MINISTRY OF WATER RESOURCES
AND METEOROLOGY,
THE KINGDOM OF CAMBODIA

PREPARATORY SURVEY
FOR
IRRIGATION AND DRAINAGE SYSTEM
REHABILITATION AND IMPROVEMENT PROJECT
IN
THE KINGDOM OF CAMBODIA

MANUAL
ON
EXECUTION
OF
PRELIMINARY FEASIBILITY STUDY
FOR
SMALL-SCALE IRRIGATION PROJECT

SEPTEMBER 2012

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NIPPON KOEI CO., LTD.

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Attachments

Abbreviations

[A]	
ADB	Asian Development Bank
[B]	
B/C	Benefit-Cost Ratio
[E]	
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
[F]	
FAO	Food and Agriculture Organization of the United Nations
F/S	Feasibility Study
FWUC	Farmer Water Users Community
FWUG	Farmer Water Users Group
[G]	
GIS	Geographic Information System
GOJ	Government of Japan
[I]	
ISF	Irrigation Service Fee
[J]	
JICA	Japan International Cooperation Agency
[M]	
MAFF	Ministry of Agriculture, Forestry and Fisheries
MOU	Minutes of Understanding
MOWRAM	Ministry of Water Resources and Meteorology
[N]	
NPV	Net Present Value
[O]	
O&M	Operation and Maintenance
[P]	
PO	Project Owner
[S]	
SISIP	Small-scale Irrigation System Improvement Project
SPPIDRIP	Southwest Phnom Penh Irrigation and Drainage Rehabilitation and Improvement Project
[T]	
TSC	Technical Service Center for Irrigation and Meteorology
[V]	
VAT	Value added tax

Measurement Units

Extent

- cm^2 = Square-centimeters (1.0 cm × 1.0 cm)
- m^2 = Square-meters (1.0 m × 1.0 m)
- km^2 = Square-kilometers (1.0 km × 1.0 km)
- ha = Hectares (10,000 m^2)

Length

- mm = Millimeters
- cm = Centimeters (cm = 10 mm)
- m = Meters (m = 100 cm)
- km = Kilometers (km = 1,000 m)

Time

- sec = Seconds
- min = Minutes
- hr = Hours

Currency

US$ 1.0 = JPY 76.8 = 4,084 Riel
(Internal Bank Rate as of July, 2011)

- US$ = United State Dollar
- JPY = Japanese Yen
- R, Riel = Cambodian Riel

Volume

- cm^3 = Cubic-centimeters (1.0 cm × 1.0 cm × 1.0 cm or 1.0 m-lit.)
- m^3 = Cubic-meters (1.0 m × 1.0 m × 1.0 m or 1.0 k-lit.)
- lit l = Liter (1,000 cm^3)
- MCM = Million Cubic Meter

Weight

- gr = Grams
- kg = Kilograms (1,000 grams)
- ton = Metric ton (1,000 kg)

Others

- ppm = parts per million
- °C = degree centigrade
- % = percent

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CHAPER 1 INTRODUCTION

1.1 Authority

This manual was prepared in accordance with the Minutes of Discussion on Preparatory Survey for Irrigation and Drainage System Rehabilitation and Improvement Project (the Project) signed by Japan International Cooperation (JICA) and the Royal Government of Cambodia (RGC) on February 25, 2011.

1.2 Background and Objective

(1) Background

The Small-scale Irrigation System Improvement Project (SISIP) is a part of the Project, which was requested to JICA by MOWRAM for its implementation by applying the Japanese loan. SISIP consists of 84 sub-projects. Three sub-projects out of them were selected as representative ones, so as to execute the preliminary feasibility study for appraisal purpose, which might be implemented under the Japanese loan if these are proved to be technically and economically sound.

As for the remaining sub-projects, it is expected that PDOWRAM will carry out the preliminary feasibility under direction of MOWRAM for implementation in future. As far as the project proposals on them prepared by PDOWRAM are concerned, however unfortunately, these would not attain at the satisfactory level from the technical and economical viewpoints. Thus, it is essential to take necessary arrangement for enabling PDOWRAM to carry out the preliminary feasibility study in a proper way. It is confident that the manual is one of effective means to strengthening the PDOWRAM capability for execution and examination of preliminary feasibility study

(2) Objective

The objective of the manual is to provide the PDOWRAM staff with the procedure of execution of preliminary feasibility study for small-scale irrigation projects, which is worked out mainly by reflecting the experiences obtained through the preliminary feasibility study for the selected three Sub-projects mentioned above. On the other hand, even the preliminary feasibility study covers many fields such as hydrology, agronomy, irrigation, drainage, economy and environment. In order to cope with such complicated situations, the manual should be therefore elaborated in a more simple and practical manner, so that the PDOWRAM staff can bear mind to easily use it.

1.3 Small-scale Irrigation System Improvement Project

(1) Number and Location

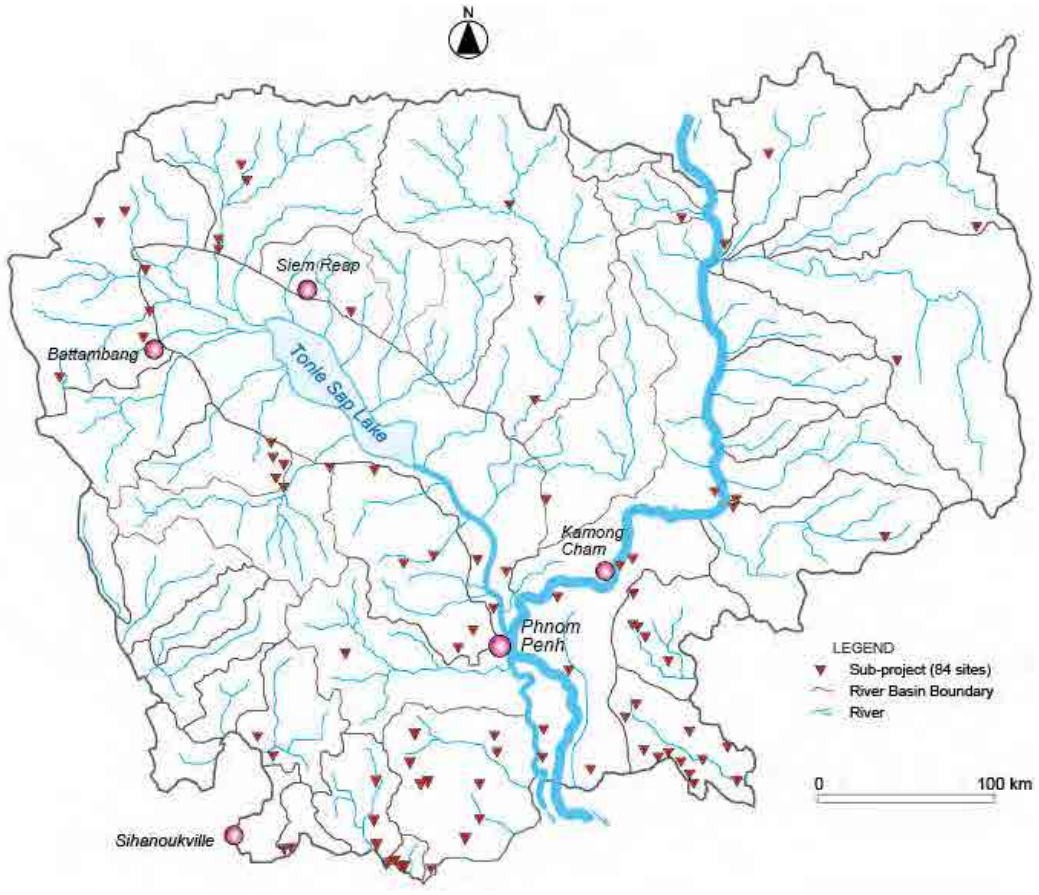
As mentioned above, SISIP consists of 84 Sub-projects located broadly in 23 provinces. The list of Sub-projects is shown in Table 1.3.1, and location of them is given in Figure 1.3.1.

Table 1.3.1 List of Sub-projects

Sub-project	Province	Commune	District	Beneficiary	Irrigation Area
(1) Mongkolbery Main Canal	Bontey Mean Chey	Bontey Neang	Bongkol Bore	1,815persons	1,116 ha
(2) Kanseng Reservoir		Soeng	Ochrouve	3,785persons	2,700 ha
(3) An Longrot Reservoir		Svay Chek	Svay Chek	3,270persons	1,350 ha
(4) O'Yes	Modul-Kiri	Sre Angkum	Koh Nhek	2,450persons	1,080 ha
(5) Sre Khum		Sre Khtum	Kao Seima	1,415persons	360 ha
(6) Khla Krap	Kampong Chhnang	Koh Thkov	Cholkiri	970persons	450 ha
(7) Daun Pue		Chiep	Teuk Phos	7,077persons	1,151 ha
(8) Canal Stung Sdatch		Tang Krasang	Teuk Phos	7,356persons	1,046 ha
(9) Main Canal 35km	Kanpong Speu	Katplug	Basedth	50,204persons	3,018 ha
(10) O Kontron		Dambok Rung	Phnom Sruct	27,152persons	3,250 ha
(11) O Ta Penn		Rassmei Samar	Oral	2,392persons	1,400 ha
(12) N5 Canal	Battambang	Bon Say Treng	Thmarkol	24,898persons	4,750 ha
(13) Anlong Rum Canal		Anlong Run	Thmarkol	9,203persons	710 ha
(14) Choy Samrong	Takeo	Baray	Doun Keo	6,174persons	300 ha
(15) Thra Peang Veng		Kampang	Prey Kabas	1,966persons	220 ha
(16) Sen Presh Ream		Prey Pdav	Prey Kabas	6,467persons	567 ha
(17) Ponas		Kampang	Kirivong	3,716persons	1,756 ha
(18) Potawa		Angprasat	Kirivong	6,423persons	2,872 ha
(19) Sea Protection Dike	Sihanouk Ville	O'oknhaheng	Prey Nop	560persons	260 ha
(20) Bot Koki Reservoir		O'oknhaheng	Prey Nop	13,392persons	386 ha
(21) Boeung Preah Ponley Reservoir	Pursat	Ptas Roop	P.Kravahh	16,872persons	2,800 ha
(22) Tuol Lopov		Svay At	Pursat City	4,048persons	360 ha
(23) Kom Peang Reservoir		Prangil	P.Kravahh	3,505persons	380 ha
(24) Kab Kraianh		Trapeang Chorr	Bakan	4,998persons	550 ha
(25) Wat Leap		Meteuk	Bakan	4,888persons	600 ha
(26) Tram Canal		Tnout Chum	Krakor	2,918persons	350 ha
(27) Ken Seng		Ansa Cham Bok	Krakor	1,920persons	235 ha
(28) Sras Prambai	Kandal	Pothy Ban	Koh Thom	6,272persons	2,500 ha
(29) Tom-or		Samron Lei	Ansnol	1,437persons	247 ha
(30) Ta Tray		Pouk-Resey	Khasch Kana	6,636persons	172ha
(31) Chak Kaek		Prek Chrey	Kandal	1,842persons	226ha
(32) Milk Krabai Kon		Chheu Kmao	Koh Tom	51,512persons	3,820ha
(33) O kleh	Stung Treng	Preak Meas	Siem Pang	1,652persons	2,895ha
(34) Khom Den		Samaki	Stung Treng	942persons	242ha
(35) Sre Choan		Sam Ang	Thalaborivat	1,109persons	984ha
(36) Rones	Kep	Poun Teuk	Dam Nak Chang	2,913persons	621ha
(37) Dem Pring		Poun Teuk	Dam Nak Chang	963persons	160ha
(38) Preg Tanen		Poun Teuk	Dam Nak Chang	986persons	75ha
(39) Veal Vong		Poun Teuk	Dam Nak Chang	1,208persons	375ha
(40) Tra Pang Boeung Reservoir	Kampot	Trapang Boeung	Chhuk	7,148persons	1,430ha
(41) Kandal		Kandal	Teuk Chhu	2,985persons	650ha
(42) Pey Phdav Reservoir		Srae Knong	Chum Kiri	7,148persons	390ha
(43) Mlach		Chres	Chum Kiri	5,608persons	1,600ha
(44) Ou Chranieng Reservoir		Kampong Trach	Kampong Trach	2,833persons	310ha
(45) 77 Reservoir		Sre Cheng	Chum Kiri	2,525persons	578ha
(46) Prawoek Pong Reservoir		Trapaing	Teuk Chhu	2,885persons	310ha
(47) Neary Canal	Siem Reap	Kampong Thk	Kralanh	1,243persons	611ha
(48) Louk Canal		Taan	Kralanh	1,135persons	1,085ha
(49)Trabek Canal		Damdek	Sothnikum	2,216persons	1,300ha
(50) Thnat Bot	Pallin	Sala Krao	Sala Krao	4,962persons	4,000ha
(51) Som Trok Reservoir	Ratana Kiri	Som Thom	O'Ya Dav	1,819persons	90ha
(52) Samaki 75 Reservoir	Kampong Cham	Batheay	Batheay	1,415persons	703ha
(53) Beung Khtum Reservoir		Prek Romdeng	Sreysanthor	1,003persons	393ha
(54) Chamlok Cham Reservoir		Prek Romdeng	Sreysanthor	510persons	379ha
(55) Bay Dei Reservoir		Baray	Sreysanthor	6,791persons	894ha
(56) Simang Reservoir		Preas Theart	Ou Rang Ov	6,284persons	487ha

Sub-project	Province	Commune	District	Beneficiary	Irrigation Area
(57) Phum Nheat Canal	Prey Veng	Thmor Pun	Kann Chroach	5,752persons	3,009ha
(58) Thmor Tek Datch Canal		Kokkong Keut	Kann Chroach	3,308persons	1,012ha
(59) Kbal Kapal Dam		Prek Tasor	Pea Raing	611persons	400ha
(60) Char		Cheach	Kamchayme	2,969persons	888ha
(61) Anlong Cha Canal		Prah Sdach	Prah Sdach	10,675persons	2,226ha
(62) Kra Chab Dam		Prey Khla	Svay Antor	8,766persons	850ha
(63) Preak Than	Svay Rieng	Kampong Chark	Rumdoul	5,976persons	2,334ha
(64) Ta Nou		Cham Bak	Svay Chrum	3,761persons	452ha
(65) Monourum		Monourum	Svay Teap	1,175persons	661ha
(66) Krang Leav		Svay Chrum	Svay Thom	4,698persons	642ha
(67) Svay Tayean		Koki	Kampong	5,318persons	653ha
(68) O Damrey Chiang		Kampong Ro	Bantey	599persons	398ha
(69) Sandort		Dun Sar	Svay Chrum	3,022persons	618ha
(70) Veal Knach		Krork Ko	Svay Chrum	1,148persons	214ha
(71) Chies Rossey		Kampong Chamlong	Svay Chrum	2,814persons	279ha
(72) So Pha		Bandey Krang	Kampong	1,538persons	650ha
(73) Svay Year		Sem Roung	Chan Trea	3,319persons	350ha
(74)O Andeng Reservoir	Kampong Thom	Tainkrosao	Prosat Sambo	1,716persons	600ha
(75) Hun Sen Canal		Baray	Baray	13,141persons	650ha
(76) Po	Kratle	Bosieav	Cheltra Borei	1,295persons	445ha
(77) O Streung Kdach		Preakprasob	Preakprasob	1,322persons	365ha
(78) O Laork		Thmor Andek	Cheltra Borei	2,124persons	501ha
(79) Saray Polder	Koh Kong	Chroy Svay	Sre Ambel	953persons	342ha
(80) Tani Polder		Chikhor Leou	Sre Ambel	889persons	241ha
(81) Promey Reservoir	Preach Vihear	Promey	Tbeng Mean Chey	1,700persons	300ha
(82) Osarakareach Reservoir		Rir Riey	Rovang	1,950persons	390ha
(83) Chong Kal	Odar Meanchey	Chong Kal	Chong Kal	2,400persons	1,450ha
(84) Ta Enn		Pong Rer	Chong Kal	4,714persons	1,543ha

Source: Minutes of Discussion on Preparatory Survey for Irrigation and Drainage System Rehabilitation and Improvement Project



Source: JICA Survey Team

Figure 1.3.1 Location Map of 84 Sub-projects

(2) Definition of Small-scale Irrigation Project

As can be seen in the above table, the irrigation area for sub-projects largely fluctuates. Table 1.3.2 shows the area-wise classification of proposed sub-projects. According to the MOWRAM's criteria, the small-scale project is defined with its irrigation area less than 200 ha. If applying this definition, the small-scale project is only 4 nos. out of 84 nos. This manual is therefore prepared for the sub-projects less than 1,000 ha.

Table 1.3.2 Area-wise Classification of Sub-projects

Irrigation Area	Nos. of Sub-projects
≦200 ha	4
200 ha< and ≦500 ha	32
500 ha < and ≦1,000 ha	21
1,000 ha< and ≦2,000 ha	14
>2,000 ha	13
Total	84

Source: JICA Survey Team

(3) Type of Sub-projects

All sub-projects proposed are categorized as gravity irrigation type. The water sources for them are classified into river, reservoir and recession water. The number of sub-projects for respective water sources is shown in Table 1.3.3. This manual is thus prepared in consideration of these three types of water sources.

Table 1.3.3 Number of Sub-project for Respective Water Sources

Water Source	Nos. of Sub-projects
River	20
Reservoir	42
Recession Water	15
Total	84

Source: JICA Survey Team

(4) Findings on Proposals for Sub-projects

PDOWRAMs have prepared the proposal for each sub-project in reply to the request of MOWRAM. After scrutinizing these proposals, there found the following defects in them:

- Water source available for irrigation is not quantified.
- Water demand for irrigation is not calculated based on cropping pattern.
- The relation between available water source for irrigation and irrigable area is not clear.
- Concept of economic cost is not taken into consideration.
- Incremental benefit is not properly estimated.

From these findings, it is deemed that PDOWRAMs need to learn more how to approach to preparation of irrigation development plan, especially execution of feasibility study. Thus, this manual is prepared keeping the above in mind.

1.4 Review of Project Proposal for Small-scale Irrigation System Improvement Project

Project proposal documents for the rehabilitation of SISIP consisting of 84 sub-projects were submitted to MOWRAM in October 2009 prior to the JICA Survey. These proposals were prepared by PDOWRAM by filling up standard proposal forms given by MOWRAM under assistance of TSC-2. The proposal is composed of an application form and annexes including the following descriptions.

Application Form	Annexes
(a) Applicant's information (PDOWRAM) - Name and address of responsible person - Number of staff and annual budget - Project implementation system - Experiences of project implementation (b) Project information - Project site - Background of project - Purpose of project - Outline of project - Project cost with breakdown cost estimation	(a) Map - Location map - Layout map - Command area map (before project) - Command area map (after project) (b) Photo (c) Project work plan (d) Project cost estimation (e) Design documents (f) Answer to questionnaire on : - FWUC,

Application Form	Annexes
- Beneficiaries - O&M cost - FWUC establishment - Expected project effect/impact - Economic evaluation (IRR)	- Land mine, - Consensus of villagers, - Necessary land acquisition, etc

These documents indicate lots of information necessary for the project appreciation, however the following problems are found in the existing project proposals and its preparation process as the results of scrutiny of them, discussion with the PDOWRAM and confirmation at the representing project sites.

(1) Lack of Technical Information on Water Resources

Though one of the most important issues is water resource for the project evaluation of the technical soundness, the proposal documents do not describe any information of it, such as mane and type of water source, catchment area, observed and/or estimated discharge and capacity of reservoirs, so that it is difficult or rather than impossible to evaluate the suitable size of irrigation area.

(2) Overestimate of Targeted Irrigation Area

Most of the proposed projects have their origin in the Por Pot regime, in which the canals (Por Pot canals) had targeted maximum extent of their command area without water balance study, hence they did not guarantee the amount of irrigation water supply with certain dependability. The rehabilitation works are so proposed as to cover the area commanded by the existing Por Poto canal networks, which are mostly overestimate of the irrigation area.

(3) Less Understanding on Project Area in Project Evaluation

Distribution of land use is not clear and the project area is misunderstood in project evaluation to compare before and after the sub-project, such as irrigated and rainfed paddy, upland field, fallow area and non-agricultural land. The sub-project area totaled of each land use shall be the same with the sub-project area before and after the rehabilitation. The sub-project area shall include the existing fallow area and non-agricultural land before rehabilitation, in case these areas will be irrigated after the sub-project. The sub-project area in the proposal is not the same in before and after the rehabilitation in most cases. In addition, the area is not clearly categorized, such as the actually irrigated, irrigable, and rainfed area.

(4) Incomplete Rehabilitation Works Proposed

In many cases, the proposed rehabilitation works do not include all necessary works for the complete irrigation system. For example in some cases, the rehabilitation is limited to main canal and related structures, while secondary canals and other facilities are not considered. In other cases, rehabilitation of only upper reach of main canal is proposed, but project benefit is considered for the whole area including lower reach of main canal.

(5) Insufficient Back Data and Breakdown

Some items of the unit cost and benefit estimate were referred to uniform standard values given by MOWRAM assisted by TSC-2, such as (i) agricultural extension service, (ii) increase of agricultural input for existing cultivated area, (iii) increase of agricultural input for newly cultivated area, and (iv) O&M cost. As there is no breakdown and source for EIRR calculation in the application form, it is difficult to review and update the calculation results.

(6) Insufficient Data Storage System in PDOWRAM

The proposal was prepared in 2009 and more than two years have passed before the JICA Survey, in which some of the technical data including topographic survey data, design calculation, drawings and work quantity and cost estimate have been lost or misplaced. This also causes difficulty in review and updating.

Thus, the manual is prepared keeping these problems in mind.

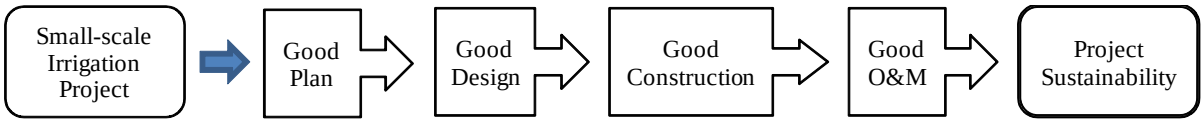
CHAPTER 2 PROCEDURE OF EXECUTION OF PRELIMINARY FEASIBILITY STUDY

2.1 Purpose

The purpose of the preliminary feasibility study is to prove that the project is technically viable and economically sound.

【Explanation】

The project is always requited to be sustainable. To realize this requirement, the project needs to follow the flow of "good plan", "good design", "good construction" and "good O&M". The project sustainability of the project could not be attained even if one of them is lacked.



Source: JICA Survey Team

Figure 2.1.1 Flow of Appropriate Procedure to Project Formulation

In this flow, the feasibility study plays a role of seeking for the "good plan" of the project. The meaning of "good plan" is nothing other than satisfying both technical and economical requirements.

【Output】

Understanding of purpose of Preliminary Feasibility Study

2.2 Work Flow

Successful execution of preliminary feasibility study is to grasp the whole of required works in advance.

【Explanation】

In general, the preliminary feasibility study should be carried out by the limited staff within the limited time. In order to effectively and smoothly execute the preliminary feasibility study, it is imperative to know the whole works in advance, and then to take the necessary steps on time to complete it as scheduled.

The preliminary feasibility study is largely divided into the following three steps (See Figure 2.2.1):

Step 1: Delineation of Irrigable Area

Balance of water resource, land resource and water demand for crop cultivation

Step 2: Plan and Design of Project Facilities

Execution of good plan and good design for project facilities to effectively distribute irrigation water to field

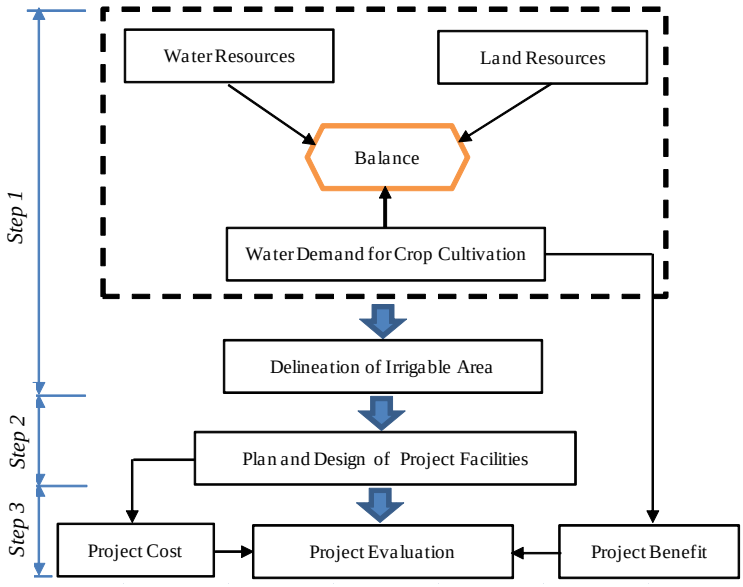


Figure 2.2.1 Outline of Work Procedure

Step3: Project Evaluation

Execution of appropriate project evaluation using project cost, project benefit by crop production and project implementation plan

Detailed work flow for preliminary feasibility study is shown in Figure 2.2.2.

【Output】

Recognition of mechanism of preliminary feasibility study

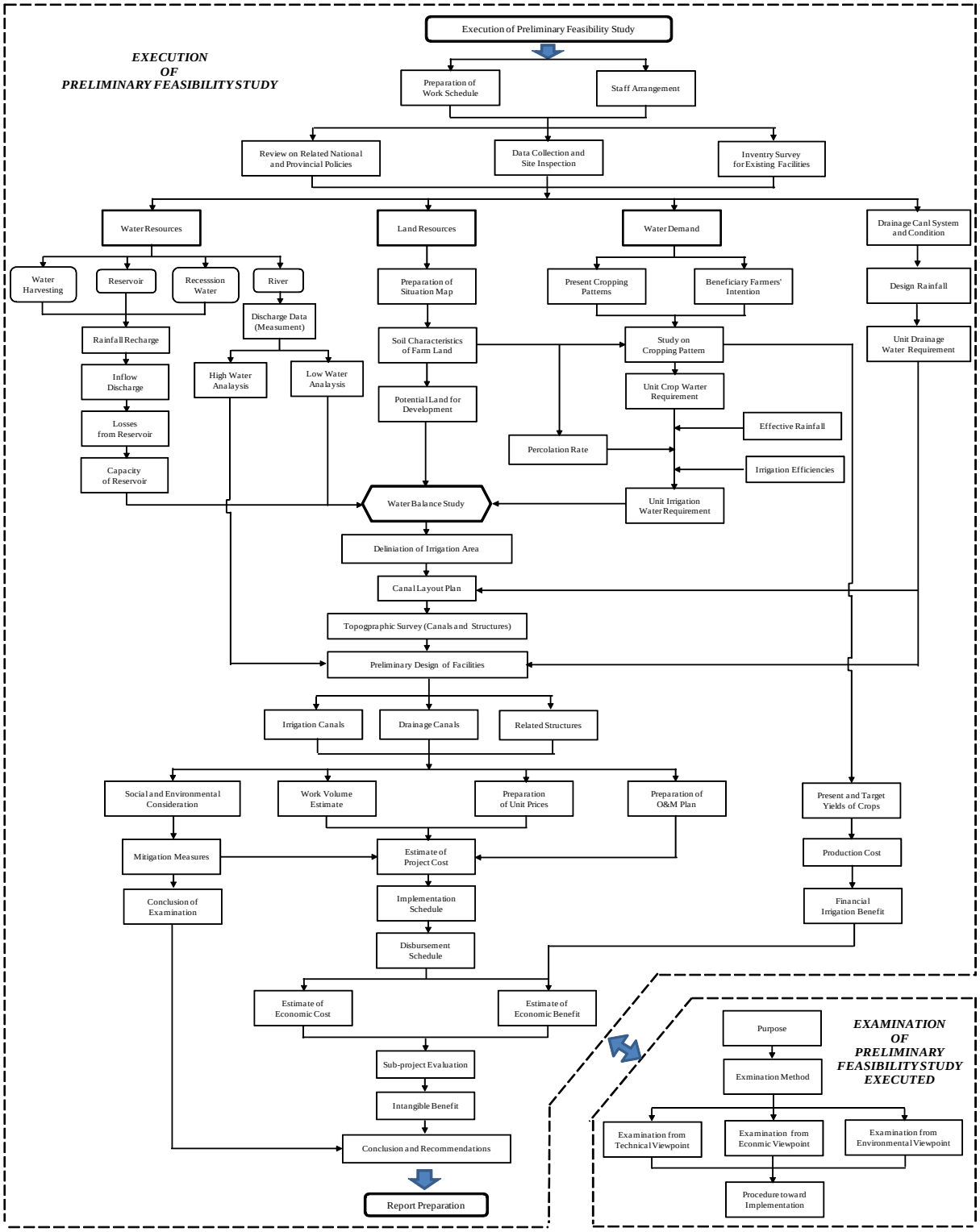


Figure 2.2.2 Detailed Work Flow for Preliminary Feasibility Study

2.3 Relevant Guidelines, Manuals and Reference Books Possessed by MOWRAM and TSC

Further understanding and knowledge on planning and designing could be deepened from relevant guidelines, manuals and reference books

【Explanation】

This manual aims to present the simplified procedure and methodology of preliminary feasibility study for small-scale irrigation project for easier understanding, therefore could not cover the detailed information. In order to know further information and knowledge on specific subjects, other relevant guidelines, manuals and reference books should be studied. Those presently kept by MOWRAM and TSC are as follows:

Table 2.3.1 List of Relevant Guidelines, Manuals and Reference Books

Organization	Title
MOWRAM	(a) Design Manual for Small and Medium Scale Irrigation System Planning, April 2004
	(b) Planning Guidelines for Rehabilitation and Reconstruction of Irrigation Systems, March 2002
	(c) Training Manual for Participatory Irrigation Management and Development, October 2003
	(d) Training Material for Agricultural Planning 27/2, Rural Development Planning, Principles, Approaches and Tools of Economic Analysis, FAO, 1991
	(e) Training Material for Agricultural Planning 34, Guidelines on Social Analysis for Rural Area Development Planning, FAO, 1993
	(f) Training Material for Agricultural Planning 38/1, Sustainability Issues in Agricultural and Rural Development Policies, FAO, 1995
	(g) Training Material for Agricultural Planning 38/2, Sustainability Issues in Agricultural and Rural Development Policies, FAO, 1995
	(h) Handbook for Incorporation of Social Dimensions in Projects, ADB, 1994
	(i) Environmental Impact Assessment for Developing Countries, Vol.1 and 2, ADB, 1997
	(j) Hydraulic Gates and Valves, 2001
TSC	(a) Cropwat :Manual and Guidelines, FAO
	(b) Crop Water Requirements, FAO, 1992
	(c) Crop Evapotranspiration, FAO, 2000
	(d) Irrigation Water Management Training Manual No.2, FAO, 1985
	(e) Irrigation Water Management Training Manual No.3, FAO, 1986
	(f) Textbook (1) to (3), Training Course on O&M of Irrigation Facilities, TSC
	(g) Textbook, Training Course on Structural Design & Calculation, TSC
	(h) Manual of Topographic Survey, TSC
	(i) Manual of Traverse Survey, TSC
	(j) Exercise in Water Requirement Training Course, TSC
	(k) Manual of Design Discharge, JICA, 2007
	(l) Manual of Meteorological Observation, TSC, 2005-2007
	(m) Textbook for Irrigation Planning, JICA
	(n) Manual of Practical Training for Measurement Technique of Evapotranspiration, TSC
	(o) Design Manual for Hydraulic Calculation of Small Scale Irrigation Canal, JICA
	(p) Water Requirement and Their Determination, TSC
	(q) Basic Design for Hydraulic Structures, JICA
	(r) Manual of Design on Small Scale Irrigation Canal and Related Structures, JICA
	(s) Hydrology for Engineers, 2001
	(j) Exercise in Water Requirement Training Course, TSC

Source: JICA Survey Team

【Output】

Learning of further information, understanding and knowledge on relevant fields

CHAPTER 3 PREPARATORY WORKS

3.1 Preparation of Work Schedule

The work schedule is indispensable for smoothly executing the preliminary feasibility study in a proper way and procedure.

【Explanation】

Without a work schedule, it is difficult to carry out the preliminary feasibility study systematically and to fulfill it on time. And also, missing of work items might occur. In order to avoid such situations, it is necessary to prepare the work schedule prior to commencement of the study. The work schedule is generally graphed by letting the work items be the vertical axis and the term horizontal axis, and the time and period of respective works are shown in a bar chart. In preparation of work schedule, an attention should be paid to the sequence of respective works, so that subsequent work could be known easily and be set out continuously.

【Output】

Efficient execution of preliminary feasibility study

3.2 Staff Arrangement

The required staff for execution of preliminary feasibility study should be clarified and assigned.

【Explanation】

The preliminary feasibility study could not be fulfilled without appropriate assignment of staff. The required staff should be determined in line with the work schedule focusing on the number and the specific field, to effectively carry out the preliminary feasibility study. In general, it is expected that Hydrologist, Irrigation Engineer, Agriculturist, Economist and Environment Expert are assigned as a minimum manpower requirement. As for the agriculturist, it might be necessary to obtain support from PDA.

【Output】

Effective works by timely input of required staff

3.3 Confirmation of Related National and Provincial Policies

The development plan should be so elaborated as to coincide with related national and provincial policies.

【Explanation】

RGC worked out many policies for agriculture and irrigation development. Presently, these are (i) Rectangular Strategy, Phase II, (ii) National Strategic Development Plan Update 2009-2013, (iii) Strategy for Agriculture and Water Program 2010-2013, (iv) Agriculture Strategic Development Plan 2009-2013, (v) Action Plan on Water Resources and Meteorology Management and Development 2009-2013, and (vi) Action Plan for Implementing Government Policy on Promotion of Paddy Production and Rice Export. Thus, development plan to be elaborated in the preliminary feasibility study should be prepared by reflecting goals, targets, and visions stipulated in these policies, to clarify significance of development for the country.

【Output】

Appropriate development plan contributing to the national and provincial policies

3.4 Data Collection and Site Inspection

Data collection and site inspection are the most fundamental activities in procedure of feasibility study, especially for obtaining important information required for analysis and study as well as clarifying site conditions, problems and constraints encountered.

【Explanation】

Data collection and site inspection are the works to be conducted immediately after starting the preliminary feasibility study. The proposed projects are characterized by various conditions, constraints and problems. The development plan for them should be elaborated so as to meet conditions and to settle constraints and problems. Site inspection is useful for clarifying various conditions, constraints and problems. In addition, site inspection would sometimes give not only valuable solutions for constrains and problems, but also appropriate ideas for development plan. It is therefore requested that the person in-charge should make site inspection as far as the time allows when facing the doubtful points in the course of the study.

The required data to be collected are as follows:

Table 3.4.1 List of Data to be Collected

Field	Data
(1) Meteorology	Rainfall, Temperature (Max. and Min.), Sunshine, Evaporation, Humidity, Wind speed
(2) Hydrology	River system, River discharge, Catchment area, Development plans in the same river basin, Existing irrigation systems related to the same river.
(3) Agriculture	Current Cropping patterns, Present crop yields, Prices of agricultural products and inputs
(4) Irrigation	Topographic map, Water source, Irrigation canal system, Canal design discharge, Irrigated area
(5) Drainage	Inundation condition, Drainage requirement, Drainage system

Source: JICA Survey Team

These data should be collected from the relevant agencies, farmers and also through site inspection

(1) Meteorology

The above-mentioned data should be collected from the Department of Meteorology, MOWRAM and/or PDOWRAM being in-charge of observatory stations. The following data might be used for the study if cold not be collected.

Meteorological Data (excluding rainfall data)

Table 3.4.2 Summary of Meteorological Data at Pochentong Station (1991 – 2010)

Item	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average or Total
Temperature	°C													
Mean		26.6	28.0	29.5	30.6	30.4	29.6	28.8	29.2	28.4	27.7	27.0	26.2	28.5
Maximum		32.3	33.9	35.6	36.4	35.6	34.7	33.4	33.2	32.9	32.0	31.7	31.5	33.6
Minimum		20.9	22.1	23.5	24.8	25.1	24.4	24.2	25.2	23.8	23.5	22.4	21.0	23.3
Humidity	%	72.0	70.4	69.7	71.4	75.9	77.8	80.3	81.3	84.1	84.1	78.5	74.0	76.6
Wind Speed	m/sec	3.2	3.8	4.1	3.9	4.3	4.9	4.3	5.4	4.4	3.1	3.9	3.9	4.0
Evaporation	mm/day	4.4	5.4	6.2	5.8	4.8	4.6	4.1	4.0	3.5	3.1	3.6	4.1	4.4
Sunshine	hr/day	8.5	8.6	8.3	8.0	7.3	6.6	5.9	5.9	5.7	6.1	7.5	8.2	7.2

Source: Pochentong Observatory, Department of Meteorology(Temperature, Humidity, Wind speed , Evaporation and Sunshine)
Note: Wind Speed data during the period from September 2005 to December 2010 were unavailable.

Rainfall Data

Table 3.4.3 Annual Rainfall (2001-2010) (Unit:mm)

Province	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Probable Year*
Banteay Meanchey	1,122	1,297	998	1,092	1,209	1,246	1,273	1,345	923	1,101	2003
Battambang	1,097	1,211	1,058	994	1,237	1,229	1,357	1,481	1,388	1,270	2003
Kampong Cham	1,324	1,133	1,958	1,183	1,407	1,591	1,559	1,495	1,867	1,372	2004
Kompong Channang	1,256	1,160	1,119	1,249	1,349	1,315	1,724	1,420	1,635	1,290	2003
Kampong Speu	1,768	937	1,049	949	1,114	1,178	1,111	1,188	1,340	1,167	2004
Kampong Thom	1,599	1,524	1,385	1,329	1,274	1,945	1,265	1,395	1,401	1,377	2005
Kampot	2,289	1,613	2,223	1,573	2,079	2,380	1,700	2,025	2,219	1,165	2004
Kandal	-	-	-	-	1,146	1,462	1,041	1,370	1,054	1,718	2007
Koh Kong	3,359	2,310	2,953	3,548	3,834	5,202	3,860	4,439	4,771	3,814	2003
Kraite	1,636	1,909	1,668	1,229	1,468	1,705	1,864	1,606	1,849	1,495	2005
PhnomPenh	1,615	1,286	1,304	1,092	1,427	1,208	1,374	1,886	1,456	1,591	2006
Preah Vihear	-	-	-	-	-	-	1,444	1,415	1,789	1,388	2010
Prey Veng	901	1,020	906	1,049	1,252	1,181	1,331	1,726	1,323	1,829	2003
Pursat	1,129	1,409	1,584	1,173	1,225	1,394	1,496	1,948	1,143	1,390	2009
Ratanak Kiri	2,367	2,543	-	2,120	2,381	2,827	2,162	2,215	1,358	344	2004
Siemreap	1,753	1,242	1,271	1,610	1,422	1,415	1,179	1,264	1,182	1,438	2009
Sihanoukville	3,375	3,121	2,608	3,353	2,956	4,065	2,948	2,807	2,286	2,131	2009
Stung Treng	1,863	1,336	1,565	1,491	1,389	1,597	1,776	1,778	1,612	1,069	2002
Svay Rieng	1,612	1,596	1,657	1,461	1,731	1,634	1,684	1,598	1,452	1,891	2004
Takeo	1,625	1,292	1,384	1,108	1,245	1,241	1,427	1,640	1,013	1,415	2004
Mondulikiri	-	-	-	-	-	-	1,537	1,503	834	324	2009
Pailin	-	-	1,011	453	969	821	1,034	1,333	1,130	1,907	2005

Source: Department of Meteorology, MOWRAM

**: 20% non-excess probability*

Generally, the drought year of 20% non-excess probability is taken for preparation of irrigation development plan. Table 3.4.3 shows the drought year corresponding to 20% non-excess probability for respective provinces where rainfall data is available. In addition, Table 3.4.4 presents the monthly rainfall for the drought year corresponding to 20% non-excess probability.

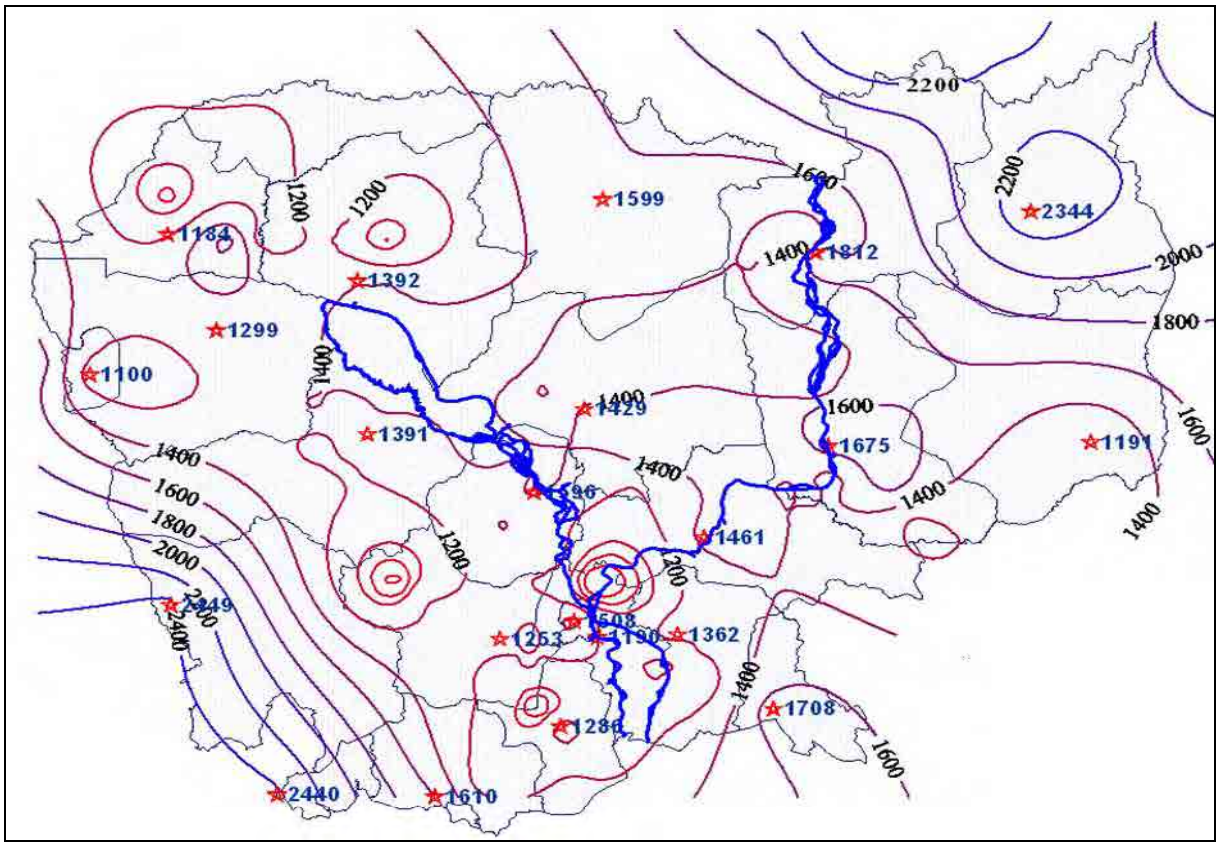
Table 3.4.4 Monthly Rainfall for 20% Non-excess Probability Year (Unit:mm)

Province	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct..	Nov.	Dec.	Probable Year*
Banteay Meanchey	0	0	14	79	158	99	149	142	211	149	0	0	2003
Battambang	0	0	29	197	78	172	111	199	132	140	0	1	2003
Kampong Cham	1	0	1	105	103	249	129	191	210	162	32	0	2004
Kompong Channang	0	0	31	42	193	190	192	119	208	122	21	0	2003
Kampong Speu	3	19	12	73	145	127	145	33	149	205	38	0	2004
Kampong Thom	0	0	14	34	140	176	299	99	243	119	142	7	2005
Kampot	0	0	0	156	85	122	262	446	220	324	70	15	2007
Kandal	0	0	0	25	143	196	92	180	164	210	31	0	2007
Koh Kong	0	38	43	111	205	186	830	596	543	401	0	0	2003
Kraite	0	0	4	31	238	132	377	132	380	114	61	0	2005
PhnomPenh	0	0	33	64	82	136	120	263	282	193	12	23	2006
Preah Vihear	0	0	0	0	136	241	248	334	214	215	0	0	2010
Prey Veng	0	0	21	33	36	54	253	199	134	154	22	0	2003
Pursat	2	28	56	118	108	126	146	186	175	163	35	0	2009
Ratanak Kiri	0	0	44	60	157	558	448	454	355	38	8	0	2004
Siemreap	0	0	28	57	92	120	301	82	341	143	16	0	2009
Sihanoukville	2	36	113	135	335	140	387	219	698	209	11	0	2009
Stung Treng	0	0	4	103	100	270	274	220	258	58	35	15	2002
Svay Rieng	0	2	0	65	243	84	153	197	300	232	185	0	2004
Takeo	0	0	52	24	241	139	62	89	121	246	133	0	2004
Mondulikiri	0	5	32	0	0	179	340	278	0	0	0	0	2009
Pailin	0	0	30	55	18	75	156	79	149	253	83	71	2005

Source: Department of Meteorology, MOWRAM

**: 20% non-excess probability year*

Furthermore, the isohyetal map for the whole country (199 to 2010) is given in Figure 3.4.1.



Source: Department of Hydrology and River Works

Figure 3.4.1 Isohyetal Map for Cambodia (1991-2010)

(3) Hydrology

River System

River system which becomes a water source for irrigation should be clarified using the available topographic map, say 1/50,000 topographic map if larger scale one is not available.

River Discharge

River discharge data is so important for determination of irrigable area. If the discharge data for the river is available, these should be collected. The period of data to be collected is desirable to be about 10 years, in order to estimate drought discharge with 20% non-exceedance probability. In case no discharge data is available, the river discharge should be calculated using the following manners:

- River discharge will be measured actually (See Sub-clause 4.2.1.1)
- River discharge will be calculated using that of another river with similar morphology (See Sub-clause 4.2.1.1)

Catchment Area

The catchment area of river system should be delineated and estimated at the water intake site, using the available topographic map, say 1/50,000 topographic map if larger scale one is not available. This data will be used mainly for calculation of flood discharge.

Development Plans in the Same River Basin

Development plans in the same river basin highly influence the available water for the sub-project, so that all development plans should be listed up, and then the required water for them should be examined. In particular, careful attention should be paid to the development plans of dam and

irrigation located upstream which severely affect the sub-project. These data will be used for water balance study, to utilize the limited water sources effectively.

Existing Irrigation Systems in the Same River Basin

It is necessary to guarantee the water for existing irrigation systems. Therefore, if there are the existing irrigation systems in the same river basin, these should be listed up and the used water should be grasped. These data will be used for water balance study.

(4) Agriculture Data

In the preliminary feasibility study for irrigated agriculture project, agriculture data are used for preparation of agricultural development plan including target crops, proposed cropping pattern, target yields and the sub-project benefit.

Current Cropping Pattern

Data on the current cropping pattern prevailing to the sub-project area will be collected from PDA and District Office. If not available, it should be clarified by interviewing with farmers though the site inspection. The required data are to know what kind of crops is cultivated, when the planting is started and when the harvesting is conducted.

Present Crop Yields

The present crop yields should be known. This data will be used for calculating the incremental benefits by crop production. Data on the present crop yields will be collected from PDA, District Office and Farmers.

Prices of Agricultural Products

Seasonal fluctuation in market prices of paddy as well as upland crops including vegetables is a common phenomenon in Cambodia. The data of market prices of agricultural products could be collected from Department of Planning and Statistics, MAFF. Table 3.4.4 shows the monthly wholesale prices of agricultural products in Phnom Penh 2010 as an example.

Table 3.4.5 Monthly Wholesale Prices of Agricultural Products in Phnom Penh 2010 (Unit:Riel/kg)

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rice (Mixed)	1,900	1,900	1,900	1,900	1,900	-	1,900	1,717	1,700	1,700	1,750	1,800
Rice (Neang Minh)	2,000	2,000	2,000	2,000	2,000	-	2,000	1,900	1,900	1,900	1,900	2,000
Rice (Phka Kanhey)	2,150	2,150	2,175	2,175	2,200	-	2,200	2,450	2,450	2,450	2,450	2,450
Rice (Somaly)	2,700	2,700	2,775	2,775	2,850	-	2,850	2,988	3,000	3,000	3,000	2,600
Ground Nut	7,000	7,000	7,000	7,000	7,000	6,071	6,000	6,189	6,733	7,000	7,433	7,511
Mung bean	6,000	5,956	5,911	6,000	6,000	6,917	7,000	7,000	6,771	6,500	5,983	5,500
Sesame (white)	6,500	6,644	7,000	7,000	7,000	7,000	6,952	7,000	7,000	7,000	7,000	7,000
Soybean	2,989	2,956	2,811	2,800	2,800	2,971	3,000	3,000	2,890	2,733	2,600	2,689
Maize (Yellow)	1,000	1,056	1,197	1,200	1,200	1,388	1,400	1,361	1,300	1,300	1,350	1,400
Beet	950	1,435	1,057	1,271	1,360	1,655	1,356	1,410	1,210	1,575	1,591	1,007
Bitter Gourd	1,540	1,530	1,504	1,559	1,650	1,700	1,378	1,200	1,120	1,838	1,717	1,831
Cabbage	1,120	1,215	1,571	1,786	1,773	1,845	1,694	1,890	1,690	1,750	1,667	1,469
Chinese Kale	1,780	2,120	1,664	1,591	1,836	2,991	4,589	2,770	2,570	5,338	4,650	1,738
Cucumber	1,465	1,455	1,347	1,591	1,482	1,645	1,278	1,290	1,210	1,425	1,533	1,292
Lettuce	1,975	915	1,061	1,727	2,400	5,905	2,889	1,240	1,630	4,757	3,125	1,554
Tomato	1,335	1,360	1,729	2,391	2,300	2,218	1,950	2,160	1,930	1,863	2,217	2,025
Long Bean	2,140	1,480	1,429	1,759	1,968	1,418	1,189	1,370	1,220	1,550	2,117	1,923
Mustard Green	1,465	945	1,075	1,395	1,168	1,255	1,233	1,020	1,080	2,325	1,317	1,031
Petsai	2,075	1,460	1,319	1,577	1,927	1,840	1,722	1,450	1,690	3,363	2,308	1,408
Cauliflower	3,000	2,610	3,693	3,991	4,400	6,020	6,083	5,820	5,910	7,188	6,542	3,992
Soiu Sum	1,905	765	1,257	1,309	1,495	1,400	1,244	1,140	1,420	2,738	1,525	1,346
Pok joy	2,005	1,270	1,425	1,805	2,090	2,688	1,856	1,350	2,130	4,438	2,125	1,531

Source: Department of Planning and Statistics, MAFF

(5) Irrigation

Topographic Map

Topographic map is essential for preparation of irrigation development plan. The available topographic map covering the sub- project area will be collected. The country is covered with 1/50,000 topographic map. However, this map is sometimes not suitable for small-scale irrigation project because of its small scale as compared with irrigation area. In this case, a preliminary map will be prepared using portable GPS, leveling instrument and measuring tape within a short time (See Clause 4.1.1).

Water Source

Available water source for irrigation should be confirmed. Generally, water source for small-scale irrigation project in Cambodia is river, reservoir and flood recession water. In case of river, river discharge data should be collected or estimated as mentioned above. As for reservoir, the reservoir capacity will be estimated using portable GPS and leveling instrument if the data is not available (See Sub-clause 4.2.2.4). Irrigation by flood recession water is almost the same with reservoir since flood water is once stored by dike, and then the stored water will gradually released to fields as flooding water recedes from fields. The store capacity will be estimated in the same manner with reservoir.

Irrigation Canal System

The small-scale irrigation project is almost characterized with the rehabilitation one. Thus, irrigation canal system already covers the agricultural land although it is incomplete. Data on the existing irrigation canal system will be collected if available. The data to be collected are layout, canal type, canal length and canal section. The number, location and kind of existing structures will be also examined.

Canal Design Discharge

In connection with the existing irrigation canal system, the canal design discharge data will be collected if possible. This data will be used for knowing the design conditions applied for the existing irrigation canal system.

Irrigated Area

In the rehabilitation project, the area being presently irrigated should be clarified if at all possible. This will become a reference data for determination of irrigable area although the irrigable area is technically determined through a water balance study between available water source and water demand by crops, which is explained later.

(6) Drainage

Inundation Condition

In order to avoid damage of crops by water stagnant, data on inundation should be collected from farmers, and be confirmed on the map or at site. The data to be collected are the inundation area, inundation period, inundation depth, and frequency of inundation. The data will be used for preparation of drainage development plan including rehabilitation and improvement.

Drainage System

The existing drainage system should be examined to reflect it into the drainage plan. Small streams and depreciated area will be carefully investigated since these generally function as natural drains. The flow direction of excess water from fields will be studied at site.

【Output】

Collection of data and information required for the preliminary feasibility study

3.5 Inventory Survey for Existing Facilities

Existing facilities should be surveyed to grasp their locations and damaged conditions, and also to prepare the suitable rehabilitation plan.

【Explanation】

In the proposed sub-projects, the required works are mainly rehabilitation and improvement of existing facilities. The location and damaged conditions of facilities largely influence the sub-project cost. Thus, it is necessary to grasp the conditions of existing facilities. The inventory survey should include the following survey items as least:

- Name of Sub-project
- Date of Execution of Survey
- Name of Surveyor
- Name of Canal
- Station No. on Canal
- Location (Northing and Easting based on Indian Datum 1954)
- Type of Facility
- Digital Photos of Existing Facility showing Whole Shape and Damaged Portions if any
- Explanation of Current Condition of Canal and Structure
- Sketch of Structure to Know Dimensions of Major Portions
- Findings if any

Sample of inventory survey sheet is given in Attachment-1. The results of inventory survey should be compiled in one or two sheet, to easily understand the conditions of facilities.

【Output】

Clarified conditions of facilities to be used for rehabilitation plan and design

CHPTER 4 EXECUTION OF PRELIMINARY FEASIBILITY STUDY

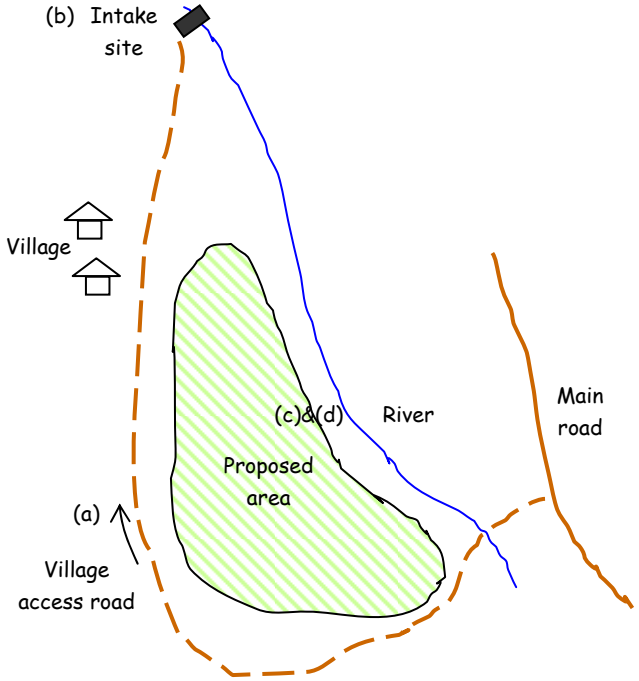
4.1 Land Resources

4.1.1 Preparation of Present Situation Map

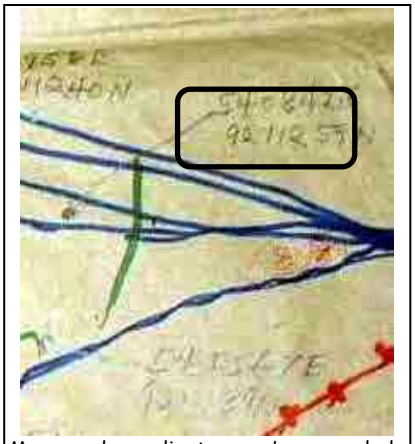
Large-scale map is essential for planning of small-scale irrigation project because topographically detailed information is necessary.

【Explanation】

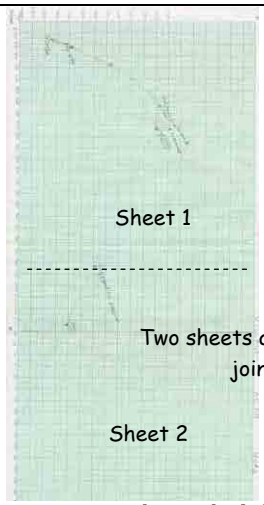
As mentioned previously, 1/50,000 topographic map is available for the whole country. However, this scale is too small to study the rehabilitation and improvement of existing canal system for the small-scale irrigation project. Satellite image is one of effective way for planning the existing irrigation system, to supplement the small-scale map. However, it is costly. It is therefore proposed to apply the following manner to prepare the simple and preliminary topographic map, taking into consideration limited budget, limited time and rehabilitation/improvement of existing small-scale irrigation project:

Sub-step 1	Decide the route to be taken on site	Determine the route to be taken on site. The following is a general route. (a) Take the access road from the downstream portion. (b) Go up to the intake site. (c)&(d) Record the boundary of the proposed area and existing irrigation facilities and the river along the area. *Order should be decided considering field conditions. 
Sub-step 2	Set GPS in UTM system	Before going to the site, the coordinate system of GPS should be confirmed. UTM should be employed for map preparation. In general, the default system is Lat/Lon, so it should be switched to UTM before the survey e.g. Lat/Lon: UTM: 5º57.628'S 345163E 37º46.374'E 9324327N (unit: degree/minutes) (unit: m)

Sub-step 3 Visit the site with a villager and record the coordinates and observations

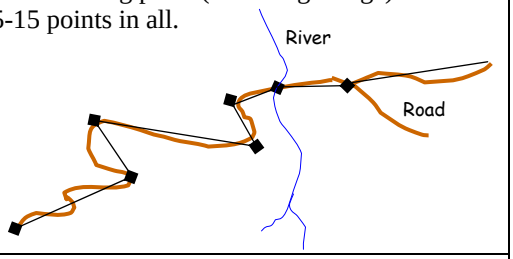
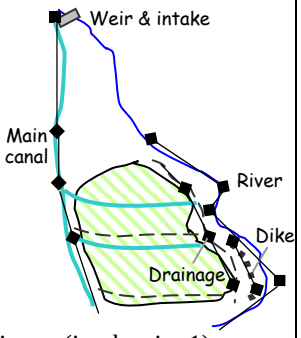
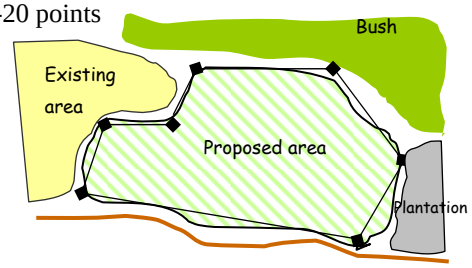


Measured coordinates can be recorded on the village resource map.



Section papers can be stitched if one sheet is not enough.

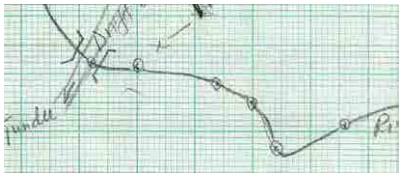
Visit the site and ask a villager to accompany the survey team. A villager who attended village resource mapping would be appropriate.
Follow the route under the guidance of him/her and record the coordinates of the route. Items and approximate number of points are shown below.

Items	Measuring point
Road	-junction -major turning point -river crossing point (including bridge) *5-15 points in all. 
River /Irrigation Facilities	River -major turning points along the proposed area Irrigation facilitiies -intake site (proposed/existing) -any canal divirsion -any junction of drainage -any route of flood dike  *5-10 points for each items (intake site:1)
Proposed area	-corner of the boundary *10-20 points 

Sub-step 4 Estimate the area to be cropped within the proposed area

Roughly estimate the cropped area within the proposed area by percentage for the crops grown in rainy and dry season based on the opinion of villgers accompanied.

Sub-step 5 Plot the coordinates on section paper and write down surrounding items.



Sample of a present situation map

(a) Pick out the coordinates including the maximum/minimum value in each axis.
(b) Set the grid in order that it may cover the max/min value. 1:10,000 (1cm=100m) is easily applied for schemes of around 50 ha. If one sheet is not enough, add some more sheets and combine them.
(c) Plot the coodinates and connect them. Write down related information such as village, forest reserve, percentage of cropped area in the proposed area etc.

Note: Indicative time required for preparation of present situation map is 2-3 days/scheme. (1-2 days for site visit and a half day for plotting.)

【Output】

Simple and preliminary large-scale map

4.1.2 Soil Characteristics of Farm Land

Crop selection and irrigation water requirement should be well-fitted to soil characteristics of farm lands, thus it is indispensable to grasp them

【Explanation】

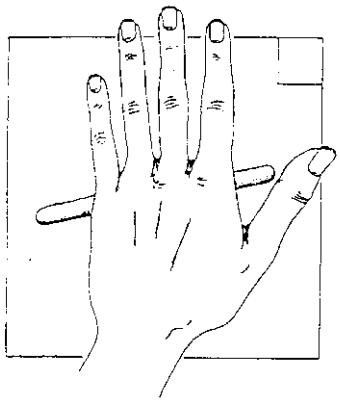
To grasp the soil conditions of farm lands is so important for planning the irrigation project. If time and budget are available, soil tests are desirable. But if not, it is proposed to apply the following simple method to know the soil texture within the short time.

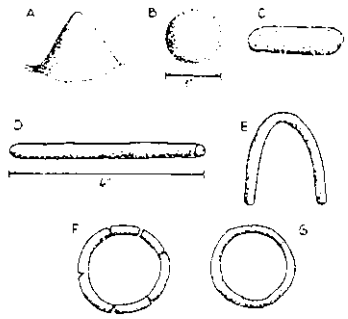
(a) Visit the survey together with commune chief and farmers.
Visit the proposed area and choose typical soil in the area with the consultation of the commune chief and farmers.

(b) Sampling of the soil
Gather a soil sample from the soil surface (sample should be about 10 x 10 x 10 cm).

(c) Knead the soil with water.
Add some water to the soil sample so it is moist but not wet. Knead it well. Pebbles should be removed.

(d) Try to create ring shapes with the soil sample and choose the most advanced shape that can be made.





A: Soil can only be shaped into a cone. No other shapes hold together.
B: Soil can be formed into a circle, but not a rod shape.
C: Soil can be formed into a stout rod shape.
D: A thin rod (about 6 mm diameter) can be formed but not bent.
E: Thin rod can be bent without breaking
F: Circle can be formed with some breaks.
G: Complete circle with no breaks can be formed.

(e) Evaluate the soil texture
According to the result of (d), circle one of the detailed soil texture types and choose a general soil texture type by conversion of the detailed soil texture type.

Detailed soil texture type			conversion		General soil texture type	
Shape A	Sand	☐	if you choose Shape A	→	Sand	☐
Shape B	Loamy Sand	☐	if you choose Shape B or C	→	Sandy Loam	☐
Shape C	Silty Loam	☐				
Shape D	Loam	☐	if you choose Shape D or E	→	Clay Loam	☐
Shape E	Clay Loam	☐				
Shape F	Light Clay	☐	if you choose Shape F or G	→	Clay	☐
Shape G	Heavy Clay	☐				

(f) Notable Soil Characteristics
If there are any notable soil characteristics such as high rock outcrop, shallow soil depth and symptom of salt accumulation, please note.
Note:

_____

【Output】

Clarified soil texture types of farm land

4.1.3 Potential Land for Development

Land resource is one of key factors for determination of irrigation area, so that its potential should be clarified.

【Explanation】

Generally, potential land for irrigation development is studied using land classification map. However, this map is not available in Cambodia. Soil map is available, but its scale is so small and not useful for preparation of development plan of small-scale irrigation project. In case of small-scale irrigation project, its area is already cultivated, so that it may be deemed that all command area is regarded as potential area although soil texture investigation is required for clarifying soil texture type.

【Output】

Clarified extent of land potential

4.2 Water Resources

4.2.1 River

4.2.1.1 Discharge Data

Discharge data is needed for high water and low water analysis on river which are used for design of river structures and water demand estimate, respectively.

【Explanation】

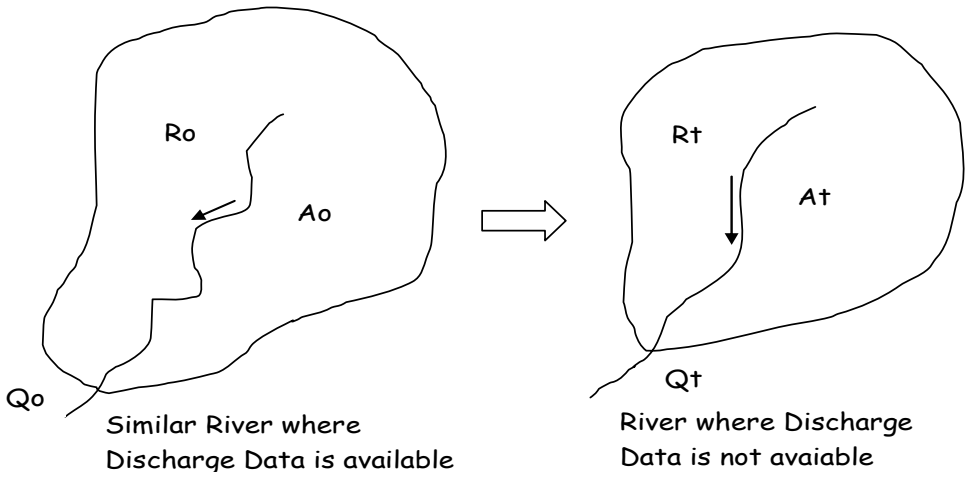
Discharge data is fundamental information for planning the irrigation project. In case the discharge data is available, it is used for probability analysis for high water and low water. If no discharge data is available, it can be estimated using the following methods:

(1) Conversion from the similar river where discharge data is available

(a) Seek for the similar river where discharge data is available
In order to prepare the discharge data for the river which is water source for irrigation, seek for the similar river where discharge data is available, and if found, collect discharge data.

(b) Calculate catchment area and collect rainfall data for both rivers
As for the both rivers, calculate catchment area and collect rainfall data to use as parameters for conversion of discharge data.

(c) Convert the discharge data from the similar river to the river as water source for irrigation
Estimate the discharge data for the river as water source for irrigation by converting that for the similar river using the following equation:



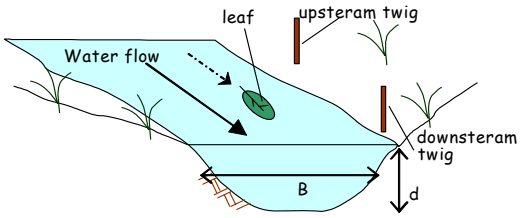
Qt = Qo x (At/Ao)x (Rt/Ro)
Where, Qt: Estimated discharge for river as water source for irrigation (m^3/sec)
Qo: Discharge data observed for the similar river (m^3/sec)
At: Catchment area of river as water source for irrigation (km^2)
Ao: Catchment area of similar river (km^2)
Rt: Rainfall data in catchment area of river as water source for irrigation (mm)
Ro: Rainfall data in catchment area of similar river (mm)

(2) Discharge measurement

(a) Determine measurement point together with village chief and villagers
Find a suitable point for measurement together with the farmers. The measurement point should be a) narrow, b) strait, c) steep, and d) upstream of any existing intake, or e) near the intake site.

(b) Estimate flow area on the day of survey
Measure average river width and water depth on the day of survey.
B = ☐ m (average river width) Dt= ☐ m (water depth today)
At= ☐ m^2 (flow area of today) (At = B x Dt)

(c) Measure water flow velocity of the day
a) Drive two twigs into the ground beside the river at a measured distance between the two twigs. b) Float a leaf on the water from the upstream twig to the downstream twig and measure the travel time. c) Calculate the flow velocity.



Ls = ☐ m (length between twigs) Tt= ☐ sec (consumed time)
Vt = ☐ m/sec (V t = Ls/ Tt)

(d) Calculate river discharge on the day of survey
Qt= ☐ m^3/sec (discharge on the day of survey) (Qt = At x Vt)

(e) Nominate river discharge record keeper
One villager who lives near the water source river should be nominated as the river discharge record keeper by the village chief. The keeper should measure the water level and velocity of the measurement point once every month.

Nominated name of the record keeper ☐

4.2.1.2 High Water Analysis

High water analysis of river is necessary for designing river structures including flood dike.

【Explanation】

High water, namely flood discharge is so important information for design of river structures. For designing river and relevant structures, the following probable design floods are proposed:

Table 4.2.1 Probable Design Floods

Structure	Probable Design Floods
Reservoir	1/100 years
Reservoir with a catchment area less than 10 km^2 or total storage capacity less than 50,000 m^3	1/20 years
Headworks and spillway for comparatively larger-scale reservoir	1/100 years
Relevant dike	1/25 years

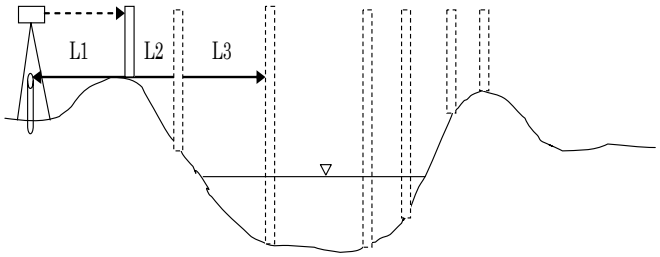
Source: Planning Guideline for Rehabilitation and Reconstruction of Irrigation Systems, March 2002

In this manual, two methods are proposed for analyzing the high water of river. One is a measuring method at site when flood occurs, and the other is an estimated method using the equations. These methods are explained below:

(1) Measuring Method at Site

(a) Measurement of Cross Section of River

A cross section of river at measurement point will be surveyed using leveling instrument and measuring tape as shown in the right figure, aiming to know the relation of cross sectional area and water depth. Based on the results of measurement, a H-A curve will be prepared.



(b) Hydraulic Calculation by Manning Formula

Manning formula expresses mean velocity as a function of the roughness of river channel, the hydraulic radius and the slope of energy gradient.

$V = (1/n) \times R^{2/3} \times I^{1/2}$

$Q = A \times V$

Where, *V: Mean flow velocity (m/sec)*
n: Roughness coefficient (see below table)
R: Hydraulic radius (=A/S)
A: Cross sectional flow area (m^2)
S: Wetted perimeter (m)
I: Hydraulic energy gradient (in case of open canal, I = h/l)
h:Differnce of water level at l m (m)
Q: Discharge (m^3/sec)

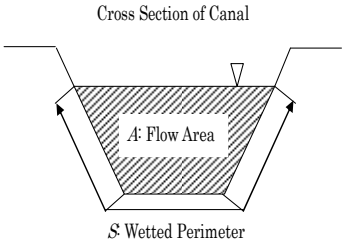


Table 4.2.2 Roughness Coefficient

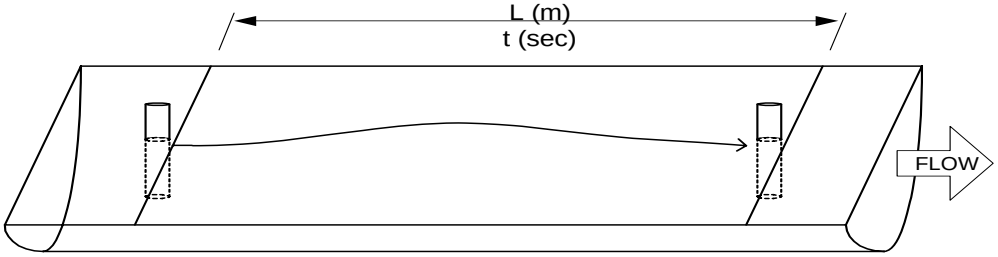
Materials and Conditions of Channel		Roughness Coefficient		
		Min.	Mean	Max.
Small river in plan				
1)	No weed, straight, no deep pools at full water level	0.025	0.030	0.033
2)	No weed, straight, no deep pools at full water level, stone and weeding exist	0.030	0.035	0.040
3)	Shallows	0.033	0.040	0.045
4)	Shallows, some stones and weed	0.035	0.045	0.050
5)	Shallows, some stones, weed and more variation of gradient/ cross section	0.040	0.048	0.055
6)	The same as item 4), but many stones	0.045	0.050	0.060
7)	Weed and deep pools in calm flow reaches	0.050	0.070	0.080
8)	Others	0.075	0.100	0.115
Rivers in hilly area having little plants in the river bed and steep gradient in river basin. Trees and shrub along banks are submerged at flood time.				
1)	Cobble stones and gravels in the riverbed	0.030	0.040	0.050
2)	Large cobble stones	0.040	0.050	0.070
Big river				
1)	Regular cross section with no large cobble stones and no trees & shrubs	0.025		0.060
2)	Irregular coarse cross section	0.035		0.100

Source: Irrigation and Drainage Handbook., Japanese Society of Irrigation, Drainage and Land Reclamation Engineering

If stream flow area can be clearly defined in such a place where a river runs through a valley, the past maximum water level can be distinguished from flood trace, vegetation alteration and interviewing inhabitants along the reaches. The past maximum flood water level pointed out by inhabitants should be measured together with the river cross section by leveling equipment mentioned above.

(c) Measurement of Flow Velocity at Flood Time as Verification Data

Pipe floats can be used for rough estimate of flood discharge. A pipe float, with some weight inside to keep it at a certain depth in the flow, is thrown into the flow, and a time to pass a certain distance is measured by a stopwatch. The length of float should be changed according to the depth of flow.



The measured flood discharge is used for seeking for the roughness coefficient for Manning formula.

(d) Calculation of Flood Discharge

A flood discharge will be calculated using the observation results of H-A curve and flow velocity at flood time.

(e) Preparation of Rating Curve (H-V Curve)

A rating curve is prepared to obtain the discharge from the water level. The results of discharge calculation after verification by discharge measurement are plotted on a graph of which the X-axis is for discharge and the Y-axis for water level. Logarithmic axes may be proposed according to the characteristics of data. The following are to be noted on preparation of rating curve:

- Extrapolation should basically not be done particularly for the high water side to avoid over- or under-estimate.
- Rating curve should be checked a few times in a year and be revised if necessary, because the river cross section might change by floods.

(2) Calculation Method using Equation

(a) IRS method

The Irrigation Rehabilitation Study in Cambodia, 1994 proposed the following equations to estimate the floods from the catchment area less than 15,000 km^2 and below El.100m:

$MAF = AREA^{0.9}$

$Q_{10} = 1.53\ MAF$

$Q_{20} = 1.78\ MAF$

$Q_{50} = 2.00\ MAF$

$Q_{100} = 2.20\ MAF$

Where, *MAF: Mean annual flood (m^3/sec),*
AREA: Catchment area (km^2)
Qn: Flood expected to occur no more than once every n years on average,
n : Return period (years)

(b) Rational Formula

Probable Rainfall

The Rational formula needs probable rainfall. Tomas method and Hazen method presented are facile to estimate probable values by plotting order statistics on probability paper according to the following plotting positions:

Tomas Method: P = 100m/(N + 1)

Hazen Method: P = 100 (2m -1)/(2N)

Return Period: R = 1/P

Where, *N: Number of annual maximum daily rainfall,*
m: Ranking from the largest annual maximum daily rainfall,
P: Plotting position (%)
R: Return period (year)

The paper shown on the next page is a sample of the probability paper. This logarithmic normal distribution paper is often utilized for estimating the excess probability of rainfall.

Rational Formula

The Rational Formula is employed for small streams with catchment area usually less than 50 km^2. The peak flood is calculated using the following equation:

$Q_{max} = 1/3.6 \times f \times r_1 \times A$

Where, Q_{max}*: Flood peak (m^3/sec)*
f: Runoff coefficient (see the below table)

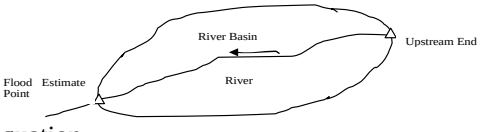
Steep Slope topography	*0.75 – 0.90*
Hilly area and forest	*0.50 – 0.75*
Plain agricultural land	*0.45 – 0.60*
Paddy field under irrigation	*0.70 – 0.80*
Small river in plain	*0.45 – 0.75*
Mountain river	*0.75 – 0.85*

r_1*: Rainfall intensity (mm/hr)*
A: Catchment area (km^2)

The flood arrival time has to be known to estimate rainfall intensity during the flood arrival time. The rainfall intensity is often estimated by the following equation in case there is no rainfall intensity data.

$r_1 = R_{24}/24 \times (24/T)^n$

where, r_1 *= T-hour maximum rainfall intensity (mm/hr)*
R_{24} *= Daily Rainfall (mm)*
n = 1/2 ∽ 2/3, generally 1/2 is applied.



The flood arrival time is calculated by the following Rziha equation.

$T = 72 \times (h/l)^{0.6}$ (km/hr)

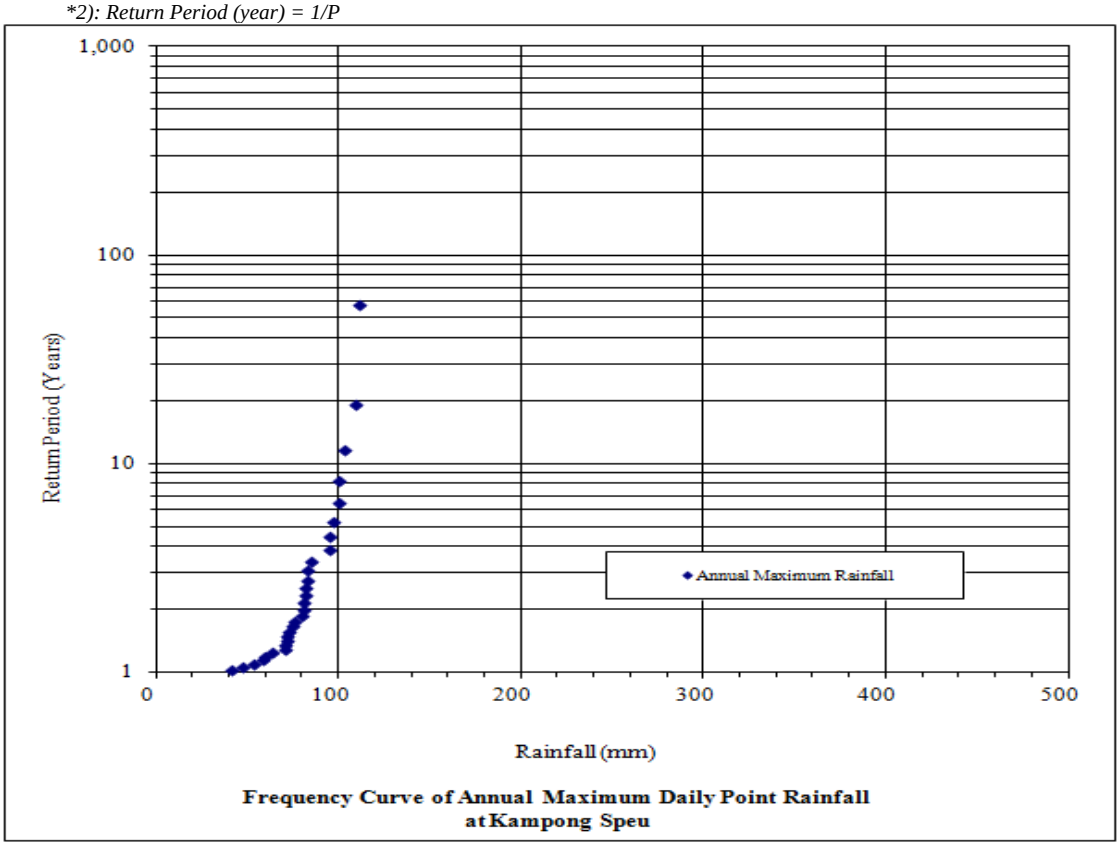
Where, *T: Flood arrival time*
l: Length of stream from flood-estimate point to upstream end of river basin (km)
h: Elevation difference between l-length (km)

If this equation gives a flood arrival time of less than one hour, one hour is employed as flood arrival time.

Annual Maximum Daily Point Rainfall at Kampong Speu

No.	Year	Annual Max. Daily Rainfall		Ranking	Plotting Position	Excess Probability*1	Return Period *2)(year)
		Date	Daily Rainfall (mm/day)				
1	1983	24-Oct-1983	81.7	13	43.1%	56.90%	2.32
2	1984	28-Sep-1984	100.1	5	15.5%	84.48%	6.44
3	1985	18-Apr-1985	95.0	7	22.4%	77.59%	4.46
4	1986	17-Nov-1986	72.3	21	70.7%	29.31%	1.41
5	1987	15-Sep-1987	60.2	25	84.5%	15.52%	1.18
6	1988	23-Oct-1988	53.4	27	91.4%	8.62%	1.09
7	1989	04-Jul-1989	70.5	23	77.6%	22.41%	1.29
8	1990	10-Nov-1990	71.0	22	74.1%	25.86%	1.35
9	1991	22-Apr-1991	48.0	28	94.8%	5.17%	1.05
10	1992	10-Oct-1992	97.5	6	19.0%	81.03%	5.27
11	1993	27-Sep-1993	41.5	29	98.3%	1.72%	1.02
12	1994	12-Sep-1994	80.3	16	53.4%	46.55%	1.87
13	1995	10-May-1995	72.6	19	63.8%	36.21%	1.57
14	1996	25-Oct-1996	83.5	10	32.8%	67.24%	3.05
15	1997	10-Jun-1997	59.0	26	87.9%	12.07%	1.14
16	1998	15-Oct-1998	81.0	15	50.0%	50.00%	2.00
17	1999	26-Jul-1999	64.0	24	81.0%	18.97%	1.23
18	2000	27-Sep-2000	109.5	2	5.2%	94.83%	19.33
19	2001	13-Jan-2001	83.0	11	36.2%	63.79%	2.76
20	2002	23-Aug-2002	111.5	1	1.7%	98.28%	58.00
21	2003	02-May-2003	76.0	17	56.9%	43.10%	1.76
22	2004	11-Sep-2004	94.9	8	25.9%	74.14%	3.87
23	2005	23-Oct-2005	81.5	14	46.6%	53.45%	2.15
24	2006	07-Apr-2006	72.5	20	67.2%	32.76%	1.49
25	2007	12-Nov-2007	82.1	12	39.7%	60.34%	2.52
26	2008	17-Oct-2008	100.4	4	12.1%	87.93%	8.29
27	2009	03-Oct-2009	75.4	18	60.3%	39.66%	1.66
28	2010	25-Mar-2010	103.1	3	8.6%	91.38%	11.60
29	2011	05-Nov-2011	85.4	9	29.3%	70.69%	3.41

*Note *1): Hazen Method: P = 100 * { (2m-1) / (2N) } , Excess Probability : E=100 - P*
where, P: plotting position (or probability) (%) , E: excess probability (%), m = rank, N = number of data,
**2): Return Period (year) = 1/P*



Frequency Curve of Annual Maximum Daily Point Rainfall at Kampong Speu

Probability Paper

4.2.1.3 Low Water Analysis

The low water analysis on river is used for determination of irrigable area through water balance study.

【Explanation】

The low water analysis on river is carried out to clarify the available water for irrigation. Generally, 1/5 years non-excess probability discharge, say 80 % dependable river discharge, is estimated and used for irrigation development plan.

(a) River where discharge data is available

In case the discharge data is available, it is given the non-excess probability analysis using the following methods.

Weibul Method: F(xi) =100 i/(N+1)

Hazen Method: F(xi) = 100(2i-1)/2N

Where, F(xi): Non-excess probability at "xi"(%)
xi: Annual minimum discharge at "i"
i: Rank number of "xi" from annual minimum discharge data
N: Number of annual discharge data,

Using the above-mentioned equation, F(xi) should be calculated for each annual minimum discharge firstly. And then the annual minimum discharge at approximately 20% of F(xi) can be regarded as 1/5 years non-excess probable discharge.

The more simple way in the non-excess probability analysis is as follows.

In case there are 20 years data, the 4^{th} lowest data is almost equivalent to the 1/5 years non-excess probability (80% dependability for irrigation).

(b) River where no discharge data is available

In this case, discharge data for river where no discharge data is available, is prepared by converting that for the similar river where discharge data is available as mentioned in Sub-clause 4.2.1.1. The non-excess probability analysis is the same as Item (a) of this Sub-clause.

【Output】

Quantification of available water for irrigation

4.2.2 Reservoir

4.2.2.1 Rainfall Charge

Rainfall should be considered as one of charges to reservoir water.

【Explanation】

Rainfall serves as charge to reservoir. Rainfall data collected from the observation station close the reservoir should be used for calculating charge volume to reservoir. If such rainfall data is not available, rainfall data shown in Table 3.4.3 might be used for the preliminary study purpose.

【Output】

Charge volume by rainfall to reservoir

4.2.2.2 Inflow Discharge

Inflow discharge to reservoir should be clarified to know possible water volume in reservoir.

【Explanation】

In general, a reservoir is constructed at depreciated area where river or small stream flows, and stores water by constructing dike to enclose the area. Thus, major inflow to reservoir is a river or small stream. Since discharge data for these river and stream is not available for most cases, it should be produced as mentioned in Sub-clause 4.2.1.1.

【Output】

Clarification of estimated inflow volume to reservoir

4.2.2.3 Water Losses from Reservoir

Water losses from reservoir should be considered to estimate net water volume in reservoir.

【Explanation】

There are two water losses from reservoir. One is percolation and the other is evaporation. In reservoir for small-scale irrigation project, it is proposed to apply the percolation rate of 0.2 mm/day. On the other hand, evaporation is used from observation data at Pochentong Station as shown in Table 3.4.2.

【Output】

Net storage volume in reservoir

4.2.2.4 Capacity of Reservoir

Capacity of reservoir should be clarified to grasp the effective storage capacity for irrigation development.

【Explanation】

In Cambodia, many small-scale irrigation projects are equipped with a reservoir as water source. However, its capacity is hardly apparent because large-scale contour map is not available. Thus, it is necessary to prepare a contour map and then a H-V curve, to grasp the reservoir capacity and to make effective use of reservoir water. A simple contour map for reservoir area and a H-V curve are prepared in the following manner, and also it is necessary to clarify the effective storage capacity:

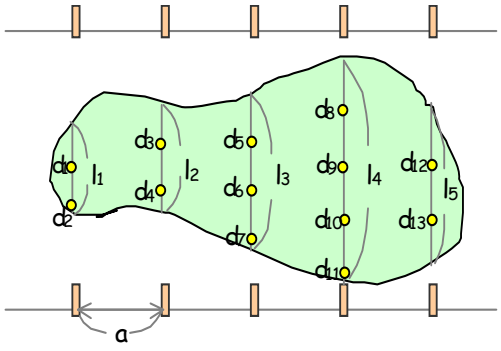
(a) Preparation of Simple Contour Map

1) Preparatory arrangement

Visit the site and drive twigs at regular intervals along the longer side of the shore.

2) Measure surface width and depth

In case of small reservoir, stretch a tape across the shore at the place pointed by the twigs. Then, a) measure the surface width (width of l_1 to l_5 in figure in the right), while b) measure the water depth along the tape at regular intervals (depth of d_1 to d_{13} in figure in the right). In case of comparatively large reservoir, the elevation and location are surveyed at d1 to d13 by leveling instrument and portable GPS, respectively. In this case, basic point for elevation is set at the bed of intake gate.



3) Calculate capacity of reservoir

Small reservoir

A= ☐ m^2 (average surface area) D= ☐ m (average depth)

V= ☐ m^3 (capacity of small reservoir) (V = A x D)

Comparatively large reservoir

Area at each contour line is measured by planimeter. If planimeter is not available, a section paper is used for measuring area at each contour line. After measuring area at each contour line, volume is calculated using the following equation:

$V_1 = (A_1 + A_2)/2 \times h_1$

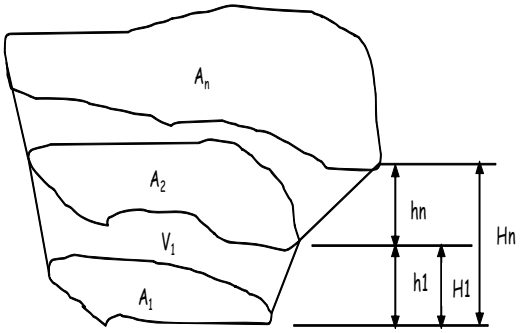
$V_n = (A_{n-1} + A_n)/2 \times h_n$

$V = V_1 + \cdots\cdots + V_n$

Where, $A_1 \cdots A_n$*: Area at each contour* (m^2)

h_1*: Contour interval (m)*

$V_1 \cdots V_n$*: Volume between two contour lines* (m^3)



V: Total volume (m^3)

When there is water in the reservoir, contour line in water would be known by measuring water depth as mentioned in item 2) of (2).

(b) Preparation of H-V Curve

In case of small reservoir, it could be assumed that a relation between H and V varies in linear pattern. On the other hand, in the case of comparatively large reservoir, a relation between H and V is shown by plotting H as X-axis and V as Y-axis based on the results of calculation of reservoir capacity mentioned above.

(c) Determination of Effective Storage Capacity

All water in reservoir could not be used. Storage water below bed level of intake gate could not be utilized as available water source, so-called dead water. Therefore, storage capacity above bed level of intake gate only is regarded as effective storage capacity for development.

【Output】

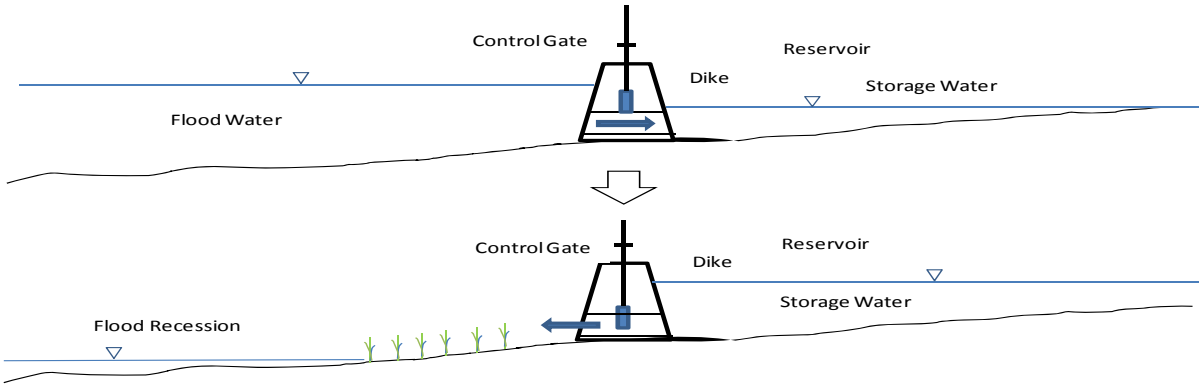
Available storage water for irrigation

4.2.3 Recession Water

Irrigable area by recession water should be clarified through flood water level analysis and storage capacity.

【Explanation】

Irrigation by recession water is a peculiar irrigation method in Cambodia. In irrigation by recession water, matters to clarify are the flood water level, and the storage volume.



There are two factors to know the storage volume. One is flood water level and the other is reservoir capacity.

(a) Flood Water Level

Water supply for irrigation project is planed based on the 80 % dependability. Thus, level of flood water from river is to correspond to that of 20 % non-excess probable river discharge. If flood water level from river is available, that of 20 % non-excess probable flood water level is determined by the fourth lowest one if 20 years data is available (the second lowest if 10 years data is available).

(b) Reservoir Capacity

Reservoir capacity is determined in the same manner as mentioned in Sub-clause 4.2.2.4.

【Output】

Available storage water for irrigation

4.2.4 Water Harvesting

Water harvesting is one of water sources for small-scale irrigation project in Cambodia.

【Explanation】

Water harvesting in Cambodia means that rain water is stored by small earthen dike on small stream or low land area in the rainy season, but no water is seen in the dry season at all. The storage volume is

generally small and uncertain because of its small catchment area. According to information farmers concerned, irrigation is supplementally made only two to three times throughout one crop season in the rainy season based on the available water in reservoir. Such water harvesting sub-project might be included in the category of small-scale irrigation project.

Water harvesting system has some difficulties in discussion on execution of preliminary feasibility study at the same level with ordinary irrigation project according to the experiences in the verification study conducted for two years in the Study on Comprehensive Agricultural Development Prek Thnot River Basin:

- Difficulty in prediction of water to store due to small catchment area and different rain in places
- Difficulty in forecast of incremental benefit due to less times of irrigation
- Difficulty in keeping the project sustainability due to unreliable and unstable water source

Taking into due consideration the above, it is deemed that water harvesting should be discussed apart from the ordinary irrigation project. Thus, water harvesting system is not taken up in this manual.

【Output】

Need of different approach to water harvesting system from technical and economical viewpoints

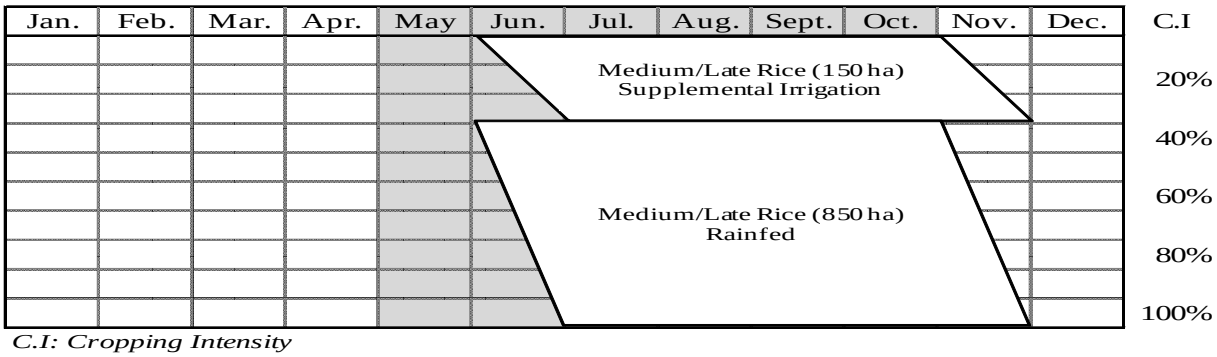
4.3 Water Demand

4.3.1 Present Cropping Pattern

Present cropping pattern in the project area should be clarified to estimate the incremental benefit by crop cultivation between "without project" and "with project".

【Explanation】

The present cropping pattern should be examined through site visit, interview with farmers and discussion with PDA, to clarify the names of crops planted, planted area of each crop and growth season and cultivation events, and finally to estimate the benefits by crop cultivation under "without project condition". It should be noted that the total area should coincide with the land use. In particular, when interviewing with farmers on cropping pattern, questions should be made for why current crops are selected. Examined cropping pattern should be illustrated as follows:



C.I: Cropping Intensity

Figure 4.3.1 Sample of Present Cropping Pattern

【Output】

Clarified present cropping pattern

4.3.2 Beneficiary Farmers' Intension

The beneficiary farmers' intension should be reflected upon selection of crops in order to prepare the practical cropping pattern.

【Explanation】

Farmers are generally highly conservative for introduction of new crops and crop calendar because of their survival. Taking into consideration this situation, it is essential to preferentially confirm the farmers' intension on kind and calendar of crops to cultivate. In the small-scale irrigation project, target crop to be cultivated is paddy. The following table shows the proposed variety of rice by MAFF.

Table 4.3.1 Proposed Variety of Rice by MAFF

Variety	Year Released	Adaptability	Photoperiod Sensitivity	Growth Period (days) or Flowering Date	Yield Level (ton/ha)	Resistance to BPH	Aroma
Early Maturity Variety (less than 120 days)							
IR66	1990	IRR/RFL	None	105～115 days	4.0～6.5	MS	None
Sen Pidao	2002	IRR/RFL	None	105～115 days	4.0～6.5	MS	Aromatic
Chul' sa	1999	IRR/RFL	None	95～110 days	4.0～6.0	MR	None
Medium Maturity Variety (longer than 120 days and less than 150 days)							
Riang Chey	1999	IRR/RFL	Sensitive	Nov.5～11	3.5～5.5	MS	None
Pkha Romeat	2007	RFL	Sensitive	Oct.15～25	3.5～5.8	S	Scented/ Soft Texture
Pkha Romdeng	2007	RFL	Sensitive	Oct.10～25	3.5～5.8	S	
Pkha Chansensor	2009	RFL	Sensitive	Oct.25～Nov.2	3.5～5.0	Unknown	
Pkha Rumduoul	1999	IRR/RFL	Sensitive	Oct.30～Nov.7	3.5～5.5	S	Aromatic
Late Maturity Variety (longer than 150 days)							
CAR 4	1995	RFL	Highly Sensitive	Nov.8～15	2.5～5.0	MS	None
CAR 6	1995	RFL	Highly Sensitive	Nov.9～16	2.5～5.0	S	None

Source: CARDI

Note: IRR=Irrigated Field, RFL=Rainfed lowland, MS=Highly Susceptible, S=Susceptible, MS=Moderately Susceptible, MR=Moderately Resistant, BPH=Brown Plant Hopper

【Output】

Type and calendar of crops reflecting farmers' intension

4.3.3 Study on Proposed Cropping Pattern

The proposed cropping pattern should be prepared in consideration of national policies, the present cropping pattern, farmers' intension, natural condition and socio-economic condition.

【Explanation】

In the study on the proposed cropping pattern, there are two activities; selection of target crops and preparation of proposed cropping pattern. These activities are explained as follows:

(a) Selection of Target Crops

Generally, target crops to be irrigated are selected by comprehensive examination of the following items:

- National and provincial policies
- Natural condition: climate and soil
- Availability of water source for irrigation
- Social and economic conditions such as profitability and marketability of crops, availability of labor force, and draft animal and inputs required
- Situation of beneficiary farmers such as awareness and willingness for crop, farming technique level, and financial capacity for investment to the required inputs,
- Possibility of introducing support programs such as extension services, input supply, credit and marketing

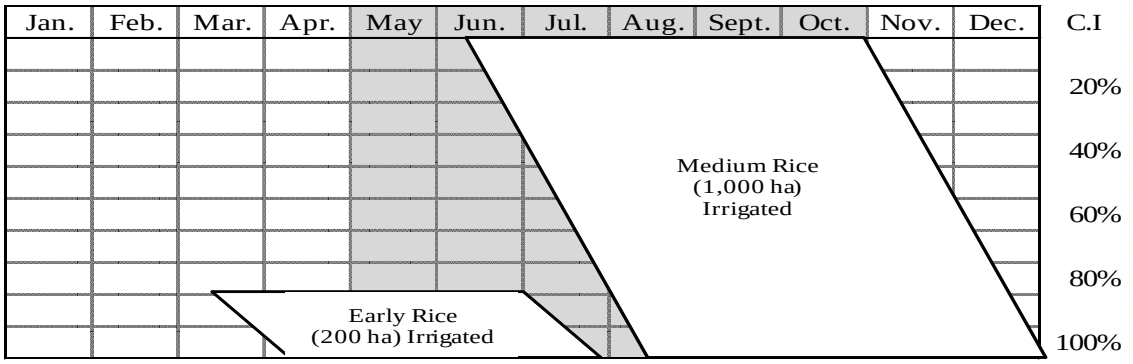
In the small-scale irrigation projects, however, main crop is rice as mentioned above. Therefore, the proposed cropping is prepared centering on rice. As for introduction of upland crops, careful consideration should be given to market demand, agricultural potential and farming practices currently undertaken. The target crops are to be selected from the range of candidate crops that are planted in and around the sub-project area and desired by the beneficiary farmers.

(b) Preparation of Proposed Cropping Pattern

The cropping pattern shows information of cropping plan in a simple format with (i) name of crop, (ii) planted area, (iii) growing season and period of crop, (iv) start and end of planting and harvesting, and (v) period of land preparation/nursery. The cropping pattern should be examined in consideration of climatic conditions during proposed harvesting and/or drying period as well as the availability of labor force, draft animals and agricultural machinery. In preparation of proposed cropping pattern, the first priority should be given to full cultivation of rainy season rice although the proposed cropping pattern is finalized through water balance study mentioned later. Land preparation period is determined mainly by availability of labor forces and farm machinery. However, in general the following land preparation time could be used for small-scale irrigation projects as a rule of thumb:

- More than 500 ha: 2 months
- Less than or equal to 500 ha: 1 month

The sample cropping pattern in the small-scale irrigation project is shown in Figure 4.3.2.



C.I: Cropping Intensity

Figure 4.3.2 Sample of Proposed Cropping Pattern

【Output】

Appropriate cropping pattern well-fitted to national policies, farmers' intension, natural condition and socio-economic condition

4.3.4 Unit Crop Water Requirement

Unit crop water requirement (consumptive use of water by crop) should be known for estimating the irrigation water requirement.

【Explanation】

The unit crop water requirement, say consumption use of water by crop, is estimated by multiplying evapo-transpiration by crop coefficient.

Unit crop water requirement (Consumption use of water: CU) = Kc x ETo

Where, Kc: Crop coefficient

Eto: Evapo-transpiration

According to the FAO Irrigation and Drainage Paper No.24, the crop coefficients for major crops are as follows:

Table 4.3.2 Crop Coefficients for Major Crops

Crop	1st	2nd	3rd	4th	5th	6th	7th	8th
Rice in dry season	1.10	1.10	1.10	1.25	1.25	1.00		
Early rice in rainy season	1.10	1.10	1.15	1.05	1.05	0.95		
Medium rice in rainy season	1.10	1.10	1.10	1.10	1.05	1.05	1.05	0.95
Upland crops	0.50	0.55	0.70	0.80	0.90	0.60		

Source: FAO Irrigation and Drainage Paper No.24

In addition, the FAO Irrigation and Drainage Paper No.24, shows the following equation of modified Penman Method to estimate evapo-transpiration:

Eto = c x [W x Rn + (1-W) x f(u) x (ea –ed)]

Where, Eto: Evapo-transpiration (mm)

c: Adjustment factor to compensate for the effect pf day and night weather conditions

W: Temperature-related weighted factor

Rn: Net radiation in equivalent evaporation (mm/day)

f(u): Wind-related function

ea-ed: Difference beween saturation vapor pressure at mean air temperature and mean actual vapor pressure of air (mbar)

Based on crop coefficient and evapo-transpiration explained above, the sample calculation of ETo for is shown below:

Table 4.3.3 Sample Calculation of ETo

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Remarks
(a) Temperature (℃)	28.4	29.6	29.8	30.8	30.8	30.8	29.0	29.0	29.3	28.2	28.5	26.4	Input
(b) RHmean (%)	68.0	69.0	74.0	76.0	77.0	77.0	78.0	80.0	84.0	83.0	79.0	73.0	Input
(c) ea (mbr)	38.8	41.5	42.0	44.4	44.4	44.4	40.1	40.1	40.8	38.3	39.0	34.5	Table 4.3.4
(d) ed (mbr)	26.4	28.6	31.1	33.7	34.2	34.2	31.3	32.1	34.3	31.8	30.8	25.2	(d)=(c)x(b)/100
(e) (ea-ed) (mbr)	12.4	12.9	10.9	10.7	10.2	10.2	8.8	8.0	6.5	6.5	8.2	9.3	(e)=(d)-(c)
(f) Wind Vw (m/s)	3.2	3.8	4.1	3.9	4.3	4.9	4.3	5.4	4.4	3.1	3.9	3.9	Input, 12m
Wind Vw (m/s)	2.2	2.6	2.8	2.7	2.9	3.3	2.9	3.7	3.0	2.1	2.7	2.7	At 2 m above
(g) U (km/day)	188.0	223.3	240.9	229.1	252.6	287.9	252.6	317.3	258.5	182.1	229.1	229.1	Input
(h) f (u)	0.78	0.87	0.92	0.89	0.95	1.05	0.95	1.13	0.97	0.76	0.89	0.89	0.27(1+U/100)
(i) (1-W)	0.23	0.22	0.22	0.21	0.21	0.21	0.23	0.23	0.23	0.23	0.23	0.25	Table 4.3.5
(j) Sunshine, n (hr)	8.5	8.7	7.4	7.4	6.9	7.0	5.4	5.1	5.5	6.0	7.9	8.6	Input
(k) W of radiation	0.77	0.78	0.78	0.79	0.79	0.79	0.78	0.78	0.78	0.77	0.78	0.75	Table 4.3.6
(l) Ra (mm/day)	12.90	14.00	15.20	15.60	15.60	15.40	15.40	15.60	15.30	14.50	13.40	12.60	Table 4.3.7
(m) N (hr)	11.50	11.80	12.00	12.30	12.60	12.80	12.70	12.40	12.10	11.80	11.60	11.40	Table 4.3.8
(n) n/N	0.74	0.74	0.62	0.60	0.55	0.55	0.43	0.41	0.45	0.51	0.68	0.75	(n)=(i)/(m)
(o) Rs (mm/day)	8.0	8.7	8.5	8.6	8.2	8.1	7.1	7.1	7.3	7.3	7.9	7.9	(0.25+0.5(n))(l)
(p) Rns (mm/day)	6.0	6.5	6.4	6.4	6.1	6.0	5.3	5.3	5.5	5.5	5.9	5.9	0.75 x (o)
(q) f (Tmean)	16.4	16.6	16.7	17.0	17.0	17.0	16.5	16.5	16.5	16.3	16.4	16.0	Table 4.3.9
(r) f (ed)	0.11	0.10	0.09	0.08	0.08	0.08	0.09	0.09	0.08	0.09	0.10	0.12	$0.34\text{-}0.044\ (d)^{0.5}$
(s) f (n/N)	0.77	0.76	0.66	0.64	0.59	0.59	0.48	0.47	0.51	0.56	0.71	0.78	0.1+0,9 (n)
(t) Rnl (mm/day)	1.4	1.3	1.0	0.9	0.8	0.8	0.7	0.7	0.87	0.8	1.1	1.5	(q) x (r) x (s)
(u) Rn (mm/day)	4.6	5.2	5.3	5.5	5.3	5.2	4.6	4.6	4.8	4.6	4.8	4.4	(p) – (t)
(v) c	1.02	1.05	1.04	1.05	1.03	1.03	0.99	0.99	0.98	0.98	1.02	1.02	Table 4.3.10
(w) Eto (mm/day)	5.8	6.8	6.6	6.7	6.4	6.6	5.5	5.6	5.1	4.6	5.5	5.5	(v) ((k)(u)+(i)(h)(e))

Source: Planning Guideline for Rehabilitation and Reconstruction of Irrigation Systems, March 2002

Table 4.3.4 Value of "ea" (unit:mbr)

Tmean	ea	Tmean	ea
20.0	23.4	28.0	37.8
20.5	24.2	28.5	39.0
21.0	24.9	29.0	40.1
21.5	25.7	29.5	41.3
22.0	26.4	30.0	42.4
22.5	27.3	30.5	43.7
23.0	28.1	31.0	44.9
23.5	29.0	31.5	46.3
24.0	29.8	32.0	47.6
24.5	30.8	32.5	49.0
25.0	31.7	33.0	50.3
25.5	32.7	33.5	51.8
26.0	33.6	34.0	53.2
26.5	34.7	34.5	54.7
27.0	35.7	35.0	56.2
27.5	36.6	35.5	57.8

Source: FAO Irrigation and Drainage Paper 24

Table 4.3.5 Value of"(1-W)"

Tmean	(1-W)
20	0.32
21	0.31
22	0.29
23	0.28
24	0.27
25	0.26
26	0.25
27	0.24
28	0.23
29	0.23
30	0.22
31	0.21
32	0.20
33	0.20
34	0.19
35	0.18

Source: FAO Irrigation and Drainage Paper 24

Table 4.3.6Value of "W"

Tmean	W
20	0.69
21	0.70
22	0.71
23	0.72
24	0.73
25	0.74
26	0.75
27	0.76
28	0.77
29	0.78
30	0.78
31	0.79
32	0.80
33	0.81
34	0.82
35	0.83

Table 4.3.7 Value of "Ra" (unit: mm)

North Latitude	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
10	13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9
11	13.0	14.1	15.2	15.7	15.6	15.4	15.4	15.6	15.3	14.6	13.5	12.7
12	12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5
13	12.6	13.8	15.0	15.7	15.8	15.6	15.6	15.7	15.2	14.2	13.1	12.3
14	12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0

Source: FAO Irrigation and Drainage Paper 24

Table 4.3.8 Value of "N" (unit: hr)

North Latitude	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
11	11.5	11.8	12.0	12.3	12.6	12.8	12.7	12.4	12.1	11.8	11.6	11.4
12	11.5	11.7	12.0	12.4	12.7	12.8	12.7	12.5	12.1	11.8	11.5	11.4
13	11.4	11.7	12.0	12.4	12.7	12.9	12.8	12.5	12.2	11.8	11.5	11.3
14	11.4	11.6	12.0	12.5	12.8	12.9	12.8	12.6	12.2	11.8	11.4	11.3
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2

Source: FAO Irrigation and Drainage Paper 24

Table 4.3.9 Value of "f (Tmean)"

Tmean	f (Tmean)	Tmean	f (Tmean)	Tmean	f (Tmean)	Tmean	f (Tmean)
20.0	14.6	24.0	15.4	28.0	16.3	32.0	17.2
20.5	14.7	24.5	15.5	28.5	16.4	32.5	17.3
21.0	14.8	25.0	15.7	29.0	16.5	33.0	17.5
21.5	14.9	25.5	15.8	29.5	16.6	33.5	17.6
22.0	15.0	26.0	15.9	30.0	16.7	34.0	17.7
22.5	15.1	26.5	16.0	30.5	16.8	34.5	17.8
23.0	15.2	27.0	16.1	31.0	17.0	35.0	17.9
23.5	15.3	27.5	16.2	31.5	17.1		

Source: FAO Irrigation and Drainage Paper 24

Table 4.3.10 Value of "c"

Rs	Rhmax.=60%				Rhmax=90%			
(mm/day)	3	6	9	12	3	6	9	12
Uday (m/sec)	**Uday/Unight = 2.0**							
0	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.83	0.91	0.99	1.05	0.89	0.98	1.10	1.14
6	0.70	0.80	0.94	1.02	0.79	0.92	1.05	1.12
9	0.59	0.70	0.84	0.95	0.71	0.81	0.96	1.06
Uday (m/sec)	**Uday/Unight = 1.0**							
0	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.78	0.86	0.94	0.99	0.85	0.92	1.01	1.05
6	0.62	0.70	0.84	0.93	0.72	0.82	0.95	1.00
9	0.50	0.60	0.75	0.87	0.62	0.72	0.87	0.96

Source: FAO Irrigation and Drainage Paper 24

In addition, the following table shows the estimated ETo for respective provinces, which might be used for calculation of unit crop water requirement (consumptive use of water by crops) if time does not allow calculation of ETo:

Table 4.3.11 Calculation of Evapo-transpiration (unit: mm/day)

Province	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct..	Nov.	Dec.
Banteay Meanchey	5.5	6.7	7.6	7.8	6.8	7.1	5.6	6.7	4.9	4.6	5.7	5.4
Battambang	5.5	6.7	7.7	7.8	6.7	7.0	5.6	6.7	4.9	4.6	5.8	5.5
Kampong Cham	5.5	6.3	7.4	7.2	7.3	6.1	6.2	6.5	5.3	5.7	6.3	6.0
Kompong Channang	5.7	6.7	7.8	7.8	7.0	7.0	5.5	6.7	5.0	4.6	5.8	5.5
Kampong Speu	5.5	6.3	7.4	7.2	7.3	6.1	6.2	6.5	5.3	5.8	6.4	6.0
Kampong Thom	5.6	6.8	7.7	7.9	7.9	7.4	6.5	6.9	5.1	4.6	5.5	5.5
Kampot	5.5	6.7	7.1	7.2	6.4	6.2	5.5	5.9	5.5	4.6	5.1	5.8
Kandal	5.4	6.6	7.0	7.1	6.5	6.2	5.5	5.9	5.5	4.5	5.1	5.7
Koh Kong	5.6	6.7	7.7	7.8	6.7	7.0	5.5	6.7	5.0	4.6	5.8	5.6

Kraite	5.6	6.8	7.7	7.9	7.9	7.4	6.5	6.8	5.1	4.7	5.6	5.5
PhnomPenh	5.8	6.8	6.6	6.7	6.4	6.6	5.5	5.6	5.1	4.6	5.5	5.5
Preah Vihear	5.8	6.9	8.0	8.0	7.4	6.6	5.7	6.1	4.9	4.3	5.4	4.7
Prey Veng	5.8	6.8	7.8	7.9	6.7	7.0	5.5	6.7	5.0	4.7	5.9	5.6
Pursat	5.6	6.3	7.6	6.9	6.5	7.1	6.0	6.6	5.2	5.5	5.8	5.8
Ratanak Kiri	5.4	6.3	7.4	7.2	7.3	6.2	6.3	6.5	5.3	5.6	6.2	5.8
Siemreap	5.5	6.2	7.5	6.9	6.5	7.1	6.0	6.7	5.2	5.4	5.8	5.7
Sihanoukville	5.7	6.4	7.7	7.0	6.4	7.0	6.1	6.7	5.3	5.7	6.0	6.0
Stung Treng	5.1	5.5	6.4	7.1	6.0	5.9	6.3	5.4	5.3	5.6	5.4	5.1
Svay Rieng	5.6	6.4	7.5	7.3	7.3	6.0	6.2	6.5	5.4	5.9	6.4	6.1
Takeo	5.6	6.4	7.5	7.3	7.3	6.0	6.2	6.5	5.4	5.9	6.4	6.1
Mondulikiri	5.6	6.2	7.5	6.9	6.5	7.1	6.0	6.7	5.2	5.4	5.8	5.8
Pailin	5.7	6.8	7.7	7.9	8.0	7.4	6.5	6.9	5.1	4.7	5.6	5.5

Source: JICA Survey Team

【Output】

Clarification of unit crop water requirement

4.3.5 Effective Rainfall

Effective rainfall should be considered since all rainfall is not useful for growing crops.

【Explanation】

If daily rainfall data is available, effective rainfall is calculated in the following manner:

- When daily rainfall is less than 5 mm, effective rainfall (ER) is 0.0 mm.
- When daily rainfall ranges from 5 mm to 80 mm, effective rainfall (ER) is equivalent to 80 % of daily rainfall.
- When daily rainfall is more than 80 mm, effective rainfall (ER) is regarded as 64 mm.

If daily rainfall is not available but monthly rainfall is available, monthly effective rainfall is assumed to be 75 % of monthly rainfall. The estimated monthly effective rainfall at 20% non-excess probable year for respective provinces is tabulated below:

Table 4.3.12 Monthly Effective Rainfall at 20% Non-excess Probability Year (Unit:mm)

Province	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct..	Nov.	Dec.	Probable Year*
Banteay Meanchey	0	0	11	59	119	74	112	107	158	112	0	0	2003
Battambang	0	0	22	148	59	129	83	149	99	105	0	1	2003
Kampong Cham	1	0	1	79	77	187	97	143	158	122	24	0	2004
Kompong Channang	0	0	23	32	145	143	144	89	156	92	16	0	2003
Kampong Speu	2	14	9	55	109	95	109	25	112	154	29	0	2004
Kampong Thom	0	0	11	26	105	132	224	74	182	89	107	5	2005
Kampot	0	0	0	117	64	92	197	335	165	243	53	11	2007
Kandal	0	0	0	19	107	147	69	135	123	158	23	0	2007
Koh Kong	0	29	32	83	154	140	623	447	407	301	0	0	2003
Kraite	0	0	3	23	179	99	283	99	285	86	46	0	2005
PhnomPenh	0	0	25	48	62	102	90	197	212	145	9	17	2006
Preah Vihear	0	0	0	0	102	181	186	251	161	161	0	0	2010
Prey Veng	0	0	16	25	27	41	190	149	101	116	17	0	2003
Pursat	2	21	42	89	81	95	110	140	131	122	26	0	2009
Ratanak Kiri	0	0	33	45	118	419	336	341	266	29	6	0	2004
Siemreap	0	0	21	43	69	90	226	62	256	107	12	0	2009
Sihanoukville	2	27	85	101	251	105	290	164	524	157	8	0	2009
Stung Treng	0	0	3	77	75	203	206	165	194	44	26	11	2002
Svay Rieng	0	2	0	49	182	63	115	148	225	174	139	0	2004
Takeo	0	0	39	18	181	104	62	47	91	185	100	0	2004
Mondulikiri	0	4	24	0	0	134	255	209	0	0	0	0	2009
Pailin	0	0	23	41	14	56	117	59	112	190	62	53	2005

Source: JICA Survey Team

**: 20% non-excess probability year*

【Output】

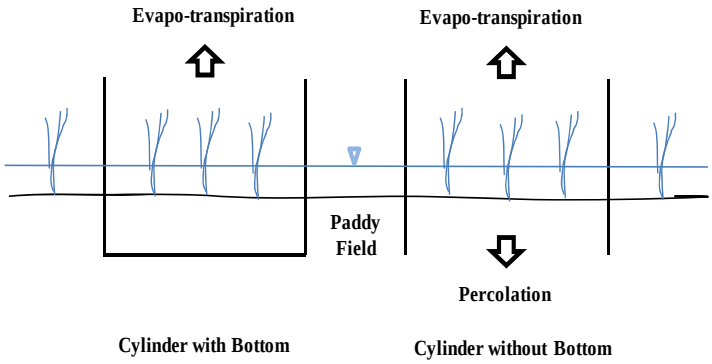
Clarification of rainfall to be effectively used for growing crops

4.3.6 Percolation Rate

Percolation rate should be considered for estimating irrigation water requirement for paddy cultivation.

【Explanation】

Percolation rate depends on soil texture. The percolation rate is measured at paddy field by observing water surface level down in cylinder with bottom and cylinder without bottom as shown in the right figure. Generally, paddy field in Cambodia is covered with sandy loam, clay loam and clay. If no time is available to make field test as shown in the above, the following percolation rate might be used:



- Sandy loam: 8 mm – 10 mm/day
- Clay loam: 4 mm – 6 mm/day
- Clay: 2 mm – 3 mm/day

【Output】

Clarification of percolation rate in paddy field

4.3.7 Irrigation Efficiencies

Water loss from intake site to field should be considered when calculating irrigation water requirement.

【Explanation】

Part of irrigation water abstracted from water source is lost on the way to reach the root zone of plants. In other words, only part of irrigation water is used efficiently for crops, and the remaining does not deliver to crops on the fields. Thus, certain amount should allow for this loss in irrigation water requirement. There are two losses to be considered: conveyance loss and application loss. These losses are calculated as conveyance efficiency and field application efficiency. In the small-scale irrigation project, the following efficiencies are proposed, which are referred to FAO Irrigation Management:

Table 4.3.13 Indicative Values of Conveyance Efficiency and Field Application Efficiency

(a) Conveyance Efficiency (Ec)				
Soil Type	Earth Canal			Lined Canal
Canal Length	Sand	Loam	Clay	
Long (> 2000m)	60 %	70 %	80 %	95 %
Medium (200-2000m)	70 %	75 %	85 %	95 %
Short (< 200m)	80 %	85 %	90 %	95 %
(b) Field Application Efficiency (Ea)				
Surface Irrigation	60 %			

Source: FAO Irrigation Management

With this table, project irrigation efficiency is calculated using the following equation:

Ef= (Ec x Ea)/100

Where, Ef: Project irrigation efficiency (%)
Ec: Conveyance efficiency (%)
Ea: Application efficiency (%)

【Output】

Appropriate irrigation amount for growing crops

4.3.8 Unit Irrigation Water Requirement

Unit irrigation water requirement is needed for determination of irrigable area through water balance study.

【Explanation】

In the proposed cropping pattern for the small-scale irrigation project, main crop is rice although upland crop may be occasionally included. Thus, unit irrigation water requirement is calculated for both rice and upland crop in the following manner:

(a) Net Irrigation Water Requirement for Rice Cultivation

For rice cultivation, net irrigation water requirement is calculated using the following equation:

NIWRp = LP + CU + P - ER

Where, NWIRp: Net irrigation water requirement for rice cultivation (mm)
LP: Land preparation (mm)
Sandy loam: 250 mm
Clay loam: 200 mm
Clay: 170 mm
In case of recession irrigation, LP is not considered.
CU: Crop water requirement (Consumptive use of water, see Sub-clause 4.3.4)
In case of nursery, Kc is 1.0
P: Percolation rate (mm, see Sub-clause 4.3.6)
ER: Effective rainfall (mm, see Sub-clause 4.3.5)

(b) Net Irrigation Water Requirement for Upland Crops

Net irrigation water requirement for upland crops is computed using the following equation.

NIWRu = PI + CU - ER

Where, NWIRu: Net irrigation water requirement for upland crop cultivation (mm)
PI: Pre-irrigation (50 mm)
CU: Crop water requirement (Consumptive use of water, see Clause 4.3.4)
ER: Effective rainfall (mm, see Sub-clause 4.3.5)

(c) Unit Irrigation Water Requirement

Unit irrigation water requirement for rice and upland crops is calculated as follows:

UIWR = (NIWRp + NIWRu)/(Ef x 15 x 0.0864)

Where, UIWR: Unit irrigation water requirement (lit/sec/ha)
NIWRp: *Net irrigation water requirement for paddy cultivation (mm)*
NWIRu: Net irrigation water requirement for upland crop cultivation (mm)
Ef: Project irrigation efficiency (%, see Clause 4.3.7)

Table 4.3.14 shows the sample calculation of unit irrigation water requirement. Although the sample calculation is made on the half month basis, it might be changed into the monthly basis in consideration of the study level and accuracy of available data.

Table 4.3.14 Sample Calculation of Unit Irrigation Water Requirement

	Month			June		July		August		September		October		November		December	
				1	2	1	2	1	2	1	2	1	2	1	2	1	2
	Cropping Pattern					Medium Rice Variety											
(1)	Evapo-Transpiration (Eto)	ETo	mm	99.0	99.0	82.5	88.0	84.0	89.6	76.5	76.5	69.0	73.6	82.5	82.5	82.5	88.0
(2)	Nursery																
	Land Preparation	LP	mm		120	120	120	120	120								
	(a) Area factor for total crop area	Afc1			0.05	0.05	0.05	0.05	0.05								
	(b) Area factor in period of nursery	Afn1			0.20	0.20	0.20	0.20	0.20								
	(c) Water Requirement of land preparation	WRLPn=LPn x Afc1 x Afn1	mm		1.20	1.20	1.20	1.20	1.20								
	After Land Preparation																
	(a) Crop factor	Kc			1.00	1.00	1.00	1.00	1.00								
	(b) Consumptive use of water	Cun= Kc x Eto	mm		99.00	82.50	88.00	64.00	89.60								
	(c) Percolation	P	mm		75.00	75.00	80.00	75.00	80.00								
	(d) Effective rainfall	ER			51.0	43.6	46.5	95.0	102.0								
	(e) Area factor to total crop area	Afc2			0.05	0.05	0.05	0.05	0.05								
	(f) Area factor in period of nursery	Afn2			0.20	0.20	0.20	0.20	0.20								
	(g) Crop water requirement for nursery	CWR= (Cun +P - ER) x Afc2 x Afn2	mm		1.23	1.14	1.22	0.44	0.68								
(3)	Main Paddy Field																
	Land Preparation	LP	mm			120	120	120	120	120							
	(a) Area factor for total crop area	Afc3				1.00	1.00	1.00	1.00	1.00							
	(b) Area factor in period of transplanting	Afp1				0.20	0.20	0.20	0.20	0.20							
	(c) Water Requirement of land preparation	WRLPm= LP x Afc3 x Afp1	mm			24.00	24.00	24.00	24.00	24.00							
	After Land Preparation																
	(a) Crop factor	Kc															
						1.10	1.10	1.10	1.10	1.05	1.05	1.05	0.95				
							1.10	1.10	1.10	1.10	1.05	1.05	1.05	0.95			
								1.10	1.10	1.10	1.10	1.05	1.05	1.05	0.95		
									1.10	1.10	1.10	1.10	1.05	1.05	1.05	0.95	
										1.10	1.10	1.10	1.10	1.05	1.05	1.05	0.95
	(b) Consumptive use of water	Cum= Kc x Eto				90.8	96.8	92.4	98.6	80.3	80.3	72.5	69.9				
							96.8	92.4	98.6	84.2	80.3	72.5	77.3	78.4			
								92.4	98.6	84.2	84.2	72.5	77.3	86.6	78.4		
									98.6	84.2	84.2	75.9	77.3	86.6	86.6	78.4	
										84.2	84.2	75.9	81.0	86.6	86.6	86.6	83.6
	(c) Percolation	P	mm			75	80	75	80	75	75	75	80	75	75	75	80
	(d) Effective rainfall	ER	mm			43.6	46.5	95.0	102.0	106.0	106.0	70.2	74.8	4.5	4.5	8.2	8.8
	(e) Crop water rquirement for each block	CRWb= Cum + P - ER	mm			122.2	130.4	72.4	76.6	49.3	49.3	77.3	75.1				
							130.4	72.4	76.6	53.2	49.3	77.3	82.5	148.9			
								72.4	76.6	53.2	53.2	77.3	82.5	157.1	148.9		
									76.6	49.3	49.3	77.3	75.1	70.5	70.5	66.8	
										53.2	53.2	80.7	86.2	157.1	157.1	153.4	154.8
	(f) Average of crop water requirement for each block	CWRa	mm			122.2	130.4	72.4	76.6	51.6	50.9	77.9	80.3	133.4	125.5	110.1	154.8
	(g) Area factor to total crop area	Afc4				0.20	0.40	0.60	0.80	1.00	1.00	1.00	1.00	0.80	0.60	0.40	0.20
	(h) Crop Water Requirement	CWR= CWRa x Afc4	mm			24.44	52.14	43.44	61.25	51.62	50.86	77.94	80.27	106.73	75.30	44.05	30.96
(4)	Net Water Requirement	NWR=WRPLn + CWR + WRPLm + CWR	mm		2.43	50.78	78.56	69.08	87.12	75.62	50.86	77.94	80.27	106.73	75.30	44.05	30.96
	(a) Irrigation efficiencies	Ef			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
(5)	Irrigation Water Requirement	IWR= NWR/Ef	mm		5.79	120.90	187.04	164.48	207.44	180.05	121.08	185.57	191.12	254.11	179.29	104.87	73.71
(6)	Irrigation Water Requirement	IWR= (NWR/Ef/half month period)/8.64	lit/sec/ha		0.04	0.93	1.35	1.27	1.50	1.39	0.93	1.43	1.38	1.96	1.38	0.81	0.53

Area required for nursery bed is assumed to be 5% of main field.

In each of half a month, 20% of nursery will be prepared.

In each of half a month, 20% of main filed will be carried out for transplanting.

Water requirement in main field is calculated for each of five blocks divided by five half months.

Area planted/Total area

Source: JICA Survey Team

4.4 Water Balance Study

Development scale of irrigation project is determined by considering balance among available water source, available land source and water demand by crop cultivation.

【Explanation】

In case that available land for irrigation development is limited as compared with available water source, it becomes a decisive factor for determination of development scale of irrigation project. In case of small-scale irrigation project in Cambodia, however generally, the available land is more abundant than available water source. In this manual, therefore, a focus is given to a water balance study between available water source and water demand by crop cultivation. The water balance

study is divided into two cases by type of water source, namely river and reservoir.

4.4.1 River

(1) Obtain river discharge of the critical months

Obtain river discharge for the rainy and dry seasons (Qd and Qr), and enter the values into the calculation form below. If discharge data is not available, it is estimated as mentioned in Sub-clause 4.2.1.1.

(2) Calculate 80% dependable river discharge

Calculate 80% dependable river discharge as mentioned in Sub-clause 4.2.1.3. If time is not allowed, it might be obtained by multiplying Qd and Qr by 0.6 for rough estimate.

(3) Obtain and enter <u>unit irrigation water requirement (UIWR)</u>

Obtain unit irrigation water requirement (UIWR) for 12 months and enter the value in the calculation form below.

(4) Calculate irrigable area in the dry and rainy season

Calculate the irrigable area of each month and determine the irrigable area in the rainy season and dry season using the following calculation form.

Table 4.4.1 Calculation Form of Water Balance Study (River) (Unit: m^3/sec)

		Dry season						Rainy season					
Month		1st Nov	2nd Dec	3rd Jan	4th Feb	5th Mar	6th Apr	1st May	2nd Jun	3rd Jul	4th Aug	5th Sep	6th Oct
River discharge (a)													
80% dependable river discharge (b)	(a) x 0.6*												
UIWR (c)													
Irrigable Area (ha) in the month (d)	(b)/(c)x 1000												
Irrigable Area (ha) in the season	minimum of (d) in the season												

Note: (i) If river discharge data is available for only one month of each season, the water balance can only be made for that month.

(ii) If water requirement in the critical month is "-", shift the critical month to the nearest month for which water requirement is available.

** If there is no time to calculate 80% dependable discharge, it might be assumed by multiplying river discharge (a) by 0.6 as a rule of thumb.*

(5) Determine development area (area to be provided with irrigation facilities)

Obtain the size of the proposed area from the present situation map by counting the squares in the map. Compare the area of the proposed area with the irrigable area in the rainy season; the smaller value should be chosen as the development area.

Proposed area (i) ☐ ha

Irrigable area in the rainy season (ii) ☐ ha

Development area ☐ ha

(smaller value of (i) and (ii))

4.4.2 Reservoir

(1) Calculate rainfall recharge (see Table 3.4.3 and Sub-clause 4.2.2.1)

Calculate rainfall recharge for each of the 12 months and enter on the calculation form.

rainfall recharge (m^3) = dependable rainfall (mm) x surface area of reservoir (m^2) /1000

(2) Obtain inflow discharge to reservoir

Obtain the average river discharge (Qd and Qr) to the reservoir, if any. Enter the average discharge in the dry season (Qd; the same value) for each of the 6 months. Enter the average rainy season discharge for each month of the rainy season (Qr).

(3) Calculate evaporation from water surface of reservoir

Obtain evaporation (mm/day) from the following table and surface area of the reservoir.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.4	5.4	6.2	5.8	4.8	4.6	4.1	4.0	3.5	3.1	3.6	4.1

Calculate evaporation for 12 months and enter the result on the calculation form.

Monthly evaporation (m^3) = evaporation (mm/day) x days of one month x water surface area of reservoir (m^2) /1000

(4) Calculate percolation from reservoir

Calculate percolation for 12 months and enter the result on the calculation form.

Monthly evaporation (m^3) = 0.2 (mm/day) x days of one month x average water surface area of reservoir (m^2) /1000

(5) Calculate diversion water requirement (DWR)

Assume some development area (A). Calculate the diversion water requirement (DWR) by multiplying (A) and unit irrigation water requirement (UIWR).

Assumed development area (A) [ ] ha

(6) Obtain capacity of reservoir and surface area

Obtain the capacity of reservoir as mentioned in Sub-clause 4.2.2.4.

(7) Calculate the storage of the month

Calculate storage of each month, Qn, from storage of the previous month, Q(n-1), and inputs and outputs for the month. For the first month, Q(n-1) should be the capacity in (e). If calculated storage is larger than the capacity obtained in (e), enter the capacity in (e) instead of the calculated value.

Table 4.4.2 Calculation Form of Water Balance Study (Reservoir) (Unit: m^3)

		Dry season						Rainy season					
Month		1st Nov	2nd Dec	3rd Jan	4th Feb	5th Mar	6th Apr	1st May	2nd Jun	3rd Jul	4th Aug	5th Sep	6th Oct
Rainfall recharge (i)													
Average inflow (ii)													
80% dependable inflow (iii)	(ii) x 0.6*												
Evaporation (iv)													
Percolation (v)													
UIWR (vi)	UIWR x (A)/1000												
Storage of the month (Qn)	Q(n-1)+(i)+(ii)-(iv)-(v)-(vi)												

Calculation should start from the dry season and continue for one year.

Note: Q(n-1) is storage in the previous month

** If no time is available for calculating 80% dependable inflow, it might be calculate by multiplying the average inflow by 0.6.*

(8) Determine development area (area to be provided with irrigation facilities)

If the calculated storage in a month is negative, or storage in the last month of the rainy season is less than obtained capacity in (5), decrease the assumed development area and re-calculate until these conditions are not met to obtain final development area.

Development area [ ] ha (the area also can be recognized as the irrigable area for both the dry and rainy season)

【Output】

Determination of development area

4.4.3 Delineation of Irrigation Area

Delineation of irrigation area on topographic map should be carried out in consideration of difference between "net irrigation area" and "gross irrigation area".

【Explanation】

Through the water balance study between available water source and water demand by crops, the development area is obtained. This development area means the net irrigation area. However, the

irrigation area to be delineated on the topographic map, if not available the situation map as mentioned in Clause 4.1.1, is duly the gross one. The gross irrigation area includes land for canals, bund of farm field, inspection roads, village roads, etc. The ratio of "net area" to "gross area" depends on scale of maps, namely it is general that 0.85 is for 1/10,000 map and 0.80 for 1/50,000 map. In the delineation of irrigation area, elevation and alignment of canals should be carefully examined. In case of small-scale irrigation project in Cambodia, irrigation system already exists in the farm land. Thus, delineation of irrigation area should be taken into consideration the maximum use of existing irrigation system as far as technically possible. If there is the flooded area in the irrigation area delineated, certain measures might be necessary for protecting crops from flood or it would be removed from the irrigation area.

【Output】

Clarified net irrigation area

4.5 Preparation of Canal Layout Plan

Canal layout plan should be worked out in consideration of maximum use of existing canal system if technically severe problems are not found.

【Explanation】

As mentioned previously, the small-scale irrigation projects listed by MOWRAM are already provided with irrigation canals. These irrigation canals, mostly so-called Pol Pot canals, are of excavation type, and are laid out on a grid without consideration of topography. There hardly exist tertiary and quaternary canals in the existing canal system. Thus, a careful study should be made for how to presently irrigate the farm lands using these canals. On the other hand, drainage canals are scarcely constructed at fields. Excess water currently drains from fields to fields and then enters into natural streams. The current conditions of existing facilities should also be examined through inventory survey as mentioned in Clause 3.5. The results of study and examination on existing canal system should be fully reflected upon the preparation of canal layout plan with the following important notices in mind.

Table 4.5.1 Important Notices for Preparation of Canal Layout Plan

Category	Contents of Notices
Technical notices	- Exist of most Pol Pot canals at 1 km to 3 km interval* - Suitable size of tertiary block, say less than 25 ha considering easy handling of irrigation water by farmers* - Application of rotational water supply within tertiary block especially for land preparation - Separation of irrigation canals from drainage function for efficient water use by farmers* - One tertiary canal commanding one tertiary block only - One tertiary canal branching off 7 quaternary canals for easily rotational operation
Economical notices	- Use of existing canal system as much as possible if severe technical problems are not found - Application of gravity system instead of pumping system as much as possible
Environmental notices	- Unnecessary land acquisition - Participatory approach by farmers

Source: JICA Survey Team

**: Design Manual for Small and Medium Scale Irrigation, System Planning, MOWRAM, July 2004*

【Output】

Appropriate canal layout plan well-fitted to local conditions

4.6 Topographic Survey

Topographic survey is essential for not only making good design, but also estimating appropriate work volume.

【Explanation】

In most small-scale irrigation project, there is existing irrigation canal system. Thus, topographic survey treated in this manual is focused on the existing irrigation system for its rehabilitation.

Topographic survey is carried out mainly for river, reservoir, canals and large structures. Proposed methods for topographic survey for them are as follows:

Table 4.6.1 Proposed Methods for Topographic Survey

Subject	Proposed Methods
River	In order to analyze the present river capacity and change in river flow after constructing structures on the river, a river profile and cross-section survey should be conducted. - Pitch of the cross-section of the river course to be taken is set between 250 m and 500 m according to the river condition. - Longitudinal measurement is taken at least every 200 m with additional measurements at place where the river condition changes. - Width of cross-section is at least 50 m beyond the river banks.
Reservoir	In order to estimate the storage volume of a reservoir, a leveling survey in the reservoir area should be conducted. - Contour lines are drawn by 0.1 m pitch. - Longitudinal survey line is set on the top of dikes and the crossing lines are set every 200 m on the longitudinal line. - Elevation should be measured every 100 m on the cross-section lines. If budget and time are so limited, topographic survey for reservoir might be conducted as mentioned in Sub-clause 4.2.24.
Canal	Profile and cross-section survey of the existing canals are conducted in the following specifications: - Longitudinal profile : 100 m pitch - Cross-section : 100 m pitch - Width of the cross-section :canal width + 20 m on both banks
Large-scale Structures	Large-scale structures such as headworks and siphon require site survey and topographic mapping - Site survey: determination of extent for survey for structure - Topographic survey : Grid interval (X=10 m, Y=10 m), Scale (1/200 to 1/500 depending on structure size), Contour interval (0.5 m)
Accuracy of Survey	Longitudinal survey - Height point: within $\pm$5 cm - Distance : better than 1/2,000 Cross sectional survey - Height point: within $\pm$5 cm + 3 cm $\sqrt{D}$ (D: measured distance in km) - Distance : better than 1/300

Source: JICA Survey Team

【Output】

Results of topographic survey useful for designing canals and large-scale structures

4.7 Preliminary Design of Irrigation and Drainage Facilities

Preliminary feasibility study requires preliminary design for major project facilities for estimating the required work volume and also project cost.

【Explanation】

In the small-scale irrigation project, generally the project facilities provided or to be provided are headworks, reservoir, irrigation canals, drainage canals and related structures. The preliminary design for these facilities is made based on the results of topographic survey and inventory survey because most of them are existing ones.

【Output】

The preliminary design of major facilities based on actual conditions

4.7.1 Irrigation Canals

Irrigation canals are designed in a concept of maximum use of existing canals, not only cost saving, but also less land acquisition.

【Explanation】

(1) Irrigation Canal System

Generally, irrigation canal system consists of main canal, secondary canal, tertiary canal and quaternary canal (watercourse). In the small-scale irrigation project, this irrigation system is incomplete. Especially, tertiary canal and quaternary canal are hardly constructed, which result in inefficient water use. In order to smooth water distribution, therefore consideration should be given to provision of tertiary canal and quaternary canal (watercourse) by making reference to the average density rate of 30m/ha and 50m/ha, respectively.

(2) Type of Irrigation System

Priority is put on gravity system taking into account the lower O&M cost. However, the existing canal, say Pol Pot canal, is excavated canal. If this canal is incorporated into the proposed irrigation canal system, it is difficult or rather impossible to apply the gravity system. In this case, application of portable pump might be considered as unavoidable measure although higher production cost would be imposed on beneficiary farmers.

(3) Canal Type

Unlined canal is prevailing to the existing canal. Since the small-scale irrigation project could not be expected to produce high incremental benefit due to the limited water source, unlined canal with sod facing is proposed from economic viewpoint. However, earth lining with suitable soil might be required for part of main canal running in dispersive soil.

(4) Design Discharge for Irrigation Canal

In order to design the irrigation canals and related structures at preliminary feasibility study level, it is necessary to determine the design discharge. The largest unit irrigation water requirement (UIWR) which is used to determine the development area in the water balance study is employed as the design discharge. In case of small-scale irrigation projects where paddy is mainly cultivated, 2.0 lit/sec/ha is proposed to be used as the design discharge at intake site taking into consideration the development level, quality of works, and operation capability by FWUC, if no time is available for calculating the unit irrigation water requirement as mentioned in Clause 4.3.8.

(5) Preliminary Design for Irrigation Canals

Preliminary design for main, secondary and tertiary canals is conducted in the following manner:

(a) Canals

- Design Canal Capacity

Design canal capacity is determined by (i) unit irrigation water requirement (see Clause 4.3.8), (ii) water supply schedule and (iii) free board.

If small-scale irrigation project has 500 ha of irrigation area, and the estimated unit water requirement is 2.0 lit/sec/ha, then canal has a capacity of 1.0 m^3/sec. For canal system, especially tertiary block, in which rotational irrigation is proposed, canal capacity is increased to supply the required irrigation water within a certain period.

Example

Irrigation area: 4 ha

Rotational interval: 7 days

Unit irrigation water requirement: 2 lit/sec/ha

Design canal capacity: 4 x 7 x 2 =56 lit/sec

- *Freeboard*

The freeboard of irrigation canal is determined using the following equation:

$$F_b = 0.05d + \beta \cdot h_v + h_w$$

Where, F_b : *freeboard (m)*

d : *depth of water (m)*

β : *conversion factor from velocity head to static head (1.0)*

h_v : *velocity head (m)* $v^2/2g$

h_w : *freeboard for water surface fluctuation (0.15 m)*

In case on small-scale irrigation project, the proposed freeboard is about 0.2 m.

(b) Design Canal Capacity

The dimension of canal is determined using Manning Formula as shown in Sub-clause 4.2.1.2. The ratio of canal depth to bed width is to be 0.8 to 1.0.

(c) Design Velocity

In the small-scale irrigation project, canal size is small on the whole. Thus, it is proposed to apply 0.3 m/sec. On the other hand, the proposed allowable maximum flow is as follows:

Table 4.7.1 Maximum Allowable Velocity

Type of Canal	Maximum Allowable Velocity
Earth canal (sandy soil)	0.45 m/sec
Earth canal (sandy loam)	0.60 m/sec
Earth canal (loam)	0.70 m/sec
Earth canal (clay loam)	0.90 m/sec
Earth canal (Clay)	1.00 m/sec
Earth canal (Clay with sand)	1.20 m/sec
Thick concrete (0.18m)	3.00 m/sec
Thin concrete (0.10m)	1.50 m/sec
Dry masonry	1.50 -2.00 m/sec
Wet masonry	2.50 m/sec
Concrete pipe	3.00 m/sec

Source: Planning Guideline for Rehabilitation and Reconstruction of Irrigation Systems

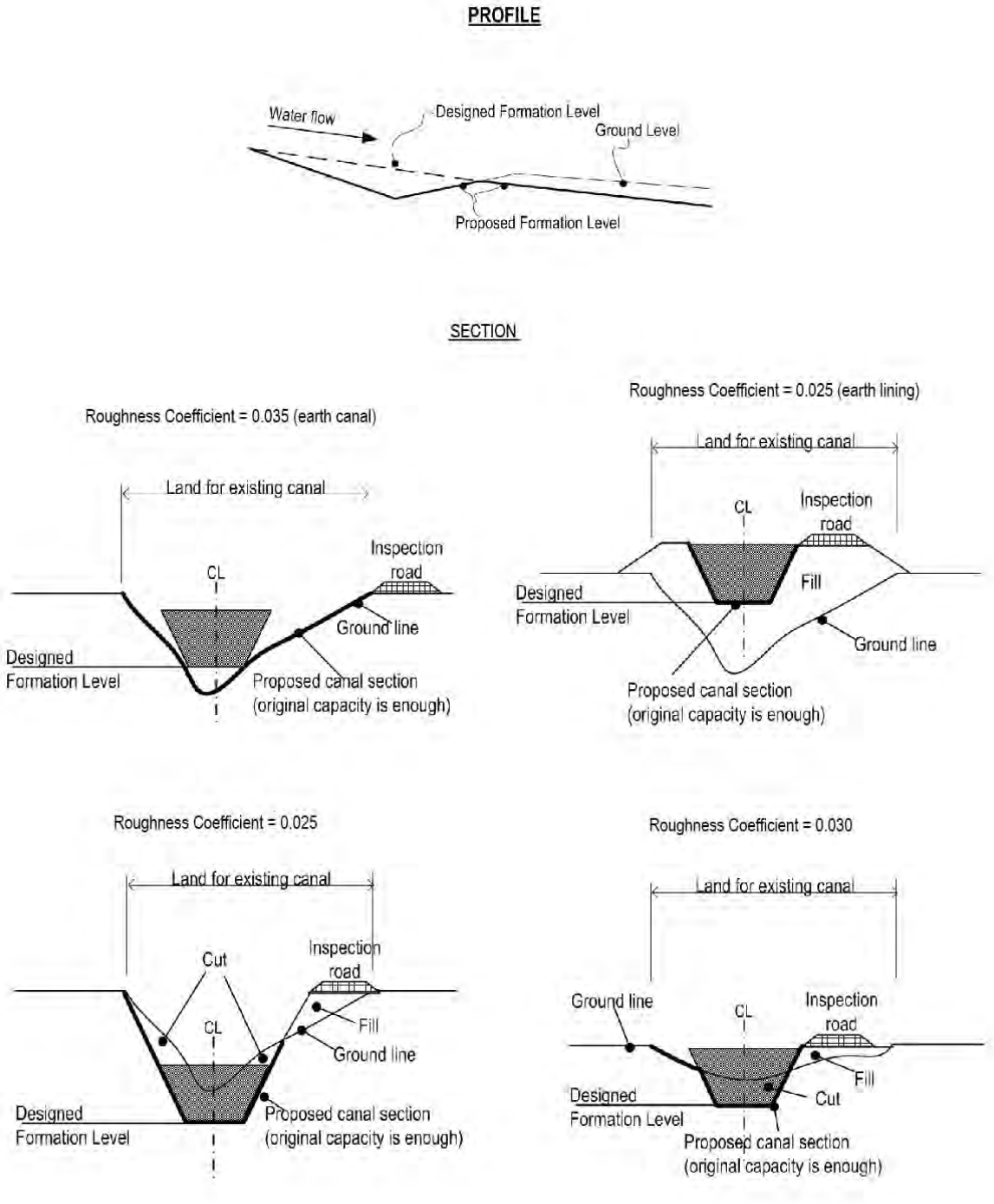
(d) Hydraulic losses

The hydraulic losses to be considered are friction loss and head losses of inlet, outlet, transition, screen, bridge pier and culverts. Head losses are calculated using Manning Formula mentioned above. But, in case of small-scale irrigation project, it might be better to apply 0.02 m to 0.05 m for each loss for time-saving.

(e) Rehabilitation method of existing canals

Rehabilitation method of existing canals is different depending on the conditions of them. If the

existing canal has enough capacity to flow the design discharge and the required water level, no rehabilitation is required. But, if the higher water level required, the existing canal is filled until ensuring the required water level. If the existing canal has insufficient capacity, the enlargement of canal section is required. Figure 2.7.1 shows how to rehabilitate the existing canals.



Source: Planning Guideline for Rehabilitation and Reconstruction of Irrigation Systems

Figure 4.7.1 Rehabilitation Method of Existing Canals

【Output】

Establishment of irrigation canal system well-fitted to local conditions

4.7.2 Drainage Canals

Proper drainage from farm land contributes to increase of crop production as well as prevention of damage of crop production.

【Explanation】

(1) Drainage Canal System and Conditions

Generally, the drainage canal system corresponding to irrigation canal system consists of main drain, secondary drain, tertiary drain and quaternary drain. In small-scale irrigation project, however, no drainage canal system is established mainly due to land acquisition problem. It is often seen that excess water from fields enters into irrigation canal, so-called combined use of canal. If budget and land acquisition problems could be settled, it is desirable to establish the drainage canal system independently from efficient water management viewpoint.

(2) Drainage Conditions

In small-scale irrigation projects, rice is a major crop. Even for rice, certain damages would occur due to inundation condition as shown below:

Table 4.7.2 Relation between Inundation Condition and Damage of Rice

Growing Stage	Duration of Inundation	1 – 2 days	3 – 4 days	5– 7 days	> 7 days
	Condition of Inundation	Decrease rate	Decrease rate	Decrease rate	Decrease rate
Tillering	Submergence by clean water	10 %	20 %	30 %	35 %
Booting	Leaf of apex above muddy water surface	20 %	50 %	85 %	90 - 100 %
	Submergence by muddy water	70 %	80 %	85 %	90 - 100 %
	Leaf of apex above clean water surface	10 %	30 %	65 %	90 - 100 %
	Submergence by clean water	25 %	45 %	80 %	90 - 100 %
Heading	Submergence by muddy water	30 %	80 %	90 %	90 - 100 %
	Submergence by clean water	15 %	25 %	30 %	70 %
Ripening	Submergence by muddy water	5 %	20 %	30 %	30 %
	Submergence by clean water	0 %	15 %	20 %	20 %

Source: Irrigation and Drainage Handbook, Japan

Accordingly, it is necessary to provide drainage facility for farm land where water stagnant frequently occurs due to heavy rainfall. Drainage condition of farm land will be clarified through site inspection with topographic map if available, or situation map as mentioned in Clause 4.1.1 and interview with village people living nearby. The items to be clarified on water stagnant are (i) frequency, (ii) duration, (iii) depth, and (iv) time. In addition, direction of drainage flow is also confirmed at site. The results of site inspection and interview with village people should be written down on the map, to make drainage condition clear.

(3) Unit Drainage Water Requirement

(a) Design Rainfall

As mentioned above, rice cultivation is prevailing to the small-scale irrigation project in Cambodia. In case of paddy cultivation, certain water stagnant at rice field is allowed as shown in Table 4.7.2. Taking into consideration this situation and prevention of excessive design of drainage facilities, it is proposed to use 3-day consecutive rainfall with 1/5 years occurrence as a design rainfall, and to drain it from rice field within 3 days.

(b) Estimate of Unit Drainage Water Requirement

The unit drainage water requirement is so estimated as to eliminate the 3-day consecutive rainfall with

1/5 years occurrence from farm field within 3 days. The proposed equation for estimating the unit drainage water requirement is as follows:

$UDWR = (C \times R \times 10^4)/(3 \times 24 \times 3,600)$

Where, *UDWR: Unit drainage water requirement (lit/sec/ha)*
C: Runoff coefficient (= 0.75)
R: 3-days consecutive rainfall (mm)

If no daily rainfall data is available so that the unit drainage water requirement cannot be estimated, 3 to 5 lit/sec/ha might be used as unit drainage water requirement.

(4) Preliminary Design of Drainage Canals

Drainage canals are also designed using the Manning Formula shown in Sub-clause 4.2.1.2 and the unit drainage water requirement which is a main factor for designing drainage canals, as calculated above. However, freeboard is not required.

【Output】

Establishment of drainage canal system acceptable for all stakeholders

4.7.3 Related Structures

Preliminary feasibility study requires preliminary design for major structures for estimating the required work volume and also project cost.

【Explanation】

In the preliminary feasibility study, the preliminary design for major structures is made based on the results of topographic survey and inventory survey for the purpose of cost estimate. Especially, the small-scale irrigation project is not new development project, but rehabilitation/improvement project, so that the results of inventory survey should be examined and referred to the preliminary design.

(1) Headworks

The headworks consist of a weir across the river, intake gates, and flush gates to remove sediments around the intake gates. Sediment traps and/or a settling basin are constructed immediately after intake structure to avoid the sediment intrusion to the canal. But, in small-scale irrigation project, these sediment traps and/or a settling basin are apt to be eliminated mainly due to its small scale and economical viewpoint. As for the weir, there are two types; fixed type and gated type, so-called "barrage". In preliminary design of headworks, major points to be checked are as follows:

Table 4.7.3 Checklist of Major Points in Preliminary Design of Headworks

Check Items	Check
General	
Are the headworks designed in accordance with the authorized criteria?	
Is the rived change checked?	
Is the crest of flood dike at upstream enough against design flood level?	
Is the stability of river course at headworks site confirmed?	
Is the flood condition confirmed at site?	
Is the proper location of headworks site determined so as to abstract water stably?	
Is the inventory survey carried out for existing facility in case of rehabilitation project?	
Is the consideration paid to practical construction method if rehabilitation is required?	

Weir	
Is the sufficient study conducted for the selection of fixed weir type and barrage type?	
Is the stability analysis of fixed weir conducted for design flood and less flood?	
Is the crest shape of fixed weir so designed no to occur negative pressure for stream?	
Is the suitable width of gate decided so as to flush out floating materials in case of barrage?	
Is the enough study made for selection of gate type in case of barrage?	
Intake	
Is the sill height of intake equivalent to about 40% of intake water depth?	
Is there more than 1m of difference between the bed level of intake and that of souring sluice?	
It the flow velocity at intake less than 0.6 m/sec?	
Flood and Scouring Sluice	
Is the length of downstream apron of flood sluice is enough?	
Does the supercritical flow occur at scouting time?	
Is the countermeasure for the floating materials like driftwoods considered?	
Is the width of flood sluice gate enough to flash out the floating materials?	
River Protection	
Is the length of riverbed protection work decided considering the relevant area of downstream apron and riverbed protection?	
Is the safety of headworks confirmed even for less flood discharge than the designed one?	
Foundation	
Is the suitable measure for foundation considered if rock crops out?	
Is the creep length considered if rock does not crop out?	
Settling Basin	
Is the study executed for need of settling basin?	
Is the study conducted for desilting method?	
Is the study made for determination of size of settling basin?	
Operation Facility	
Is the design load confirmed?	
Is there enough free board at design flood time?	
Is the study given to O&M method?	
Is the study made for ensuring energy for electric operation?	
Coffering and Dewatering Works	
Is the study made for temporary facilities?	
Is the necessary cost for coffering and dewatering works included on construction cost?	

Source: JICA Survey Team

It is proposed that design of headworks should be made by referring to the relevant guidelines, manual and reference books possessed by MOWRAM and TSC as listed in Table 2.3.1. Sample of preliminary design of headworks is given in Attchmewnt-2.

(2) Reservoir

In general, a “reservoir” is defined as a dam whose height is less than 15 m. In the small-scale irrigation project, most reservoirs have homogeneous embankment of local materials and a height of less than

10 m. The effective depth of water that is available for irrigation is less than 1.0 m in many reservoirs. The function of the reservoir expected is as "supplemental irrigation and regulation of water flow in the rainy season"

(a) Design flood

The design flood for reservoirs is proposed to confirm the following criteria:

Table 4.7.4 Design Flood for Reservoir

Condition on Reservoirs	Proposed Design Flood
Design flood for spillway on the perennial river with catchment area more than or equal to 10 km^2 or total storage capacity more than or equal to 50,000 m^3	1/100 years probable flood, which is estimated as explained in Sub-clause 4.2.1.2
Design flood for small reservoirs with catchment area less than 10 km^2 or total storage capacity less than 50,000 m^3	1/20 years probable flood, which is estimated as explained in Sub-clause 4.2.1.2

(b) Dike

Reservoir dike is generally constructed with earth materials. The maximum dike height should basically be limited to 5 m so that stability of the dike is maintained. If the dike height exceeds 5 m, stability analysis should be conducted. Local materials near the proposed location can be used if the materials are not sandy or dispersible. The slope on the reservoir side should be protected with impervious materials and rip rap. If impervious materials could not be obtained, the embankment slope would have to be changed to be gentler so that the stability of the dike could be secured. As for rehabilitation of the existing dikes, it is proposed to provide reinforcement works such as removal of surface soil, provision of gentle slope of 2.5 to 3.0, provision of riprap with sand and gravel, and pavement of top using laterite or gravel as shown in Figure 4.7.1.

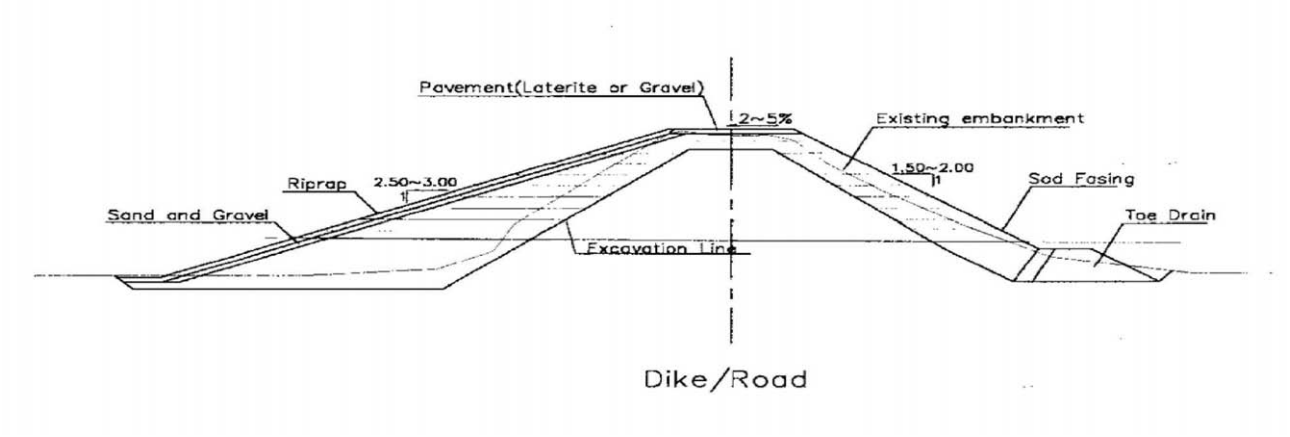


Figure 4.7.2 Rehabilitation of Dike/Road

And also, attention should be paid to whether the freeboard which is specified below is satisfied or not.

(c) Intake

The intake structure should consist of gates that can be operated manually. Gate size should be determined so that maneuverability is secured. The gate sill level would be set at the estimated dead storage level after 20 years of operation.

(d) Spillway

There are two types of spillway. One is gated type and the other is overflow type. These two types have the following advantages and disadvantages:

Table 4.7.5 Advantages and Disadvantages by Spillway Type

Study Items	Gated Type*	Overflow Type
Construction cost	High	Low, but if considering bridge, its cost is

		similar with gated type
O&M cost	High	Low
Operation	Easy, but risky due to occurrence of mechanical problem	Easy
Length	Short	Long
Storage water	Effectively used	No control

**: Automatic flap gate is generally equipped.*

As mentioned in the above table, there are advantages and disadvantages in both types. Thus, suitable type should be selected from overall viewpoints, especially the project conditions.

The capacity of spillway should be determined based on the probable flood mentioned above. In case of rehabilitation/improvement of existing spillway, its current conditions, especially its capacity should be carefully checked using the probable design flood proposed in Sub-clause 4.2.1.2.

The capacity and dimension of spillway is determined using the following equation:

$$Q = CBH^{3/2}$$

Where, *Q: Spill out discharge (m^3/sec)*
C: Coefficient, generally use 1.7 for safety side
B: Overflow length of crest (m)
H: Overflow depth (m)

(e) Freeboard

The freeboard of a reservoir should be basically not less than 0.90 m. For small reservoirs with a catchment area less than 10 km^2 or total storage capacity less than 50,000 m^3, a freeboard of 0.60 m could be adopted.

(f) Sedimentation

Sedimentation of the reservoirs is estimated for determining the required dead storage capacity. A standard unit sedimentation rate of 0.1 mm/km^2/year can be used for estimation of the sediment volume. The sediment level after 20 years is adopted as the "low water level", i.e. the intake sill level.

(2) Canal Related Structures

In the irrigation project, lots of structures are required for proper conveyance and distribution of irrigation water to the fields. However, the small-scale irrigation project is provided with less number of structures, which leads to inefficient water use. It is found that even provided structures could not function well due to less quality in design. Thus, it is expected that appropriate number and design of structures are provided for the existing irrigation system for smooth O&M of irrigation canal system.

The canal related structures are largely divided into 3 categories; control structures, crossing structures and safety structures.

(a) Control Structures

Control structures consist of diversion, off-take, check, drop and water measurement structures. These structures play a role of water distribution in the irrigation canal system.

Table 4.7.6 Explanation of Control Structures

Structure	Explanation
Diversion	A diversion structure equipped with sluice gate(s), is constructed at the place where secondary canal branches off from main canal. The diversion structure is mostly combined with check structure, to maintain water level in main canal for smooth distribution.
Off-take	An off-take is provided at the diversion point to tertiary canal. The off-take is also equipped with small sluice gate (s) to regulate diversion water.
Drop	A drop is provided on canal to adjust the longitudinal slope of canal and to keep the flow velocity lower than the maximum allowable velocity as shown in Table 4.15.2. The drop is

	sometimes combined with diversion and check structures to save construction cost.
Water Measurement	Water measurement structure is generally provided at beginning point of main, secondary and tertiary canals, to calibrate the diverted discharge. Although there are many types on water measurement structure, generally a broad-crested weir is proposed from viewpoint of less water head. A portable Parshall flume is one of alternatives to avoid much head loss.

Source: JICA Survey Team

(b) Crossing Structures

Crossing structures are culvert (box and pipe), siphon, aqueduct, cross drain and bridge. These structures are provided at the crossing points with road, river and drainage canal. As for culvert and bridge, the following selection criteria might be applied as a rule of thumb:

Table 4.7.7 Selection Criteria of Culvert and Bridge

Condition	Structure
Top width of canal is more than 5 m	Bridge
Top width of canal is less than 5 m and canal discharge is more than 0.5 m^3/s	Box culvert
Top width of canal is less than 5 m and canal discharge is less than 0.5 m^3/s	Pipe culvert

Source: JICA Survey Team

As for siphon and aqueduct, the similar criteria might be applied for preliminary feasibility study.

Table 4.7.8 Selection Criteria of Siphon and Aqueduct

Condition	Structure
- Enough head in canal - Comparatively larger canal discharge - Difficulty in obtaining clearance height at flood time	Siphon
- Except conditions mentioned above - Stable foundation condition	Aqueduct

Source: JICA Survey Team

Cross drain is constructed at point where irrigation canal crosses with drainage canal. Selection of box culvert and pipe culvert is made based on drainage discharge mentioned above and considering the allowable time for construction.

(c) Safety Structures

Safety structures are spillway and drainage inlet. When canal flow is more than the design discharge, the excess water spills out through spillway. Spillway is generally provided at upstream of diversion structure and also natural stream flows nearby. Drainage inlet is provided at deeply excavated canal portion so that drainage water can flow into canal. In this connection, the elevated canal at downstream of drainage inlet is provided with spillway so as to protect canal from larger flow than the designed one.

【Output】

Good design of related structures required for the preliminary feasibility study

4.8 Preparation of O&M Plan

4.8.1 Establishment of FWUC

FWUC needs to be established and strengthened at each irrigation system, and registered with the assistance of MOWRAM and PDOWRAM to carry out water management and O&M of irrigation facilities.

【Explanation】

(1) Relevant Laws and Regulations

Participatory Irrigation Management and Development is currently promoted according to MOWRAM

policy in order to establish sustainable irrigation management set-up. To do so, FWUC needs to be established and strengthened with the assistance of MOWRAM and PDOWRAM to carry out water management and O&M of irrigation facilities as elaborated in "Training Manual for Participatory Irrigation Management and Development (MOWRAM, 2003) and other documents. Relevant laws and regulations for establishment and strengthening of FWUC are listed as follows, which need to be fully considered for institutional development and irrigation system O&M planning in the course of F/S:

- Prakas 306 including Circular No.1 on the Implementation Policy for Sustainable Irrigation Systems, MOWRAM, June 2000
- Steps in the Formation of a Farmer Water Users Community 2000
- Draft National Water Resources Strategy, MOWRAM, May 2001
- Training Manual for Participatory Irrigation Management and Development (MOWRAM, 2003)
- Program Design Document for Strategy for Agriculture and Water 2010-2013
- Sub-Decree on Farmer Water User Community, 2008 (Draft)
- Sub-Decree on Water Allocation and Licensing, 2008 (Draft)

(2) Procedure

Based on the Manual and lessons learnt from JICA Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the following steps should be carried out with additional or proposed improvement activities for effective FWUC establishment and strengthening.

Steps for Establishing and Developing the FWUC	Proposed Improvement Activities
(a) Hold initial meetings at system or sub-system level	
(b) Identify irrigation service area and potential members of FWUC and conduct participatory rural appraisal	1) Land holding map preparation 2) Water use map preparation 3) Water loss identification and education
(c) Agree to form FWUC and plan organizing activities by farmers	
(d) Prepare and adopt FWUC statute and by-laws by farmers	
(e) Establish FWUC and select leaders by farmers	4) FWUC sub-group establishment 5) FWUC administration improvement
(f) Build capacity of FWUC to prepare an irrigation service plan	6) Proper irrigation water use education 7) Irrigation service plan preparation
(g) Adopt and implement initial irrigation service plan by FWUC	
(h) Prepare and adopt management transfer agreement	8) On-farm irrigation facility construction
(i) Repair and improvement of irrigation structures	8) On-farm irrigation facility construction 9) Water course construction
(j) Continue capacity building and provision of support services	10) Water management training 11) FWUC meeting building construction

Source: JICA Study on Comprehensive Agricultural Development of Prek Thnot River Basin

Figure 4.8.1 Procedure of FWUC Establishment and Proposed Improvement Activities

As illustrated above, proposed steps in the training manual is a good guideline for establishment and strengthening of FWUC. Since different irrigation systems under small-scale irrigation project have

different technical, institutional and cultural background, therefore, step needs to be flexible and good practice obtained in the previous projects such like the JICA Prek Thnot Study should be fully utilized. Improvement activities tried in the Prek Thnot Study are summarized in the following table.

Table 4.8.1 Improvement Activities carried out under Pilot Projects in JICA Study on Comprehensive Agricultural Development of Prek Thnot River Basin

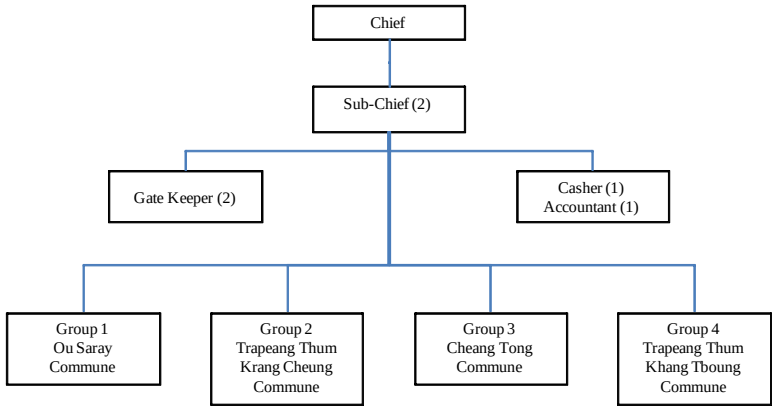
Improvement Action	Objective
(a) Land holding map preparation	to identify water users in the pilot project area
(b) Water Use Map Preparation	to deeply understand the situation of the project area
(c) Water Loss Identification and Reduction	to make FWUC members understand the importance of their efforts for minimizing water loss
(d) FWUC Sub-group Establishment	to organize active sub-groups of the FWUC based on the canal layout
(e) FWUC Administration Improvement	to improve administration of the FWUC, such as meeting arrangements and accounting
(f) Proper Irrigation Water Use Education	to make FWUC members understand the necessity and importance of proper irrigation water use
(g) Irrigation Service Plan Preparation	to support FWUC in preparation of an irrigation service plan as preparation of the irrigation service plan by the FWUC recognized to be one of the most important activities
(h) On-farm Irrigation Facility Construction	to provide minimally required on-farm irrigation facilities and to contribute to efficient water use in the command area

Source: JICA Study on Comprehensive Agricultural Development of Prek Thnot River Basin

For details, refer to Final Report of JICA Study on Comprehensive Agricultural Development of Prek Thnot River Basin, Volume-IV: Pilot Projects, 2008).

(3) Organization

The FWUC's jurisdiction in the irrigation system is based on hydraulic boundaries rather than administrative boundaries. FWUC will be formulated in tiered structure, each layer of which have each roles for conducting appropriate irrigation system management. FWUC is managed by its board members, which should be generally elected by member farmers in transparent manner.



Source: JICA Survey Team based on Interview to Kpob Trobek FWUC

Figure 4.8.2 Sample Organization of FWUC

Kpob Trobek FWUC existing as of September 2011 at Upper Slakou Irrigation System in Takeo Province

The standard committee generally consists of following members.

- One chairman in charge of overall supervision of committee
- One first-vice chairman in charge of maintenance and repair of facilities and planning
- One second-vice chairman in charge of water distribution and record keeping
- One treasurer in charge of finance
- Chiefs from all the communes relevant to irrigation system in charge of general supervision in their communes

These members would often vary and need to be flexible depending upon size and facilities of

irrigation system, existing farmers' group, geographical locations, any cultural background etc. Sample organizational structure is shown in Figure 4.8.2. In the course of institutional development and O&M planning in F/S, farmers' participation is essential in order to raise awareness for the project implementation and O&M. Field level staff, in particular, PDOWRAM staff is required to prepare institutional development plan in collaboration with farmers in each irrigation system by organizing public consultation and workshop.

【Output】

Plan for the establishment of enhanced FWUC for effective water management and O&M of irrigation facilities particularly at secondary and tertiary levels

4.8.2 O&M Responsibility

Clarification of stakeholders and their roles in O&M of irrigation systems are required as part of system O&M planning.

【Explanation】

Clear O&M responsibility sharing among stakeholders is of critical importance to enhance sustainability of irrigation systems. MOWRAM classifies irrigation systems into three categories based on their size as follows:

Table 4.8.2 Classification of Irrigation Systems defined by MOWRAM

Classification	Size	Managed by
Small Scale	Less than 200 ha	Managed by the District Office. If more than one District is involved, the PDOWRAM is responsible for the management. O&M are the responsibility of the FWUCs.
Medium Scale	Between 200 and 5,000 ha	Managed by PDOWRAM. If more than one Province is involved, MOWRAM is responsible for the management of the scheme.
Large Scale	More than 5,000 ha	Managed by MOWRAM

Source: MOWRAM

More practically, for the sub-projects listed in Small Scale Infrastructure Project, following task demarcation among PDOWRAM, FWUC, FWUG and Sub-FWUG is generally proposed.

Table 4.8.3 General O&M Responsibility among Stakeholders for Irrigation Systems

Level of Facilities / O&M Activities	Reservoir/ Headworks	Main Canals	Secondary Canals	Tertiary Canals and Below
Annual O&M Planning	PDOWRAM	PDOWRAM	PDOWRAM/ FWUC	Sub-FWUG
Cropping Schedule Preparation	-	-	FWUC/FWUG	Sub-FWUG
Operation	PDOWRAM	PDOWRAM	FWUC/FWUG	Sub-FWUG
Maintenance	PDOWRAM	PDOWRAM	FWUC/FWUG	Sub-FWUG

Source: JICA Survey Team

It should be understood that the responsibility needs to be determined in a flexible manner since the capability of farmers' group and/or FWUC is different in each irrigation system, responsibility of O&M is determined by considering experiences and capabilities of PDOWRAM and farmers at the field level. Out of 84 numbers of proposed sub-projects in SISIP, four numbers are categorized in small-scale irrigation systems, less than 200 ha as defined by MOWRAM. In such case, all the O&M are the responsibility of FWUCs.

【Output】

Confirmation of stakeholders and their roles in O&M of irrigation systems

4.8.3 O&M Activities

Activities required to carry out irrigation services and to maintain planned function of irrigation facilities needs to be listed up for each irrigation system.

【Explanation】

Major activities for O&M are shown as follows. Based on the responsibility demarcation, each stakeholder needs to perform his tasks and duties at each level of facilities.

Table 4.8.4 Major O&M Activities

O&M	General Description	Major Activities
Operation	Rehabilitated irrigation facilities needs to be operated based on planned irrigation schedule and water availability through appropriate and timely monitoring.	- Setting-up of water supply schedule - Operation of canal system for water supply and distribution - Operation for water saving irrigation method, if necessary - Publicity of water supply schedule and operation procedure - Monitoring of water level of the reservoir and/or discharge of the river
Maintenance	Maintenance aims at restoring the system to its full functional performance. It is imperative that in order to remain engaged in agricultural development and consolidation continuously, the irrigation facilities shall always be kept in serviceable condition.	- Routine maintenance: To carry out on a day to day basis, as and where and when required. It is essentially a low-cost activity carried out on local basis, but it is very effective for preventing further damages the repair of which might involve large funding. - Periodical maintenance: A planned activity and its aim is to prepare the irrigation system for specific services related to cropping calendar and its requirement. - Emergency maintenance: To carry out to restore a sudden and/or serious damage which has caused, or may cause, interruption to irrigation - Annual maintenance: The works requiring large volumes and/or special technical skill and know-how

Source: JICA Survey Team

Based on above table, PDOWRAM and FWUC assisted by MOWRAM are required to list up activities of O&M necessary for each irrigation system to carry out irrigation services and to maintain function of irrigation facilities.

【Output】

List of activities required for O&M of irrigation systems at level of main, secondary and tertiary canals by each stakeholder

4.8.4 O&M Cost

Budgetary arrangement for O&M requires calculation of O&M cost based on necessary O&M activities customized for each irrigation system.

【Explanation】

O&M cost needs to be arranged based on the responsibility demarcation among stakeholders and required activities and/or input for each irrigation system. Major items to be considered for O&M cost are: (i) salary and wages for board members of FWUC and FWUGs, (ii) direct cost such as office expenses, labors for maintenance and materials required for O&M. Sample calculation of O&M cost is tabulated below.

Table 4.8.5 Annual O&M Cost for Sub-Projects (Sample):
Target Area of West Tonle Sap Irrigation Rehabilitation and Improvement Project

Item	Unit	Qty.	Unit Rate (US$)	Amount (US$) for 12,700 ha	Amount (Riels.) for 12,700 ha
(1) Salary and Wages					
(a) FWUCs					
1) Chairperson	MM	72	30	2,160	8,886,240
2) Deputy chairperson	MM	72	25	1,800	7,405,200
3) Other staff	MM	288	20	5,760	23,696,640
(b) FWUGs					
1) Leader	MM	660	20	13,200	54,304,800
2) Other staff	MM	1,980	15	29,700	122,185,800
(2) Direct costs					
1.1. Office expenses	month	732	10	7,320	30,114,480
1.2. Labor for minor maintenance	MD	39,260	1	39,260	161,515,640
1.3. Other expenses (gate maintenance)	L.S.	1	20,000	20,000	82,280,000
Total				**119,200**	**490,388,800**
			=	US$9.34	**per ha**
			say	**US$10.00**	**per ha**

Source: JICA Special Assistance for Project Formation for West Tonle Sap Irrigation and Drainage Rehabilitation and Improvement Project

【Output】

Calculated O&M cost required for each irrigation system

4.8.5 Irrigation Service Fee

After irrigation facilities are rehabilitated, ISF needs to be collected from beneficiary farmers to cover O&M cost of rehabilitated facilities. ISF value should be decided based on technically required amount through consensus among member farmers.

【Explanation】

In order to arrange O&M cost necessary for irrigation facilities, irrigation service fee (ISF) needs to be collected from member farmers of FWUC benefitted from irrigation water supply based on cropping schedule and irrigation service area. According to the Policy for Sustainability of Operation and Maintenance of Irrigation Systems, ISF should be calculated using the following formula.

$$Y = \frac{X_1 + X_2 + X_3 + X_4 + X_5}{\text{Irrigation Service Area}} + 20\% \text{ of Increased Production}$$

Where, *Y= ISF per ha*
X1= expenditure on maintenance and repair
X2= expenditure on fuel in case of pumping
X3= expenditure on contribution to the Community Board
X4= expenditure on administration
X5= expenditure on contingency

More simply and practically, determination of price of ISF is made based on required O&M activities and its cost for each irrigation system. Many irrigation systems in Cambodia involve two categories of farm land under single irrigation system: (i) gravity irrigation area and (ii) pump irrigation area. According to the empirical evidences, ISF for former area is fixed to be higher, while latter is lower by considering convenience on accessibility to irrigation water. In addition, ISF setting needs consensus building among FWUC members under the command area. Sample ISF settings and collection rates surveyed JICA Study on Comprehensive Agricultural Development of Prek Thnot River Basin are

tabulated as follows:

Table 4.8.6 Comparison of Relatively Advanced FWUCs in ISF (Sample)

FWUC / Item	Ou Treang FWUC	Sdau Kaong FWUC	Phoum Roung FWUC	Ou Veaeng FWUC
Province	Kampong Speu	Prey Veng	Kampong Speu	Kampong Speu
Value	Rainy season (i) Gravity and pump: Riel 20,000 ($5)/ha (ii) Pump: Riel 10,000 ($2.5) /ha Dry season (i) and (ii): Riel 40,000 ($10.0)/ha	1st year: Riel 7,000 ($1.75)/ha 2nd year: Riel 8,000 ($2.0)/ha 3rd year: Riel 11,000 ($2.75)/ha	(i) Gravity: Riel 40,000 ($10)/ha (ii) Pump: Riel 10,000 ($2.5)/ha	(i) Gravity: Riel 30,000 ($7.5)/ha (ii) Gravity and pump: Riel 20,000 ($5)/ha (iii) Pump Riel 10,000 ($2.5)/ha
Ratio of Collection	80-85%	99%	35%	10%

Source: Extracted from the pilot project under the Comprehensive Agricultural Development of Prek Thnot River Basin (2008), JICA

During F/S, ISF calculation is to be made in compliance with the estimated O&M cost for each irrigation system as well as useful references and practices in ISF setting and collection at other similar irrigation systems.

【Output】

Plan of ISF based on consensus among farmers

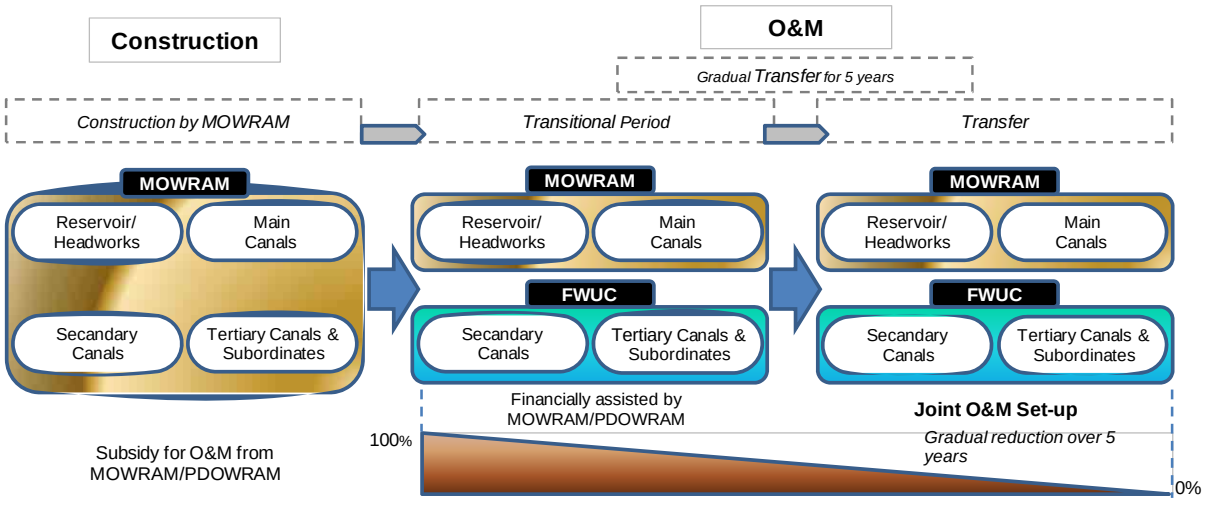
4.8.6 Transfer of Responsibility of O&M

According to MOWRAM policy, rehabilitated facilities are transferred to FWUC after five years from completion of the facilities rehabilitation. Transferring process needs to be properly carried out through gradual and step-wise approach considering FWUC's capability.

【Explanation】

(1) Transfer Process

Transfer of facilities (secondary level facilities in case of SPPIDRIP) to FWUC will be gradually carried out in conformity with Circular No.1 on the Implementation Policy for Sustainable Irrigation Systems showing that step-by-step reduction of government subsidy for the irrigation facilities over five years after completion of the construction works. This concept is illustrated in the following figure:



Source: JICA Survey Team

Figure 4.8.3 Transfer of O&M of Rehabilitated Facilities

Share of O&M cost by government and FWUC is made in gradual transition manner as referred to the following table according to MOWRAM policy.

Table 4.8.7 Share of O&M Cost

Year after completion	Government	Beneficiary Farmers (FWUC)
First year	80%	20%
Second year	60%	40%
Third year	40%	60%
Fourth year	20%	80%
After Fifth year	0%	100%

Source: MOWRAM

In this process, involvement of existing FWUCs or new FWUC to be established in all the sub-project areas is of necessity from D/D to operation stage in order to raise awareness and sense of ownership for irrigation facilities by them. On the basis of abovementioned principles, O&M cost to be incurred by both government and FWUC should be calculated.

(2) Memorandum of Understanding

In Cambodia, O&M of only Prey Nup Polder System in Sihanoukville Municipality has been transferred to FWUC in 2007. Before transferring of O&M to FWUC, it is required to prepare Memorandum of Understanding (MOU) to be signed by MOWRAM, local government and representative of FWUC, contents of which are as follows:

Table 4.8.8 Contents of MOU on Joint Management of Irrigation Facilities

Article	Clause	Contents/Remarks
(a) Objective	◆ Aim of MOU	Aim of MOU including legal status needs to be clearly described in the document.
(b) Responsibilities of FWUC	◆ Principles ◆ Responsibility on Operation and Maintenance ◆ Responsibilities on Financial and Administrative Management	Responsibility of O&M of FWUC from technical and financial viewpoints needs to be clarified.
(c) Responsibilities of MOWRAM	◆ Principles ◆ Responsibilities on Operation and Maintenance ◆ FWUC Activities Supervision ◆ Support to FWUC Activities ◆ Consultation and Representation	Responsibility of O&M of MOWRAM from technical and financial viewpoints needs to be clarified.
(d) Responsibilities of Local Government	◆ Principle ◆ Responsibilities	Responsibility of O&M of local government from technical and financial viewpoints needs to be clarified.
(e) Property	◆ Ownership of Facilities by Relevant Parties	In addition to O&M responsibility, ownership of facilities also should be agreed among stakeholders.
6. Monitoring and Evaluation	◆ Procedure of Monitoring and Evaluation ◆ Necessity of Agreement on Monitoring and Evaluation	Although after irrigation system is transferred monitoring and evaluation by MOWRAM and local government would be integral part to ensure sustainability.
(f) Conflict resolution	◆ Necessity of coordination among stakeholders on conflict resolution ◆ Responsibility among Stakeholders on Conflict Resolution	Conflict resolution over public goods would be solved by FWUC with the assistance of MOWRAM and local government. Intervention to this process needs to be defined.
(g) Validity and End of MOU	◆ Validity and termination of MOU	This is general item of MOU.

Source: JICA Survey Team

During F/S, feature transfer process also needs to be understood and agreed among MOWRAM, PDWORAM and farmers. MOU prepared for Prey Nup Polder System signed by MOWRAM, Governor of Sihanoukville Municipality and chairman of Prey Nup system is shown in Attachment-3.

【Output】

Plan for the establishment of joint O&M system among MOWRAM, PDOWRAM, local government and FWUC based on MOU

4.9 Estimate of Sub-project Cost

4.9.1 Work Volume Estimate

Work volume should be estimated based on preliminary design for project facilities in order to estimate direct construction cost.

【Explanation】

In the preliminary feasibility study, work volume for major facilities should be calculated based on the drawings prepared at preliminary feasibility level.

Table 4.9.1 Methods for Estimating Work Volume

Works	Methodology
Main and secondary canals	Volume of earth works such as excavation, embankment and stripping are calculated based on the longitudinal and cross sections drawings which are prepared using topographic survey.
Tertiary canals	From typical section of tertiary canal, earth works such as excavation, embankment and stripping are calculated for one km. On the other hand, total length of tertiary canal is estimated by multiplying density of 30 m/ha by irrigation area (ha). Thus, total volume of earth works such as excavation, embankment and stripping are calculated by multiplying those per one km by total length of tertiary canal.
Drainage canals	Work volume for drainage canals is estimated in the same manner with that for irrigation canals.
Structures	At first, the number of required structures to be newly constructed and rehabilitated is counted based on the results of inventory survey and study on canal layout plan. Volume of concrete and earth works such as excavation and backfilling for typical structure of every structure is estimated, and then total volume is estimated by multiplying volume of concrete and earth works per one structure by respective numbers. Volume of reinforcement bar and form is calculated by rate to concrete volume (50 kg to 100 kg to concrete 1 m^3 for reinforcement bar and 5 m^2 to concrete 1 m^3 for form).

Source: JICA Survey Team

【Output】

Estimated work volume at preliminary feasibility level

4.9.2 Preparation of Unit Prices

Unit prices for each work item are analyzed using base costs of labor, materials and equipment and required work quantity of them.

【Explanation】

Unit prices of the main work items for construction are analyzed using base costs and required work quantity of labor, material and equipment.

(a) Base Costs (see Attachment-4))

Prior to estimate unit prices for main work items for construction, base costs for labor, construction materials and depreciation or lease cost of construction equipment should be surveyed and collected in markets, NCDD and other relevant agencies.

(b) Unit Price Analysis

As mentioned above, unit prices of the main work items for construction are analyzed using base costs and required work quantity of labor, material and equipment. In analysis of unit prices, reference is made to similar projects in Cambodia and South-east countries for cross-check. These unit prices comprises of foreign currency portion (F/C) and local currency portion (L/C). Labor cost and cost of local materials obtained from sites such as sand, gravel, embankment soil are counted as L/C, and cost of imported materials such as equipment depreciation or lease cost, fuel, reinforcement bar, cement are counted as F/C. Table 4.9.3 shows sample analysis of unit price.

Table 4.9.2 Sample of Unit Price Analysis

Project : SPPIDRIP
No. : EW-03
Work Item : Excavation common by equipment
Remarks : 100 m^3/sec
Payment Unit : m^3

No	Component	Unit	Q'ty	L/C (US$)		F/C (US$)	
				U.Price	Amount	U.Price	Amount
(i) Labor							
	Heavy equipment Operator	MD	0.56	14.00	7.81		
	Foremen	MD	0.22	12.50	2.79		
	Common labor	MD	1.12	4.50	5.02		
	Assistant operator	MD	0.56	8.00	4.46		
	Sub-total				20.09		
(ii) Material							
	Diesel	Lit	60.27			1.10	66.29
	Miscellaneous	L.S			4.02		13.26
	Sub-total				4.02		79.55
(iii) Equipment							
	Backhoe 0.6 m^3	Hrs.	0.56			133.00	74.22
	Miscellaneous	L.s					
	Sub-total				0.00		74.22
(iv)	Sub-total((i)+ (ii) + (iii))				24.11		
(v)	Profit & Overhead (10% of (iv))						17.79
(vi)	Total Price by Currency /Volume (US$/$m^3$)				0.42		1.54
(vii)	Total Price by (L/C + F/C) /Volume (US$/$m^3$)						1.96

Source: JICA Survey Team

Attachment-5 presents the unit prices for main work items as of August 2011.

【Output】

Unit prices estimated based on reliable data and information in systematic manner

4.9.3 Estimate of Sub-project Cost

Sub-project cost covers not only direct construction cost, but also other many items such as administration cost, consulting service cost, land acquisition cost, taxes and duties, interest during construction time, physical contingency and price contingency.

【Explanation】

(1) Initial Investment Cost

In the small-scale irrigation project, project cost is generally composed of direct construction cost, administration cost, consulting service cost, relocation and land acquisition cost, tax and duties, physical contingency and price contingency. In addition to them, software components and O&M equipment procurement cost, if required, should be included in sub-project cost. In case of the small-scale irrigation project, taxes and duties and interest during construction period might not be

taken into consideration because of their small amount.

(a) Direct Construction Cost
This is the direct physical cost for the construction works including mobilization and demobilization, machines and man power, preparatory works, temporary works and related activities on the construction.

(b) Administration Cost
Administration cost includes the salary and per diem costs of administrative staff of the project during the implementation period, operation cost of facilities, equipment and related expenditure for the implementation. According to MEF, administration is equivalent to 3 % of direct construction cost.

(c) Consulting Service Cost
Consulting service cost includes costs for survey, design, supervision and other cost for consulting activities necessary for the implementation of the project. MEF suggests that consulting service cost is less than 10 % of the direct construction cost.

(d) Relocation and Land acquisition cost
If relocation of houses and land acquisition are necessary for implementing the project, the cost should be estimated.

(e) Taxes and duties
According to the government regulation, tax (VAT) is 10 % of (a) to (d).

(f) Physical contingency
Physical contingency is set at a certain percentage of the total of the above mentioned costs assuming a certain increase in work volume or expenditure that might arise at the implementation stage. In general, physical contingency is 10 % of (a) to (e).

(g) Price contingency
Price contingency is set assuming certain price escalation both for L/C and F/C portions. In SPPIDRIP, price escalation of 1.6 % was adopted for F/C portion and 6.7% was adopted for L/C portion. The price escalation is set according to the actual changes of the prices in the past.

(2) O&M Cost

Annual O&M cost includes (i) salary and wages for staff personnel of FWUC and direct cost for minimum office expenses. Clause 4.18.5 shows the sample calculation of O&M cost. If no time is allowed for calculation, it might be estimated at 0.5 % of direct construction cost.

(3) Replacement Cost

Some project facilities and equipment have a shorter economic life than the project life and will require replacement during the proposed 50 years of the project life. The following table shows the economic life time for facilities.

Table 4.9.3 Economic Life Time for Facilities

Description	Economic Life Time
Office / Facilities	30 years
Gates	25 years
Steel Plate	10 years
Transportation Equipment & Generator	10 years
Administrative Equipment	8 years
Marketing Equipment	8 years
Wooden Stoplog	5 years

Source: Planning Guideline for Rehabilitation and Reconstruction of Irrigation Systems, March 2002

【Output】

Estimate of sub-project cost considering project component

4.10 Preparation of Implementation Schedule

Implementation schedule covers many activities from project fund arrangement to handing over of minor facilities to FWUC.

【Explanation】

Overall schedule for implementing the hardware components would be as follows:

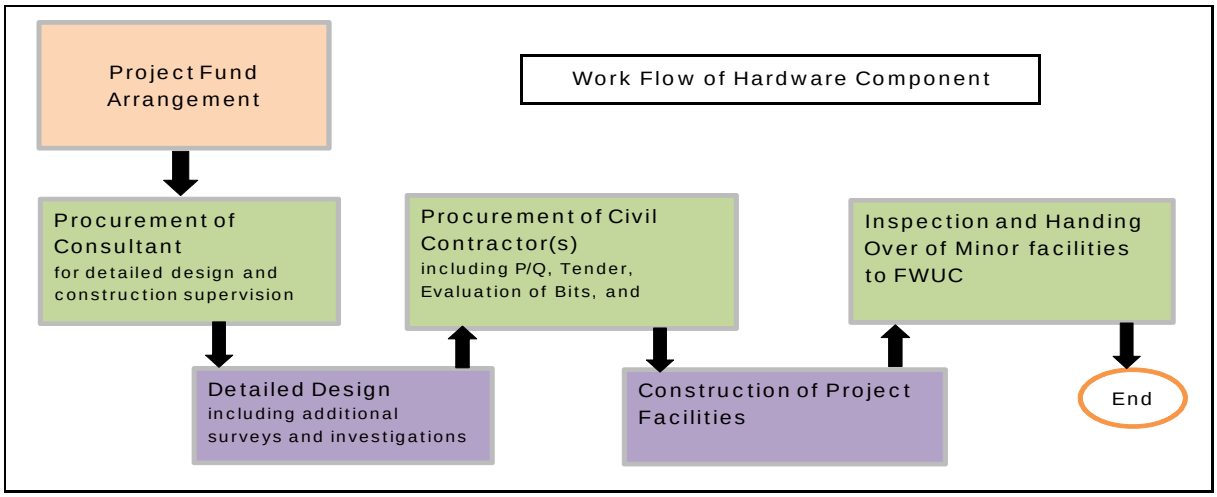


Figure 4.10.1 Work Flow of Hardware Components

In preparation of implementation schedule, consideration should be given to construction package. If implementation period is limited, it might consider that construction works are carried out by plural construction packages although the small-scale irrigation project would be mostly implemented by single construction package judging from work volume and sub-project cost.

【Output】

Appropriate implementation schedule well-fitted to project conditions

4.11 Preparation of Disbursement Schedule

Disbursement schedule is prepared for sub-project evaluation.

【Explanation】

Disbursement of the sub-project cost should be determined according to the implementation schedule of the sub-project. The initial investment cost would be distributed for the sub-project period.

【Output】

Annual disbursement schedule

4.12 Estimate of Sub-project Benefit

4.12.1 Present and Target Yields of Crops

Present and target yields of crops are used as one of factors for calculation of incremental benefit by crop production.

【Explanation】

Present and target yields of crops are studied as follows:

(a) Present yield of major crops

The present yields of major crops are examined by discussing with District Office, PDA, MAFF and CARDI. Interview with farmers is also useful for knowing the present yields of crops. The following table gives the general yields of crops under condition of "without Project" in Cambodia.

Table 4.12.1 Present Yields of Major Crops under "Without Sub-project" Condition

Crop	Under Irrigation (ton/ha)	Under Rainfed Condition (ton/ha)
Early Rice	2.0 to 3.0	1.0 to 2.0
Medium Rice	2.0 to 3.0	1.0 to 2.0

Late Rice	Not proposed	1.0 to 2.0
Sweet Potato	3.5 to 4.5	-
Pumpkin	2.0 to 3.0	-
Watermelon	2.5 to 3.5	-
Beans	0.3 to 0.7	-

Source: JICA Survey Team

(b) Target Yield of Major Crops

The anticipated yields of target crops under condition of "With Sub-project", say irrigation condition, is estimated on the basis of the following data and information:

- Present yield level under irrigation in and around the project area,
- Yield in years of appropriate climatic conditions in and around the project area,
- Opinions of extension workers and agronomist of District Office, PDA and MAFF,
- Yield at field level trials by CARDI and agricultural research centers,
- Possibility of extension activity and other support program in the project area, and
- Possibility of improvement of farming practices such as application of good seeds, fertilizers and plant protection

The yield will gradually increase after water supply and improvement of farming practices and supporting services by the sub-project. The target yields of crops under irrigated condition are roughly estimated based on the data in other projects in Cambodia:

Table 4.12.2 Target Yields of Major Crops under "With Sub-project" Condition

Crop	Dry Season (ton/ha)	Rainy Season (ton/ha)
Early Rice	4.0 to 5.0	4.0 to 5.0
Medium Rice	3.0 to 3.5	3.0 to 3.5
Late Rice	Not proposed	3.0 to 3.5
Sweet Potato	4.5 to 5.5	4.5 to 5.5
Pumpkin	4.5 to 5.5	4.5 to 5.5
Watermelon	4.5 to 5.5	4.5 to 5.5
Beans	0.8 to 1.5	0.8 to 1.5

Source: JICA Survey Team

【Output】

Well-selected present and target yields of crops under conditions of "Without Sub-project" and "With Sub-project"

4.12.2 Production Cost

Production cost should be considered for calculating the net income by crop production.

【Explanation】

Direct production cost is given on the basis of the required quantities and the unit prices of inputs, hired labor force, draft animal and others. Cost of family labor force is usually excluded from production cost. Production cost in the small-scale irrigation project is roughly calculated at US$ 430/ha for gravity irrigation system, US$540/ha for pump irrigation system and US$ 480/ha for recession irrigation system. Sample calculation of production cost is shown in Attachment-6

【Output】

Calculated production cost

4.12.3 Financial Irrigation Benefit

Financial irrigation benefit by crop production is estimated for sub-project evaluation.

【Explanation】

Financial irrigation benefit is estimated in the following manner:

(a) Gross Income by Crop Production

Gross income by crop production is estimated by multiplying the anticipated target yield by farm gate price of the product.

(b) Net Income by Crop Production

Net income by crop production is estimated by deducting production cost from gross income by crop production

(c) Financial Irrigation Benefit

Financial irrigation benefit by crop production is given by difference between the total net income under "With Sub-project" and "Without Sub-project", so-called "Incremental Benefit". A sample calculation is shown in Table 4.12.3.

Table 4.12.3 Sample Calculation of Financial Irrigation Benefit

Item	Per ha (US$/ha)			Sub-project Area (1000US$/ha)			
	Gross Income	Production Cost	Net Income	Sub-project Area(ha)	Gross Income	Production Cost	Net Income
1) With Project Condition							
Early Rice	74	29	45	1,000	74	29	45
Medium Rice	78	29	49	200	16	6	10
Rice Total				1,200	90	35	55
Maize	77	18	59	120	9	2	7
Bean	103	27	76	180	19	5	14
Vegetables	250	56	194	60	15	3	12
Total				1,560	133	45	88
2) Without Project Condition							
Early Rice	34	15	19	950	32	14	18
Medium Rice	31	15	16	180	6	3	3
Rice Total				1,130	38	17	21
Maize	39	10	29	60	2	1	1
Bean	42	17	25	30	1	0	1
Vegetables	143	36	107	10	1	0	1
Total				1,230	42	18	24
3) Incremental Benefit (=1) – 2))							
Early Rice	40	14	26	50	42	15	27
Medium Rice	47	14	33	20	10	3	7
Rice Total				70	52	18	34
Maize	38	8	30	60	7	1	6
Bean	61	10	51	150	18	5	13
Vegetables	107	20	87	50	14	3	11
Total					91	27	64

Source JICA Survey Team

【Output】

Effect of Irrigated Crops

4.13 Sub-project Evaluation

Sub-project evaluation is carried out to know whether the project is technically viable and economically sound.

【Explanation】

Sub-project evaluation is conducted in two ways; economic evaluation and financial evaluation. In case of the preliminary feasibility study for the small-scale irrigation project, it is deemed that economic evaluation only is enough. In economic evaluation, price contingency is not taken into consideration.

【Output】

Justified project by economic evaluation

4.13.1 Estimate of Economic Cost

Economic cost necessary for economic evaluation is converted from the financial one.

【Explanation】

In order to make economic evaluation, it is necessary to estimate the economic cost. The economic cost covers direct cost of civil works, procurement cost of equipment and consulting services, O&M cost of project facilities, and physical contingency for the respective cost items. In SPPIDRIP, the economic cost is estimated by converting the financial cost estimated above by applying the standard conversion factor (SCF) of 1.00 to foreign currency portion and 0.978 to local currency portion of each cost item, and also the shadow wage rate factor of 0.601 to skilled labor cost and 0.363 to unskilled labor cost, both included in local currency portion of the direct cost of civil works and O&M cost. Although SCF is influenced by prevailing economic conditions and changeable, the above mentioned one could be used for preliminary feasibility study for small-scale irrigation project for the time being.

【Output】

Economic project cost converted from financial project cost

4.13.2 Estimate of Economic Benefit

Economic benefit is estimated for economic evaluation of the sub-project.

【Explanation】

Based on the financial crop budget, the economic crop budget is prepared under the "with and without sub-project conditions" by applying requirements for farm inputs and total labor, unit crop yield, and their economic prices. The anticipated yield is assumed to be increased under the without sub-project condition or set at the same level based on the past trend of yield and local condition as explained in Clause 4.12.1. The economic prices are converted from the financial prices using the conversion factors. Sample calculation of economic prices is shown below, which is used for SPPIDRIP as of November 2011.

Table 4.13.1 List of Price Conversion

Particulars	Unit	Financial Price	Conversion Factor	Economic Price
1. Farm Product				
- Paddy (Early maturity variety)	Riel/kg	1,150	a	1,153
- Paddy (Medium maturity variety)	Riel/kg	1,250	a	1,153
- Upland crop (Mungbean)	Riel/kg	3.850	b	3,766
- Vegetable (Cucumber)	Riel/kg	1,400	b	1,369
- Vegetable (String bean)	Riel/kg	1,900	b	1,858
- Vegetable (Tomato)	Riel/kg	1,800	b	1,761
2. By-products				
- Crop residue (Rice straw)	Riel/kg	350	b, c, d	342
- Crop residue (equivalent to 100% of mungbean yield)	Riel/kg	50	b	49
- Crop residue (equivalent to 10% of vegetable yield)	Riel/kg	50	b	49
3. Seed				
- Paddy (Early maturity variety)	Riel/kg	1,800	b	1,761
- Paddy (Medium maturity variety)	Riel/kg	2,400	b	2,347
- Paddy (Newly introduced variety)	Riel/kg	2,600	b	2,543
- Upland crop (Mungbean)	Riel/kg	11,000	b	10,759
- Vegetable (Cucumber)	Riel/kg	6,000	b	5,869
- Vegetable (String bean)	Riel/kg	6,000	b	5,869
- Vegetable (Tomato)	Riel/kg	15,000	b	14,671
4. Fertilizer				
- Urea	Riel/kg	2,300	a	1,531
- DAP	Riel/kg	3,000	a	2,456

	- KCl	Riel/kg	2,700	a	1,641
	- Farm manure	Riel/kg	200	b	196
5.	Agro-chemicals				
	- Liquid type	Riel/lit	15,000	b	14,671
6.	Farming Equipment and Tools				
	- Annual depreciation cost	Riel/ha	8,000	b	7,825
7.	Farm Labor				
	- Hired labor	man-day	7,000	b, e	2,487
	- Family labor	man-day	0	f	2,487
8.	Paid Services				
	- Land preparation (1st time operation by draft animal)	Riel/ha	140,000	b, e	81,928
	- Land preparation (2nd time operation by draft animal)	Riel/ha	180,000	b, e	105,336
	- Land preparation (1st time operation by hired tractor)	Riel/ha	230,000	b, g	135,212
	- Land preparation (2nd time operation by hired tractor)	Riel/ha	250,000	b, g	146,969
	- Irrigation using water pump	Riel/ha	800,000	b, e	284,238
	- Harvesting by combine harvester	Riel/ha	500,000	b, g	293,938
	- Manual cutting and threshing	Riel/ha	450,000	b, e	159,884
	- Carrying of harvest from field to yard	Riel/ha	170,000	b, g	99,939
9.	Transportation				
	- Carrying out of dried harvests from yard	Riel/kg	20	b	19

Remarks on conversion factors:

a; The projected prices for 2020 in 2011 constant price are determined by adjusting forecasted prices at 2000 constant price presented in "Projections as of June 2, 2011" by the World Bank Economic Policy and Prospects Group

b; Financial prices are converted to economic prices by multiplying with SCF of 0.98.

c; Among by-products of paddy, financial and economic values of broken rice, rice bran and rice husk are not counted as rice millers take advantages as a part of milling cost.

d; Rice straw weight is equivalent to 90% of early maturity variety paddy yield and 100% of medium variety paddy yield.

e; Financial hired farm labor cost is converted to economic price by multiplying with SCF and SWRF of 0.361 for unskilled labor.

f; Economic price of family labor is considered as the same price of economic price of hired labor.

g; Financial cost of land preparation is converted to economic cost by multiplying with SCF and SWRF of 0.597 for skilled labor.

Source: JICA Survey Team

Direct irrigation and drainage benefits will be accrued from increases in cropping areas and productivity of target crops of the project. The economic benefit is estimated as the increment in Net Production Value (NPV) between the future with and without sub-project conditions. The increment of the benefit will gradually increase year by year and reach full benefit several years after the initiation of the irrigation water supply and other support activities, i.e. usually assumed at three to five years depending on the beneficiaries' capacity and the project assistance. Simple calculation of incremental benefit by crops is shown below:

Table 4.13.2 Simple Calculation of Incremental Benefit by Crops

(a) Without sub-project condition (present condition)

1) Estimate benefit during rainy season

Rainy season crop		Average Yield **(kg/ha)**		Average Price **(US$/kg)**		Cropped Area in Development Area **(ha)**		Benefit (Bro) **(US$)**
i)	x		x		x		=	
ii)	x		x		x		=	

2) Estimate benefit during dry season

Dry season crop		Average Yield **(kg/ha)**		Average Price **(US$/kg)**		Cropped Area in Development Area **(ha)**		Benefit (Bdo) **(US$)**
i)	x		x		x		=	
ii)	x		x		x		=	

3) Estimate production cost during rainy season

Rainy season crop		Production Cost **(US$/ha)**		Cropped Area in Development Area **(ha)**		Production Cost (Prc) **(US$)**
i)	x		x		=	
i)	x		x		=	

4) Estimate production cost during dry season

Dry season crop		Production Cost **(US$/ha)**		Cropped Area in Development Area **(ha)**		Production Cost (Pdc) **(US$)**
i)	x		x		=	
i)	x		x		=	

5) Estimate total net benefit without sub-project Bro1+Bro2+Bdo1+Bdo2-Prc1-Prc2-Pdc1-Pdc2= (I)

(b) With sub-project condition (after project implementation)

1) Estimate benefit during rainy season

Rainy season crop		Average Yield **(kg/ha)**		Average Price **(US$/kg)**		Development area **(ha)**		Benefit (Brw) **(US$)**
i)	x		x		x		=	
ii)								

2) Estimate benefit during dry season

Dry season crop under irrigation		Average Yield **(kg/ha)**		Average Price **(US$/kg)**		Irrigable Area in Dry Season **(ha)**		Benefit (Bdw) **(US$)**
i)	x		x		x		=	
ii)								

3) Estimate production cost during rainy season

Rainy season crop		Production Cost **(US$/ha)**		Cropped Area in Development Area **(ha)**		Production Cost (Prc) **(US$)**
i)	x		x		=	
i)	x		x		=	

4) Estimate production cost during dry season

Dry season crop		Production Cost **(US$/ha)**		Cropped Area in Development Area **(ha)**		Production Cost (Pdc) **(US$)**
i)	x		x		=	
i)	x		x		=	

5) Estimate total net benefit with sub-project Brw1+Brw2+Bdw1+Bdw2-Prc1-Prc2-Pdc1-Pdc2= (II)

(c) Obtain incremental agricultural benefit

Incremental agricultural benefit ((II) – (I))

【Output】

Economic benefit estimated by the incremental benefit between the future with and without sub-project conditions

4.13.3 Evaluation Method

Sub-project evaluation is carried out by net present value (NPV), B/C and Economic Internal Rate of Return (EIRR)

【Explanation】

Sub-project evaluation is conducted in two ways; economic evaluation and financial evaluation. In case of the preliminary feasibility study for the small-scale irrigation project, it is deemed that economic evaluation only is enough. In economic evaluation, price contingency is not taken into consideration.

(a) Economic Cost

Economic cost for the project is estimated by multiplying financial cost by SCF as explained in Clause 4.13.1.

(b) Economic Benefit

Economic benefit for the project is estimated as the increment in Net Production Value (NPV) between

the future with and without project conditions as explained in Clause 4.13.2.

(c) Cash Flow of Economic Cost and Benefit

Cash flow is prepared by allocated economic cost and O&M cost based on disbursement schedule and also economic benefit after completion of the project as shown in the following sample table.

Table 4.13.3 Sample Table for Cash Flow (Unit: US$1,000)

Item	2013	2014	2015	2016	2017	2018	2019	**2020**	**2021**	**2022**	**2023**	**2024**
Economic cost	347	1,021	574	879	4,363	6,166	811	385	-	-	-	-
O&M cost	-	-	-	-	2	20	46	47	48	48	48	48
Economic benefit	-	-	-	-	-	483	1,088	1,795	2,179	2,321	2,354	2,354

Source: Economic evaluation for USIRRSP

(d) Economic Evaluation

Based on the above cash flow of economic cost and benefit, the economic evaluation is made in terms of NPV, B/C ratio and EIRR of the proposed rehabilitation plan. In case of NPV and B/C calculation, a discount rate is assumed, say 10 % to 12%. EIRR calculation is easily made using excel sheet in computer. Sample calculation results are shown below:

Table 4.13.4 Sample Table of Economic Evaluation

Evaluation Item	**Evaluation Results**			
NPV at 12% discount rate	NPV of benefit (US$)	9,245,698	NPV (US$)	689,876
	NPV of cost (US$)	8,555,822		
B/C ratio and EIRR	B/C ratio	1.08	EIRR (%):	12.9

Source: Economic evaluation for USIRRSP

【Output】

Justified sub-project by economic evaluation

4.13.4 Indirect Benefit

As project may generate the indirect benefit which could not be expressed by economic evaluation, it should be clarified for further justify the appropriateness of sub-project implementation

【Explanation】

As a typical case of indirect benefits generated through implementation of the proposed rehabilitation works, temporary employment opportunities will be generated in and around the project area. This will bring the extra cash income for farmers concerned. In addition, some socio-economic impacts might be created by the proposed sub-project:

- To enable them to improve nutritionally balanced diet and primary health care conditions of their family members;
- To ensure their children complete primary schooling, access higher education and participate in the early childhood education program; and;
- To enable them to buy goods and services as well as luxuries for meeting families' needs contributing to rural economy with positive effects.

【Output】

Clarification of positive impacts created by project implementation

4.14 Social and Environmental Consideration

Initial Environmental Impact Assessment (IEIA) is required for irrigation development even if the development area is less than 5,000 ha.

【Explanation】

"The Sub-Decree on Environmental Impact Assessment Process" explains that EIA or IEIA is required for irrigation development with more than 5,000 ha prior to the implementation. However, even if the development area is less than 5,000 ha and the project aims at

rehabilitation of existing facilities, IEIA is required subject to the instruction by MOE.

In IEIA, the Project Owner (PO), say MOWRAM should execute the environmental scoping using the impact matrix. As a sample, the impact matrix which was conducted for USISRSP is shown in Table 4.14.1, although the likely impact items should be modified based on the scope of the project:

Table 4.14.1 Sample of Environmental Scoping

No.		Likely Impact	Project-related Activities			
			Overall Rating	Planning / Design Phase	Construction Phase	Operation Phase
Pollution Control	1	Air pollution	B-	-	B-	-
	2	Water pollution	B-	-	B-	B-
	3	Soil contamination	-	-	-	-
	4	Waste	B-	-	B-	-
	5	Noise and vibration	B-	-	B-	-
	6	Ground subsidence	-	-	-	-
	7	Offensive odor	-	-	-	-
	8	Bottom sediment	-	-	-	-
	9	Disaster	-	-	-	-
Natural Environment	10	Topography and geographical features	-	-	-	-
	11	Soil erosion	B-	-	-	B-
	12	Groundwater	-	-	-	-
	13	Hydrological situation	C-	-	-	C-
	14	Coastal zone	-	-	-	-
	15	Flora, fauna and biodiversity	B-	-	-	B-
	16	Meteorology	-	-	-	-
	17	Landscape	-	-	-	-
	18	Global warming	-	-	-	-
Social Environment	19	Involuntary resettlement	-	-	-	-
	20	Local economy such as employment and livelihood, etc.	B-/A+	A-	B+	A+
	21	Land use and utilization of local resources	B-/B+	-	-	B-/B+
	22	Social institutions (including regional severance)	-	-	-	-
	23	Existing social infrastructures and services	B-	-	B-	B-
	24	Socially vulnerable groups such as the poor, indigenous and ethnic people (including gender matter)	B+	-	-	B+
	25	Misdistribution of benefit and damage	B-	B-	-	
	26	Historical and cultural heritage (including religious matters)	-	-	-	-
	27	Water usage or water rights and rights of common	A+	-	-	A+
	28	Local conflict of interests	B-	-	B-	B-
	29	Sanitation	B-	-	B-	-
	30	Hazardous (risk) infectious diseases such as HIV/AIDS	B-	-	B-	-
	31	Accident	B-	-	B-	-

Source: JICA Survey Team

<Rating>

A-: Serious impact is expected, if any measure is not implemented to the impact.

B-: Some impact is expected, if any measure is not implemented to the impact.

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

-: 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.

Overall rating: Highest rate will be the overall rating among the rating of relevant project-related activities for negative and positive ratings, respectively. (e.g. Even only one "A-" is included in an environmental item, overall rating of the environmental item becomes "A-".)

The sample check list of environmental scoping is shown in Attachment-7.

【Output】

Clarified environmental impact by sub-project implementation

4.14.1 Sub-project Impact and Mitigation Measures

Mitigation measures should be proposed to cope with sub-project impact.

【Explanation】

From the results of environmental scoping, sub-project impact is clarified. Thus, it is necessary to propose the mitigation measures to settle the project impact. According to the experiences in planning the irrigation projects in Cambodia, major mitigation measures imposed to the irrigation project (rehabilitation project) are as follows:

- To conduct detailed socio-economic survey of affected people during early stage of project preparation to identify all losses from land adjustment
- To establish joint committee as decision making body to implement land adjustment process, consisting of executing agencies, related agencies and local authorities.
- To conduct stakeholder meetings with local people including affected people by the project
- To decide compensation policy among joint committee and affected people
- To prepare adequate and realistic schedule of land adjustment through joint committee and inform affected people early
- To educate construction workers for adequate traffic rule of construction vehicles
- To limit construction time. e.g. at daytime only
- To conduct stakeholder meetings to obtain consensus about the construction time with surrounding people.
- To design and re-construct canal crossing to minimize negative impact as much as possible
- To enact the local rules to construct new canal crossings by themselves
- To enact the local rules to stipulate environmental consideration measures
- To conduct stakeholder meetings with local people including affected people on project contents

【Output】

Clarified environmental impact by project implementation and proposed mitigation measures

4.14.2 Conclusion of Examination

Countermeasures which the Project Owner should take are proposed as conclusion of examination.

【Explanation】

In IEIA, environmental scoping is executed to clarify the project impact, and then necessary mitigation measures are proposed. On the basis of the results of a series of such environmental examination, conclusions are deduced. The conclusions relate the important matters on sub-project implementation and what the Project Owner takes, from environmental viewpoints.

【Output】

Environmentally clarified necessary matters to be taken in connection with sub-project implementation

4.15 Conclusion and Recommendations

The results of study should be concluded from technical and economical viewpoints and important issues to be taken on project implementation should be mentioned as recommendations.

【Explanation】

In conclusion, the justification of the sub-project implementation which is obtained through the preliminary feasibility study should be concisely mentioned. Especially it is to be stressed that the sub- project is technically viable and economically sound as the results of study.

In recommendations, crucial matters for smooth implementation of the sub-project should be briefly written down. Generally, budget and staff arrangement and land acquisition are taken as urgent activities in recommendations.

【Output】

Precisely summarized conclusion and recommendations toward sub-project implementation

4.16 Report Preparation

The report should be concisely prepared so that the readers easily understand the contents and need of project.

【Explanation】

The report for the preliminary feasibility study is generally composed of summary, main text and annexes. In case of small-scale irrigation project, summary and main text with drawings only might be enough. Major contents of main text are background, the sub-project area and the sub-project. In the background, the reasons why the project is taken up should be mentioned. The sub-project area presents the natural and socio-economic conditions in and around the sub-project area. The sub-project clarifies the development plan, the sub-project justification, the required cost, the expected benefit and the results of sub-project evaluation. Anyhow, the report should be prepared in logical way, so that the readers could easily understand the need of sub-project implementation.

【Output】

Substantial report to convince the readers

CHAPTER 5 EXAMINATION ON PRELIMINARY FEASIBILITY STUDY

5.1 Purpose

The preliminary feasibility study executed for small-scale irrigation project should be examined whether it is carried out in a proper manner or not.

【Explanation】

PDOWRAM prepared proposal for 84 sub-projects under request of MOWRAM. This proposal presents the information on the sub-project site, background of the sub-project, outline of the sub-project, sub-project cost, sub-project benefit and EIRR. However, it became clear through site inspection and discussion with PDOWRAM that it was difficult to grasp not only actual situations but also development plan on the proposed sub-project from this proposal only because of so rough investigation, study and description. Out of 84 sub-projects, 3 sub-projects are short-listed through screening in this preparatory survey. For the remaining 81 sub-projects, further study, say preliminary feasibility study will be necessary for justification of implementation in the near future. This manual is prepared accordingly. On the other hand, it is also necessary to work out a method to examine the preliminary feasibility study executed. This chapter presents how to examine and manage the preliminary feasibility study executed toward implementation.

【Output】

Preparation of method to examine the results of preliminary feasibility study for small-scale irrigation project

5.2 Examination Method

Examination of preliminary feasibility study executed aims at whether the preliminary feasibility study is executed in proper way or not.

【Explanation】

In the preliminary feasibility study for the small-scale irrigation project, the sub-project should be justified from the following viewpoints:

- Is the sub-project is technically viable?
- Is the sub-project is economically sound?
- Is the sub-project is environmentally friendly?

In other words, the preliminary feasibility study executed should satisfy these three viewpoints mentioned above. Thus, the preliminary feasibility study executed should be examined using the checklist prepared from these viewpoints.

【Output】

Establishment of efficient examination method

5.2.1 Examination from Technical Viewpoints

The proposed development/rehabilitation plan including project facilities should be prepared in technically proper way.

【Explanation】

Even in the small-scale irrigation project, lots of technical items to be studied are included. These

items should be examined whether appropriate technical approach is taken or not. The major technical check items are listed as follows:

Table 5.2.1 Checklist of Major Technical Items

Check Items	Check
Basic Concept	
Is the purpose of irrigation development clarified?	
Is the purpose of irrigation development coincided with government policy?	
Land Use	
Is it compatible with other similar irrigation development plan?	
Agriculture	
Is the data on present land use, cropping pattern, crop production collected?	
Are the present farming practices investigated?	
Is the data of crop prices and farm input collected?	
Are the data and information of farmers' intension to farming practice collected?	
Are the proposed crops properly studied?	
Yields and Products	
Are the target crop yields determined properly?	
Is the reasonable period to attain the target crop yields taken?	
Hydrology and Meteorology	
Is enough rainfall data collected?	
Is enough river discharge data collected?	
Is enough meteorological data (temperature, humidity, wind velocity, sunshine, evaporation) collected?	
Is enough river water level data (high water and low water) collected?	
Are flood marks investigated by observing and hearing with inhabitants at site?	
Water Requirement	
Is the soil condition in the sub-project area examined?	
Is the percolation rate checked with that for neighboring sub-projects?	
Is the water requirement estimated based on proposed cropping patterns?	
Is the applied crop coefficient appropriate?	
Is the water requirement for land preparation suitable?	
Is the effective rainfall considered?	
Are the irrigation efficiencies considered in water requirement?	
Is the drainage water requirement estimated?	
Water Resource	
Is water source for the sub-project confirmed?	
Is the reservoir capacity estimated?	
Is the high water analysis conducted?	
Is the low water analysis executed?	
Is the probability analysis on high water conducted?	
Is the probability analysis on low water carried out?	
Water Balance Study	
Is the water balance study among water source and water demand executed?	
Is the irrigable area determined (80% dependability)?	
Preliminary Design	

Check Items	Check
Is the design discharge determined?	
Is the canal layout plan prepared?	
Is topographic survey for major canals conducted?	
Is the preliminary design for major facilities carried out based on survey results?	
Is the work volume calculated based on preliminary design?	
Are the unit prices prepared properly?	
Is the project cost consisting of direct construction cost, administration cost, consulting service cost, software component cost, land acquisition cost, physical contingency and price contingency estimated?	
Is the physical contingency estimated properly?	
Is the implementation schedule prepared considering enough time for detailed design, contractor selection and construction?	

Source: JICA Survey Team

【Output】

Satisfactory preliminary feasibility study from technical viewpoint

5.2.2 Examination from Economic Viewpoints

The project should be endorsed by appropriate economic evaluation.

【Explanation】

Economic evaluation is one of key factors to prove the appropriateness of project. Thus, the economic evaluation should be made in logically proper way. In order to avoid the insufficient economic evaluation, the following checklist for major economic items is proposed:

Table 5.2.2 Checklist of Major Economic Items

Check Items	Check
Disbursement Schedule	
Is the disbursement schedule prepared based on implementation schedule?	
Economic Cost	
Is the economic cost converted from the financial cost using SCF?	
Is the O&M cost estimated suitably?	
Is the replacement cost considered based on economic life time?	
Economic Benefit	
Is the economic benefit converted from financial benefit?	
Is the incremental benefit between "with sub-project" and "without sub-project" calculated properly?	
Is the production cost reasonable?	
Economic Evaluation	
Is the cash flow of economic cost and economic benefit prepared properly?	
Is the economic evaluation made for NPV, B/C and EIRR?	
Is the discount rate for NPV and B/C reasonable?	
Indirect Benefit	
Is the indirect benefit mentioned clearly?	

Source: JICA Survey Team

【Output】

Satisfactory preliminary feasibility study from economic viewpoint

5.2.3 Examination from Environmental Viewpoints

The project is regarded as public work, so that it should be environmentally friendly for stakeholders.

【Explanation】

The implementation of the sub-project would produce the positive impacts and the negative impacts for environmental condition. Thus, it is essential to clarify them prior to implementation of the sub-project, to consider the suitable mitigation measures in advance. The following table shows the environmental checklist for major items which the sub-project owner should considers:

Table 5.2.3 Checklist of Major Environmental Items

Likely Impact			Project-related Activities		
			Planning / Design Phase	Construction Phase	Operation Phase
Pollution Control	1	Air pollution			
	2	Water pollution			
	3	Soil contamination			
	4	Waste			
	5	Noise and vibration			
	6	Ground subsidence			
	7	Offensive odor			
	8	Bottom sediment			
	9	Disaster			
Natural Environment	10	Topography and geographical features			
	11	Soil erosion			
	12	Groundwater			
	13	Hydrological situation			
	14	Coastal zone			
	15	Flora, fauna and biodiversity			
	16	Meteorology			
	17	Landscape			
	18	Global warming			
Social Environment	19	Involuntary resettlement			
	20	Local economy such as employment and livelihood, etc.			
	21	Land use and utilization of local resources			
	22	Social institutions (including regional severance)			
	23	Existing social infrastructures and services			
	24	Socially vulnerable groups such as the poor, indigenous and ethnic people (including gender matter)			
	25	Misdistribution of benefit and damage			
	26	Historical and cultural heritage (including religious matters)			
	27	Water usage or water rights and rights of common			
	28	Local conflict of interests			
	29	Sanitation			
	30	Hazardous (risk) infectious diseases such as HIV/AIDS			
	31	Accident			

Source: JICA Survey Team

【Output】

Satisfactory preliminary feasibility study from environmental viewpoint

5.3 Procedure toward Implementation

The sub-projects which the preliminary feasibility study was conducted should be prioritized toward implementation.

【Explanation】

It is expected that respective PDOWRAMs will carry out the preliminary feasibility study for the remaining 81 sub-projects at least based on this manual. After completion of the preliminary feasibility study, the PDOWRAMs will submit the project proposal accompanied with the preliminary feasibility study report to MOWRAM. MOWRAM will scrutinize and prioritized the submitted project proposals accompanied with the preliminary feasibility study report from the following points:

- Degree of completeness of preliminary feasibility study
- Consistency with government policy
- Degree of matureness of sub-project for implementation
- Results of sub-project evaluation

Based on the results of prioritization, MOWRAM will select the highly priorized sub-projects to be implemented in the light of available financial source including donor's assistance and will submit the application to MEF.

【Output】

Smooth implementation of prioritized sub-projects

Attachment-1

Form of Inventory Survey

Inventory Survey Form

Canal Name:	Kind of Structure:		Date:
			Executed by:
Station No.:	Coordinate:	Northing:	District:
		Easting:	Commune:
Photo 1	Photo 2		Photo 3

Sketch

Current Condition (Explanation)

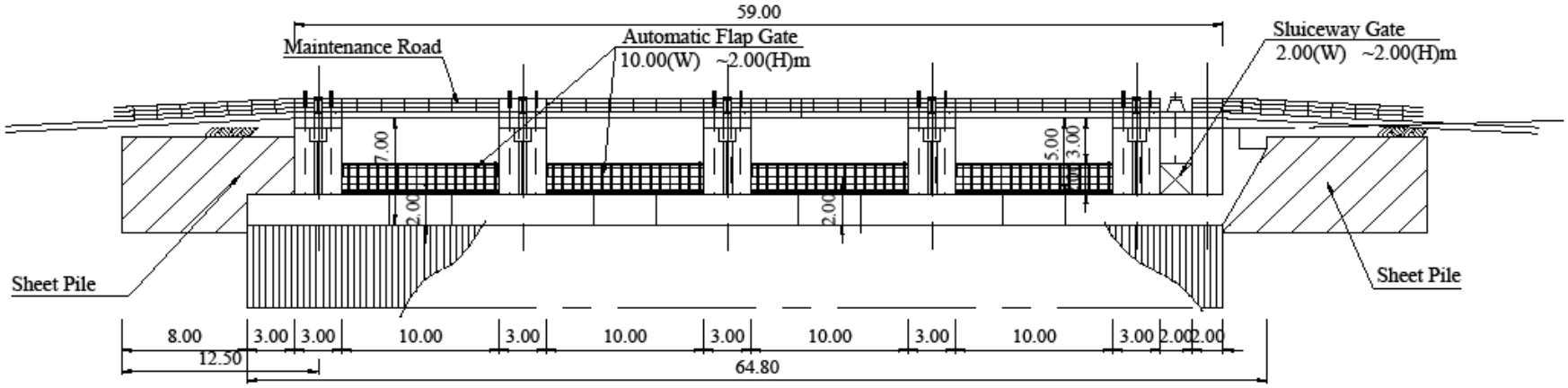
Judgement:

A	: Fully functioning	
B	: Partly damaged, but still functioning	
C	: Damaged and does not function well	
D	: Completely damaged, and does not function at all	

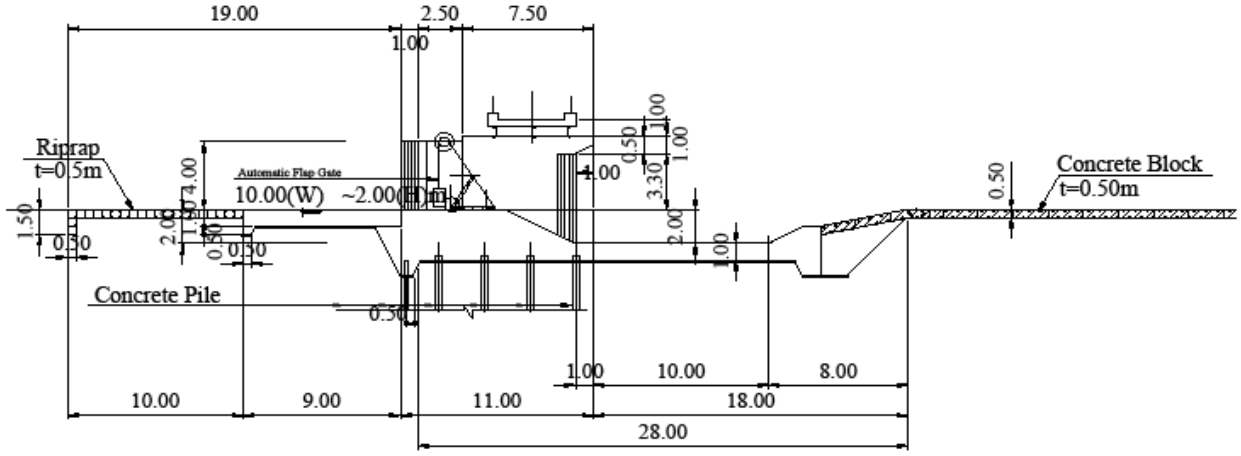
Attachment-2

Sample of Preliminary Design for Headworks

AT-2-1



Scale 1:400



PREPARATORY SURVEY FOR IRRIGATION AND DRAINAGE SYSTEM REHABILITATION AND IMPROVEMENT PROJECT IN THE KINGDOM OF CAMBODIA Japan International Cooperation Agency (JICA)	Title of Drawing Preliminary Design of Daun Pue Regulator	Date DWG. No.

Attachment-3

Memorandum of Understanding between
The Ministry of Water Resources and Meteorology,
The Municipality of Sianouk Ville,
The Farmer Water Users Community of Pre Nub Polders
On the Sharing of Responsibility over
Prey Nup Polders Management

KINGDOM OF CAMBODIA

NATION RELIGION KING

Memorandum Of Understanding

Between

- The Ministry of Water Resources and Meteorology

- The Municipality of Sihanouk Ville

- The Farmer Water Users Community of Prey Nup Polders

On the

Sharing of Responsibility over Prey Nup Polders Management

Considering:

- Circular Number 1 of the Royal Government of Cambodia, dated January 1999 on the implementation policy for sustainable irrigation systems;
- Prakas 306 of MOWRAM, dated 20 July 2000 on the official use of principal documents on the creation and development of Farmer Water Users Community;
- Prakas 410 of MOWRAM, dated October 2000 on approving the Statutes of Prey Nup Polders Farmer Water Users Community;
- Municipal "Deyka" DK043, dated of March 2003 on the Creation and Regulation of a Sub-Steering Committee of Prey Nup Polders Rehabilitation Project;
- The Statutes of Prey Nup Polders Farmer Water Users Community
- The conclusion of the field mission report of Polders Prey Nup monitoring commission of the MOWRAM, dated January 2007;
- The conclusion of the field mission report of Polders Prey Nup monitoring commission of the MOWRAM, dated February 2007.

This MOU

Implement by

The Ministry of Water Resources and Meteorology of the Royal Government of Cambodia,represented by His Excellency **Lim Kean Hor**, Minister, hereafter referred to as "MOWRAM"

And

The Municipality of Kampong Som, represented by His Excellency **Say Hak**, Governor hereafter referred to as "The Municipality of Kampong Som"

And

The Prey Nup Polders Farmer Water Users Community, represented by Mr. **Yim Boy**, Chairman of the Board, hereafter referred to as "FWUC"

It is agreed what follows.

Article 1- Object

1. The present Memorandum of Understanding (MOU) aims at defining in details the conditions of Shared Management of Prey Nup Polders,
2. This MOU details the responsibilities of all parties above.

Article 2- Responsibilities of FWUC

2.1- Principles

1- The FWUC declares having sufficient knowledge of concerned infrastructures, equipment and their Management Guidelines to fulfill the following responsibilities.

2- The FWUC undertakes to decide and implement all actions aiming at sustainable management of the scheme in the framework of its responsibilities.

3- The FWUC undertakes to facilitate the implementation of the other parties' responsibilities.

2.2- Responsibility on Operation and Maintenance

The FWUC undertakes to ensure proper Operation and Maintenance of the following infrastructures (as described in details in annex 1):

1. Intermediary dykes.
2. Canals located in polders area.
3. Structures (except their rehabilitation/reconstruction whenever the top of the valve is below highest tide level).
4. Protect maintain and take care of boat ladders on all dykes and ensure that the boat dragging to pass the dykes has to follow these boats ladders.

2.3- Responsibilities on Financial and Administrative Management

1. Ensure ISF collection (with support from local authorities).
2. Implement all necessary measures and actions to ensure efficient, democratic and transparent functioning of FWUC as well as clear and accountable relationships with its members.
3. Actively cooperate with the Administration (MOWRAM and Local Authorities), mainly in the framework of the Sub-Steering Committee, to implement the Management Guidelines and Rules and Regulations of Prey Nup Polders.

Article 3- Responsibilities of MOWRAM

3.1- Principles

1. MOWRAM certifies that infrastructures and equipments that have been rehabilitated under its responsibility are performing correctly and that MOWRAM will undertake any necessary legal action against companies in charge of the rehabilitation or the controller of works in case of defects or problems linked to construction. This is particularly relevant to actions in the framework of the guarantee applicable to all works that have been implemented.
2. MOWRAM undertakes to plan and implement all necessary action for smooth implementation of the present MOU.

3.2- Responsibility on Operation and Maintenance

1. Decide, finance and execute or order to the institution under its instruction (department of water resources and meteorology) to execute under its responsibility for all activities necessary to the **Operation and Maintenance of primary dyke** (except primary hydraulic structures which are of the responsibility of FWUC).
2. Decide, finance and execute (or order to the institution under its instruction to execute under its responsibility), after consultation with FWUC, **reconstruction and/or rehabilitation of primary hydraulic structures (main dykes and structures)**, whenever the top of its level is below of 30 cm lower than the level that defined in the construction plan.
3. Decide, finance and execute on the **Operation and Maintenance of canals and preks located downstream the main dyke**.
4. Decide, finance and execute (or order to the institution under its instruction to execute under its responsibility) all activities necessary to the **reconstruction or rehabilitation of all infrastructures in case of natural disaster.**
5. Inspect, at least once in a year, the state of primary dyke and structures, and finance and execute (or order to the institution under its instruction to execute under its responsibility) a topographic survey and topographic profile of all primary dykes and structures
6. Send to FWUC for its consideration and comments the annual maintenance plan of infrastructure it is responsible for,.

3.3- FWUC activities supervision

1. MOWRAM undertakes to supervise all activities of FWUC through report of activities and financial report prepared and delivered by FWUC on a yearly basis, as well as financial audit report, infrastructure visits and all means, respecting statutory autonomy of FWUC.

3.4- Support to FWUC activities

1. Supply support services as requested by FWUC, concerning mainly technical management of infrastructures, financial management and training of Staff that proposed by FWUC or with the identification that it is the necessary need of FWUC (in the framework of its PIMD policy implementation program).
2. Express its opinion on Water Management Plans produced and implemented by FWUC through participation of Municipal Department of Water Resources and Meteorology in Polder Assembly.
3. Study and decide on the feasibility of works causing new construction or modifications of existing infrastructures submitted by FWUC.
4. Provide to FWUC free access and use of topographic survey landmarks located on main and secondary dykes.

3.5- Consultation and representation

1. MOWRAM undertakes to facilitate coordination of interventions among all public institutions directly or indirectly involved in the management of the polders.
2. In the framework of its participation in the Sub-Steering Committee and to Polder Assemblies, the Municipal Department of Water Resources and Meteorology provides, on behalf of MOWRAM, all opinions required by FWUC on Water Management Plans, Budget and on the basis for calculation and amount of ISF.

Article 4- Responsibilities of Municipality of Sihanouk Ville

4.1. Principle

1. The Municipality of Sihanouk Ville undertakes to facilitate smooth implementation of this Memorandum of understanding and to promote sustainable management of Prey Nup Polders.

4.2- Responsibilities

In this condition, the municipality of Sihanouk Ville undertakes to:

1. Supervise the implementation of Sub-Steering Committee;
2. Organize and support any necessary cooperation and consultation between FWUC and Public Authorities;
3. In liaison with the Commune Councils, make use of its role, its duty and its authority and all means of communication available to enforce the implementation of this MOU and all the documents it refers to (especially Management Guidelines);
4. After consultation with MOWRAM and FWUC, or upon their request, publish any necessary Municipal standard letters to ensure sustainable management of Prey Nup Polders.

Article 5 – Property

1. Primary and Secondary Infrastructures described in annex 1 **remain property of the State**.
2. FWUC is and remain owner of all goods acquired or received in the course of the Prey Nup Polder Rehabilitation Project. This applies to constructions, tools and equipments given to FWUC for management of the infrastructure it is responsible for.

Article 6- Monitoring and Evaluation

1. A procedure of Monitoring and Evaluation of this MOU will be established and agreed by the three parties.
2. This procedure will approve by MOWRAM after approval of the three parties.

Article 7- Conflict resolution

1. All parties have to coordinate with highest possibility depend on the Management Guidelines sharing of responsibility as mention in the article above.
2. The municipality of Sihanouk Ville and the MOWRAM is the two parties that will negotiate for solving the problem exist during the work implementation of FWUC.

Article 8- Validity and End of the MOU

(1) The validity of the present MOU is for an undetermined period.
(2) The parties will agree on the possibility to write and sign any appendix to the present MOU to adapt its content to the evolution of the situation.
(3) The denunciation of this MOU by one of the parties will not end its validity.
(4) When this MOU is ended, the entire responsibility over management of the polders will be given to MOWRAM.

Chairman
of FWUC of Prey Nup

Governor
of the Municipality of
Sihanouk Ville

Minister
of Water Resources and
Meteorology

Attachment-4

Base Cost for Labor, Materials and Equipment

Base Costs for Labor, Materials and Equipment (as of August 2011)

Table AT-4.1 Base Cost of Labor Wages

No.	Item	Unit	Price (US$)	Remarks
L-1	Common labor	MD	4.50	
L-2	Skilled labor	MD	10.00	
L-3	Foreman	MD	12.50	
L-4	Heavy equipment operator	MD	14.00	
L-5	Light equipment operator	MD	9.00	
L-6	Dump truck driver	MD	6.50	
L-7	Assistant operator	MD	8.00	
L-8	Welder	MD	8.00	
L-9	Electrician	MD	12.00	
L-10	Mechanic	MD	12.00	
L-11	Carpenter	MD	12.00	
L-12	Mason	MD	8.00	
L-13	Concrete worker	MD	5.00	
L-14	Steel worker	MD	5.00	
L-15	Painter	MD	6.00	
L-16	Pipe worker	MD	7.00	
L-17	Junior engineer (5 year experience)	MM	900.00	
L-18	Senior engineer (15 year experience)	MM	1,740.00	
L-19	Surveyor	MM	750.00	
L-20	Assistant surveyor	MM	470.00	
L-21	CAD-operator	MM	630.00	
L-22	Accountant	MM	630.00	
L-23	Office clerk	MM	500.00	
L-24	Secretary	MM	300.00	
L-25	Typist	MM	240.00	

Source: JICA Survey Team

Table AT-4.2 Base Cost of Labor Wages

No.	Item	Unit	Price (US$)	Remarks
L-1	Common labor	MD	4.50	
L-2	Skilled labor	MD	10.00	
L-3	Foreman	MD	12.50	
L-4	Heavy equipment operator	MD	14.00	
L-5	Light equipment operator	MD	9.00	
L-6	Dump truck driver	MD	6.50	
L-7	Assistant operator	MD	8.00	
L-8	Welder	MD	8.00	
L-9	Electrician	MD	12.00	
L-10	Mechanic	MD	12.00	
L-11	Carpenter	MD	12.00	
L-12	Mason	MD	8.00	
L-13	Concrete worker	MD	5.00	
L-14	Steel worker	MD	5.00	
L-15	Painter	MD	6.00	
L-16	Pipe worker	MD	7.00	
L-17	Junior engineer (5 year experience)	MM	900.00	
L-18	Senior engineer (15 year experience)	MM	1,740.00	
L-19	Surveyor	MM	750.00	
L-20	Assistant surveyor	MM	470.00	
L-21	CAD-operator	MM	630.00	
L-22	Accountant	MM	630.00	
L-23	Office clerk	MM	500.00	

No.	Item	Unit	Price (US$)	Remarks
L-24	Secretary	MM	300.00	
L-25	Typist	MM	240.00	

Source: JICA Survey Team

Table AT-4.3 Base Cost of Construction Materials

No.	Item	Unit	Price (US$)	Remarks
M-1	Ordinary portland cement	kg	0.10	for 1,000 ton
M-2	Fine aggregate (sand) for concrete	m^3	10.97	
M-3	Coarse aggregate	m^3	21.42	
M-4	Bolder(300-500 mm) / Crushed stone	m^3	16.20	
M-5	Sand	m^3	8.78	
M-6	Gravel / Crushed stone	m^3	17.14	
M-7	Reinforcement bar (deformed)	kg	0.82	for 100 ton
M-8	Reinforcement bar (round)	kg	0.85	
M-9	Iron wire	kg	0.85	
M-10	Timber	m^3	520.00	
M-11	Reinforced concrete pipe, Dia 600 mm	m	20.85	
M-12	Reinforced concrete pipe, Dia 800 mm	m	35.76	
M-13	Reinforced concrete pipe, Dia 1,000 mm	m	51.05	
M-14	Concrete pile, 0.4 m × 0.4 m	m	98.04	Rectangular shape
M-15	Steel slide gate, 2.0 m × 2.0 m	unit	2,490.00	
M-16	Steel slide gate, 1.5 m × 1.5 m	unit	1,780.00	
M-17	Steel slide gate, 1.0 m × 1.0 m	unit	1,350.00	
M-18	Steel slide gate, 0.8 m × 0.8 m	unit	1,090.00	
M-19	Steel slide gate, 0.6 m × 0.6 m	unit	850.00	
M-20	Gasoline	liter	1.30	
M-21	Diesel oil	liter	1.10	
M-22	Light oil	liter	2.33	
M-23	Grass	m^2	2.00	

Source: JICA Survey Team

Table AT-4.4 Base Cost of Equipment

No.	Item	Unit	Price (US$)	Remarks
E-1	Bulldozer 21 ton	MD	150.00	
E-2	Bulldozer 15 ton	MD	120.00	
E-3	Backhoe 0.6 m^3	MD	133.00	
E-4	Wheel loader 2.3 m^3	MD	250.00	
E-5	Wheel loader 1.0 m^3	MD	180.00	
E-6	Tire roller 8 ton	MD	107.00	
E-7	Vibration roller 2.5 ton	MD	75.00	
E-8	Water tanker (5000-6000 liter)	MD	111.00	
E-9	Motor grader 3.1 m	MD	135.00	
E-10	Dump truck 8 ton	MD	85.00	
E-11	Cargo truck 6 ton	MD	70.00	
E-12	Truck crane 20 ton	MD	150.00	
E-13	Truck crane 10 ton	MD	128.00	
E-14	Truck crane 6 ton	MD	90.00	
E-15	Trailer 15 ton	MD	97.00	
E-16	Agitator truck 1.6 m^3	MD	192.00	
E-17	Concrete mixer 0.2 m^3	MD	68.00	
E-18	Concrete mixer 0.05 m^3	MD	200.00	
E-19	Hand guide roller 0.5 ton	MD	33.00	
E-20	Tamper 80kg	MD	30.00	
E-21	Batching plant 0.5 m^3 excluding generator	MD	320.00	
E-22	Dragline or clamshell 0.6 m^3	MD	70.00	

No.	Item	Unit	Price (US$)	Remarks
E-23	Chain block 10 ton	MD	20.00	
E-24	Welding machine 70-150 A	MD	99.00	
E-25	Air compressor 8.5 kg/cm^2	MD	70.00	
E-26	Submergible drain pump dia 2"	MD	25.00	
E-27	Submersible drain pump dia 3"	MD	25.00	
E-28	Diesel generator (50 kVA)	MD	125.00	

Source: JICA Survey Team

Table AT-4.5 Base Cost of Construction Materials

No.	Item	Unit	Price (US$)	Remarks
M-1	Ordinary portland cement	kg	0.10	for 1,000 ton
M-2	Fine aggregate (sand) for concrete	m^3	10.97	
M-3	Coarse aggregate	m^3	21.42	
M-4	Bolder(300-500 mm) / Crushed stone	m^3	16.20	
M-5	Sand	m^3	8.78	
M-6	Gravel / Crushed stone	m^3	17.14	
M-7	Reinforcement bar (deformed)	kg	0.82	for 100 ton
M-8	Reinforcement bar (round)	kg	0.85	
M-9	Iron wire	kg	0.85	
M-10	Timber	m^3	520.00	
M-11	Reinforced concrete pipe, Dia 600 mm	m	20.85	
M-12	Reinforced concrete pipe, Dia 800 mm	m	35.76	
M-13	Reinforced concrete pipe, Dia 1,000 mm	m	51.05	
M-14	Concrete pile, 0.4 m × 0.4 m	m	98.04	Rectangular shape
M-15	Steel slide gate, 2.0 m × 2.0 m	unit	2,490.00	
M-16	Steel slide gate, 1.5 m × 1.5 m	unit	1,780.00	
M-17	Steel slide gate, 1.0 m × 1.0 m	unit	1,350.00	
M-18	Steel slide gate, 0.8 m × 0.8 m	unit	1,090.00	
M-19	Steel slide gate, 0.6 m × 0.6 m	unit	850.00	
M-20	Gasoline	liter	1.30	
M-21	Diesel oil	liter	1.10	
M-22	Light oil	liter	2.33	
M-23	Grass	m^2	2.00	

Source: JICA Survey Team

Table AT-4.6 Base Cost of Equipment

No.	Item	Unit	Price (US$)	Remarks
E-1	Bulldozer 21 ton	MD	150.00	
E-2	Bulldozer 15 ton	MD	120.00	
E-3	Backhoe 0.6 m^3	MD	133.00	
E-4	Wheel loader 2.3 m^3	MD	250.00	
E-5	Wheel loader 1.0 m^3	MD	180.00	
E-6	Tire roller 8 ton	MD	107.00	
E-7	Vibration roller 2.5 ton	MD	75.00	
E-8	Water tanker (5000-6000 liter)	MD	111.00	
E-9	Motor grader 3.1 m	MD	135.00	
E-10	Dump truck 8 ton	MD	85.00	
E-11	Cargo truck 6 ton	MD	70.00	
E-12	Truck crane 20 ton	MD	150.00	
E-13	Truck crane 10 ton	MD	128.00	
E-14	Truck crane 6 ton	MD	90.00	
E-15	Trailer 15 ton	MD	97.00	
E-16	Agitator truck 1.6 m^3	MD	192.00	
E-17	Concrete mixer 0.2 m^3	MD	68.00	
E-18	Concrete mixer 0.05 m^3	MD	200.00	

No.	Item	Unit	Price (US$)	Remarks
E-19	Hand guide roller 0.5 ton	MD	33.00	
E-20	Tamper 80kg	MD	30.00	
E-21	Batching plant 0.5 m^3 excluding generator	MD	320.00	
E-22	Dragline or clamshell 0.6 m^3	MD	70.00	
E-23	Chain block 10 ton	MD	20.00	
E-24	Welding machine 70-150 A	MD	99.00	
E-25	Air compressor 8.5 kg/cm^2	MD	70.00	
E-26	Submergible drain pump dia 2"	MD	25.00	
E-27	Submersible drain pump dia 3"	MD	25.00	
E-28	Diesel generator (50 kVA)	MD	125.00	

Source: JICA Survey Team

Attachment-5

Unit Price for Main Work Items

Unit Price for Main Work Items (As of August 2011)

Table AT-5.1 Unit Price for Main Work Items, Earth Work

No.	Description	Unit	Unit price (US$)		
			L/C	F/C	Total
EW-01	Clearing and Grubbing	m^2	0.06	0.19	0.25
EW-02	Stripping of top soil of 0.2 m thickness	m^2	0.08	0.29	0.37
EW-02-1	Excavation by Bulldozer 21 ton	m^3	0.27	1.18	1.45
EW-03	Excavation common by Equipment	m^3	0.42	1.54	1.96
EW-04	Excavation common in water by Equipment	m^3	1.13	4.31	5.44
EW-05	Excavation, loading and transportation of soil with hauling distance less than 500 m	m^3	0.53	2.87	3.40
EW-06	Excavation, loading and transportation of soil with hauling distance more than 500 m & less than 5,000 m	m^3	0.93	4.13	5.06
EW-07	Excavation, loading and transportation of soil with hauling distance more than 5,000 m & less than 10,000 m	m^3	1.63	6.97	8.60
EW-08	Excavation, loading and transportation of soil with hauling distance more than 10,000 m & less than 15,000 m	m^3	2.07	8.51	10.58
EW-09	Excavation, loading and transportation of soil with hauling distance more than 15,000 m & less than 20,000 m	m^3	2.44	10.01	12.45
EW-10	Backfill by manpower by tamper with excavated material	m^3	3.88	0.25	4.13
EW-10-1	Backfill by manpower with tamper (transported material less than 500 m)	m^3	4.43	3.26	7.69
EW-10-2	Backfill by manpower with tamper (transported material 500m< L < 5,000 m)	m^3	4.83	4.58	9.41
EW-11	Backfill by equipment with transported soil material (less than 500 m)	m^3	1.61	8.72	10.33
EW-12	Backfill by equipment with transported soil material (500m < L < 5,000 m)	m^3	2.01	10.05	12.06
EW-13	Embankment / Backfill by equipment with excavated material	m^3	1.26	5.65	6.91
EW-13-1	Embankment by equipment with soil material with transportation (less than 500 m)	m^3	1.80	8.66	10.46
EW-13-2	Embankment by equipment with soil material with transportation (500 m < L < 5,000 m)	m^3	2.20	9.99	12.19
EW-13-3	Embankment by Bulldozer with excavated soil	m^3	0.31	1.25	1.56
EW-14	Soil cement placing	m^3	3.10	26.65	29.75
EW-15	Sod facing	m^2	2.70	0.00	2.70
EW-16	Foundation gravel	m^3	22.09	3.64	25.73
EW-17	Foundation of sand	m^3	13.05	2.07	15.12
EW-18	Demolishment of small concrete structure without disposal	m^3	0.60	2.68	3.28
EW-19	Demolishment of concrete structure with disposal	m^3	7.02	15.11	22.13
EW-20	Riprap placing with transportation	m^3	19.76	5.70	25.46
EW-21	Sub-base course, well graded sand & gravel of max size 100 mm, hauling from stockpile or r-deposit at any distance	m^3	14.98	1.58	16.56
EW-22	Sub-base course, common soil of max size 100 mm, hauling from stockpile at any distance	m^3	8.11	2.35	10.46
EW-23	Base course, well graded sand & gravel of max size 40 mm, hauling from stockpile or river deposit at any distance	m^3	20.46	7.31	27.77
EW-24	Laterite pavement (t=0.1 m)	m^3	1.78	7.75	9.53
EW-101	Construction of new tertiary canal (Combined unit price)	ha	69.28	206.11	275.39
EW-102	Rehabilitation of tertiary canal (Combined unit price)	ha	38.82	129.54	168.36
EW-103	Construction of new tertiary system including drainage canal (Combined unit price)	ha	89.79	219.14	308.93

Source: JICA Survey Team

Table AT-5.2 Unit Price for Main Work Items, Concrete Work

No.	Description	Unit	Unit price (US$)		
			L/C	F/C	Total
CW-01	Mixing concrete (Reinforced concrete 1:2:4) by concrete plant 0.5 m^3	m^3	31.87	44.38	76.25
CW-02	Mixing concrete (Plain concrete 1:3:6) by concrete plant 0.5 m^3	m^3	30.75	39.08	69.83

No.	Description	Unit	Unit price (US$)		
			L/C	F/C	Total
CW-03	Mixing concrete (lean concrete) by concrete plant 0.5 m^3	m^3	30.04	35.86	65.90
CW-04	Placing concrete by Chute	m^3	1.70	0.00	1.70
CW-05	Carrying concrete, L=1,000 m	m^3	1.41	10.83	12.24
CW-06	Carrying concrete, L=2,000 m	m^3	2.06	15.82	17.88
CW-07	Mixing concrete by portable concrete mixer 0.25 m^3 for reinforcement concrete (1:2:4)	m^3	41.37	45.03	86.40
CW-08	Mixing concrete by portable concrete mixer 0.25 m^3 for plain concrete (1:3:6)	m^3	40.25	39.88	80.13
CW-09	Mixing concrete by portable concrete mixer 0.25 m^3 for plain concrete (lean concrete)	m^3	39.54	36.75	76.29
CW-10	Reinforcing bar, deformed (Cut and installation)	kg	0.29	0.94	1.23
CW-11	Placement of concrete pipe φ600 mm	m	6.32	38.41	44.73
CW-12	Placement of concrete pipe φ800 mm	m	7.96	48.40	56.36
CW-13	Placement of concrete pipe φ1,000 mm	m	9.61	58.38	67.99
CW-101	Placing concrete (1:2:4) including form, curing & other miscellaneous works using portable mixer	m^3	65.97	45.03	111.00
CW-102	Placing concrete (1:3:6) including form, curing & other miscellaneous works using portable mixer	m^3	63.22	39.88	103.10
CW-103	Placing concrete (lean concrete) including form, curing & other miscellaneous works using portable mixer	m^3	53.33	36.75	90.08

Source: JICA Survey Team

Table AT-5.3 Unit Price for Structure Works

No.	Description	Unit	Unit price (US$)		
			L/C	F/C	Total
For RCHRSP structure works					
CW-301	Spillway (NMC-22)	no	130,321.39	75,036.73	205,358.12
CW-302	Spillway (SMC-18)	no	35,295.20	23,785.81	59,081.01
CW-303	Spillway (SMC-24)	no	68,936.52	38,510.96	107,447.48
CW-304	Spillway (SMC-25)	no	569.56	3,564.60	4,134.16
CW-305	Check structure on main canal, replacement with new	no	40,203.43	51,703.50	91,906.93
CW-306	Check structure on main canal, new	no	37,907.24	46,762.53	84,669.76
CW-307	Turnout, replacement with new	no	1,306.30	2,738.49	4,044.80
CW-308	Turnout, new	no	1,226.68	2,567.14	3,793.82
CW-309	Construction of bridge with demolition of existing bridge	no	15,969.66	20,664.75	36,634.41
CW-310	Construction of new Bridge	no	13,813.23	19,435.24	33,248.47
CW-311	Construction of foot bridge	no	6,629.89	6,701.83	13,331.72
CW-312	Drainage inlet	no	308.08	596.67	904.75

Source: JICA Survey Team

Table AT-5.4 Unit Price for Miscellaneous Works

No.	Description	Unit	Unit price (US$)		
			L/C	F/C	Total
Stone works					
SW-01	Gabion mattress	m^3	54.52	31.06	85.58
SW-02	Stone masonry with 1:3 cement/sand ratio mortar	m^3	39.96	19.31	59.26
SW-03	Riprap placing with transported material	m^3	19.76	5.70	25.47
Mechanical Works					
GW-01	Installation of gate, 2.0m × 2.0m	unit	489.08	3,006.45	3,495.53
GW-02	Installation of gate, 1.5m × 1.5m	unit	357.84	2,225.38	2,583.21
GW-03	Installation of gate, 1.0m × 1.0m	unit	271.22	1,697.43	1,968.65
GW-04	Installation of gate, 0.8m × 0.8m	unit	200.25	1,326.05	1,526.30
GW-05	Installation of gate, 0.6m × 0.6m	unit	178.29	1,241.66	1,419.95

Source: JICA Survey Team

Attachment-6

Sample Calculation of Economic Production Cost

Summary of Financial and Economic Prices

Particulars	Unit	Financial Price (Riel)	Conversion Factor	Economic Price (Riel)
1. **Farm Products**				
- Dry Paddy				
- Early variety (HYV)	kg	1,150	a	1,138
- Medium variety (Local)	kg	1,250	a	1,138
- Upland crop (Mung bean)	kg	3,850	b	3,773
- Vegetable (Pumpkin)	kg	1,000	b	980
- Vegetable (Watermelon)	kg	1,200	b	1,176
- Vegetable (Sweet potato)	kg	800	b	784
2. **By-Products**				
- Crop residue (Rice straw)	kg	350	b,c,d	343
- Crop residue (equivalent in 100% of mung bean yield)	kg	50	b	49
- Crop residue (equivalent in 10% of vegetable yield)	kg	50	b	49
3. **Seeds**				
- Paddy (Early maturity rice)	kg	1,800	b	1,764
- Paddy (Medium maturity rice)	kg	2,400	b	2,352
- Paddy (Newly introduced rice)	kg	2,600	b	2,548
- Upland crop (Mung bean)	kg	11,000	b	10,780
- Vegetable (Pumpkin)	kg	80,000	b	78,400
- Vegetable (Watermelon)	kg	80,000	b	78,400
- Vegetable (Sweet potato)	kg	15,000	b	14,700
4. **Fertilizer**				
- Urea	kg	2,300	a	1,232
- DAP	kg	3,000	a	2,119
- KCL	kg	2,700	a	1,257
- Farm manure	kg	200	b	196
5. **Chemical (average)**				
- Liquid type	lit.	15,000	b	14,700
6. **Farming Equipment and Tools**				
- Annual depreciation cost	per ha	8,000	b	7,840
7. **Farm Labour**				
- Hired Labor	man-day	7,000	b, e	2,476
- Family Labour	man-day	0	f	2,476
8. **Paid Services**				
- Draft Animal				
- Land preparation (1st plowing)	per ha	140,000	b, g	81,928
- Land preparation (second plowing, harrowing & levelling)	per ha	180,000	b, g	105,336
- Hand Tractor				
- Land preparation (1st plowing)	per ha	230,000	b, g	134,564
- Land preparation (second plowing, harrowing & levelling)	per ha	250,000	b, g	146,265
- Water pump	per ha	800,000	b, g	468,048
- Harvesting				
- Harvesting by combine harvester	per ha	500,000	b, g	292,530
- Cutting and threshing	per ha	450,000	b, g	263,277
- Carrying from field to yard	per ha	170,000		
9. **Transportation**	(Riel/kg)	20	b	19

Remarks on conversion factors:

a; The projected prices for 2020 in 2011 constant price are determined by adjusting forecasted prices at 2000 constant price presented in "Projections as of June 2, 2011" by the World Bank Economic Policy and Prospects Group

b; Financial prices are converted to economic prices by multiplying with SCF of *0.98*.

c; Among by-products of paddy, financial and economic values of broken rice, rice bran and rice husk are not counted as rice millers take advantages as a part of milling cost.

d; Rice straw weight is equivalent to 90% of early maturity variety paddy yield and 100% of medium variety paddy yield

e; Financial hired farm labor cost is converted to economic price by multiplying with SCF and SWRF of *0.361* for unskilled labor.

f; Economic price of family labor is considered as the same price of economic price of hired labor

g; Financial cost of land preparation is converted to economic cost by multiplying with SCF and SWRF of *0.597* for skilled labor.

Financial Production Costs on Paddy Cultivation

(1) under Present and Without-project Conditions

(Unit: ha)

Name of crops	Unit	Rainfed			Irrigation (Supplementary)		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			3,130			4,695
Main products	kg	2,000	1,250	2,500	3,000	1,250	3,750
By-product	kg	1,800 (straw)	350	630	2,700 (straw)	350	945
2. Total Production Cost	Riel			1,844			2,340
2.1 Inputs	Riel			734			922
Seed (self-stocked)		80		0	130		0
Seed (early rice)	kg	0	1,800	0	70	1,800	126
Seed (medium rice)	kg	0	2,400	0	0	2,400	0
Farm manure (wet)	ton	2,000	200	400	2,000	200	400
Fertilizer Urea	kg	60	2,300	138	100	2,300	230
DAP	kg	60	3,000	180	50	3,000	150
KCl	kg	0	2,700	0	0	2,700	0
Agro-chemicals	liter	0.5	15,000	8	0.5	15,000	8
Farming equipment and tools	LS	1	8,000	8	1	8,000	8
2.2 Labor	P-d	100		140	40		28
Hired labor	P-d	20	7,000	140	4	7,000	28
Family labor	P-d	80		0	36	0	0
2.3 Machinery	Riel			970			1,390
Land preparation	LS	2		480	2		480
Plowing	LS	1	230,000	230	1	230,000	230
Paddling	LS	1	250,000	250	1	250,000	250
Water pump	LS	0	800,000	0	0.5	800,000	400
Harvesting	LS	1	450,000	450	1	450,000	450
Transportation	kg	2,000	20	40	3,000	20	60
3. Net Return	Riel			1,286			2,355
(N.Return/P. Cost Ratio)				0.70			1.01

Summary Table

1. Gross Income per ha	1,000 Riel	3,130		4,695
	US$	766		1,150
2. Production Cost per ha	1,000 Riel	1,844		2,340
	US$	452		573
3. Net Return per ha	1,000 Riel	1,286		2,355
	US$	315		577

Note: exchange rate: US$ 1 = Riel 4,084
Source: JICA Survey Team

(2) under With-project Condition

(Unit: ha)

Name of crops	Unit	Gravity Irrigation			Pump Irrigation			Recession Irrigation		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			6,260			6,260			6,260
Main products	kg	4,000	1,250	5,000	4,000	1,250	5,000	4,000	1,250	5,000
By-product	kg	3,600 (straw)	350	1,260	3,600 (straw)	350	1,260	3,600 (straw)	350	1,260
2. Total Production Cost	Riel			2,359			3,159			2,759
2.1 Inputs	Riel			1,139			1,139			1,139
Seed (self-stocked)				0						
Seed (early rice)	kg	50	1,800	90	50	1,800	90	50	1,800	90
Seed (medium rice)	kg		2,400	0		2,400	0		2,400	0
Farm manure (wet)	kg	3,000	200	600	3,000	200	600	3,000	200	600
Fertilizer Urea	kg	100	2,300	230	100	2,300	230	100	2,300	230
DAP	kg	45	3,000	135	45	3,000	135	45	3,000	135
KCl	kg	25	2,700	68	25	2,700	68	25	2,700	68
Agro-chemicals	liter	0.5	15,000	8	0.5	15,000	8	0.5	15,000	8
Farming equipment and tools	LS	1.0	8,000	8	1.0	8,000	8	1.0	8,000	8
2.2 Labor	Riel	110		210	110		210	110		210
Hired labor	P-d	30	7,000	210	30	7,000	210	30	7,000	210
Family labor	P-d	80		0	80		0	80		0
2.3 Paid Services	Riel			1,010			1,810			1,410
Land preparation	LS	2		480	2		480	2		480
Plowing (1st)	LS	1	230,000	230	1	230,000	230	1	230,000	230
Paddling / 2nd Plowing	LS	1	250,000	250	1	250,000	250	1	250,000	250
Water pump	LS	0	800,000	0	1	800,000	800	0.5	800,000	400
Harvesting	LS	1	450,000	450	1	450,000	450	1	450,000	450
Transportation	kg	4,000	20	80	4,000	20	80	4,000	20	80
3. Net Return	Riel			3,901			3,101			3,501
(N.Return/P. Cost Ratio)				1.65			0.98			1.27

Summary Table

1. Gross Income per ha	1,000 Riel	6,260	6,260	6,260
	US$	1,533	1,533	1,533
2. Production Cost per ha	1,000 Riel	2,359	3,159	2,759
	US$	578	774	676
3. Net Return per ha	1,000 Riel	3,901	3,101	3,501
	US$	955	759	857

Note: exchange rate: US$ 1 = Riel
Source: JICA Survey Team

Financial Production Costs on Upland Crops Cultivation

(1) under Present and Without-project Conditions

(Unit: ha)

Name of crops	Unit	Mung Beans			Pumpkin			Watermelon			Sweet Potato		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			1,950			2,513			3,615			3,220
Main products	kg	500	3,850	1,925	2,500	1,000	2,500	3,000	1,200	3,600	4,000	800	3,200
By-product	kg	500	50	25	250	50	13	300	50	15	400	50	20
2. Total Production Cost	Riel			1,121			1,098			1,958			1,978
2.1 Inputs	Riel			631			568			568			568
Seed/cuttings	kg	50	11,000	550	0.5	80,000	40	0.4	80,000	32	40,000	(cuttings)	0
Farm manure (wet)	kg	0	200	0	2,000	200	400	2,000	200	400	2,000	200	400
Fertilizer Urea	kg	15	2,300	35	40	2,300	92	40	2,300	92	40	2,300	92
DAP	kg	10	3,000	30	20	3,000	60	20	3,000	60	20	3,000	60
KCl	kg	0	2,700	0	0	2,700	0	0	2,700	0	0	2,700	0
Agro-chemicals	liter	0.5	15,000	8	0.5	15,000	8	0.5	15,000	8	0.5	15,000	8
Farming equipment and tools	LS	1	8,000	8	1	8,000	8	1	8,000	8	1	8,000	8
2.2 Labor	P-d	50		0	70		0	80		0	80		0
Hired labor	P-d	0	7,000	0	0	7,000	0	0	7,000	0	0	7,000	0
Family labor	P-d	50	0	0	70		0	80	0	0	80	0	0
2.3 Machinery	Riel			490			530			1,390			1,410
Land preparation	LS	2		480	2		480	2		480	2		480
Plowing	LS	1	230,000	230	1	230,000	230	1	230,000	230	1	230,000	230
Paddling	LS	1	250,000	250	1	250,000	250	1	250,000	250	1	250,000	250
Water pump	LS	0.0	800,000	0	0	800,000	0	0.5	800,000	400	0.5	800,000	400
Harvesting	LS	0	450,000	0	0		0	1	450,000	450	1	450,000	450
Transportation	kg	500	20	10	2,500	20	50	3,000	20	60	4,000	20	80
3. Net Return	Riel			829			1,415			1,657			1,242
(N.Return/P. Cost Ratio)				0.74			1.29			0.85			0.63

Summary Table

1. Gross Income per ha	1,000 Riel	1,950	2,513	3,615	3,220
	US$	477	615	885	788
2. Production Cost per ha	1,000 Riel	1,121	1,098	1,958	1,978
	US$	274	269	479	484
3. Net Return per ha	1,000 Riel	829	1,415	1,657	1,242
	US$	203	346	406	304

Note: exchange rate: US$ 1 = Riel 4,084
Source: JICA Survey Team

(2) under With-project Condition

(Unit: ha)

Name of crops	Unit	Mung Beans			Pumpkin			Watermelon			Sweet Potato		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			3,900			5,025			6,025			4,025
Main products	kg	1,000	3,850	3,850	5,000	1,000	5,000	5,000	1,200	6,000	5,000	800	4,000
By-product	kg	1,000	50	50	500	50	25	500	50	25	500	50	25
2. Total Production Cost	Riel			2,218			2,388			2,788			2,388
2.1 Inputs	Riel			918			938			1,338			938
Seed (self-stocked)		50	11,000	550	0.5	80,000	40	0.4	80,000	32	40,000	(cuttings)	0
Farm manure (wet)	kg	0	200	0	2,000	200	400	4,000	200	800	2,000	200	400
Fertilizer Urea	kg	55	2,300	127	100	2,300	230	100	2,300	230	100	2,300	230
DAP	kg	50	3,000	150	50	3,000	150	50	3,000	150	50	3,000	150
KCl	kg	25	2,700	68	50	2,700	135	50	2,700	135	50	2,700	135
Agro-chemicals	liter	1.0	15,000	15	1.0	15,000	15	1.0	15,000	15	1.0	15,000	15
Farming equipment and tools	LS	1	8,000	8	1	8,000	8	1	8,000	8	1	8,000	8
2.2 Labor	Riel	60		0	120		70	120		70	120		70
Hired labor	P-d	0	7,000	0	10	7,000	70	10	7,000	70	10	7,000	70
Family labor	P-d	60	0	0	110	0	0	110	0	0	110	0	0
2.3 Paid Services	Riel			1,300			1,380			1,380			1,380
Land preparation	LS	2		480	2		480	2		480	2		480
Plowing (1st)	LS	1	230,000	230	1	230,000	230	1	230,000	230	1	230,000	230
Paddling / 2nd Plowing	LS	1	250,000	250	1	250,000	250	1	250,000	250	1	250,000	250
Water pump	LS	1	800,000	800	1	800,000	800	1	800,000	800	1	800,000	800
Harvesting	LS	0		0	0		0			0	1	0	0
Transportation	kg	1,000	20	20	5,000	20	100	5,000	20	100	5,000	20	100
3. Net Return	Riel			1,682			2,637			3,237			1,637
(N.Return/P. Cost Ratio)				0.76			1.10			1.16			0.69

Summary Table

1. Gross Income per ha	1,000 Riel	3,900	5,025	6,025	4,025
	US$	955	1,230	1,475	986
2. Production Cost per ha	1,000 Riel	2,218	2,388	2,788	2,388
	US$	543	585	683	585
3. Net Return per ha	1,000 Riel	1,682	2,637	3,237	1,637
	US$	412	646	793	401

Note: exchange rate: US$ 1 = Riel
Source: JICA Survey Team

Economic Production Costs on Paddy Cultivatio

(1) under Present and Without-project Condition

(Unit: ha)

Name of crops	Unit	Rainfed			Irrigation (Supplementary)		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			2,893			4,340
Main products	kg	2,000	1,138	2,276	3,000	1,138	3,414
By-product	kg	1,800 (straw)	343	617	2,700 (straw)	343	926
2. Total Production Cost	Riel			1,397			1,652
2.1 Inputs	Riel			608			759
Seed (self-stocked)		80	2,352	188	130	2,352	306
Seed (early rice)	kg	0	1,764	0	70	1,764	123
Seed (medium rice)	kg	0	2,352	0	0	2,352	0
Farm manure (wet)	ton	2,000	196	392	2,000	196	392
Fertilizer Urea	kg	60	1,232	74	100	1,232	123
DAP	kg	60	2,119	127	50	2,119	106
KCl	kg	0	1,257	0	0	1,257	0
Agro-chemicals	liter	0.5	14,700	7	0.5	14,700	7
Farming equipment and tool	LS	1	7,840	8	1	7,840	8
2.2 Labor	P-d	100		248	40		99
Hired labor	P-d	20	2,476	50	4	2,476	10
Family labor	P-d	80	2,476	198	36	2,476	89
2.3 Machinery	Riel			541			794
Land preparation	LS	2		240	2		240
Plowing	LS	1	134,564	135	1	134,564	135
Paddling	LS	1	105,336	105	1	105,336	105
Water pump	LS	0	468,048	0	0.5	468,048	234
Harvesting	LS	1	263,277	263	1	263,277	263
Transportation	kg	2,000	19	38	3,000	19	57
3. Net Return	Riel			1,496			2,688
(N.Return/P. Cost Ratio)				1.07			1.63

Summary Table

1. Gross Income per ha	1,000 Riel	2,893	4,340
	US$	708	1,063
2. Production Cost per ha	1,000 Riel	1,397	1,652
	US$	342	405
3. Net Return per ha	1,000 Riel	1,496	2,688
	US$	366	658

Note: exchange rate: US$ 1 = Riel 4,084

Source: JICA Survey Team

(2) under With-project Condition

(Unit: ha)

Name of crops	Unit	Gravity Irrigation			Pump Irrigation			Recession Irrigation		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			5,787			5,787			5,787
Main products	kg	4,000	1,138	4,552	4,000	1,138	4,552	4,000	1,138	4,552
By-product	kg	3,600 (straw)	343	1,235	3,600 (straw)	343	1,235	3,600 (straw)	343	1,235
2. Total Production Cost	Riel			1,738			2,206			1,972
2.1 Inputs	Riel			940			940			940
Seed (self-stocked)				0						
Seed (early rice)	kg	50	1,764	88	50	1,764	88	50	1,764	88
Seed (medium rice)	kg		2,352	0		2,352	0		2,352	0
Farm manure (wet)	kg	3,000	196	588	3,000	196	588	3,000	196	588
Fertilizer Urea	kg	100	1,232	123	100	1,232	123	100	1,232	123
DAP	kg	45	2,119	95	45	2,119	95	45	2,119	95
KCl	kg	25	1,257	31	25	1,257	31	25	1,257	31
Agro-chemicals	liter	0.5	14,700	7	0.5	14,700	7	0.5	14,700	7
Farming equipment and tools	LS	1.0	7,840	8	1.0	7,840	8	1.0	7,840	8
2.2 Labor	Riel	110		272	110		272	110		272
Hired labor	P-d	30	2,476	74	30	2,476	74	30	2,476	74
Family labor	P-d	80	2,476	198	80	2,476	198	80	2,476	198
2.3 Paid Services	Riel			526			994			760
Land preparation	LS	2		187	2		187	2		187
Plowing (1st)	LS	1	81,928	82	1	81,928	82	1	81,928	82
Paddling / 2nd Plowing	LS	1	105,336	105	1	105,336	105	1	105,336	105
Water pump	LS	0	468,048	0	1	468,048	468	0.5	468,048	234
Harvesting	LS	1	263,277	263	1	263,277	263	1	263,277	263
Transportation	kg	4,000	19	76	4,000	19	76	4,000	19	76
3. Net Return	Riel			4,049			3,581			3,815
(N.Return/P. Cost Ratio)				2.33			1.62			1.93

Summary Table

1. Gross Income per ha	1,000 Riel	5,787	5,787	5,787
	US$	1,417	1,417	1,417
2. Production Cost per ha	1,000 Riel	1,738	2,206	1,972
	US$	426	540	483
3. Net Return per ha	1,000 Riel	4,049	3,581	3,815
	US$	991	877	934

Note: exchange rate: US$ 1 = Riel 4,084

Source: JICA Survey Team

Economic Production Costs on Upland Crops Cultivation

(1) under Present and Without-project Conditions

(Unit: ha)

Name of crops	Unit	Mung Beans			Pumpkin			Watermelon			Sweet Potato		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			1,912			2,462			3,543			3,156
Main products	kg	500	3,773	1,887	2,500	980	2,450	3,000	1,176	3,528	4,000	784	3,136
By-product	kg	500	49	25	250	49	12	300	49	15	400	49	20
2. Total Production Cost	Riel			1,008			1,000			1,268			1,287
2.1 Inputs	Riel			593			498			498			498
Seed/cuttings	kg	50	10,780	539	0.5	78,400	39	0.4	78,400	31	40,000	(cuttings)	0
Farm manure (wet)	kg	0	196	0	2,000	196	392	2,000	196	392	2,000	196	392
Fertilizer Urea	kg	15	1,232	18	40	1,232	49	40	1,232	49	40	1,232	49
DAP	kg	10	2,119	21	20	2,119	42	20	2,119	42	20	2,119	42
KCl	kg	0	1,257	0	0	1,257	0	0	1,257	0	0	1,257	0
Agro-chemicals	liter	0.5	14,700	7	0.5	14,700	7	0.5	14,700	7	0.5	14,700	7
Farming equipment and tools	LS	1	7,840	8	1	7,840	8	1	7,840	8	1	7,840	8
2.2 Labor	P-d	50		124	70		173	80		198	80		198
Hired labor	P-d	0	2,476	0	0	2,476	0	0	2,476	0	0	2,476	0
Family labor	P-d	50	2,476	124	70	2,476	173	80	2,476	198	80	2,476	198
2.3 Machinery	Riel			291			329			572			591
Land preparation	LS	2		281	2		281	2		281	2		281
Plowing	LS	1	134,564	135	1	134,564	135	1	134,564	135	1	134,564	135
Paddling	LS	1	146,265	146	1	146,265	146	1	146,265	146	1	146,265	146
Water pump	LS	0.0	468,048	0	0	468,048	0	0.5	468,048	234	0.5	468,048	234
Harvesting	LS												
Transportation	kg	500	19	10	2,500	19	48	3,000	19	57	4,000	19	76
3. Net Return	Riel			904			1,462			2,275			1,869
(N.Return/P. Cost Ratio)				0.90			1.46			1.79			1.45

Summary Table

1. Gross Income per ha	1,000 Riel	1,912	2,462	3,543	3,156
	US$	468	603	868	773
2. Production Cost per ha	1,000 Riel	1,008	1,000	1,268	1,287
	US$	247	245	310	315
3. Net Return per ha	1,000 Riel	904	1,462	2,275	1,869
	US$	221	358	557	458

Note: exchange rate: US$ 1 = Riel 4,084

Source: JICA Survey Team

(2) under With-project Condition

(Unit: ha)

Name of crops	Unit	Mung Beans			Pumpkin			Watermelon			Sweet Potato		
		Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	Riel			3,822			4,925			5,905			3,945
Main products	kg	1,000	3,773	3,773	5,000	980	4,900	5,000	1,176	5,880	5,000	784	3,920
By-product	kg	1,000	49	49	500	49	25	500	49	25	500	49	25
2. Total Production Cost	Riel			1,684			1,848			2,240			1,848
2.1 Inputs	Riel			767			707			1,099			707
Seed (self-stocked)		50	10,780	539	0.5	78,400	39	0.4	78,400	31	40,000	(cuttings)	0
Farm manure (wet)	kg	0	196	0	2,000	196	392	4,000	196	784	2,000	196	392
Fertilizer Urea	kg	55	1,232	68	100	1,232	123	100	1,232	123	100	1,232	123
DAP	kg	50	2,119	106	50	2,119	106	50	2,119	106	50	2,119	106
KCl	kg	25	1,257	31	50	1,257	63	50	1,257	63	50	1,257	63
Agro-chemicals	liter	1.0	14,700	15	1.0	14,700	15	1.0	14,700	15	1.0	14,700	15
Farming equipment and tools	LS	1	7,840	8	1	7,840	8	1	7,840	8	1	7,840	8
2.2 Labor	Riel	60		149	120		297	120		297	120		297
Hired labor	P-d	0	2,476	0	10	2,476	25	10	2,476	25	10	2,476	25
Family labor	P-d	60	2,476	149	110	2,476	272	110	2,476	272	110	2,476	272
2.3 Paid Services	Riel			768			844			844			844
Land preparation	LS	2		281	2		281	2		281	2		281
Plowing (1st)	LS	1	134,564	135	1	134,564	135	1	134,564	135	1	134,564	135
Paddling / 2nd Plowing	LS	1	146,265	146	1	146,265	146	1	146,265	146	1	146,265	146
Water pump	LS	1	468,048	468	1	468,048	468	1	468,048	468	1	468,048	468
Harvesting	LS												
Transportation	kg	1,000	19	19	5,000	19	95	5,000	19	95	5,000	19	95
3. Net Return	Riel			2,138			3,077			3,665			2,097
(N.Return/P. Cost Ratio)				1.27			1.67			1.64			1.13

Summary Table

1. Gross Income per ha	1,000 Riel	3,822	4,925	5,905	3,945
	US$	936	1,206	1,446	966
2. Production Cost per ha	1,000 Riel	1,684	1,848	2,240	1,848
	US$	412	452	548	452
3. Net Return per ha	1,000 Riel	2,138	3,077	3,665	2,097
	US$	524	753	897	513

Note: exchange rate: US$ 1 = Riel

Source: JICA Survey Team

Attachment-7

Checklist of Environmental Scoping (Sample)

Checklist of Environmental Scoping
(Sample)

No	Likely Impacts	Rating Over all	Explanation on Potential Impacts (Project-related activity is shown in the parenthesis"< >".)
Pollution			
1	Air pollution	B-	*<Operation of construction equipment and vehicles>* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* Emission of exhaust gas from construction equipment and vehicles and dust pollution due to operation of the construction equipment and vehicles would cause air pollution in and around the construction sites during the construction. However, the impact is limited and temporary.
2	Water pollution	B-	*<Operation of construction equipment and vehicles>* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* Muddy water from construction site and oil spill from construction equipment and vehicles would cause water pollution in the existing canals in and around the construction site.
3	Soil contamination	-	The project does not have any factor which may cause the soil contamination in terms of project location and construction method.
4	Waste	B-	*<Operation of construction equipment and vehicles>* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* Construction waste including residue soil and concrete waste would be produce by construction work.
5	Noise and vibration	B-	*<Operation of construction equipment and vehicles>* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* - Vibration caused by such construction works would cause damage to residential people, existing houses and other kinds of building structures.
6	Ground subsidence	-	The project does not have any factor which may cause the ground subsidence in terms of project location and construction method.
7	Offensive odor	-	The project does not have any factor which may cause the offensive odor in terms of project location and construction method.
8	Bottom sediment	-	The project does not have any factor which may cause the bottom sediment in terms of project location and construction method.
9	Disaster	-	The project does not have any factor which may cause the disaster in terms of project location and construction method.
10	Topography and geographical features	-	The project does not have any factor which may cause the disaster in terms of project location and construction method because project site is already developed as .
11	Soil erosion	B-	*<Control of Maintenance of canals and drainage>* Rehabilitation work canals/drainage would cause soil erosion in some sections.
12	Groundwater	-	The project does not have any factor which may cause the groundwater in terms of project location and construction method because USISRSP does not utilize groundwater.
13	Hydrological situation	C-	*<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* Rehabilitation work canals/drainage in some sections would affect hydrological situation in project area without adequate control of maintenance of those structure. Detailed hydrological analysis undertook in this study.
14	Coastal zone	-	The project does not have any factor which may cause the c in terms of project location.
15	Flora, fauna and biodiversity	B-	*<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* After Rehabilitation work, Tumnup Lok Reservoir will occurred upstream Slakou River. If water flow of downstream, downstream ecosystem will be affected.
16	Meteorology	-	The project does not have any factor which may affect and/or be related to the meteorology.

No	Likely Impacts	Rating Over all	Explanation on Potential Impacts (Project-related activity is shown in the parenthesis"< >".)
17	Landscape	-	The project does not have any factor which may cause the groundwater in terms of project location and construction method.
18	Global warming	-	The project does not have any factor which may cause the groundwater in terms of project location and construction method because USISRSP is only rehabilitation and improvement project and not including new development.
19	Involuntary Resettlement	-	It is expected that no large scale of involuntary resettlement (more than 200 persons to be displaced) will be caused by USISRSP.
20	Local economy such as employment and livelihood, etc.	B-/A+	*<Design of Main canal and secondary canals and other facilities >* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* -Overall, the construction of USISRSP will make more employment and business opportunities for local residents during construction. -After operation of USISRSP, regional formers around USISRSP would have positive impact due to improvement irrigation water availability during dry season.
			<Rehabilitation of existing Main canal and secondary canals and other facilities> *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* -USISRSP will cause loss of paddy field (illegal use) on Tumnup Lok Reservoir -USISRSP will cause loss of structure (house, shop and other facilities) along main and secondary canals (illegal use)
21	Land use and utilization of local resources	B-/B+	*<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* -USISRSP will cause loss of accessibility from road to residential houses and shops along Main and Secondary Canals.
			<Operation of Main canal and secondary canals and other facilities > After operation of the RCHRSP, regional formers around the USISRSP would have positive impact due to improved irrigation water availability
22	Social institutions	-	The project does not have any factor which may cause social institution in terms of project location and construction method.
23	Existing social infrastructures and services	B-	*<Land acquisition>* Land acquisition for the project, involving relocation of public and/or community facilities, would affect local communities to some extent.
			<Operation of construction equipment and vehicles> *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Traffic restriction in construction area>* Construction work and traffic restriction would disturb access to the existing social infrastructures and services.
24	Socially vulnerable groups such as the poor, indigenous and ethnic people	B+	*<Operation of new regulator and canals >* After operation of the USISRSP, all regional Project Affected Persons (PAPs) around the USISRSP would also have positive impact due to improved irrigation water provision during dry season.
25	Misdistribution of benefit and damage	B-	*<Design of Main canal and secondary canals and other facilities >* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* -Local farmers will benefit from USISRSP directly. Meanwhile people live along MC and SC will be affected by USISRSP, will not benefit from USISRSP directly. It will be occurred misdistribution of benefit and damage without adequate mitigation measure.
26	Historical and cultural heritage (including religious matters)	-	The project does not have any factor which may cause historical and cultural heritage in terms of project location and construction method.
27	Water usage or water rights and rights of common	A+	*<Operation of Main/Secondary canal/ drainage and other faicilitates >* After operation of the USISRSP new regulator and canals/drainage will provide a substantial improvement in irrigation water provision without adequate water resource management.
28	Local conflict of interests	B-	*<Design of Main canal and secondary canals and other facilities >* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>*

No	Likely Impacts	Rating Over all	Explanation on Potential Impacts (Project-related activity is shown in the parenthesis"< >".)
			-Local farmers will benefit from USISRSP directly. Meanwhile people live along MC and SC will be affected by USISRSP, will not benefit from USISRSP directly. It will be occurred local conflict of interests between farmers and non-farmers without adequate mitigation measure.
29	Sanitation	B-	*<Operation of construction equipment and vehicles>* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* -Sanitary issues would occur in labor camp and neighboring area in the case sanitary facility is not adequately installed such as toilet and septic tank.
30	Hazardous (risk) infectious diseases such as HIV/AIDS	B-	*<Operation of construction equipment and vehicles>* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* -Risk of infectious diseases by labors would be expected during construction due to the inflow of the construction workers from outside.
31	Accident	B-	*<Operation of construction equipment and vehicles>* *<Rehabilitation of existing Main canal and secondary canals and other facilities>* *<Rehabilitation of existing dike and construction of the reservoir facilities (Tumnup Lok Reservoir)>* -Some accidents are inevitable during construction.

Source: JICA Survey Team

*Note: * Regarding the impacts on "Gender" and "Children's Right", might be related to all criteria of Social Environment.*

<Rating>

A-: Serious impact is expected, if any measure is not implemented to the impact.

B-: Some impact is expected, if any measure is not implemented to the impact.

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

-: No impact is expected. Therefore, EIA is not required.

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.

Overall rating: Highest rate will be the overall rating among the rating of relevant project-related activities for negative and positive ratings, respectively. (e.g. Even only one "A-" is included in an environmental item, overall rating of the environmental item becomes "A-".)