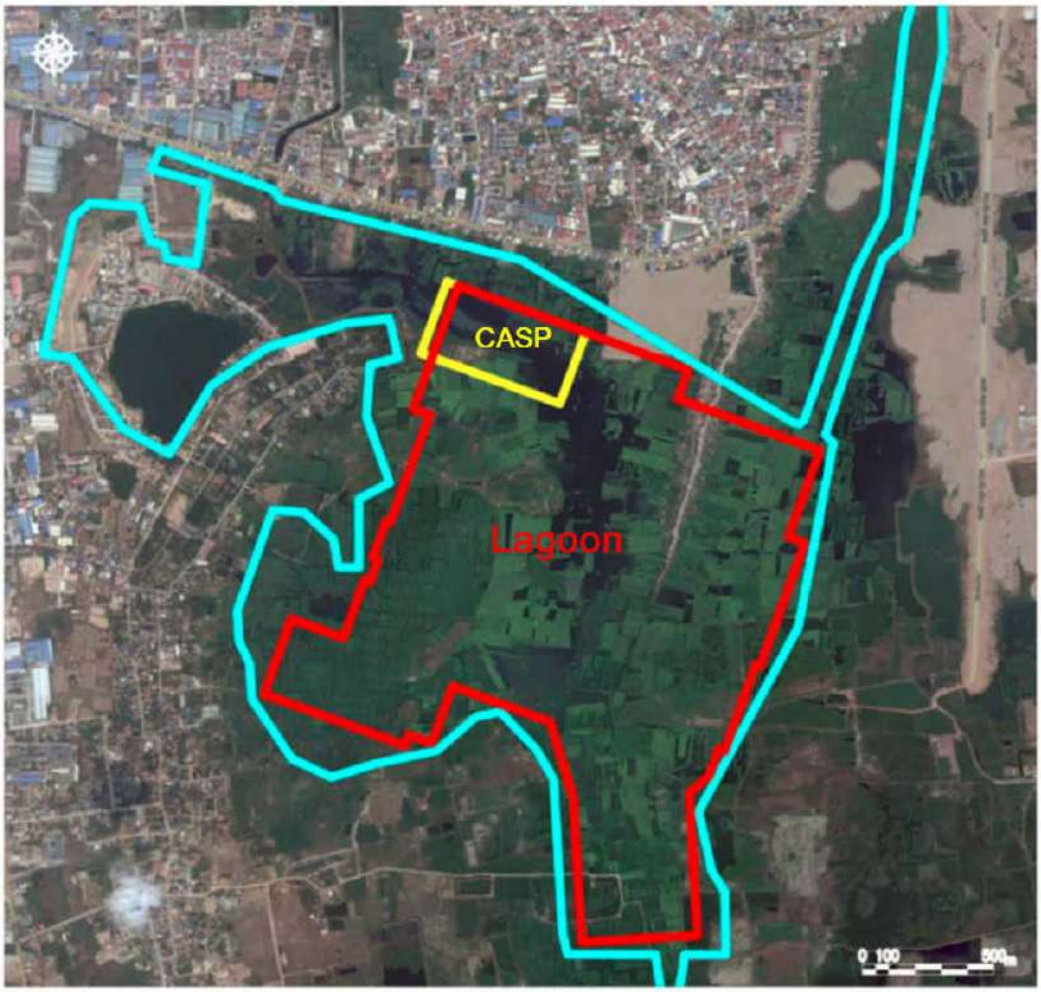
- Land Requirement: Land requirements of PTF and SBR are almost the same and smallest among six methods (PTF:13.0 ha, SBR:13.4 ha). Maximum is Lagoon with requirement of 262.4 ha. OD is second-ranked with area of 43.1 ha.

- Construction Cost: OD has the highest (397.9 million USD), followed by TF. Lowest one is 214.2 million USD of Lagoon.

- O&M Cost: Lagoon's cost is lowest (about 1.9 million USD/year) and OD's is highest (about 18.0 million USD/year).

- EIRR: EIRR in **Tables 4.1.4** and **4.1.5** are estimated as reference, in consideration of loss of social value with the reclamation of Cheung Aek Lake, which is surrounded by large development and housing area. The tables show that EIRR of Lagoon is smallest because its reclamation area amounts to more than 10 times of those of the other methods.

- Environmental and Social Aspects: If applying Lagoon, large-scale resettlement (about 100 households) will be required and almost all Cheung Aek Lake will be reclaimed, as shown in **Fig. 4.1.1**, in which land requirements of the lagoon and typical mechanical method of CASP are depicted for comparison. In addition, control of offensive odour is difficult. As a result, Lagoon will much affect the surrounding environment.



Source: JICA Study Team

Fig. 4.1.1 Comparison of Land Requirement of Lagoon and CASP

In addition to above discussion, result of quantitative evaluation, focusing on construction cost, O&M cost, easiness of O&M, number of application in large-scale STP and environmental and social aspects due to reclamation and offensive odour, are summarized in the tables. Based on the evaluation, Lagoon is the best option in terms of low construction and O&M cost, as well as easiness of O&M. On the other hand, Lagoon has such disadvantages as (i) social impact due to large-scale resettlement and reclamation is quite large, (ii) the reclaimed land will no longer be used for the protected area or cultivation area for aquatic plants, and (iii) it has a lot of negative environmental impacts such as uncontrolled offensive odour. In consideration of the disadvantages of Lagoon, application of CASP is recommendable and PTF is will also be a good option, although the method has so far not applied to large-scale STP.

Table 4.1.4 Comparison of Wastewater Treatment Method applied to Cheung Aek STP (1/2)

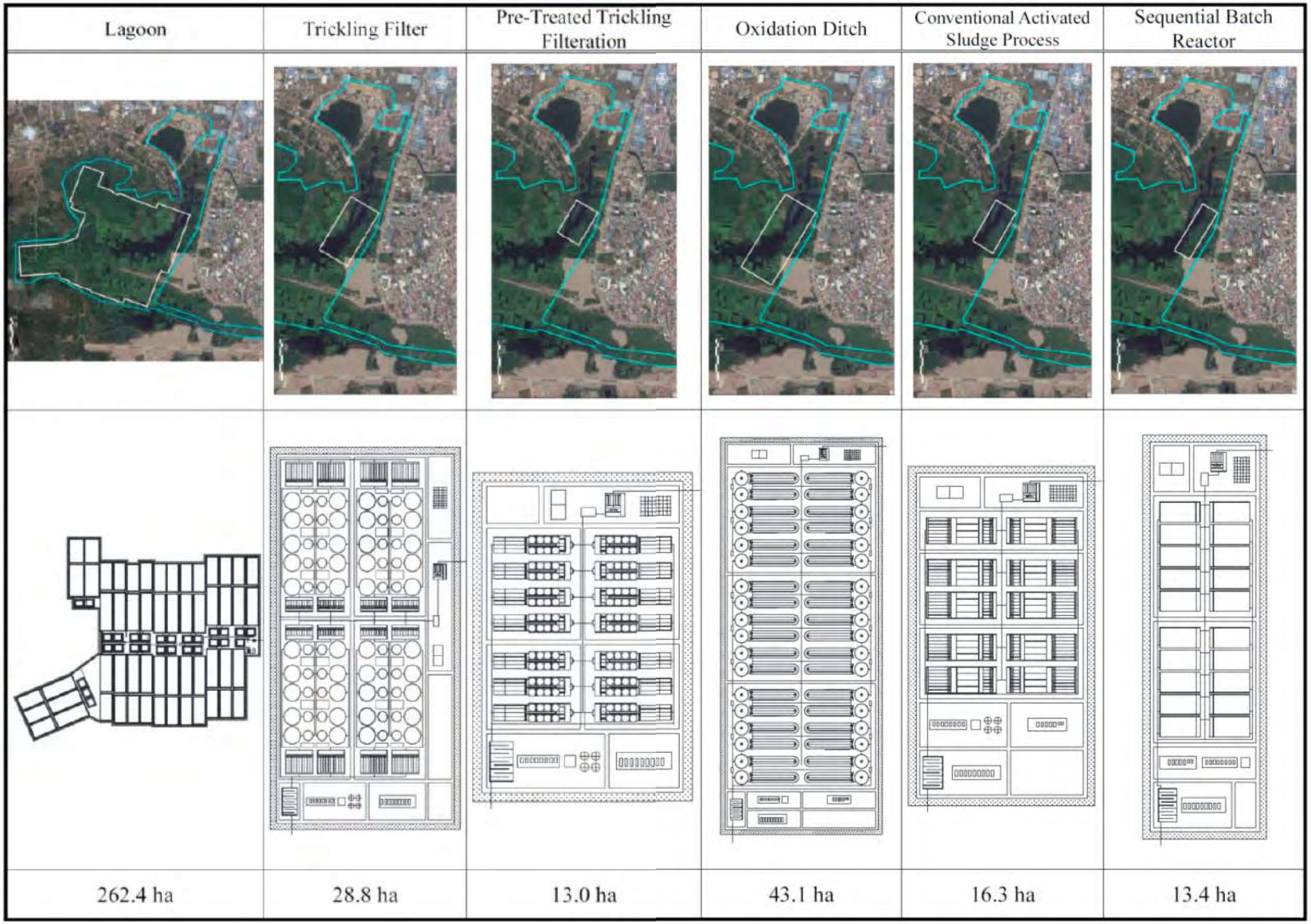
	Lagoon	Trickling Filter (TF)	Pre-treated Trickling Filtration (PTF)
Land requirement (ha)	262.4	28.8	13.0
Construction cost (million USD)			
STP	214.2	328.5	271.8
Sewer	130.7	130.7	130.7
Sludge dumping site	16.5	16.5	16.5
Total	361.4	475.7	419.0
O&M cost (million USD/year)			
STP	1.559	10.979	9.853
Sewer	0.157	0.157	0.157
Sludge dumping site	0.174	0.174	0.174
Total	1.890	11.310	10.184
EIRR	-0.4%	9.4%	12.1%
Number of resettlement anticipated	• About 100 households	• No resettlement	• No resettlement
Pros and cons	• Large-scale resettlement is required and adverse social impact due to large-scale reclamation is anticipated. • Construction and O&M costs are lowest. • O&M is easy but control of offensive odour by covering is difficult due to the reason that the system has to introduce sunshine into the lagoons for provision of oxidization and disinfection. • This method has strength in coping with fluctuation of water quality but periodical removal of sludge is required so as not to reduce capacity.	• Land requirement is 2nd largest, which is twice as large as that of PTF. • 3rd lowest of O&M cost due to low energy consumption. • Control of offensive odour and outbreak of filter bed flies are difficult. • Application to large-scale STP is small in number.	• Land requirement is the minimum among 6 treatment method. • 2nd lowest of O&M cost due to low energy consumption. • Periodical mixing of media keeps filter bed clean and thus prevented from out-break of filter flies. • This method has strength in coping with first flush and hence this method is applicable to combined system. • At present, there is no application to large-scale STP. Only in operation in: 1. Demo plant in Da Nang, 300 m^3/day 2. Under construction plant in Hoi An, 2,000 m^3/day 3. Demo plant in Japan, 6,750 m^3/day
Evaluation[1)]			
Construction cost	+++++	+++	++++
O&M cost	+++++	+++	++++
Easiness of O&M	+++++	++++	++++
Number of application in large-scale STP[2)]	++	++	+
Number of resettlements	+	+++++	+++++
Environmental and social aspects	+	+++	+++++
Total	+19	+20	+23

Note1: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+".
Note2: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team

Table 4.1.5 Comparison of Wastewater Treatment Method applied to Cheung Aek STP (2/2)

	Oxidation Ditch (OD)	Conventional Activated Sludge Process (CASP)	Sequential Batch Reactor (SBR)
Land requirement (ha)	43.1	16.3	13.4
Construction cost (million USD)			
STP	397.9	302.9	260.9
Sewer	130.7	130.7	130.7
Sludge dumping site	16.5	16.5	16.5
Total	545.1	450.1	408.1
O&M cost (million USD/year)			
STP	17.711	14.564	16.433
Sewer	0.157	0.157	0.157
Sludge dumping site	0.174	0.174	0.174
Total	18.042	14.895	16.764
EIRR	7.1%	10.5%	11.7%
Number of resettlement anticipated	• No resettlement	• No resettlement	• No resettlement
Pros and cons	• O&M is easy because of its simplified structure. On the other hand, land requirement of OD reaches 2.5 times of CASP's. • In general, this method is applicable to STP with capacity of less than 10 thousand m^3/day. • Application of this method to large-scale plant tends to be relatively high in cost.	• Construction cost is higher but O&M is lower than those of SBR. In addition, O&M is easier compared to SBR. • Large in number of application to large-scale plants and operation methods are well-established.	• Construction cost is lower than that of CASP. O&M cost is higher than that of CASP. • Skilled techniques including formulation of appropriate sequence are required, because this method treat wastewater in one reactor. This method is as a whole applicable to a site in which available land is limited.
Evaluation[1)]			
Construction cost	+++	+++	++++
O&M cost	+	++	+
Easiness of O&M	++++	+++	+++
Number of application in large-scale STP[2)]	++	+++++	+++
Number of resettlements	+++++	+++++	+++++
Environmental and social aspects	+++	+++++	+++++
Total	+18	+23	+21

Note1: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+".
Note2: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team



Source: JICA Study Team

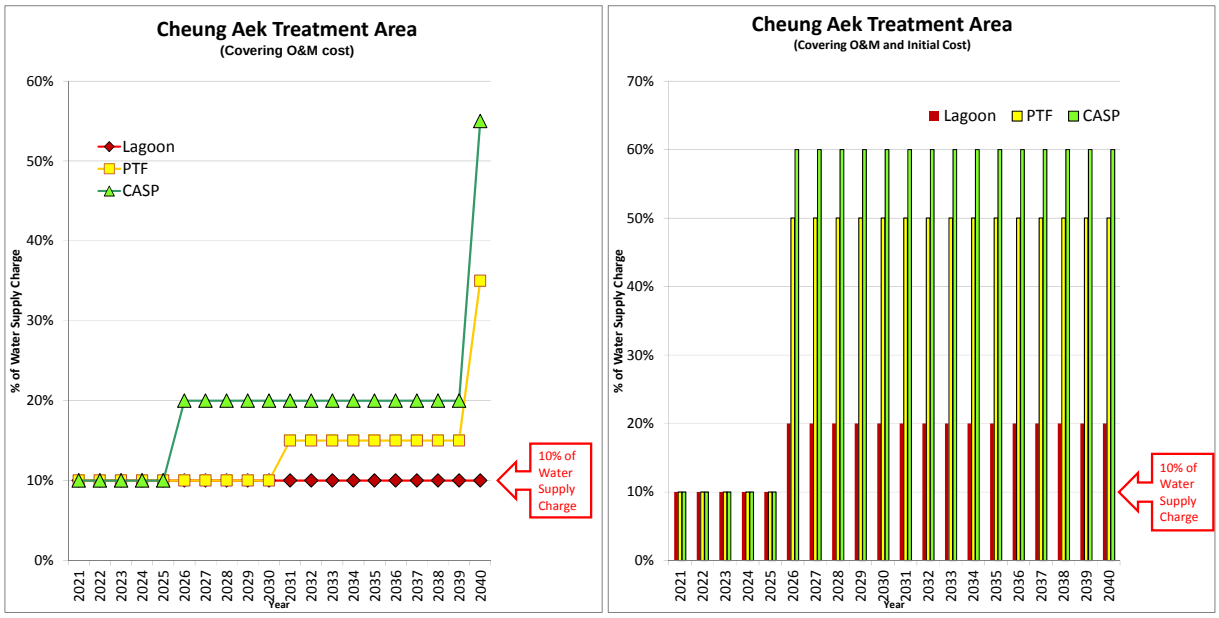
Fig. 4.1.2 Layout Plan of Cheung Aek STP

(3) Financial Analysis

Financial analysis is performed based on the result described above, targeting CASP and PTF, which are 1st ranked in the quantitative evaluation, as well as Lagoon which has strength in terms of low-cost.

The financial analysis figures out: (i) sewerage fee, and (ii) charge on vacuum truck dumping on-site facilities' sludge/septage to the proposed sludge dumping site**,** in order to cover O&M cost only or to cover both O&M and construction cost. The analysis result is summarized in transition of estimated total charge (expressed in percent) as presented in **Fig. 4.1.3**.

As shown in **Fig. 4.1.3**, for example, sewerage fee of 10% to water tariff can cover O&M cost of Lagoon system. In contrast, sewerage fee of 10%, up to year 2025, will be required to cover O&M cost of CASP system, and then the fee amounts to 20% up to year 2039 and 55% in and after year 2040.



Source: JICA Study Team

Fig. 4.1.3 Transition of Sewerage Fee to cover Cost of Cheung Aek Treatment Area

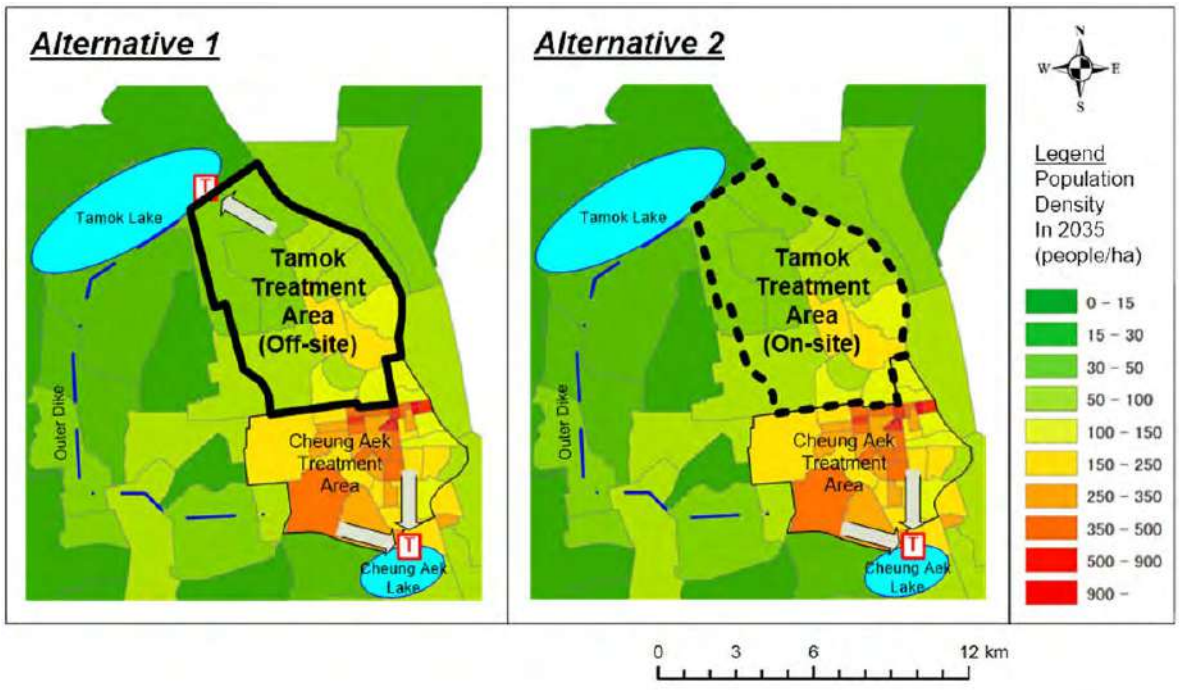
(4) Conclusion

Based on the above discussion, Lagoon system is not preferable in consideration of social and environmental negative impacts due to extensive land reclamation. Rather, a typical mechanical treatment system of CASP or PTF, which is new Japanese treatment system being advantageous to O&M cost reduction and minimization of land acquisition, are recommendable. However, in applying the PTF, careful attention should be paid on the risks because the method is not yet applied to large-scale STP. Additionally, more attention should be paid to PPCC's strategies and priorities for sustainable sewage management when selecting and finalizing wastewater treatment method. Therefore, the selection of wastewater treatment method was discussed in the T/C and S/C meeting.

In response, CASP was selected for M/P and Pre-F/S for Cheung Aek STP in the discussions of S/C with PPCC, held in September 2016, because it is too early to apply PTF due to the fact that the method is not yet applied to large-scale STPs.

4.1.2 Tamok Treatment Area

Alternative study of (i) Alternative 1, off-site and (ii) Alternative 2, on-site, have been carried out, targeting an area in Tamok basin having a population density of more than 50 persons/ha in the year 2035, as schematically illustrated in **Fig. 4.1.4**[12].



Source: JICA Study Team

Fig. 4.1.4 Alternative Study on Tamok Treatment Area

(1) Study Result of Off-site Treatment (Alternative 1)

As discussed in **Subsection 3.2.2**, the study on off-site treatment application has been conducted on the following assumptions.

- Sewage collection system: Separate system
- Sewage treatment methods: 6 methods are evaluated

(a) Sewage Collection System

As shown in **Table 4.1.6**, evaluation results show that treatment area amounts to 6,019.2 ha with population of 481 thousand. Total length of trunk sewer is 66.1 km (diameter from φ200 mm to φ1,650 mm). Pumping station should be installed at nine locations, of which seven pumping stations are manhole type. Construction cost of sewer system is estimated at 397.7 million USD, higher than that of Cheung Aek area, as shown in **Tables 4.1.9** and **4.1.10**, because branch sewers are required for the entire Tamok Treatment Area, unlike the Cheung Aek Treatment Area.

[12] Thus, area in Tamok basin with population density of less than 50 persons/ha is integrated into "Other Area"

Table 4.1.6 Outline of Tamok Treatment Area

Item	Contents
Area (ha)	6,019.2
Population (year 2035)	481,423
Sewage collection system	Separate system
Trunk sewer (km)	66.1 (φ200 mm-φ1,650 mm)
Requirement of installing branch sewer	Required
Pumping station	Large-scale 2 locations Manhole type 7 locations
Construction cost of sewer network	See **Tables 4.1.10** and **4.1.11**

Source: JICA Study Team

(b) Sewage Treatment Plant

Based on the population in **Tables 4.1.6** and sewage generation per capita discussed in **Chapter 3**, design inflow to STP and pollution load are projected as shown in **Tables 4.1.7** and **4.1.8**. In addition, evaluation results of 6 treatment methods are summarized in **Tables 4.1.9** and **4.1.10**, as well as layout plan of STP in Tamok Lake as illustrated in **Fig. 4.1.5.**

Table 4.1.7 Design Inflow to Tamok STP

	Sewage (m^3/day)	Groundwater (m^3/day)	Total (m^3/day)	Design inflow (m^3/day)
Daily average	98,692	15,652	114,344	115,000
Daily maximum	108,320	15,652	123,972	124,000
Hourly maximum	163,684	15,652	179,336	180,000

Note: (Groundwater estimate 1)= 6,019.2 ha×7.5 m^3/day/ha=45,144 m^3/day…..(1)
(Groundwater estimate 2)=Population×(160+95)L/capita/day×0.85×15%=15,562 m^3/day.....(2
The results shows that (2)<(1). Therefore, (Groundwater estimate 2) is adopted.
Source: JICA Study Team

Table 4.1.8 Design Water Quality of Cheung Aek STP

	Daily average inflow (m^3/day)	Concentration calculated (mg/L)	Design water quality (mg/L)	Remarks
BOD	115,000	191	195	Total BOD load: 21,991 kg/day Of which domestic and commercial: 21,664 kg/day Industrial: 327 kg/day
TSS	115,000	201	205	BOD×1.05

Note: (Domestic and commercial BOD load)=(Population)×45 g/capita/day×10^{-3}
(Industrial BOD load)=(Population)×8.5 L/capita/day (amount of water use)×80 mg/L×10^{-6}
Source: JICA Study Team

Evaluation results show that Lagoon is the best option in terms of lowest construction and O&M cost. Unlike Cheung Aek Lake, Lagoon requires largest land requirement but negative environmental impact to Tamok Lake is limited because the lake has a considerably large surface area. In addition, resettlement will not be required.

Based on the quantitative evaluation in terms of construction cost, O&M cost, easiness of O&M, number of application in large-scale STP and environmental and social aspects, Lagoon, PTF and CASP are given the highest scores in the evaluation.

Table 4.1.9 Comparison of Wastewater Treatment Method applied to Tamok STP (1/2)

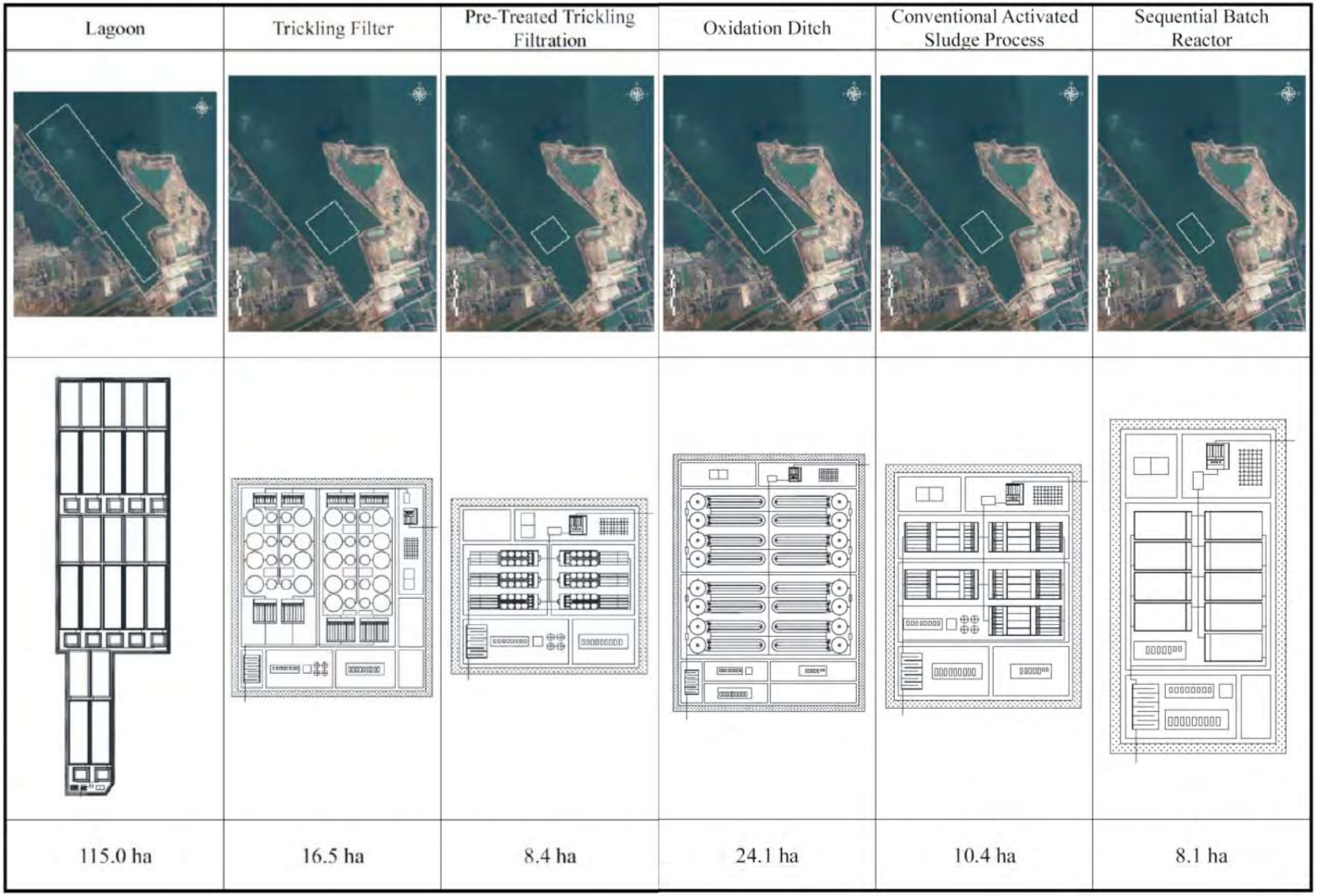
	Lagoon	Trickling Filter (TF)	Pre-treated Trickling Filtration (PTF)
Land requirement (ha)	115.0	16.5	8.4
Construction cost (million USD)			
STP	109.7	201.3	176.7
Sewer[1)]	397.7	397.7	397.7
Pumping station	1.7	1.7	1.7
Sludge disposal site[2)]	-	-	-
Total	509.1	600.7	576.1
O&M cost (million USD/year)			
STP	0.752	5.056	4.549
Sewer	1.492	1.492	1.492
Pumping station	0.075	0.075	0.075
Sludge disposal site[1)]	-	-	-
Total	2.319	6.623	6.116
EIRR	4.3%	3.2%	3.5%
Number of resettlements anticipated	• No resettlement	• No resettlement	• No resettlement
Pros and cons	• Large-scale resettlement is not required and social impact due to large-scale reclamation is limited, compared to Cheung Aek Lake. • Construction and O&M costs are lowest. • O&M is easy but control of offensive odour by covering is difficult due to the reason that the system has to introduce sunshine into the lagoons for provision of oxidization and disinfection. • This method has strength in coping with fluctuation of water quality but periodical removal of sludge is required so as not to reduce capacity.	• Land requirement is 2nd largest, which is twice as large as that of PTF. • 3rd lowest of O&M cost due to low energy consumption. • Control of offensive odor and outbreak of filter bed flies is difficult. • Adoption to large-scale STP is small in number.	• Land requirement is less than half of TF's. • 2nd lowest of O&M cost due to low energy consumption. • Periodical mixing of media keeps filter bed clean and thus prevent from outbreak of filter flies. • This method has strength in coping with first flush and hence applicable to combined system. • At present, there is no application to large-scale STP. Only in operation in 1. Demo plant in Da Nang, 300 m^3/day 2. Under construction plant in Hoi An, 2,000 m^3/day 3. Demo plant in Japan, 6,750 m^3/day
Evaluation[3)]			
Construction cost	++++	+++	++++
O&M cost	+++++	+++	++++
Easiness of O&M	+++++	++++	++++
Number of applications in large-scale STP[4)]	++	++	+
Number of resettlements	+++++	+++++	+++++
Environmental and social aspects	++	+++	+++++
Total	+23	+20	+23

Note 1: Construction cost includes cost of branch sewer installation.
Note 2: Construction and O&M costs of sludge dumping site are included in **Table 4.1.4** and **Table 4.1.5**.
Note 3: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+".
Note 4: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team

Table 4.1.10 Comparison of Wastewater Treatment Method applied to Tamok STP (2/2)

	Oxidation Ditch (OD)	Conventional Activated Sludge Process (CASP)	Sequential Batch Reactor (SBR)
Land requirement (ha)	24.1	10.4	8.1
Construction cost (million USD)			
STP	235.3	198.8	168.3
Sewer[1)]	397.7	397.7	397.7
Pumping station	1.7	1.7	1.7
Sludge disposal site[2)]	-	-	-
Total	634.7	598.2	567.7
O&M cost (million USD/year)			
STP	8.039	6.681	7.463
Sewer	1.492	1.492	1.492
Pumping station	0.075	0.075	0.075
Sludge disposal site[1)]	-	-	-
Total	9.606	8.248	9.030
EIRR	2.8%	3.1%	3.4%
Number of resettlements anticipated	• No resettlement	• No resettlement	• No resettlement
Pros and cons	• O&M is easy because of its simplified structure. On the other hand, land requirement of OD reaches 2.5 times of CASP's. • In general, this method is applicable to STP with capacity of less than 10 thousand m^3/day. • Application of this method to large-scale plant tends to be relatively high in cost.	• Construction cost is higher but O&M is lower than that of SBR. In addition, O&M is easier compared to SBR • Large in number of application to large-scale plant and operation methods are well-established.	• Construction cost is lower than that of CASP. • O&M cost is higher than that of CASP. • Skilled techniques including formulation of appropriate sequence are required because this method treat wastewater in one reactor. This method is as whole applicable to the site in which available land is limited.
Evaluation[3)]			
Construction cost	+++	+++	++++
O&M cost	+	++	+
Easiness of O&M	++++	+++	+++
Number of applications in large-scale STP[4)]	++	+++++	+++
Number of resettlements	+++++	+++++	+++++
Environmental and social aspects	+++	+++++	+++++
Total	+18	+23	+21

Note 1: Construction cost includes cost of branch sewer installation.
Note 2: Construction and O&M costs of sludge dumping site are included in **Table 4.1.4** and **Table 4.1.5**.
Note 3: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+".
Note 4: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team



Source: JICA Study Team

Fig. 4.1.5 Layout Plan of Tamok STP

(2) Study Result of On-site Treatment (Alternative 2)

More than 90% of households in Phnom Penh have pit latrine or septic tank. Therefore, most probably, roughly 90% of households in Tamok treatment area have pit latrine or septic tank. In order to select the appropriate on-site treatment method for the Tamok treatment area, on-site treatment methods of pit latrine, septic tank, Johkasou and community plant have been evaluated. As a result, Johkasou has been selected as the appropriate on-site treatment method in Tamok treatment area for the following reasons.

- On-site treatment facilities, which exceed the capacity of septic tank, is appropriate in consideration of the present deterioration of water environment in Tamok basin under the condition that most of the households install septic tank or pit latrine, and the estimated increase in population as well as pollution load generated

- Johkasou and community plant are candidates for the facilities exceeding septic tank, but in particular Johkasou has advantages over community plant since (i) it can be fabricated in factory and be easily installed on the site, (ii) it has in principle functionality equivalent to community plant, and (iii) it has wide range of line-up covering community-based size.

Evaluation results applying Johkasou are summarized in **Table 4.1.11,** as described below.

- Construction and O&M Costs: Construction and O&M costs are estimated at 396 million USD and 15.8 million USD/year. This construction cost is more than 100 million USD lower than that of Lagoon, which is lowest in construction cost (509 million USD) of off-site treatment system. This result arises from the reason that Tamok basin needs branch sewer installation, unlike Cheung Aek treatment area. On the other hand, O&M cost (15.8 million USD/year) is 1.90 times of CASP's (8.3 million USD/year). However, total cost including construction cost and O&M is lower than that of CASP.

- Others: Johkasou have advantages that phased construction and commission is easy because it is generally installed individually. Moreover, unlike off-site treatment system, reclamation of Tamok Lake is not required and EIRR is higher than those of the other 6 off-site treatment methods.

Table 4.1.11 Outline of On-site Treatment System applied to Tamok Treatment Area

Item	Contents
Title of facilities	On-site treatment (Johkasou)
Target population	481,423
Quantities of facilities[1)]	Small scale (for 5 persons) : 48,085 units Community-based scale (for 300 person) : 805 units
Construction cost (million USD)	396.2
O&M cost (million USD/year)	15.797
EIRR	6.5%
Pros and cons	• Construction cost is lower than any other off-site treatment methods (6 methods). • O&M cost is higher than that of typical off-site treatment method of CASP. • Phased construction is easy because Johkasou can be in commissioned individually. • Reclamation of Tamok Lake is not required.
Evaluation[2)]	
Construction cost	+++++
O&M cost	+
Easiness of O&M	++++
Number of application	+++

Item		Contents
	Number of resettlement	+++++
	Environmental and social aspect	+++++
	Total	+23

Note 1: Number of Johkasou is computed under assumption that 50% of population uses small-scale Johkasou, while others use community-based Johkasou.
Note 2: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+", as with in **Tables 4.1.9 and 4.1.10.**
Source: JICA Study Team

Based on the discussion in **Tables 4.1.9** and **4.1.10**, which summarise quantitative evaluation of six off-site treatment methods, as well as **Table 4.1.11**, which outlines quantitative evaluation of on-site treatment, off-site treatment applying Lagoon, CASP and PTF or on-site treatment applying Johkasou are preferable as a whole.

(3) Financial Analysis

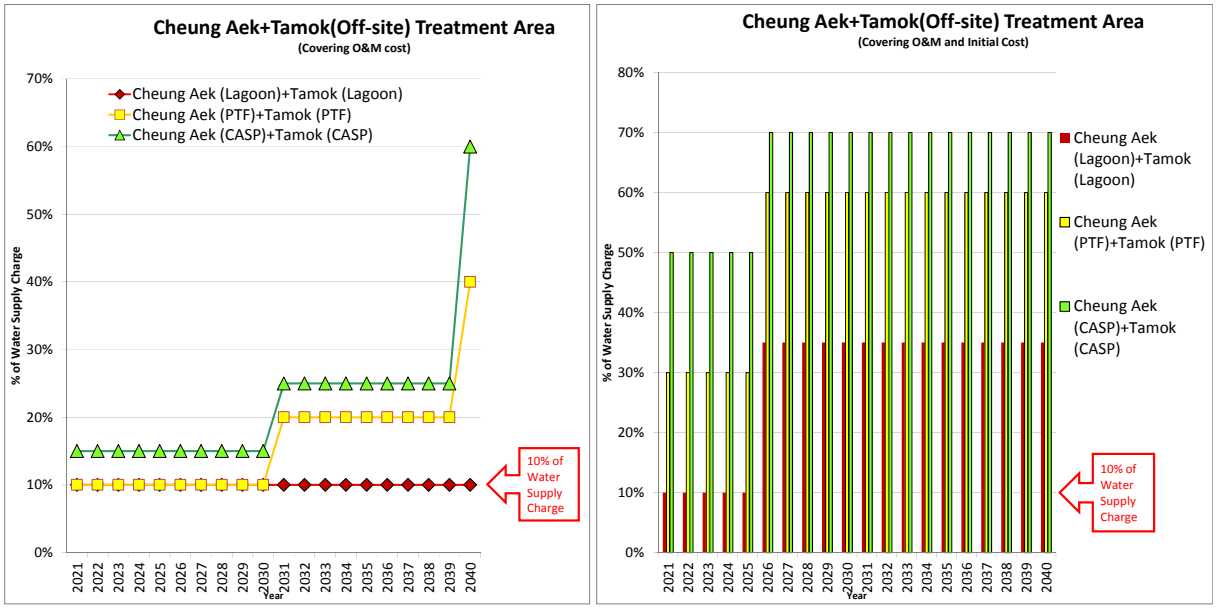
Based on the discussion above, financial evaluation is performed focusing on off-site treatment of Lagoon, CASP and PTF, as well as on-site treatment of Johkasou, because the four methods obtain the same score. It is noted that the financial analysis is performed to compute sewerage fee and sludge dumping fee posed to vacuum truck, in order to cover cost of Tamok as well as Cheung Aek Treatment areas, since Cheung Aek Treatment Area is covered by sewerage fee, regardless of selection of treatment methods for Tamok Treatment Area.

Tables 4.1.12 and **4.1.13** illustrates application of treatment in Cheung Aek and Tamok treatment areas, and **Figs. 4.1.6** and **4.1.7** respectively present transitions of sewerage fee covering O&M cost only or covering both O&M and construction cost, depending on the cases of : (i) Tamok Treatment Area is serviced applying off-site treatment of Lagoon, PTF and CASP and (ii) Tamok Treatment Area is serviced applying on-site treatment of Johkasou, in cases of application of Lagoon, PTF and CASP in Cheung Aek Treatment Area.

Table 4.1.12 Image of Application of Treatment (Tamok: Off-site)

Case	**Tamok Treatment Area is serviced applying off-site treatment of Lagoon (including cost of Cheung Aek Treatment Area is serviced applying Lagoon)**	**Tamok Treatment Area is serviced applying off-site treatment of PTF (including cost of Cheung Aek Treatment Area is serviced applying PTF)**	**Tamok Treatment Area is serviced applying off-site treatment of CASP (including cost of Cheung Aek Treatment Area is serviced applying CASP)**
Image of application of on- and off-site	Tamok (off-site) Lagoon Cheung Aek (off-site) Lagoon	Tamok (off-site) PTF Cheung Aek (off-site) PTF	Tamok (off-site) CASP Cheung Aek (off-site) CASP

Source: JICA Study Team



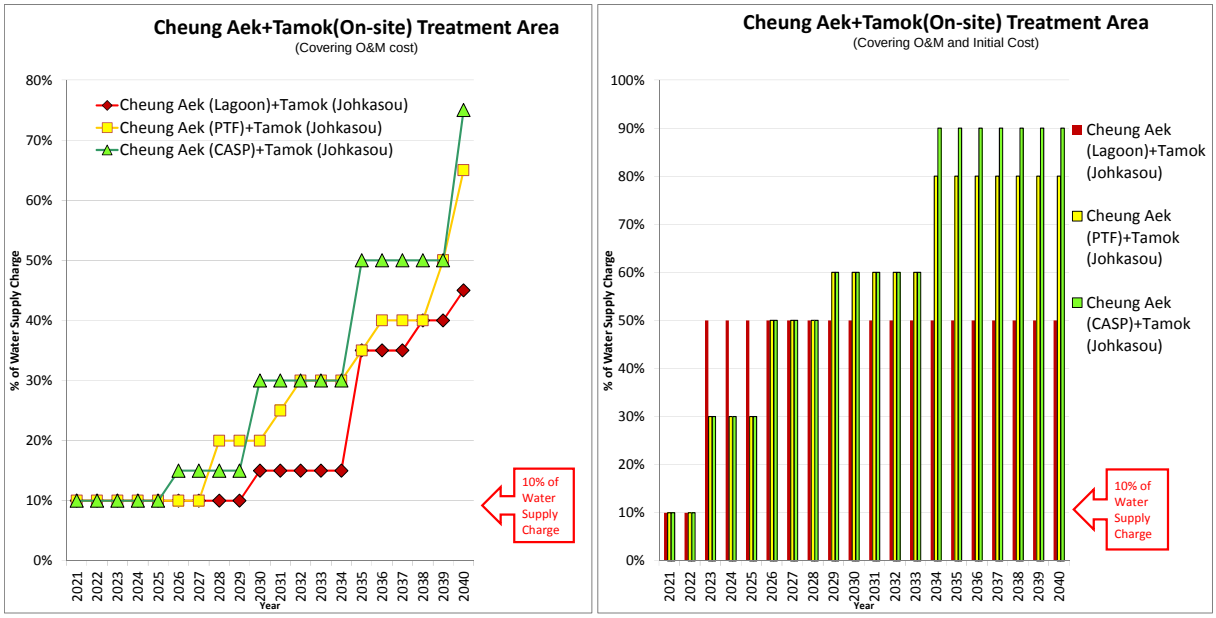
Source: JICA Study Team

Fig. 4.1.6 Transition of Sewerage Fee to cover Costs for Cheung Aek and Tamok Treatment Area (Tamok Treatment Area: Off-site)

Table 4.1.13 Image of Application of Treatment (Tamok: On-site)

Case	**Tamok Treatment Area is serviced applying on-site treatment of Johkasou (including service cost of Cheung Aek Treatment Area applying Lagoon)**	**Tamok Treatment Area is serviced applying on-site treatment of Johkasou (including service cost of Cheung Aek Treatment Area applying PTF)**	**Tamok Treatment Area is serviced applying on-site treatment of Johkasou (including service cost of Cheung Aek Treatment Area applying CASP)**
Image of application of on- and off-site	Tamok (on-site) Johkasou / Cheung Aek (off-site) Lagoon	Tamok (on-site) Johkasou / Cheung Aek (off-site) PTF	Tamok (on-site) Johkasou / Cheung Aek (off-site) CASP

Source: JICA Study Team



Source: JICA Study Team

Fig. 4.1.7 Transition of Sewerage Fee to cover Cost of Cheung Aek and Tamok Treatment Area (Tamok Treatment Area: On-site)

Results in **Figs 4.1.6** and **4.1.7** suggest that it is not realistic to cover construction cost by sewerage fee. It is recommendable for sewerage to cover only O&M cost while construction cost is borne by subsidy from the government.

To clarify sewerage fee per capita, sewerage fee presented by percentage in **Figs 4.1.6** and **4.1.7,** are converted to O&M cost per capita per month, as shown in **Table 4.1.14**, depending on the case analysis.

As in **Table 4.1.14**, O&M cost per capita per month ranges from 0.23 USD/month to 1.63 USD/month, by which Cheung Aek and Tamok treatment areas are serviced applying lagoon in both areas, as well as CASP in Cheung Aek and Johkasou in Tamok, respectively. However, total cost including construction cost and O&M of Johkasou is lower than that of CASP[13].

Table 4.1.14 O&M Cost per Capita per Month

	Treatment area	Contents					
Population	Cheung Aek	1,093,155					
	Tamok	481,423					
	Total	1,574,578					
Treatment method	Cheung Aek	Lagoon	Lagoon	PTF	PTF	CASP	CASP
	Tamok	Johkasou	Lagoon	Johkasou	PTF	Johkasou	CASP
Construction cost (million USD) (Reference)	Cheung Aek	361.4	361.4	419.0	419.0	450.1	450.1
	Tamok	396.2	509.1	396.2	576.1	396.2	598.2
	Total	757.6	870.5	815.2	995.1	846.3	1,048.3
O&M cost (million USD/year)	Cheung Aek	1.890	1.890	10.184	10.184	14.895	14.895
	Tamok	15.797	2.319	15.797	6.116	15.797	8.248
	Total	17.687	4.209	25.981	16.300	30.692	23.143
O&M cost per capita (USD/month)		**0.94**	**0.23**	**1.38**	**0.87**	**1.63**	**1.23**

Source: JICA Study Team

[13] It takes about 27 years to balance difference in construction cost of 202.0 (598.2-396.2) million USD and accumulated difference in O&M cost of 7.549 (15.797-8.248) million USD/year.

(4) Conclusion

Above discussion reveals that (i) introduction of off-site treatment system in Tamok Treatment Area has a disadvantage that it is too costly and it takes a long time to install branch sewers in the entire basin, and thus water environment is not improved immediately; (ii) the adaptation of off-site treatment system in both Cheung Aek and Tamok Areas should be a financial burden to PPCC, considering present budgetary allocation for sewage and drainage management sector; and (iii) there is an advantage in introducing on-site treatment system in Tamok area because step-by-step implementation approach can easily be applied. Ultimately, selection of on- and off-site treatment in Tamok depends on the strategies and policies on sewerage management of PPCC as with the case of Cheung Aek Area. Thus, selection of on- and off-site treatment in Tamok Area was finalised through discussion in T/C and S/C meetings to be held in Phnom Penh.

In response, Johkasou was selected for M/P and Pre-F/S for Tamok Treatment Area in the discussions of S/C with PPCC, held in September 2016, because overall cost (construction cost and O&M cost) is lowest and step-by-step implementation approach can easily be applied in Johkasou system.

4.1.3 Other Area

It is not timely to introduce off-site treatment system and high-grade on-site treatment facilities such as Johkasou, which is proposed in Tamok area, because population projection and population density estimated for the year of 2035 is too low and status of development is immature. Installation of septic tank should be therefore promoted in the area (outer area of Cheung Aek and Tamok). Introduction of high-grade on-site treatment or off-site treatment should be discussed after the target year of 2035.

4.1.4 Summary of Application of On-site and Off-site Treatment System

Based on the discussion above, study on the sewage management M/P is hereinafter detailed, according to the classification of on- and off-site treatment area in PPCC, as shown in **Table 4.1.15**.

Table 4.1.15 Summary of Application of On-site and Off-site Treatment

	Treatment system applied
Cheung Aek area	Off-site treatment
Tamok and other area	On-site treatment

Source: JICA Study Team

(1) Reduction of Pollution Load in the Implementation of the Master Plan

Effect of implementation of the M/P are evaluated by comparing pollution load at present (year 2015) and target year (year 2035), based on classification in **Table 4.1.15** and planning and design conditions described in **Chapter 3** and **Table 4.1.16**.

Table 4.1.16 Conditions for Evaluation of Pollution Load Reduction

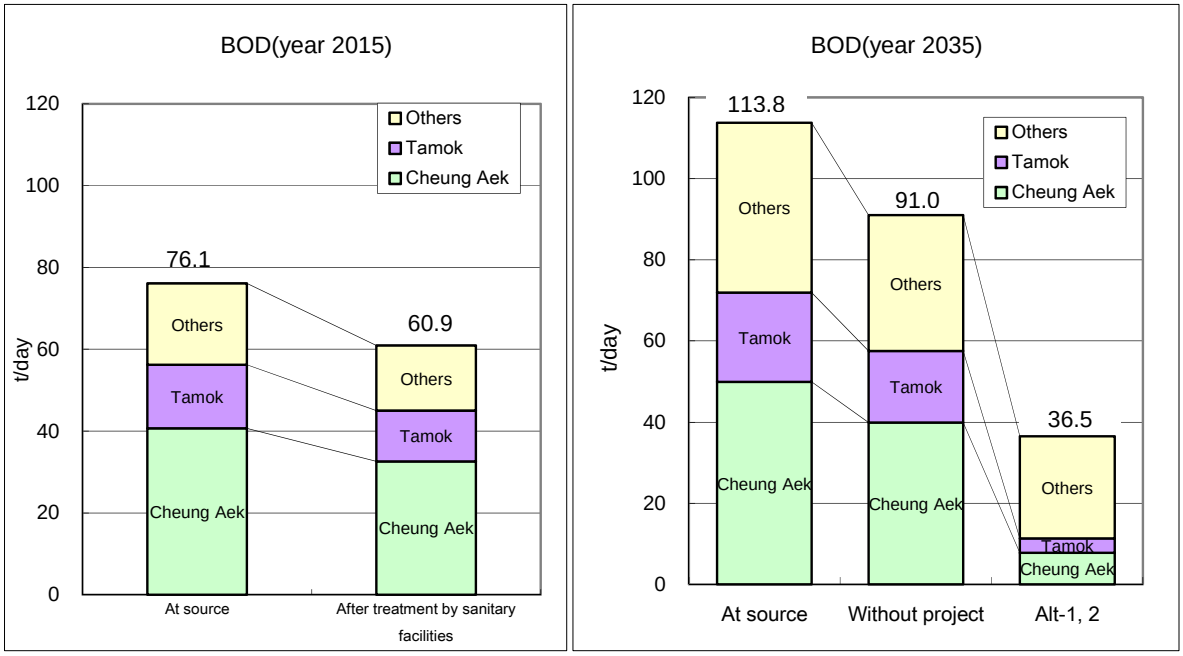
Items		Contents	Remark
BOD load per capita (g/capita/day)		45	
Removal rate of septic tank (%)	Without project (at present and target year of 2035)	20	Note 1)
	With project (year 2035)	40	Note 2)
Effluent from the facilities (STP or Johkasou) in Alternative1 and 2 (mg/L)		30	

Note 1: Removal rate [(240-200)/240×100×20%] is set up, employing typical value obtained in the monitoring survey (about 200 mg/L at Trabek pumping station) and assumed BOD at the source (240 mg/L=45g/capita/day÷150 L(assumed sewage generation per capita in 2015)×1,000).

Note 2: Removal rate under the condition that desludge is appropriately conducted with reference to "Preparatory Survey Report on the Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City in the Republic of the Union of Myanmar", March 2014, JICA and "Project for Capacity Development of Wastewater Sector through reviewing the Wastewater Management Master Plan in DKI Jakarta", Final Report, March 2012, JICA.

Source: JICA Study Team

As shown in **Fig. 4.1.8**, pollution load of 76.1 t/day, generated at present (year 2015), will increase to 113.8 t/day or 1.5 times of present in the target year 2035 but the pollution load discharged (after treatment) is reduced from 60.9 t/day to 36.5 t/day by implementing proposed Master Plan.



Source: JICA Study Team

Fig. 4.1.8 Reduction of Pollution Load

(2) Others

Occurrence of water-borne diseases such as itches, the major symptoms manifested in social survey conducted in the Study, would be reduced and dirty sewage in drainage canals would disappear with the implementation of the M/P.

4.2 Facilities Plan

4.2.1 Sewer Network Plan in Cheung Aek Treatment Area

(1) Basic Strategy

Cheung Aek Treatment Area is located at the southern part of central PPCC. This area covers the whole area of Khan 7 Makara and a part of the surrounding five (5) Khans. The area is 4,702 ha and the total population is estimated at 1,093,155 in 2035. In Cheung Aek Treatment Area, interceptor system is applied since the existing drainage pipe covers in almost all of the area.

(2) Design Criteria for Sewer

(a) Design Sewer Volume

Considering the condition of the existing drainage system, the possibility of conversion to separate sewer systems in the future and the examples in surrounding countries, the design sewage flow in PPCC is determined as the same volume as hourly maximum sewage flow in the dry season.

(b) Equation of Hydraulic Calculation

The Manning's equation is applied for hydraulic calculation with roughness coefficient of 0.013.

(c) Minimum Diameter of Sewer

Diameter of sewer is set to prevent sewage from being suspended caused by insufficient capacity and unexpected obstruction, and to ease maintenance work. Therefore, the minimum diameter of 200 mm is set in the M/P.

(d) Minimum Earth Covering Depth

Considering the above, the minimum earth covering depth is determined as 2.0 m for trunk and main sewers. In case of branch sewers which will directly connect with households, the minimum earth covering depth will be 1.0 m.

(e) Flow Velocity

Minimum velocity of 0.8 m/sec and maximum velocity of 3.0 m/sec are applied.

(3) Sewer Network Plan

Covered area and population in Cheung Aek treatment area is summarized in **Table 4.2.1**.

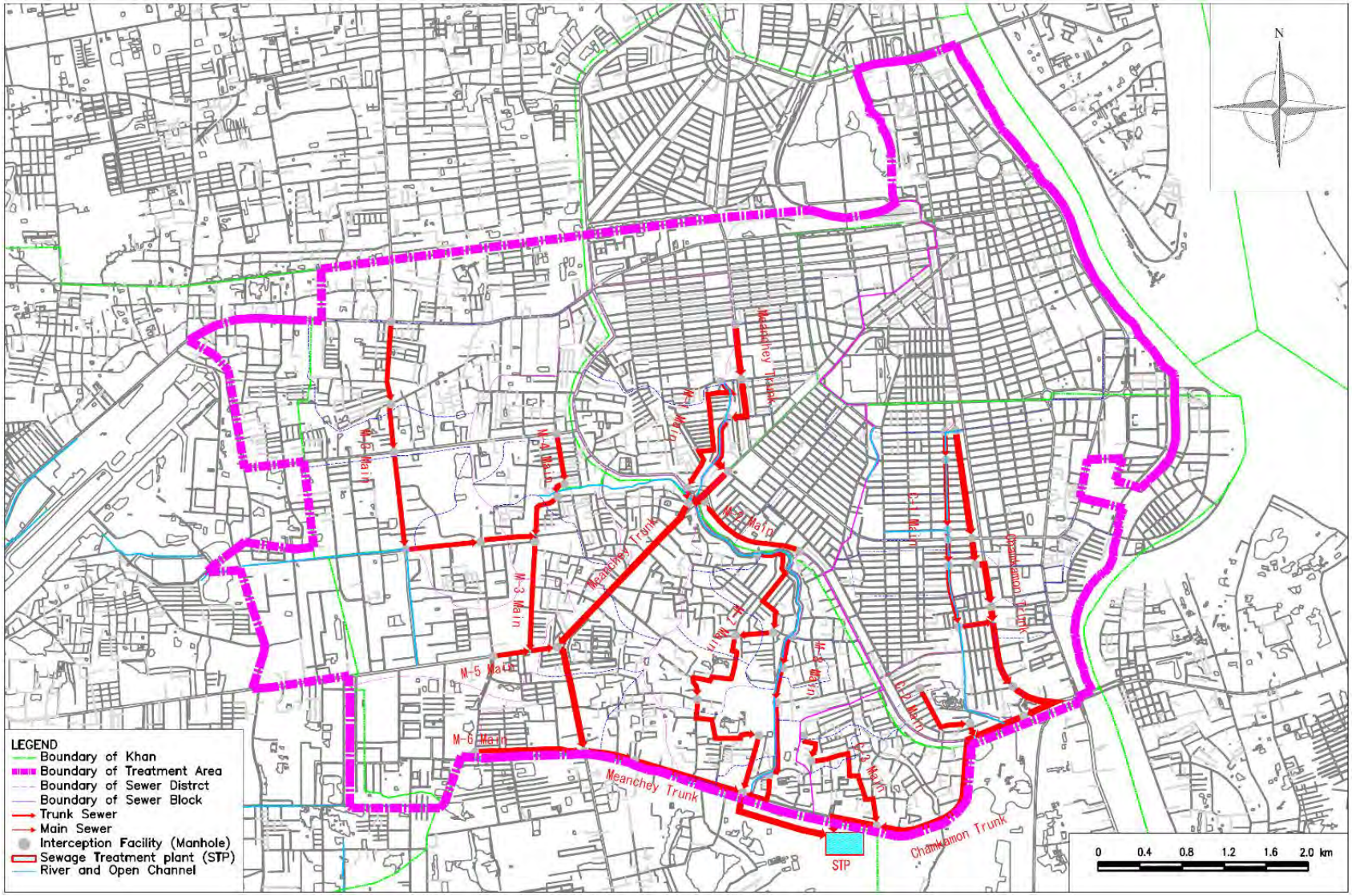
Table 4.2.1 Covered Area and Population of Cheung Aek Treatment Area

Name of Khan and Sangkat		Covered Area (ha)	Covered Population (Cheung Aek Treatment Area)				
			2016	2020	2025	2030	2035
01	**Chamkarmon**	**919.0**	**184,118**	**188,126**	**199,900**	**211,674**	**223,448**
0101	Tonle Basak1	9.3	481	481	481	481	481
0102	Tonle Basak2	104.5	10,036	10,845	13,719	16,593	19,467
0103	Tonle Basak3	155.1	12,000	13,100	16,600	20,100	23,600
0104	Boeng Keng Kang Muoy	99.7	14,000	14,000	15,333	16,667	18,000
0105	Boeng Keng Kang Pir	29.2	11,700	11,700	11,700	11,700	11,700
0106	Boeng Keng Kang Bei	65.8	23,700	24,300	24,967	25,633	26,300
0107	Oulampik	30.3	10,000	10,600	11,100	11,600	12,100
0108	Tuol SvayPreyTiMuoy	58.9	14,700	14,700	15,300	15,900	16,500

Name of Khan and Sangkat		Covered Area (ha)	Covered Population (Cheung Aek Treatment Area)				
			2016	2020	2025	2030	2035
0109	Tuol SvayPreyTiPir	35.0	11,600	11,900	12,367	12,833	13,300
0110	Tumnob Tuek	78.6	18,900	18,900	18,900	18,900	18,900
0111	Tuol TumpungTiPir	47.0	11,300	11,300	11,300	11,300	11,300
0112	Tuol TumpungTiMuoy	62.6	13,800	14,400	15,433	16,467	17,500
0113	Boeng Trabaek	45.9	9,600	9,600	10,067	10,533	11,000
0114	Phsar Daeum Thkov	97.1	22,300	22,300	22,633	22,967	23,300
02	**Daun Penh**	**592.1**	**106,336**	**108,438**	**111,535**	**114,631**	**117,728**
0201	PhsarThmeiTiMuoy	16.5	5,300	5,500	5,767	6,033	6,300
0202	PhsarThmeiTiPir	10.7	7,500	7,400	7,200	7,000	6,800
0203	PhsarThmeiTiBei	31.4	10,400	10,400	10,300	10,200	10,100
0204	Boeng Reang	41.6	7,100	7,500	7,767	8,033	8,300
0205	Phsar KandalTiMouy	40.9	11,400	12,300	13,367	14,433	15,500
0206	PhsarKandalTiPir	14.7	7,500	8,400	9,533	10,667	11,800
0207	Chakto Mukh	149.7	12,000	12,000	13,000	14,000	15,000
0208	CheyChummeah	72.9	12,400	12,400	11,900	11,400	10,900
0209	PhsarChas	10.1	6,900	7,100	7,400	7,700	8,000
0210	SrahChak1	75.5	5,707	6,676	7,154	7,633	8,112
0211	SrahChak2	63.7	10,429	9,762	9,580	9,398	9,216
0212	VoatPhnum	64.4	9,700	9,000	8,567	8,133	7,700
03	**7 Makara**	**219.9**	**95,100**	**96,600**	**98,633**	**100,667**	**102,700**
0301	Ou Ruessei Ti Muoy	8.5	8,300	8,100	7,900	7,700	7,500
0302	Ou Ruessei Ti Pir	8.7	9,200	8,900	8,533	8,167	7,800
0303	Ou Ruessei Ti Bei	4.9	7,800	7,400	6,900	6,400	5,900
0304	Ou Ruessei Ti Buon	8.3	8,600	8,500	8,433	8,367	8,300
0305	Monourom	13.9	11,500	11,400	11,300	11,200	11,100
0306	Mittakpheap	38.7	10,800	11,600	12,367	13,133	13,900
0307	Veal Vong	96.9	28,100	29,100	30,400	31,700	33,000
0308	Boeng Prolit	40.1	10,800	11,600	12,800	14,000	15,200
04	**Toul Kork**	**492.1**	**148,857**	**148,051**	**148,012**	**147,973**	**147,935**
0401	Phsar Depou Ti Muoy	32.4	11,700	12,000	12,333	12,667	13,000
0402	Phsar Depou Ti Pir	20.5	11,500	11,300	11,300	11,300	11,300
0403	Phsar Depou Ti Bei	30.6	8,600	9,200	9,700	10,200	10,700
0404	Tuek L'ak Ti Muoy	90.8	16,300	17,300	18,800	20,300	21,800
0405	Tuek L'ak Ti Pir	42.5	13,600	13,600	13,300	13,000	12,700
0406	Tuek L'ak Ti Bei	117.1	32,900	31,600	30,833	30,067	29,300
0407	Phsar Daeum Kor	69.5	22,257	22,851	23,345	23,840	24,335
0408	Boeng Salang	88.7	32,000	30,200	28,400	26,600	24,800
05	**Po Senchey**	**220.4**	**10,558**	**13,145**	**13,145**	**13,145**	**13,145**
0501	Chaom Chau1	115.7	3,573	4,444	4,444	4,444	4,444
0502	Kakab1	104.6	6,985	8,700	8,700	8,700	8,700
06	**Meanchey**	**1,587.9**	**271,000**	**301,700**	**319,200**	**336,700**	**354,200**
0601	Stueng Mean Chey1	321.9	11,400	13,000	13,767	14,533	15,300
0602	Stueng Mean Chey2	804.7	157,900	178,200	188,733	199,267	209,800
0603	Boeng Tumpun	461.4	101,700	110,500	116,700	122,900	129,100
07	**Sen Sok**	**670.5**	**97,400**	**110,400**	**118,267**	**126,133**	**134,000**
0701	Tuek Thla	670.5	97,400	110,400	118,267	126,133	134,000
	Total	**4,701.9**	**913,369**	**966,459**	**1,008,691**	**1,050,923**	**1,093,155**

Source: JICA Study Team

Fig. 4.2.1 shows the sewer network plan and **Table 4.2.2** summarizes sewer network facilities in the treatment area. This area is divided into two (2) sub-treatment areas and 14 sewer districts considering the existing drainage system, road and topographic condition. STP will be located near Tumpun Pumping Station at the Cheung Aek Lake. Design sewage volume in 2035 is 282,000 m^3 at the daily maximum. Relay pumping station will not be required in this treatment area.



Source: JICA Study Team

Fig. 4.2.1 Sewer Network Plan in Cheung Aek Treatment Area

Table 4.2.2 Summary of Sewer Network Facilities in Cheung Aek Treatment Area

Item	Length (m)	Diameter (mm)	Covering (m)	Remark
1. Trunk Sewer				
1) Chamkamon Trunk	5,984	1,000 ~ 1,650	4.36 ~ 10.25	
2) Meanchey Trunk	7,665	900 ~ 2,200	2.47 ~ 10.01	
2. Main Sewer		~	~	
1) C-1 Main	2,201	800 ~ 1,000	3.93 ~ 7.00	Connecting to
2) C-2 Main	843	250 ~ 400	2.70 ~ 10.25	Chamkarmon Trunk
3) C-3 Main	1,544	300 ~ 400	2.64 ~ 11.59	
4) M-1 Main	1,226	600 ~ 800	4.32 ~ 9.33	Connecting to
5) M-2 Main	1,295	500 ~ 700	4.43 ~ 7.69	Meanchey Trunk
6) M-3 Main	4,812	600 ~ 1,350	2.09 ~ 9.30	
7) M-4 Main	1,161	500 ~ 600	2.50 ~ 7.78	
8) M-5 Main	352	600 ~	4.32 ~ 4.32	
9) M-6 Main	1,044	400 ~	4.54 ~ 8.33	
10) M-7 Main	4,100	300 ~ 900	2.64 ~ 12.01	
11) M-8 Main	1,877	300 ~ 600	2.64 ~ 11.72	
Total Length	**34,104**			
Interception Facilities (Overflow Chamber)			Amount	
1) Chamkamon Trunk and connected Main			17	
2) Meanchey Trunk and Connected Main			33	
Total Amount			**50**	

Source: JICA Study Team

In the Cheung Aek Treatment Area, sewer is about 34 km in length and installation depth is 12 m at a maximum considering collection of sewage utilizing existing drainage system. Therefore, relay pumping station will not be required.

4.2.2 Sewage Treatment Plan Facilities Plan in Cheung Aek Treatment Area

Overview of the Cheung Aek STP is shown in **Table 4.2.3**. Sludge treatment system is simply organized with the configuration of sludge thickener and dehydrator. Sludge digester is not proposed because it has a number of accessories and thus operation of the facilities is not easy, especially in controlling input depending on the condition of sludge. Sludge recycle facilities are not proposed in the M/P because no great needs in PPCC has been recognized in the social survey conducted in the Study. Instead, the sludge recycle facilities should be considered in the future.

Table 4.2.3 Overview of STP

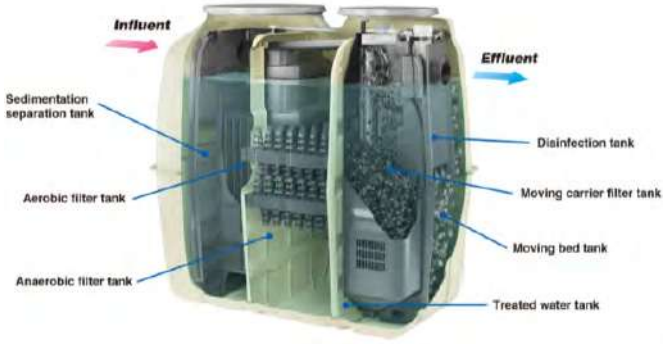
Facilities	Items
Pumping station	Grit chamber and pumping equipment
Administration building	Staff room/laboratory and so on
Wastewater treatment facilities	Primary and final sedimentation chamber and reactor and so on
Sludge treatment facilities	Gravity thickener/mechanical thickener/dehydrator
Disinfection chamber	Chlorine chamber
Others	Distribution chamber/ generator/ receiving and transforming station

Source : JICA Study Team

4.2.3 On-site Treatment Plan in Tamok Area

As discussed in **Subsection 4.1.2**, Johkasou is applied in Tamok treatment area. Johkasou can simultaneously treat black and grey water and have a wide line-up, ranging from a household size (for 5 persons: see image in **Fig. 4.2.2**) and community based size (for several hundred persons: see image in **Figs. 4.2.3** and **4.2.4**) to large-scale type for 1,000 persons. BOD removal rate of Johkasou reaches 90%, which is equivalent to off-site treatment facilities. Moreover, Johkasou can be fabricated in factories and be easily installed on site.

Johkasou has advantages in treating wastewater but it was very costly compared to other on-site treatment facilities such as septic tank and thus not so popular in the developing countries. But in the recent years, a great deal of effort have made in cost reduction by localizing procurement of parts and materials as well as fabrication. For instance, in the neighbouring country of Myanmar, installation of Johkasou has been in progress especially in the capital city of Yangon. Considering the status of Johkasou, there exists great potential for cost-reduction and dissemination of Johkasou in Phnom Penh if some manufacturers expand their business to Cambodia or establish an affiliated company. Therefore, Johkasou is introduced for alternative study in the M/P.

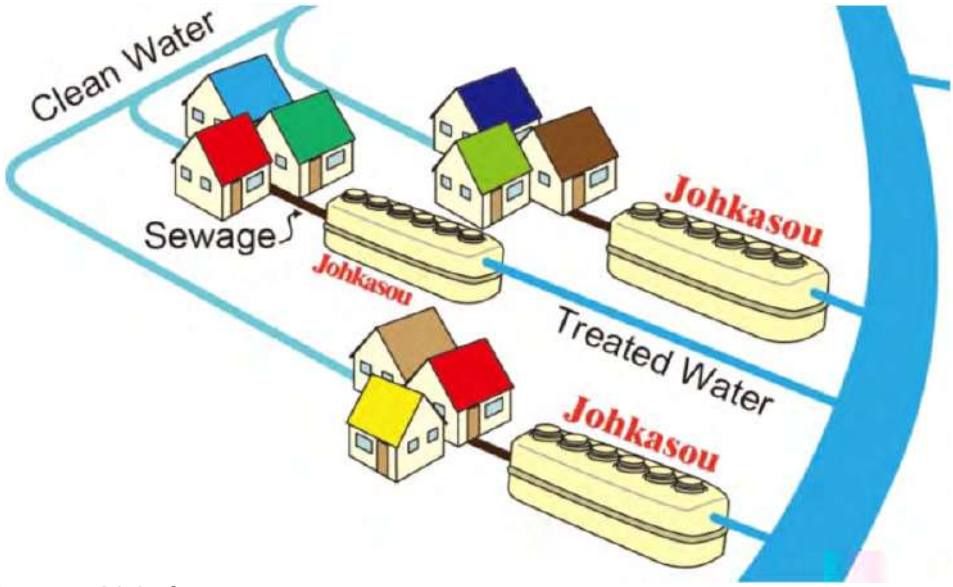


Source: Japanese Manufacturer

Fig. 4.2.2 Image of Johkasou (for 5 persons)

Source: Japanese Manufacturer

Fig. 4.2.3 Image of Johkasou (for 300 persons)



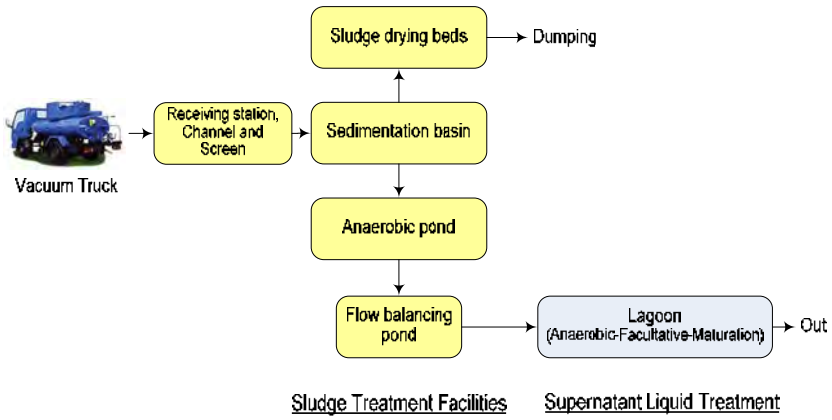
Source : JICA Study Team

Fig. 4.2.4 Image of Community-Based Sewage Treatment applying Johkasou

4.2.4 Sludge Disposal Plan

At present, in PPCC, more than 90% of households have installed on-site facilities such as septic tank but unfortunately PPCC has no septage disposal site. Meanwhile, in the M/P, Cheung Aek STP is proposed as one of off-site treatment facilities and thus there exist additional need to dispose sludge generated in STP. In response, sludge disposal site, in which septage, sludge withdrawn from Johkasou and treated sludge from STP can be disposed, is proposed in the M/P.

Anaerobic and/or aerobic digestion system is a candidate of septage treatment facilities but they are as a whole costly in terms of construction and O&M, so that the following simple septage treatment facilities are proposed in the M/P (see **Fig. 4.2.5**). The treatment facilities consist of (i) receiving station in which sludge unloaded from vacuum trucks are received, as well as sedimentation basin and anaerobic pond in which septage are treated and (ii) lagoon consisting of anaerobic, facultative and maturation lagoon, in which overflow water is treated. Treated sludge from STP is disposed in the site. Land requirement of this sludge disposal site is estimated at 35 ha (i.e., 30 ha for treated sludge disposal site and 5 ha for septage and Johkasou sludge treatment facilities). Expected lifetime of the site will be about 15 to 20 years. If needs to establish sludge recycle system increase in the future, such sludge recycle uses as construction material, aggregate for concrete, agricultural use, and material for landfill, are to be proposed.



Source : JICA Study Team

Fig. 4.2.5 Treatment Facilities for Septage and Johkasou Sludge

4.3 Operation and Maintenance Plan

4.3.1 Sewer Network

(1) Operation and Maintenance for Sewer Networks

It is essential to establish sewerage ledger and to record the operation and maintenance works in operating and maintaining sewer network. In sewerage ledger, it is required to organize such information as sewer length, diameter, manhole depth and dimension of each sewer and manhole. Based on the sewerage ledger, operation and maintenance plan shall be prepared in order to effectively manage sewerage facilities.

In implementing operation and maintenance works, it is required to establish a management group for the sewerage facilities. At present, DSD in DPWT is responsible for the drainage system operation and maintenance work and their performance is good, because the works is conducted in accordance with a work plan prepared by them. Therefore, it is desirable to establish a management group for sewerage facilities in DSD. Items for sewer network maintenance works are briefly described as below.

(a) Sewers and Manholes

Sewers and manholes will generally be installed under road or public land. Therefore, the following maintenance works are required.

i) Recording and registration of operation and maintenance works
ii) Daily or weekly site inspection
iii) Checking and cleaning inside of sewers and manholes
iv) Periodical inspection inside sewers and manholes by manually or by television (CCTV camera)
v) Detailed survey and evaluation of capacity of sewers and function of manholes
vi) Repair or rehabilitation

(b) Interception Facilities (Overflow Chambers)

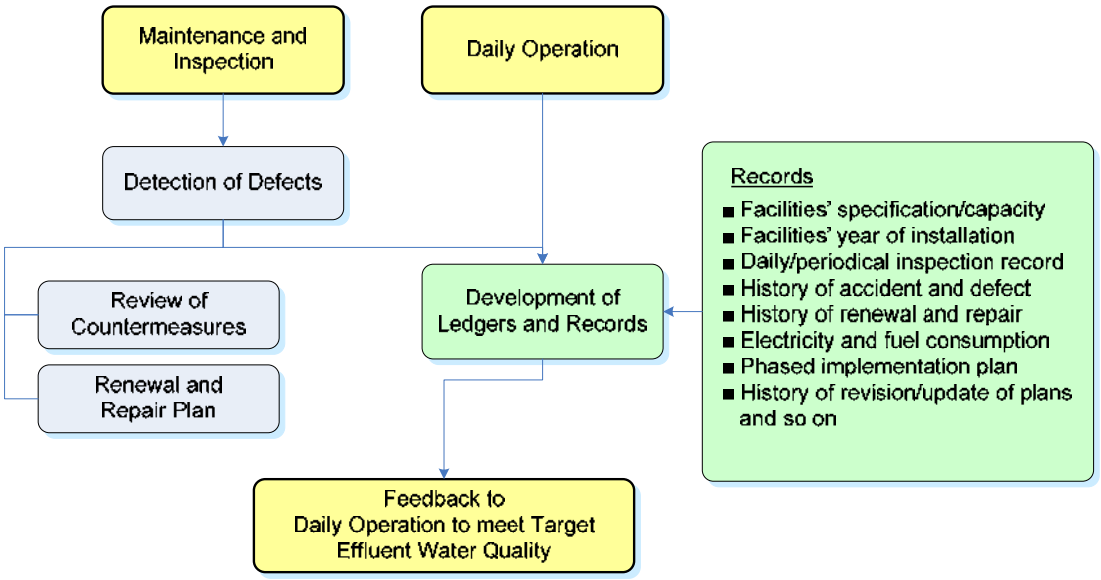
Interceptor facilities are very important facilities to collect sewage and proper maintenance works are:

i) Situation of sewage collection and water level of sewage
ii) Checking no overflow of sewage in the dry condition
iii) Checking weir and other equipment
iv) Removing suspended solids and debris

4.3.2 Sewage Treatment Plant and Sludge Disposal Site

(1) Sewage Treatment Plant

O&M in STP is implemented with objectives of optimizing the function of treatment facilities, thereby complying with effluent and targeted standards, improving water environment, and conserving water quality of public water bodies. Flowchart of O&M in STP is shown in **Fig. 4.3.1**.



Source: JICA Study Team, based on Tentative Guidelines for Optimization of Operation and Maintenance of Sewage Works in developing Countries, October 2001

Fig. 4.3.1 Flowchart of O&M in STP

O&M items in STP are as summarised in **Table 4.3.1**.

Table 4.3.1 O&M Items in STP

Facilities		Items
Grit chamber/pumping station		・ Removal of debris
Influent channel		・ Record of inflow
Sewage treatment facilities	Sedimentation chamber	・ Removal of scum ・ Control of putrefaction and floatation of sludge ・ Inspection of wearing and putrefaction and sludge collector ・ Control of sludge overflow from overflow weir
	Reactors	・ Control of bulking ・ Prevention of floatation and deflocculation of activated sludge
Sludge treatment facilities	Gravity thickener	・ Check of floatation of sludge and rise of sludge-liquid interface
	Mechanical thickener/dehydrator	・ Check of abnormal vibration and rotation ・ Control of injection ratio of flocculants
Chlorine chamber		・ Check of chlorine consumption
Water quality analysis		・ pH, DO, BOD, TSS, COD, Coliform and so on

Source: JICA Study Team

(2) Sludge Disposal Site

In sludge disposal site, activities such as drying up of sludge and ground levelling in order to extend lifetime of the site, are required. O&M items of septage and Johkasou sludge treatment facilities are as listed below.

- Sludge receiving station : Removal of debris
- Lagoon and flow regulation pond : Removal of scum and algae
- Sludge drying bed : Check of sludge thickness and removal of sludge

4.3.3 On-site Treatment Facilities

Septic tank and Johkasou requires periodical desludging. In addition, Johkasou requires periodical operation and maintenance such as control of aeration, circulated water, backwashing, flushing flow rate in toilets in order to comply with the discharge criteria.

4.4 Review of Organization and Legal Framework of Sewage Management

4.4.1 Review for Proposal of a New Organization to Implement the Sewer Network Service

Based on the issues identified and described in **Section 3.1**, the option of creating a new organization specialized for sewage management in the large, rapidly growing city of PPCC, is discussed in this section. The organization will carry out planning of a sewer network service plan; and will have a leadership who has strong abilities (authority and organizational strength) to carry out the implementation plan based on the M/P, while coordinating and negotiating with relevant ministries and agencies and respective authorities of the PPCC, with staff to support the leader and to carry out the service, to set fee schedules and to be responsible for publicity. A phased plan to enhance the organization, following M/P policy of staged establishment and improvement (short term, medium term, and long term), is also considered[14].

The new organization will be headed by the Director and has at least two sections as below.

- **Sewerage Project Section**: Responsible for publicity, fee schedule, financial plan, coordination with relevant divisions, and so forth.
- **Sewerage Technical Section**: Responsible for formulating service plan, preparing implementation plan, training of the engineers to plan and build sewage facilities (sewer, pumping station and sewage treatment plant) and the engineers with technical expertise in sewage treatment, and so forth.

It is assumed that the Sewerage Project Division will be staffed with selected employees selected from general accountancy areas in such organizations as MPWT, MEF, and PPCC. Meanwhile, as the Sewerage Technical Division will need to formulate the sewer network service plan and be engaged in designing and construction of sewage treatment plants alongside installation of pipes and culverts within three to four years of establishment of the organization. Therefore, during the initial stage of the project, the staff requirement for the sewer network service plan, implementation plan, designing and construction of sewer facilities, etc., should be met with the sewer policy specialists trained through utilization of the technical cooperation projects, etc. Those specialists will also be responsible for disseminating expertise related to the sewer network service throughout Cambodia, as well as for training of other engineers. For instance, based on the experience with SRSWTPU (Siem Reap Sewerage Works Treatment Plant Unit), it is thought that some 15 to 20 staff members will be required at the initial stage after establishment of the organization.

Meanwhile, collaboration (integration) with PPWSA has been proposed as an option for carrying out the sewer network service in PPCC. PPWSA had developed and expanded a water supply system project for PPCC within just over ten years, and has become a major organization supplying 450,000 m^3 of water daily for over 90% of the entire population of the Capital City, known as “Miracle of Phnom Penh.” Therefore, it will be very beneficial in the initial stage of the sewer network service for PPCC to draw on PPWSA’s experience and expertise in project implementation and service operation. Meanwhile, the JICA Study Team obtained the following information through discussions with relevant people, including the General Director in PPWSA, and other means of information gathering:

- At this point in time, PPWSA’s consider that the sewer network service body is too immature to collaborate with PPWSA in the sewer network service.
- Although the government is the 85% majority shareholder, PPWSA has already become an independent private corporation and a listed company. Making an investment in a project with such little profit potential would not be accepted by its shareholders and other stakeholders.

[14] The proposed plan should be coordinated with financial and human resources development plan of PPCC and related organizations

- PPWSA still has loans to pay back to such donors as JICA, ADB, and AFD. Although loan payments are not currently delayed, it will need to expand water supply service into less profitable areas to address poverty, etc. and its financial condition will be tighter in the future.
- PPWSA has been instructed by the government (MIH) to consider lowering fees. (It cannot raise fees.)
- As a result, PPWSA would like to continue the current system to collect a 10% sewer user fee alongside the water supply fees.

Aside from the matters listed above, there are other issues similar to Japan such as: water supply services (MIH) and sewer services (MPWT) are under separate authorities in Cambodia; each project/service body has a different accounting system; drinking water supply and wastewater treatment services have different methods of treatment and particulars of water quality management; and operation including fee collection except for general affairs business, as well as technical matters, differs largely between project/service bodies.

Furthermore, although all water supply service clients have signed a contract with PPWSA concerning their water supply use, the contract only covers water supply use, but not covers sewerage use. If the clients have to pay a sewerage fee to PPWSA, a new contract needs to be signed. In addition, currently no law is available to impose payment of sewerage fees to users and the legislation of such fee rule will be politically difficult. At present, there is only a Governor's ordinance for collecting 10% of water supply use fee from the water supply users within the areas subject to the ADB Water Supply and Drainage Project.

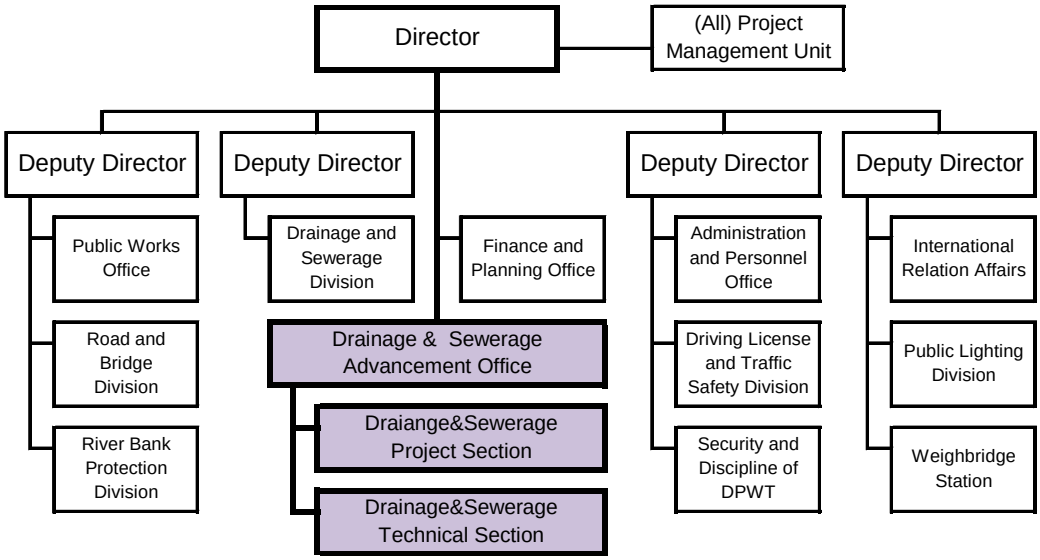
However, it is widely known that establishment of a sewer system contributes to improvement of water environment in lakes, swamps, rivers, etc. At PPCC, also, better water quality at Sap Lake, Mekong River, Sap River and so on, will help ensure good sources of water supply, and thus establishment of a sewer system, will sufficiently benefit PPWSA. Furthermore, there are cases in Japan in which water supply and sewer services have separate accounts (even in the administration division which can easily be integrated), with a mechanism to avoid sewerage project negatively impacting the water supply service, and thus water supply and sewer services are effectively operated.

Therefore, in order for both the sewer and water supply project bodies to establish a win-win relationship, it is recommended that a committee chaired by the Deputy Governor of PPCC or the Director of DPWT for implementing sewage and water supply projects in PPCC, be established to facilitate full discussion before reaching a conclusion.

Accordingly, the option to collaborate or integrate with PPWSA shall be considered a review topic in and after Medium-Term (after year 2021), when the sewer pipes and the sewage treatment plant have been established and the sewer network service will have a certain level of future prospects. In this M/P, the following (proposals) shall be reviewed assuming that the organization to implement the sewer network service will be established within DPWT.

(1) Organization Proposed

Based on the above discussion, the following organization in DPWT is proposed based on the alternative study.



Note 1): Shaded items show the structure not in current organization
Source: JICA Study Team

Fig. 4.4.1 Organizational Chart based on the Proposed Organization 1

The organization in **Fig. 4.4.1**, the Sewerage and Drainage M/P Project Advancement Office will be established directly under the Office of the Director of DPWT, to be initially operated in a two-division structure of the Sewerage Project Section and Sewerage Technical Section, with some 15 staff members.

Its primary tasks will be planning of the sewer network service plan, preparation and implementation of an implementation plan, coordination with relevant divisions and bureaus, publicity, fee schedule, planning and designing for installation of sewer pipes and treatment plants/facilities, management of treatment facilities and so forth. As the project progresses such organizations as Project Division, Planning Division, Design Division, Works Division, Facility Management Division, Water Quality Monitoring Division, Operations Division, and Marketing Division will be enhanced and staffed.

Meanwhile, the organizations within DSD that are responsible for maintenance and management of drainage facilities will maintain their current structures. As the project expands, the divisions involved in maintenance and management of wastewater pipes and cannels and sewage treatment plant will be enhanced.

(2) Policy for Staged Organizational Improvement in the Organizations that Implement the Project

For the new organization to be established within DPWT, according to the M/P Policy for staged streamlining of organizations (Short-Term, Medium-Term, and Long-Term), those posts listed in **Table 4.4.1** shall be established according to the order. (Duties of respective posts are listed in **Table 4.4.2**). It is noted that, for at least ten years until the end of the Medium-Term, when the sewer network service will start to run its course, technical cooperation projects such as JICA's (for training of sewer project human resources) need to be utilized for continuing human resource training.

Table 4.4.1 Policy for Staged Streamlining of Organizations that Implement the Project

	Short-Term (–2020)	Medium-Term (2021–2030)	Long-Term (2031-)
Posts	Sewerage Project Section	Project Division Operations Division Marketing Division	Same as to the left (Marketing branches)

	Short-Term (–2020)	Medium-Term (2021–2030)	Long-Term (2031-)
	Sewerage Technical Section	Planning Division Design Division Works Division Facility Management Division Water Quality Monitoring Division Service Division	(Work offices) Drainage Supervision Division

Note 1: Drainage Supervision Division will be separated from the Water Quality Monitoring Division and will carry out water quality control and supervision of wastewater from commercial facilities and plants and discharged into sewer (while the water directly discharged into public watercourse will be under the jurisdiction of MOE).

Note 2: The marketing branches and work offices under Long- Term will be established as branch offices of the government in each Khan, according to the progress of sewerage and drainage facilities in the Khans.

Source: JICA Study Team

Table 4.4.2 Division Offices to implement Projects and their Work

Posts	Tasks/Responsibilities
Project Division	Project implementation plan planning, project policy formulation, and coordination between relevant departments and bureaus
Planning Division	Project implementing plan formulation, monitoring and assessment of development, supervision and training of work contractors
Design Division	Designing standards of wastewater or drainage pipes/culverts, designing of treatment plants, pumping stations, or similar facilities
Works Division	Management and supervision of sewerage and drainage works, assessment and inspection of drainage facilities (connection to sewer)
Facilities Management Division	Management of facilities and utilities at treatment plants, pumping stations, or similar facilities, facilities design, sludge treatment
Water Quality Monitoring Division	Water quality management at treatment plants, management and supervision of sewerage and drainage (commercial facilities and plants)
Operations Division	Financial planning, management of budget and accounting, asset management, publicity and education for the citizens, dissemination
Marketing Division	Fee conciliation (coordination with PPWSA), levy, management of customer information
Service Division	Connection to sewer, promotion of installation of wastewater treatment facilities such as septic tanks and Johkasou, maintenance and management

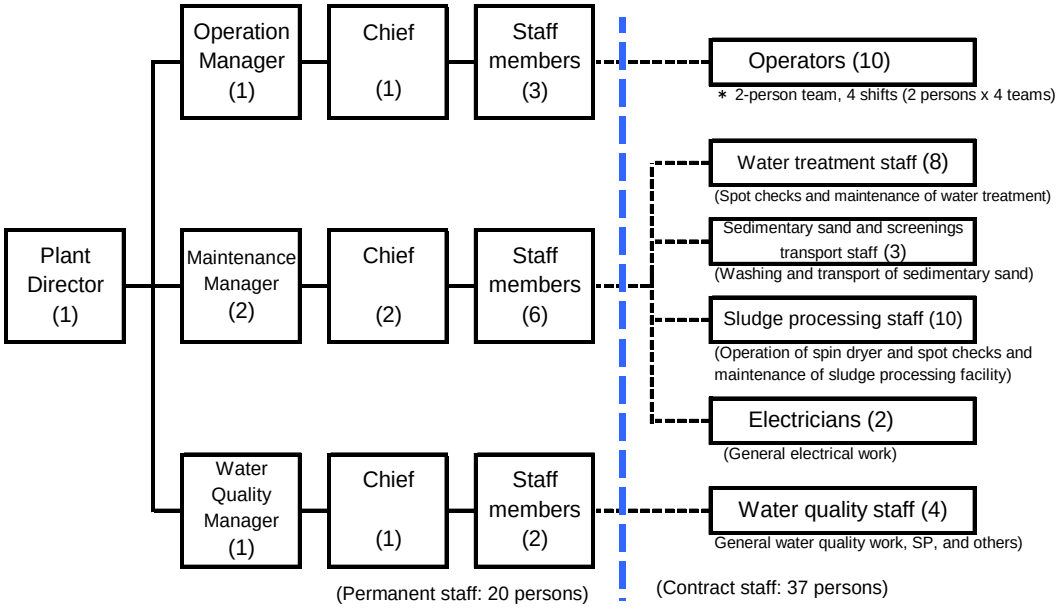
Note 1: Standards, guidelines, manuals and so forth are under jurisdiction of respective responsible divisions
Note 2: DSD is responsible for operation and management of treatment plants.
Note 3: Sewerage sludge disposal sites are under jurisdiction of WMD of PPCC.
Source: JICA Study team

The organization in **Fig 4.4.1** is proposed in DPWT to improve the sewerage and drainage management at PPCC. However, considering the current arrangement at PPCC; namely, WMD (Waste Management Division) of PPCC is managing environmental matters including sewerage and drainage sectors under the leadership of the Deputy Governor, it is imperative to establish a strong partnership between the new organization at DPWT and the WMD of PPCC. Since waste management at PPCC is under the jurisdiction of the WMD of PPCC, strong partnership between the WMD and DPWT of PPCC will also be important in promoting septic tank or Johkasou installation as on-site treatment facilities, formulating manuals for maintenance and management (such as spot checks, disposal of septage, monitoring treated water, etc.) and securing disposal sites to meet the future demand of sewerage sludge.

(3) Organization and Staffing at STP

The following chart shows the organization and staffing at the sewage treatment plant proposed in Cheung Aek Treatment Area (Capacity: about 280,000 m^3/day, applying combined system), assuming application of CASP, based on the case at the City of Kitakyushu. (This organization is equivalent to the Wastewater Treatment Plant Unit in **Fig. 2.6.5**)

Staffing categories are in line with DSD's staffing structure, consisting of fulltime and contracted employees. However, the staffing in sludge treatment work would be changed considerably depending on the method of sludge treatment and disposal. In this chart (**Fig. 4.4.2**), the case of Thickener -Digester-Dewatering-Landfill System is considered. However, if the sludge treatment system includes incineration, fuel recovery and sludge recycling system, staffing would increase by 10-15 workers.



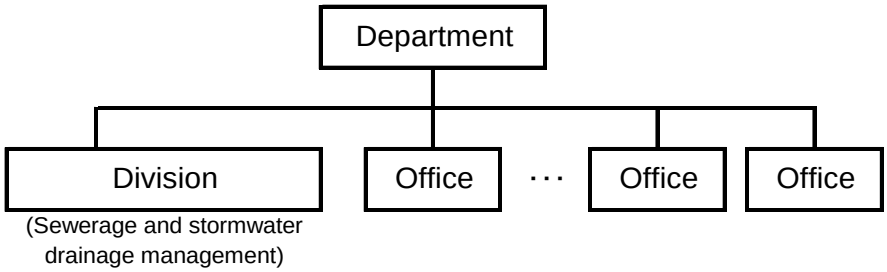
Source: JICA Study Team

Fig. 4.4.2 Example of Management Organization in STP

4.4.2 Review of Legal Framework

Although the Cambodian legal framework for management of wastewater and stormwater drainage is not yet completed, the interviews at MPWT found that it currently has a plan for rebuilding organizations of sewerage and drainage. Therefore, if the plan is approved and implemented, preparation of a legal framework for sewerage and drainage will be accelerated.

According to the interviews, the new organization is created from an existing department, namely, the Department of National Urban Infrastructure and Engineering (see **Fig. 2.6.1)**, strengthening sewerage and stormwater management capacities. Then a division specialised in sewerage and stormwater drainage will be established. This organizational structure sets up various frameworks and systems concerning sewerage and drainage policies, as well as establishes technical standards, criteria, guidelines, sludge management and human resource training and so forth in Cambodia. The following chart (**Fig. 4.4.3**) shows the concept of the new organization responsible for legal preparation, etc. (with Division being a main driving force). No stipulation in such regulation as sub-decree is required to establish the offices in the figure. Only the decision of director is required for the establishment. The office has the same power as the division.



Source: JICA Study Team

Fig. 4.4.3 Concept of the New Organization established in MPWT of Sewerage and Drainage Management

Under this organization, a Drainage & Sewerage Unit (equivalent of Division) will be established at each Municipality or Province, and will be responsible for sewerage and drainage management in the respective region.

Ideally, the proposed M/P should be implemented in PPCC in accordance with the legal framework for sewerage and drainage management and the national policies established by the central government (MPWT and DPWT). However, for the time being, MPWT (DPWT) should consider a special legislative provision to designate areas in which urgently sewer system is required so as to improve the current status of PPCC, in which rapid urbanization and absence of a sewer system accelerates deterioration of water environment, headed by the Deputy Governor through a partnership with PPCC.

As previously discussed in **Subsection 2.6.1(3)**, the "Law on Land Use Plan, Urbanization and Construction 940524" clearly states the principle that major development projects and land use in Cambodia must conform to the urban development Master Plan of the local government, as well as the land use plan based on the urban development Master Plan. In addition, for construction of a structure larger than a certain scale, a construction permit must be obtained pursuant to Ordinance No. 86, concerning construction permits. On the other hand, major development projects and private development projects are rapidly progressing.

To develop a sound city and good urban environment, a legal framework must be established to govern major development project and land use areas, as discussed above. In addition, standards and guidelines on development areas should be formulated in accordance with an urban development Master Plan and relevant laws, specifying such matters as population size, roads, public facilities or facilities for public benefits, water supply and drainage facilities, disaster resilience and safe facilities, green belt plan, etc., to regulate land development. However, in PPCC, standards and regulation on major development areas are particularly obscure, and responsibility of administrative unit(s) for regulation is unclear. Those jurisdictions therefore need to be clarified.

For instance, the City of Kitakyushu in Japan has formulated the "City Planning Master Plan in the City of Kitakyushu," as well as "Ordinance on Permission for Development Activity in the City of Kitakyushu" and "Rules on Permits, etc., for Development Activities in the City of Kitakyushu," based on the "City Planning Act" (a national statute). The City has developed the "Development Activity Manual" in accordance with the City Planning Master Plan, the Ordinance and the Rule for unified regulation of development areas.

The Development Activity Manual consists of five chapters: Chapter 1 (Principle of Development Permit System); Chapter 2 (Definition of Development Activity); Chapter 3 (Permission for Development Activity); Chapter 4 (Procedure for Development Activity; and Chapter 5 (Criteria of Development Permission). Chapter 5 also lists specific matters subject to regulation in development activities. It also has detailed description of the criteria for permission of drainage facilities and water supply facilities.

Furthermore, concerning the technical standards of sewerage and drainage facilities, the City developed detailed criteria for installation and structure of drainage facilities, pursuant to the

ordinance of the City of Kitakyushu on the sewer system. The City implements these technical criteria (standards) on drainage facilities, aiming for technical unification of installation and structure of drainage facilities in the City.

Table 4.4.3 summarizes the organization and legal system options proposed in this section, following **Section 3.1** (Identification of the issues).

Table 4.4.3 Summary of Discussions and Proposals on Organization and Legal System

Current State and Issues	Summary of Actions to meet the Issues (Summary of Discussions and Proposals)
(1) Structure of the project implementing organizations (posts and staffing) to be established	
At present, agencies responsible for planning of projects concerning wastewater is unclear	• Based on the three proposed options in **Subsection 4.4.1**, an organization managing wastewater is established in DPWT. The organization formulates sewage management plan in accordance with the phased schedule of Short-Term, Medium-Term, and Long-Term, aiming for synergic effect with the Sewage Management Master Plan. • The new organization in DPWT shall be the main body of project plan planning. • A system shall be established, in which the project planning is carried out through a partnership with WMD, which is responsible for the environmental administration in PPCC, while obtaining a consensus with PPCC. • The subject areas need to have wastewater treatment measures, including on-site treatment; therefore, agencies responsible for management of septic tanks, promotion of switching to Johkasou, standards of maintenance and management, and so on. • The departments engaged in septic tanks shall be unified and procedural rules and technical standards shall be established, including those regarding installation, inspection, and maintenance of septic tanks. • The responsibilities of the house owners of septic tanks shall be specified. • Systems for registering and giving companies permission to install, maintain, or inspect septic tanks shall be established and a law shall be enacted so that only registered companies can handle septic tanks.
(2) Determining task descriptions for central and regional organizations	
Task descriptions are not determined for either central (MPWT) or regional organization (DPWT)	• The central organization (MPWT) shall be responsible for establishing policies and legal framework, stipulating technical standards and criteria, medium to long term national project planning, human resource training plan, and coordination with other ministries and agencies on laws, ordinances, ministerial orders, and so on. • In terms of the human resource training plan, in particular, it shall carry out coordination in relation to international technical support programs. • Regional organization (DPWT or provincial) shall be responsible for drawing up manuals and guidelines based on the central legal framework, central technical standards and criteria, and the central project plan, while incorporating regional and geographical features, human resource training, and other aspects. • It shall strive for enhancing partnership (and sharing information) among the organizations in PPCC under jurisdictions of MOI and the organizations under other ministries and agencies so that the project is smoothly implemented. Tasks shall be clarified after reviewing the provisions of No.425 BrK.SK.BT, Prakas: Article 2 (Jobs of MPWT) and Article 8 (Treatment of wastewater and flood prevention); and No.274 BRK.SK.BT, Declaration: Section 3 of Chapter 4 (Jobs of DPWT) and Section 2 of Chapter 5 (Drainage, pumps, and treatment of polluted water).
(3) Securing the technical standards and human resources concerning wastewater management	

Current State and Issues	Summary of Actions to meet the Issues (Summary of Discussions and Proposals)
Shortage of technicians for management and operation of wastewater treatment facilities	• To cultivate sewerage specialists utilizing technical cooperation projects (for training of sewerage engineers, etc.) and inviting sewerage specialists from other countries. • To establish training program, in which trainees are dispatched to cites with advanced sewer systems in foreign countries for short-term (1-3 months) or long-term (1-2 years), for training of technicians. • Technicians trained in the above program shall establish a human resource training cycle, in central and regional level, to make technicians meet the progress of the sewer network service. • To establish section to administrate training program for cultivating sewerage specialists in the central and regional governments. • To establish "Sewer Association" (provisional name) or a similar specialized organization on sewer system and to carry out such tasks as research, investigation, development of standards and technologies of sewer systems, training, publicity, securing sewer technicians and continuous training of technicians.
(4) Insufficient management for effluent from factories	
MIH, the responsible ministry, has not implemented sufficient monitoring of status at plants/factories such as installation of treatment facilities and compliance with standards	• As well as assess criteria for issuing factory/plan operation permit, the MIH shall make factories report status of wastewater treatment after commission and the water quality monitoring data, and shall work with them to check status. Strict management of the effluent treatment facilities especially in a major source of industrial effluent discharge in such areas as the Special Economic Zone (SEZ), are required. • MIH shall work with the MOE, which is another regulatory authority. • DPWT shall discuss with related ministries (MIH and MOE) to establish regulations on installation of treatment facilities, standards for drainage and monitoring, and to confirm structure and treatment capacity in the factories. • Allocation of responsibilities among the related organizations (MIH, DOE, DLMUPC, DPWT, WMD, and so forth) shall be discussed and protocols and framework of management of factory/plant effluent shall also be discussed.
(5) Pollution control guideline, as well as land use regulation guideline for large-scale development areas, are unclear	
There is no guideline to control wastewater in large-scale development areas, which are rapidly increasing recently. Each development area manage wastewater by themselves since no unified guideline is available in PPCC	• To work with the committee in order that PPCC's Urban Development Master Plan is promptly approved. • To clarify agencies responsible for regulating development, develop a guideline and thoroughly supervise the developer with the guideline. • To clarify agencies responsible for the regulation, as well as the procedures for notification, application and so forth, concerning permission of development.

Source: JICA Study Team

4.4.3 Financial Review

(1) Sewerage Financing in Phnom Penh

Revenues of the sewerage can be i) rate to the water supply (PPWSA) use payments and ii) other additional rate or new taxes such as property tax or wastewater tax.

i) rate to water use payments is the present system, but if it becomes official (legalized) and the rate is raised, it will be difficult because every customer has an agreement with PPWSA for use of water and payment and it does not include sewerage payment. The present additional 10% of PPWSA's water use charge revenues payment to PPCC for drainage is based on the PPCC Governor's regulation (ordinance) demanded by the ADB when the ADB decided its loan for Phnom Penh water supply and drainage project. It was suggested that if the rate raise is proposed, the customers will oppose and even before that the governor and the government will not allow it being concerned about the election. Actually, however, the Governor decided in January 2015 to expand the ADB project area to the entire PPCC to impose 10% of PPWSA's water use charge revenue for drainage and sewerage service. The people in PPCC, however, seem to be far from expressing strong opposition to the Governor's decision.

ii) new tax introduction is also difficult similarly to the rate increase above. Customers do not want to pay for sewerage. Therefore, the present 10% of PPWSA's water use charge revenues payment is inevitably the starting method. However, it may not be enough even for operational costs of the sewerage project.

At first, it is necessary to legalize the sewerage tariffs as rate to the water use charges as well as defining that water use includes wastewater discharge.

Then, campaigns and public relations that wastewater treatment is essential for environmental protection and human health (wastewater without treatment may go to water supply intake of PPWSA and also the downstream people who use downstream river water for drinking) and the user-pay principle is the worldwide trend technique should be conducted. Then, after the customers are convinced, the rate will be raised gradually to cover the operational costs. However, the object customers should be those within the new sewerage service coverage areas based on the user-pay principle. In addition, the following are to be considered.

- Sludge disposal costs from the septic tanks etc. can be new revenues for the sewerage treatment entity.
- It may be difficult to cover the investment cost (CAPEX) so that it is aimed to cover the operational cost with sewerage use revenues.
- The government should shoulder soft loan for the CAPEX.

4.5 Implementation Plan

As discussed in **Subsection 3.2.3**, the implementation plan is formulated on a phased schedule of Short-Term, Medium-Term and Long-Term.

4.5.1 Short-term

As described in **Subsection 3.1.1**, priority should be placed on Cheung Aek Treatment Area, because (i) the area is fully urbanized and (ii) water pollution is more serious compared to any other areas in Phnom Penh.

Cheung Aek treatment is further subdivided into the Trabek and Tumpun system, as shown in **Table 4.5.1**. The Cheung Aek Treatment Area, which consists of STP with capacity of 282,000 m^3/day and pipe network totalling 34.1 km, covers huge catchment area and, in particular, the construction scale of the STP is large. Therefore, based on the overviews of the two systems in **Table 4.5.1**, priority is placed on improvement of the Trabek system, in which urbanization and water pollution is in progress in comparison with the Tumpun system.

Table 4.5.1 Overview of Trabek and Tumpun System

Item	Trabek System	Tumpun System
Progress of urbanization	This system covers the most urbanised area in Phnom Penh, accommodating a large number of governmental and commercial buildings.	This system is located west of Trabek system, and has been characterized with on-going and rapid urbanization in the recent years.
Current situation of water pollution	Water pollution is worst in Phnom Penh. In particular, BOD concentration exceeds 250 mg/L in the dry season at the downstream end of Trabek Pumping Station, based on the water quality monitoring conducted in the Study.	Water pollution is second-worst in Phnom Penh, next to Trabek system. For instance, BOD concentration ranges from 150 to 250 mg/L in the dry season at the downstream end of Tumpun Pumping Station, based on the water quality monitoring conducted in the Study.
Conditions in the year 2035		

Item			Trabek System	Tumpun System
	Area		1,581 ha	3,121 ha
	Population		394,400 person	702,800 person
	Population density		247 person/ha	225person/ha
	Wastewater generated	Daily ave.	80,000 m^3/day	158,000 m^3/day
		Daily max	99,700 m^3/day	181,500 m^3/day
	Estimated reduction of BOD load[1)]		15.1 t/day	27.0 t/day

Source: JICA Study Team

As shown in **Fig. 4.5.1**, Trabek system is further subdivided into Trabek East and Trabek West areas. Trabek East area encompasses the most urbanised area in Phnom Penh with populations of 237,900 in 2035, while Trabek West is located adjacent to Trabek East with population of 152,500 in 2035. In the implementation plan, Trabek East, which encompasses the most urbanized area in Phnom Penh is termed as the "Phase 1 Project" to be firstly implemented. Then, Trabek West area is called the "Phase 2 Project", followed by the "Phase 3 project", which represents projects in the Tumpun system.

In addition, a "Preparatory Project" is proposed to be implemented ahead of "Phase 1 Project", in due consideration that: (i) institutional and legal framework is urgently needed before commencement of full-scale construction and installation of sewerage facilities; (ii) it is commendable for Phnom Penh to mainly implement non-structural measures focusing on institutional and legal framework and to put them on track particularly in Short-Term period; and (iii) it is also essential to accumulate technical skills step-by-step in order to smoothly enter into full-scale construction and installation of sewerage facilities in parallel with the establishment of institutional and legal framework. The Preparatory Project is composed of a small-scale STP and the pipe collects and conveys wastewater equivalent to the STP's capacity, as detailed in subsequent **Subsection 4.9**.

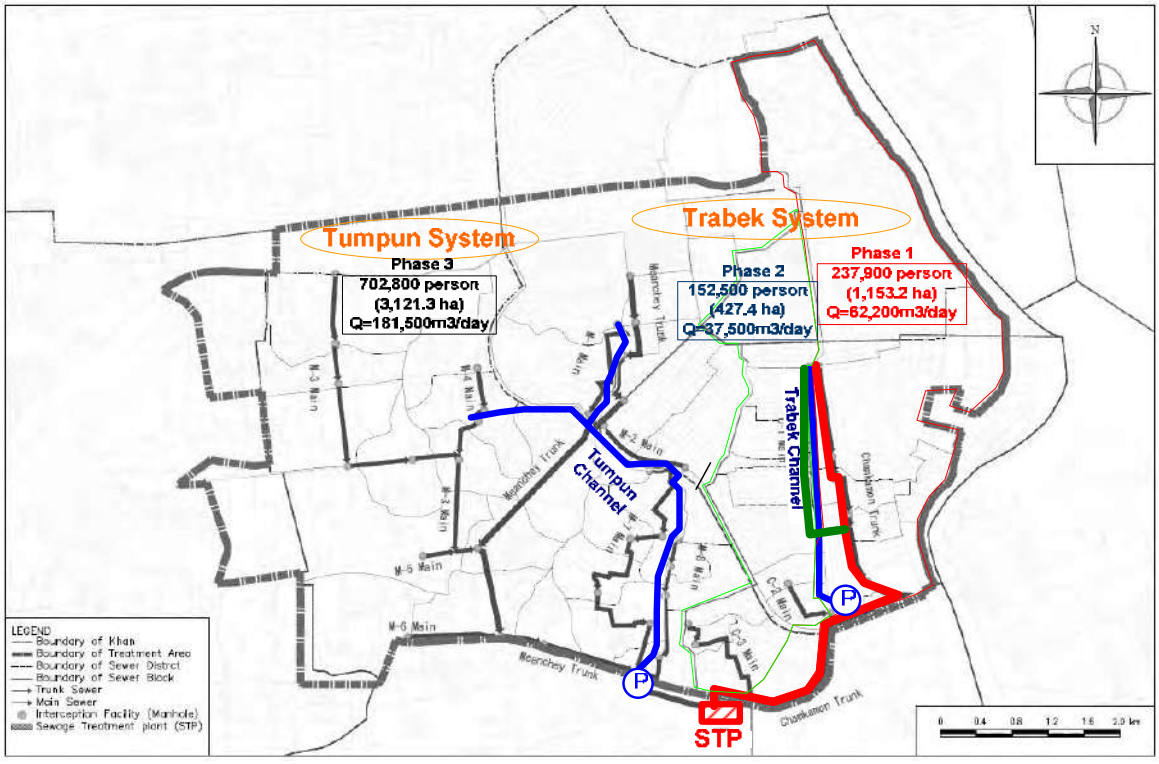


Fig. 4.5.1 Trabek and Tumpun System in Cheung Aek Treatment Area

4.5.2 Medium-Term and Long-Term

As described in **Subsection 4.5.1**, a Preparatory Project is proposed to be implemented in the Short-Term period in Cheung Aek Treatment Area. The Phase 1 Project is then subsequently

implemented together with Phase 2 in the Medium-Term period. After that, the Phase 3 Project is implemented in the Long-Term period from 2031 to 2040. The Long-Term period of 10 years is set to equalize the volume of projects implemented in each period. On the other hand, implementation of projects in the Tamok Treatment Area is commenced in the Medium-Term and ended in 2040, the last year of the Long-Term period.

Non-structural measures are continuously implemented, mainly focusing on review and improvement of the issues on institutional and legal framework established and operated, throughout the course of Medium- and Long term period.

Based on the above discussion, the phased implementation plan for sewage management is as summarised in **Table 4.5.2**, and out of which construction schedule of the facilities are summarised in **Table 4.5.3**.

Table 4.5.2 Phased Implementation Schedule (Sewage Management)

Items		Short-Term (to year 2020)					Medium-Term (year 2021 to year 2030)										Long-Term (year 2031 to year 2040)										Remarks
Year		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	
Structural Measures																											
Facilities design and construction																											
Construction of sewage facilities in Cheung Aek area							Design/ Fund arrangement			Construction			Design/ Fund arrangement		Construction				Design/ Fund arrangement		Construction						
	Phase 1																										
	Phase 2																										
	Phase 3		Design/ Fund arrangement		Construction																						
	Preparatory Project																										
Construction of sewage sludge and septage disposal site			Design/ Fund arrangement								Design/ Fund arrangement								Construction								
Installation of sewage facilities in Tamok area																											
Project cost (Million USD)																											Total
Construction of sewage facilities in Cheung Aek area																											
Phase 1	STP							65.9																			65.9
	Sewer pipe							29.5																			29.5
Phase 2	STP												120.8														120.8
	Sewer pipe												12.3														12.3
Phase 3	STP																		157.4								157.4
	Sewer pipe																		109.6								109.6
Preparatory Project	STP			20.9																							20.9
	Sewer pipe			6.0																							6.0
Construction of sewage sludge and septage disposal site				9.1				16.1																			25.2
Installation of sewage facilities in Tamok area												34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2		478.8
Total				36.0				111.5				34.2	167.3	34.2	34.2	34.2	34.2	34.2	301.2	34.2	34.2	34.2	34.2	34.2	34.2		1,025.0
O&M cost (Million USD/year)																											
Cheung Aek area (including sludge disposal site)							0.38	0.38	0.38	0.38	0.38	2.95	2.98	3.02	3.05	3.09	5.20	5.24	5.28	5.32	5.37	5.37	5.37	5.37	5.37	14.90	79.75
Tamok area													0.88	1.75	2.63	3.65	4.78	5.91	7.03	8.39	9.80	11.32	12.70	14.23	15.80	15.80	114.65
Total							0.38	0.38	0.38	0.38	0.38	2.95	3.86	4.77	5.68	6.74	9.98	11.15	12.31	13.71	15.17	16.69	18.07	19.60	21.17	30.70	194.41
Non-structural Measures																											
Legal and institutional set-up																											
Establishment of sewage management body and HRD													HRD is continued														
Establishment of sewage implementation entity																											
Formulation of guideline for sewage treatment													In operation														
Procedures																											
Securing Cheung Aek STP construction site																											
Securing site for sewage sludge and septage disposal site																											
Strengthening of management of industrial wastewater																											
Formulation of guideline and starting of operation													In operation														
Strengthening of management of large-scale development																											
Formulation of guideline and starting of operation													In operation														

Source: JICA Study Team

Table 4.5.3 Phased Implementation Plan for Construction Works

Area		Schesule	Year 2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Cheung Aek Area																											
Phase1	Cheung Aek STP (Capacity 58,000m$^{3/}$day)	F/S					■																				
		Fund Arrangement						■																			
		D/D							■																		
		Construction								■	■	■															
	Chamkamon Trunk	F/S					■																				
		Fund Arrangement						■																			
		D/D							■																		
		Construction								■	■	■															
	Sludge Disposal Yard	F/S		■			■																				
		Fund Arrangement			■			■																			
		D/D				■			■																		
		Construction				■				■																	
Phase2	Cheung Aek STP (Capacity 38,000m$^{3/}$day)	F/S										■															
		Fund Arrangement											■														
		D/D												■													
		Construction													■	■	■										
	C-1, C-2, C-3 Main	F/S										■															
		Fund Arrangement											■														
		D/D												■													
		Construction													■	■	■										
Phase3	Cheung Aek STP (Capacity 181,000m$^{3/}$day)	F/S																■									
		Fund Arrangement																	■								
		D/D																		■							
		Construction																			■	■	■	■			
	Meanchey Trunk, M-1, M-2, M-3, M-4, M-5, M-6, M-7, M-8	F/S																■									
		Fund Arrangement																	■								
		D/D																		■							
		Construction																			■	■	■	■	■	■	
Pre-paratory Project	Cheung Aek STP (Capacity 5,000m$^{3/}$day)	F/S		■																							
		Fund Arrangement			■																						
		D/D				■																					
		Construction				■	■																				
	Trunk Sewer	F/S		■																							
		Fund Arrangement			■																						
		D/D				■																					
		Construction				■	■																				
Tamok Area																											
Johkasou		F/S									■																
		Fund Arrangement										■															
		D/D											■														
		Construction												■	■	■	■	■	■	■	■	■	■	■	■	■	

For Preparatory Project

Source: JICA Study Team

4.6 Cost Estimate

4.6.1 Construction Cost (Project Cost)

Project cost consists of construction cost, administration cost, engineering cost and land expropriation/compensation cost. These costs are estimated at the exchange rate of 1USD=119.64JPY, and 1Riel=0.030JYP, as of April 2015. The Project cost for sewage management has been estimated as shown in **Table 4.6.1**. According to the table, the project cost for the Cheung Aek treatment area amounts to 450.1 million USD and that of Tamok treatment area amounts to 396.2 million USD. Cost disbursement schedule for the sewage management projects is shown in **Table 4.6.2**.

Table 4.6.1 Project Cost for Sewerage Management

Unit: million USD

Items	Foreign currency	Local currency	Total
I. Construction Cost (1+2)	512.7	333.6	846.3
(1) Cheung Aek Treatment Area (a+b+c+d+e)	263.5	186.6	450.1
a) Phase1 (i+ii)	55.9	33.4	89.3
i) STP Construction	37.5	17.1	54.6
ii) Sewer Pipe Construction	14.6	9.9	24.5
b) Phase2 (i+ii)	57.1	53.5	110.6
i) STP Construction	53.3	47.1	100.4
ii) Sewer Pipe Construction	3.8	6.4	10.2
c) Phase3 (i+ii)	137.5	84.1	221.6
i) STP Construction	88.4	42.2	130.6
ii) Sewer Pipe Construction	49.1	41.9	91.0
d) Preparatory Project (i+ii)	11.8	10.5	22.3
i) STP Construction	9.8	7.5	17.3
ii) Sewer Pipe Construction	2.0	3.0	5.0
e) Sludge Disposal Yard (i+ii)	5.0	11.5	16.5
i) Construction in Short-Term	1.2	5.1	6.3
ii) Construction in Medium-Term	3.8	6.4	10.2
(2) Tamok treatment area	249.2	147.0	396.2
II. Administration Cost	0.0	42.3	42.3
III. Engineering Cost	67.7	16.9	84.6
IV. Physical Contingency	29.0	17.5	46.5
V. Land Expropriation	0.0	5.3	5.3
Total Project Cost (I+II+III+IV+V)	609.4	415.6	1,025.0

Source: JICA Study Team

Table 4.6.2 Disbursement Schedule of Project Cost for Sewerage Management

Unit: million USD

Item	2016			2017			2018			2019			2020			2021			2022		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	17.0	33.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.2	37.0	103.2
1. Construction cost (a+b+c+d)	0.0	0.0	0.0	0.0	0.0	0.0	13.0	15.6	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.9	33.4	89.3
a) Cheung Aek area: STP							9.8	7.5	17.3										37.5	17.1	54.6
b) Cheung Aek area: Pipe							2.0	3.0	5.0										14.6	9.9	24.5
c) Cheung Aek area: Sludge disposal site							1.2	5.1	6.3										3.8	6.4	10.2
d) Tamok area: Johkasou																					
2. Consultant fee	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.6	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	1.8	8.9
3. Phisical contingency	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	1.8	5.0
B : Cost not covered by loan (4+5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3
4. Administration cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.5
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.8
Total (A+B)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	19.9	36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.2	45.3	111.5

Item	2023			2024			2025			2026			2027			2028			2029		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.1	11.7	32.8	90.3	70.1	160.4	21.1	11.7	32.8	21.1	11.7	32.8
1. Construction cost (a+b+c+d)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	10.5	28.3	74.9	64.0	138.9	17.8	10.5	28.3	17.8	10.5	28.3
a) Cheung Aek area: STP													53.3	47.1	100.4						
b) Cheung Aek area: Pipe													3.8	6.4	10.2						
c) Cheung Aek area: Sludge disposal site																					
d) Tamok area: Johkasou										17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3
2. Consultant fee	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.6	2.9	11.1	2.8	13.9	2.3	0.6	2.9	2.3	0.6	2.9
3. Phisical contingency	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.6	4.3	3.3	7.6	1.0	0.6	1.6	1.0	0.6	1.6
B : Cost not covered by loan (4+5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	6.9	6.9	0.0	1.4	1.4	0.0	1.4	1.4
4. Administration cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	6.9	6.9	0.0	1.4	1.4	0.0	1.4	1.4
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (A+B)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.1	13.1	34.2	90.3	77.0	167.3	21.1	13.1	34.2	21.1	13.1	34.2

Item	2030			2031			2032			2033			2034			2035			2036		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	21.1	11.7	32.8	21.1	11.7	32.8	21.1	11.7	32.8	184.1	104.6	288.7	21.1	11.7	32.8	21.1	11.7	32.8	21.1	11.7	32.8
1. Construction cost (a+b+c+d)	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	155.3	94.6	249.9	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3
a) Cheung Aek area: STP										88.4	42.2	130.6									
b) Cheung Aek area: Pipe										49.1	41.9	91.0									
c) Cheung Aek area: Sludge disposal site																					
d) Tamok area: Johkasou	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3
2. Consultant fee	2.3	0.6	2.9	2.3	0.6	2.9	2.3	0.6	2.9	20.0	5.0	25.0	2.3	0.6	2.9	2.3	0.6	2.9	2.3	0.6	2.9
3. Phisical contingency	1.0	0.6	1.6	1.0	0.6	1.6	1.0	0.6	1.6	8.8	5.0	13.8	1.0	0.6	1.6	1.0	0.6	1.6	1.0	0.6	1.6
B : Cost not covered by loan (4+5)	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	12.5	12.5	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4
4. Administration cost	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	12.5	12.5	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (A+B)	21.1	13.1	34.2	21.1	13.1	34.2	21.1	13.1	34.2	184.1	117.1	301.2	21.1	13.1	34.2	21.1	13.1	34.2	21.1	13.1	34.2

Item	2037			2038			2039			2040			Total		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	21.1	11.7	32.8	21.1	11.7	32.8	21.1	11.7	32.8	0.0	0.0	0.0	609.4	368.0	977.4
1. Construction cost (a+b+c+d)	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	0.0	0.0	0.0	512.7	333.6	846.3
a) Cheung Aek area: STP													189.0	113.9	302.9
b) Cheung Aek area: Pipe													69.5	61.2	130.7
c) Cheung Aek area: Sludge disposal site													5.0	11.5	16.5
d) Tamok area: Johkasou	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3				249.2	147.0	396.2
2. Consultant fee	2.3	0.6	2.9	2.3	0.6	2.9	2.3	0.6	2.9	0.0	0.0	0.0	67.7	16.9	84.6
3. Phisical contingency	1.0	0.6	1.6	1.0	0.6	1.6	1.0	0.6	1.6	0.0	0.0	0.0	29.0	17.5	46.5
B : Cost not covered by loan (4+5)	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	0.0	0.0	0.0	47.6	47.6
4. Administration cost	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	0.0	0.0	0.0	42.3	42.3
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.3
Total (A+B)	21.1	13.1	34.2	21.1	13.1	34.2	21.1	13.1	34.2	0.0	0.0	0.0	609.4	415.6	1,025.0

Source: JICA Study Team

4.6.2 Operation and Maintenance Cost

Annual operation and maintenance cost is summarized in **Table 4.6.3**. According to the table, annual operation and maintenance cost of Cheung Aek and Tamok treatment area in year 2040, in which all the construction of facilities are completed, are estimated at 14.895 million USD, and 15.797 million USD, respectively.

Table 4.6.3 Annual Operation and Maintenance Cost for Sewerage Management

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
a) Cheung Aek area: STP						0.368	0.368
b) Cheung Aek area: Pipe						0.005	0.005
c) Cheung Aek area: Sludge disposal site						0.006	0.006
d) Tamok area: Johkasou						0.000	0.000
Total						0.379	0.379

Year	2023	2024	2025	2026	2027	2028	2029
a) Cheung Aek area: STP	0.368	0.368	0.368	2.858	2.893	2.927	2.962
b) Cheung Aek area: Pipe	0.005	0.005	0.005	0.029	0.029	0.029	0.029
c) Cheung Aek area: Sludge disposal site	0.006	0.006	0.006	0.060	0.060	0.060	0.060
d) Tamok area: Johkasou	0.000	0.000	0.000	0.000	0.876	1.751	2.627
Total	0.379	0.379	0.379	2.947	3.858	4.767	5.678

Year	2030	2031	2032	2033	2034	2035	2036
a) Cheung Aek area: STP	2.996	5.028	5.071	5.115	5.158	5.201	5.201
b) Cheung Aek area: Pipe	0.029	0.050	0.050	0.050	0.050	0.050	0.050
c) Cheung Aek area: Sludge disposal site	0.060	0.117	0.117	0.117	0.117	0.117	0.117
d) Tamok area: Johkasou	3.652	4.779	5.906	7.033	8.386	9.799	11.322
Total	6.737	9.974	11.144	12.315	13.711	15.167	16.690

Year	2037	2038	2039	2040			
a) Cheung Aek area: STP	5.201	5.201	5.201	14.564			
b) Cheung Aek area: Pipe	0.050	0.050	0.050	0.157			
c) Cheung Aek area: Sludge disposal site	0.117	0.117	0.117	0.174			
d) Tamok area: Johkasou	12.700	14.229	15.797	15.797			
Total	18.068	19.597	21.165	30.692			

Source : JICA Study Team

4.7 Financial Analysis

4.7.1 Cheung Aek System

Ten percent (10%) of the PPWSA's revenues in the ADB project area had been paid to PPCC as drainage and sewerage costs until 2014, but from 2015 according to the Governor's decision, this charging system was expanded from the ADB project area to the total Phnom Penh area, However, small garment manufacturers and their landowners contributing to exports are partially exempted (4.4% on the 10% of water supply sales revenues basis). It is assumed that this exemption does not exist and 10% of the PPWSA's sales revenue is sewerage and drainage revenues for maintenance and management. However, 9% is taken out by PPWSA for management and operation and so 91% becomes the sewerage and drainage use revenue. Assuming that this is adopted to the 2014 sales revenue of PPWSA, the sewerage and drainage use revenue is calculated as $137{,}018 \times 0.1 \times 0.91 = 12.47$ billion Riels, but it is less than the actual maintenance and operation costs, 13.03 billion Riels, of DSD. In addition, sewerage operation entities cannot cover the investment costs with their user fee revenues usually. Therefore, operational balance is analysed at first.

(1) Revenues

At least it is expected that 10% of PPWSA revenues in the ADB project area continue or the revenues start from this. At present, the revenues are used for drainage, but they should be considered sewerage use fee revenues. Polluter-Pay principle should be adopted. Similarly, although the sewerage and drainage cost burden was expanded to all the water supply users in 2015, the exempted garment manufacturers should be subsidized in the other way. Tax exemption or other purpose subsidy should be implemented. It is not reasonable for the sewerage and drainage operator to exempt use charges. Therefore, this exemption system should be abolished in the future, by the time when the sewerage operation starts at the latest. Namely, it is assumed that the sewerage use charge revenues start from 10% of PPWSA's sales revenues. However, assuming that PPWSA takes out 9% as a commission, the remaining 91% become the sewerage use revenues. It is also supposed that 10% of PPWSA revenues or ratio of water supply revenues (payment) for sewerage user fee payment is legalized and water use is defined not only water supply but also wastewater. Since the sewerage treatment plant operation is supposed to start in 2021, the campaign and PR will convince the citizens that users or polluters must pay. If 10% is not enough, the ratio is raised until the revenues exceed the expenditures. There is a possibility of water supply tariff raise around 2017, but this analysis is based on constant price, namely real without inflation and the raise may reflect inflation. Thus, tariff raise and inflation are excluded and it is considered how many percent ratio of the sewerage charge revenues to the water supply revenues is necessary. In fact, if water supply tariffs are raised, the ratio (10%) to water supply revenues may be reduced excluding the inflation portion.

In addition, it is assumed that the average water supply user fee revenue per cubic meter will increase because water use per customer per month will increase with the annual household income increase (6.11%). Both of water supply user fee revenue per cubic meter and water use per customer per month are estimated using linear regression analysis result.

In addition to the user fee revenues, there are other revenues as sludge disposal fee revenues from the sludge truck services with vacuum hose, which remove sludge from household Johkasou or septic tanks and carry it to sewerage sludge disposal site. It is supposed that the disposal fee revenue is supposed 5USD per sludge truck, which is equivalent to one-sixth of desludge cost of 34.5USD per household on average based on the Social Survey result.

(2) Operational Balance

Based on the above revenues and expenditures, the operational profit or loss is estimated, imposing charges only on Cheung Aek treatment area, as shown in **Table. 4.7.1**, In the estimation, depreciation is excluded because IRR calculation deals in only cash flow and if investment costs are covered by the government, depreciation should be excluded. As a result, profits are estimated from 2021 when the Preparatory Project starts to operate, but losses are estimated from 2026 to and after 2040. In order to get profits every year, it is necessary to increase 10% ratio to 20% in 2026 and to 55% in 2040.

Table 4.7.1 Operational Profit or Loss Excluding Depreciation (Imposing Charges only on Cheung Aek Area)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	2.01	2.09	2.17	2.25
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	2.37	2.45	2.54	2.63
Expenditure	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Profit/ Loss	1.80	1.87	1.94	-0.58	-0.53	-0.47	-0.42

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	2.34	2.43	2.53	2.63	2.74	2.85	2.85
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	2.73	2.80	2.92	3.02	3.15	3.27	3.28
Expenditure	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Profit/ Loss	-0.36	-2.39	-2.32	-2.26	-2.17	-2.10	-2.09

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	2.85	2.85	2.85	2.85	47.37		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	3.29	3.30	3.30	3.20	55.17		
Expenditure	5.37	5.37	5.37	14.90	79.75		
Profit/ Loss	-2.08	-2.07	-2.06	-11.69	-24.58		

Source: JICA Study Team

(3) FIRR (Financial Internal Rate of Return)

Next, profit and loss including investment costs are estimated although generally it is considered difficult to cover sewerage investment costs. If the estimate is stopped in the final year on the way that the invested facilities (assets) are not fully depreciated, profits covering the investment costs can be brought about after that and so the calculation does not reflect that correctly. Therefore, residual value of the investment assets needs to be included into the calculation as negative costs, namely, the positive revenue side, in the final year.

The result of the case in which sewerage charges are imposed on the total planned area population from the start, namely **Table 4.7.1** including investment costs and residual values, is shown in **Table 4.7.2** to estimate how many percent ratio should be raised to cover the investment costs. The result is that 60% ratio from 10% is necessary from 2026 and FIRR is almost positive zero, namely sum of cash flow becomes zero. However, if FIRR is zero and the total investment costs are funded by loans, even interest cannot be paid. In order to pay interest, more than 60% ratio is necessary. It may be difficult to get agreement with more than water supply use charges so that it is appropriate for the government (public) to burden the investment costs.

Table 4.7.2 Cash Flow of Sewerage Project (Sewerage Use Fee of 60% to Water Use Fee Case)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74
Investment			36.00				111.50
Cashflow			-36.00			1.67	-109.76

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	12.09	12.52	13.04	13.52
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	12.44	12.89	13.41	13.90
Expenditure	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Profit/ Loss	1.80	1.87	1.94	9.49	9.90	10.39	10.85
Investment					133.20		
Cashflow	1.80	1.87	1.94	9.49	-123.30	10.39	10.85

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	14.02	14.55	15.17	15.76	16.44	17.10	17.10
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	14.41	14.93	15.56	16.16	16.85	17.52	17.53
Expenditure	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Profit/ Loss	11.33	9.73	10.32	10.87	11.53	12.15	12.16
Investment				267.00			
Cashflow	11.33	9.73	10.32	-256.13	11.53	12.15	12.16

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	17.10	17.10	17.10	17.10	238.79		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	17.53	17.54	17.55	17.45	246.59		
Expenditure	5.37	5.37	5.37	14.90	79.75		
Profit/ Loss	12.17	12.18	12.18	2.55	166.84		
Investment					547.70		
Cashflow & IRR	12.17	12.18	12.18	2.55	25.38	FIRR=	0.48%
Residual value				406.24			

Source: JICA Study Team

4.7.2 Tamok System

The Tamok Lake basin system is based on the on-site plants such as Johkasou and different from the Cheung Aek basin system. The investment starts from 2026 and finishes in 2039. The annual investment costs (only construction) are constant and USD 28.3 million. The annual operation costs change from USD 0.876 million in 2027 to USD 15.797 million in 2039 and after 2039 they are constant. The annual investment costs, USD 28.3 million, correspond to population of 25,000 and so the per capita cost is USD 1,132. The annual per capita operation cost is USD 35.04. Assuming that household size is approximately 5, these costs per household are USD 5,660 and USD 175.2, respectively. The average monthly household income is estimated US$ 793 in 2017 and so the Johkasou investment cost is (5,660÷793=) 7.1 months of income, that is, the burden seems a little too heavy, especially to lower income household.

4.7.3 Financing of Sewerage Systems

The Cheung Aek sewerage system consists of STP and pipes and it seems that the operation costs can be covered by the user fee revenues, but the investment needs to be burdened by the government since it cannot be covered by the user fee revenues which are more than water supply user revenues. The government does not have enough fund by itself and so it depends on soft loans such as the ADB's or JICA's.

On the other hand, the Tamok sewage system consists of every user's individual or community's Johkasou and so every user has to finance independently in principle. However, operation costs can be covered by each user although low income users need public support. The investment cost of Johkasou seems too expensive for each user. The government does not have funds. Then there is a problem whether the government can get soft loans for each user's Johkasou investment. Johkasou belongs to each user and usually soft loans cannot be used for private citizens. If two-step loan can be available, soft loan may be possible, but the second step loan is borrowed by each user (private) from the government (or the central bank) with usual commercial interest although the first step loan is between the international organization such as the ADB or JICA and the Cambodian government with long tenure, grace period and low interest rate. In that case, the second step loan is not supportive to each user. If the second step loan conditions are similar to the first step, it will be a problem of competition with commercial loans. If this problem is solved because users need support for Johkasou investment, the next problem that Johkasou users have to cover the investment costs while STP users do not need to cover the investment costs and it can be mentioned that it is unfair. In order to solve this unfair problem, it can be considered that the sewerage user fees in the Cheung Aek system should be a little expensive than necessary and the surplus should be used to reduce the investment costs of Johkasou in

the Tamok system. It should be designed at the implementation stage how much is fair to both system users including some support of operation and investment costs for low income households.

Looking at the Tamok system from a different angle, it can be considered that the Johkasou are supplied by the new sewerage operation entity operating the Cheung Aek system instead of each user's ownership. For example, since there is a limit for individual households to bear the costs of Johkasou, each municipal government in Japan establishes a municipal Johkasou promotion policy introducing a system to view Johkasou as public assets, bear the investment and maintenance costs and collect user charges from the residents instead of a simple subsidy system. Since an STP system for the Tamok basin area is not efficient, an independent on-site Johkasou system is selected and so these Johkasou are operated by the entity instead of STP. Although there is a problem that Johkasou appear each user's asset, the sewerage entity invests each Johkasou at user's site and collect user fee revenues from users. In this case, the user fees are similar to those of the Cheung Aek system.

Table 4.7.3 shows the result of profit and loss including Cheung Aek and Tamok areas, in order to make profits. The ratio should be 10% from 2021 to 2025, 15% from 2026, 30% from 2030, 50% from 2035 and 75% from 2040. Furthermore, in order to cover the investment costs including the Tamok system, the ratio to water supply charge revenues should be 10% from 2021 to 2022, 30% from 2023 to 2025, 50% from 2026 to 2028, 60% from 2029 to 2033 and 90% from 2034 so that cash flow becomes a little positive, as shown in **Table 4.7.4**.

Table 4.7.3 Profit or Loss Including Tamok (10% to 75% of Water Use Revenue)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	3.02	4.48	4.67	4.85
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	3.37	4.84	5.04	5.23
Expenditure	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Profit/ Loss	1.80	1.87	1.94	0.43	0.99	0.27	-0.45

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	10.06	10.45	10.90	11.33	11.83	20.52	20.52
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	10.45	10.83	11.29	11.73	12.24	20.94	20.95
Expenditure	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Profit/ Loss	3.71	0.85	0.15	-0.58	-1.47	5.78	4.26

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	20.52	20.52	20.52	30.78	214.08		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	20.96	20.97	20.98	31.13	221.88		
Expenditure	18.07	19.60	21.17	30.69	194.41		
Profit/ Loss	2.89	1.37	-0.19	0.44	27.47		

Source: JICA Study Team

Table 4.7.4 Cash Flow Including Tamok

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74
Investment			36.00				111.50
Cashflow			-36.00			1.67	-109.76

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	5.44	5.64	5.84	10.07	14.94	15.57	19.39
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	5.81	6.01	6.21	10.43	15.30	15.94	19.76
Expenditure	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Profit/ Loss	5.43	5.63	5.83	7.48	11.44	11.17	14.09
Investment	0.00	0.00	0.00	34.20	167.40	34.20	34.20
Cashflow	5.43	5.63	5.83	-26.72	-155.96	-23.03	-20.11

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	20.12	20.90	21.81	22.67	35.50	36.94	36.94
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	20.51	21.28	22.19	23.06	35.91	37.36	37.37
Expenditure	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Profit/ Loss	13.77	11.30	11.05	10.75	22.20	22.19	20.68
Investment	34.20	34.20	34.20	301.20	34.20	34.20	34.20
Cashflow	-20.43	-22.90	-23.15	-290.45	-12.00	-12.01	-13.52

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	36.94	36.94	36.94	36.94	422.96		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	37.38	37.38	37.39	37.29	430.76		
Expenditure	18.07	19.60	21.17	30.69	194.41		
Profit/ Loss	19.31	17.79	16.23	6.60	236.35		
Investment	34.20	34.20	34.20	0.00	1,026.50		
Cashflow&IRR	-14.89	-16.41	-17.97	6.60	4.89	FIRR=	0.06%
Residual value				795.04			

Source: JICA Study Team

4.8 Economic Analysis

4.8.1 Preconditions for Economic Analysis

(1) Costs

Costs consist of investment cost and operation costs similarly to financial analysis. However, in economic analysis, costs and benefits must be modified from market price to economic price. In particular, prices of imported goods must be border prices excluding customs and results of other trading policies, etc. When monetary amounts are expressed in foreign currency, market prices of imported equipment and materials are converted to border prices with conversion factors, which are specific to the countries. In Cambodia, The conversion factors are shown in ADB's Urban Water Supply Project report. (http://www.adb.org/projects/documents/Cambodia-urban-water-supply-project-rrp)

The conversion factors for capital costs and O&M costs are 0.96 and 0.92, respectively. The operational costs are the same as those in financial analysis.

(2) Benefits

In economic analysis, financial profits are excluded. Instead, social benefits of the project are included in the calculation. Social benefits of sewerage can be considered in several ways. At first, satisfaction of sewerage users can be mentioned. For this benefit, willingness-to-pay prices are surveyed. However, most users cannot imagine the un-existing service effects and additionally, people in developing countries cannot and do not want to pay for environmental purposes such as sewerage or pollution improvement. In this project, Social Survey is conducted, but the willingness-to-pay results are very low. Less than USD 1.5 per month accounts for more than 90%. This amount corresponds to 10% to 20% of water supply use monthly payments. That is similar to the actual ADB project drainage payments of 10% water supply charge. Since the willingness-to-pay price is too cheap, affordable price, that is, 1.5% of disposable household income for sewerage (or about 97.8% of average household income), based on the World Bank or ADB references is used instead of willingness-to-pay results in this economic analysis. In addition, benefits such as (i) increased land value, (ii) agricultural harvest improvement of water spinach, and (iii) decreasing cost medical care for such as itchy skin diseases, caused by the dirty wastewater, are considered.

4.8.2 Cheung Aek System EIRR

The investment costs are converted as the imported part is converted to border price described above using conversion factor, 0.96. The operation costs are the same as those of the financial analysis.

Concerning the benefits, users' benefits are calculated multiplying water volume and affordable sewerage price instead of sewerage use tariff. However, user numbers can be two alternatives. One is sewerage user numbers similar to those of financial analysis. The other is user numbers, which are final project object user numbers. The former is the actual user number in the year, but the latter is the planned area population in the year. Of course, the latter (benefit) is more than the former. The former concept is that the actual users are the benefit takers, but the latter concept is that the final project area users are the participants to pay for the project from the beginning. The latter seems appropriate.

Land value increase benefit is supposed to be 3% of land value. The land width is 50 meters and length of the Cheung Aek Lake is 32.3 km. The total land value increases are supposedly fulfilled when the project was completed 100% and so the change at each implementation stage reflects land values. Land value around the Cheung Aek Lake is supposedly USD 320/m^2 based on the web site information. If those sites are developed as housing lots, the land values may be more expensive, but

these are adopted as conservative values. However, the land values are estimated to increase as household income increases in the future.

Concerning water spinach in the Cheung Aek, the affected area, where wastewater directly discharged is too dirty to cultivate water spinach, is supposed to be 10% of the Cheung Aek Lake, that is, (total area-STP area)×0.1=(520 ha-16.3 ha)×0.1= 50.37 ha. Potentially, this area has USD 1,533/ha/dry season, but it is assumed that the productivity is recovered 100% at the project completion and till then it is proportional to the population coverage of the project. Rice fields around both lakes are supposed outside of the directly affected areas, but since water used for rice cultivation is polluted, rice growth and harvest are affected proportionally to the project coverage.

Medical care costs of farmers for dermatitis are supposed proportional to household income growth yearly. The total farmer numbers are calculated using cultivation areas and producers numbers according to "Spatial Analysis of Human Activities Performed in Cheung Aek inundated Lake, Cambodia" (Phearith Teang and Puy Lim, 2010).

EIRR result of total project user case (total final users) is shown in **Table 4.8.1**. The EIRR is 28.78%. Although it is usually said that 12% of EIRR is minimum, the calculated EIRR exceeds this 12%.

Table 4.8.1 Cheung Aek System EIRR (Final Users)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						35.01	37.48
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Medical Care						0.000	0.000
Operational Costs						0.38	0.38
Investment			35.36				108.85
Cash flow			-35.36			34.98	-71.75

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	40.12	42.94	45.96	49.18	52.63	56.32	60.26
Land Value Rise	0.00	0.00	0.00	5.46	0.02	0.02	0.03
Agri. & Fishery	0.01	0.01	0.01	0.10	0.10	0.11	0.12
Medical Care	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Operational Costs	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Investment					130.43		
Cash flow	39.75	42.57	45.59	51.79	-80.65	53.44	57.36

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	64.48	68.98	73.79	78.94	84.43	90.31	90.31
Land Value Rise	0.03	5.39	0.01	0.01	0.01	0.01	0.00
Agri. & Fishery	0.13	0.22	0.24	0.25	0.27	0.28	0.28
Medical Care	0.001	0.002	0.002	0.002	0.002	0.002	0.002
Operational Costs	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Investment				260.48			
Cash flow	61.54	69.39	68.80	-186.56	79.39	85.24	85.23

Year	2037	2038	2039	2040	Total		
Users' Benefit	90.31	90.31	90.31	90.31	1,332.37		
Land Value Rise	0.00	0.00	0.00	30.88	42.21		
Agri. & Fishery	0.28	0.28	0.28	0.79	3.77		
Medical Care	0.002	0.002	0.002	0.006	0.030		
Operational Costs	5.37	5.37	5.37	14.90	79.75		
Investment					535.12		
Cash flow	85.23	85.23	85.23	107.09	1,212.36	EIRR=	28.78%
Residual value				448.85			

Source: JICA Study Team

4.8.3 Tamok System EIRR

The method is similar to that of the Cheung Aek system. However, the Tamok system benefits and costs are added. Concerning the Tamok system, the following information is added.

- The length of the Tamok Lake is 29 km. Land value around the Tamok Lake is USD 220/m^2.
- Around the Tamok Lake, lotus cultivation is similar to water spinach in the Cheung Aek and it is assumed that present production is 3 million riels/ha/year×70 ha, but it is at the project completion stage and by then it is proportional to the project population coverage.
- Fishery benefits in the Tamok Lake are assumed similar to the rice cultivation affected.

The EIRR result of total project user case is shown in **Table 4.8.2**. The EIRR is 26.31%.

Table 4.8.2 Both Systems EIRR (Final Users)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						35.01	37.48
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Medical Care						0.000	0.000
Operational Costs						0.38	0.38
Investment			35.36				108.85
Cash flow			-35.36			34.98	-71.75

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	40.12	42.94	45.96	49.18	75.34	80.68	86.40
Land Value Rise	0.00	0.00	0.00	5.46	0.56	0.55	0.54
Agri. & Fishery	0.01	0.01	0.01	0.10	0.14	0.15	0.16
Medical Care	0.000	0.000	0.000	0.001	0.002	0.002	0.002
Operational Costs	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Investment				33.36	163.79	33.36	33.36
Cash flow	39.75	42.57	45.59	18.44	-91.60	43.27	48.07

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	92.52	99.06	106.05	113.53	121.53	130.08	130.08
Land Value Rise	0.66	6.06	0.67	0.65	0.82	0.83	0.87
Agri. & Fishery	0.18	0.28	0.30	0.32	0.35	0.38	0.38
Medical Care	0.002	0.003	0.003	0.004	0.004	0.004	0.004
Operational Costs	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Investment	33.36	33.36	33.36	293.84	33.36	33.36	33.36
Cash flow	53.26	62.07	62.52	-191.65	75.64	82.77	81.30

Year	2037	2038	2039	2040	Total		
Users' Benefit	130.08	130.08	130.08	130.08	1,806.28		
Land Value Rise	0.93	0.95	0.89	30.98	51.78		
Agri. & Fishery	0.39	0.39	0.38	0.80	4.74		
Medical Care	0.004	0.004	0.004	0.012	0.055		
Operational Costs	18.07	19.60	21.17	30.69	194.41		
Investment	33.36	33.36	33.36	0.00	1,002.10		
Cash flow	79.99	78.48	76.83	131.18	1,491.13	EIRR=	26.31%
Residual value				824.79			

Source: JICA Study Team

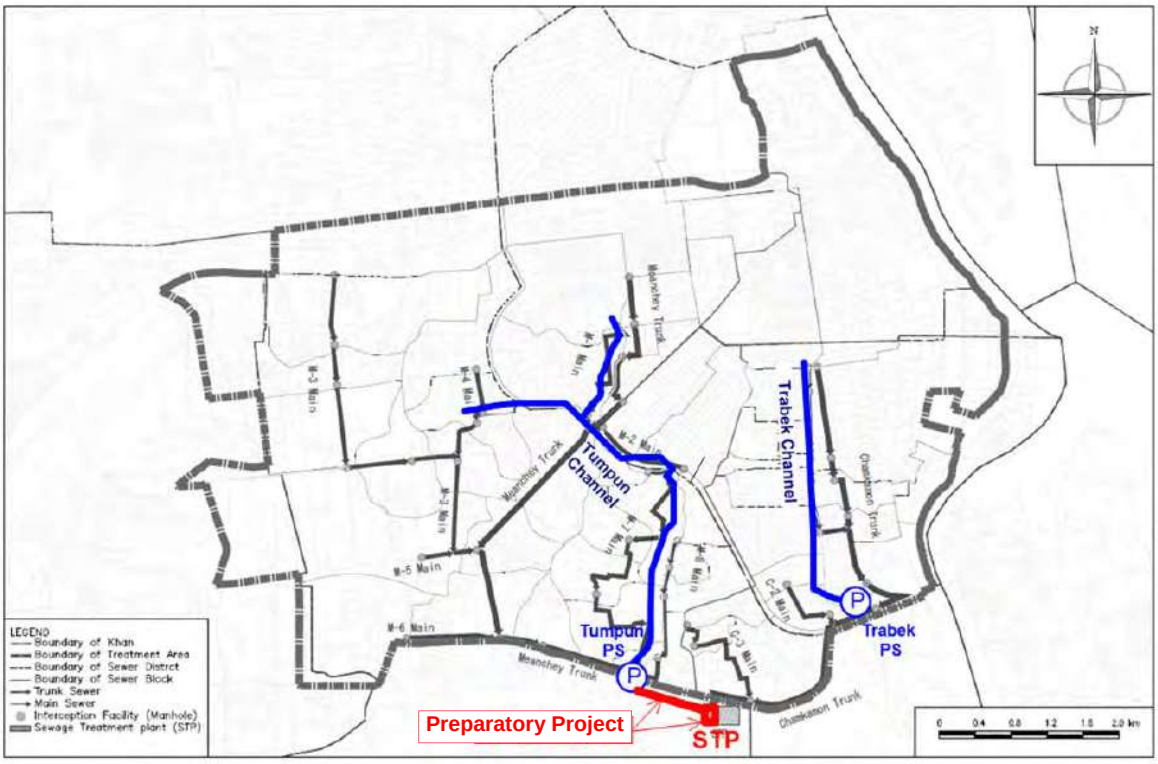
4.9 Selection of Priority Projects for Pre-F/S

As described in **Subsection 4.5**, a Preparatory Project is proposed in the Short-Term period to achieve technical skills for the preparation of full-scale construction and operation of sewage facilities, in parallel with establishing institutional and legal framework, considering current lack of institutional and legal provisions for sewage management in Phnom Penh.

The Preparatory Project is composed of small-scale STP and sewer pipe to collect and convey wastewater equivalent to the STP's capacity.

Capacity of the STP is set at 5,000 m^3/day, which deems to be a minimum unit to demonstrate the performance of the STP as well as the effectiveness of treatment method applied, and to accumulate technical skills and experience covering construction, operation and maintenance work. The sewer pipe for the STP is proposed to collect wastewater from outlet of Tumpun Pumping Station, which is located in the west of construction site of the STP. Thus the STP and sewer pipe, as shown in **Fig. 4.9.1** and **Table 4.9.1**, are provided for priority projects for Pre-F/S.

Along with the sewage treatment facilities, some measures such as landscaped pond for the people will be proposed in the Pre-F/S to visualize accomplishments and enhance public relations.



Source: JICA Study Team

Fig. 4.9.1 Location Map of Preparatory Project (Priority Project)

Table 4.9.1 Components of Preparatory Project (Priority Project)

Component	Contents
Sewer Pipe	Diameter : φ500 mm Length :about 1,300 m
STP	Capacity:5,000 m^3/dairy maximum

Source: JICA Study Team

CHAPTER 5 STRATEGY FOR FORMULATION OF DRAINAGE MANAGEMENT MASTER PLAN

5.1 Summary of Issues

Based on the study results discussed in **Chapter 2**, the current condition and issues related to drainage improvement in PPCC are summarized below:

- In many parts of the city center (inside of the inner ring dike), the drainage condition has been improved under the Japan's Grant Aid projects for drainage improvement (Phase 1, Phase 2 and Phase 3) and ADB's loan project. These projects were implemented on the basis of the Master Plan for drainage improvement in Phnom Penh City formulated in "The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh (1999)". On the other hand, drainage improvement on the northern side of Wat Phnom (eastern half of Sangkat Srah Chak) and most parts of Tuol Kok District have lagged behind other areas. Since these areas are densely-populated and still vulnerable to inundation damage, drainage improvement is important and urgently necessary. The rehabilitation or construction of new pumping stations, rehabilitation of drainage channels and improvement of drainage pipe network are necessary for these areas.

- In the drainage catchment area of Trabek Pumping Station located in the southern part of the city center, Trabek Pumping Station and Trabek Drainage Channel were improved under the ADB's loan project in 2003 and drainage pipes are being installed under the Japan's grant aid project. Since land development and reclamation have kept encroaching the Trabek regulation pond little by little year by year during 10 years after completion of the ADB project, the capacity of Trabek regulation pond has decreased, resulting in the decreased function of the Trabek drainage system. In addition, the indiscriminate land development in many parts of Phnom Penh metropolitan area has reduced the area of water body which has been functioning as temporary storage of stormwater. It is expected that these circumstances will generate other inundation damage in the near future.

- In the area between the inner ring and outer ring dikes, although urbanization is proceeding vigorously, drainage issues are not so prominent and hence drainage facility development has not been performed sufficiently in this area. However, inundation has increased and has recently become a new problem in the area. There are now strong requests for drainage improvement at the eastern side of Pochentong Airport, Chroy Changvar area and Chbar Ampov area.

- Nine (9) massive satellite city development zones, including completed and undergoing zones, exist in Phnom Penh at present. The respective developers planned and designed drainage facilities by themselves, but not under the unified standard. In addition, impact onto outside of development zone such as increase of ratio of run-off is not generally considered. One of the reasons for the issue above is that MLMUPC and PPCC which issues the permission for development, do not have any standard for drainage facility in large-scale land development. Accordingly, besides the provision that "stormwater drainage should be managed under the responsibility of developer in satellite city" defined in Sub-Decree No. 86, it is necessary to enact a law or set regulations, such as standard for installation of rainwater regulation reservoirs for disaster prevention in satellite city, and strengthen the enforcement capacity.

- As the result of capacity development of DPWT/DSD staff members through assistance from Japan and other countries, the capacity to operate and maintain the drainage facilities of DPWT/DSD has been improving. However, since the number of staff occupying management positions in the organization is still insufficient, it is necessary and important to continue enhancing the capacity development of DPWT/DSD staff.

- Although equipment for operation and maintenance (O&M) work of drainage facilities has been increasing gradually, they are still deficient in covering the whole PPCC area. Although more equipment is necessary for proper O&M work, in parallel with the enhancement of the equipment, it is also necessary to increase the number of personnel and strengthen the organizational structure to operate equipment properly.

5.2 Planning Frame

5.2.1 Target Year

Target year of the M/P should be 2035, same as that of sewage management.

5.2.2 Planning Scale

Planning scale of drainage facilities in the 1999 M/P was set with reference to the previous scale or case of similar cities. Since the previous drainage projects in Phnom Penh were implemented based on the planning scale set in the 1999 M/P and that the planning scale is considered as adequate, the same conditions shall be adopted for the new M/P.

- Major drainage facilities such as pumping stations, floodgates/sluiceways, regulation ponds, drainage mains, canals and channels (catchment area more than 1 km^2) will be designed as 5-year probable rainfall.

- Branch drainage pipes, channels/canals and sewer pipes will be designed as 2-year probable rainfall.

5.2.3 Drainage Area for Master Plan

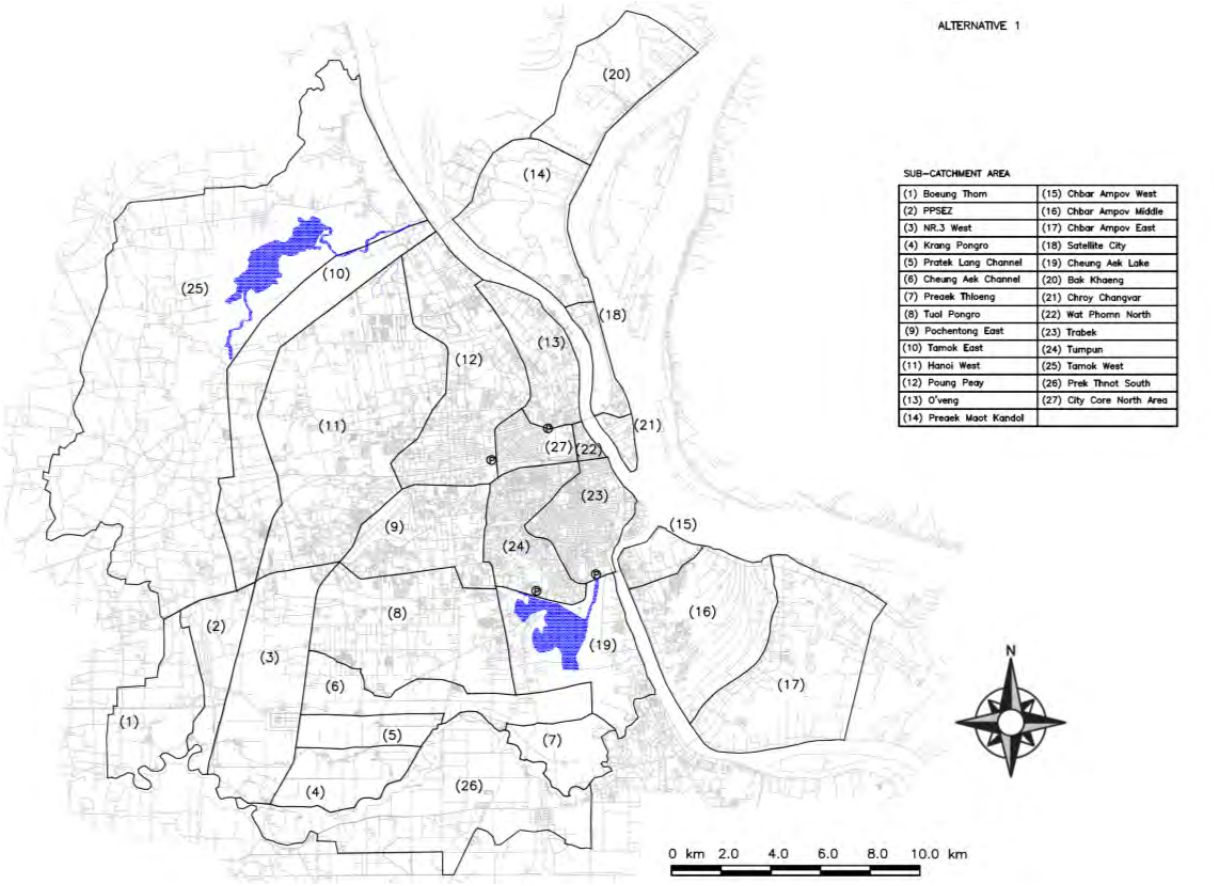
The Study Area, which is the whole administrative area of Phnom Penh Capital City, is divided into 27 drainage areas as shown in **Table 5.2.1** and **Fig. 5.2.1** for the formulation of M/P. The drainage plan for each drainage area will be formulated respectively.

Table 5.2.1 List of Drainage Areas

No.	Sub-Catchment Area	Area (km^2)
1	Boeung Thom	15.39
2	PPSEZ	10.56
3	NR.3 West	27.36
4	Krang Pongro	11.01
5	Pratek Lang Channel	7.17
6	Cheung Aek Channel	16.46
7	Preaek Thloeng	8.53
8	Tuol Pongro	32.98
9	Pochentong East	18.23
10	Tamok East	26.60
11	Hanoi West	59.46
12	Poung Peay	31.46
13	O'veng	12.15
14	Preaek Maot Kandol	22.43
15	Chbar Ampov West	4.77
16	Chbar Ampov Middle	25.63
17	Chbar Ampov East	34.32
18	Satellite City	4.63
19	Cheung Aek Lake	23.28
20	Bak Khaeng	18.74
21	Chroy Changvar	2.10
22	Wat Phnom North	1.17
23	Trabek	13.01

No.	Sub-Catchment Area	Area (km^2)
24	Tumpun	14.49
25	Tamok West	133.85
26	Prek Thnot South	39.97
27	City Core North Area	5.80
Total		621.73

Source: JICA Study Team



Source: JICA Study Team

Fig. 5.2.1 Map of Drainage Areas

5.2.4 Drainage Management Plan per Drainage Area

The optimum drainage plan will be formulated with consideration and comparison of alternatives in each drainage area. Tentative alternatives are listed in **Table 5.2.2**.

Table 5.2.2 List of Alternatives (Tentative)

No.	Drainage Area	Tentative Alternatives for Drainage Plan				
		Improvement of Drainage Pipes / Canals/ Channels	Construction / Extension of Drainage Pumping Station	Preservation/ Extension/ Creation of Regulation Pond/ Retarding Basin	No Change	Note
1	Boeung Thom	•	•	•	-	
2	PPSEZ	•	•	•	-	
3	NR.3 West	•	•	•	-	
4	Krang Pongro	•	•	•	-	
5	Pratek Lang Channel	•	-	-	-	
6	Cheung Aek Channel	•	-	-	-	
7	Preaek Thloeng	•	•	•	-	
8	Tuol Pongro	•	•	•	-	

No.	Drainage Area	Tentative Alternatives for Drainage Plan				
		Improvement of Drainage Pipes / Canals/ Channels	Construction / Extension of Drainage Pumping Station	Preservation/ Extension/ Creation of Regulation Pond/ Retarding Basin	No Change	Note
9	Pochentong East	•	•	•	-	
10	Tamok East	•	•	•	-	
11	Hanoi West	•	•	•	-	
12	Poung Peay	•	•	•	-	
13	O'veng	•	•	•	-	
14	Preaek Maot Kandol	•	•	•	-	
15	Chbar Ampov West	•	•	•	-	
16	Chbar Ampov Middle	•	•	•	-	
17	Chbar Ampov East	•	•	•	-	
18	Satellite City	•	-	-		*3
19	Cheung Aek Lake	•	-	-		*3
20	Bak Khaeng	•	•	•	-	
21	Chroy Changvar	•	•	•	-	
22	Wat Phnom North	•	•	•	-	
23	Trabek	•	•	•	-	*2
24	Tumpun	•	•	•	-	
25	Tamok West	•	-	•	•	*1
26	Prek Thnot South	•	-	-	•	*1
27	City Core North Area	•	•	•	-	

*1) Currently, non-inundation area; future land use is planned to be agriculture field.
*2) Area of ongoing project for flood protection and drainage improvement in the municipality of Phnom Penh.
*3) Area for large-scale development; responsibility for installation of drainage facilities falls under the developer.
Source: JICA Study Team

With the consideration and comparison of the above alternatives, the optimum drainage plan will be formulated. Following items are considered and presented in the M/P:

- *Structural Measures*: Preliminary drawings, construction cost estimate, O&M cost estimate and construction plan for drainage channels, pumping stations, drainage pipes and regulation ponds/retarding basin.
- *Non-Structural Measures:* Development of laws regarding standards for installation of stormwater regulation reservoirs in satellite city, environmental education, strengthening organization, human resource capacity development, securing financial resource.
- *Economic and Financial Analysis*

5.3 Design Criteria

5.3.1 Rainfall

Design rainfall will be prepared by model pattern of center-concentrated type. Hourly rainfall and daily rainfall are shown in **Table 5.3.1** as mentioned in **Subsection 2.1.3**.

Table 5.3.1 Design Rainfall

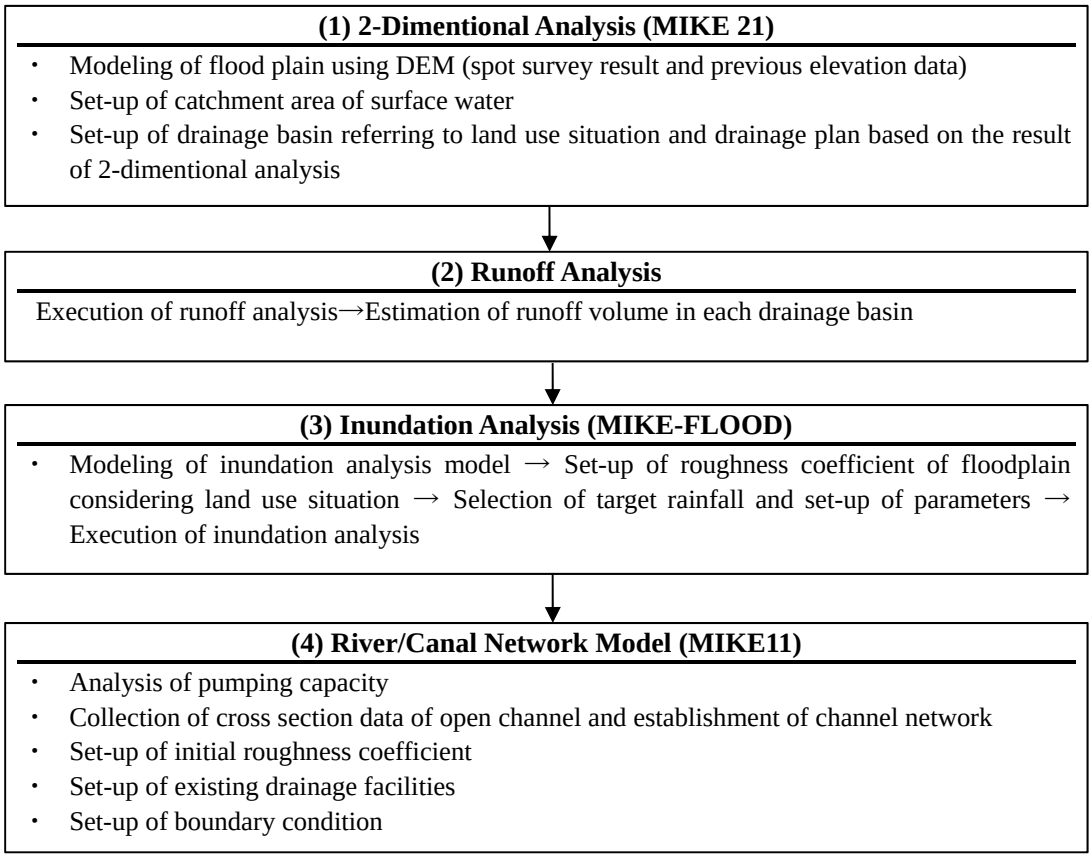
Scale of Probable Year	Hourly Rainfall (mm/h)	Daily Rainfall (mm/day)
2 year	44.8	87.8
5 year	63.2	112.3

Source: JICA Study Team

5.3.2 Catchment Area, Run-off and Inundation Analysis

(1) Methodology

Inland flooding is a very complicated phenomenon influenced by overflow, volume of runoff and topographical condition. Therefore, runoff and inundation analysis model must reappear past inland flooding and predict future flooding area. The procedure for establishing runoff and inundation analysis model and parameter fitting for reproducing flood situations is shown in **Fig. 5.3.1**.



Source: JICA Study Team

Fig. 5.3.1 Procedure of Establishment of Hydrological and Hydraulic Model

(2) Setup of Catchment Area

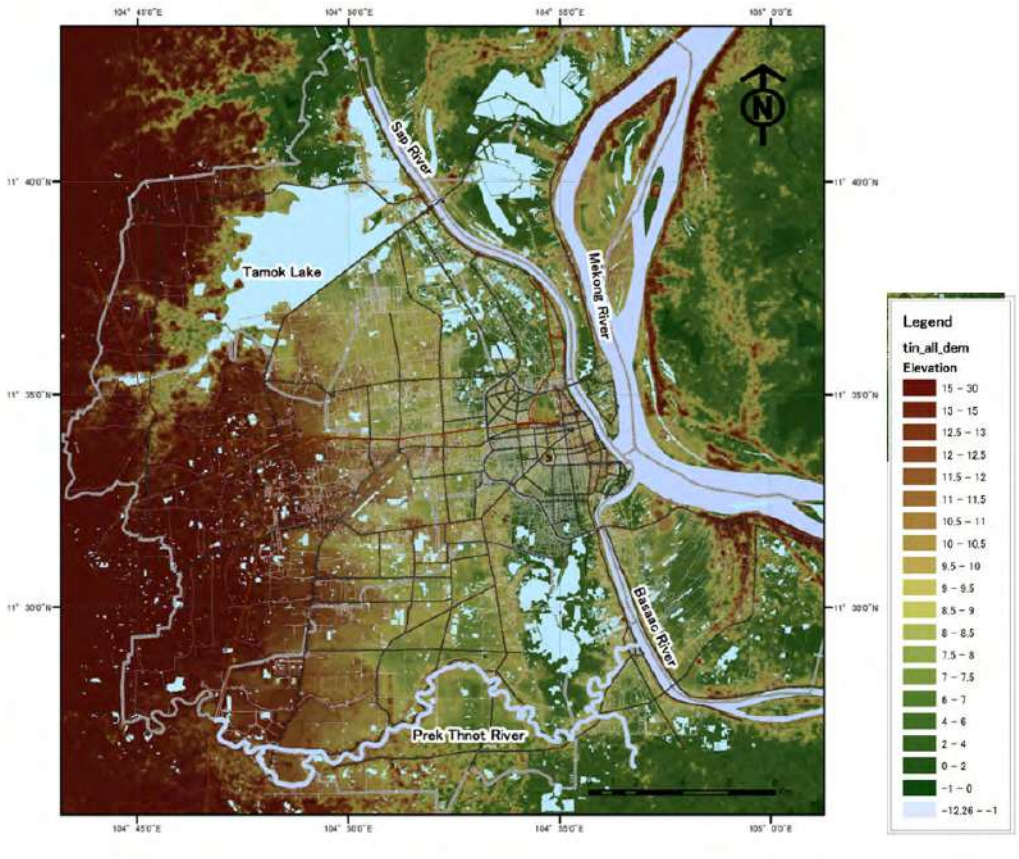
Catchment areas are set considering analysis of behaviour of surface water based on the relations between rainfall and inundation area. The analysis is performed using 2-dimentional unsteady flow model (MIKE 21); its outline is summarized in **Table 5.3.2**.

Table 5.3.2 Outline of Two-Dimensional Unsteady Flow Model (MIKE 21)

Items	Contents
Software	DHI MIKE 21
Grid Size	100 m×100 m
Elevation	Setup based on spot survey result and KOICA's survey result
Roughness Coefficient	Set up based on present land-use
Rainfall Pattern	Actual rainfall pattern of 26 September 2012
Computing Time	24 hrs

Source: JICA Study Team

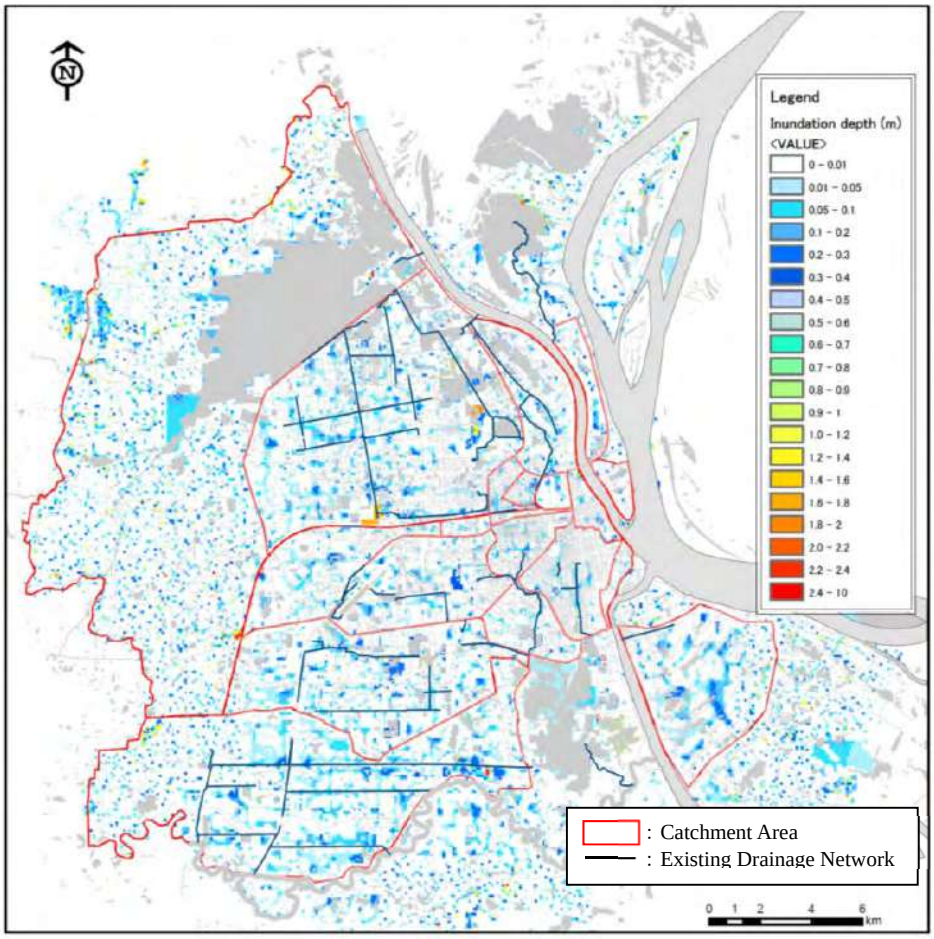
Elevation data of floodplain is set based on spot survey result in this Study and previous survey result of KOICA Project (The production of the National Base Map and the Establishment of the Master Plan for the National Spatial Data Infrastructure in Cambodia, KOICA, 2011) and SRTM's (Shuttle Radar Topography Mission) digital elevation data with 90 m resolution. Ground elevation of Phnom Penh metropolitan area is shown in **Fig. 5.3.2**.



Source: JICA Study Team using data of "The production of the National Base Map and the Establishment of the Master Plan for the National Spatial Data Infrastructure in Cambodia, KOICA" and SRTM (Shuttle Radar Topography Mission 3sec) and topographical survey result in the Study

Fig. 5.3.2 Ground Elevation of Phnom Penh Metropolitan Area

Fig. 5.3.3 shows the result that stormwater tends to inundate ponds and low-land (low-elevation area) and do not reach the existing channels. Hence, inundation occurs in PPCC. This phenomenon arises from the following reasons: (i) stormwater cannot easily travel due to gentle slope in the area and thus the stormwater is locally stored in the low-lying area; (ii) drainage channels as a whole have insufficient capacity due to limited gradient.



Source: JICA Study Team

Fig. 5.3.3 Catchment Area and Present Inundation Area (Analysis based on Rainfall on 26 September 2012)

(3) Calculation of Run-off (Run-off Analysis: Rational Formula)

(a) Selection of Run-off Model

Inundation in urban area usually occurs due to insufficient drainage capacity for peak flow caused by high-intensity rainfall in short-time duration. Therefore, the rational formula, with which run-off discharge can be computed on the safe side, is employed in consideration of present and future land-use in the target area, as enumerated below. The rational formula is shown below.

Rational formula $$Q = \frac{1}{360} \cdot C \cdot I \cdot A$$

Where,

Q : Run-off (m^3/s)
C : Run-off coefficient
I : Rainfall intensity (mm/h)
A : Drainage area (ha)

- Almost all target areas are developed and transformed into housing, commercial and industrial development, based on the land-use plan for the target year 2035.

- Above development is likely to accompany installation of secondary and tertiary drainage pipe/channel in the area. As a result, stormwater immediately concentrate on the channels evaluated in the analysis.

- Stormwater should quickly be conveyed and discharged to prevent inundation especially in urban area.

(b) Run-off Coefficient

Run-off coefficient is set up based on run-off coefficient by land-use (**Table 5.3.3**) and future land-use and then overall run-off coefficient is computed. Future land-use in the computation is set up based on the following concepts.

【Concepts of Future Land-use Setting】

- Land-use is based on PPCC's Land-use plan of 2035
- All large-scale development are completed by 2035
- Small-scale development is not considered except for development designated in PPCC's Land-use plan of 2035

≪Overall Run-off Coefficient≫

$$C = \sum_{m=1}^{m} Ci \cdot Ai / \sum_{m=1}^{m} Ai$$

where; C : Overall Run-off Coefficient
Ci : Run-off coefficient by land use
Ai : Area by land use
m : Number of land use

Table 5.3.3 Run-off Coefficient by Land Use

Land Use		Run-off Coefficient
Residential Area	Residential area with little unused area	0.80
Suburban Area 1	Suburban area with small gardens	0.65
Suburban Area 2	Suburban area with large gardens	0.40
Industrial Area		0.65
Agricultural Area		0.30
Park		0.25

Source: JICA Study Team

Overall run-off coefficient, which is set up based on the methodology described above, is summarized in **Table 5.3.4**.

Table 5.3.4 Overall Run-off Coefficient

No.	Name of Drainage Area	Area (km^2)	Area (km^2)								Overall Run-off Coefficient
			Residential Area	Sub-urban Area 1	Sub-urban Area 2	Industrial Area	Agri-cultur-al Area	Park	Pond	Total Area (except pond area)	
1	Boeung Thom	15.39	0.00	0.00	0.00	0.00	15.39	0.00	0.00	15.39	0.30
2	PPSEZ	10.56	0.00	0.00	0.00	3.48	7.08	0.00	0.00	10.56	0.42
3	NR.3 West	27.36	0.00	0.00	3.08	1.82	22.46	0.00	0.00	27.36	0.33
4	Krang Pongro	11.01	0.00	0.00	0.00	0.00	11.01	0.00	0.00	11.01	0.30
5	Pratek Lang Channel	7.17	0.00	0.00	0.00	0.00	7.17	0.00	0.00	7.17	0.30
6	Cheung Aek Channel	16.46	0.00	0.00	3.52	0.00	12.95	0.00	0.00	16.46	0.32

No.	Name of Drainage Area	Area (km^2)	Area (km^2)								Overall Run-off Coefficient
			Residential Area	Sub-urban Area 1	Sub-urban Area 2	Industrial Area	Agri-cultur-al Area	Park	Pond	Total Area (except pond area)	
7	Preaek Thloeng	8.53	0.00	0.00	0.00	0.00	8.53	0.00	0.00	8.53	0.30
8	Tuol Pongro	32.98	3.50	0.00	20.49	3.61	4.77	0.00	0.62	32.36	0.46
9	Pochentong East	18.23	0.00	0.00	18.23	0.00	0.00	0.00	0.00	18.23	0.40
10	Tamok East	26.60	0.00	0.00	0.00	6.72	19.88	0.00	0.00	26.60	0.39
11	Hanoi West	59.46	4.58	0.00	12.41	4.80	35.37	2.31	0.00	59.46	0.39
12	Poung Peay	31.64	7.28	12.18	12.18	0.00	0.00	0.00	0.00	31.64	0.59
13	O'veng	12.15	0.00	12.15	0.00	0.00	0.00	0.00	0.00	12.15	0.65
14	Preaek Maot Kandol	22.43	0.00	0.00	8.92	6.03	7.48	0.00	0.00	22.43	0.43
15	Chbar Ampov West	4.77	4.77	0.00	0.00	0.00	0.00	0.00	0.00	4.77	0.80
16	Chbar Ampov Middle	25.63	1.67	0.00	23.96	0.00	0.00	0.00	0.00	25.63	0.43
17	Chbar Ampov East	34.32	0.00	0.00	0.00	0.00	34.32	0.00	0.00	34.32	0.30
18	Satellite City	4.63	0.00	0.00	4.63	0.00	0.00	0.00	0.00	4.63	0.40
19	Cheung Aek Lake	23.28	3.39	0.00	7.82	0.00	7.84	0.00	4.23	19.05	0.43
20	Bak Khaeng	18.74	0.00	0.00	0.00	0.00	18.74	0.00	0.00	18.74	0.30
21	Chroy Changvar	2.10	0.00	0.00	2.10	0.00	0.00	0.00	0.00	2.10	0.40
22	Wat Phnom North	1.17	1.17	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.80
23	Trabek	13.01	2.58	10.23	0.00	0.00	0.00	0.00	0.20	12.81	0.68
24	Tumpun	14.49	1.99	3.34	8.82	0.00	0.00	0.00	0.34	14.15	0.52
25	Tamok West	133.85	1.99	0.00	0.00	0.00	0.00	0.00	0.34	1.99	0.80
26	Prek Thnot South	39.97	0.00	0.00	0.00	0.00	39.97	0.00	0.00	39.97	0.30
27	City Core North Area	5.80	1.17	0.00	4.62	0.00	0.00	0.00	0.00	5.80	0.48
Total		621.73	34.08	37.90	130.78	26.46	252.96	2.31	5.72	484.49	—

Source: JICA Study Team

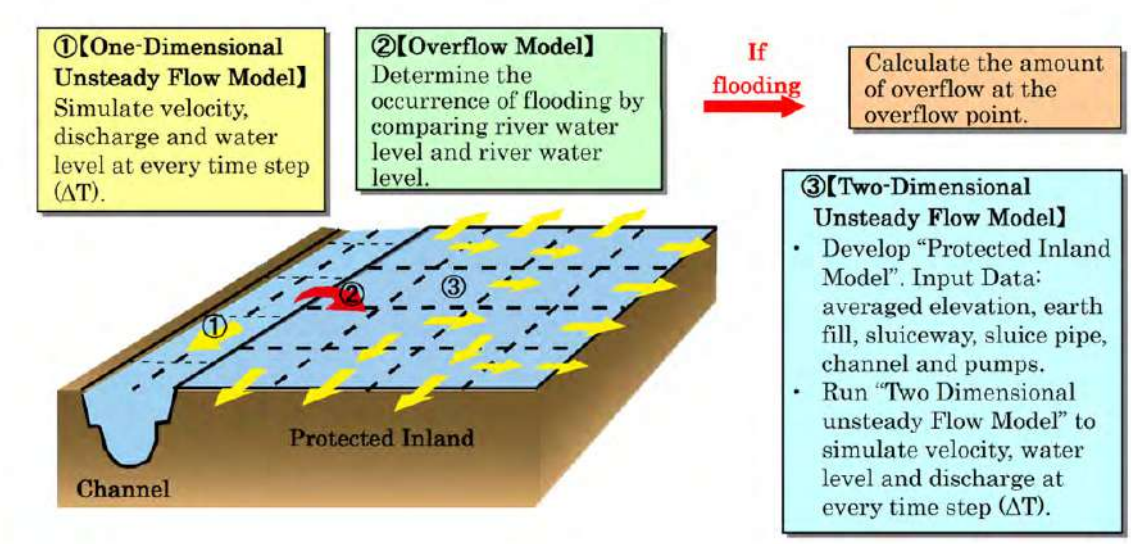
(c) Evaluation of Inundation (Inundation Analysis: Without-Project)

For the inundation analysis in floodplain, the two-dimensional unsteady flow analysis model is employed. Outline of inundation analysis model and image of analysis model is shown in **Table 5.3.5** and **Fig. 5.3.4**.

Table 5.3.5 Outline of Inundation Analysis Model

Items	Contents
Software	DHI MIKE-FLOOD
Grid Size	100 m×100 m
Elevation	Setup based on spot survey result and previous survey result
Evaporation	4 mm/day
Roughness Coefficient	Setup based on land-use (2035)

Source: JICA Study Team



Source: JICA Study Team

Fig. 5.3.4 Image of Inundation Analysis

CHAPTER 6 DRAINAGE MANAGEMENT MASTER PLAN

6.1 Improvement Plan for Stormwater Drainage Management

In principle, the improvement plan for stormwater drainage management is formulated primarily based on the following considerations:

- Original flow direction of existing drainage network in each drainage area
- Status of existing drainage facilities (drainage channel, pumping station and so forth)

Basic conditions for the formulation of the drainage management plan are enumerated below.

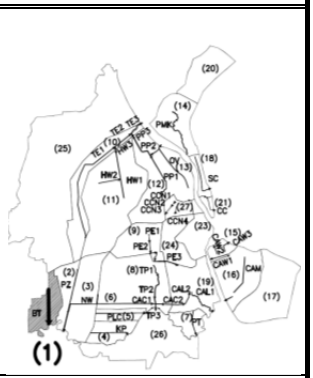
- One drainage area has one outlet.
- Flow direction of each drainage area is determined in consideration of topographical condition, land-use and status of existing drainage facilities.
- Priorities are placed on improvement of existing drainage facilities to minimize cost.
- Stormwater is in principle collected and conveyed by gravity
- Pumping station and sluiceway are proposed at crossing points of ring dikes and rivers, if necessary.

6.1.1 Improvement Plan for Each Drainage Area

Flow direction of each drainage area is in general determined based on topographical condition, status of existing drainage facilities and land-use. However, studies on the alternatives to "No.6 Cheung Aek Channel Drainage Area" and "No.8 Toul Pongro Drainage Area", as well as "No.12 Poung Peay Drainage Area" and "No.13 O'veng Drainage Area", are conducted to determine if these drainage areas are to be combined or separated.

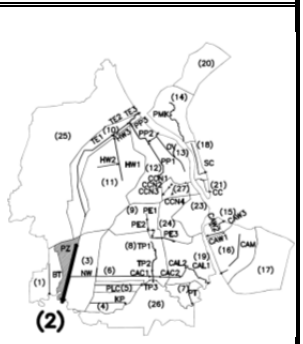
Improvement plan for drainage areas other than "No.6 Cheung Aek Channel Drainage Area" and "No.8 Toul Pongro Drainage Area", as well as "No.12 Poung Peay Drainage Area" and "No.13 O'veng Drainage Area", are thus summarised below.

(1) Boeung Thom Drainage Area (Drainage Area No.1)

Item	Contents	
Location	An area located in the southwestern edge of PPCC, and on the west of PPSEZ, bordered by National Road No.4 on the north, Prek Thnot River on the south, PPSEZ on the east and the city boundary of PPCC on the west.	
Land-use	Present: Almost all of the area is farmland Future: Farmland	
Salient features of drainage area	Ground surface elevation of the area is over 15 meter, gently sloping from west to east. Existing drainage channel of Pratek Lan drains stormwater with flow direction from west to east by gravity.	
Issues	PPSEZ and its adjacent area in the west annually suffer from inundation in about 1 to 5 days in the rainy season, due to the reasons that (i) Pratek Lan channel has a bottleneck at the crossing point of railway and (ii) capacity of Pratek Lan channel is not enough.	
Strategy for improvement	New construction of drainage channel is proposed to drain stormwater by gravity from north to south in order to reduce burden to existing Pratek Lang Channel.	
Structural measure	Drainage channel (Sluiceway)	

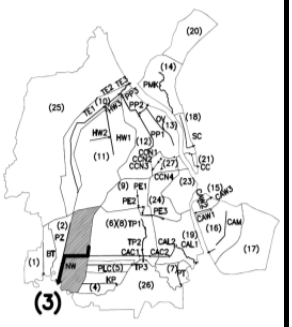
Source: JICA Study Team

(2) PPSEZ Drainage Area (Drainage Area No.2)

Item	Contents	
Location	An area bordered by National Road No. 4 on the north, Prek Thnot River on the south, PPSEZ on the west and railway on the east.	
Land-use	Present: Industrial area and farmland Future: SEZ, used as industrial and farmland	
Salient features of drainage area	This area is new development area flatly reclaimed. Residential development is in progress along National Road No.4. An existing channel of Pratek Lan, which is utilized for irrigation and drainage drains stormwater by gravity, running from west to east in the premise of PPSEZ.	
Issues	PPSEZ and its adjacent area in the west suffer from inundation in about 2 to 5 days in the rainy season once in about 2 years, due to the reasons that (i) Pratek Lan Channel has a bottleneck at the crossing point of railway and (ii) capacity of Pratek Lan Channel is not enough.	
Strategy for improvement	Improvement of existing drainage channel is proposed to drain stormwater from PPSEZ and its adjacent area in the east to Prek Thnot River by gravity.	
Structural measure	Drainage channel	

Source: JICA Study Team

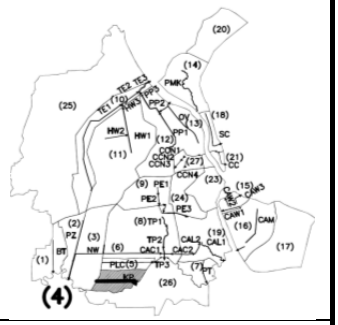
(3) NR.3 West Drainage Area (Drainage Area No.3)

Item	Contents	
Location	An area bordered by National Road No.4 on the north, Prek Thnot River on the south, railway on the west and National Road No.3 on the east.	
Land-use	Present: About 20% of the total or area along National Road No.4 is industrial and residential area. The other area is farmland. Future: About 30% is urbanized area and SEZ and the other area is farmland.	
Salient features of drainage area	Land development is in progress from north to south. Existing channels of Pratek Lan and Cheung Aek is utilized for irrigation and drainage but they have insufficient capacity. There exists another channel along National Road No.3, running from north to south, but being disconnected in spots. Irrigation channels are widely installed in a grid pattern in the southern part of the drainage area (paddy field area). At present no inundation damage is detected.	
Issues	The northern part of the area will be developed for residential use and SEZ, and would suffer from inundation. Thus, construction of drainage channel running from west to east is required to drain stormwater of the area.	
Strategy for improvement	New construction of drainage channel is proposed to drain stormwater to Prek Thnot River by gravity, since the area is bordered by roads and railway in higher elevation on the north, east and west side.	
Structural measure	Drainage channel	

Source: JICA Study Team

(4) Krang Pongro Drainage Area (Drainage Area No.4)

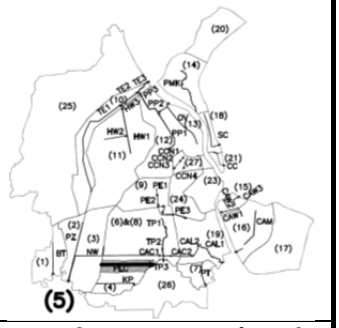
Item	Contents
Location	An area in the catchment area of Krang Pongro Channel, bordered by Prek Thnot River in the south and east.
Land-use	Present: Farmland Future: Farmland and low density residential area
Salient features of drainage area	This area gradually slopes from west to east. An existing channel named Krang Pongro, which is utilized for irrigation and drainage, crosses the area from west to east but has small capacity. At present no inundation damage is detected and the damage in the future will be limited because the area is dominated by farmland.
Issues	Improvement of existing channel is required.
Strategy for improvement	Improvement of existing Krang Pongro Channel is proposed to accommodate stormwater from the area and drain them to Prek Thnot River by gravity.
Structural measure	Drainage channel



Source: JICA Study Team

(5) Pratek Lang Channel Drainage Area (Drainage Area No.5)

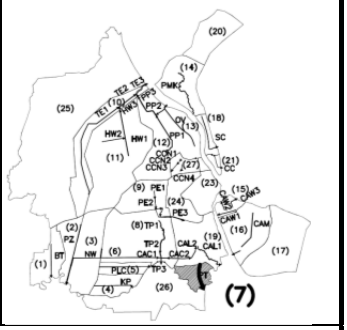
Item	Contents
Location	A part of Pratek Lang channel's catchment area, covering area along National Road No.3 in the east, bordered by Prek Thnot River on the east.
Land-use	Present: Farmland Future: Farmland and low density residential area
Salient features of drainage area	This area gradually slopes from west to east. An existing channel named Pratek Lang, which is utilized for irrigation and drainage, cross the area from west to east but has small capacity. At present no inundation damage is detected and the damage in the future will be limited because the area is dominated by farmland.
Issues	Improvement of existing channel is required.
Strategy for improvement	Improvement of existing Pratek Lang Channel is proposed to accommodate stormwater from the area and drain them to Prek Thnot River by gravity.
Structural measure	Drainage channel



Source: JICA Study Team

(6) Preaek Thloeng Drainage Area (Drainage Area No.7)

Item	Contents
Location	An area in the south of Cheung Aek lake, bordered by Prek Thnot River on the east, west and south. This area is also a part of large-scale development area of ING City.
Land-use	Present: Farmland and wetland Future: Low density residential area
Salient features of drainage area	This area is topographically flat and is occupied by wetland in the centre of the area. At present no inundation damage is detected. In the land-use plan for year 2035, this area is categorized into low density residential area but is likely to be developed because the area is included in ING City.
Issues	Installation of new drainage channel is required for future provisions.
Strategy for improvement	Specification for the new drainage channel is proposed to drain stormwater to Prek Thnot River by gravity. It is recommendable that the drainage channel should be installed by developer of ING City or be installed by PPCC depending on the progress of development.
Structural	Drainage channel

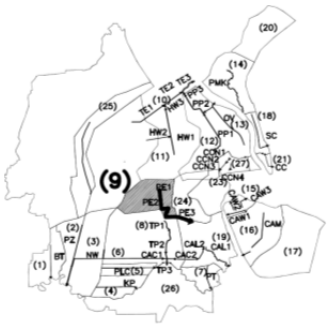


Item	Contents
measure	

Source: JICA Study Team

(7) Pochentong East Drainage Area (Drainage Area No.9)

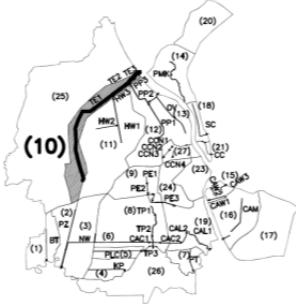
Item	Contents
Location	An area including Phnom Penh International Airport (former Pochentong International Airport) and its adjacent area in the east and southeast, bordered by National Road No. 4 on the north and west, Veng Sreng road (former BOT road) on the south, and catchment boundary of Tumpun Drainage Area on the east.
Land-use	Present: high density residential area, commercial and industrial area (factory, shop). Future: high density residential areas, commercial and industrial area, economic development zone.
Salient features of drainage area	This area is topographically flat and is in most urbanized area of Phnom Penh in parallel with expansion of urbanization toward west in recent years.
Issues	Installation of drainage facilities have not been catching up with rapid urbanization. Inundation occurs especially in the southern part of the area. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	Installation of new box culvert is proposed to connect exiting drainage channels/pipes, and drain stormwater to Cheung Aek Lake, through Veng Sreng road (former BOT road) and new pumping station and Moul drainage channel.
Structural measure	Box culvert, Pumping station, Regulation pond and Drainage channel.



Source: JICA Study Team

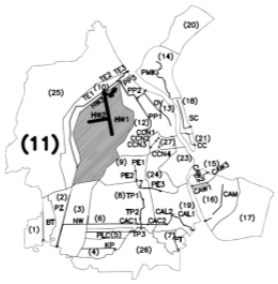
(8) Tamok East Drainage Area (Drainage Area No.10)

Item	Contents
Location	An area located in the north and west of Kop Srov Dike, which forms outer ring dike of Phnom Penh.
Land-use	Present: Farmland, wetland Future: Economic development zone, farmland and low density residential area
Salient features of drainage area	Drainage facilities is required to drain stormwater from proposed large-scale development area, which is located in the north of intersection of Kop Srov Dike and National Road No.4. At present no inundation damage is detected,
Issues	Installation of drainage channel is required for future provisions.
Strategy for improvement	Stormwater from the area is drained toward north because National Road No.4 forms watershed dividing Phnom Penh into the north and south. New drainage channel is proposed along Kop Srov Dike, by which stormwater is drained to Sap river via Tamok Lake.
Structural measure	Drainage channel



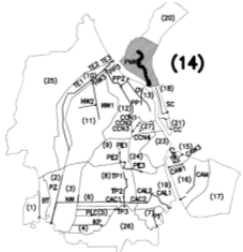
Source: JICA Study Team

(9) Hanoi West Drainage Area (Drainage Area No.11)

Item	Contents	
Location	An area located inside of Kop Srov Dike, which forms outer ring dike of Phnom Penh, bordered by Kop Srov Dike on the north and west, Hanoi road (or St.1019) on the east and National Road No.4 on the south.	
Land-use	Present: High density residential area, commercial and industrial area along National Road No.4 in the south and Hanoi Road in the east. The other area is farmland and low density residential area. Future: Residential area, commercial and industrial area in the south and east, farmland and low density residential area in the north and west.	
Salient features of drainage area Issues	This area, including an area in the north-western region of international airport and National Road No.4, is topographically flat and suffers from inundation. Stormwater from the area is drained to Toul Sampov Channel and pumped up by Tuol Sampov Pumping Station (located in the west of Kop Srov Pumping Station), and finally discharged to Tamok Lake. As with Pochentong East Drainage Area, urbanization in the southern part of the area is in progress.	
Issues	Installation of drainage facilities has not been catching up with rapid urbanization, and thus inundation occurs in the area. With the progress of urbanization, inundation damage will be bigger.	
Strategy for improvement	Drainage channel starting from downstream end is proposed for future provisions. Existing drainage facilities, namely, Tuol Sampov Channel, Tuol Bakha 1 Channel and Tuol Dampov Pumping Station, are augmented to accommodate stormwater from the area. At the same time, the other existing channels are maintained to keep present condition. Additionally, a regulation pond is proposed to reduce initial investment, as well as O&M cost for the pumping station.	
Structural measure	Drainage channel, Pumping station and Regulation pond	

Source: JICA Study Team

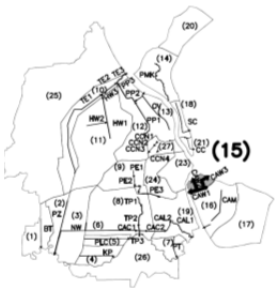
(10) Preaek Maot Kandol Drainage Area (Drainage Area No.14)

Item	Contents	
Location	An area located at the northern peninsular part of Chroy Changvar District, sandwiched between Mekong River and Sap River.	
Land-use	Present: Low density residential area along with National Road No.6. The other area is wetland Future: Economic development zones and low density residential area	
Salient features of drainage area	This area is located on lowland and wetland. Northern part of the area is developed for economic development zone. At present not inundation damage is detected.	
Issues	Improvement of existing channel is required for future provision.	
Strategy for improvement	In principle the developer should improve existing drainage channels to drain stormwater from the area to Sap River by gravity when present wetland is developed into residential area, or PPCC should install drainage facilities on behalf of the developer, depending on the progress of the development.	
Structural measure	Drainage channel	

Source: JICA Study Team

(11) Chbar Ampov West Drainage Area (Drainage Area No.15)

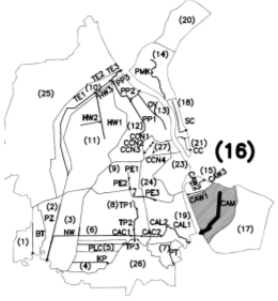
Item	Contents
Location	An area located at the north-western part of Chbar Ampov District and in the north of Barang Channel, sandwiched between Mekong River and Bassac River.
Land-use	Present: Residential and commercial area located on the west half, as well as wetland and future development area on the east half Future: high density residential area and cluster of high-rise buildings
Salient features of drainage area	This area is topographically flat and the urbanization is in progress, especially in the western part of the area. All of the area will be urbanized in the future
Issues	River water flows back to Barang Channel in the rainy season because of high water level of Bassac. A lot of houses and large amount of garbage are found in and along the Barang Channel. Installation of drainage facilities has not been catching up with rapid urbanization and thus inundation occurs. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	Improvement of Barang Channel and construction of new pumping station is proposed to drain stormwater in the rainy season. Improvement of existing channel is also proposed to drain stormwater from the northern part of National Road No.1 and discharge them to Bassac River and Mekong River by gravity, when the area is developed in the future.
Structural measure	Drainage channel and Pumping station



Source: JICA Study Team

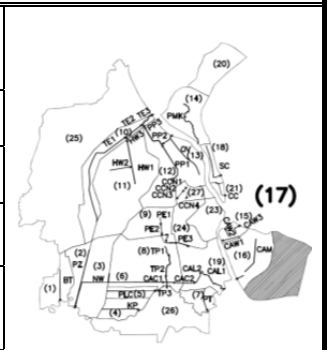
(12) Chbar Ampov Middle Drainage Area (Drainage Area No.16)

Item	Contents
Location	An area located at the central part of Chbar Ampov District, sandwiched between Mekong River and Bassac River.
Land-use	Present: Residential and commercial area along National Road and dike road in the west, and wetland and farmland in the east Future : high and low density residential area
Salient features of drainage area	This area is topographically flat and almost all area is in wetland. Urbanization in the western part of the area, being adjacent to city centre, has been in progress, and in the future the area is developed into residential area. On the other hand, the eastern part of the drainage area is wetland in which stormwater is retained.
Issues	In parallel with urbanization, inundation problem has emerged because wetlands in the drainage area have no outlet. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	In principle the developer should install drainage channels and pumping station to drain stormwater from the area even to high water level observed in the rainy season, and the should also install regulation pond to reduce initial investment, as well as O&M cost for the pumping station, when the wetlands in the area is developed into residential area, or PPCC should, on behalf of the developer, install drainage facilities depending on the progress of development.
Structural measure	Drainage channel, Pumping Station and Regulation Pond



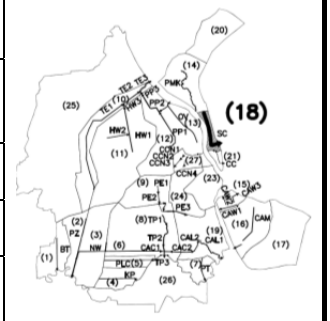
Source: JICA Study Team

(13) Chbar Ampov East Drainage Area (Drainage Area No.17)

Item	Contents	
Location	An area located at the eastern part of Chbar Ampov District, sandwiched between Mekong River and Bassac River.	
Land-use	Present: Wetland and low density residential area Future: No land-use plan	
Salient features of drainage area	Almost all area is wetland.	
Issues	Not available.	
Strategy for improvement	No plan is proposed since at present and in the future no inundation is detected or anticipated. In addition, future land-use plan is not available.	
Structural measure	Not proposed.	

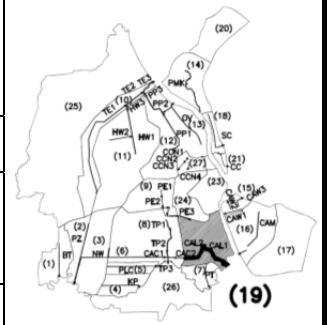
Source: JICA Study Team

(14) Satellite City Drainage Area (Drainage Area No.18)

Item	Contents	
Location	An area located at the central peninsular part of Chroy Changvar District, sandwiched between Mekong River and Sap River.	
Land-use	Present: low density residential area along National Road No.6. The other area is being developed into residential area Future: Low density residential area	
Salient features of drainage area	No drainage facilities are installed. Almost all area is located in large-scale development area of Satellite City.	
Issues	Installation of drainage facilities is required in parallel with development.	
Strategy for improvement	In principle the developer should install drainage facilities. Specifications for the drainage facilities are proposed to drain stormwater to Mekong or Sap Rivers by gravity.	
Structural measure	Drainage channel	

Source: JICA Study Team

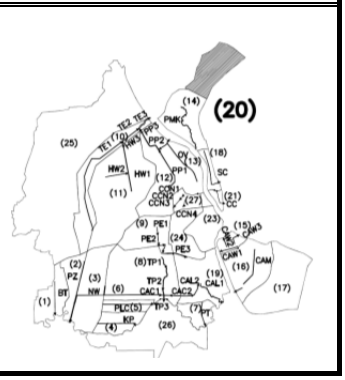
(15) Cheung Aek Lake Drainage Area (Drainage Area No.19)

Item	Contents	
Location	An area including Cheung Aek Lake and its surrounding area, bordered by Tumpun ring Dike (St.371) and St.271 on the north, National Road No.2 on the east, Cheung Aek road on the west, and Prek Thnot River on the southeast. The area is also a part of large-scale development area of ING City.	
Land-use	Present: Farmland, lake and wetland Future: Low and high density residential and commercial area	
Salient features of drainage area	This area is located in ING City. ING City has ownership of the land except for water bodies. All the area under the ING's ownership is reclaimed in the future in parallel with development.	
Issues	In principle ING should install drainage facilities in the area in parallel with land development.	
Strategy for improvement	Specification for the drainage facilities is proposed to drain stormwater to Prek Thnot River by gravity. Based on the specification, ING or PPCC should install the drainage facilities depending on the progress of development	
Structural measure	Drainage channel	

Source: JICA Study Team

(16) Bak Khaeng Drainage Area (Drainage Area No.20)

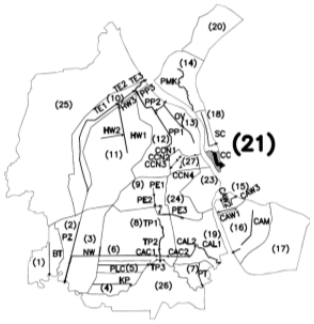
Item	Contents
Location	An area located along National Road No.6 and on the northern edge of Chroy Changvar District.
Land-use	Present: Wetland and low-density residential area along National Road Future: No land-use plan
Salient features of drainage area	Almost all area is wetland.
Issues	Not available.
Strategy for improvement	No plan is proposed since at present and in the future no inundation is detected or anticipated. In addition, future land-use plan is not available.
Structural measure	Not proposed.



Source: JICA Study Team

(17) Chroy Changvar Drainage Area (Drainage Area No.21)

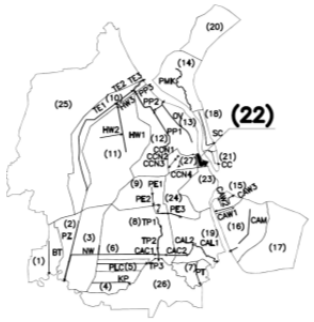
Item	Contents
Location	An area located at the southern edge of peninsular part of Chroy Changvar District, sandwiched between Mekong River and Sap River.
Land-use	Present: Low density residential area and wetland Future: Low density residential area
Salient features of drainage area	Urbanized area is formed on the reclaimed area. Existing residential area located at the centre of peninsula suffers from inundation with the expansion of reclamation in the surrounding area. All the area is developed into low density residential area according to future land-use plan of Phnom Penh.
Issues	Inundation occurs due to the absence of existing drainage channel and outlet to discharge stormwater from the central lowland area. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	New construction of drainage channel is proposed to drain stormwater to Mekong River or Sap River by gravity.
Structural measure	Drainage channel



Source: JICA Study Team

(18) Wat Phnom North Drainage Area (Drainage Area No.22)

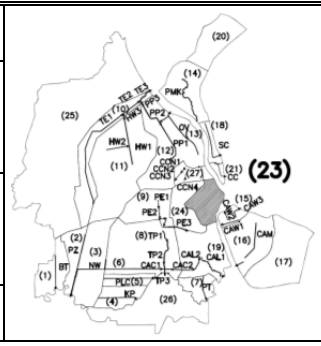
Item	Contents
Location	An area located in the northeast of city centre of Phnom Penh, bordered by the approach road of Japan Bridge on the north, Sap River on the east, Monivong street on the west and St.102 on the south.
Land-use	Present: High density residential area, commercial and administrative area Future: High density residential area, commercial and administrative area
Salient features of drainage area	Improvement work in the area was requested and studied in Phase 2(*1) but was finally excluded from the project components from viewpoint of project size and priority. Priority of improvement of this area is therefore very high.
Issues	Inundation frequently occurs in the rainy season. Furthermore, lots of facilities like hospital and governmental office situate in the area, so that improvement of drainage facilities is urgent.
Strategy for improvement	Establishment of drainage pipe network is proposed, along with construction of underground reservoir and pumping station to drain stormwater to Sap River. In addition, installation of



Item	Contents
	interceptor is proposed to divert sewage to Trabek Channel in the dry and rainy season.
Structural measure	Drainage channel, Regulation Pond and Pumping Station

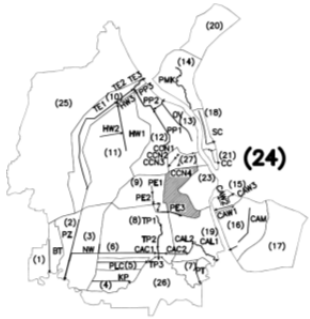
(*1) The Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh (Phase 2)
Source: JICA Study Team

(19) Trabek Drainage Area (Drainage Area No.23)

Item	Contents	
Location	An area located at the eastern part of city center of Phnom Penh.	
Land-use	Present: High density residential area, commercial and administrative area Future: High density residential area, commercial and administrative area	
Salient features of drainage area	This area is the target area of Phase 2(*1) and Phase 3(*2), and is located in the catchment area of existing Trabek Pumping Station. Urgent and minimum improvement work is done with the implementation of Phase 2 and 3 projects.	
Issues	Screens installed in Phase 2 project are not functioning due to clogging triggered by extensive amount of trash than expected.	
Strategy for improvement	Improvement of the screen installed in Phase 2 project is proposed.	
Structural measure	Mechanical screen (4 locations)	

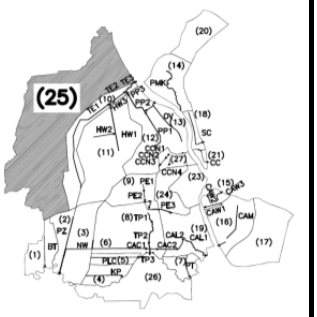
(*1) The Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh (Phase 2)
(*2) The Project for Flood Protection and Drainage Improvement in the Phnom Penh Capital City (Phase 3)
Source: JICA Study Team

(20) Tumpun Drainage Area (Drainage Area No.24)

Item	Contents	
Location	An area located in the western part of city centre of Phnom Penh.	
Land-use	Present: High density residential area, commercial and administrative area Future: High density residential area, commercial and administrative area	
Salient features of drainage area	This area is located on the target area of Phase 1(*1) and is in the catchment area of Tumpun Pumping Station. With the implementation of Phase 1 project, urgent and minimum improvement works in the downstream of the drainage area are already done.	
Issues	There exists newly urbanized area in which drainage facilities are not installed.	
Strategy for Improvement	No project is proposed in the M/P.	
Structural measure	Not proposed.	

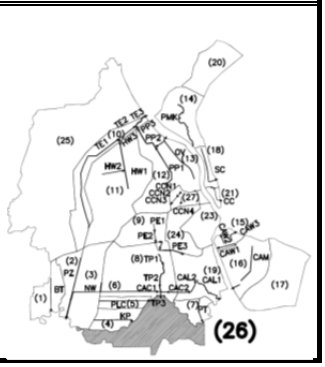
(*1) The Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh
Source: JICA Study Team

(21) Tamok West Drainage Area (Drainage Area No.25)

Item	Contents	
Location	An area located at outer area of Kop Srov Ring Dike, bordered by the north-western city boundary.	
Land-use	Present: Farmland, lowland and low density residential area Future: Farmland, lowland, low density residential area. No land-use planning available	
Salient features of drainage area	This area is located in the catchment area of Tamok Lake with natural river flowing to Tamok Lake. At the outlet of Sap River, a weir is installed with the assistance of Korea to control water level because the area is affected by fluctuation of water level of Sap River. In the rainy season, stormwater is discharged to wetland located in the north of Tamok Lake. Urbanization is not in progress and the drainage area is dominated by farmland except for Tamok Lake and wetland surrounding the lake.	
Issues	Not available.	
Strategy for improvement	No improvement work is proposed because the drainage area gradually slopes from west to east and no inundation is detected at present and in the future.	
Structural measure	Preservation of existing rivers.	

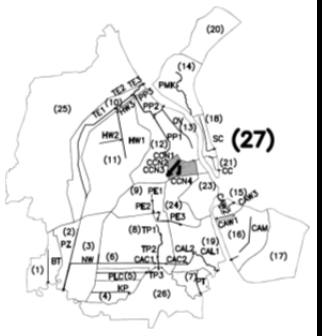
Source: JICA Study Team

(22) Prek Thnot South Drainage Area (Drainage Area No.26)

Item	Contents	
Location	An area located at the southern edge of PPCC, bordered by south bank of Prek Thnot River.	
Land-use	Present: Farmland and low density residential area Future: No land-use plan	
Salient features of drainage area	Almost all area is farmland.	
Issues	Not available.	
Strategy for improvement	No plan is proposed since at present and in the future no inundation is detected or anticipated, and future land-use plan is not available.	
Structural measure	Not proposed.	

Source: JICA Study Team

(23) City Core North Area Drainage Area (Drainage Area No.27)

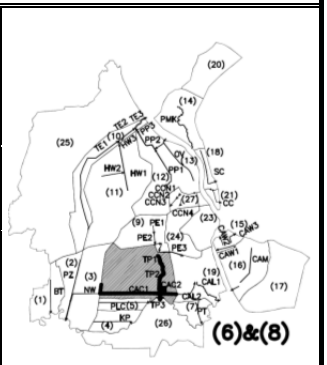
Item	Contents	
Location	An area located inside inner ring dike and in the north-western part of city centre, covering the northern part along National Road No. 4 in Tuol Kok District and the reclaimed area of Boeung Kak Lake, bordered by St.598 on the west; St.355, St.273 and St.70 on the north; Monivong Boulevard on the east; and Russian Boulevard on the south.	
Land-use	Present: High density residential and commercial area Future: High density residential and commercial area	
Salient features of drainage area	Improvement of this area is proposed in 1999 M/P but is not yet implemented in viewpoint of priority, so that the priority is very high. The drainage area includes catchment area of Tuol Kork and Tuol Kork 2 Pumping Stations in Tuol Kork District. SHUKAKU reclaimed Boeung Kak Lake and now installing drainage facilities in parallel with the development.	
Issues	Inundation frequently occurs especially in the northern part of Tuol Kok District in the rainy season. The northern part of Tuol Kok District has high population density and a large number of commercial facilities, so that the installation of drainage facilities is urgent.	
Strategy for	Construction of new box culvert and a sluice way is proposed in the northern part of Tuol Kok	

Item	Contents
improvement	District to drain stormwater from inside inner ring dike by gravity. On the other hand, SHUKAKU should install drainage facilities in the reclaimed area of Boeung Kak Lake
Structural measure	Box culvert and Sluiceway

Source: JICA Study Team

6.1.2 Alternative Study on Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8)

In this subsection, alternative study on whether to combine Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8) is conducted. Based on the alternative study, the two drainage areas are combined in the drainage management M/P.

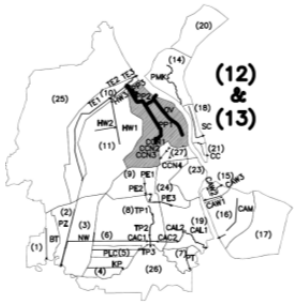
Item	Contents
Location	An area located in the south of Pochentong East Drainage Area and in the catchment area of Cheung Aek Channel, bordered by Veng Sreng road (former BOT road) on the north, National Road No.3 on the west and Cheung Aek Channel on the south. 
Land-use	Present: Farmland, wetland, residential area and factories Future: low and high density residential area, economic development zone
Salient features of drainage area	This area gradually slopes from west to east. The existing channels cannot drain stormwater especially in the rainy season due to lack of capacity. The stormwater is thus retained in wetlands scattered in the area. Land development in the northern part of the area is in progress and the area will be finally developed from farmland into residential area.
Issues	Inundation damage is already detected in the northern part of the drainage area. Almost all Tuol Pongro Drainage Area will be highly urbanized in the future, and as a result the inundation damage will be bigger. Drainage facilities in the area should be improved in the early stages.
Strategy for improvement	Preservation of existing Tuol Pongro Channel and its tributaries is proposed. In addition, installation of new drainage channel, which runs through wetlands in the eastern part of the drainage area, is proposed to drain stormwater to the downstream end by gravity. New pumping station is also proposed at the downstream end of the new channel to discharge the stormwater to Prek Thnot River. Further, new regulation pond is proposed to downsize the pumping equipment and reduce initial investment and O&M cost. Improvement of existing Cheung Aek Channel is also proposed to connect it to the new regulation pond and drain stormwater to Prek Thnot River.
Structural measure	Drainage channel, Pumping Station, Regulation pond

Source: JICA Study Team

6.1.3 Alternative Study on Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13)

In this subsection, alternative study on whether to combine Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13) is conducted. Based on the alternative study, the two drainage areas are combined in the drainage management M/P.

Item	Contents
Location	An area located inside of Kop Srov Ring Dike in the north of Phnom Penh, bordered by Hanoi Street on the west; Kop Srov Dike on the north; National Road No.5 on the east; and St.355, St.273 and St.70 on the south.
Land-use	Present: Southern part of the area is high density residential area, commercial and industrial area, while northern part of the area is residential development area and wetland. Future: High density residential area and commercial and industrial area
Salient features of drainage area	This area includes inundated area sandwiched between National Road No.4 and railway. Stormwater from the drainage area is conveyed to the north through Poung Peay and O'veng Channels and discharged through Kop Srov Pumping Station or Svay Pak Sluiceway. Urbanization in the southern part of the drainage area is in progress. Almost entire area, including wetland, is to be developed into residential, commercial area in the future.
Issues	Installation of drainage facilities has not been catching up with rapid urbanization and thus inundation occurs in the area. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	Improvement of drainage channel starting from downstream end is proposed for future provisions. The improvement work includes (i) connection of Poung Peay and O'veng Channels at the north of Poung Peay Lake, (ii) augmentation of Poung Peay and O'veng Channels to accommodate stormwater from the area, (iii) preservation of the other drainage channels to keep present condition and (iv) construction of regulation pond at Kop Slov Pumping Station to reduce initial investment, as well as O&M cost for the pumping station. On the other hand, improvement of Svay Pak Pumping Station is not proposed in the M/P.
Structural measure	Drainage channel, Pumping station and Regulation pond

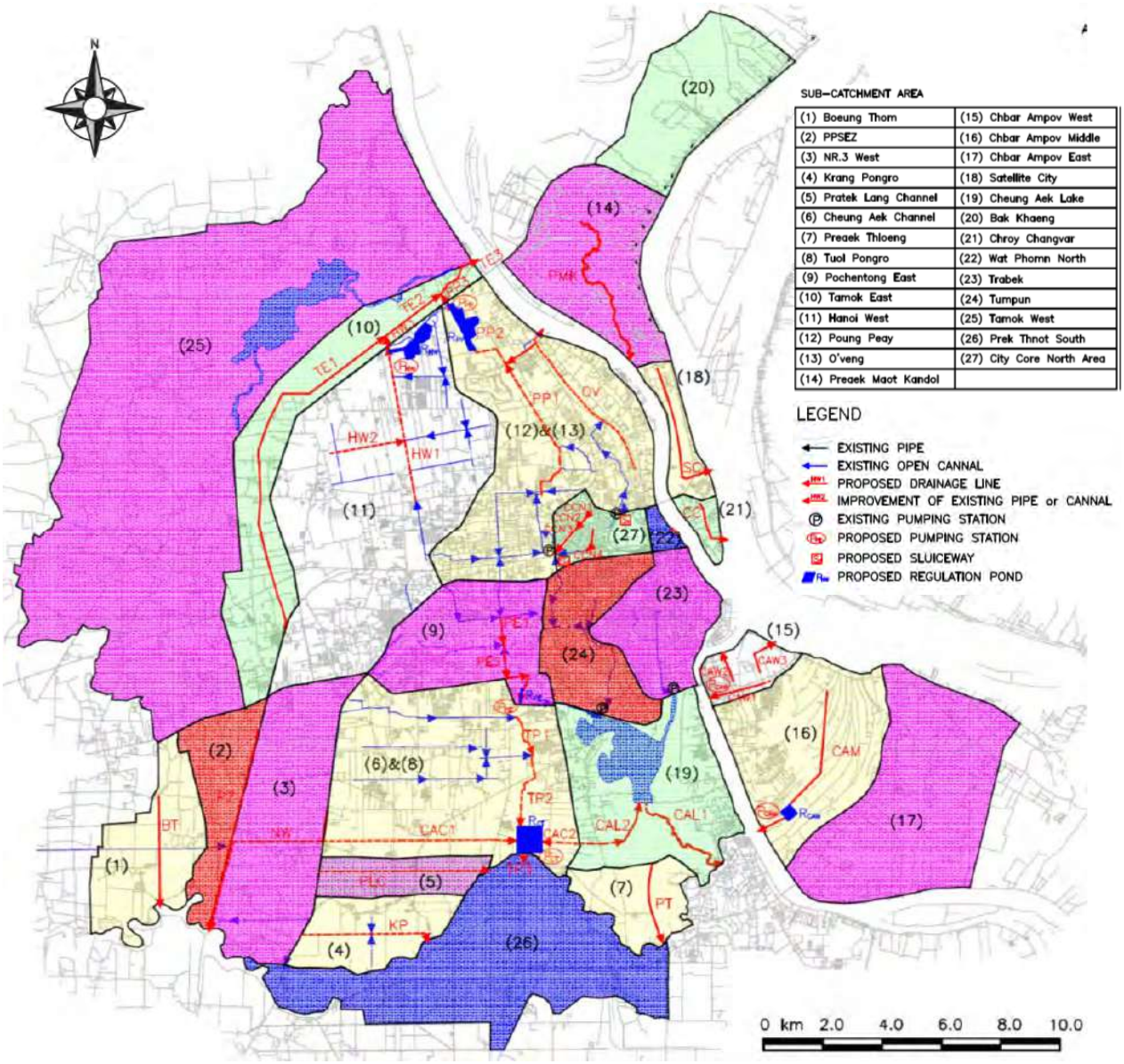


Source: JICA Study Team

6.2 Drainage Facilities Plan

6.2.1 General Layout of Drainage Management Plan

Based on the above discussion, general layout of drainage management plan is shown in **Fig. 6.2.1**.



Source : JICA Study Team

Fig. 6.2.1 General Layout of Proposed Drainage Management Plan

6.2.2 Run-off Analysis

Result of run-off analysis applying Rational Formula is summarized in **Tables 6.2.1** and **6.2.2**.

Run-off (m^3/s) $$Q = \frac{1}{360} \cdot C \cdot I \cdot A$$

Where,

Q : Run-off (m^3/s)
C : Run-off coefficient
I : Rainfall intensity (mm/h):$I=5{,}009.12 \times (T+31.38)^{-0.98}$
[Return period of 5 years, and T:duration of rainfall (min)]
A : Drainage area (ha)

Table 6.2.1 Run-off Analysis (1/2)

No.	Sub-Catchment Area	Name of Facilities	Area km^2	Time of Concentration										R_5	Overall run-off coefficient	Run-off calculated m^3/s	Design Flow m^3/s	Proposed Works
				Inlet Time					Drain Flow Time				Tc min	5-Year Rainfall mm/hr				
				Li m	n: roughness	Starting G.L.	End G.L.	Ti min	Ld m	Starting G.L.	End G.L.	Td min						
1	Boeung Thom	BT	15.39	1,940	0.20	16.90	16.60	180.9	3,670	16.60	16.20	68.0	248.9	20.0	0.30	25.65	26.00	New Construction
2	PPSEZ	PZ	10.56	2,670	0.15	16.30	14.70	133.8	7,010	14.70	12.58	116.8	250.7	19.9	0.42	24.50	25.00	Improvement
3	NR.3 West	NW	27.36	5,560	0.15	13.33	12.29	247.4	7,150	12.29	11.96	132.4	379.8	13.7	0.33	34.46	35.00	Improvement
4	Krang Pongro	KP	11.01	1,430	0.15	13.57	11.71	83.4	4,490	11.71	8.82	74.8	158.3	29.3	0.30	26.93	27.00	Improvement
5	Pratek Lang Channel	PLC	7.17	780	0.15	11.62	11.28	81.1	5,720	11.30	8.86	95.3	176.5	26.8	0.30	16.02	17.00	Improvement
6 & 8	Cheung Aek Channel & Tuol Pongro	CAC1	10.26	1,010	0.10	12.95	12.37	71.0	7,730	12.37	7.58	128.8	199.9	24.2	0.40	27.55	28.00	Improvement
		CAC2	2.02	1,160	0.10	9.77	9.57	100.4	1,840	9.57	7.58	20.4	120.8	36.4	0.40	8.16	9.00	Improvement
		TP1	11.68	6,110	0.06	13.00	7.90	118.8	2,220	7.90	5.90	37.0	155.8	29.7	0.46	44.33	45.00	Improvement
		TP2	33.00	6,110	0.06	13.00	7.90	118.8	4,560	8.07	7.70	84.4	203.3	23.8	0.46	100.39	101.00	New Construction
		TP3	45.28	6,110	0.06	13.00	7.90	118.8	7,450	7.70	7.63	138.0	256.8	19.5	0.46	112.62	113.00	New Construction
7	Preaek Thloeng	PT	8.53	2,820	0.10	7.91	4.50	96.4	2,740	4.50	4.44	50.7	147.2	31.1	0.30	22.13	23.00	New Construction
9	Pochentong East	PE1	7.57	2,930	0.06	11.40	11.00	128.7	1,010	11.00	9.10	11.2	139.9	32.4	0.40	27.27	28.00	New Construction
		PE2	18.23	2,930	0.06	11.40	11.00	128.7	3,890	11.00	9.60	64.8	193.5	24.8	0.40	50.26	51.00	New Construction
10	Tamok East	TE1	22.52	2,620	0.15	14.60	14.00	166.0	12,460	14.00	7.00	207.7	373.7	13.9	0.39	34.02	35.00	New Construction
		TE2	25.46	2,620	0.15	14.60	14.00	166.0	14,780	14.00	6.30	246.3	412.4	12.8	0.39	45.18	46.00	New Construction
		TE3	26.60	2,620	0.15	14.60	14.00	166.0	16,620	14.00	10.43	307.8	473.8	11.2	0.39	57.36	58.00	New Construction
11	Hanoi West	HW1	59.46	9,460	0.10	14.50	10.30	214.4	5,290	10.30	8.70	88.2	302.6	16.8	0.39	108.53	109.00	Improvement
		HW2	12.20	2,370	0.10	12.90	10.16	89.8	2,560	10.16	8.87	42.7	132.5	33.8	0.39	44.72	45.00	Improvement
12&13	Poung Peay & O'veng	PP1	24.98	5,690	0.06	8.38	7.21	159.4	5,460	7.90	7.20	101.1	260.6	19.2	0.62	82.70	83.00	Improvement
		PP2	49.59	5,690	0.06	8.38	7.21	159.4	8,740	7.90	7.50	161.9	321.3	16.0	0.62	136.41	137.00	Improvement
		OV	15.04	3,580	0.06	8.80	7.80	119.6	7,310	7.80	7.20	135.4	254.9	19.6	0.62	50.74	51.00	Improvement

Source: JICA Study Team

Table 6.2.2 Run-off Analysis (2/2)

No.	Sub-Catchment Area	Name of Facilities	Area km^2	Time of Concentration										R_5 5-Year Rainfall mm/hr	Overall run-off coefficient	Run-off calculated m^3/s	Design Flow m^3/s	Proposed Works
				Inlet Time					Drain Flow Time				Tc min					
				Li m	n: roughness	Starting G.L.	End G.L.	Ti min	Ld m	Starting G.L.	End G.L.	Td min						
14	Preaek Maot Kandol	PMK	22.43	2,770	0.06	11.40	7.19	71.4	7,000	7.19	6.54	129.6	201.0	24.0	0.43	64.39	65.00	Improvement
15	Chbar Ampov West	CAW1	1.22	1,060	0.06	11.00	10.60	63.1	2,140	10.60	9.70	35.7	98.8	42.4	0.80	11.49	12.00	Improvement
		CAW2	1.36	990	0.06	10.50	10.40	83.2	1,040	9.51	9.29	19.3	102.4	41.3	0.80	12.51	13.00	Improvement
		CAW3	2.19	730	0.06	10.40	10.20	57.2	1,460	11.00	10.72	27.0	84.2	47.7	0.80	23.24	24.00	Improvement
16	Chbar Ampov Middle	CAM	25.63	2,040	0.06	9.80	8.40	74.5	5,300	7.70	6.80	98.1	172.7	27.3	0.43	83.57	84.00	New Construction
17	Chbar Ampov East																	
18	Satellite City	SC	4.63	720	0.06	9.75	8.76	39.0	4,780	7.11	7.02	88.5	127.5	34.9	0.40	17.96	18.00	New Construction
19	Cheung Aek Lake	CAL1	27.45	4,250	0.10	5.66	4.69	172.4	4,230	4.69	8.80	78.3	250.7	19.9	0.43	65.18	66.00	Improvement
		CAL2	4.05	740	0.10	9.02	8.49	58.3	2,820	8.49	4.69	31.3	89.7	45.5	0.43	22.04	23.00	Improvement
20	Bak Khaeng																	No Proposed Works
21	Chroy Changvar	CC	2.10	870	0.06	10.07	10.00	82.6	1,650	10.72	10.56	30.6	113.1	38.3	0.40	8.92	9.00	New Construction
22	Wat Phnom North			Drainage pipes, pumping station and underground reservoir will be constructed in the Project for Flood Protection and Drainage Improvement in the Phnom Penh Capital City (Phase 4)														New Construction
23	Trabek			Drainage pipes, pumping station and underground reservoir will be constructed in the Project for Flood Protection and Implemented in the Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh (Phase 2 and 3) Mechanical screens will be installed in the existing pumping stations in the Project for Flood Protection and Drainage Improvement in the Phnom Penh Capital City (Phase 4)														Improvement
24	Tumpun			Implemented in the Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh (Phase 1)														No Proposed Works
25	Tamok West																	No Proposed Works
26	Prek Thnot South																	No Proposed Works
27	City Core North Area	CCN1 CCN2 CCN3 CCN4 S1 S2		Box culvert and sluiceway will be constructed in the Project for Flood Protection and Drainage Improvement in the Phnom Penh Capital City (Phase 4)														New Construction

Source: JICA Study Team

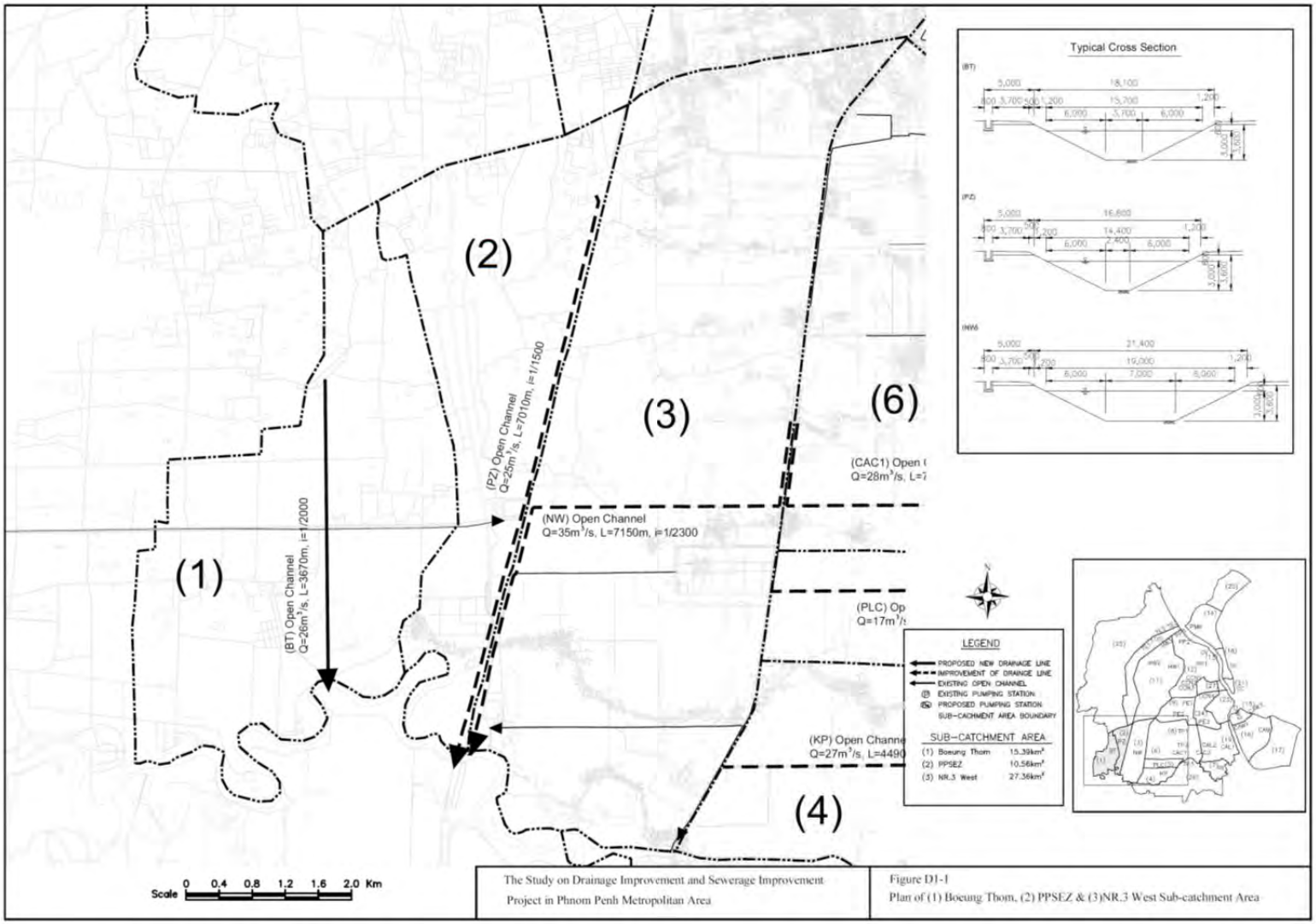
6.2.3 Planning of Drainage Channels and Pipes

Based on the result of run-off, drainage channels and pipes are proposed as summarised in **Table 6.2.3,** and general map of each drainage area is shown in **Fig.6.2.2** to **Fig.6.2.8**.

Table 6.2.3 Summary of Proposed Drainage Channels and Pipes

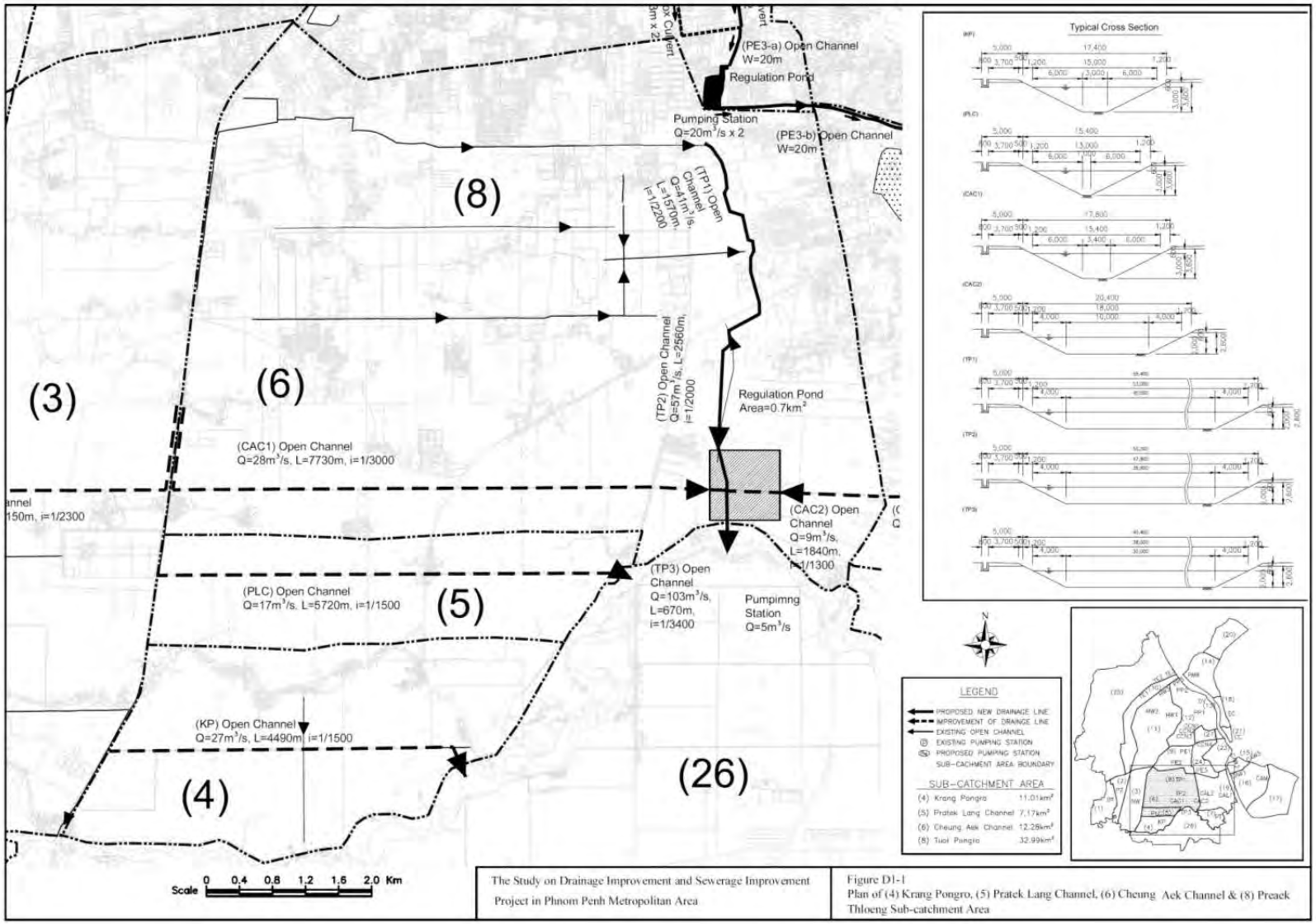
No.	Drainage Area	Name of Facilities	Area	R_5 5-Year Rainfall Int.	Discharge Q_5	Proposed Works	Facilities	Length	Slope	Drainage Channel /Box Culvert Width b	Drainage Channel /Box Culvert Depth h
			km2	mm/hr	m^3/s			m	1/I	m	m
1	Boeung Thom	BT	15.39	20.0	26.00	New Construction	Open Cannal	3,670	2,000	15.7	3.6
2	PPSEZ	PZ	10.56	19.9	25.00	Improvement	Open Cannal	7,010	1,500	14.4	3.6
3	NR.3 West	NW	27.36	13.7	35.00	Improvement	Open Cannal	7,150	2,300	19.0	3.6
4	Krang Pongro	KP	11.01	29.3	27.00	Improvement	Open Cannal	4,490	1,500	15.0	3.6
5	Pratek Lang Channel	PLC	7.17	26.8	17.00	Improvement	Open Cannal	5,720	1,500	13.0	3.6
6&8	Cheung Aek Channel & Tuol Pongro	CAC1	10.26	24.2	28.00	Improvement	Open Cannal	7,730	3,000	22.0	3.6
		CAC2	2.02	36.4	9.00	Improvement	Open Cannal	1,840	1,300	18.0	2.6
		TP1	11.68	29.7	45.00	Improvement	Open Cannal	2,220	2,200	38.0	2.6
		TP2	33.00	23.8	101.00	New Construction	Open Cannal	2,560	2,000	53.0	2.6
		TP3	45.28	19.5	113.00	New Construction	Open Cannal	670	3,400	47.9	3.6
		P_{CT}				New Construction	Pumping Station				
		R_{CT}				New Construction	Regulation Pond				
7	Preaek Thloeng	PT	8.53	31.1	23.00	New Construction	Open Cannal	2,740	1,800	14.6	3.6
9	Pochentong East	PE1	7.57	32.4	28.00	New Construction	Box Culvert	1,010	2,600	W3.5m x H2.5m x 3 Barrel	
		PE2	18.23	24.8	51.00	New Construction	Box Culvert	2,880	2,600	W4m x H3m x 4 Barrel	
		P_{PE}				New Construction	Pumping Station				
		R_{PE}				New Construction	Regulation Pond				
		PE3						2,660	1,800	20.0	
10	Tamok East	TE1	22.52	13.9	35.00	New Construction	Open Cannal	12,460	3,000	24.5	3.6
		TE2	25.46	12.8	46.00	New Construction	Open Cannal	2,320	2,000	57.0	3.6
		TE3	26.60	11.2	58.00	New Construction	Open Cannal	1,840	2,000	102.0	3.6
11	Hanoi West	HW1	59.46	16.8	109.00	Improvement	Open Cannal	5,290	2,700	42.4	3.6
		HW2	12.20	33.8	45.00	Improvement	Open Cannal	2,560	2,000	21.0	3.6
		HW3				New Construction	RCP	450		φ1800 x 3 Barrel	
		P_{HW}				New Construction	Pumping Station				
		R_{HW}				New Construction	Regulation Pond				
12&13	Poung Peay & O'veng	PP1	24.98	19.2	83.00	Improvement	Open Cannal	5,460	3,200	36.8	3.6
		PP2	49.59	16.0	137.00	Improvement	Open Cannal	3,100	3,600	56.8	3.6
		PP3				New Construction	RCP	310		φ2000 x 4 Barrel	
		P_{PP}				New Construction	Pumping Station				
		OV	15.04	19.6	51.00	Improvement	Open Cannal	7,310	2,800	24.9	3.6
		R_{PP}				New Construction	Regulation Pond				
14	Preaek Maot Kandol	PMK	22.43	24.0	65.00	Improvement	Open Cannal	7,000	3,000	30.1	3.6
15	Chbar Ampov West	CAW1	1.22	42.4	12.00	Improvement	Open Cannal	2,140	1,900	13.0	3.6
		CAW2	1.36	41.3	13.00	Improvement	Open Cannal	1,040	2,100	13.0	3.6
		CAW3	2.19	47.7	24.00	Improvement	Open Cannal	1,460	1,900	14.9	3.6
		P_{CAW}				New Construction	Pumping Station				
16	Chbar Ampov Middle	CAM	25.63	27.3	84.00	New Construction	Open Cannal	5,300	3,200	37.2	3.6
		P_{CAM}				New Construction	Pumping Station				
		R_{CAM}				New Construction	Regulation Pond				
17	Chbar Ampov East										
18	Satellite City	SC	4.63	34.9	18.00	New Construction	Open Cannal	4,780	1,700	13.0	3.6
19	Cheung Aek Lake	CAL1	27.45	19.9	66.00	Improvement	Open Cannal	4,230	3,000	30.5	3.6
		CAL2	4.05	45.5	23.00	Improvement	Open Cannal	2,820	1,500	18.5	3.6
20	Bak Khaeng					No Proposed Works					
21	Chroy Changvar	CC	2.10	38.3	9.00	New Construction	Box Culvert	1,650	1,000	W3.0m x H3.0m	
22	Wat Phnom North		Drainage Pipe Under Ground Reservoir Pumping Station, will be constructed in Phase IV.								
23	Trabek		Implemented in Phase II & Phase III but mechanical screen will be installed in existing Pumping Station.								
24	Tumpun		Implemented in Phase I.								
25	Tamok West					No Proposed Works					
26	Prek Thnot South					No Proposed Works					
27	City Core North Area		Box Culvert and Sluiceway will be constructed in Phase IV.								

Source : JICA Study Team



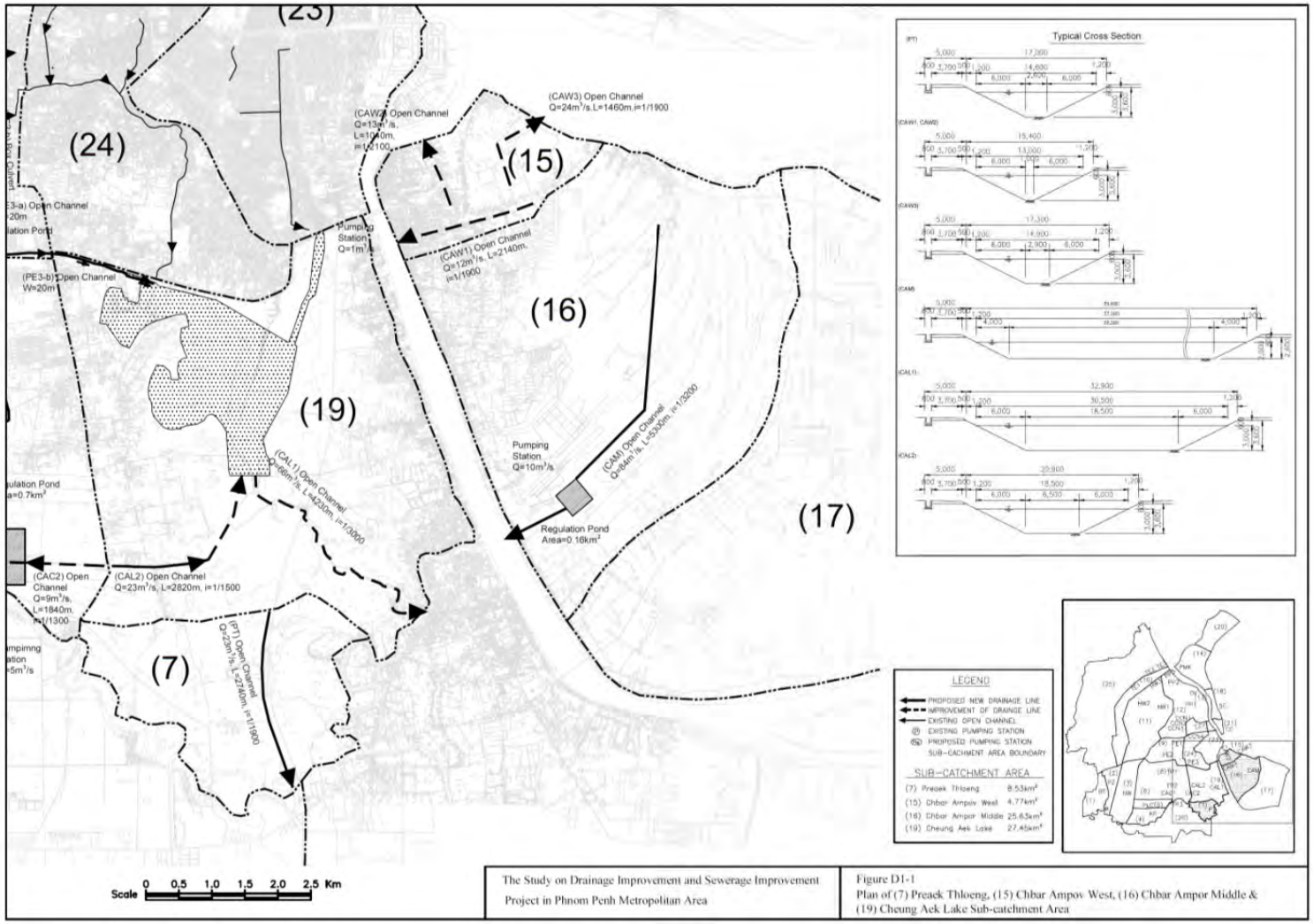
Source: JICA Study Team

Fig. 6.2.2 General Map of Drainage Improvement (1/7) (Boeung Thom/PPSEZ/NR. 3 West Drainage Areas)



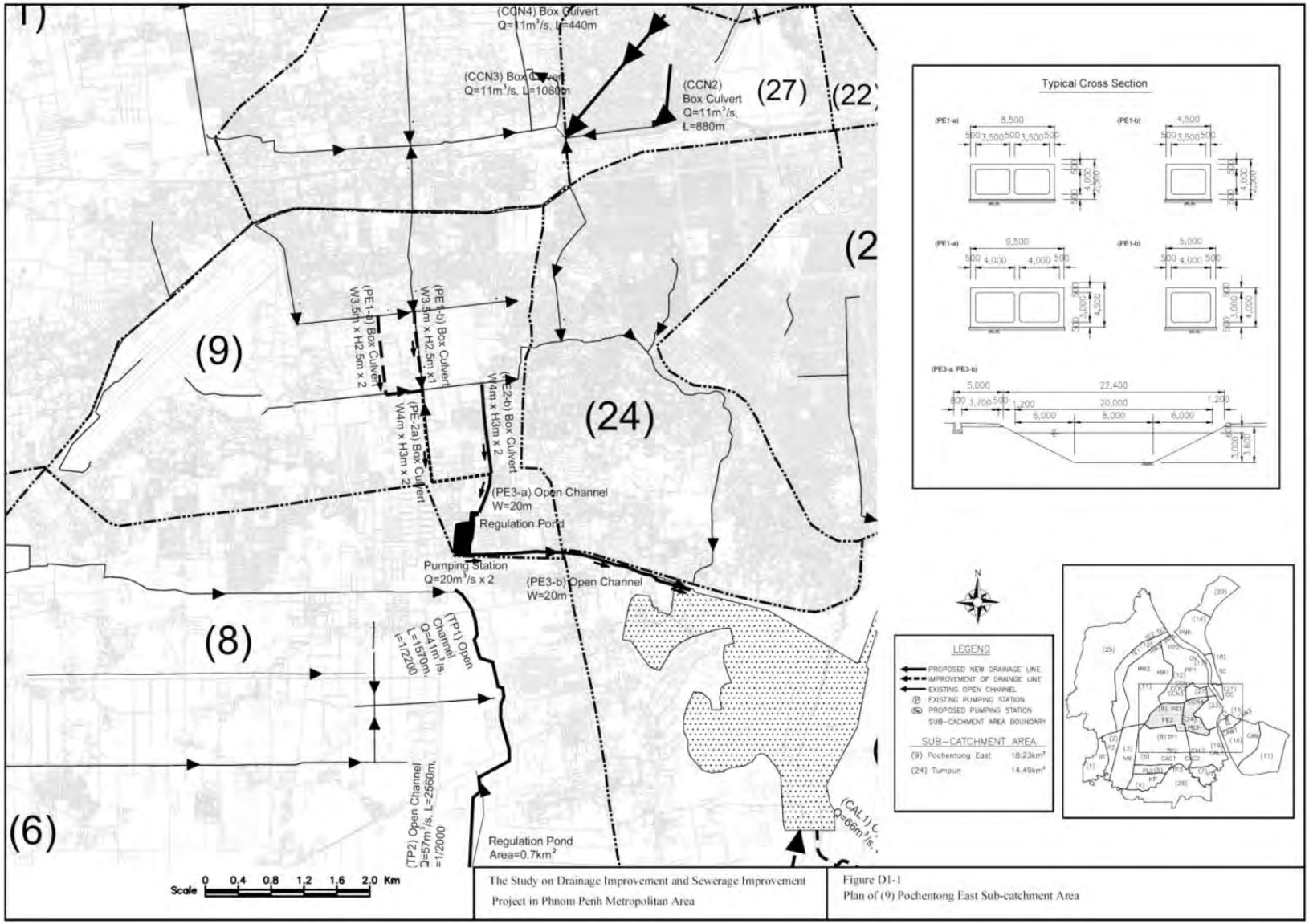
Source: JICA Study Team

Fig. 6.2.3 General Map of Drainage Improvement (2/7) (Krang Pongro/Pratek Lang Channel/Tuol Pongro Drainage Areas)



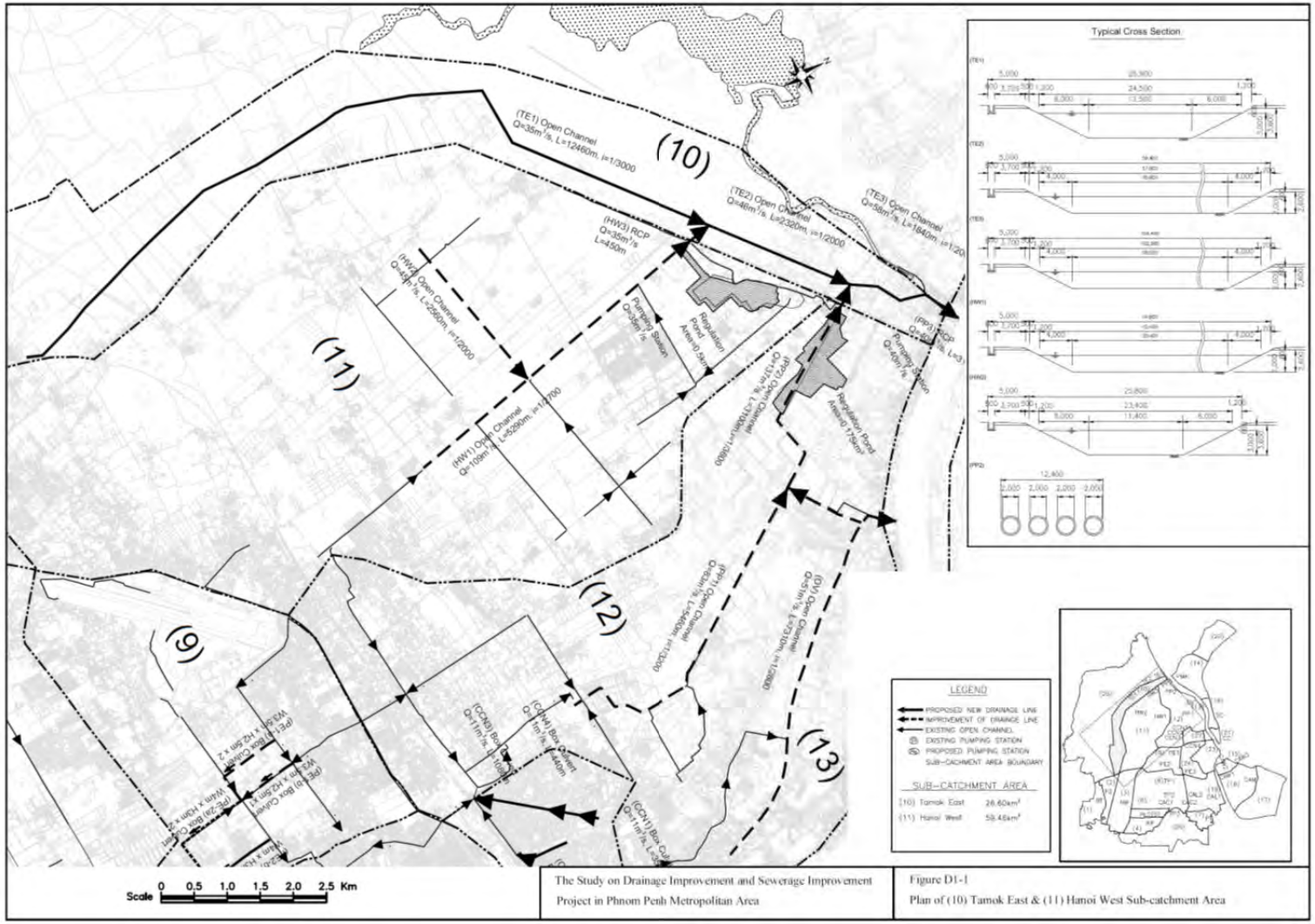
Source: JICA Study Team

Fig. 6.2.4 General Map of Drainage Improvement (3/7) (Preaek Thloeng/Chbar Ampov Middle/Cheung Aek Lake Drainage Areas)



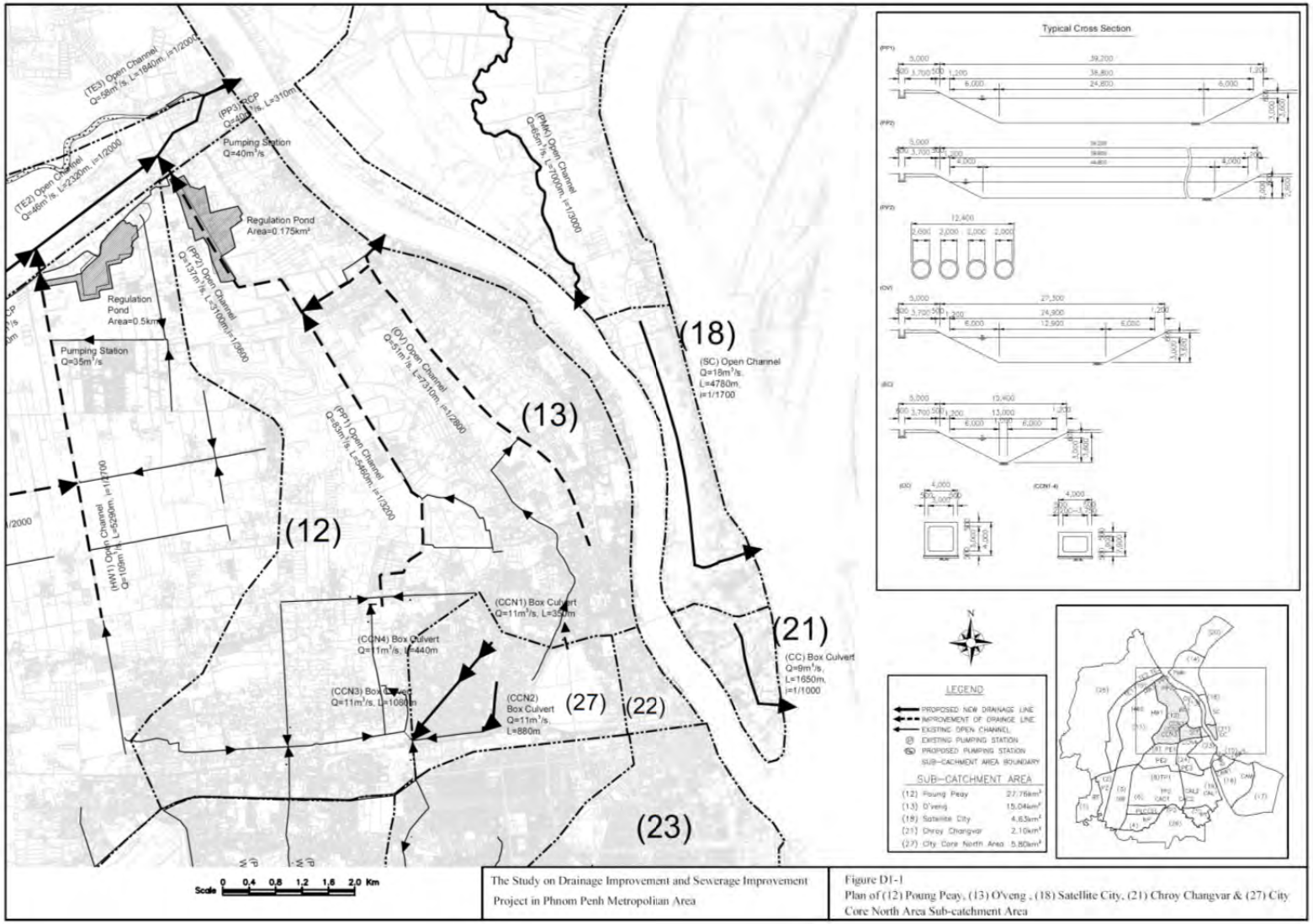
Source: JICA Study Team

Fig. 6.2.5 General Map of Drainage Improvement (4/7) (Pochentong East Drainage Area)



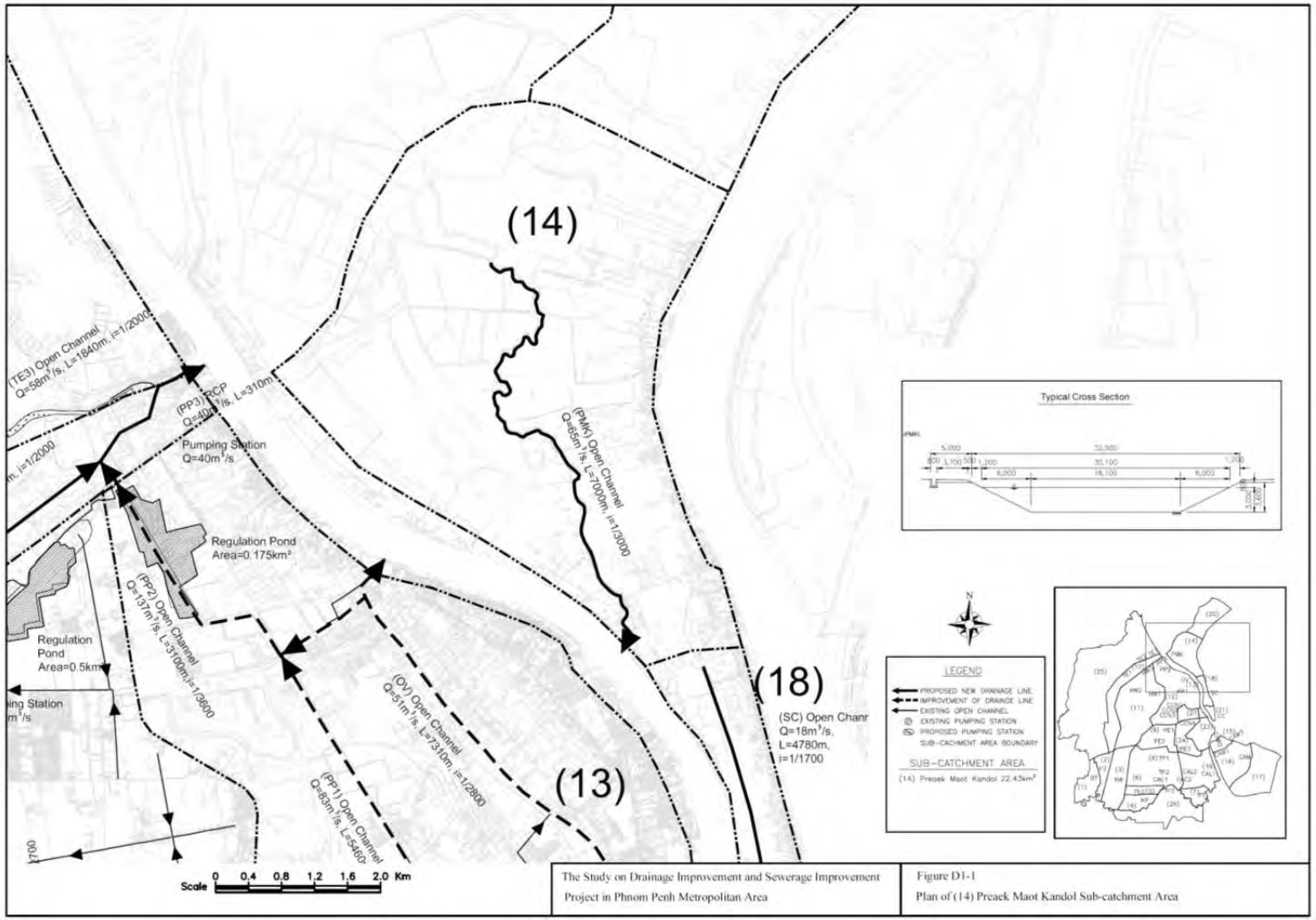
Source: JICA Study Team

Fig. 6.2.6 General Map of Drainage Improvement (5/7) (Tamok East/Hanoi West Drainage Areas)



Source: JICA Study Team

Fig. 6.2.7 General Map of Drainage Improvement (6/7) (Poung Peay/O'veng/Satellite City/Chroy Changvar/City Core North Area Drainage Areas)



Source: JICA Study Team

Fig. 6.2.8 General Map of Drainage Improvement (7/7) (Preaek Moat Kandol Drainage Area)

6.2.4 Planning of Pumping Stations

(1) Calculation of Discharge Capacities (Model of River Channel Analysis: One-Dimensional Unsteady Flow Model)

Flow conditions of channels flowing through low-lying areas are influenced by confluences of branch channels, as well as retention in the channels. Therefore, evaluation of fluctuation of water level and flow rate are necessary to estimate capacities of pumping stations. As shown in **Table 6.2.4**, one-dimensional unsteady flow model, which can estimate water level and flow rate for each section, is employed.

Table 6.2.4 Summary of River Channel Analysis Model

Item	Contents
Hydraulic model	One dimensional unsteady flow model (Dynamic wave model: DHI-MIKE11 HD model)
Drainage network of planning	Determination of drainage network for each alternative
Cross sections	Set according to planned cross sections
Structure	Drainage facilities (Pumping station)
Flow hydrograph	Hydrograph is drawn using synthetic rational formulas, obtaining the same peak flow by shortening or lengthening the graph.

Source : JICA Study Team

(2) Calculation Results of Capacity for Pumping Station

Pumping stations are necessary to pump water from low-land area to the higher outlet located at the downstream end. Discharge capacity of pumping stations is computed employing one-dimensional unsteady flow to consider retention in channels and not to allow water overflow. The results are summarised in **Table 6.2.5**.

Table 6.2.5 Summary of Capacity of Pumping Station

Catchment No.	Catchment Name	Capacity (m^3/s)	Head (m)	Land requirement (m^2)	Land owner
6&8	Cheung Aek Channel & Tuol Pongro	5	5	2,500	Private
9	Pochentong East	40	5	6,000	Public
11	Hanoi West	35	5	5,500	Public
12&13	Poung Peay & O'veng	40	5	6,000	Public
15	Chbar Ampov West	1	4	500	Public
16	Chbar Ampov Middle	10	6	4,000	Private

Source：JICA Study Team

(3) Plan of Regulation Pond

Required area and volume of regulation pond at the end of each drainage area, is summarized in **Table 6.2.6**.

Table 6.2.6 Summary of Regulation Pond

Drainage Area No.	Name of Drainage Area	Area (m^2)	Volume (m^3)	Land owner
6&8	Cheung Aek Channel & Tuol Pongro	700,000	700,000	Private
9	Pochentong East	25,000	100,000	Public
11	Hanoi West	500,000	600,000	Private/public
12&13	Poung Peay & O'veng	175,000	350,000	Private/public
16	Chbar Ampov Middle	160,000	160,000	Private

Source：JICA Study Team

6.3 Maintenance Plan

6.3.1 Drainage Channels and Pipes

(1) Agency in Charge

DSD/DPWT is responsible for operation and maintenance of the drainage channels and pipes as before.

(2) Methodology for Maintenance

The items of maintenance of channels and pipes are shown in **Table 6.3.1**.

Table 6.3.1 Items of Maintenance for Drainage Channels and Pipes

	Details	Frequency
Periodical inspection	● Check of amount of sedimentation ● Check of damage of road above pipelines ● Check of damage (crack, penetration of root of street trees) ● Check of infiltration of groundwater ● Check of illegal connection ● Check of status of manhole covers ● Record of inspection works	Once at least every 2 to 3 years
Cleaning/dredging	● Implementation of clearing or dredging according to results of inspection (Cleaning works is implemented using high pressure cleaning equipment)	Frequency is set based on volume of sedimentation
Repair/rehabilitation	● Repair and rehabilitation of damaged part	

Source : JICA Study Team

6.3.2 Pumping Station and Regulation Pond

(1) Agency in Charge

DSD/DPWT is responsible for operation and maintenance of the drainage channels and pipes as before.

(2) Methodology for Maintenance

Required maintenance items for pumping station and regulation ponds are summarized in **Table 6.3.2**.

Table 6.3.2 Items of Maintenance for Pumping Station and Regulation Pond

	Details	Frequency
Pumping station	● Check of current and voltage ● Check of abnormal noise/vibration ● Check of leakage/ float switch ● Check of main body ● Check of lubricating oil ● Overhaul	Everyday Everyday Once a month Once every 3 months Once every 3 months (Oil change: once a year) Once every 2 years
Regulation pond	● Removal of trash/sludge in the pond	At least once before the rainy season

Source: JICA Study Team

6.4 Review of Organization and Legal Framework of Drainage Management

PPCC has established its drainage facilities in an orderly fashion, in accordance with the details stipulated in the "M/P 1999." In the PPCC, in the areas in need of large-scale and systematic work or urgent measures, ADB's financial assistance, Japanese Grant Aid project (Phases 1-3), and other programs helped the progress of the City's drainage issues. As a result, in PPCC, especially in the existing suburban areas, drainage pipes, channels, manholes, and pumping stations were installed and/or established, eliminating flood damage. The total length of drainage pipes installed is growing year after year.

However, in PPCC, in addition to its topographical constraint making natural drainage impossible in many areas, disorderly reclamation of lakes, swamps, and wetlands, has reduced regulating capacity of stormwater. Further, the rapid urbanization in recent years in the areas surrounding the existing urban zones and large-scale housing developments without sufficient drainage infrastructures, are another issues. As one cause of those is the lack of or poor regulation, standards and legal framework concerning establishment of drainage infrastructures, review of legal framework concerning stormwater drainage shall be considered.

6.4.1 Review of Organization

As discussed above, stormwater drainage infrastructure has been established in an orderly manner, thanks to donations and aids, and, the DSD, a division within DPWT responsible for maintenance and management of the infrastructure, has been organized and their staffing and assets have been improved. However, the capacity of the DSD is still insufficient to manage the drainage infrastructure that covers the entire PPCC, proposed in this M/P. It is essential to develop their capacities for formulating drainage infrastructure plan and stipulating design standards, in relation to the large-scale development rapidly growing in recent years, as well as to clarify the scope of responsibilities.

Against this backdrop, with the aim to clarify which posts are responsible for the drainage infrastructure establishment/improvement in relation to the large-scale development and development of their abilities, it is proposed that the current DSD Technical Section is divided into two sections to be responsible for respective tasks as presented in **Fig. 6.4.1**. (For information on current organizational structure, refer to **Fig. 2.6.5**, DSD Organizational Chart.)

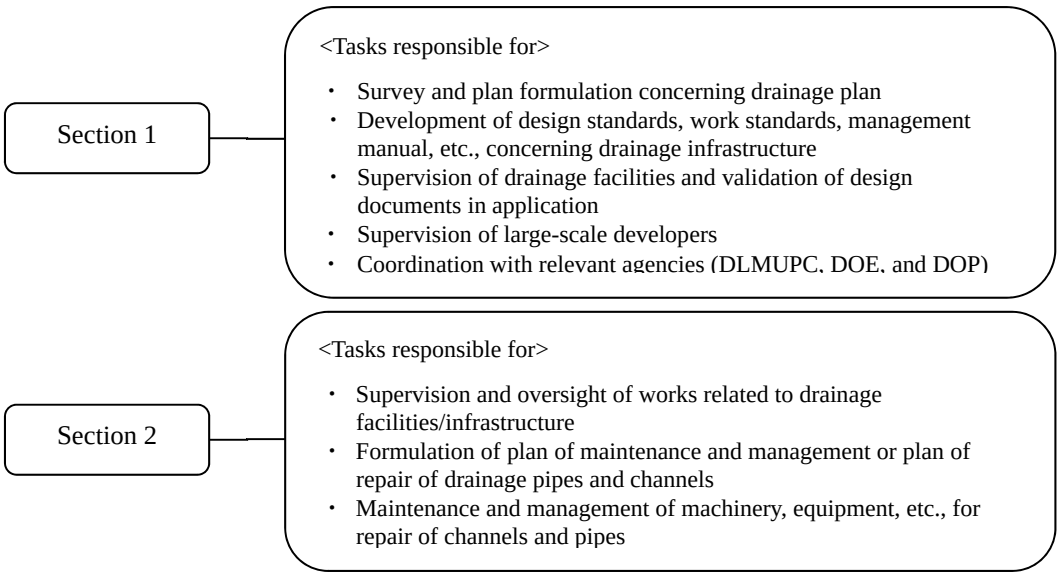


Fig. 6.4.1 Proposal to divide DSD Technical Section

To develop their capacities to carry out work, drainage technicians shall be invited (for 2-3 year term) to enhance available technician workforce. In addition, young staff shall be sent to developed countries, to be trained to become key persons. Those key persons shall be the core of the technicians in DSD. At the same time, the internal training system based on such activities as OJT, shall be established in DSD.

6.4.2 Review of Legal Framework

In Cambodia, if a Master Plan for land-use has not been provided, a large-scale residential development or similar project requires MLMUPC's approval, in accordance with Royal Decree No. 86 concerning construction permits. Although Article 31 of the decree provides rules for sewer connection, there is no clear indication of specific permission criteria for stormwater drainage facilities/infrastructure.

To control stormwater drainage for large-scale residential development or similar projects, it is necessary to clarify such matters as the legal criteria and regulation of improving or developing infrastructure in the areas, and obligations and responsibilities of the developer.

As described in **Subsection 4.4.2**, to realize sound development in the City and a good urban environment in the development area in accordance with the Urban Development Master Plan and relevant laws, a developer engaging in large-scale residential development needs to provide a part of infrastructures such as roads, public facilities, public facilities, waste facilities, water supply facilities, drainage facilities, disaster management and safety facilities, and/or planned green zones, as a condition of development permit, after negotiation with relevant offices (such as MIH, DOE, DLMUPC, DPWT, and WMD). Therefore, the Study Team proposes that the relevant offices collaborate to develop the standards of development, criteria, and guidelines on improving/establishing the infrastructure in the development area, so as to determine a unified process of notifying the development area, condition of permit, obligations of developer, and administrative procedures necessary for development and to ensure thorough supervision of the developers.

In principle, the criteria/standards of development permit closely related to drainage management shall enforce the developers to install drainage facilities to discharge stormwater from entire development area into public water. However, if the drainage capacity of the downstream of the area is not enough, it is proposed that the developer can create regulating reservoir within the development area to temporarily retain stormwater.

6.5 Phased Implementation Plan

Phased implementation plan is formulated in consideration with the following preconditions.

(1) Each drainage area is classified into 4 groups by priority.
(2) Four groups are formulated, based on EIRR.
(3) Drainage area located in large-scale development area is categorized into lower group regardless of EIRR, because drainage facilities in the area should be constructed by the developer and progress of the development is unclear.

Based on the above preconditions, priority of each drainage area is set as shown in **Table 6.5.1**.

Table 6.5.1 Priority of Implementation for Each Drainage Area

No.	Sub-Catchment Area	Population in 2035 (person)	Area (km^2)	Population density person/km	Resettle-ment (house)	Land expropriation (m^2)	Con-struction cost M USD	O&M cost M USD	EIRR %	Ranking of EIRR	Priority	Remarks
1	Boeung Thom	19,900	15.39	1,293	0	71,932	5.8	0.028	2.7	14	3	Subsequently implemented after improvement of PPSEZ
2	PPSEZ	13,800	10.56	1,307	5	10,655	10.9	0.047	10.2	7	2	EIRR 10~15
3	NR.3 West	43,100	27.36	1,575	36	54,340	14.4	0.070	2.3	15	4	EIRR<5
4	Krang Pongro	8,100	11.01	736	2	7,184	8.6	0.032	0.0	18	4	EIRR<5
5	Pratek Lang Channel	7,400	7.17	1,032	10	6,864	9.0	0.032	-3.3	19	4	EIRR<5
6&8	Cheung Aek Channel & Tuol Pongro	122,800	49.44	2,484	81	879,943	48.2	0.384	12.9	5	2	EIRR 10~15
7	Preaek Thloeng	29,600	8.53	3,470	2	51,293	3.7	0.019	0.3	17	4	Commercial area developed in medium- or long-term
9	Pochentong East	183,300	18.23	10,055	40	26,915	89.6	1.172	13.3	4	2	EIRR 10~15
10	Tamok East	63,100	26.60	2,372	154	549,374	53.6	0.318	-9.2	20	4	EIRR<5
11	Hanoi West	287,200	59.46	4,830	28	512,273	62.6	1.167	5.7	10	3	EIRR 5~10
12&13	Poung Peay & O'veng	359,000	43.79	8,198	90	182,507	82.0	1.409	10.4	6	2	EIRR 10~15
14	Preaek Maot Kandol	78,100	22.43	3,482	47	20,160	24.8	0.122	3.6	12	4	Commercial area developed in medium- or long-term
15	Chbar Ampov West	67,600	4.77	14,172	179	0	8.8	0.087	8.4	8	3	EIRR 5~10
16	Chbar Ampov Middle	118,200	25.63	4,612	17	355,040	27.0	0.423	0.6	16	4	Commercial area developed in medium- or long-term
17	Chbar Ampov East	61,700	34.32	1,798	-	-	-	-	0	-	-	
18	Satellite City	42,000	4.63	9,071	4	83,363	9.4	0.027	5.4	11	3	EIRR 5~10
19	Cheung Aek Lake	212,800	23.28	9,141	152	50,760	18.3	0.091	3.6	13	4	Commercial area developed in medium- or long-term
20	Bak Khaeng	10,200	18.74	544	-	-	-	-	-	-	-	
21	Chroy Changvar	23,700	2.10	11,286	42	0	6.1	0.002	6.3	9	3	EIRR 5~10
22	Wat Phomn North	20,000	1.17	17,094	0	0	10.3	0.007	15.8	2	1	EIRR>15
23	Trabek	372,400	13.01	28,624	0	0	2.5	0.040	16.1	1	1	EIRR>15
24	Tumpun	471,800	14.49	32,560	-	-	-	-	-	-	-	
25	Tamok West	121,700	133.85	909	-	-	-	-	-	-	-	
26	Prek Thnot South	54,500	39.97	1,364	-	-	-	-	-	-	-	
27	City Core North Area	74,800	5.80	12,897	18	0	9.1	0.002	15.2	3	1	EIRR>15
TOTAL		2,866,800	621.73		907	2,862,603	504.7	5.479				

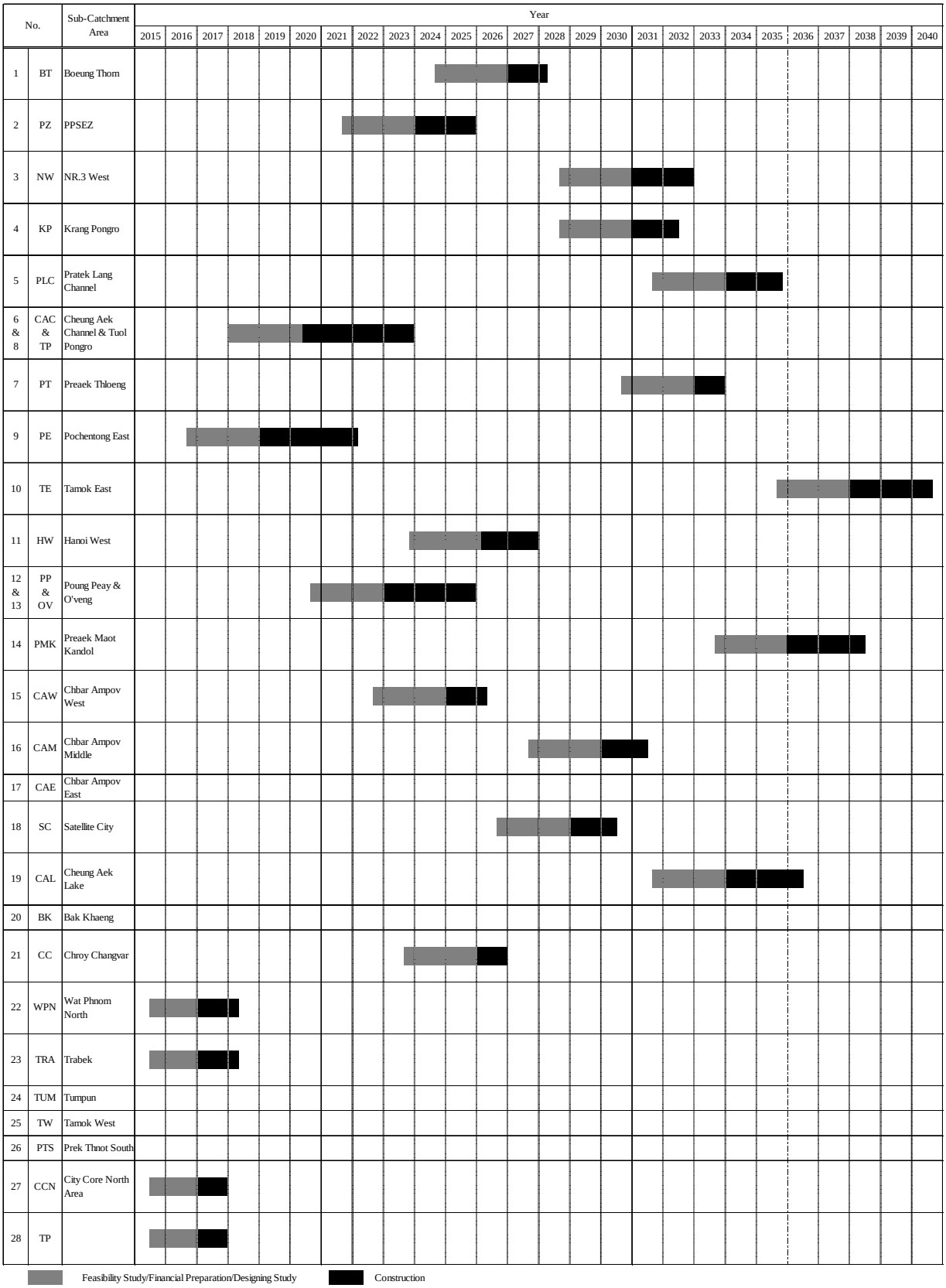
Note 1) Priority is firstly classified into the following 4 groups based on the EIRR
- Group 1: Drainage area with EIRR of 15% or more
- Group 2: Drainage area with EIRR of 10% to less than 15%
- Group 3: Drainage area with EIRR of 5% to less than 10%
- Group 4: Drainage area with EIRR of less than 5%

Note 2) Boeung Thom Drainage is grouped under Group 3, because the area should be improved immediately after PPSEZ area to optimize the improvement works done in the areas.

Source: JICA Study Team

Phased implementation plan based on the order of priority in **Table 6.5.1** is shown in **Table 6.5.2**. Construction period in the implementation plan is established based on the similar projects implemented in PPCC.

Table 6.5.2 Phased Implementation Plan



Source: JICA Study Team

6.6 Cost Estimate

6.6.1 Construction Cost (Project Cost)

The Cost Estimate is summarized in **Table 6.6.1**. As shown in the table, total project cost is estimated at 662.2 million USD, of which construction cost amounts to 506.5 million USD. In addition, cost disbursement schedule for drainage management projects is shown in **Tables 6.6.2** and **6.6.3**.

Table 6.6.1 Summary of Cost Estimate

Unit: million USD

Item	Foreign currency	Local currency	Total
I. Construction Cost	86.4	420.1	506.5
1) Boeung Thom	0.1	5.7	5.8
2) PPSEZ	0.1	10.8	10.9
3) NR.3 West	0.2	14.2	14.4
4) Krang Pongro	0.1	8.5	8.6
5) Pratek Lang Channel	0.1	8.9	9.0
6&8) Cheung Aek Channel & Tuol Pongro	3.6	44.6	48.2
7) Preaek Thloeng	0.0	3.7	3.7
9) Pochentong East	31.4	58.2	89.6
10) Tamok East	0.6	53.0	53.6
11) Hanoi West	19.1	43.5	62.6
12&13) Poung Peay & O'veng	16.8	65.2	82.0
14) Preaek Maot Kandol	0.3	24.5	24.8
15) Chbar Ampov West	0.7	8.1	8.8
16) Chbar Ampov Middle	6.4	20.6	27.0
17) Chbar Ampov East			
18) Satellite City	0.1	9.3	9.4
19) Cheung Aek Lake	0.2	18.1	18.3
20) Bak Khaeng			
21) Chroy Changvar	0.7	5.4	6.1
22) Wat Phnom North	1.1	9.2	10.3
23) Trabek	2.0	0.5	2.5
24) Tumpun			
25) Tamok West			
26) Prek Thnot South			
27) City Core North Area	1.2	7.9	9.1
28) Drainage Pump Vehicle[1)]	1.6	0.2	1.8
II. Administration cost	0.0	25.3	25.3
III. Engineering cost	40.5	10.1	50.6
IV. Physical contingency	6.3	21.5	27.8
V. Land expropriation/ compensation cost	0.0	52.0	52.0
Grand total (I+II+III+IV+V)	133.2	529.0	662.2

Note 1) Drainage pump vehicle is a component not included in specific drainage area but covers all drainage areas for emergency. Similarly, **Tables 6.6.2** and **6.6.3** are formulated including procurement of drainage pump vehicle.

Source: JICA Study Team

Table 6.6.2 Cost Disbursement Schedule (Drainage Management 1/2)

Items	2016			2017			2018			2019			2020			2021			2022			2023			2024			2025			2026			2027			2028		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A. Cost covered by loan（I+II+III）	8.2	19.2	27.4	0.0	0.0	0.0	40.5	63.0	103.5	7.9	47.9	55.8	0.0	0.0	0.0	0.0	0.0	0.0	24.6	70.1	94.7	1.1	11.6	12.7	1.5	8.7	10.2	26.6	52.8	79.4	0.6	6.1	6.7	0.0	0.0	0.0	0.9	10.0	10.9
I. Construction cost	5.9	17.8	23.7	0.0	0.0	0.0	31.4	58.2	89.6	3.6	44.6	48.2	0.0	0.0	0.0	0.0	0.0	0.0	16.8	65.2	82.0	0.1	10.8	10.9	0.7	8.1	8.8	19.8	48.9	68.7	0.1	5.7	5.8	0.0	0.0	0.0	0.1	9.3	9.4
1 Boeung Thom																															0.1	5.7	5.8						
2 PPSEZ																						0.1	10.8	10.9															
3 NR.3 West																																							
4 Krang Pongro																																							
5 Pratek Lang Channel																																							
6&8 Cheung Aek Channel & Tuol thloeng										3.6	44.6	48.2																											
7 Preaek Thloeng																																							
9 Pochentong East							31.4	58.2	89.6																															
10 Tamok East																																							
11 Hanoi West																												19.1	43.5	62.6									
12&13 Poung Peay & O'veng																			16.8	65.2	82.0																		
14 Preaek Maot Kandol																																							
15 Chbar Ampov West																									0.7	8.1	8.8												
16 Chbar Ampov Center																																							
17 Chbar Ampov East																																							
18 Satellite City																																					0.1	9.3	9.4
19 Cheung Aek Lake																																							
20 Bak Khaeng																																							
21 Chroy Changvar																												0.7	5.4	6.1									
22 Wat Phnom North	1.1	9.2	10.3																																				
23 Trabek	2.0	0.5	2.5																																				
24 Tumpun																																							
25 Tamok West																																							
26 Prek Thnot South																																							
27 City Core North Area	1.2	7.9	9.1																																				
28 Drainage Pump Vehicle	1.6	0.2	1.8																																				
II. Consultant fee	1.9	0.5	2.4	0.0	0.0	0.0	7.2	1.8	9.0	3.9	1.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	6.6	1.6	8.2	0.9	0.2	1.1	0.7	0.2	0.9	5.5	1.4	6.9	0.5	0.1	0.6	0.0	0.0	0.0	0.8	0.2	1.0
III. Phisical contingency	0.4	0.9	1.3	0.0	0.0	0.0	1.9	3.0	4.9	0.4	2.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.3	4.5	0.1	0.6	0.7	0.1	0.4	0.5	1.3	2.5	3.8	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.5	0.5
B. Cost not covered by loan (IV＋V)	0.0	2.2	2.2	0.0	14.0	14.0	0.0	4.5	4.5	0.0	6.0	6.0	0.0	0.3	0.3	0.0	9.7	9.7	0.0	4.1	4.1	0.0	2.0	2.0	0.0	0.4	0.4	0.0	3.4	3.4	0.0	7.1	7.1	0.0	0.0	0.0	0.0	1.8	1.8
IV. Administration cost	0.0	1.2	1.2	0.0	0.0	0.0	0.0	4.5	4.5	0.0	2.4	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	4.1	0.0	0.5	0.5	0.0	0.4	0.4	0.0	3.4	3.4	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.5	0.5
V. Land expropriation/compensation cost	0.0	1.0	1.0	0.0	14.0	14.0	0.0	0.0	0.0	0.0	3.6	3.6	0.0	0.3	0.3	0.0	9.7	9.7	0.0	0.0	0.0	0.0	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	6.8	0.0	0.0	0.0	0.0	1.3	1.3
Total（A＋B）	8.2	21.4	29.6	0.0	14.0	14.0	40.5	67.5	108.0	7.9	53.9	61.8	0.0	0.3	0.3	0.0	9.7	9.7	24.6	74.2	98.8	1.1	13.6	14.7	1.5	9.1	10.6	26.6	56.2	82.8	0.6	13.2	13.8	0.0	0.0	0.0	0.9	11.8	12.7

Source: JICA Study Team

Table 6.6.3 Cost Disbursement Schedule (Drainage Management 2/2)

Items	2029			2030			2031			2032			2033			2034			2035			2036			2037			2038			2039			2040			合計		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A. Cost covered by loan（I+II+III）	9.0	22.2	31.2	2.2	24.4	26.6	0.0	0.0	0.0	0.3	4.0	4.3	2.6	28.9	31.5	0.0	0.0	0.0	2.4	26.3	28.7	0.0	0.0	0.0	5.1	56.8	61.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.2	451.7	584.9
I. Construction cost	6.4	20.6	27.0	0.3	22.7	23.0	0.0	0.0	0.0	0.0	3.7	3.7	0.3	27.0	27.3	0.0	0.0	0.0	0.3	24.5	24.8	0.0	0.0	0.0	0.6	53.0	53.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	86.4	420.1	506.5
1 Boeung Thom																																					0.1	5.7	5.8
2 PPSEZ																																					0.1	10.8	10.9
3 NR.3 West				0.2	14.2	14.4																															0.2	14.2	14.4
4 Krang Pongro				0.1	8.5	8.6																															0.1	8.5	8.6
5 Pratek Lang Channel													0.1	8.9	9.0																						0.1	8.9	9.0
6&8 Cheung Aek Channel & Tuol thloeng																																					3.6	44.6	48.2
7 Preaek Thloeng										0.0	3.7	3.7																									0.0	3.7	3.7
9 Pochentong East																																					31.4	58.2	89.6
10 Tamok East																									0.6	53.0	53.6										0.6	53.0	53.6
11 Hanoi West																																					19.1	43.5	62.6
12&13 Poung Peay & O'veng																																					16.8	65.2	82.0
14 Preaek Maot Kandol																			0.3	24.5	24.8																0.3	24.5	24.8
15 Chbar Ampov West																																					0.7	8.1	8.8
16 Chbar Ampov Center	6.4	20.6	27.0																																		6.4	20.6	27.0
17 Chbar Ampov East																																							
18 Satellite City																																					0.1	9.3	9.4
19 Cheung Aek Lake													0.2	18.1	18.3																						0.2	18.1	18.3
20 Bak Khaeng																																							
21 Chroy Changvar																																					0.7	5.4	6.1
22 Wat Phnom North																																					1.1	9.2	10.3
23 Trabek																																					2.0	0.5	2.5
24 Tumpun																																							
25 Tamok West																																							
26 Prek Thnot South																																							
27 City Core North Area																																					1.2	7.9	9.1
28 Drainage Pump Vehicle																																					1.6	0.2	1.8
II. Consultant fee	2.2	0.5	2.7	1.8	0.5	2.3	0.0	0.0	0.0	0.3	0.1	0.4	2.2	0.5	2.7	0.0	0.0	0.0	2.0	0.5	2.5	0.0	0.0	0.0	4.3	1.1	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.5	10.1	50.6
III. Phisical contingency	0.4	1.1	1.5	0.1	1.2	1.3	0.0	0.0	0.0	0.0	0.2	0.2	0.1	1.4	1.5	0.0	0.0	0.0	0.1	1.3	1.4	0.0	0.0	0.0	0.2	2.7	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	21.5	27.8
B. Cost not covered by loan（IV＋V）	0.0	1.4	1.4	0.0	4.3	4.3	0.0	0.2	0.2	0.0	10.7	10.7	0.0	1.4	1.4	0.0	0.0	0.0	0.0	1.2	1.2	0.0	0.0	0.0	0.0	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.3	77.3
IV. Administration cost	0.0	1.4	1.4	0.0	1.2	1.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0	1.4	1.4	0.0	0.0	0.0	0.0	1.2	1.2	0.0	0.0	0.0	0.0	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.3	25.3
V. Land expropriation/compensation cost	0.0	0.0	0.0	0.0	3.1	3.1	0.0	0.2	0.2	0.0	10.5	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.0	52.0
Total（A＋B）	9.0	23.6	32.6	2.2	28.7	30.9	0.0	0.2	0.2	0.3	14.7	15.0	2.6	30.3	32.9	0.0	0.0	0.0	2.4	27.5	29.9	0.0	0.0	0.0	5.1	59.5	64.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.2	529.0	662.2

Source: JICA Study Team

6.6.2 Operation and Maintenance Cost

Annual operation and maintenance cost is summarized in **Table 6.6.4**. According to the table, annual operation and maintenance cost is estimated at 5.5 million USD for the target year 2040.

Table 6.6.4 Summary of O&M Cost

Unit: million USD

Item	Annual O&M cost
1) Boeung Thom	0.028
2) PPSEZ	0.047
3) NR.3 West	0.070
4) Krang Pongro	0.032
5) Pratek Lang Channel	0.032
6&8) Cheung Aek Channel & Tuol Pongro	0.384
7) Preaek Thloeng	0.019
9) Pochentong East	1.172
10) Tamok East	0.318
11) Hanoi West	1.167
12&13) Poung Peay & O'veng	1.409
14) Preaek Maot Kandol	0.122
15) Chbar Ampov West	0.087
16) Chbar Ampov Middle	0.423
17) Chbar Ampov East	
18) Satellite City	0.027
19) Cheung Aek Lake	0.091
20) Bak Khaeng	
21) Chroy Changvar	0.002
22) Wat Phnom North	0.007
23) Trabek	0.040
24) Tumpun	
25) Tamok West	
26) Prek Thnot South	
27) City Core North Area	0.002
28) Drainage Pump Vehicle	0.022
Annual total O&M cost	5.501

Note 1) Drainage pump vehicle is a component not included in specific drainage area but covers all drainage areas for emergency.

Source: JICA Study Team

6.7 Economic Analysis

6.7.1 Preconditions for Economic Analysis

The investment and operational costs are clarified in **Section 6.6**. However, the investment costs are converted to border prices similarly to the economic analysis on sewerage project.

The benefits of drainage project as follows are different from those of the sewerage project. The first benefit of the drainage project is avoidance of inundation. The inundation damage can be estimated based on the Social Survey result and **Table 6.7.1**.

Table 6.7.1 Average House Damages per Household in Three Districts

Relative water depth with average year water level (m)	House Damages in USD per household	Calculated recovery year = Damage/Recovery cost per year	Remarks
0	129.34	0.7	Actual damages in 2006
0.5	162.307	0.9	Potential damages
1	193.20	1.0	Potential damages
1.5	327.23	1.8	Potential damages
2	468.73	2.5	Potential damages

Source: Badri Bhakta Shrestha et al., International Centre for Water Hazard and Risk Management (ICHARM), "Assessment of Flood Hazards and Vulnerability in Cambodian Floodplain," 2013

However, the table above is derived from the rural areas in Cambodia. Therefore, the data above should be converted to damage in Phnom Penh using household income statistics. In addition, it is supposed that the damages are proportional to household income change year by year. Based on the frequency and depth of inundation in the Social Survey and **Table 6.7.1**, the damages per household in Phnom Penh are estimated as shown in **Table 6.7.2**.

Table 6.7.2 Average House Damage per Household in Phnom Penh

Depth (cm)	Damage (USD/HH)	Frequency		Share		Damage (USD/HH)		
		1/ year (Including heavy rain)	2/ year	1/ year (Including heavy rain)	2/ year	1/ year (Including heavy rain)	2/ year	
	A	B	C	D	E	F = A×D	G = A×2E	Total (2016)
10	45.48	8	4	0.3265306	0.119403	14.85	10.86	225
25	58.03	7.5	19.5	0.3061224	0.582090	17.77	67.57	↑ increase
50	87.12	8	7	0.3265306	0.208955	28.45	36.41	Total (2006)
75	130.78	1	2	0.04081633	0.059702	5.34	15.62	F×B/(B+C)
100	196.34	0	1	0	0.029851	0	11.72	+G×C/(B+C)
Total		24.5	33.5	100: Total sample number		66.41	142.18	110

HH: Household
Source: JICA Study Team

The inundation damage per household and covered population (converted to household number with household size, 5) is multiplied and inundation avoidance benefits can be estimated. The drainage project aims to avoid inundations of once in five years and so it seems that the above Social Survey results can be avoided.

The second benefit is avoidance of inundation impacts as work damage such as "Cannot go out for business" or "Cannot open for business" in the Social Survey. Cross-analysis of frequency, duration and troubles in the Social Survey results is shown in **Table 6.7.3**. Multiplying the annual total below, household income (converted to day from month) and covered population (converted to household number with household size, 5), the lost production (avoided production loss) can be estimated.

Table 6.7.3 Production Loss Recovery in Phnom Penh

Duration (day)	Frequency		Share		Annual Total
	1/year (Including heavy rain)	2/year	1/year	1/year (Including heavy rain)	
0.0625	4	1	0.0139	0.00463	0.02315
0.09375	7	7	0.0365	0.04861	0.13368
0.3125	3	12	0.0521	0.27778	0.60764
0.625		3	0	0.1389	0.27778
0.7		1	0	0.05185	0.10370
1	4	3	0.222	0.2222	0.66667
	18	27	0.325	0.74398	0.57625

Source: JICA Study Team

Similarly, large-scale factories production losses are obtained multiplying employee number and the average household income damage above.

The third benefit is khans' cost reduction of discharging water after inundation and the fourth benefit is medical cost reduction of the diseases caused by inundation.

6.7.2 EIRR

Based on the preconditions in **Subsection 6.7.1**, EIRR for the proposed drainage management M/P is estimated at 12.6%, as shown in **Table 6.7.4**.

Table 6.7.4 EIRR of Drainage Management Projects

Year	2016	2017	2018	2019	2020	2021	2022
Inundation benefit	0	0	2.73	2.88	3.05	3.23	18.47
Production	0	0	0.32	0.34	0.36	0.38	1.65
Pumping Diesel Oil	0	0	0.01	0.01	0.00	0.00	0.01
Medical Care	0	0	0.005	0.005	0.005	0.005	0.015
Operational Costs		0	0.06	0.07	0.07	0.07	1.05
Investment	28.47	0.00	107.18	71.88	0.00	0.00	101.4
Cash flow	-28.47	0.00	-104.18	-68.73	3.34	3.54	-82.32
Year	2023	2024	2025	2026	2027	2028	2029
Inundation benefit	19.65	40.42	42.97	59.46	63.38	71.81	76.45
Production	1.76	3.32	3.53	4.95	5.29	6.08	6.48
Pumping Diesel Oil	0.01	0.02	0.02	0.02	0.02	0.03	0.03
Medical Care	0.016	0.023	0.024	0.036	0.038	0.046	0.049
Operational Costs	1.24	1.63	1.63	3.14	3.17	4.36	4.37
Investment	13.456	12.34	90.036	8.076	0	12.7	37.7
Cash flow	6.74	29.81	-45.12	53.25	65.56	60.93	40.89
Year	2030	2031	2032	2033	2034	2035	2036
Inundation benefit	81.33	86.95	94.38	102.24	109.00	116.05	126.03
Production	6.90	7.40	8.11	8.78	9.39	10.01	10.90
Pumping Diesel Oil	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Medical Care	0.053	0.057	0.064	0.070	0.075	0.080	0.088
Operational Costs	4.38	4.61	4.83	4.92	4.94	4.94	5.02
Investment	29.012	0	5.288	35.296	0	30.604	0
Cash flow	54.92	89.83	92.45	70.90	113.55	90.62	132.04
Year	2037	2038	2039	2040			Total
Inundation benefit	134.20	142.79	155.06	165.64			1,718.14
Production	11.63	12.39	13.57	14.52			148.05
Pumping Diesel Oil	0.03	0.03	0.03	0.03			0.47
Medical Care	0.094	0.101	0.113	0.122			1.18
Operational Costs	5.06	5.12	5.18	5.29			75.14
Investment	74.096	0	0	0			657.6
Cash flow	66.79	150.18	163.58	175.02		EIRR	**12.6%**
Residual value	-	-	-	-			303.1

Source: JICA Study Team

6.8 Selection of Priority Project for Pre-Feasibility Study

As shown in **Table 6.8.1**, construction of drainage facilities in Pochentong East Drainage Area (Drainage Area No. 9) is selected as the priority projects for Pre-F/S, because implementation plan for (i) construction of drainage facilities in Wat Phnom North Area (Drainage Area No.22) and City Core North Area (Drainage Area No.27) and (ii) installation of mechanical screen at 4 locations in Trabek Drainage Area (Drainage Area No.23), is to be formulated in "The Project for Flood Control and Drainage Improvement in Phnom Penh Capital City (Phase 4)".

Table 6.8.1 Priority Project for Pre-Feasibility Study

	Facilities	Specification/capacity
Construction of drainage facilities in Pochentong East Drainage Area (Drainage Area No. 9)	Drainage channel	• Box culvert: 5,220 m • Inlet channel: 480 m • Rehabilitation of existing channel: 2,660 m
	Pumping station	• 1 location: Capacity 40 m^3/s
	Regulation pond	• 1 location :Area required: 25,000 m^2

Source: JICA Study Team

CHAPTER 7 ENVIRONMENTAL AND SOCIAL CONSIDERATION OF MASTER PLAN

7.1 Consideration at the Master Plan Formulation

To evaluate the M/P and select the priority projects, items to be considered and the evaluation methods are to be proposed by applying the SEA approach in accordance with both Cambodian environmental related laws and regulations and JICA's Guidelines for Environmental and Social Consideration.

7.2 Alternative Comparison

Alternatives of the sewage management M/P and the drainage management M/P are compared in **Chapter 4** and **Chapter 6**. Potential impacts associated with the projects of the M/P are as described below.

(1) Environmental Consideration for the Sewage Management Master Plan

In accordance with the M/P alternatives, potential impacts of the plans are as presented in **Table 7.2.1**. The ratings are not based on absolute comparison but on relative comparison.

Table 7.2.1 Comparison of Alternatives of Sewage Management M/P (April 2015)

Alternative		Alternative 1 (2 STPs, one each for Cheung Aek and Tamok Lakes)	Alternative 2 (Combined development plan on-site and off-site treatment; 1 STP at Cheung Aek area and On-site treatment in Tamok area)	Alternative 3 (Without Project) No project implementation
Rating		---	--	Not applicable
Environmental & Social Consideration	Natural Environment	Seasonal wetland area is to be transformed into the STP construction in Cheung Aek Lake and Tamok Lake. Large scale of land reclamation may be required for the Tamok Lake due to the depth of water at the candidate site in the lake, which is adjacent to the existing pumping station.	Seasonal wetland area is to be transformed into the STP area in Cheung Aek Lake.	Water quality in Tamok Lake and Cheng Aek Lake will decline due to the decline of natural purification function; Biological diversity of the lakes may remain poor; Habitat for wildlife may be reduced; Further eutrophication of the lakes in the capital may progress.
	Social Environment	Farmers and fisheries who are working at the lakes are to be affected in both lake areas.	Farmers and fisheries who are working at the lakes are to be affected in Cheung Aek Lake area.	Water pollution affects quality of crops from the wetland which may cause some health problems to consumers. Further eutrophication of the lakes may reduce crop yield in future.
	Pollution	Water quality at Cheung Aek Lake is expected to be improved through STP operation. Water quality flowing into Tamok Lake area is expected to be improved through STP operation.	Water quality of Cheung Aek Lake area is expected to be improved through STP operation. Water quality of Tamok Lake area is expected to be improved through applying on-site treatment and strict control over them.	Poor water quality of the wetland may cause health problems to farmers and fishermen who work at the lakes.

Legend: ---: high negative impact; --: less negative impact)
Source: JICA Study Team

(2) Environmental Consideration for the Drainage Management Master Plan

In accordance with the M/P alternatives, potential impacts of the plans were identified in **Table 7.2.2**. The ratings are not based on absolute comparison but on relative comparison.

Table 7.2.2 Comparison of Alternatives of Drainage Management M/P (April 2015)

Alternative		Alternative 1	Alternative 2	Without Project
		(27 Sub-catchment areas)	(25 Sub-catchment areas)	
		Regulation pond: 5 locations (North 3 and South 2 locations) **Pumping station: 6 locations** (North 3 and South 3 locations) **Channel (Total length): 123 km** New open canal: 33 km Canal improvement: 77 km New box culvert: 12 km RCP: 1 km	**Regulation pond: 5 locations** (North 2 and South 3 locations) **Pumping station: 6 locations** (North 2 and South 4 locations) **Channel (Total length): 123 km** New open canal: 36 km Canal improvement: 78 km New box culvert: 8 km RCP: 1 km	-
Rating		---	--	-
Environmental & Social Consideration	Natural Environment	**<Improvement of Drainage Pipes/Canals/Channels>** ・ As a positive impact, flood problems are expected to be reduced with project implementation. **< Construction /Extension of Drainage Pumping Station>** ・ No significant negative impact is expected. ・ As a positive impact, tentative habitat for wildlife may be provided even in the city area by cleaning currently polluted ditches. ・ Reduction of wetland in the city area may be facilitated by improvement of drainage. **<Creation of Regulation Pond /Retarding basin>** ・ As a positive impact, tentative habitat for wildlife may be provided even in the city area by creating ponds.	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Same as the left. **< Construction /Extension of Drainage Pumping Station>** ・ Same as the left. ・ Same as the left. ・ Same as the left. **<Creation of Regulation Pond /Retarding basin>** ・ Same as the left.	Inundation problems in the city area will continue.
	Social Environment	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Some residents are living close to existing ditches in city area. Approximately 1,000 structures are located at surrounding area of existing ditch which requires improvement. At the improvement of the existing ditches, impact to the residents should be avoided and minimized based on survey for the existing ditched at planning stage. ・ In the installation work of the new pipe under the existing road, road traffic hazards such as traffic jam and accidents may occur.	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Some residents are living close to existing ditches in city area. Approximately 900 structures are located at surrounding area of existing ditch which requires improvement. At the improvement of the existing ditches, impact to the residents should be avoided and minimized based on survey for the existing ditched at planning stage. ・ Same as the left.	Current inundation problems will continue/ worsen. Those are: ・ Drainage improvement in the northern area of Wat Phnom and most parts of Tuol Kok District will lag behind other area. ・ Due to land development and reclamation, the area of Trabek regulation pond has been reduced

Alternative		Alternative 1	Alternative 2	Without Project
		< Construction /Extension of Drainage Pumping Station> ・ Construction of new pumping station may require additional land acquisition (sometimes resettlement are required) in city area. ・ Expansion of the existing pumping station may affect the residents nearby without any consideration. ・ Land values in the area may increase. ・ In the rainy season, easy traffic in inundated road will be obtained. **< Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ Additional land and resettlement/land acquisition associated with expansion of existing pond, should be avoided and minimized based on detailed survey at the planning stage. ・ Without adequate instruction to the users, the regulation pond will be a source of pollution, as with current condition of water ditches in city area.	**< Construction /Extension of Drainage Pumping Station>** ・ Same as the left. ・ Same as the left. ・ Same as the left. ・ Same as the left. **<Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ Same as the left. ・ Same as the left.	and capacity of Trabek regulation pond has been decreased and cause inundation problems. Present capacity of existing Trabek pumping station is insufficient. ・ Explosive land developments reduce water body area and cause other inundation damage in near future. ・ In the area between inner ring dike and outer ring dike (especially in drastically urbanized area), drainage facilities are not properly installed and it increases inundation problem (in the area at eastern side of Pochentong airport, Chroy Changvar area and Chbar Ampov area.

Alternative		Alternative 1	Alternative 2	Without Project
	Pollution	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Stormwater will be treated separately from the sewage applying separate sewer system, and water flow in the capital will be purified. ・ At the construction stage, disturbance of river bottom sediment due to bed excavation and foundation works, offensive odor may be generated in limited area and period. **< Construction /Extension of Drainage Pumping Station>** ・ During construction, water turbidity in the area will be increased. ・ During construction, water leakage from the old system to the new system may temporarily contaminate the area **<Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ In operating facilities, people dispose garbage in the sites without routine maintenance of the system/adequate education to the people.	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Same as the left. ・ Same as the left. **< Construction /Extension of Drainage Pumping Station>** ・ Same as the left. ・ Same as the left. **<Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ Same as the left.	Water pollution at the current existing ditches may cause some health problems such as infectious diseases.

Legend: ---: high negative impact; --: less negative impact)
Source: JICA Study Team

CHAPTER 8 PRE-FEASIBILITY STUDY ON PRIORITY PROJECT OF SEWAGE MANAGEMENT

8.1 Components of Priority Project

The Preparatory Project is a component for Pre-F/S, as shown in **Table 8.1.1**. Design flow of the Preparatory Project is summarised in **Table 8.1.2**.

Table 8.1.1 Component of Priority Project (Preparatory Project) in Sewage Management

Component	Contents
Sewer Pipe	Diameter : φ500 mm Length :about 1,300 m
STP	Capacity:5,000 m^3/dairy maximum

Source : JICA Study Team

Table 8.1.2 Design Flow

	Design flow for Preparatory Project (m^3/day)	(Reference) Design flow for ultimate stage (m^3/day)
Daily average	4,600	260,000
Daily maximum	5,000	282,000
Hourly maximum	7,300	407,000

Source : JICA Study Team

8.2 Preliminary Design of Sewer Line

8.2.1 Design Flow

Sewer is designed based on hourly maximum of 7,300 m^3/day, which is equivalent to 0.085 m^3/s.

8.2.2 Study on Sewage Interception and Conveyance

(1) Location of Sewage Interception

In the Preparatory Project, sewer is planned from discharging point of Tumpun Pumping Station to STP. The sewerage facilities will be constructed inside of the Cheung Aek Lake.

Location of sewage interception is to be determined not to disturb drainage stream discharged from Tumpun Pumping Station and to ensure intercepting design sewage volume. Therefore, the location of sewage interception will be determined at around 80 m distance from the discharge point of the Tumpun Pumping Station, considering annual variability of water level in the Lake.

(2) Conveyance of Sewage to STP

Sewage is conveyed to the STP by gravity considering cost effectiveness and easiness of maintenance.

(3) Route of Sewer

Proposed sewer will be installed at the southern side of the access road to STP, considering future expansion of the sewer system.

(4) Sewer and Manhole

(a) Sewer

(i) Selection of Pipe Material

Two options for pipe material are considered. One is concrete pipe (CP) and another is hard vinyl chloride pipe (uPVC). Based on the comparison, uPVC will not applicable considering covering depth. As a result, concrete pipe is applied to this project.

(ii) Diameter

Diameter of the sewer is 500 mm based on design sewage volume and hydraulic calculation.

(5) Preliminary Design of Sewer Line

Fig. 8.2.1 shows plan and sectional drawing of the sewer line in the Preparatory Project. The length of the sewer is 1,271 m and depth of the sewer line ranges from 6.7 m to 9.2 m.

Source: JICA Study Team

Fig. 8.2.1 Plan and Profile of Sewer Line in the Preparatory Project

8.3 Preliminary Design of Sewage Treatment Plant

8.3.1 Construction Site

Construction site of STP is located in Cheung Aek Lake, as shown in **Fig. 8.3.1**. The area reclaimed for STP is 3.5 ha for the Preparatory Project.

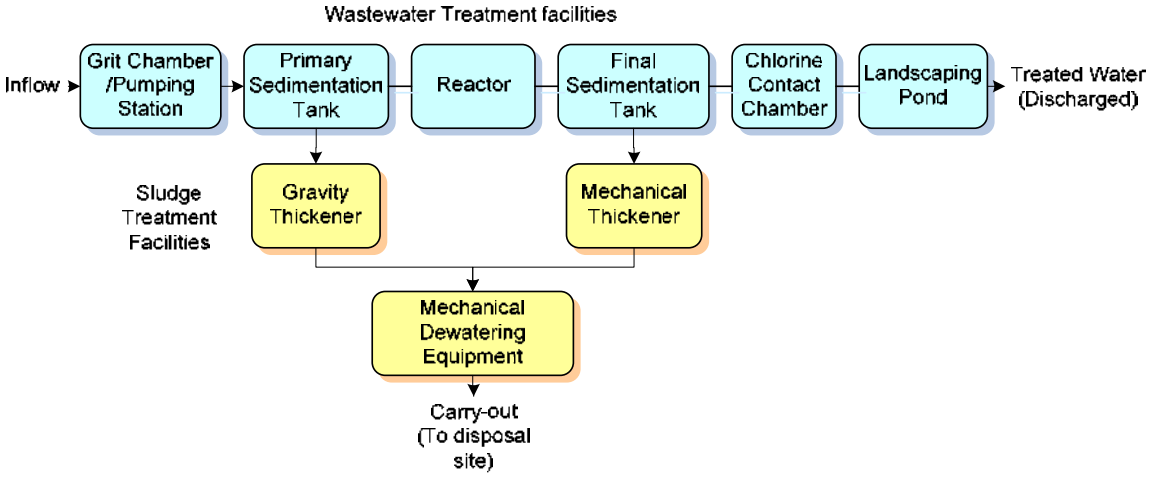
Source: JICA Study Team, based on Google Earth

Fig. 8.3.1 Proposed STP Site in Cheung Aek Lake

8.3.2 Treatment Facilities

(1) Processing Flow

Treatment flow is shown in **Fig. 8.3.2**. Applied wastewater treatment method is CASP (Conventional Activated Sludge Process).



Source: JICA Study Team

Fig. 8.3.2 Processing Flow of STP

(2) Specification of Treatment Facilities

Specification of treatment facilities for Preparatory Project are summarised in **Table 8.3.1**.

Table 8.3.1 Specification of Treatment Facilities (Preparatory Project)

Name	Specification	Remarks
Grit chamber/pumping station	Grit chamber: W0.80 m×L2.6 m×2 ponds Pumping station: 3.0 m^3/min×3 units (1stand-by)	Generator for pumping station will be equipped.
Primary sedimentation tank	W3.6 m× L15.0 m× D3.0 m×2 ponds	
Reactor	W7.55 m× L34.0 m× D6.0 m×1 reactor	
Final Sedimentaton tank	W3.6 m× L35.0 m×D3.5 m×2 ponds	
Chroline contact chamber	W3.0 m× L10.0 m× D4.0 m	
Blower	20 m^3/min×2 units (1 stand-by)	Roots blower type
Gravity thickener	Diameter3.0 m×1 unit	
Mechanical thickener	10 m^3/hr×2 units (1 stand-by)	Belt type filteing
Mechanical dewatering equipment	110 kg-DS/hr×2 units (1 stand-by)	High-efficiency screw press type
Others	Administration building and landscaping pond	

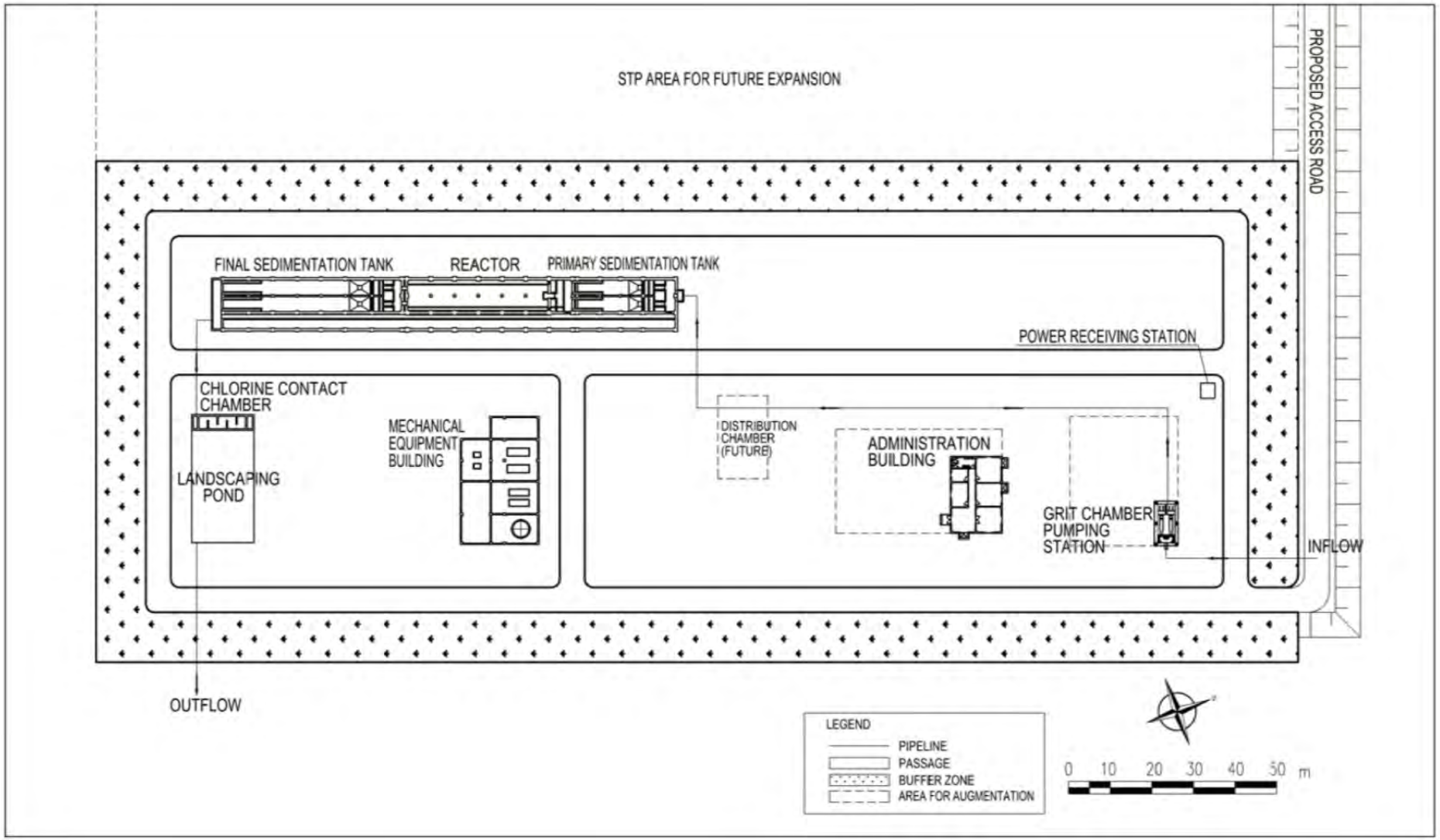
Source: JICA Study Team

Based on the specifications in the above table, general layout plan of the STP and wastewater treatment facilities are illustrated in **Figs. 8.3.3** and **8.3.4**. As a reference, specification of STP in ultimate stage is shown in **Table 8.3.2** and also transition from Preparatory Project to ultimate stage (final stage of construction of STP) is illustrated in **Fig. 8.3.5**.

Table 8.3.2 Specification of Treatment Facilities (Ultimate Stage)

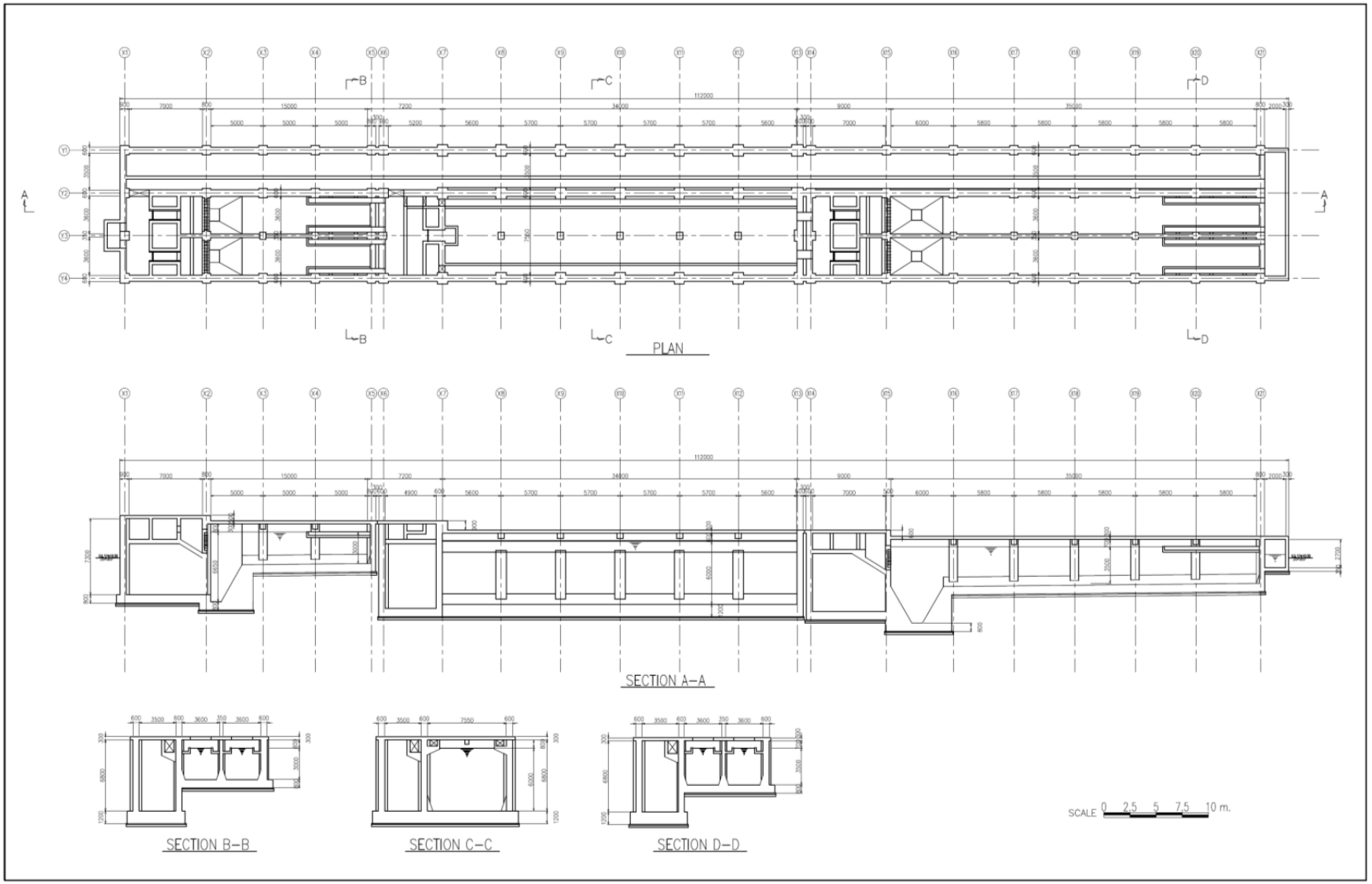
Item	Specification	Remark
Grit chamber/pumping station	Grit chamber: W3.00 m×L13.0 m×6 ponds Pumping station: 50.0 m^3/min×7units (1stand-by)	
Primary sedimentation tank	W3.6 m×L15.0 m×D3.0 m×8 ponds×2 lanes W5.3 m×L 15.0 m×D3.0 m×8 ponds×8 lanes	
Reactor	W7.55 m×L 34.0 m×D6.0 m×4 ponds×2 lanes W10.95 m×L 34.0 m×D6.0 m×4 ponds×8 lanes	
Final Sedimentaton tank	W3.6 m×L 35.0 m×D3.5 m×8 ponds×2 lanes W5.3 m×L 35.0 m×D3.5 m×2 ponds×8 lanes	
Chroline contact chamber	W30.0 m×L 50.0 m×D4.0 m×1 pond	
Blower	90 m^3/min×2 units 180 m^3/min×5 units (1 stand-by)	Turbo blower
Gravity thickener	Diameter 11.0 m×4 units	
Mechanical thickener	50 m^3/hr×8 units (1 stand-by)	Belt type filteing
Mechanical dewatering equipment	840 kg-DS/hr×9 units(1 stand-by)	High-efficiency screw press type
Others	Administration building, generator, power receiving station and landscaping pond	

Source: JICA Study Team



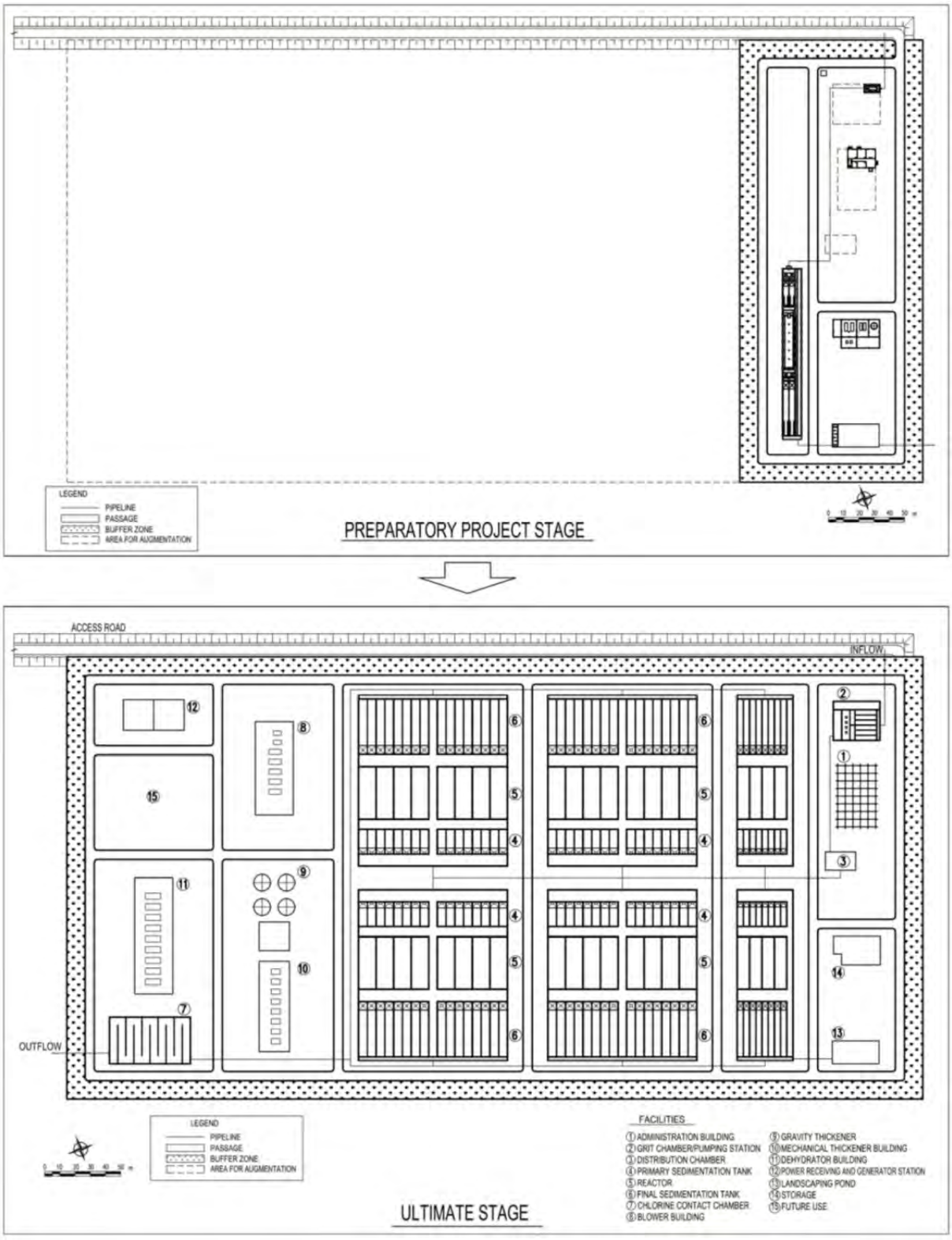
Source: JICA Study Team

Fig. 8.3.3 General Layout Plan of STP in the Preparatory Project



Source: JICA Study Team

Fig. 8.3.4 General Layout Plan of Wastewater Treatment Facilities in the Preparatory Project

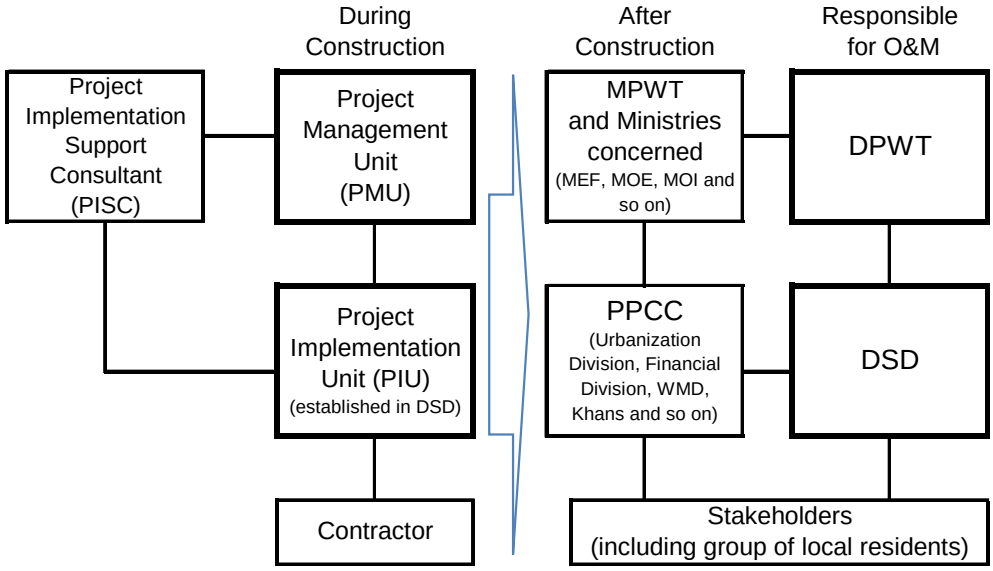


Source: JICA Study Team

Fig. 8.3.5 Transition of STP from Preparatory Project Stage to Ultimate Stage

8.4 Implementation Framework

Implementation framework is established to construct and operate STP with capacity of 5,000 m^3/day, as shown in **Fig. 8.4.1**. The framework consists of Project Management Unit (PMU), Project Implementation Unit (PIU), Project Implementation Support Consultant (PISC) and so on.



Source: JICA Study Team

Fig. 8.4.1 Implementation Framework for Preparatory Project

8.5 Cost Estimate

Project cost is summarized in **Table 8.5.1**. The cost consists of construction cost, engineering cost, administration cost, and physical contingency, is computed with exchange rate of 1USD=122.85JPY and 1Riel=0.030JPY. Summary of O&M cost is shown in **Table 8.5.2**.

Table 8.5.1 Project Cost (Preparatory Project)

Unit: million USD

Item	Local currency	Foreign currency	Total
I. Construction cost ((1)+(2)+(3))	14.01	5.76	19.77
(1) STP	10.27	5.27	15.54
1) Civil	8.69	0.52	9.21
Reclamation (3.5 ha)	3.37	0.04	3.41
Structure	5.32	0.48	5.80
2) Architecture	1.31	0.04	1.35
3) Mechanical work	0.23	4.39	4.62
4) Electrical work	0.04	0.32	0.36
(2) Sewer	1.97	0.32	2.29
(3) Access road	1.77	0.17	1.94
II. Engineering cost	0.44	1.75	2.19
III. Administration cost	0.99	0	0.99
IV. Physical contingency	0.72	0.38	1.10
Total (I+II+III+IV)	16.16	7.89	24.05

Source: JICA Study Team

Table 8.5.2 Summary of O&M Cost (Preparatory Project)

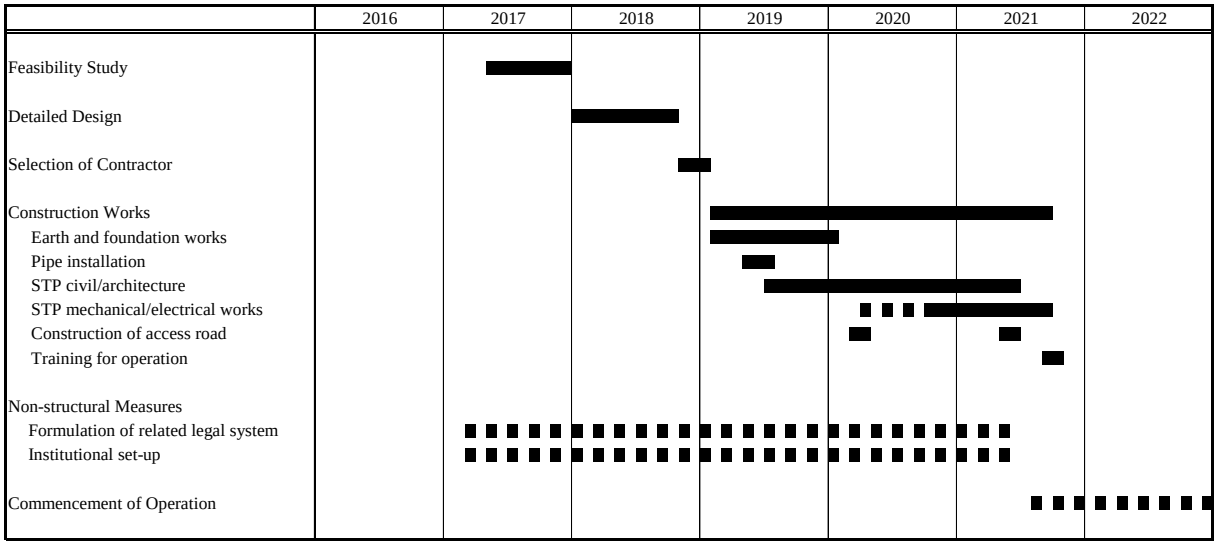
Unit: USD

Item	Total	Remark
I. Treatment facilities ((1)+(2)+(3)+(4))	407,119	
(1) Personnel expenses	126,240	Based on estimated number of 5 regular, including chief of STP and 15 contracted employees
(2) Electricity	175,262	Based on electrical requirements of machinery
(3) Chemicals	72,380	sodium hypochlorite and high-polymer coagulant
(4) Repair and spare parts	23,820	1% of construction cost of machinery
(5) Sludge disposal	9,417	Transportation of sludge
II. Sewer	5,621	
III. Access road	2,700	
Annul O&M total cost (I+II+III)	415,440	

Source : JICA Study Team

8.6 Implementation Schedule

Implementation schedule is formulated as shown in **Fig.8.6.1** in consideration with setting-up of duration of designing, selection of contractor and construction works.



Source: JICA Study Team

Fig. 8.6.1 Implementation Schedule for Preparatory Project

8.7 Financial Analysis

In the financial analysis for the Preparatory Project, at first, profit and loss in the case of 10% of Preparatory Project beneficiaries' water supply use revenues is estimated. In this case, the sewerage use revenues are very small and cannot cover the operation costs. Then, the case result including Phase 1 beneficiaries' revenues is estimated. In this case, sum of profit minus loss from the start to 2040 is positive.

8.8 Economic Analysis

The method in this Preparatory Project is similar to that described in **Section 4.8**. Concerning the benefits of sewerage users, the method is similar and it is an issue whether the objects are only sewerage users or the total final planned area population from the start because they can get water pollution improvement benefits. In particular, wastewater to be treated in this Preparatory Project is partially taken in from the total wastewater so that it means all the water supply users relate to this

Preparatory Project wastewater (of course, the total wastewater is not treated, though). At first, the beneficiaries are supposed to be population responding to the treated wastewater volume and EIRR is estimated. The result is positive, 0.57%, but very low. Next, the case result supposing Phase 1 users as objects is estimated. In this case, users' benefits become larger responding to Phase 1 users number and EIRR becomes 25.22%, sufficiently high. It will be higher if the beneficiaries are supposed to be the Cheung Aek system area users, but it is not necessary because the Phase 1 users case is sufficient.

8.9 Project Evaluation

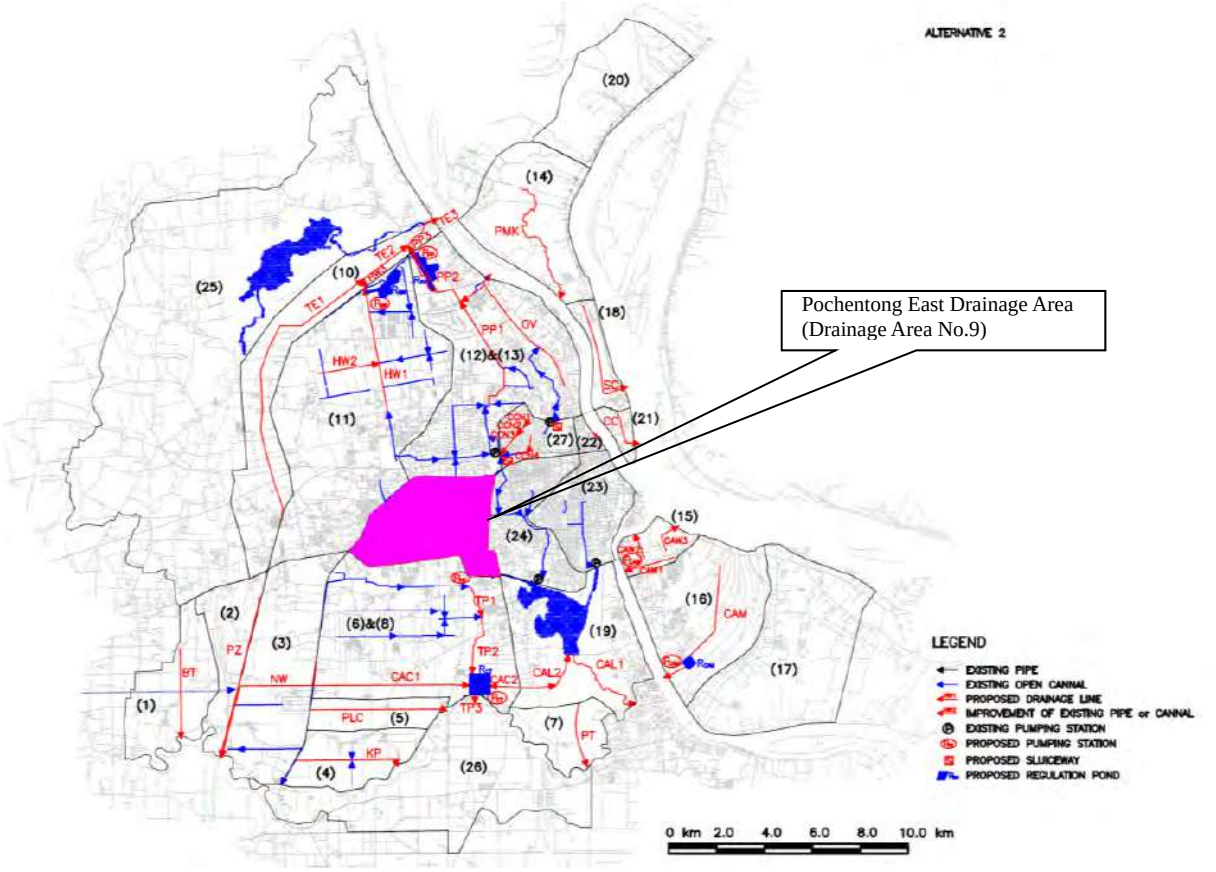
Project evaluation based on the result of Pre-F/S is summarized as follows.

- Preparatory Project contributes accumulation of knowledge and experience for full-operation of the STP because all processes (elements) of STP are equipped in the facilities installed in the Preparatory Project.
- In parallel to implementation of the Preparatory Project, establishment of institutional and legal framework is required to smoothly implement sewerage projects proposed for year 2020 or after.
- Preparatory Project beneficiaries' water supply use revenues (10% of water supply fee) cannot cover operation costs for the Preparatory Project. On the other hand, Phase 1 beneficiaries' revenues (10% of water supply fee) can cover the cost. In other words, sum of profit minus loss from the start to 2040 is positive.
- EIRR of 0.47% is expected depending on population (19,000 people in 2035) equivalent to 5,000 m^3/day, whereas the EIRR of 25.22% is expected depending on entire population of Phase 1 area in Cheung Aek treatment area (238,000 people in 2035).
- Resettlement is not required to implement the Preparatory Project because the STP is constructed in Cheung Aek Lake. Reclaimed area for Preparatory Project stage and ultimate stage are 3.5 ha and 16.3 ha, which are equivalent to 0.67% and 3.1% of total area of the Cheung Aek Lake (520 ha).
- Negative impacts such as traffic interruption, noise, dust and vibration would be unavoidable during the construction stage. However, the impacts could be minimized by introducing counter measures such as setting up of diversion road, sprinkling water and selecting low-noise and/or low-vibration type construction equipment as far as practicable.
- PPCC needs to secure land to dispose dewatered sludge from STP.

CHAPTER 9PRE-FEASIBILITY STUDY ON PRIORITY PROJECT OF DRAINAGE MANAGEMENT

9.1 Components of Priority Project

Priority project in drainage management is improvement in Pochentong East Drainage Area. The location of the Pochentong East Drainage Area is shown in **Figs. 9.1.1** and **9.1.2**. Components in Pochentong East Drainage Area are subdivided into two sub-components, as shown in **Table 9.1.1**.



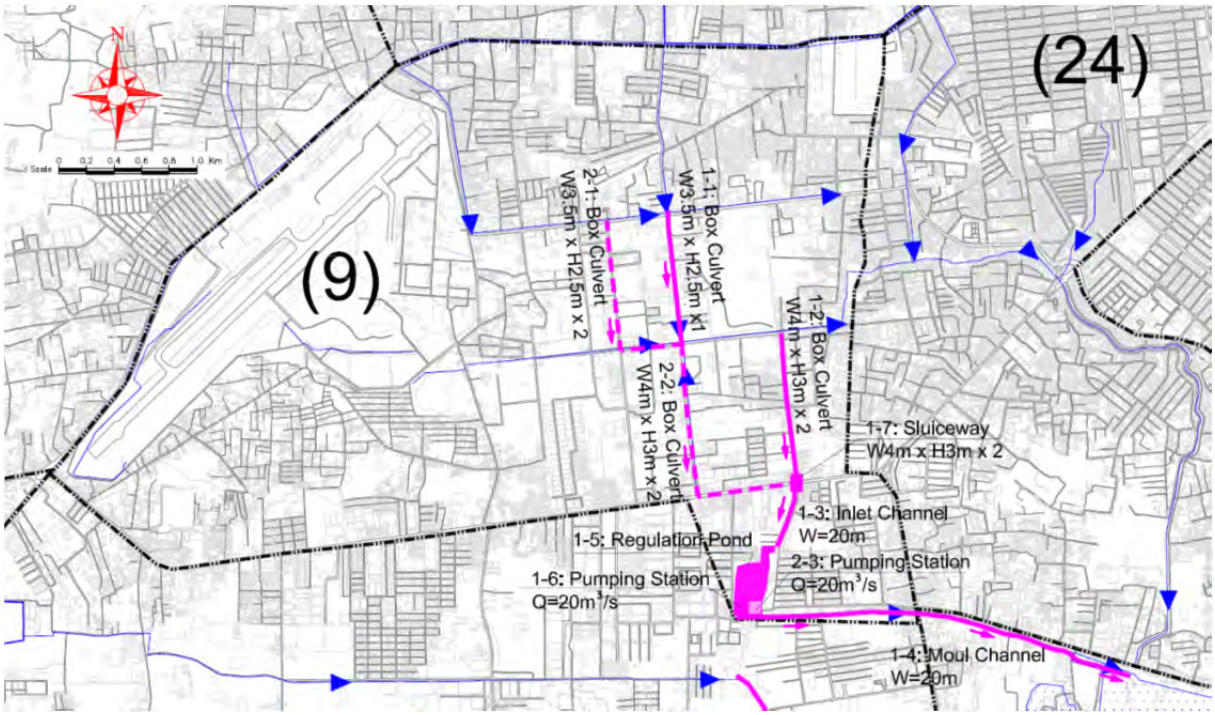
Source: JICA Study Team

Fig. 9.1.1 Location of Pochentong East Drainage Area

Table 9.1.1 Components in Pochentong East Drainage Area

No.	Type	Specification
Sub-component 1		
1-1	Construction of box culvert	W3.5 m×H2.5 m, L=1,010 m
1-2	Construction of box culvert	W4.0 m×H3.0 m×2 lanes, L=1,080 m
1-3	Construction of inlet channel	W20 m, L=480 m
1-4	Rehabilitation of Moul drainage channel	W20 m, L=2,660 m
1-5	Construction of regulation pond	Volume: 100,000 m^3
1-6	Construction of Pochentong East pumping station	Capacity:20 m^3/s
1-7	Construction of sluiceway crossing road	W4.0 m×H3.0 m×2 lanes, L=10 m
Sub-component 2		
2-1	Construction of box culvert	W 3.5 m×H2.5 m×2 lanes, L=1,370 m
2-2	Construction of box culvert	W 4.0 m×H3.0 m×2 lanes, L=1,760 m
2-3	Augmentation of Pochentong East pumping station	Capacity:20 m^3/s

Note : W=Width, H=Height, L=Length
Source: JICA Study Team



Source: JICA Study Team

Fig. 9.1.2 Location of Components in Pochentong East Drainage Area

9.2 Framework of Implementation

Similar framework in DPWT established in the past drainage projects under the supports from donors, is applied to this priority project, because the implementation framework was functional.

9.3 Cost Estimation

Project cost is summarized in **Table 9.3.1**. The cost consists of construction cost, engineering cost, administration cost, physical contingency and land expropriation/compensation cost, and is computed with exchange rate of 1USD=122.85JPY and 1Riel=0.030JPY. Summary of O&M cost is shown in **Table 9.3.2**.

Table 9.3.1 Project Cost

Unit: million USD

Item	Local currency	Foreign currency	Total
I. Construction cost ((1)+(2))	51.93	23.89	75.82
(1) Sub-component 1	23.77	11.36	35.13
1) Construction of box culvert (W3.5 m×H2.5 m)	5.63	0.71	6.34
2) Construction of box culvert (W4.0m×H3.0m×2)	9.39	1.18	10.57
3) Construction of inlet channel (480m)	0.81	0.01	0.82
4) Rehabilitation of drainage channel (2,660m)	4.50	0.06	4.56
5) Construction of regulation pond	0.13	0.01	0.14
6) Construction of pumping station	2.08	9.24	11.32
7) Construction of sluiceway crossing road	1.23	0.15	1.38
(2) Sub-component 2	28.16	12.53	40.69
1) Construction of box culvert (W3.5m×H2.5m×2)	10.79	1.36	12.15
2) Construction of box culvert (W4.0m×H3.0m×2)	15.29	1.93	17.22
3) Augmentation of pumping station	2.08	9.24	11.32
II. Engineering cost	1.68	6.71	8.39
III. Administration cost	3.79	0	3.79

	Item	Local currency	Foreign currency	Total
IV.	Physical contingency	2.68	1.53	4.21
V.	Land expropriation / compensation cost	0	0.80	0.80
	Total (I+II+III+IV+V)	60.08	32.93	93.01

Source: JICA Study Team

Table 9.3.2 Summary of O&M Cost

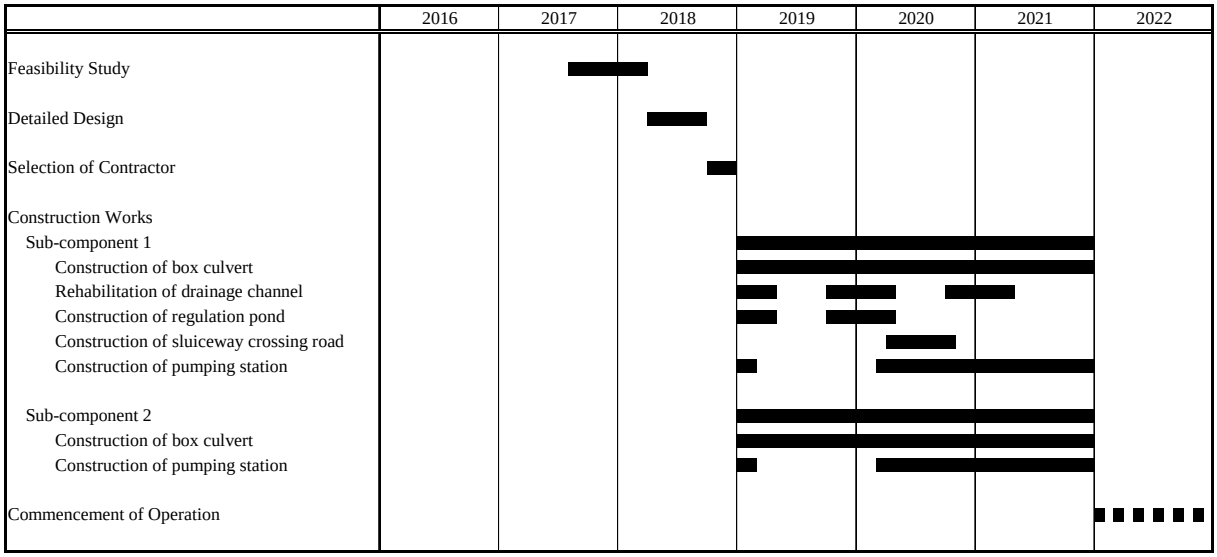
Unit: million USD

	Item	Total	Remark
I.	Pumping station	1.19	
	Electricity	0.97	Based on actual unit cost of existing pumping station
	Personnel expenses	0.04	Based on estimated number of 5 regular and 15 contracted employee
	Fuel	0.12	Based on actual unit cost of existing pumping station
	Repair and spare parts	0.05	1% of construction cost of machine and electronic facilities
	Others	0.01	Cleaning and miscellaneous expense
II.	Drainage channel and regulation pond	0.04	
Annul O&M total cost (I+II)		1.23	

Source: JICA Study Team

9.4 Implementation Schedule

Implementation schedule is formulated as shown in **Fig. 9.4.1** in consideration of setting-up of duration of designing, selection of contractor and construction works.



Source: JICA Study Team

Fig. 9.4.1 Implementation Schedule

9.5 Economic Analysis

EIRR is computed considering relation between benefit (mitigation of inundation damage) and investment and O&M cost. The EIRR is estimated at 12.72%

9.6 Project Evaluation

Project evaluation based on the result of Pre-F/S is summarized as follows.

- Inundation damage to households, commercial and industrial activities, traffic interruption associated with access to Phnom Penh International Airport, are reduced by implementing the project in Pochentong East Drainage Area.
- EIRR of 12.72%, obtained by improvement in Pochentong East Drainage Area (Drainage Area No.9), shows significant economic effect.
- Resettlement of 40 households is anticipated to implement the project for Pochentong East Drainage Area. Detailed survey in the succeeding Feasibility Study will therefore be required to minimize the number of resettlement.
- Negative impacts such as traffic interruption, noise, dust and vibration would be unavoidable during the construction stage. However, the impacts could be minimized by introducing counter measures such as setting up of diversion road, sprinkling water and selecting low-noise and/or low-vibration type construction equipment as far as practicable.

CHAPTER 10 ENVIRONMENTAL AND SOCIAL CONSIDERATION OF PRE-FEASIBILITY STUDY

10.1 Impact Assessment for the Pre-Feasibility Study

Assistance on the preparation of the IEE level information was provided during the study period.

10.1.1 Impact Assessment for Preparatory Project in Sewage Management

Anticipated impacts associated with the implementation of the Preparatory Project in Sewage Management are compiled in **Table 10.1.1**.

Table 10.1.1 Preliminary Scoping for Preparatory Project in Sewage Management (December 2015)

Classification	No.	Items	Reason and Description	Rating
Social Environment	1	Involuntary resettlement	**Planning phase, Construction phase:** Some residents are living closely to the Discharge point of the existing Tumpun Station where new construction of Sewage interception facility and Sewer to the Plant are currently proposed. Also, There are dense population at existing road of No.371 (Outer ring-road). At the improvement of the existing ditches, impact to the residents should be avoid/minimized based on the adequate survey for the existing ditched at planning. **Planning phase, Construction phase:** There are some raised floor structures in the Cheung Aek lake and people may be living permanently or temporally. At the planning phase, impact to those residents should be avoided/minimized resettlement and area of land acquisition. The Cheung Aek lake which is planned for the STP site has been used for agriculture and domestic fishery. Some resident may lose their income source partly/fully. Although the land of the Cheung Aek is declared as Public State Land, adequate socio-economic survey may require for establishing compensation /rehabilitation schemes in accordance with the JICA environmental and social guideline (2010).	C-
	2	Local economy such as employment and livelihood, etc.	**Planning phase, Construction phase:** Residents who live in Cheung Aek lake may include some poor household, are likely affected to be loose a part of their income source of the farm land. In the case, supporting programs such as resettlement plan and rehabilitation plan will be required. **Construction phase:** The project is expected to increase working opportunity for construction.	C-
	3	Land use and utilization of local resources	**Planning phase, Construction phase:** Associated to the STP construction, water bodies/wet land where local people are using for agriculture and fishery will be reclaimed. Although the scale of the Plants area might not be large, less than approximately 16ha, at the planning, the impact should be avoided/ minimized. In case of no fully avoidable, adequate compensation should be made based on the socio economic survey in the area.	B-
	4	Social institutions	**Planning phase, Construction phase:** In the capital, there are many land development project that the wetland is diverted to the other land use such as residential area and industrial area. Associated to those developments, there are some problems in flood and land use. Adequate information disclosure by implementation agency to project affected peoples (PAPs) may require at actual planning phase.	B-
	5	Existing social infrastructures and services	**Construction phase:** In the Preparatory Project, the pipe systems are planned to be installed under the access roads which connects Road 371 and proposed STP. Associated to the construction work of access road, the disturbance to the road traffic movement in Road 371 is likely to occur.	B-

Classification	No.	Items	Reason and Description	Rating
	6	The poor, indigenous and ethnic people	**Planning phase, Construction phase:** For selection of the STP, special consideration should be taken to poor households in the wetland. There are some raised floor structures in the Cheung Aek Lake where people may be living permanently or temporarily. Also, some residents are living closely to existing ditches in the city area. At the planning phase, impact to these residents should be avoided or resettlement and area of land acquisition should be minimized.	B-
	7	Misdistribution of benefit and damage	**Planning phase:** Although the project aims to contribute environmental improvement of the capital, there are possible residents in the STP candidate area and along the existing ditches. The impact to residents should be avoided /minimized considering current situation based on adequate survey at the planning phase.	B-
	8	Historical and cultural heritage	No particular impact is identified at the moment.	D
	9	Local conflict of interests	**Planning phase:** In the capital city, there are many land development project where the wetland is diverted to the other land use such as residential area and industrial area. Associated to those developments, there are some problems in flood and land use. The city government is currently proceeding on the identification of land rights. Some conflicts on land right is will likely to occur if private land is involved in the project area.	B-
	10	Water usage or water rights and rights of common	No particular impact is identified at the moment.	D
	11	Sanitation	**Operation phase:** The project is expected to improve the current water environment situation in the capital.	A+
	12	Hazardous (risk) infectious diseases such as HIV/AIDS	**Operation phase:** After operation, the risk of the water related diseases is expected to be reduced, through the sewerage projects and drainage projects.	A+
Natural Environment	13	Topography and geographic features	**Construction phase:** At the construction phase, some topographical modification will occur associated with land filling in the current water area in Cheung Aek Lake.	B-
	14	Groundwater	**Operation phase:** At the operation of the STP, water quality in groundwater is expected to improve.	A+
	15	Soil erosion	For the construction of the STP, land reclamation for access road and STP in the Cheung Aek Lake is planned. Adequate countermeasures to protect the slope surface should be considered.	B-
	16	Hydrological situation	**Planning phase, Construction phase:** The project will be planned based on the current water flow and no large hydrological change is associated. No particular impact is identified at the moment. The land reclamation in the Cheung Aek Lake will possibly affect current water flow in the area depending on the site selection and adequate hydrological study may be needed to avoid flood damage.	B-
	17	Coastal zone	There is no coastal zone in project area.	D
	18	Fauna and flora and biodiversity	**Planning phase, Construction phase:** There is no legally protected area such as National Park, Wildlife preserve, Protected scenic view area and Multi-purpose area in the project area. Habitats for the common fish species in the Cheung Aek Lake will likely be affected to be decreased. The Cheung Aek Lake is functioning as natural waste water treatment lagoon for the capital city and water quality will highly deteriorate. Due to decline of the water quality, poor biodiversity can only be remained and the impacts are limited. **Operation phase:** Through the water quality improvement by the project, biological value of the lakes may increase.	B-/B+
	19	Meteorology	No particular impact is identified at the moment.	D

Classification	No.	Items	Reason and Description	Rating
	20	Landscape	No particular impact is identified at the moment.	D
	21	Global warming	The candidate site for the STP is contributing as natural pond in the watershed and the excessive global warming gas emission is not expected.	D
Pollution	22	Air pollution	**Construction phase:** During construction, the suspended dust and gas emission from the construction machinery are expected even if limited in area.	B-
	23	Water contamination	**Construction phase:** Associated with earthwork in the construction turbidity of the water will be likely increased at the downstream even if temporarily.	B-
	24	Soil contamination	**Construction phase:** During construction, accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	B-
	25	Waste	**Construction phase:** During construction and operation, the project owner should implement adequate handling of waste (including sludge).	B-
	26	Noise and vibration	**Construction phase:** During construction period noise pollution will be generated by vehicles, stone crushing, generators etc.	B-
	27	Ground subsidence	Ground modification and ground water exploitation are not planned and no any impact is anticipated.	D
	28	Offensive odor	**Construction phase:** During construction work, associated with the disturbance of the river bottom sediment such as bed excavation and foundation works, offensive odour may be generated. **Operation phase:** Associated with the operation of STP, offensive odour at surrounding area may increase. The wetlands which are candidate sites for STP, already contribute as actual waste water treatment lagoons for water purification in the Phnom Penh Capital City. Odour at the surrounding area of existing ditches and lagoon may be improved at the operation of STP.	B-/B+
	29	Bottom sediment	**Operation phase:** With the operation of the STP, situation of the bottom sedimentation at existing ditches will be improved through separate systems for sewer and rainwater.	A+
	30	Accidents	**Construction phase:** During construction, operation of heavy vehicles and machineries may cause traffic accidents to residents and labours in and around the proposed project sites.	B-

Rating
- A-: Serious impact is expected, if no measure is implemented against the impact.
- B-: Some impact is expected, if no measure is implemented against the impact.
- C-: Extent of impact is unknown (Examination is needed. Impact may become clear as study progresses.)
- D: No impact is expected.
- A+: Remarkable effect is expected due to the project implementation itself and environmental improvement caused by the project.
- B+: Some effect is expected due to the project implementation itself and environmental improvement caused by the project.

Source: JICA Study Team

10.1.2 Impact Assessment for Priority Project in Drainage Management

Anticipated impacts associated with the implementation of the Priority Project in Drainage Management are compiled in **Table 10.1.2**.

Table 10.1.2 Preliminary Scoping for Priority Project in Drainage Management (December 2015)

Classification	No.	Items	Reason and Description	Rating
Social Environment	1	Involuntary resettlement	**Planning phase, Construction phase:** Some residents are living closely to existing ditches such as Phum Mor Canal at downstream of the catchment area(Approximately 100 structures are located closely in approximately 1km of Phum Mor Canal up to the area of bridge on the Road 217). At the improvement of water flow/drainage in the catchment, impact to the residents in downstream should be avoided/minimized based on the adequate survey in downstream. To some extent, the project may require the resettlement of the residents who lives near the existing ditches/canals. **Planning phase, Construction phase:** Construction of box culvert, new pumping station, and new regulation pond may require additional land acquisition and sometime associated with resettlement in the city area (approximately 40 structure is likely relocated in the estimation in the Master Plan stage). Expansion of the existing pumping station may affect the residents nearby without any consideration.	C-
	2	Local economy such as employment and livelihood, etc.	**Planning phase, Construction phase:** Residents who live in marginal areas such as wetland and ditch side may include some poor households which will likely be affected and loss a part of their income source or to be resettled/lost the land. In the case, supporting programs such as resettlement plan and rehabilitation plan will be required. **Operation phase:** With the operation of the drainage system, flood damage risks would decrease and the local economy is expected to improve. At the construction, the project is expected to increase working opportunity for construction. **Planning phase, Construction phase:** During construction, the project would increase work opportunities.	C-/B+
	3	Land use and utilization of local resources	**Operation phase:** With the operation of drainage system, there will be a decrease in flood damage risks and land use is expected to improve.	B+
	4	Social institutions	**Planning phase, Construction phase:** In the capital city, there are many land development project so that the wetland are converted to other land use such as residential area and industrial area. Associated to those developments, there will be some problems with flood and land use. Adequate information disclosure by implementation agency to project-affected people is required at the actual planning phase.	B-
	5	Existing social infrastructures and services	**Construction phase:** The drain systems are basically planned to be installed under existing roads. Associated to the installation works, disturbance to road traffic will likely to occur. **Planning phase:** The proposed site for the box culvert includes some newly improved or planned roads such as Veng Sreng Blvd., Northbridge Street, St. Doung Neap II and St. 2004. Adequate coordination with the road construction plan may be needed. **Operation phase:** With the operation of drainage system, traffic movement in rainy season may be improved.	B-/ B+
	6	The poor, indigenous and ethnic people	**Planning phase, Construction phase:** Some residents are living closely to existing ditches in the city area. At the planning phase, impact to those residents should be avoided with minimized resettlement and area of land acquisition.	C-
	7	Misdistribution of benefit and damage	No particular impact is identified at the moment.	D
	8	Historical and cultural heritage	No particular impact is identified at the moment.	D
	9	Local conflict of interests	**Planning phase:** In the capital city, there are many land development project that the wetland are converted to the other land uses such as residential area and industrial area. Associated to these developments, there are some problems with flood and land use. The city government is currently proceeding with the identification of land rights. Associated with the above-mentioned land acquisition and resettlement (if involved), some conflicts on the land right is will likely to occur and need a long	B-

Classification	No.	Items	Reason and Description	Rating
			resolution procedure. Especially in the target area where some box culvert installations are planned, Veng Sreng Blvd. and Trung Morn Street (North Bridge Road) are currently being expanded and paved. Frequent resettlement and setback may generate conflict between the government and the residents.	
	10	Water usage or water rights and rights of common	**Planning phase:** No particular impact is identified at the moment. Some canals in Phnom Penh Capital City are managed by the water resource department for the irrigation purpose. For water flow improvement, adequate coordination with the irrigation is required.	B-
	11	Sanitation	**Operation phase:** The project is expected to improve the current water environmental situation in the capital.	A+
	12	Hazardous (risk) infectious diseases such as HIV/AIDS	**Operation phase:** After operation of the sewerage and drainage projects, the risk from water related diseases is expected to be reduced.	A+
Natural Environment	13	Topography and geographic features	**Construction phase:** With the construction, some topographical modification of waterway is expected.	B-
	14	Groundwater	No particular impact is identified at the moment.	D
	15	Soil erosion	No large soil erosion is anticipated because the area is generally flat. Water way modification,	D
	16	Hydrological situation	**Planning, Construction and Operation phase:** With new pumping station and regulation ponds, modification of the water flow may be associated.	B-
	17	Coastal zone	There is no coastal zone	-
	18	Fauna and flora and biodiversity	**Planning phase:** There are no legally protected area such as national parks, wildlife preserves, protected scenic view areas and multi-purposes areas in the project area. Most existing ditches and regulation ponds in the capital are highly polluted for habitation of wildlife. At the planning phase, the situation may be confirmed in the survey.	D/B+
	19	Meteorology	No particular impact is identified at the moment.	-
	20	Landscape	No particular impact is identified at the moment.	D
	21	Global warming	No particular impact is identified at the moment.	D
Pollution	22	Air pollution	**Construction phase:** At the construction, the suspended dust and gas emission from the construction machinery is expected to be limited.	B-
	23	Water contamination	**Construction phase:** Associated with earthwork in the construction, turbidity of the water will be likely increased at the downstream.	B-
	24	Soil contamination	**Construction phase:** During construction, accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	B-
	25	Waste	**Construction phase:** During construction and operation, the project owner should implement adequate handling of waste (including sludge).	B-
	26	Noise and vibration	**Construction phase:** During construction, noise pollution will be generated by the use of vehicles, stone crushing, generators etc.	B-
	27	Ground subsidence	Ground modification and groundwater exploitation are not planned and no any impact is anticipated.	-
	28	Offensive odor	**Construction phase:** Associated with disturbance of the river bottom sediment due to bed excavation and foundation works in the construction phase, offensive odour may be generated.	B-
	29	Bottom sediment	**Operation phase:** With the operation of existing ditches, the improved water flow may reduce sedimentation.	B+
	30	Accidents	**Construction phase:** During construction, operation of heavy vehicles and machinery may cause traffic accidents to residents and labours in and around the proposed project sites.	B-

Rating

A-: Serious impact is expected, if no measure is implemented against the impact.

B-: Some impact is expected, if no measure is implemented against the impact.

C-: Extent of impact is unknown (Examination is needed. Impact may become clear as study progresses.)

D: No impact is expected.

A+: Remarkable effect is expected due to the project implementation itself and environmental improvement caused by the project.

B+: Some effect is expected due to the project implementation itself and environmental improvement caused by the project.

Source: JICA Study Team

CHAPTER 11 CONCLUSION AND RECOMMENDATION

11.1 Conclusion

11.1.1 Sewage Management

For sewage management, PPCC is subdivided into three areas (Cheung Aek, Tamok and Other areas) and the on-site and off-site treatment methods for the target year 2035 are evaluated as structural measures. As a result, off-site treatment is applied to the Cheung Aek Treatment Area and the Sewage Treatment Plant (STP) employing the Conventional Activated Sludge Process (CASP) is proposed. On the other hand, on-site treatment introducing Johkasou is proposed for the Tamok Treatment Area. In the "Other area", the installation of septic tank, which is the most popular sanitary device in PPCC, is recommended, especially in households in which no toilet or pit latrine is equipped, and the introduction of advanced wastewater facilities such as Johkasou is recommended beyond the target year.

Due to the lack of institutional and legal provisions in sewage management, the establishment of institutional and legal framework of sewage management in PPCC is indispensable to commence and sustainably implement full-scale sewage management, particularly, the construction and operation of STP. Sewerage and Drainage Advancement Office under the Director of DPWT/PPCC is therefore proposed in the M/P, with the approach of "Start small and grow big". After the establishment of the Advancement Office, phased implementation plan for establishing independent sewage implementing body, in parallel with human resource development, is proposed.

In parallel with the establishment of institutional and legal framework of sewage management, phased construction plan is formulated to gradually accumulate experience and knowledge of sewage management. Based on the phased construction plan, "Preparatory Project", followed by three phases of STP construction, is proposed for Cheung Aek Treatment Area. The Preparatory Project is outlined in the Pre-F/S.

Phased establishment of institutional and legal framework, along with implementation of the Preparatory Project, will realize the smooth and sustainable implementation of subsequent sewage projects in PPCC.

11.1.2 Drainage Management

In the drainage management, PPCC is subdivided into 25 catchment areas. Structural measures consisting of drainage channels, pumping stations and regulation ponds are proposed considering topographical conditions as well as availability of existing drainage facilities for the target year 2035.

Institutional and implementation framework in drainage management is already established to some extent through implementation of drainage improvement projects such as "The Project for Flood Protection and Drainage Improvement Project in Phnom Penh Capital City (Phase 1, 2 and 3)". However, strengthening of institutional framework is proposed because the present framework is insufficient to smoothly implement the number of drainage projects proposed in the M/P to address rapid urbanization.

Pre-F/S in drainage management is conducted targeting one of the prioritized drainage areas of Pochentong East, because "The Preparatory Survey on the Project for Flood Protection and Drainage in the Phnom Penh Capital City (Phase 4) is commenced from end of March 2016, targeting the other prioritized drainage areas of Wat Phnom Northern Area and Tuol Kok.

After the Phase 4 project, implementation of the project in Pochentong East Drainage Area is recommendable to mitigate inundation damage recently identified in the newly developed area in PPCC.

11.2 Recommendation

11.2.1 Sewage Management

Recommendations for sewage management are enumerated as follows.

- CASP is selected in the M/P and Pre-F/S as the applicable wastewater treatment method for Cheung Aek STP, for the reason that it is premature to apply the PTF (Pre-Trickling Filtration) method employed in large-scale STPs. However, re-evaluation of the PTF in the implementation stage is required based on actual performances in other countries, because the PTF has the advantage of reducing O&M cost and minimizing land acquisition, and the introduction of advanced technologies is essential in order to promote “quality infrastructure investment”.

- Establishment of institutional and legal framework in sewage management is essential to smoothly implement full-scale construction and operation of sewerage facilities, considering the current lack of institutional and legal provisions in sewage management in PPCC. In the establishment of the framework, assistance from donors in collaboration with MPWT is beneficial.

11.2.2 Drainage Management

Recommendations for drainage management are enumerated as follows.

- A number of small to large-scale development projects are on-going in PPCC. As a result, swamps and lakes, which have been protecting PPCC from inundation, rapidly disappear. Therefore, PPCC should impose severe restrictions on the reclamation of swamps and lakes by land developers in order to prevent inundation and require them to install drainage facilities in accordance with the drainage management plan in the M/P.

- In PPCC, garbage disposed to drainage channels severely affects function of drainage channels especially in the rainy season. In order to improve the condition, PPCC should educate people with such slogans as “Do not dispose garbage to drainage channels”, “Drainage channel is not garbage box”, and “Disposed garbage in drainage channel leads to inundation and inconvenience in your daily life” in a repetitive manner.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