Appendix-D
Irrigation and Drainage

BASIN-WIDE BASIC IRRIGATION AND DRAINAGE MASTER PLAN STUDY
IN
THE KINGDOM OF CAMBODIA

FINAL REPORT

APPENDIX-D IRRIGATION AND DRAINAGE

Table of Contents

Tables

Figures

CHAPTER D1 PRESENT CONDITION OF IRRIGATION AND DRAINAGE

D1.1 Inventory Survey for Irrigation Systems by JICA

D1.1.1 Objective and Scope

(1) Objective of the Work

Irrigation inventory and analyses of existing systems had been formulated by Cambodian JICA Office in collaboration with MOWRAM in 2006, and reported in "The Survey on The Irrigation System Inventory for The River Basins of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot", 31 August, 2006, by JICA Cambodia Office, Cambodia Engineering Groups Co., Ltd., referred to as "JICA Inventory", herein after).

In this irrigation system inventory and analyses, field survey and interview was carried out to collect the following highlighted data using data format, over the River Basins of Battambang, Dauntri (Moung Russey), Pursat, Boribo and part of Prek Thnot:

- Part I: Outline of the irrigation system: history, main objectives, scope of work
- Part II: Detail of the irrigation system: Current condition of each of the irrigation system components

(2) Result of Irrigation Inventory

Project area covers 29,201km^2, including River Basins of Battambang, Dauntri (Moung Russey), Pursat and Boribo that are related to this irrigation and drainage master plan study. There are 320 systems in the above 4 basins, and these systems were evaluated in three stages (fully function, partly function and mal function), that currently serve as complete and supplementary irrigation over existing areas of 145,315ha (130,740ha in 4 basins, herein after) in which 128,531ha (117,658ha) in the wet season and 16,784ha (13,082ha) in dry season and the total potential areas of 292,318ha (268,413ha) in which 256,165ha (239,462ha) in the wet season and 36,153ha (28,951ha) in the dry season.

Most of irrigation systems were constructed under the Pol Pot regime (1975-1979) and not appropriately designed or incomplete systems that caused serious problems in operation and maintenance.

JICA Inventory revealed and pointed out the following findings that can be used as basic information for future improvement and updating on the current irrigation system inventory:

- Most of the irrigation systems are inappropriate design;
- Most of the irrigation systems are uncompleted systems;
- Most of the irrigation systems are deteriorated;
- Poor operation and maintenance;
- Lack of beneficiaries participation;
- Cropping pattern is unclear;

D1.1.2 Definition of Irrigation System

(1) Classification of Irrigation Systems

Classification of irrigation systems was carried out based on the following criteria on the size of irrigation command area, referring to the Article 1.3.2 on pp.2 of the "Part 2 Policy for Sustainability of Operation and Maintenance Irrigation System" in Circular No.1, prepared by MOWRAM, June, 2000.

- Small Scale : up to 200 ha (A< 200 ha)
- Medium Scale : 200 to 5,000 ha (200 ha - 5,000 ha)
- Large Scale : over 5,000 ha (5,000 ha < A)

(2) Types of Irrigation System

In the JICA inventory report, the irrigation type was broadly classified into three (3) categories from the viewpoint of water resources. Moreover, these types are further classified into eight (8) sub-types as follows.

1. Reservoir irrigation type
   - 1a Reservoir irrigation with irrigation canal(s)
   - 1b Reservoir irrigation without irrigation canal
2. River irrigation type
   - 2a River irrigation type equipped with an intake structure together with a weir
   - 2b River irrigation type equipped with a free intake structure without a weir
3. Pond irrigation type
   - 3a Pond constructed on a flat area, which equips a weir and an intake structure in the source river as a water supply system.
   - 3b Pond constructed on a flat area, which equips a free intake structure in the source river as a water supply system.
   - 3c Pond constructed across a small stream with a very small catchment area
   - 3d Pond constructed on a flat area without a catchment area

(3) Categorization of the Irrigation Area

In this series of inventory survey, the meaning of the terms related to irrigation is explained or roughly defined as follows:

- Existing irrigation area: Paddy field to which complete (or continuous) irrigation and/or supplementary irrigation is applied.
- Potential irrigation area: Piece of land which is adjacent to the existing irrigation area and/or water resources. These lands have a potential to be cultivated as irrigated paddy

field from the view point of landscape or topography, land resource, water resources, soil classification.

- Complete (continuous) irrigation: Paddy field where irrigation water is applied to meet the full water demand of crops. Many cases, water is applied from rivers, streams, reservoirs.
- Supplementary irrigation: Paddy field where irrigation water is applied to up to meet partial water demand of crops.

D1.1.3 Classification of Inventoried Irrigation Systems

(1) Result on Basin-wise number of systems under classification

Classification of irrigation systems was conducted over various sizes of 320 irrigation systems based on the result of inventoried irrigation systems by JICA[2] in 2006, on two bases; the "Potential Irrigation Area" and the "Existing Irrigation Area". The following tables show the results of classification on the above "Potential" and "Existing" bases, respectively.

It is shown that the numbers of irrigation systems based on the "Potential" are 9 (3% of 320) systems as "large scale", 159 (50%) as "medium scale" and 152 (47%) as "small scale". On the other hand, when based on the "Existing", the numbers are 5 (2% of 320) systems, 113 (35%), 202 (63%), respectively.

Basin-wise Number of Irrigation Systems Based on Potential Area

River Basin	PDOWRAM Concerned	Size Classification			Total (nos.)
		< 200 Ha (nos.)	200 - 5,000 Ha (nos.)	> 5,000 Ha (nos.)	
Battambang	Battambang	69	18	1	88
Moung Russey	Basin sub total	13	31	1	45
	Battambang	(13)	(17)	(1)	(31)
	Pursat	(0)	(14)	(0)	(14)
Pursat	Pursat	1	22	5	28
Boribo	Basin sub total	69	88	2	159
	Pursat	(0)	(15)	(0)	(15)
	Kg. Chhnang	(47)	(65)	(2)	(114)
	Kg. Speu	(8)	(3)	(0)	(11)
	Kandal	(14)	(5)	(0)	(19)
Total		152	159	9	320

Numbers in ( ) :province wise, included in "Basin sub total"

The difference in the number of the "Large Scale" systems in the two bases can be analyzed as that 4 systems listed in the table above have rather smaller command area on "Existing" basis due to lack of water resources caused by deterioration of irrigation facilities.

Basin-wise Number of Irrigation Systems Based on Existing Area

River Basin	PDOWRAM Concerned	Size Classification < 200 Ha (nos.)	200 - 5,000 Ha (nos.)	> 5,000 Ha (nos.)	Total (nos.)
Battambang	Battambang	76	11	1	88
Moung Russey	Basin sub total	26	19	0	45
	Battambang	(26)	(5)	(0)	(31)
	Pursat	(0)	(14)	(0)	(14)
Pursat	Pursat	5	21	2	28
Boribo	Basin sub total	95	62	2	159
	Pursat	(1)	(14)	(0)	(15)
	Kg. Chhnang	(68)	(44)	(2)	(114)
	Kg. Speu	(11)	(0)	(0)	(11)
	Kandal	(15)	(4)	(0)	(19)
Total		202	113	5	320

Numbers in ( ) :province wise, included in "Basin sub total"

The shift in numbers of systems from "Medium scale" to "Small scale" in the above two bases is higher in Boribo river basin (26 (30%) of 88 systems), that seems to reflect the excess water supply is relatively low in this basin, compared to the other 3 basins.

Irrigation Systems Shifted from Large Scale to Medium Scale Based on Existing Area

River Basin Sytem Code	PDOWRAM Concerned	System Name	System Area Potential (Ha)	Existing (Ha)
Moung Russey MRS-002	Battambang	Prek Chik	18,470	490
Pursat				
KND-002	Pursat	Kbal Hong	7,140	4,790
KND-006	Pursat	Charek	5,540	4,030
SPM-004	Pursat	Wat Loung	5,700	75

System Code: Based on JICA Inventory[1]

(2) Result on Basin-wise irrigation area under classification

Classification of irrigation area was also conducted over 320 irrigation systems, based on the "Potential Irrigation Area" and the "Existing Irrigation Area", as done in the previous section. The following tables show the results of classification on the above "Potential" and "Existing" bases, respectively.

It is shown that based on the "Potential irrigation area", the "irrigation area" classified as in the "Large scale systems" is about 42% of the grand total area, "Medium scale" is about 53%, and "Small scale" is about 5 %, respectively. On the other hand, based on the "Existing irrigation area", it is shown that the "area" in the "Large scale" is about 28% of the grand total area, "Medium scale" is about 64%, and "Small scale" is about 8 %, respectively.

Basin-wise Irrigation Area Based on Potential Area (Paddy)

River Basin	PDOWRAM concerned	Size Classification (Paddy)								
		< 200 Ha			200 - 5,000 Ha			> 5,000 Ha		
		Wet	Dry	Sub total	Wet	Dry	Sub total	Wet	Dry	Sub total
Battambang	Battambang	3,932	1,077	5,009	23,040	505	23,545	15,000	0	15,000
Moung Russey	Basin sub total	875	30	905	33,365	3,220	36,585	18,470	0	18,470
	Battambang	(875)	(30)	(905)	(23,460)	(400)	(23,860)	(18,470)	(0)	(18,470)
	Pursat	(0)	(0)	(0)	(9,905)	(2,820)	(12,725)	(0)	(0)	(0)
Pursat	Pursat	95	10	105	22,624	3,052	25,676	42,118	7,629	49,747
Boribo	Basin sub total	2,296	3,558	5,854	54,164	4,505	58,669	23,665	6,051	29,716
	Pursat	(0)	(0)	(0)	(12,891)	(1,200)	(14,091)	(0)	(0)	(0)
	Kg. Chhnang	(1,671)	(2,797)	(4,468)	(37,723)	(3,055)	(40,778)	(23,665)	(6,051)	(29,716)
	Kg. Speu	(625)	(0)	(625)	(2,400)	(0)	(2,400)	(0)	(0)	(0)
	Kandal	(0)	(761)	(761)	(1,150)	(250)	(1,400)	(0)	(0)	(0)
Total	Total	7,198	4,675	11,873	133,193	11,282	144,475	99,253	13,680	112,933
Grand Total				(4.4%)			(53.7%)			(41.9%)
		Numbers in ( ) :province wise, included in "Basin sub total"								269,281

Basin-wise Irrigation Area Based on Existing Area (Paddy)

River Basin	PDOWRAM concerned	Size Classification (Paddy)								
		< 200 Ha			200 - 5,000 Ha			> 5,000 Ha		
		Wet	Dry	Sub total	Wet	Dry	Sub total	Wet	Dry	Sub total
Battambang	Battambang	2,315	640	2,955	11,945	67	12,012	7,000	0	7,000
Moung Russey	Basin sub total	290	20	310	8,767	3,086	11,853	0	0	0
	Battambang	(290)	(20)	(310)	(1,480)	(460)	(1,940)	(0)	(0)	(0)
	Pursat	(0)	(0)	(0)	(7,287)	(2,626)	(9,913)	(0)	(0)	(0)
Pursat	Pursat	378	20	398	26,594	1,235	27,829	12,933	1,170	14,103
Boribo	Basin sub total	3,795	3,320	7,115	29,782	2,565	32,347	13,445	1,535	14,980
	Pursat	(120)	(0)	(120)	(7,975)	(440)	(8,415)	(0)	(0)	(0)
	Kg. Chhnang	(2,904)	(2,439)	(5,343)	(20,707)	(2,125)	(22,832)	(13,445)	(1,535)	(14,980)
	Kg. Speu	(721)	(0)	(721)	(0)	(0)	(0)	(0)	(0)	(0)
	Kandal	(50)	(881)	(931)	(1,100)	(0)	(1,100)	(0)	(0)	(0)
Total	Total	6,778	4,000	10,778	77,088	6,953	84,041	33,378	2,705	36,083
Grand Total				(8.2%)			(64.2%)			(27.6%)
		Numbers in ( ) :province wise, included in "Basin sub total"								130,902

It is also shown by comparing two tables that the grand total of the "Existing irrigation area" is about 50 % of that of "Potential". In the "Large scale", the ratio of the above areas is about 30%, while in the "Medium scale" the said ratio becomes 60%. In the "Small scale", this tendency is low and the "Existing area" is about 90% of the "Potential".

These results imply the following the condition:

- Small scale systems : relatively realistic system size, relying on water potential
- Medium scale systems : relatively high effort and high water potential is required
- Large scale systems : high effort and high water potential is required

(3) Result on Basin-wise irrigation area under classification

The distribution of irrigation types in each scale classification is summarized below for each of the four river basins.

- In the Battambang River Basin, river type systems rely mainly on the Battambang River, and water sources of other systems are irrigation ponds or reservoirs constructed in flat area.

Type of Irrigation Systems in the Battambang River Basin

(Unit: ha)

Classification	No. of System	Reservoir Type		River Type		Pond Type			
		1a	1b	2a	2b	3a	3b	3c	3d
< 200 ha	76	-	-	30	19	-	10	5	12
200 – 5000 ha	11	2	-	2	7	-	-	-	-
> 5000 ha	1	-	-	1	-	-	-	-	-
Total	88	2	0	33	26	0	10	5	12

Source: *JICA, Aug., 2006: Final Report of The Survey on The Irrigation System Inventory for The River Basin of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot*

- In the Moung Russey River Basin, reservoir and pond irrigation systems and river irrigation systems occupy 50%, respectively.

Type of Irrigation System in the Moung Russey River Basin

(Unit: ha)

Classification	No. of System	Reservoir Type		River Type		Pond Type			
		1a	1b	2a	2b	3a	3b	3c	3d
< 200 ha	26	-	-	2	4	12	3	2	3
200 – 5000 ha	19	3	-	14	2	-	-	-	-
> 5000 ha	0	-	-	-	-	-	-	-	-
Total	45	4	1	16	6	11	2	2	3

Source: *JICA, Aug., 2006: Final Report of The Survey on The Irrigation System Inventory for The River Basin of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot*

- In the Pursat River Basin, the numbers of pond irrigation systems are limited because of the Pursat river with abundant water resources.

Type of Irrigation System in the Pursat River Basin

(Unit: ha)

Classification	No. of System	Reservoir Type		River Type		Pond Type			
		1a	1b	2a	2b	3a	3b	3c	3d
< 200 ha	5	-	-	3	1	-	-	1	-
200 – 5000 ha	21	2	2	11	4	-	-	2	-
> 5000 ha	2	-	-	1	1	-	-	-	-
Total	28	2	2	15	6	-	-	3	-

Source: *JICA, Aug., 2006: Final Report of The Survey on The Irrigation System Inventory for The River Basin of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot*

- In the Boribo River Basin, there are two characteristic irrigation types; they are small river irrigation and small pond irrigation systems.

Type of Irrigation System in the Boribo River Basin

(Unit: ha)

Classification	No. of System	Reservoir Type		River Type		Pond Type			
		1a	1b	2a	2b	3a	3b	3c	3d
< 200 ha	95	-	-	31	1	19	-	-	44
200 – 5000 ha	62	25	2	30	3	-	-	-	2
> 5000 ha	2	2	-	-	-	-	-	-	-
Total	159	27	2	61	4	19	-	-	46

Source: *JICA, Aug., 2006: Final Report of The Survey on The Irrigation System Inventory for The River Basin of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot*

D1.1.4 Other Major Findings and Problems Encountered

Other major findings through the inventory survey are as follows:

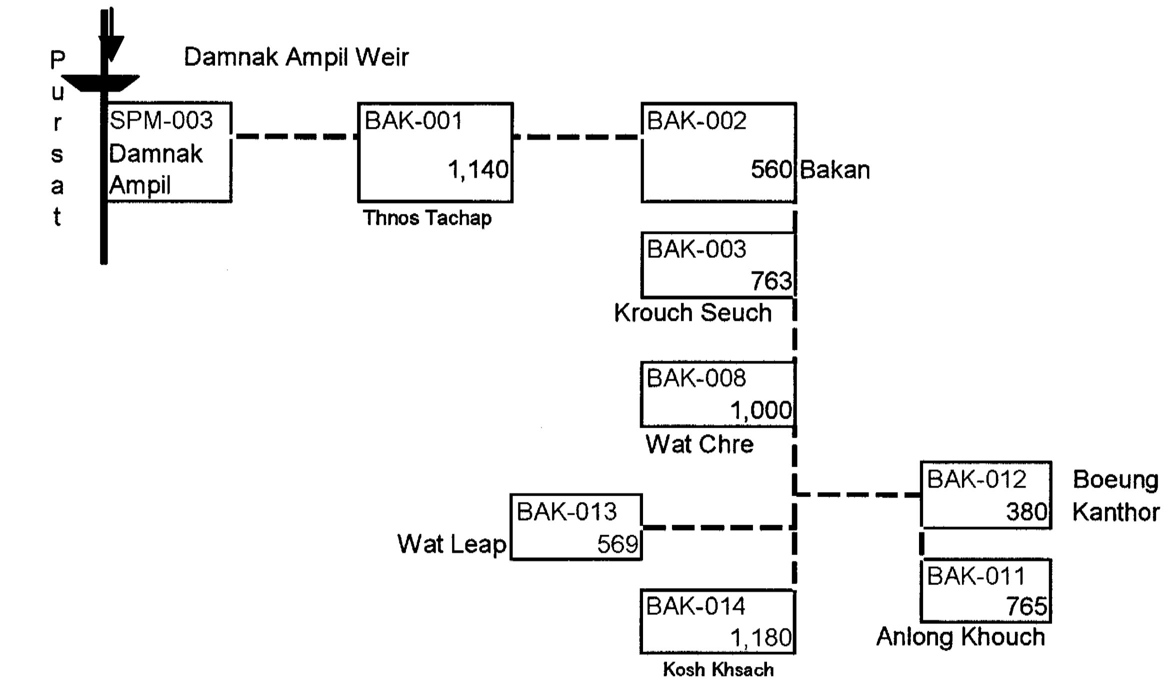
- Upland crops: Mostly rely on rain fed and mainly planted around houses for domestic use. In Battambang river basin, "Battambang orange" and "corn" are found planted over some hilly land, under rain fed and/or private pressurized irrigation systems. These crops are at this point, not included into planned irrigation systems.
- Overlapping of irrigation systems: In few irrigation systems, command areas are found to be overlapped, since these command areas are based on the secondary canal beneficially.
- Crop density: According to cropping patterns derived from JICA Inventory, most of the current irrigated land is planted 1 time a year. It seems that the most of the farmers currently plant local variety paddy, so called "Battambang rice", that takes longer duration to grow and more suitable to be planted in rainy season.

  Since this variety is planted in June to August, after the rainfall is assured, namely "Wet-2", and harvested in October to January, it may be difficult to plant dry paddy continuously on the same land. This tendency is high in Battambang Province where stable rainfall seems to start a little bit later than Pursat and provinces east of Pursat. In Pursat and the above eastern provinces, early paddy variety, namely "Wet-1", are planted in some portion in April to June. In few systems mostly in Boribo river basin, double cropping of early Paddy and local variety and of local variety and dry paddy were found.
- Adjustment for systems in East of Moung Russey: Through examination on the location of the following systems shown in the figure below, in Bakan District in Pursat Province, it has been revealed that those systems are supplied water from Damnak Ampil Weir on Pursat river, nonetheless they are topographically located within Svay Don Keo River Basin as a part of "Moung Russey River Basin". Therefore, these systems are classified and totaled as a component of Pursat River Basin systems. It is also applied to the following analyses in Chapter D2.

Basin-wise Irrigation Area (season-wise) Based on Existing Area (Paddy)

River Basin / Province	Size Classification of Irrigation System (Paddy)														
	< 200 Ha					200 - 5,000 Ha					> 5,000 Ha				
	Wet-1	Wet-2	Dry	Recession	Sub total	Wet-1	Wet-2	Dry	Recession	Sub total	Wet-1	Wet-2	Dry	Recession	Sub total
Battambang Rv. Basin	**5**	**2,310**	**562**	**78**	**2,955**	**0**	**11,945**	**67**	**0**	**12,012**	**0**	**7,000**	**0**	**0**	**7,000**
1) Battambang	(5)	(2,310)	(562)	(78)		(0)	(11,945)	(67)	(0)		(0)	(7,000)	(0)	(0)	
Moung Russey Rv. Basin	**70**	**220**	**0**	**20**	**310**	**2,851**	**5,916**	**1,535**	**1,551**	**11,853**	**0**	**0**	**0**	**0**	**0**
1) Battambang	(70)	(220)	(0)	(20)		(590)	(890)	(450)	(10)		(0)	(0)	(0)	(0)	
2) Pursat	(0)	(0)	(0)	(0)		(2,261)	(5,026)	(1,085)	(1,541)		(0)	(0)	(0)	(0)	
Pursat Rv. Basin	**35**	**343**	**20**	**0**	**398**	**1,327**	**25,267**	**780**	**455**	**27,829**	**650**	**12,283**	**1,170**	**0**	**14,103**
1) Pursat	(35)	(343)	(20)	(0)		(1,327)	(25,267)	(780)	(455)		(650)	(12,283)	(1,170)	(0)	
Boribo Rv. Basin	**170**	**3,625**	**1,240**	**2,080**	**7,115**	**880**	**28,902**	**1,530**	**1,035**	**32,347**	**0**	**13,445**	**1,535**	**0**	**14,980**
1) Pursat	(20)	(100)	(0)	(0)		(880)	(7,095)	(440)	(0)		(0)	(0)	(0)	(0)	
2) Kampong Chhnang	(150)	(2,754)	(1,120)	(1,319)		(0)	(20,707)	(1,090)	(1,035)		(0)	(13,445)	(1,535)	(0)	
3) Kampong Speu	(0)	(721)	(0)	(0)		(0)	(0)	(0)	(0)		(0)	(0)	(0)	(0)	
4) Kandal	(0)	(50)	(120)	(761)		(0)	(1,100)	(0)	(0)		(0)	(0)	(0)	(0)	
Total	280	6,498	1,822	2,178	**10,778**	5,058	72,030	3,912	3,041	**84,041**	650	32,728	2,705	0	**36,083**

Numbers in ( ) :province wise, included in "Basin"



Adjustment of Systems in Moung Russey/ Pursat River Basins

Basin and Province-wise Actual Irrigation Area (adjusted with cropping density) Based on Existing Area (Paddy)

River Basin	PDOWRAM concerned	< 200 Ha		200 - 5,000 Ha		> 5,000 Ha	
		No. of System	Sub total Area (Ha)	No. of System	Sub total Area (Ha)	No. of System	Sub total Area (Ha)
Battambang	Battambang	76	2,659	11	11,945	1	7,000
Moung Russey	Basin sub total	26	310	19	11,748	0	0
	Battambang	(26)	(310)	(5)	(1,940)	(0)	(0)
	Pursat	(0)	(0)	(14)	(9,808)	(0)	(0)
Pursat	Pursat	5	378	21	26,869	2	12,933
Boribo	Basin sub total	95	7,115	62	31,907	2	13,445
	Pursat	(1)	(120)	(14)	(7,975)	(0)	(0)
	Kg. Chhnang	(68)	(5,343)	(44)	(22,832)	(2)	(13,445)
	Kg. Speu	(11)	(721)	(0)	(0)	(0)	(0)
	Kandal	(15)	(931)	(4)	(1,100)	(0)	(0)
Total	Total	202	10,462	113	82,469	5	33,378
Grand Total		(63.1%)	(8.3%)	(35.3%)	(65.3%)	(1.6%)	(26.4%)
						320	126,309

Numbers in ( ) :province wise, included in "Basin sub total"

D1.2 Topographic and Supplemental Inventory Survey

D1.2.1 Objectives and Scope

(1) Objective

There were few well-organized data and drawings concerning irrigation systems in the study area. In this context, JICA conducted the irrigation system inventory survey in the study area in 2006, prior to commencement of the "Basin-wide Basic Irrigation and Drainage Master Plan Study". The JICA inventory survey clarified the salient features of 320 irrigation systems from small to large scale.

In addition to the JICA inventory survey, the study team carried out quantitative data collection about irrigation system through additional survey works for the following objectives.

Main purposes of topographic survey work are:

- to clarify quantitatively the existing conditions of irrigation and drainage canals in various types of projects, and
- to collect basic data on existing canal for formulating rehabilitation plan of irrigation facilities.

Supplemental Inventory Survey aims at:

- clarifying the present conditions of canal system and canal related structures which were constructed in Pol Pot regime,
- clarifying development level of project, especially facility level of project already rehabilitated, and
- collection of data and information concerning activities of Farmer Water User Community (FWUC) from engineering viewpoint.

(2) Scope of Work

Canals' location, alignments and length to be surveyed were prepared based on the JICA Inventory survey. Scope of work prepared was as follows.

1) Topographic Survey

- Profile leveling survey along canals, rivers, and irrigation pond dykes

Canal:	Irrigation Canal	12 sites with a total length of 100 km
River:		4 sites with a total length of 2.5 km
Irrigation pond dyke:		2 dykes with a total length of 11 km

- Cross section survey along the following canals, rivers, and irrigation pond dykes

Canal:	470 sections (interval of 250 m)
River:	25 sections (interval of 250 m)

Irrigation pond dyke: 50 Sections (interval of 250 m)

- All survey results above shall be input to digital data as specified by JICA Study Team.

2) Supplemental Inventory Survey

- Canal supplemental inventory survey:
  Measurement of location and length by handheld GPS
  Survey of the canal shape

- Canal related structures supplemental inventory survey
  Measurement of location and dimensions: all the existing irrigation and drainage canal related structures in 12 sample project site
  Data collection: construction year, working conditions, etc. about existing irrigation and drainage structures.

- Data compilation on both analog and digital data basis.

The scope of work was summarized as follows.

Summary of Scope of work

Description	unit	Quantity	Remarks
1. Installation of TBM and Vertical Control Point			
1.1 TBM installation	point	12	
1.2 Vertical Control Point	point	470	
2. Profile Leveling			
2.1 River profile leveling	km	2.5	
2.2 Canal profile leveling	km	100.0	
2.3 Irrigation pond dyke leveling	km	11.0	
3. Cross Section Survey			
3.1 River	section	25	100 m in width
3.2 Canal			
3.2.1 Main Canal	section	220	60 m in width
3.2.2 Secondary Canal	section	250	40 m in width
3.3 Irrigation pond dyke	section	50	80 m in width
4. Supplemental inventory survey			
4.1 Inventory survey	km	290	Including data collection
5. Output	L.S.	1	

D1.2.2 Selection of Sample Area

(1) Considerations for Selection of Sample Irrigation Systems

Prior to commencement of topographic survey work, 12 topographic and supplemental inventory survey systems and 12 supplemental inventory survey systems were selected.

The points considered for selection of sample irrigation systems were as follows.

1) Request from provincial government
2) Development/rehabilitation level of system
3) Location in the basin

4) Type of irrigation system

5) Scale of irrigation system (Large, Medium, and Small)

6) Existence of farmer water user community (FWUC)

7) Accessibility by jeep type car

8) Safety from land mines

(2) Request from provincial government

Irrigation systems for rehabilitation requested by PDOWAM based on demands of farmers are as follows.

Battambang river basin	:	Kong Hort	(15,000ha)*
Moung Ruessei river basin	:	Prek Chik	(18,470ha)*
	:	Ream Kon	(4,700ha)*
	:	Por Canal	(2,500ha)*
Pursat river basin	:	Wat Loung	(5,700ha)*
	:	Beoung Preah Ponley	(2,820ha)*
		Wat Chre	(850ha)*
Boribo river basin	:	Lum Hach	(18,165ha)*
	:	Chak Teum	(530ha)*
	:	Khvet	(560ha)*

The irrigation areas shown above with asterisk (*) are potential areas of paddy in wet season presented in the JICA inventory report.

Basically, irrigation systems requested were selected for candidates of sample survey systems.

(3) Type of irrigation system

Irrigation systems are broadly classified into three (3), namely reservoir irrigation, river irrigation and pond irrigation. Different characteristics of these types were considered.

(4) Location in the river basin

Irrigation system location, such as upper, middle and lower basin, could make difference in system facilities ant the rehabilitation level. In this connection, location in river basin was taken into consideration.

(5) Scale of irrigation system

The Circular No.1 issued by MOWRAM classified irrigation systems in terms of irrigation areas as follows:

Small scale irrigation scheme/system:	command area up to 200 ha
Medium scale irrigation scheme/system:	200 ha to 5,000 ha
Large scale irrigation scheme/system:	above 5,000 ha

Scale of irrigation systems was also considered in order to compare difference of irrigation facility level in each scale.

(6) Development / rehabilitation level

The systems fully or partly functioning after rehabilitating irrigation system would be valuable samples to find suitable development/rehabilitation level in the study area. In this regard, systems recently rehabilitated were selected as candidates for supplementary inventory survey. Candidates for topographic survey were selected among mal-function irrigation system to formulate irrigation plan.

(7) Existence of farmer water user community (FWUC)

Government of Cambodia is promoting participatory irrigation management and development (PIMD). FWUC is a key organization to manage irrigation facilities. Some FWUCs have been established already in the study area.

For the purpose of studying actual activities of the FWUCs, the system managed by a FWUC was selected as a candidate for supplementary inventory survey.

(8) Accessibility by a jeep type car

Most of the existing roads in the study area are not paved. In rainy season, some roads are not passable even by a jeep type car. The system, which has no passable road in rainy season, and is located in remote area, was not selected for this survey works in consideration of rainy weather condition during survey period.

(9) Safety from land mines

It will take time and cost for clearing land mines. For the safety reason, the areas where land mines or UXO were confirmed or suspected are excluded. The minefield and bombing areas were confirmed on the CMAC database maps prepared in May, 2007.

D1.2.3 Methodology

Topographic and supplemental inventory survey works were sub-let to FINNMAP Cambodia. The survey work commenced on 19th June with the condition of survey period for 60 days.

In consideration of weather condition in wet season, available survey period, and site condition, the following methodology for survey work was introduced.

- Twelve (12) TBMs were installed at the beginning point of each sample irrigation system for profile and cross section surveys. TBMs were set up on the existing permanent structures or on the concrete stake installed newly by the contractor.
- The elevation control of TBM was conducted by using the Static Dual Frequency GPS.
- At a location for cross sectional survey, a temporary concrete stake was installed to control vertical level at intervals of 250m. Coordinates of the location were measured by handheld GPS.
- Profile survey for a canal or a river was carried out along the canal or river bank

because of high water in the canal or river.

- All canals and structures in an irrigation system were investigated by supplemental inventory survey.
- Locations of structures and canals were measured by handheld GPS.
- Differences between canal bank top elevations and paddy field elevations were measured by leveling.

  The locations measured were:

  a. at the beginning of the canal,

  b. in the middle of the canal

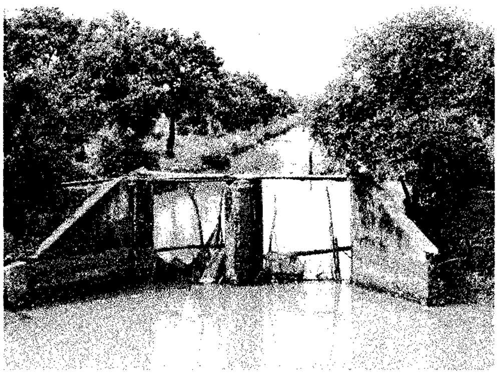
  c. at the end of the canal, and

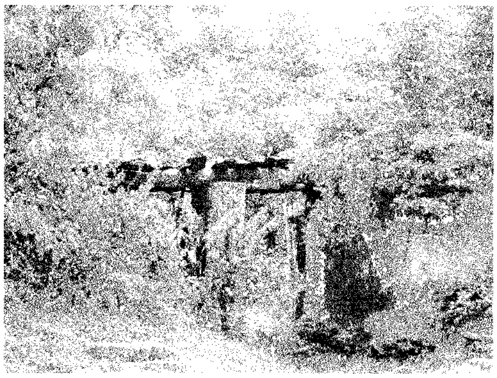
  e. at the structure sites, if any.

D1.2.4 Major Findings

- Lack of irrigation and drainage canals
- Lack of irrigation structures

  Density of irrigation structures confirmed by the supplemental inventory survey was approximately 0.5 nos./km. Water control structures such as check and intake were limited in number. Moreover, the water control structures were deteriorated seriously.

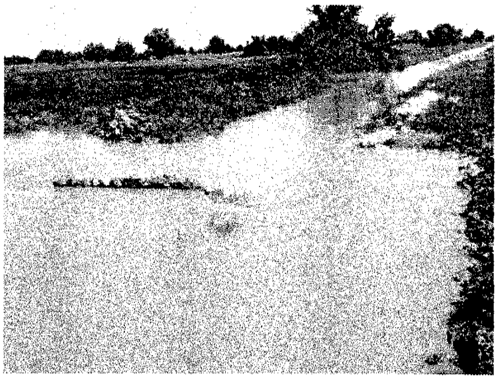




Intake structures to be replaced by new ones with gates

- Difficulty in confirming irrigation and drainage structures

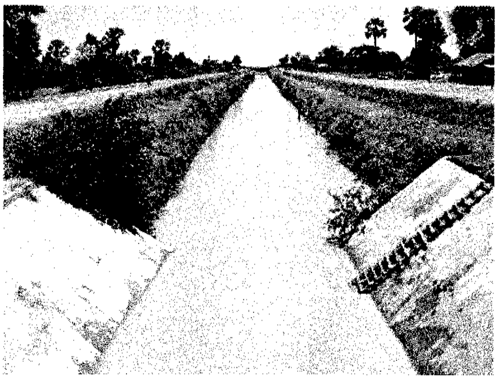
  Some structures such as drainage culvert pipe and intake pipe were not confirmed because of high water levels in canals.



Culvert underwater

- Lack of inspection (farm) roads along canals

  Excluding large scale main irrigation canals, inspection/farm roads were not constructed. Therefore, inventory survey work had to be carried out on foot in the irrigation system areas.

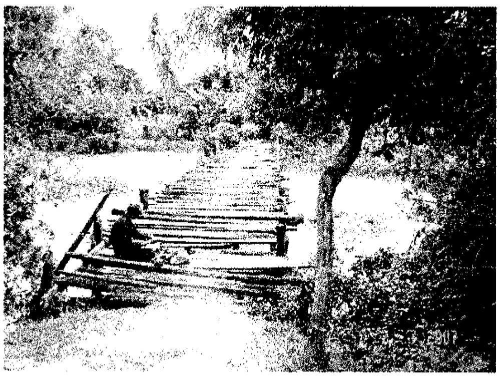


Large scale main canal with inspection road
Damnak Ampil Main Canal

Secondary and Tertiary canals without farm road

- Many wooden bridges need to be replaced

  Damaged wooden bridges were obstacles for smooth movement by a car and motor cycles on site.



Wooden Bridge to be replaced

- Low canal water levels in comparison with paddy fields

Canal water levels were normally lower by 20 to 40 cm than paddy fields to irrigate by gravity. The water levels in the canals would be raised to enough level for gravity irrigation only when the source water levels would become high enough by flood flows. Moreover, canal embankments were not provided.


Ground height of paddy field was higher than canal water level.

D1.2.5 Results of the Survey Work

(1) Summary of Survey Work

The following table shows the summary of survey work volume.

Summary of Survey Work Volume

Description	unit	Surveyed
1. Installation of TBM and Vertical Control Point		
1.1 TBM installation	point	17
1.2 Vertical Control Point	point	510
2. Profile Leveling		
2.1 River profile leveling	km	3.2
2.2 Canal profile leveling	km	104.0
2.3 Irrigation pond dyke leveling	km	5.3
3. Cross Section Survey		
3.1 River	section	24
3.2 Canal		
3.2.1 Main Canal	section	235
3.2.2 Secondary Canal	section	223
3.3 Irrigation pond dyke	section	28
4. Supplemental inventory survey		
4.1 Inventory survey	km	297.1
5. Output	L.S.	1

(2) Result of Topographic Survey Work

Topographic survey was conducted for 16 irrigation systems. Total survey length was 112.6 km. The following table shows the surveyed irrigation systems and their surveyed length.

Topographic Survey Result

No.	System Name	TBM			Irrigation Canal		River Profile	Irrigation Pond Dyke
		X	Y	Elevatio (m)	Main	Secondary		
Battambang River Basin								
1	Thmat Pong	303627.6	1440331.4	18.98	1.4 km	3.4 km	-	-
2	Vat Balat	306739.4	1450151.1	13.86	4.3 km	0.4 km		
3	Bot Sala	302003.7	1437673.7	18.78	2.0 km	-		
Moung Russey River Basin								
4	Prek Chik	325897.0	1397864.6	33.21	6.3 km	13.1 km	0.7 km	
5	Por Canal	332465.6	1412839.7	17.84	6.9 km	4.0 km		
6	Ream Kon	333212.0	1412839.7	19.59	5.8 km	3.2 km	0.6 km	
Pursat River Basin								
7	Wat Chre	361557.0	1398492.3	14.05	4.6 km	4.0 km	1.0 km	
8	Wat Loung	375489.5	1382468.8	20.95	7.5 km	1.7 km	-	
9	Beoung Preah Ponley	361537.0	1369821.5	31.37	7.3 km	3.1 km		0.7 km
Boribo Rivewr Basin								
10	Lum Hach	425890.7	1362350.8	39.78	6.3 km	9.1 km	0.7 km	
11	Khvet	421902.5	1315588.9	138.89	0.7 km	-	0.2 km	
12	Ta Ram	425351.9	1317554.7	114.88	1.8 km			0.5 km
13	Chan Keak	471096.3	1317459.6	10.27				0.4 km
14	Teuk Laak	442966.0	1331850.0	53.50		3.7 km		1.7 km
15	Trapeang Thlann	445911.0	1331716.0	47.50		1.5 km		2.0 km
16	Toul Champei	448882.0	1326116.0	45.50		2.0 km		
	Total				54.8 km	49.2 km	3.2 km	5.3 km

Note: Coordinate System is the " Indian 1954"

TBM setting was conducted using Static Dual frequency GPS receivers connecting with the National Bench Mark network.

Coordinates of No.14,15 and 16 were measured by handy GPS.

(3) Result of Additional Inventory Survey Work

Additional Inventory survey was conducted in the following 27 irrigation systems.

Result of Additional Inventory Survey

(unit: km)

No.	System Name	Irrigation Canal		Irrigation Pond
		Main	Secondary	
Battambang River Basin				
1	Thmat Pong	1.5	7.3	
2	Vat Balat	4.2	0.8	
3	Bot Sala	3.5		
4	Bour Khnar	1.0		
5	Brasat Sang Ker	1.8		
6	Ckhaoung Dra Dork	0.2		
Moung Russey River Basin				
7	Prek Chik	6.3	61.5	
8	Por Canal	9.5	12.0	
9	Ream Kon	12.8	38.4	
10	Preak Ta Am	7.4		
Pursat River Basin				
11	Bakan Irrigation	8.2		
12	Krouch Seuch	0.5	3.6	
13	Wat Chre	4.8	10.9	
14	Wat Loung	17.1	4.1	
15	Beoung Preah Ponley	7.3	2.8	0.7
16	Kom Peang Reservoir	5.8		4.2
17	Lolok Sar	3.0	6.5	
Boribo River Basin				
18	Lum Hach	7.3	25.9	
19	Khvet	0.7	0.1	
20	Ta Ram	5.0		0.4
21	Pok Pen	4.6		
22	Spean Dek	2.4		
23	Chan Keak	0.6		0.6
24	Sbar Thom	0.9		
25	Teuk Laak*		3.3	1.7
26	Trapeang Thlann*		2.0	1.9
27	Toul Champei*		2.0	
	Total	116.1	181.0	9.5

D1.3 Major On-going, Promised, and Studied Projects in the Study Area

D1.3.1 North West Irrigation Sector Project (NWISP)

The immediate objective of the project is the better use of water resources and potential for irrigated agriculture through (i) a comprehensive policy and strategic framework to be applied in the development of water resources; (ii) a better understanding knowledge and application of the integrated water resources management approach in a river basin context; (iii) improve water resources management through rehabilitated/upgraded small to medium-scale irrigation schemes and other water control infrastructure, (iv) a strengthened capacity of communities and institutions in planning, implementing , managing and maintaining such infrastructure, and (v) improved agricultural support services to the beneficially water users.

The project has the following components:

1. Institutional Strengthening
2. Irrigation Infrastructure Development and Management
3. Support to irrigated agriculture development

Under NWISP the screening process for candidate sub-projects included in the following study phases:

- Identification
- River basin and water use study
- Feasibility study
- Detailed design

Thirty nine subprojects were initially identified in five Provinces, namely Kampong Chhnang, Pursat, Battambang, Banteay Meanchey, Siem Reap Provinces by the previous study in the NWISP. Out of 39 subprojects, 21 subprojects were identified as "Stand alone scheme"[1], 18 subproject were identified river basin schemes which will contain river diversion works, reservoir upgrading, flood control dikes, and flood spreading infrastructure, etc. The candidate sub-projects above will be under process of further selection through the process above mentioned. 10 to 12 sub-projects will be selected finally for construction. The budget for facilities rehabilitation (civil works only) is about US$ 9.5 millions for 10 to 12 sub-projects.

The construction work will commence in the middle of 2008.

Relation to the Study:

Out of 39, 17 candidate sub-projects are located in the Study area. Those are listed in Table D1.3-1. Out of 17 candidate sub-projects:

- 2 candidate sub-projects will enter the detailed design phase after completion of feasibility studies; Kuch Noup (KK8-11) and Chork reservoir (M53)
- 7 candidate sub-projects will enter the feasibility study phase after completion of river basin studies; Momnak (KK3), Anlong Svay (BK2), Ronean Prayol (BK3), Dang Tuek Leach (PUR2), Krouch Saeuch (BK5), Tram Mneash (KK51), and Prek Chik (M51)

The total area is figured out about 18,000 ha for the above 17 candidate sub-projects though some candidate sub-projects are not yet confirmed for further studies. Those irrigation areas are to be taken into account the water balance study in the Study, but excluded in the Master

[1] The stand alone scheme means irrigation scheme typically draw water from a reservoir supplied by one discreet catchment. The rehabilitation of such schemes is not expected to result in negative downstream impacts on water availability of preclude future development possibilities.

Plan.

D1.3.2 Multi-purpose Water Resources Development in Krang Ponley River Basin (KOICA)

The project is located in Krang Ponley River sub-basin which is located southern part of Boribo River Basin. The project aims at to secure stability of irrigation water supply and provide rural water supply and electricity so that agricultural productivity is stabilized and increased. The main water sources of the project is Krang Ponley River and Prek Thnot River by providing river diversion facilities.

Irrigation area 16,982ha (16,982ha in wet season + 3220ha in dry season)

Irrigated paddy = 16,982 ha in wet season paddy, 833ha in dry season paddy, 2,387ha upland crops in wet and dry seasons.

The project was planned to be implemented in approximately four years including detailed design, bidding, construction supervision. Proposed project works are summarized in Table D1.3-2.

Project cost was estimated at US$33.5 million including contingency (10%). However, the cost for improvement of secondary and tertiary irrigation canals was not included in the above cost since the separate project will implemented by RGC (US$3,742,000). The feasibility study revealed that the project was economically feasible at 8.6% of EIRR.

The detailed design work was commenced by Korea Water Resources Corporation in April 2007.

Relation to the Study:

The project will cover large part of irrigation systems in the southern part of Boribo River Basin, and will contribute irrigation development in the country. The Krang Ponley River sub-basin, accordingly, is to be excluded from the Study except for some small irrigation systems which are located most upstream from junction point with the Krang Ponley River and the diversion canal from Prek Thnot River. Those small irrigation systems are excluded from the project and all drainage canal flow into the Krang Ponley River.

D1.3.3 Damnak Ampil Weir Construction Project

Damnak Ampil weir and intake were constructed on the Pursat River in 2006 to replace an unfunctioning old weir which was constructed during Pol Pot regime. Overall objectives of the project is to support and contribute to the regional agricultural production needs by increasing crop production and to alleviated poverty in the rural area and to reduce economic gap between rural and urban area through enhancement of irrigated agricultural development. The beneficiary area is planed to be 27,467ha, 39,299 population in 12 communes in 3 districts

The project work comprised of the following component and completed in January 2006.

1. Reconstruction of diversion weir across the river

   Total length: 130m

Slide gate: W× H× no. of set=1.9m×3.50m×4sets

Nerpic type automatic gate: W× H× no. of set=10.25m×4.06m×7sets

Concrete pile foundation (W× D× L× nos. =0.30m×0.30m×6.0m×120nos.)

High water level=EL. 17.00m

Low water level=EL. 13.50m

2. Construction of regulator (2 structures, its function is to take water from Pursat River to main canal; so it should be called as "Intake")

   Slide gate: W× H× no. of set=1.95m×2.5m×3sets per one regulator

   Water level: EL. 17.00m

   Bottom level: EL. 15.00m

3. Rehabilitation of main canal

   Total length of rehabilitation=7,316m

   Bottom width=7.0m

   Total depth=3.0m (a 1.0m wide berm is provided at 2.0m height from bottom)

   Type of canal=trapezoidal cross section earth canal (inside slope=1:1.5),

   Top width of embankment=4.0m for right and left side each

   Width of laterite pavement=3.0m for right and left side each

4. Construction of box culverts (10 structures)

   Box culvert: W× H=1.50m×1.50m

   Slide gate: W× H× no. of set=1.95m×3.50m×1set per one box culvert

5. Construction of operation and maintenance office 1 structure

   Floor 40m2

Project cost was estimated at US$3.9 million approximately.

Relation to the Study:

In the wet season 2007 the new automatic gates had a problem not automatically to close (to stand) until upstream water level fall to nearly low water level (EL. 13.50m). On the other hand, bottom of main canal was designed at EL. 15.00m. So, the river water hardly flew into the main canal even wet season. The gates were wrongly designed such as too low water level, too light counter weight, too much friction or some obstruction between the counter weight and wall, etc. One of the important issue is no facility was provided to raise gate by man (manual or motorized).

Damnak Ampil weir is one of the most important weir in the Pursat River for irrigation. The Pursat River has the large water resources potential in the Study area. The irrigation area by Pursat River can be extended by improving the gate and expanding canals. The weir and its irrigation systems are to be studied in the Study.

D1.3.4 Char Rek Weir Construction Project

Char Rek weir is under construction on the Pursat River by MOWRAM force account using

RGC budget. The construction is scheduled to complete 2008. The weir is located about 50km downstream in bee line from Damnak Ampil weir. Irrigation areas is assumed to be about 7,000Ha, and mostly located inside of transition zone of Tonle Sap reserve area.

Relation to the Study:

The project is on-going. The project area is to be taken into account in the water balance study in the Study, but excluded in the Master Plan.

D1.3.5 Battambang Rural Area Nurture and Development Project (BRAND)

Battambang Agricultural Productivity Enhancement Project (BAPEP) was jointly implemented by RGC and JICA from April 2003 to March 2006 in Kamping Puoy area in order to enhance farmers' productivity through the improvement of rice cultivation and farm management technology and the promotion of group activities. Following BAPEP, BRAND was started December 2006 by JICA in Battambang Province.

BRAND contains various activities such as formulation and implementation of appropriate extension plans and services, further improvement of farming technology, capacity building of stake holders through training.

Overall goal: improvement of farming system in the target districts

Objective of the project: enhancement of agricultural service delivery to farmers in the target communes

Output 1: formulate agricultural extension plans

Activities;

- Agro-ecosystem analysis
- Additional survey on market and circulation of agricultural products and inputs
- Develop extension plans, revision and updating

Output 2: develop and improve agricultural technologies and methods appropriate fro extension

- Develop research and development plan in line with agricultural extension plans
- Conduct experiment and demonstration on rice and non-rice cultivation
- Improve guidelines and extension materials on rice and non-rice cultivation
- Improve guidelines for rice-based farming system and agricultural diversification

Output 3: deliver improved agricultural extension services

- Capacity building of related organization and personnel through training on farm management and rice and non-rice cultivation
- Promotion and facilitation on quality rice seeds
- Promotion and facilitation on animal husbandry and fish farming

- Facilitation and promotion of farmer group activities

Output4: enhance collaboration among parties involved

- Assist target commune councils to form commune investment plan
- Collaborate with market actors to enhance market access for farmers
- Exchange information and coordinate activities with other programs and project
- Present achievement and lessons learnt by the project to the central government and make recommendations

Target districts/communes:

- Battambang/ Wat Kor
- Sangker/ Kampong Preah
- Ek Phnum/ Prek Luong
- Thamrkol/ Boueng Pring

Relation to the Study:

The project is on-going but does not contain irrigation and drainage development. Accordingly, the above communes or irrigation area, if any, can be taken into account in the Study. The possibility of inclusion of those communes in the Master Plan will be determined comprehensively in the irrigation and drainage plan in the Study.

D1.3.6 Bassac Reservoir Rehabilitation Project

Bassac reservoir was constructed in upstream of Moung Russey River in Moung Russey District in 1975-1979. The construction work of the reservoir and irrigation facilities were not completed, and abandoned up today. The Government of Japan decided to assist the rehabilitation work of the project by Non-project Grant Aid based on the request from MOWRAM and PDOWRAM Battambang Province.

The project scope contains as follows:

- Dike rehabilitation; slope protection by stone pitching, laterite surfacing on top
- Spillway rehabilitation; reconstruction
- Intake structure for Stung Sa Canal; construct a new structure
- Canal rehabilitation; excavation
- Access road; 10km laterite pavement

After the rehabilitation, the reservoir is reported to have 32 million m3 of effective storage[2], and possible to irrigate 20,000 ha.

2 Project Proposal for Bassac Reservoir Rehabilitation Project in Battambang Province, MOWRAM, October 2005

Relation to the Study:

The Study Team also agrees that the reservoir is located at a vital point in the Moung Ruessy River though the storage capacity is not yet confirmed. The above scope appears lack of some facilities such as irrigation and drainage canals, etc. The project has to be contained in the Study for not only water balance study but also in the Master Plan. The necessary additional cost is to be reviewed in the Study.

D1.3.7 Thlea Maom Irrigation Rehabilitation Project

Thlea Maom Irrigation Rehabilitation Project is located in Boeung Kantuot Commune, Krakor District, Pursat Provinve in the Thlea Maom River basin which is one of the tributaries of Boribo River. The irrigation system was constructed in 1978, but deteriorated severely.

The PDOWRAM has strong intention to rehabilitate the system to irrigate about 1,700 Ha. The design of rehabilitation work has been executed in Technical Service Center under JICA as a model pilot project for on-the-job training.

The project scope contains as follows:

- Repairing barrage
- Rehabilitation of main canal 6.6km
- Rehabilitation of secondary canal 15.6km
- Rehabilitation of tertiary canal 40km
- Construction of canal related structures in the irrigation canals

The project will be implemented in 3 phases, and the total cost is estimated at about US$ 1.1 million. The construction work will be executed by force account by MOWRAM/PDOWRAM. The budget will be expected to be financed by RGC.

Relation to the Study:

The project is already promised for implementation by MOWRAM. Accordingly, the project area is to be taken into account in the water balance study in the Study, but excluded in the Master Plan.

D1.3.8 Toul Kou Irrigation Project

The project is located at Kien Villages, Kos Chum Commune, Sompovmeas District, Pursat Province in the Pursat River Basin. The project was constructed in 1976, and left severely deteriorated. In 2004, the dike and intake structure were rehabilitated under Japanese Grant Assistance for Grass-roots project. The irrigation system, however, needs canals and related structures to deliver irrigation water to fields.

The Government of Japan decided to assist irrigation development as a Gross-roots Project. The project scope contains as follows:

- Construction of dike of 1,274m
- Construction of canal of 3,109m

- Construction of related structures 18 nos.
- Laterite surface spreading in 2,505m

The total cost is estimated at US$79,810. After the rehabilitation work, the wet season and dry season irrigation area are expected to increase remarkably.

Relation to the Study:

The project area is located in the downstream of the Pursat River Basin, and contains recession rice area. The project will be a model of similar irrigation of reservoir and recession system in the Study area.

The project has been already promised. Accordingly, the project area is to be taken into account in the water balance study in the Study, but excluded in the Master Plan. However, the project will be a model of similar irrigation system in which a combination of reservoir and recession system is contained.

D1.3.9 Tonle Sap Lowland Stabilization Project

The development objectives is to improve livelihoods of households inhabiting the lowland project area so that they will be less inclined to unsustainably extract the natural resources of the Core and Buffer Zones of the TSBSR, thereby reducing the pressure on the natural resources vital to the integrity of the TSBR.

The objective of the project is to prepare a design of a bankable project for possible ADB financing taking into account i) sustainable livelihood activities, ii) environmental considerations, iii) consultations of the stakeholders concerned and iv) packaging of suitable investments in subprojects.

The project (Study) selected 31 communes in six Provinces in the Tonle Sap basin. The project proposed the following components:

1. Support to rural infrastructure such as irrigation facility, rural roads, bridges, culverts,
2. Increasing options in rural communities such as on-farm income generating options, improving off-farm income generation options, improving access to micro-credit,
3. Skills and awareness raised such as training and capacity development, enhance skills of farmer beneficiaries for income generation, agriculture and off-farm vocations, awareness of gender equality and environmental issue in rural community,
4. Environmental and social safeguards

The study estimated the total project cost at US$32 million which contains US$27 million grant. ADB mission who was attended the workshop expressed as follows:

a. The project will cover comprehensive range of intervention
b. The scope of the project and subprojects will be reviewed taking into consideration other similar projects activity in the target area
c. ADB will finance US$20 million for project implementation in 2007

d. The project will be approved by board last quarter of 2007

The target area selected in the four river basins are listed as follows.

Selected Communes of Tonle Sap Lowland Stabilization Project (14 March 2007)
(Related to the Study only)

Province	District	Commune	Category	River basin
Pursat	Bakan	Boeng Khnar	*1	Pursat
	Bakan	Rumlech	*2	Pursat
	Bakan	Khnar Toteng	*1	Pursat
	Kandieng	Srae Sdok	*2	Pursat
	Kandieng	Anlong Vil	*1	Pursat
	Krakor	Tnaot Chum	*1	Boribo
	Krakor	Kbal Trach	*1	Boribo
Kg. Chhnang	Boribo	Khor Rang	*1	Boribo
	Boribo	Melum	*1	Boribo
	Boribo	Kg. Preah Koki	*1	Boribo
	Kg, Tralach	Saeb	*1	Boribo

*1 Selected target communes of TSLSP (30 November 2006)
*2 Selected core communes of TSLSP (22 January 2007
Source: Draft Final Report TA No. 4756-CAM Tonle Sap Lowland Stabilization Project

Relation to the Study:

The above communes and or its irrigation area will not be eliminated in the initial stage of the Study because:

1. The project does not guarantee water source to the communes though it will contain rehabilitation work of irrigation facilities.
2. The rehabilitation of irrigation facilities by the project may partly contribute to tertiary irrigation system development which will be proposed by the Study, provided that the area would be included in the Master Plan of the Study.

Those communes are not eliminated in the Study. The inclusion of those communes in the Master Plan will be determined comprehensively in the irrigation and drainage plan in the Study.

D1.3.10 Study on Water Resources Potential for Hydropower and Irrigation Development in Cambodia

In March 1999, MOWRAM collected information on the water resources potential for hydropower and irrigation development. The information was collected from previous studies as follows:

1. Inventory of Promising Water Resources Projects Outside the Lower Mekong Basin in the Khmer republic, November 1973
2. Summary of Project Possibilities of Lower Mekong Water Resources Inventory, September 1984
3. Review and Assessment of Water Resources for Hydropower and Identification of Priority Projects in Cambodia, MRC, June 1995

In the MOWRAM study, 48 name were listed up. Out of them 11 names seem to be related to the Study as shown in Table D1.3-3. Out of 11, the situation of 4 names have been developed by applying technical assistance, already constructed, etc as follows:

a. In the Table D1.3-3, No. 1 and 2 Battambang 1 and 2 was proposed to feasibility study and is waiting list of technical assistance by KOICA.

b. No. 3 Battambang diversion weir seems to be same as Kong Hort Irrigation System. There is a unfunctioning weir which was constructed during Pol Pot days.

c. No. 4 Lower Moung diversion weir seems to be same as Prek Chik Irrigation System in the Mount Russey River. There is a unfunctioning diversion weir which was constructed during Pol Pot days. This system is included in the candidate sub-project of NWISP as described in D1.3.1.

Relation to the Study:

The above communes and or its irrigation area will not be eliminated in the initial stage of the Study because:

1) In the Table D1.3-3, No. 3 Battambang diversion weir seems to be same as Kong Hort Irrigation System. The development possibility of Kong Hort Irrigation system will be studied as well as the others irrigation systems in the Study.

2) No. 10 Stung Pursat diversion weir seems to be replaced by Damnak Ampil diversion weir as described in section D1.3.3. Accordingly, the development possibility of Damnak Ampil weir and irrigation system will be studied as well as the others irrigation systems in the Study.

3) The possibility of water resources development by dams proposed in the MOWRAM's study is hardly studied because no technical data and information is available such as reliable long-term river runoff data at the proposed site, topographic map of dam and reservoir site, etc. Accordingly, the considered dam and water resources development projects is hardly incorporated in the Study.

D1.4 Irrigation and Drainage Systems

D1.4.1 General Condition of Irrigation Systems

(1) Characteristics of Irrigation Systems

The following tables show the irrigation command area by system size and irrigation systems by type.

Irrigation Area by System Size

Classification	No. of System	Irrigation Command Area	Paddy Field	Cropping Area of Paddy				
				Total	Wet-1	Wet-2	Dry	Reces-sion
< 200 ha	202	10,462		10,778	280	6,498	1,822	2,178
200 – 5000 ha	113	82,489		98,603	5,058	74,592	3,912	15,041
> 5000 ha	5	33,368		36,083	650	32,728	2,705	0

Sub-Total					5,988	113,818	8,439	17,219
Total	320	126,319	494,310	145,464				

Source: JICA inventory 2004

Irrigation Systems by Type

Classification	No. of System	Reservoir Type		River Type		Pond Type			
		1a	1b	2a	2b	3a	3b	3c	3d
< 200 ha	202	0	0	66	25	31	13	8	59
200 – 5,000 ha	113	32	4	57	26	0	0	2	2
5,000 ha <	5	2	0	2	1	0	0	0	0
Sub-Total	320	35	5	125	42	30	12	10	61

Source: JICA inventory 2004

Note: The systems categorized in reservoir by JICA inventory were re-evaluated in consideration of the size. Basically, the system with area of less than 200 ha was categorized as a pond type in the table above.

As presented in the tables, small systems occupy 63% of all system. The average size of the systems is 50 ha. Around 55% of the systems are categorized into the pond type, which have multi-function such as irrigation and domestic water supply.

The average size of medium size systems is 730 a, and the systems occupy 65 % of irrigated paddy field. These systems play a key role in the study area.

The number of large systems is limited to five (5). These systems were constructed in the Battambang, Pursat and Boribo river basins where the rivers have relatively abundant water sources.

(2) Irrigation Ratio

Ration of irrigated agricultural land is calculated at 26% in the study area. In addition, most of the irrigation systems are suffering from serious deterioration of irrigation and drainage facilities. Consequently, the actual ratio would be much smaller than 26%. In this regard, rehabilitation of existing irrigation systems is urgent needs.

(3) Irrigation Canals

Technical problems are pointed out in irrigation canal network. In order to clarify the problems, canal capacity of irrigation canals was examined based on the topographic survey result conducted by the Study team.

The uniform-flow formula, Manning's formula, is employed for the analysis. Basic dimensions for canal section are based on the "Design Manual For Small and Medium Scale Irrigation System Planning" prepared by MOWRAM in 2004.

The following table shows the result of the canal capacity analysis.

Canal Capacity of Existing Canals

unit	ha		(m^3/s)	(m^3/s)	(m^3/s)
Battambang River basin					
1 Thmat Pong	310	1/ 2,000	0.6	1.7 - 2.2	2.0
2 Vat Balat	330	1/ 3,000	0.7	1.9 - 15.6	5.0
3 Bot Sala	260	1/ 2,000	0.5	17.2 - 32.7	20.0
Moung Russey River Basin					
4 Prek Chik					
Main Canal	18,470	1/ 1,500	34.0	1.6 - 39.4	20.0
5 Por canal					
Main Canal 1	2,500	1/ 1,400	4.6	5.4 - 24.9	15.0
Main Canal 2		1/ 3,400		1.2 - 5.1	1.5
6 Ream Kon	4,700	1/ 2,000	8.6	1.1 - 7.4	5.0
Pursat River Basin					
7 Wat Loung	5,700	1/ 7,000	9.7	0.4 - 16.5	6.0
8 Beoung Preah Ponley	2,820	1/ 1,600	4.8	0.4 -10.9	3.0
9 Wat Chre					
Main Canal 1	1,000	1/ 1,300	1.7	0.2 - 27.1	3.0
Main Canal 2		1/ 20,000		1.3 - 17.0	2.0
Boribo River basin					
10 Lum Hach	18,165	Reverse slope	33.1	-	-
11 Khvet	560	1/ 220	1.0	0.1 - 11.5	-
12 Ta Ram	380	1/ 300	0.7	0.4 - 5.1	2.0
13 Chan Keak	170	-	0.3	-	-
14 Teuk Laak					
Secondary 1	180	1/ 600	0.3	0.6 - 9.7	3.0
Secondary 2		1/ 1,600		0.2 - 1.2	0.5
15 Trapeang Thlann: Sec.	220	1/ 900	0.4	3.5 - 11.2	8.0
16 Toul Champei	360	1/ 900	0.7	8.7 - 27.4	10.0

In general, existing canals have enough capacity to irrigate potential irrigation areas excluding some sections. These canals may be used as storage and regulating ponds.

Some sections of these canals lose their original shapes completely, and require re-shaping to recover their original capacity.

D1.4.2 General Condition of Drainage Systems and Flood

(1) Present Condition of Drainage Systems in the Study Area

According to "JICA inventory", topographic survey and supplementary inventory survey by the study team, there found very few numbers of irrigation system in which apparent drainage systems are installed in the study area; there are two systems in the Battambang River Basin and Boribo River Basin, 1 system in Pursat River Basin, none in Moung Russey River Basin. The present conditions of 5 drainage systems found in the study area were described as follows:

Present Condition of Drainage Systems in the Four River Basins

Description / River Basin	No. of System w/ Drain	Code, Name of System		Drainage Canal Dimension					Remarks
		Code by JICA		Type	Length (km)	Width (m)	Height (m)	Density (m/ha)	
Battambang RB	2	BAN005	Chheu Teal	Main	3.1	4 - 6	0.8-1.4	4.0	SC-MD-Stream
		SNK005	Vat Balat	Main	1.4	6 - 7	0.6-1.0	4.2	MCend-Stream
Moung Russey RB	0	-	-	-	-	-	-	-	MC-SP-Stream

Pursat RB	1	SPM002	O Roka	Main	1.0	5 - 10	1.0-1.5	0.6	MCend-Stream
Boribo RB	2	KRK007	Bantey Krorng	Main	2.8	5 - 6	2.0-4.0	9.7	Identical w/ MC?
		RLP004	Bantey Chea	Main	2.0	15 - 20	1.5-2.0	11.8	Pond-Stream
Total/ (Average)	5	-	-	-	10.3	(8.4)	(1.6)	(6.1)	

Source: Prepared by the Study Team based on: Final Report of The Survey on The Irrigation System Inventory for The River Basin of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot, JICA, Aug., 2006

(2) Type of Present Drainage Systems in the Study Area

From the location of water sources (streams, pond), irrigation canal net works (MC: main canal, SC: secondary canal), related structures (SP: spillway, etc.), the above existing drainage systems are described and roughly categorized as follows:

D1) Drainage of excess water from main canal, at

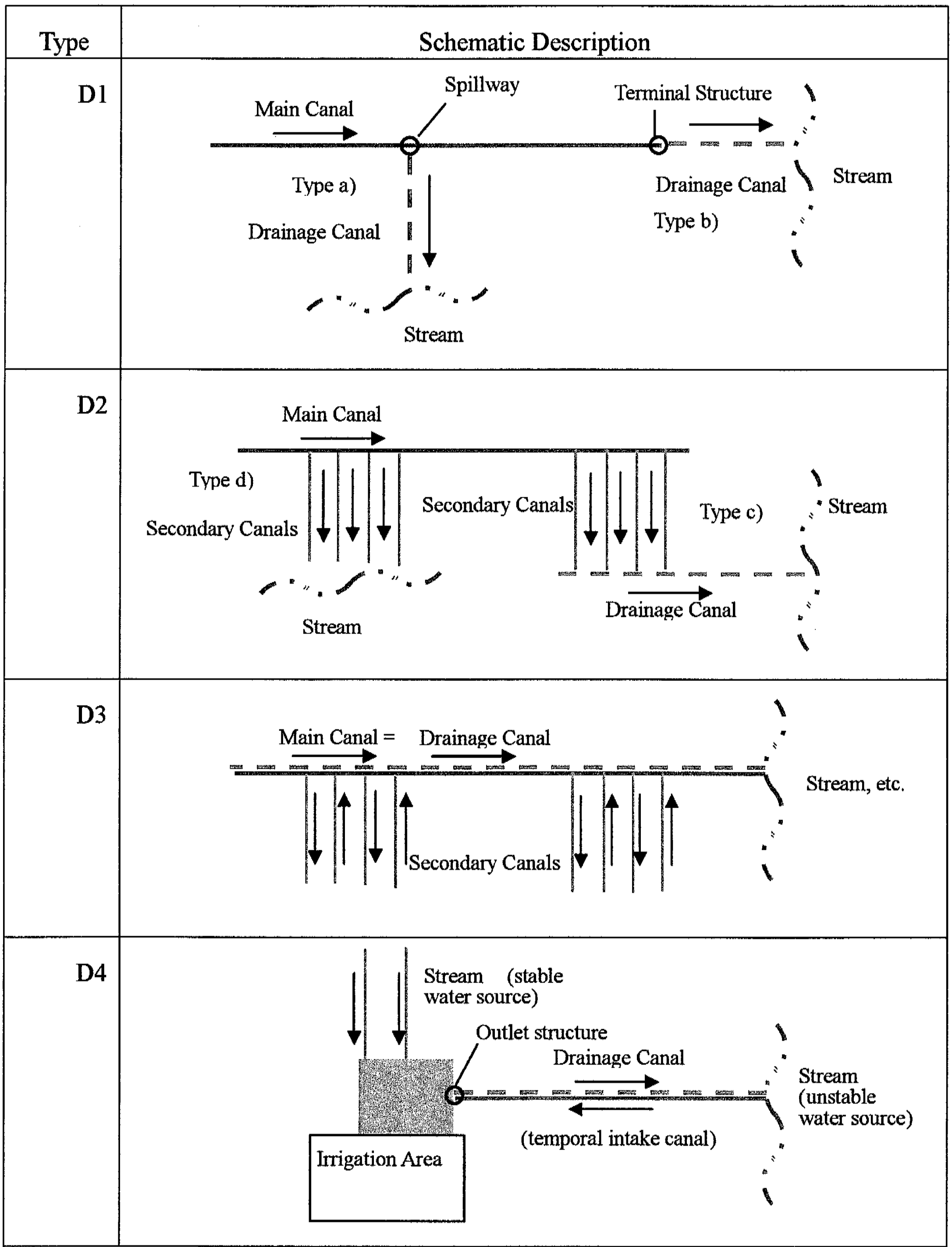
- a) mid-point of MC, using spillway connected to drainage canal to stream: O Roka
- b) tail-end of MC, using terminal structure connected to drainage canal to stream: Vat Balat

D2) Drainage of run-off water from secondary canal, at

- c) tail-end to drainage canal to stream: Chheu Teal,
- d) tail-end, direct drainage to stream: O Roka

D3) Using main canal as drainage canal to stream: Bantey Krorng

D4) Connecting stream and pond by a canal, mainly used as main drainage canal, temporary used as intake canal depend on water level: Banteay Chea



Description of Drainage System Types Found in Study Area

(3) Overall Condition of Present Drainage Systems

Overall, in the study area, most of the systems, which were not clearly categorized nor mentioned in the JICA Inventory, fall into category of Type D3. Since in many systems, water is supplied to paddy field through so called "plot to plot" irrigation under rain-fed and/or partially irrigated condition, it works under an adequate rainfall condition. However, under a moderate heavy to heavy rainfall, it seems that the excess water remained over paddy field sometimes inundating crops, due to lack of adequate intake nor terminal structures with poor water management. Therefore, installation of an adequate drainage system is desirable for the drainage of excess water from paddy field to increase as well as to stabilize rice production.

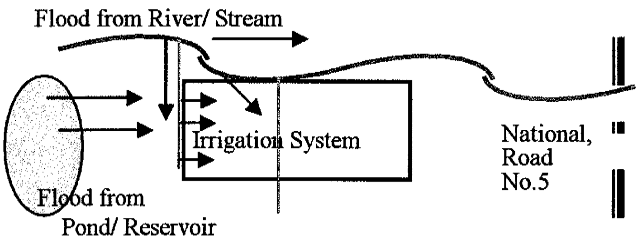
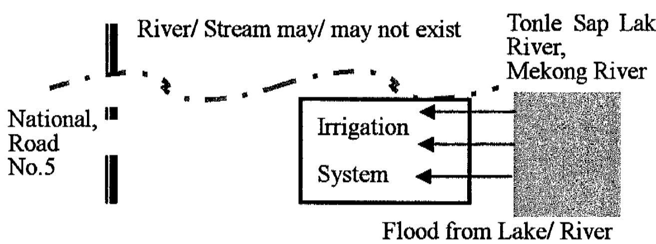
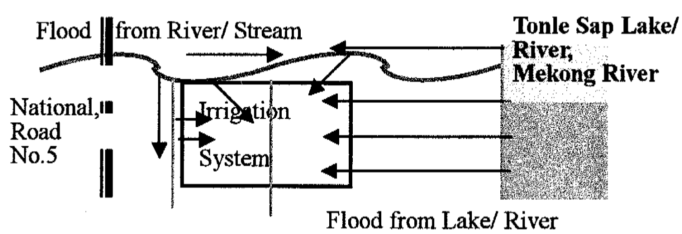
(4) Present Condition of Flood in the Study Area

According to "JICA inventory" and the survey results by the study team (topographic survey and supplementary inventory survey as well as socio-economic survey in the sample areas) the flood conditions in the study area was able to classified mainly into the following 3 types:

F1) Damaged due to flush water from upstream of rivers/streams or ponds/reservoirs, especially rather upstream region of the National Road No.5

F2) Affected and damaged due to flooding of Mekong River, Tonle Sap River, Tonle Sap Lake, especially downstream region and vicinity of the National Road No.5

F3) Affected and damaged due to both upstream flush water and flood in downstream

<table>
<tr><th>Type</th><th>Schematic Description</th><th>Remarks/ Cause of Flood</th></tr>
<tr><td>F1</td><td>
</td><td>- River/ Canal section is insufficient compared to flood discharge
- Lack of Drainage system
- Storage capacity of Pond/ Reservoir is relatively small to run-off water
- Dyke of Pond/ Reservoir is damaged</td></tr>
<tr><td>F2</td><td>
</td><td>- Protection dyke is installed partially / Not installed along irrigation system
- Flood discharge from upstream is stagnated by higher water level in the Lake/ River or by flux flow from downstream (under existence of a river/ stream)</td></tr>
<tr><td>F3</td><td>
</td><td>- Combination of causes in Types F1 and F2
- Flood discharge from upstream is stagnated by higher water level in the Lake/ River or by flux flow from downstream</td></tr>
<tr><td colspan="3">Description of Flood Condition Types Found/Estimated in Study Area</td></tr>
</table>

Following table shows the results of flood type classification in the study area. It was found that 85 systems (27% of 320) or about a total area of 12,400 ha (10% of actual existing area) are affected by either above 3 types of flood. It is noted that since Type F3 is difficult to distinguish from Type F2, the systems between National Road 5 and Lake/Mekong, part of Type F3 is included in Type F2.

Based on flood type-wise, 18 systems (21%) or 5,430ha (44%) of the affected area fall into Type 1, while 64 systems (75%) or 6,490ha (52%) of the affected area into Type 2. 3 systems (4%) or 474ha (4%) of the affected area are classified as intermediate type.

On the other hand, in basin-wise, 16 systems (19%) or 3,665ha (29%) of the affected area are in the Battambang River Basin, and 5 (6%) or 1,230ha (9%) of the affected area in the Moung Russey River Basin. There are 2 systems or 600ha of the affected area in the Pursat River Basin. The Boribo River Basin has the largest in number of the affected systems or areas by flood; 62 (73%) systems and 6,909ha (56%). Among the Basin, most of these affected systems are concentrated in Kampong Chhnang District, between the National Road No.5 and Tonle Sap Lake/River or the Mekong River; 47 systems (76% of the Basin, 55% of the study area) or 5,978ha (86% of the Basin, 42% of the study area), where the Type 2 is the dominant with 40 systems or 4134ha (60% and 33% of the all affected areas in the Basin and in the study area, respectively.

Present Condition of Flood Type in the Four River Basins

Description / River Basin	Flood Type 1)		Flood Type 2)		Flood Type 3)		Remarks
	No. of Systems	Affected Area (ha)	No. of Systems	Affected Area (ha)	No. of Systems	Affected Area (ha)	
Battambang RB	12	3,070	4	585	-	-	16 nos.(19%), 3,655ha (29%)
	(6)	(2,940)	(-)	(-)	-	-	Aek Phnum District
	(6)	(130)	(4)	(585)	-	-	Sang Ker, Banan Districts
Moung Russey RB	1	490	4	740	-	-	5 nos.(6%), 1,230ha (10%)
	(1)	(490)	(3)	(690)	-	-	Moung Russey River *
	-	-	(1)	(50)	-	-	Svay Don Keo River *
Pursat RB	1	500	1	100	-	-	2 nos.(2%), 600ha (5%) Pursat River Basin *
Boribo RB	4	1,370	55	5,065	3	474	62 nos.(73%), 6,909ha (56%)
Pursat	-	-	-	-	-	-	Krakor District
Kg. Chhnang	(3)	(970)	-	-	-	-	Tuek Phos District
	-	-	(4)	(435)	-	-	Kg. Chhnang District
	-	-	(9)	(1,255)	-	-	Roleaphiear District
	(1)	(400)	(27)	(2,444)	(3)	(474)	Kg. Tralach District
Kandal	-	-	(15)	(931)	-	-	Ponheo Lueu District
Kg. Speu	-	-	-	-	-	-	
Total	18	5,430	64	6,490	3	474	85 nos., 12,400 ha

Source: Prepared by the Study Team based on: Final Report of The Survey on The Irrigation System Inventory for The River Basin of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot, JICA, Aug.,2006

**:Referred to Socio- economic survey (interview) results on the sample system in by the Study Team*

(6) Analyses on Flood Damage in the Study Area

Through the examination of the above flood condition, the followings were pointed out:

1) Damage/ destruction of weirs due to flush water from upstream of rivers:

- Lack of "Design Flood Discharge" data due to lack of chronicle rainfall data statistical analyses on rainfall and run-off/ river discharge

- Therefore, the structures were not properly designed, as example below:

  a) free board of inspection bridge against the flood discharge water level was insufficient so that the top slab was flushed away by flood.

  b) Size of spillway against the flood discharge was insufficient so that the structure was damaged by flood.

- The following irrigation systems have specific "Design Flood Discharge" data for weirs in the study area, however the return periods for flood discharge must be revised:

Irrigation Systems with Design Flood Discharge

Description / River Basin	Name of Irrigation System	Code by JICA	Flood Gate (W x H x Nos)	Design Flood Discharge (m^3/s)	Remarks Total Width (m)
Battambang RB	Bour Khnar	SNK-003	Flood gate: 2.0 x 2.5 x 1 Scourring Sluice: 2.0 x 1.5 x 1	7.0	Fixed Type B=20m
Moung Russey RB	Dai Ta Chan	MRS-018	No Data	25.0	Fixed Type, 30m
	Nikom Le	MRS-017	No Data	20.0	Fixed Type, 25m
	Prek Chic	MRS-006	2.35 x 5.2 x 7 Non-Gate	93.0	Fixed Type, 20m
	Ream Kon	MRS-006	1.45 x 1.2 x 10	7.0	Fixed Type, 20m
	Por Canal	MRS-005	1.45 x 1.2 x 10	7.0	Fixed Type, 20m
Pursat RB	Damnak Ampil	SPM-003	10.0 x 5.0x 7		Fixed Type, 144m
	Kbal Hong	KND-002	2.85 x 3.37 x 27	690.0	Fixed Type, 132m
Boribo RB	Thlea Maam	KRK-003	2.25x3.0x5, 3.0x3.0x10, 52.0	101.8	Fixed Type, Overflow 41.25m, Non-overflow 10.07m

2) Damage/ destruction of ponds and reservoirs due to flush water from upstream of rivers:

   - Lack of "Design Flood Discharge" data, etc., as pointed out in the above, so that the structures were not properly designed as example below:

     a) Size of spillway against the flood discharge was insufficient so that the structure as well as dykes, dam embankment was damaged/ destroyed by flood.

3) Damage/ deterioration of irrigation systems by flooding of downstream water sources:

   - Flood water from downstream water sources, such as Tonle Sap Lake (for Battambang, Pursat Provinces), Tonle Sap River and Mekong River (especially for a part of Kampong Chhnang and Kandal Provinces) covers, damages and deteriorates irrigation systems.

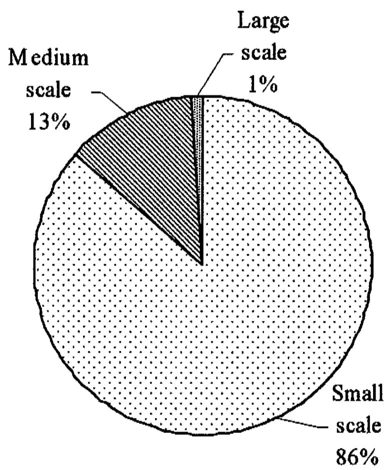
   - The above condition may be a "Trade-off" with the Traditional "Recession Irrigation method", however, forces farmer's effort to rehabilitate canal systems and related structures after flood event/ season every year.

   - In some cases, the flood water seem to intrude through week points on protection dykes along irrigation systems and damages the systems.

D1.4.3 Irrigation Systems in the Battambang River Basin

(1) The number and scale of irrigation systems

There are 88 irrigation systems[3] in Battambang River basin. These systems are classified into three (3) scales in conformity with the Cambodian standard as follows.



Irrigation Scale	Number / Ratio
Small scale (less than 200 ha)	76 systems (86.4 %)
Medium scale (from 200 to 5000 ha)	11 systems (1 2.5 %)
Large scale (more than 5000 ha)	1 system (1.1 %)

Scale Classification of Irrigation System

As shown in the figure above, small system occupies 86 % of 88 systems, and the large numbers of small systems is characteristic of the river basin.

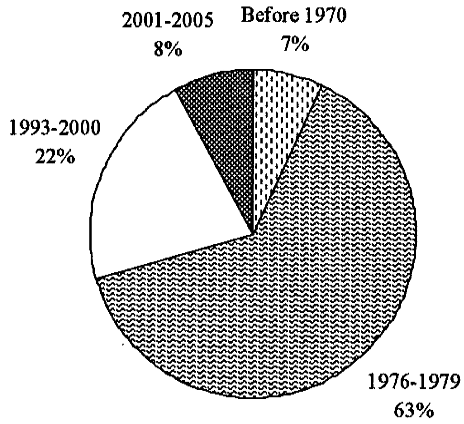
The reasons why the small systems occupies large ratio may be:

- no existing irrigation weir in the Battambang River,
- water supply to irrigation system depending on pumps along the Battambang River, and
- no other stable water sources than the Battambang River.

(2) Construction works

A total of fifty-six (63 %) irrigation systems were constructed in four (4) years from 1976 to 1979. These systems were damaged in a few years after construction, and lost their functions. Construction works of irrigation systems were re-started in 1993, and 26 systems have been constructed by the end of 2005.

[3] JICA, Aug., 2006: " Final report of the survey on the irrigation system inventory for the river basins of Battambang, Dauntri, Pursat, Boribo and Remaining Part of Prek Thnot"

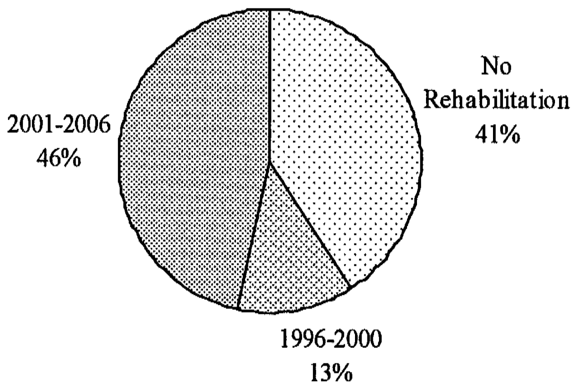


Construction Year of Irrigation System

(3) Rehabilitation works

Rehabilitation works commenced in 1996, and rehabilitated a total of 52 systems by 2006. Thirty-six (36) systems remain un-rehabilitated.

As for rehabilitation fund sources, government and SEILA program occupy 46 %, and NGO follows with the ratio of 21 %. Local peoples' contribution and commune funds account for 6 % respectively.



Rehabilitation Year of Irrigation System

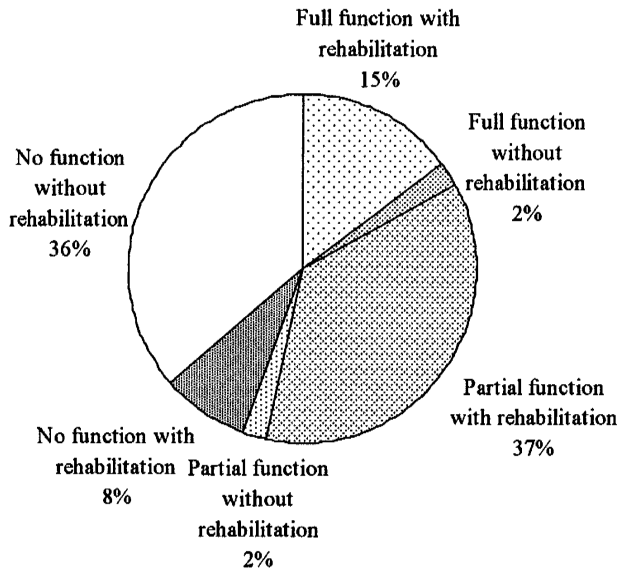
(4) Present status of irrigation system

Irrigation systems are categorized into the following 6 in consideration of their present function.

- Full function without rehabilitation works
- Full function after rehabilitation works
- Partial function without rehabilitation works
- Partial function after rehabilitation works

- No function without rehabilitation works
- No function after rehabilitation works

The following figure shows the ratio of each classification.



Present status of irrigation system

Despite the rehabilitation works to 52 systems, only 14 (27%) systems recovered their full function. The main reasons of this low ratio of achievement of system recovery are considered to be:

- lack of funds for comprehensive rehabilitation works,
- lack of irrigation canals, and
- lack of water control facilities.

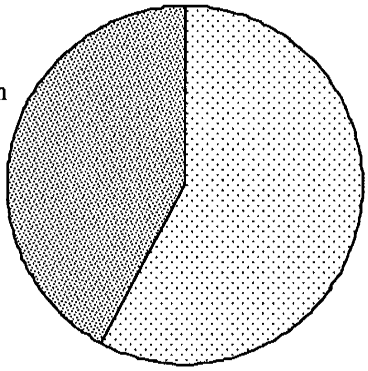
Many projects rehabilitated only a part of emergency works such as culverts construction. Water control structures such as check and turnout with gate have not yet been restored in most systems.

As shown in the figure above, around 80 % of systems belong to the status of "No Function" or "Partial Function". Moreover, some systems in the category of "Full Function" still require rehabilitation.

D1.4.4 Irrigation and Systems in the Moung Russey River Basin

(1) The number and scale of irrigation systems

There are 45 irrigation systems in Moung Russey River basin. These systems are classified into three (3) scales in conformity with the Cambodian standard as follows.

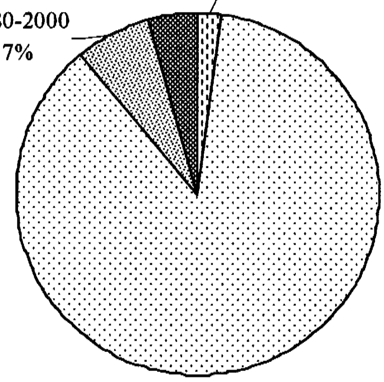


Irrigation Scale	Number / Ratio
Small scale (less than 200 ha)	26 systems (58 %)
Medium scale (from 200 to 5000 ha)	19 systems (42 %)
Large scale (more than 5000 ha)	0 system (0 %)

Scale of Irrigation Systems

(2) Year of construction and rehabilitation

In four (4) years from 1976 to 1979, the government constructed 39 (87%) irrigation systems. Unfortunately, these systems lost their function in a few years after completion by many reasons such as flood damage, lack of well-considered design, and low quality of construction materials. Since 1994, five (5) systems have been constructed.



Construction Year of Irrigation System

Local people, central and local governments, NGOs, and foreign donors have rehabilitated 12 systems since 1997.

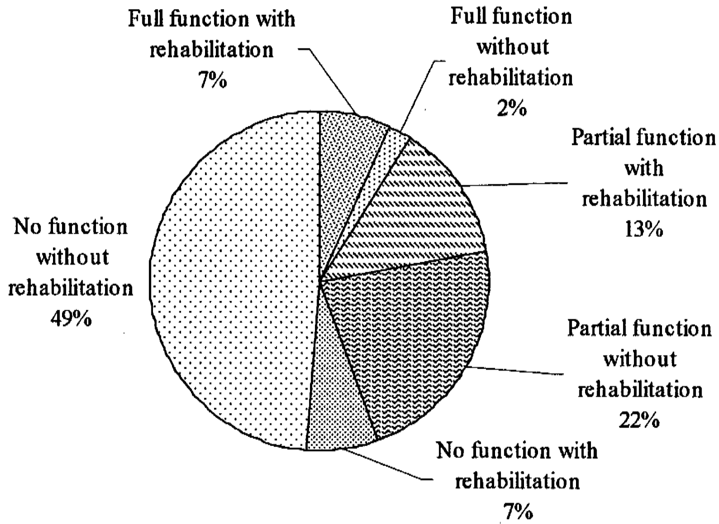
Despite the rehabilitation works to 12 systems, only 3 (25 %) systems recovered their full function. The main reasons of this low rate of achievement of system recovery are considered to be:

- lack of funds for comprehensive rehabilitation works,
- lack of irrigation canals, and
- lack of water control facilities.

Many projects rehabilitated only a part of emergency works such as culverts construction. Water control structures such as check and turnout with gate have not yet been restored in most systems.

(3) Present status of irrigation system

Irrigation systems are categorized into the following six (6) in consideration of their present function. As shown in the figure below, around 85 % of systems belong to the status of "No Function" or "Partial Function", which requires rehabilitation works. Moreover, according to the JICA inventory survey, some systems in the category of "Full Function" still require rehabilitation.

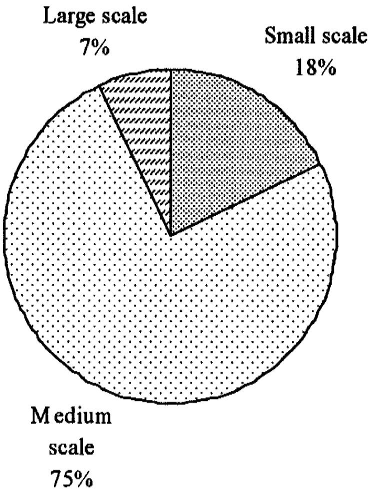


Present status of irrigation system

D1.4.5 Irrigation Systems in the Pursat River Basin

(1) The number and scale of irrigation systems

There are 28 irrigation systems in the Pursat River basin. These systems are classified into three (3) scales in conformity with the Cambodian standard as follows.

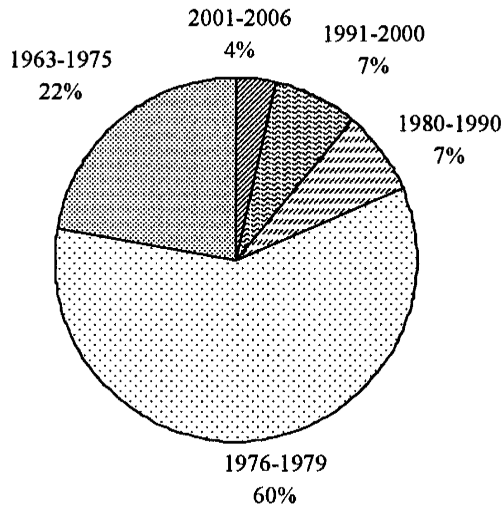


Scale of Irrigation Systems

Irrigation Scale	Number / Ratio
Small scale (less than 200 ha)	5 systems (18 %)
Medium scale (from 200 to 5000 ha)	21 systems (75 %)
Large scale (more than 5000 ha)	2 system (7 %)

(2) Year of construction and rehabilitation

In four (4) years from 1976 to 1979, the government constructed 16 irrigation systems, which are equivalent to 60% of a total of 28 projects. Unfortunately, these systems lost their function in a few years after completion by many reasons such as flood damage, lack of well-considered design, and low quality of construction materials. Since 1994, five (5) systems have been constructed.



Construction Year of Irrigation System

Local people, central and local governments, NGOs, and foreign donors have rehabilitated 12 systems since 1997.

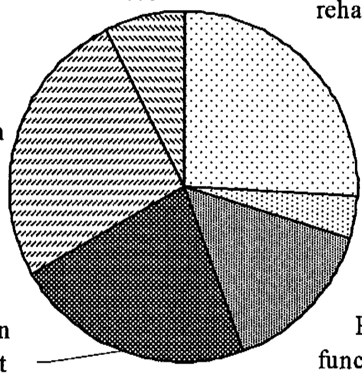
Despite the rehabilitation works to 12 systems, only 3 (25 %) systems recovered their full function. The main reasons of this low rate of achievement of system recovery are considered to be:

- lack of funds for comprehensive rehabilitation works,
- lack of irrigation canals, and
- lack of water control facilities.

Many projects rehabilitated only a part of emergency works such as culverts construction. Water control structures such as check and turnout with gate have not yet been restored in most systems.

(3) Present status of irrigation system

Irrigation systems are categorized into the following six (6) in consideration of their present function. As shown in the figure below, around 70 % of systems belong to the status of "No Function" or "Partial Function", which requires rehabilitation works. Moreover, according to the JICA inventory survey, some systems in the category of "Full Function" still require rehabilitation.

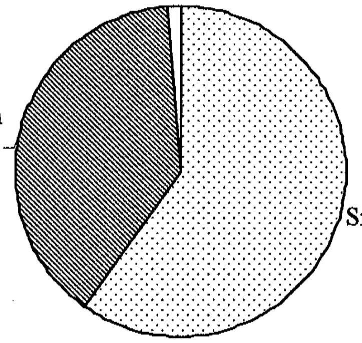


Present status of irrigation system

D1.4.6 Irrigation and Systems in the Boribo River Basin

(1) The number and scale of irrigation systems

There are 159 irrigation systems in the Boribo River basin. These systems are classified into three (3) scales in conformity with the Cambodian standard as follows.

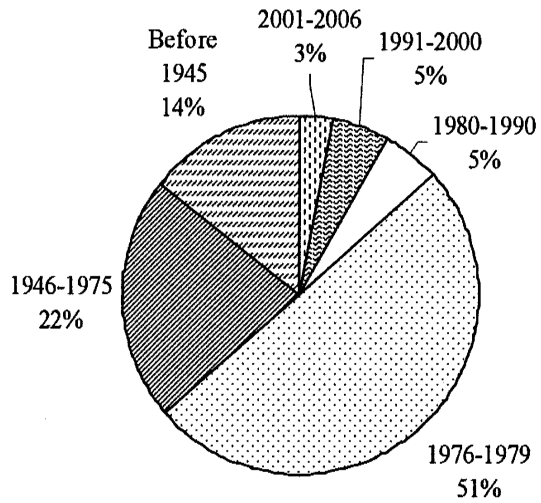


Scale of Irrigation Systems

Irrigation Scale	Number / Ratio
Small scale (less than 200 ha)	95 systems (39%)
Medium scale (from 200 to 5000 ha)	62 systems (60%)
Large scale (more than 5000 ha)	2 system (1%)

(2) Year of construction and rehabilitation

In four (4) years from 1976 to 1979, the government constructed 80 irrigation systems, which are equivalent to 51% of a total of 159 systems. Unfortunately, these systems lost their function in a few years after completion by many reasons such as flood damage, lack of well-considered design, and low quality of construction materials. Since 1980, 21 systems have been constructed by the end of 2006.



Construction Year of Irrigation System

Local people, central and local governments, NGOs, and foreign donors have rehabilitated 112 systems since 1979.

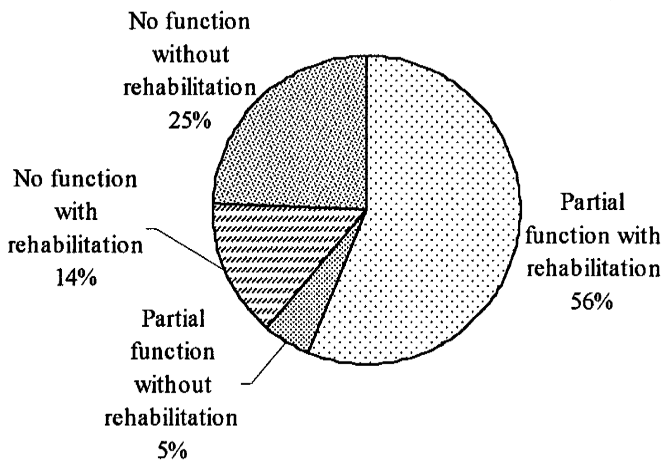
Despite the rehabilitation works to 112 systems, no systems recovered their full function. The main reasons of this low rate of achievement of system recovery are considered to be:

- lack of funds for comprehensive rehabilitation works,
- lack of irrigation canals, and
- lack of water control facilities.

Many projects rehabilitated only a part of emergency works such as culverts construction. Water control structures such as check and turnout with gate have not yet been restored in most systems.

(3) Present status of irrigation system

Irrigation systems are categorized into the following four (4) in consideration of their present function. As shown in the figure below, around 40 % of systems belong to the status of "No Function". In spite of rather frequent maintenance works, all the system requires rehabilitation in this river basin.



Present status of irrigation systems

D1.5 Operation and Maintenance, Water Management

D1.5.1 Responsible Organization

The responsible organization for operation maintenance including water management is the Irrigated Agriculture Department (IAD) of MOWRAM.

IAD consists of the following five (5) offices.

- Administration Office
- Irrigation and Drainage Office

  Main activities: Rehabilitation of small-scale irrigation system, and O&M

- Pumping Station Office

  Main activities: Fuel supply to pump irrigation system

- Community Office

  Main activities: Formation and registration of Farmer Water User Community

- Emergency Relief Office

  Main activities: Dispatch of pump units in an emergency flood time

D1.5.2 Government Policy

According to Policy for Sustainability of O&M Irrigation system of Circular No.1 prepared by MOWRAM, the government intends to transfer O&M to FWUCs in a gradual manner as shown below.

In year one: the government shares 80% and the farmer members 20%

In year two: the government shares 60% and the farmer members 40%

In year three: the government shares 40% and the farmer members 60%

In year four: the government shares 20% and the farmer members 80%

and in year five: the government shares 100% and the farmer members 0%.

The policy also stipulates that the FWUC and the government shall jointly manage irrigation system not fully transferred because of lack of capacity of the FWUC.

D1.5.3 Present Status of O&M including Water Management

O&M activity is very limited because of lack of enough budgets. Fuel supplies to existing pump irrigation systems are not always enough to irrigate throughout a crop season.

Operation and maintenance activities of irrigation systems are depending on the NGO or donor agencies that rehabilitated the systems in many cases.

In order to improve the present situation of O&M, increase of collection rate of the Irrigation Service Fee (ISF) is of importance. For the ISF collection, the following measures are necessary.

- Timely and enough water supply to each filed of member farmers
- O&M training of farmers
- Technical support to farmers by MOWRAM and concerned agencies
- Involvement of village chief and village development committee
- Making clear rule of responsibilities for O&M between MOWRAM and FWUC

D1.6 Current Problems

Problems identified through study on existing documents, additional inventory survey and preliminary topographic survey results are as follows.

a) Low ratio of irrigated agriculture

Calculated ratio of irrigated agriculture is 26 % nearly the same as the national average of 22%. However, judging from the request for system rehabilitation, actual ratio would be lower than statistics.

b) Lack of comprehensive rehabilitation works

One hundred seventy-one (171) systems still require rehabilitation after conducting rehabilitation works. Moreover, one hundred twenty-one (121) systems, which are left without rehabilitation, are waiting for rehabilitation. Lack of funds maybe limited rehabilitation works. For stable irrigation water supply even in wet season, systems need comprehensive rehabilitation works.

c) Deterioration of dyke in pond irrigation system

Many irrigation pond dykes lost their original cross sectional shape because of flood flow, inundation, erosion, etc. Consequently, the storage capacity of pond became smaller than the original one. Rehabilitation works of dyke body, spillway and intake structure would be minimum and essential components.

d) Low establishment ratio of FWUC

In the basin, the establishment ratio of FWUC is 17%, while the ratio of rehabilitated irrigation system is 60%. For maintenance of irrigation facilities, acceleration of establishment of FWUC in accordance with the government policy is fundamentally important.

e) Large fluctuation in water level of the Battambang River

River water level in the Battambang River fluctuates largely after rainfall. This fluctuation makes stable water supply by gravity difficult, and loses remarkable amount of water resources. In case the circumstances permit, water resources development together with weir construction would eliminate this problem. As an alternative, only weir construction would reduce the water losses.

f) Lack of canal capacity

Canals without maintenance lost their capacity. Existing irrigation system conveys floodwater to paddy fields. Floodwater, which contains considerable amount of silt and sand, accumulates in canals.

g) Deteriorated irrigation structures

Irrigation systems deteriorated seriously, especially systems constructed in the late 1970's, which occupies approximately 60% of all system. These structures need demolition and reconstruction.

h) Lack of irrigation structures

Existing irrigation systems lack canal related structures, especially water control and canal crossing structures.

CHAPTER D2 WATER RESOURCES POTENTIAL STUDY

D2.1 General

This section mainly focuses assessment of basin-wise irrigable area. In the assessment, the river discharge data derived in Appendix A Meteorology and Hydrology was utilized. In the assessment on the water demand, the following quantities is considered; irrigation water demand, other water demands, such as domestic use, industrial use, river maintenance flow for conservation of environment and ecosystem.

The available water for irrigation was figured out by "water resources" minus "other water demands". Finally, basin-wise irrigable area was estimated through dividing the "available water" by irrigation water demand per unit area. In this assessment, irrigable area for each river basin was estimated by monthly discharge and specific discharge at 80% dependability, based on rainfall at 80% dependability.

D2.2 Water Resources in the Study Area

(1) Type of Water Resources

The type of water resources in each River Basin are the followings:

- River/stream : Large/small streams supply water to irrigation systems.
- Reservoir : No detailed technical data available. (For Bassac, see below.)
- Pond : Take into account, but no quantitative assessment due to lack of data
- Great Lake, Tonle Sab River, Mekong River (Area between National Road No.5):

  Water level and discharge of the above river/streams are affected.
- Ground water : Available. Mostly for domestic use through shallow wells

Among the above types, it is reasonable and reliable to estimate potential water availability for rivers, since their catchment areas are known and monthly discharge data have been monitored and collected at stations along 4 main river basins. Therefore, potential water availability for sub basins were analyzed and estimated by applying specific discharge within basins and catchment areas.

Since in Moung Russey River Basin, Bassac Reservoir is planned to be constructed by MOWRAM, water balance study on the said reservoir was conducted based on the document "Project Proposal for Basac Reservoir Rehabilitaion Project in Battambang Province, MOWRAM, Oct. 2005".

(2) Method for Water Resources Assessment

Water resource assessment within each sub river basin was carried out by the following steps:

STEP		Remarks
1) Assume catchment area	:	effective catchment area at intake/diversion point

in each sub river basin

2) Calculate Monthly discharge : catchment area multiplied by specific discharge q

3) Calculate other water demands : domestic use, industrial use, maintenance flow

4) Calculate Irrigation water demand: design cropping pattern, Evapotranspiration, etc.

5) Select critical month : balance of irrigation water demand and available q

6) Calculate available water amount: (STEP2) – (STEP3) for critical month

7) Calculate irrigable area : (STEP6) / (STEP4) for critical month

(3) STEP 1) Effective Catchment Area for Each Sub River Basin

Based on the hydrologic analysis described in Appendix A Meteorology and Hydrology, effective catchment area for each sub basin was determined as follows in table below, taking into consideration the location of the main intake/diversion point and topographic condition of each river basin:

The Boribo River branches off into two rivers at Bomnak, i.e. the Boribo River to Kmpong Chhnang Province, and Thlea Maam River to Pursat Province. It is noted that in Thlea Maam river basin, feasibility studies have been conducted by ADB.[1] over 4 irrigation systems (Kouch Noup, Kanseng, Damnak Kranh, Vaot Run). Referring to the above study, the discharge from Bomnak sub river basin (g1) was allocated to two sub river basins as follows:

- Bomnak-Thlea Maam River Basin (Pusat Province) : allocation between 0 - 50 %
- Bomnak-Boribo River Basin (Kg. Chhnang Province) : allocation between 50 - 100 %

(Ref: Northwest Irrigation Sector Project ADB Loan 2035 CAM (SF) AFD Grant CHK 3003.01, Draft Completion Report, Aug. 2007, Submitted to MOWRAM)

Therefore, in this potential water assessment, effective catchment area of sub basin (g1) was allocated to the above two river basin by 50% each.

Effective Catchment Area for Sub River Basin in 4 River Basins

River Basin	Sub River Basin	Catchment Area (km^2)			
		Gross Area	Effective Ratio	Effective Area	Remarks
Battambang (Sangker) River Basin (4 sub basins)	(a1) Battambang RB (Hill)	2,265	0.9	2,039	2,596 for Main river
	(a2) Battambang RB (Plain)	929	0.6	557	
	(b1) Other RB up to NH5	883	0.2	177	Residual
	(b2) Other RB betw/NH5 & GLake	1,976	0.2	395	-ditto-
Moung Russey (Dauntri) River Basin (4 sub basins)	(c) Moung Russey RB (Hill)	785	0.7	550	Main river
	(d1) Svay Don Keo RB (Hill)	805	0.6	483	Main river
	(d2) Other RB up to NH5	915	0.2	183	Residual
	(d3) Other RB betw/NH5 & GLake	1,191	0.2	238	-ditto-
Pursat River Basin (4 sub basins)	(e1) Pursat RB (Hill)	4,235	1.0	4,235	Main river
	(e2) Pursat RB (Plain)	361	0.0	0	Residual
	(f1) Other RB up to NH5	393	0.2	79	-ditto-
	(f2) Other RB betw/NH5 & GLake	976	0.2	195	-ditto-
Boribo River	(g1) Bomnak Boribo RB	384	0.5	192	360 for Boribo river
	(g4) Boribo River Basin-UptoNR5	419	0.4	168	

Basin	(g5) Boribo RB betw/NH5 & GL	30	0.2	6	Residual
	(g1) Bomnak-Boribo RB	384	0.5	192	360 for
	(g2) Thlea Maam RB up to NH5	468	0.4	187	ThleaM river
(13 sub basins)	(g3)Thlea Maam RB betw/NH5& GL	121	0.2	24	Residual
	(h1) Boribo-North-UptoNH5	559	0.2	112	for streams
	(h2) Boribo North- betw/GL	266	0.2	53	Residual
	(i1) Boribo Middle North-UptoNH5	759	0.2	152	for streams
	(i2) Boribo Middle North-betw/GL	223	0.2	45	Residual
	(j1) Boribo Middle South-UptoNH5	1,736	0.2	347	for streams
	(j2) Boribo Middle South- betw/GL	306	0.2	61	Residual
	(k1) Boribo South-UptoNH5	1,835	0.2	367	for streams
	(k2) Boribo South- betw/GL	48	0.2	10	Residual

(4) STEP 2) Monthly Discharge for Each Sub River Basin

Based on the hydrologic analysis describe in Appendix A Meteorology and Hydrology, specific discharge for each main sub river basin were presented as shown in the following table. As explained in Sections D2.3, D2.4, the critical month regarding the proposed cropping pattern in this study will be May for Early Paddy (wet-1), July for Medium Paddy (wet-2), February for Dry Paddy (dry), monthly discharge for these 3 months are depicted in the following table. (RB=River Basin, SRB=Sub River Basin.)

Monthly Discharge for Main Sub River Basins in 4 River Basins

River Basin	Sub River Basin	Catchment Area	Effective Catchment Area	Available Specific Discharge	Available River Discharge	Available Monthly River Discharge	Sub Basin Effective Monthly Discharge
		CA	CA'	qm	q0	q0'	q0''
			CA*Eff. ratio		CA'*qm/1000	q0*0.0864*30	
		(km²)	(km²)	(lit/s/km²)	(m³/s)	(MCM)	(MCM)
	a1) Battambang RB (Hill)	2,265	2,039				a1) +a2)
Battambang	Wet-1 (May)		Effective	1.3	2.7	7.2	7.2
River Basin	Wet-2 (July)		ratio= 0.9	11.8	24.1	64.5	72.3
(RB)	Dry (Feb)			0.6	1.2	2.9	2.9
	a2) Battambang RB in Plain	929	557				
Total Area =	Wet-1 (May)		Effective	0.0	0.0	0.0	-
6,053 km2	Wet-2 (July)		ratio= 0.6	5.2	2.9	7.8	-
(a1+a2+b1+b2)	Dry (Feb)			0.0	0.0	0.0	-
	c) Moung Russey RB (Hill)	785	550				c)
Moung Russey	Wet-1 (May)		Effective	3.0	1.7	4.6	4.6
River Basin	Wet-2 (July)		ratio= 0.7	4.5	2.5	6.7	6.7
	Dry (Feb)			0.9	0.5	1.2	1.2
	d1) Svay Don Keo RB (Hill)	805	483				d1)
Total Area =	Wet-1 (May)		Effective	3.0	1.4	3.7	3.7
3,696 km2	Wet-2 (July)		ratio= 0.6	4.5	2.2	5.9	5.9
(c+d1+d2+d3)	Dry (Feb)			0.9	0.4	1.0	1.0
	e1) Pursat RB Hill (PR-H)	4,235	4,235				e1)+e2)
Pursat	Wet-1 (May)		Effective	1.6	6.8	18.2	18.2
River Basin	Wet-2 (July)		ratio= 1.0	8.1	34.3	91.9	91.9
	Dry (Feb)			1.2	5.1	12.3	12.3
	e2) Pursat RB in Plain	361	0				
Total Area =	Wet-1 (May)		Effective	1.4	0.0	0.0	-
5,965 km2	Wet-2 (July)		ratio= 0.0	5.8	0.0	0.0	-
(e1+e2+f1+f2)	Dry (Feb)			0.0	0.0	0.0	-
	Bomnak-Tlea Maam-Boribo (1,422 km²)						
	g) Bomnak-Boribo River Basin (833 km²)						g1)+g4)
Boribo (L)	g1) Bomnak River Basin	384	192				
River Basin	Wet-1 (May)		Effective	3.1	0.6	1.6	2.9
	Wet-2 (July)		ratio= 0.5	8.0	1.5	4.0	7.5
	Dry (Feb)			2.7	0.5	1.2	2.4
	g4) Boribo River Basin (NH5)	419	168				
	Wet-1 (May)		Effective	3.1	0.5	1.3	-
	Wet-2 (July)		ratio= 0.4	8.0	1.3	3.5	-
	Dry (Feb)			2.7	0.5	1.2	-
Total Area =	g') Bomnak-Thlea Maam River Basin (BOM-TM, 589 km²)						g1)+g2)
7,154 km2	g1) Bomnak River Basin	384	192				
(g1+g2+g3+g4+g5	Wet-1 (May)		Effective	3.1	0.6	1.6	4.0
+h1+h2+i1+i2	Wet-2 (July)		ratio= 0.5	8.0	1.5	4.0	7.2
+j1+j2+k1+k2)	Dry (Feb)			2.7	0.5	1.2	1.7
	g2) Thlea Maam RB	468	187				
	Wet-1 (May)		Effective	5.0	0.9	2.4	-
	Wet-2 (July)		ratio= 0.4	6.4	1.2	3.2	-
	Dry (Feb)			0.9	0.2	0.5	-
	h) Boribo North RB (BOR-N, 825 km²)						h1)
	h1) BOR-N up to NH5	559	112				
	Wet-1 (May)		Effective	5.0	0.6	1.6	1.6
	Wet-2 (July)		ratio= 0.2	6.4	0.7	1.9	1.9
	Dry (Feb)			0.9	0.1	0.2	0.2
	i) Boribo Middle North RB (BOR-MN, 982 km²)						i1)
	i1) BOR-MN up to NH5	759	152				
	Wet-1 (May)		Effective	8.3	1.3	3.5	3.5
	Wet-2 (July)		ratio= 0.2	11.0	1.7	4.6	4.6
	Dry (Feb)			0.8	0.1	0.2	0.2
	j) Boribo Middle South RB (BOR-MS, 2,042 km²)						j1)
	j1) BOR-MS up to NH5	1,736	347				
	Wet-1 (May)		Effective	3.7	1.3	3.5	3.5
	Wet-2 (July)		ratio= 0.2	7.6	2.6	7.0	7.0
	Dry (Feb)			0.9	0.3	0.7	0.7
	k) Boribo South RB (BOR-S, 1,883 km²)						k1)
	k1) BOR-S up to NH5	1,835	367				
	Wet-1 (May)		Effective	2.6	1.0	2.7	2.7
	Wet-2 (July)		ratio= 0.2	3.8	1.4	3.7	3.7
	Dry (Feb)			1.1	0.4	1.0	1.0

D2.3 Proposed Irrigation Water Requirement

D2.3.1 Basic Consideration

(1) Introduction of Water Saving Irrigation Concept

The irrigation water requirements are estimated on the condition that the following water saving irrigation methods will be introduced for paddy cultivation.

Paddy fields after land preparation and transplanting will not be submerged in water, and are to be supplied with only enough water to keep the soil moisture content at the root depth at not less than 75% of full saturation throughout the total growing period. The paddy field is to be submerged only during a period of 30 days starting at head initiation until the end of flowering. In the calculation, this is converted to a decrease of percolation loss for every 5 days as presented in Table D2.3-1. In this irrigation practice, percolation losses could be reduced by 20% to 25% of total net irrigation water requirements.

(2) Calculation Procedure

The irrigation water requirements were estimated based on the following procedures and conditions.

a) Estimate of Reference Crop Evapotranspiration

b) Determination of crop coefficient and consumptive use of water

c) Estimate of field water requirement

d) Estimate of effective rainfall

e) Estimate of net irrigation water requirement and gross irrigation requirement

f) Estimate of diversion water requirement

D2.3.2 Calculations

(1) Reference Crop Evapotranspiration (ETo)

Penman-Montieth method with the available meteorological data from each river basin was used according to the Guideline for Crop Evapotranspiration, FAO Irrigation and Drainage Paper 56: The calculation was made for every month. The result are summarized in the following table.

Reference Crop Evapotranspiration by the Penman-Montieth Method (mm/day)

River Basin	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ave
Battambang	3.94	4.46	5.16	5.10	4.85	4.35	4.43	3.98	3.85	3.77	3.59	3.61	4.26
Moung Ru.	3.94	4.36	4.89	4.81	4.63	4.10	4.26	3.85	3.82	3.81	3.61	3.58	4.14
Pursat	3.86	4.27	4.71	4.64	4.45	3.87	4.06	3.70	3.72	3.74	3.51	3.46	4.00
Boribo	4.07	4.70	5.20	5.30	5.03	4.66	4.38	4.45	4.13	3.75	3.87	3.85	4.45

(2) Crop coefficient and consumptive use of water

To determine the Crop Coefficients of paddy and other crops, reference was made to the above Guideline, and the consumptive use of water for each crop was obtained by multiplying the Reference Crop Evapotranspiration and Crop Coefficient.

Paddy; 1.10 – 0.95, 0.00 at the last 15 days

Upland crop; 0.5 – 0.90, 0.00 at the last 15 days

The consumptive use of water was calculated for every 5 days in accordance with cropping calendar proposed.

(3) Field water requirements

i) Percolation rate in the paddy field

The percolation rate was measured at 12 places by the Study Team in July 2007 by a simple method using a dial gauge and open ends cylinder. Based on the field test the percolation rate was determined as follows:

- Battambang River Basin; 5 mm/day
- Moung Russey River Basin; 3.5 mm/day
- Pursat River Basin; 2.5 mm/day
- Boribo River Basin; 3.0 mm/day

ii) Water requirement for land preparation in the paddy field

Water requirement for land preparation in the paddy field was determined by arithmetical equation used in Japan, which contains the following factors such as water layer replacement, evaporation from water surface, percolation rate, and effective rainfall in the paddy field.

- Period for land preparation; N=20 days
- Water layer replacement; do=120mm
- Evaporation from water surface; E=as discussed above
- Percolation rate; p=as discussed above
- Effective rainfall; Re=as discussed below

The calculation was carried out every day and summarized to obtain average 5-day water requirement.

iii) Pre-irrigation

In case of direct sowing of paddy and or upland crops, the field is dry in general. A pre-irrigation is proposed to raise soil moisture content. A 10mm depth of water in 5 day (=2mm/day) is assumed for pre-irrigation.

iv) Field water requirement

The field water requirement was obtained by summing above water requirements;

- Water requirement of Paddy = consumptive use of water + percolation rate + land preparation

  In this regard, water saving irrigation was proposed in the Study as discussed in the previous paragraph.

- Water requirement of upland crop = consumptive use of water + pre-irrigation

A sample calculation is presented for Early Paddy, Long Paddy, Dry Season Paddy, and Upland crop in Tables D2.3-2 to D2.3-6 respectively in Battambang River Basin. The calculation was made for 6 to 9 blocks which are staggered in accordance with the proposed cropping calendar.

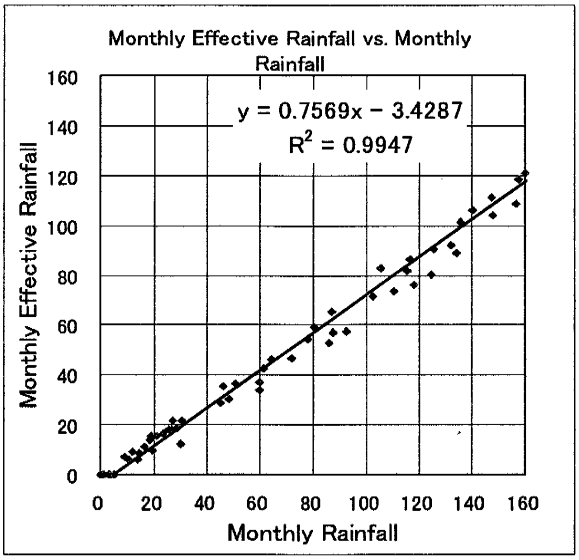
(4) Effective Rainfall

The effective rainfall to crops was calculated based on the Guideline in Japan for paddy field, and USDA Standard 1969 for upland field.

i) Paddy field

- When daily rainfall is less than 5mm; effective rainfall=0
- When daily rainfall ranges from 5mm to 80mm; effective rainfall=80% of the daily rainfall
- When daily rainfall is more than 80mm; effective rainfall=64mm

The effective rainfall was calculated in daily basis on the above conditions for 6 to 10 years when daily rainfall data is available. Monthly effective rainfall was obtained by summation of the daily effective rainfall. An regression analysis was made to develop an equation between monthly effective rainfall and monthly rainfall. For example in Battambang rainfall station the following equation was obtained; see the right figure:



Re=R×0.75-3.43 (r^2=0.997)

Where; Re=Monthly effective rainfall (mm, Re>=0.0),

R=Monthly rainfall (mm)

At the same time, a percentage of every 5-day effective rainfall to the monthly effective rainfall was also calculated for an average year using the above calculation results (se table below as an example).

Average 5-day effective rainfall (mm)

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 - 5	1.1	0.0	0.0	6.2	16.3	10.8	25.1	27.0	14.8	27.2	7.0	1.1
6 - 10	0.8	0.8	2.5	4.2	14.1	21.3	12.8	13.0	11.5	14.0	4.9	0.0
11 - 15	1.2	1.9	2.5	17.8	16.2	23.2	18.9	27.2	34.2	39.7	6.2	1.9
16 - 20	0.7	5.9	7.5	7.5	29.2	42.1	11.0	22.8	22.5	6.0	5.6	2.8
21 - 25	0.0	0.0	4.3	26.7	8.2	10.5	25.6	23.4	20.4	11.8	5.1	5.0
26 - end	0.0	0.0	10.9	18.7	14.3	32.6	25.4	36.4	18.4	35.9	0.0	0.0
Total	3.8	8.6	27.7	81.1	98.2	140.5	118.8	149.7	121.9	134.7	28.8	10.7

Percent of 5-day effective rainfall to monthly effective rainfall

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 - 5	28.3	0.0	0.0	7.6	16.6	7.7	21.2	18.0	12.1	20.2	24.2	10.0
6 - 10	21.2	9.6	9.0	5.1	14.3	15.2	10.7	8.7	9.5	10.4	16.9	0.0
11 - 15	31.8	21.9	9.0	22.0	16.5	16.5	15.9	18.1	28.1	29.5	21.6	17.8
16 - 20	18.7	68.5	27.0	9.3	29.7	29.9	9.2	15.2	18.5	4.5	19.5	25.9
21 - 25	0.0	0.0	15.7	32.9	8.3	7.5	21.6	15.6	16.7	8.8	17.8	46.4
26 - end	0.0	0.0	39.4	23.1	14.5	23.2	21.4	24.3	15.1	26.7	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The 5-year return period probable monthly effective rainfall, $Re_{1/5}$, was calculated using the above equation and probable monthly rainfall estimated in Meteorology and Hydrology. The 5-day probable effective rainfall was calculated by multiplying the percentage above and the $Re_{1/5}$ in every month.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Probable rainfall	1.3	0.0	26.2	48.1	78.3	150.4	104.2	130.9	126.2	144.6	15.8	0.7
Monthly Probable effective rainfall	0.0	0.0	16.2	32.6	55.3	109.4	74.7	94.7	91.2	105.1	8.4	0.0
5-day effective rainfall												
1 – 5	0.0	0.0	0.0	2.5	9.2	8.4	15.8	17.1	11.1	21.2	2.0	0.0
6 – 10	0.0	0.0	1.5	1.7	7.9	16.6	8.0	8.2	8.6	10.9	1.4	0.0
11 – 15	0.0	0.0	1.5	7.2	9.1	18.1	11.9	17.2	25.6	31.0	1.8	0.0
16 – 20	0.0	0.0	4.4	3.0	16.4	32.7	6.9	14.4	16.8	4.7	1.6	0.0
21 – 25	0.0	0.0	2.5	10.7	4.6	8.2	16.1	14.8	15.2	9.2	1.5	0.0
26 – end of month	0.0	0.0	6.4	7.5	8.0	25.3	16.0	23.0	13.8	28.0	0.0	0.0

The above calculation was executed for one or a few rainfall stations in the respective Sub-river Basins.

River Basin	Rainfall station applied
Battambang	Battambang
Moung Russey	Moung Russey, Svay Don Keo, Talo
Pursat	Bouneg Khnar, Pursat, Boeung Kantout
Boribo g), h), i)	Boribo
Boribo j)	Samaki Meanchey, Kompong Tralach

The 5-day probable effective rainfall in the River Basin was figured out by averaging those of a few stations. The result is summarized in Table D2.3-7. The effective rainfall calculated is used in the calculation of water requirement in the paddy field.

ii) Upland crop field

The effective rainfall for upland crop field was calculated by the probable monthly rainfall described in Meteorology and Hydrology in chapter 4 and USDA Standard. The calculation and result are summarized in Table D2.3-8.

(5) Net Field Irrigation Water Requirement

Net field irrigation water requirement is obtained by deducting the probable effective rainfall from the field water requirement.

(6) Irrigation Efficiency

In general, it is assumed that a quarter to a half of the total quantity of water diverted will be lost before it reaches the rice plant due to operational waste, evaporation and seepage. Losses by evaporation and seepage are generally small in comparison with operational waste.

During field survey, the Study Team frequently saw many farmers used small pump for irrigation. They seem to be aware of economic value of water in Cambodia. From this, farmers appear to have a potential to execute water saving activity provided that sufficient facility and training are provided. Irrigation efficiency for the Study was assumed as follows:

i) For paddy irrigation

The irrigation efficiency of paddy irrigation is determined based on the concept abovementioned and following assumptions.

a) In the tertiary unit, low water loss can be achieved by farmers, so low water loss rate of 15 % is applied, efficiency=100-15 %=85 %

b) In the secondary canal, it will take some time to train farmers and to disseminate water technology, so high water loss rate of 15 % similarly with that at current condition is conservatively applied, efficiency=100-12 %=88 %

c) In the main canal, as explained in b) above, same efficiency×100-12 %=88 %

d) Overall efficiency can be figured out by multiplying the above efficiency conjunctively. Overall irrigation efficiency = 85 × 88 × 88 % = 65.8 % = 66 %

ii) For upland crop irrigation

A surface irrigation method was proposed such as furrow irrigation for upland crops other than rice. There is an inevitable water loss in the upland crop irrigation such as seepage in the furrow and operational loss in the field. Such loss or reversely called as Field Application Efficiency was assumed at 80 % (=100-20 %) of water reached to the entrance of the field. The others efficiencies from intake to tertiary canal are set at same as for paddy irrigation above.

The overall irrigation efficiency for upland crop is figured out at 53 % as follows: Overall irrigation efficiency for upland crop =80 × 85 × 88 × 88 % = 52.6 = 53 %

(6) Unit Diversion Water Requirement

The diversion water requirement at intake site or water source of a irrigation system were calculated by dividing the net field irrigation water requirement by irrigation efficiency. A sample calculation of unit diversion water requirement is presented in the Tables D2.3-2 to 6. The unit diversion water requirement is generally presented in liter per second per ha.

(7) Results

The cropping calendar is usually staggered due to various reasons such as availability of water source, agricultural labor force, agricultural machinery, etc. The diversion water requirement of a project can be obtained by multiplying the cropping area factor to the unit diversion water requirement. A sample calculation is shown in Table D2.3-9. The peak unit diversion water requirements of the proposed cropping calendar were calculated to be 1.98 lit/sec/ha for Early Paddy, 1.33 for Medium Paddy, 2.01 for dry season paddy transplanted in the Battambang River Basin as shown in the following table.

Peak Unit Diversion Water requirement in the Four River Basins (unit: ℓ/sec/ha)

River basin	Early paddy Transplanting	Medium paddy Transplanting	Medium paddy Direct sowing	Dry paddy Transplanting	Upland crop
Battambang	1.98	1.33	1.22	2.01	0.77
Moung Russey	1.68	1.15	0.83	1.84	0.81
Pursat	1.66	0.95	0.78	1.71	0.78
Boribo g), h), i), j)	1.71	1.01	-	1.82	0.84
Boribo k)	1.71	1.15	-	1.82	0.84

Source: JICA Study Team

The 5-day unit irrigation water requirements in the four river basins are summarized in Table D2.3-10.

D2.3.3 Irrigation Water Requirement for River Basin-wide Water Balance Study

(1) Return Flow

A half of irrigation loss or 17% {(100-66)÷2} from upstream irrigation area and or a system was conservatively assumed to be re-used in the downstream system. This quantity is generally called as Return Flow. Accordingly, the irrigation efficiency of 83% (=66+17) was applied in the water balance study.

(2) Second Maximum Water Requirement in Every Month

In general, paddy has a tolerance for drought of 5 days except for flowering stage. If the maximum 5-day irrigation water requirement is applied in the water balance study, the potential irrigation area obtained will be too conservative. Therefore, the second maximum water requirement in every month was applied in the study. The second maximum water requirement for each crop every month by river basin are summarized in Table D2.3-11.

(3) Ratio of transplanting area and direct sowing area of paddy

The proposed ratio of mix farming of transplanting area and direct sowing area is applied in the calculation as shown in Table D2.3-10.

(4) Irrigation water requirement for water balance study

Applying the above factors and assumptions, irrigation water requirement for water balance study was calculated. The river runoff of the Study area varies from month to month in accordance with some typical pattern, namely start rising in May until October, and downing to April. This pattern repeats every year. Therefore, the peak monthly water requirement of every cropping calendar proposed was calculated i.e. May for Early Paddy, July for Medium Paddy, and February for Dry Season Upland Crop respectively as shown in Table D2.3-11. In the table, the peak water requirement was calculated by two units i.e. liter per second per hectare and cubic meter per month.

D2.4 Other Water Demands

Other than irrigation water demands were estimated for "Domestic Demand" for drinking water and daily use, "Industrial Demand" for factories, and "River maintenance Discharge" for conservation of environment and ecosystem.

D2.4.1 Domestic and Industry Water Demands

(1) Domestic Water Demands

4 river basins in this study are classified as "rural region", however referring to the "National Census 2005", the proportion of urban population to provincial population is assumed to be 15% in each province. Other condition and assumptions used for the estimation of domestic water use are as follows:

- Population : Growth rate, 2020 projection derived from National Census 2005.
  : Proportion in provincial population: Urban =15%, Rural=85%
- Domestic use : Urban use 100 liter/day/person x 120% = 120 liter/day/person
  : Rural use 40 liter/day/person x 120% = 48 liter/day/person
  20%: excess for commercial and public use were considered.

(2) Industry Water Demands

In this study, Industry water demand was assumed to be 30 % of "urban use" for each province.

- Industry use : 30 % of urban use/day

(3) Estimation of Domestic and Industrial Water Demands

Based on the above condition and assumptions, domestic and industrial water demands (D.I.W.D) for each province were estimated as follows:

Province-wise Estimation of Domestic and Industrial Water Demands (D.I.W.D)

Province	Total Area (km^2)	Population Related Condition				D.I.W.D (MCM/yr)		
		2005 (person)	Growth Rate (%)	2020 (million)	Urban/ Rural (million)	Domestic Urban/ Rural	Industry (30%of Urban)	Total
Battambang	11,702	506,188	7.1	1.33	0.20/ 1.13	8.7/ 19.8	2.6	31.2
Pursat	12,692	221,125	3.1	0.58	0.09/ 0.49	3.8/ 8.7	1.1	13.6
Kg. Chhnang	5,521	266,680	3.8	0.70	0.11/ 0.60	4.6/ 10.4	1.4	16.4

(4) Allocation of D.I.W.D to Sub River Basin

D.I.W.D estimated for provinces were allocated to each sub river basin in accordance with its coverage area and population distribution among the provinces. The result on sub river basin wise allocation of D.I.W.D is shown in below. Note that in Battambang Province, about 34 % of provincial area is in other river basins, hence the total of sub river basin ratio is 66%.

Sub River Basin-wise Allocation of D.I.W.D

Province	D.I.W.D		Provincial Area (km^2)	Sub River Basin		Sub River Basin wise Ratio	Allocated D.I.W.D (m^3/s)
	(MCM/yr)	(m^3/s)		Name	Gross CA (km^2)		
Battambang	31.2	1.0	11,702	Battambang RB	6,053	50%	0.500
				Moung Russey RB	1,758	16%	0.160
Pursat	13.6	0.5	12,692	Svay Don Keo RB	1,938	15%	0.075
				Pursat RB	5,965	70%	0.350
				Bomnak-TM RB	781	15%	0.075
Kg.Chhnang	16.4	0.6	5,521	Bomnak-Borobo RB	641	13%	0.078
				Boribo-North RB	825	14%	0.084
				Boribo-MN RB	982	15%	0.094
				Boribo-MS RB	2042	29%	0.174
				Boribo-South RB	1883	29%	0.174

It is also noted that the allocated D.I.W.D listed above are actually collected from "Net catchment area" located in the upstream of urban area. Additionally, the D.I.W.D to be derived from the effective catchment (Eff. CA) was allocated in proportion to the catchment area, since intake/diversion points are located in rather upstream portion of the net catchment area.

Effective Allocation of Sub River Basin –wise D.I.W.D (qms)

River Basin	Sub River Basin	D.I.W.D (m^3/s)	Net CA (km^2)	Eff.CA (km^2)	q_{ms} (m^3/s)	Remarks
Battambang RiverBasin	Battambang RB	0.500	3,194	2,596	0.406	a1)+a2)
Moung Russey River Basin	Moung Russey RB	0.160	785	550	0.112	c)
	Svay Don Keo RB	0.075	805	483	0.045	d1)
Pursat River Basin	Pursat RB	0.350	4,235	4,235	0.350	e1)
Boribo River Basin	Bomnak-TM RB	0.075	611	379	0.047	g1)+g2)
	Bomnak-Borobo RB	0.078	660	360	0.043	g1)+g4)
	Boribo-North RB	0.084	559	112	0.016	h1)
	Boribo-MN RB	0.090	759	152	0.018	i1)
	Boribo-MS RB	0.174	1,736	347	0.035	j1)
	Boribo-South RB	0.174	1,835	367	0.035	k1)

D2.4.2 River Maintenance Discharge

Based on commonly used guideline of Ministry of Construction in Japan, "river maintenance discharge" for conservation of river environment and ecosystem, is desirable in the range of 0.1-0.3 $m^3/s/100km^2$ derived from catchment area. In the study, 0.1 $m^3/s/100km^2$ was adopted to determine the river maintenance flow from effective catchment area as presented in the following table.

Estimation of Sub River Basin –wise River Maintenance Discharge

River Basin	Sub River Basin	Eff..CA (km^2)	q_{re} ($m^3/s/100km^2$)	q_e (m^3/s)	Remarks
Battambang RiverBasin	Battambang RB	2,596	0.1	2.60	a1)+a2)
Moung Russey River Basin	Moung Russey RB	550	0.1	0.55	c)
	Svay Don Keo RB	483	0.1	0.48	d1)
Pursat River Basin	Pursat RB	4,235	0.1	4.24	e1)
Boribo River Basin	Bomnak TM RB	379	0.1	0.38	g1)+g2)
	Bomnak-Borobo RB	360	0.1	0.36	g1)+g4)
	Boribo-North RB	112	0.1	0.11	h1)
	Boribo-MN RB	152	0.1	0.15	i1)
	Boribo-MS RB	347	0.1	0.35	j1)
	Boribo-South RB	367	0.1	0.37	k1)

D2.5 Water Balance Study

D2.5.1 Calculation of Available Water for Irrigation (q_a, Q_a)

The "Available discharge (q_a,) and amount (Q_a) of water for irrigation" were calculated using the following equation:

$$q_a = q_0 - (q_{ms} + q_e)$$

$$Q_a = q_a \times 86400 \times 30 / 10^6$$

Where,

q_a : available monthly river discharge (m^3/s) for irrigation use for each sub river basin

q_0 : available monthly river discharge (m^3/s) for each sub river basin

q_{ms}: sub river basin-wise river discharge (m^3/s) for domestic & industrial water demand

q_e : sub river basin-wise river discharge (m^3/s) for river maintenance flow

Q_a : available monthly water amount (MCM) for irrigation use for each sub river basin

Note: ($q_{ms} + q_e$) = yearly constant for each sub river basin

As explained in the former sections, there are 3 main cropping seasons for paddy; namely "Wet-1 or Early Paddy" of which critical month is May, "Wet-2 or Medium Paddy" in July, "Dry or Dry Paddy" in February.

Calculation of Sub River Basin –wise River Maintenance Discharge

River Basin	Sub River Basin	Cropping Season	Q_0 (m^3/s)	q_{ms} (m^3/s)	q_e (m^3/s)	q_a (m^3/s)	Qa (MCM)
Battambang RiverBasin	Battambang RB (a1)+a2))	Wet-1(May)	2.6	0.406	2.60	0	0
		Wet-2(July)	26.9			23.9	64.0
		Dry(Feb.)	1.3			0	0
Moung Russey River Basin	Moung Russey RB (c))	Wet-1(May)	1.7	0.112	0.55	1.00	2.7
		Wet-2(July)	2.5			1.84	4.9
		Dry(Feb.)	0.5			0	0
	Svay Don Keo RB (d1))	Wet-1(May)	1.4	0.045	0.48	0.88	2.4
		Wet-2(July)	2.2			1.68	4.5
		Dry(Feb.)	0.4			0	0
Pursat River Basin	Pursat RB (e1))	Wet-1(May)	6.8	0.350	4.24	2.21	5.9
		Wet-2(July)	34.3			29.7	79.5
		Dry(Feb.)	5.1			0.51	1.2
Boribo River Basin	Bomnak TM RB (g1)+g2))	Wet-1(May)	1.5	0.047	0.38	1.07	2.9
		Wet-2(July)	2.7			2.27	6.1
		Dry(Feb.)	0.7			0.27	0.7
	Bomnak-Borobo RB (g1)+g4))	Wet-1(May)	1.1	0.043	0.36	1.10	2.9
		Wet-2(July)	2.8			2.40	6.6
		Dry(Feb.)	1.0			0.60	1.5
	Boribo-North RB (h1))	Wet-1(May)	0.6	0.016	0.11	0.97	2.6
		Wet-2(July)	0.7			0.57	1.6
		Dry(Feb.)	0.1			0	0
	Boribo-MN RB (i1))	Wet-1(May)	1.3	0.018	0.15	1.13	3.0
		Wet-2(July)	1.7			1.53	4.1
		Dry(Feb.)	0.1			0	0
	Boribo-MS RB (j1))	Wet-1(May)	1.3	0.035	0.35	0.92	2.4
		Wet-2(July)	2.6			2.22	6.1
		Dry(Feb.)	0.3			0	0
	Boribo-South RB (k1))	Wet-1(May)	1.0	0.035	0.37	0.60	1.6
		Wet-2(July)	1.4			1.00	2.7
		Dry(Feb.)	0.4			0	0

D2.5.2 Water Balance in the Battambang River Basin

For each Sub River Basin considered, c) "Total irrigation water requirement in critical month" for each season were calculated based on a) "Existing Area" and b) "Unit monthly irrigation requirement (m^3/ha)" derived in Section 5.2.3. Then c) was compared with d) "Available water for Irrigation for the critical month" to analyze whether the River Basin considered has sufficient potential to feed the "Existing area". If "Sufficient (e) Water surplus > 0)", then f) "Potential irrigable area" was computed by dividing d) by b), and g) "Development potentiality" was estimated by the ratio "Potential area" based on d) to "Existing area".

(1) Battambang River Basin

For Battambang Sub River Basin, the main sub basin in Battambang RB, the results were as follows (Note: d) = Available Water for irrigation in critical month):

Estimation of Sub River Basin –wise Water Potential in Battambang SRB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
BattambangRB	Wet-1(May)	5	3,750	0.02	0	(-0.1)	0	0
(Battambang	Wet-2(July)	18,285	2,268	41.5	64.0	21.7	28,000	1.53
SRB a1)+a2))	Dry(Feb.)	608	1,820	1.11	0	(-1.1)	0	0

- Wet-1 (May) : d) =0 ((q_{ms} + q_e) > (q_0)), insufficient to feed the existing area
- Wet-2 (July) : d)=64 sufficient for existing 18,285ha, a potential for 28,000 ha.
- Dry (Feb.) : d) =0 ((q_{ms} + q_e) > (q_0)), insufficient to feed the existing area

(2) Residual Sub River Basins in Battambang River Basin

For the residual Sub River Basin, results were as follows:

(a) Battambang Plain SRB b1:

- Wet-1 (May) : d) = 0.9, Sub basin showed a potential for extra 200 ha.
- Wet-2 (July) : d) = 2.5, insufficient for existing area, a potential for 1,100 ha.
- Dry (Feb.) : d) was 0 ((q_{ms} + q_e) > (q_0)), insufficient to feed the existing area

(b) Residual SRB b2:

- Wet-1 (May) : d) = 1.9, Sub basin showed a potential for extra 500 ha.
- Wet-2 (July) : d) =5.6, a potential for 2,400 ha.
- Dry (Feb.) : d) was 0

Estimation of Sub River Basin –wise Water Potential in Residual SRB in Battambang RB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Battambang RB	Wet-1(May)	0	3,750	0.00	0.9	0.9	200	-
(Battambang-P	Wet-2(July)	2,970	2,268	6.73	2.5	(-4.2)	1,100	0.37
SRB b1))	Dry(Feb.)	21	1,886	0.04	0	(-0.3)	0	0
Battambang RB	Wet-1(May)	0	3,750	-	1.9	1.9	500	-
(Residual SRB	Wet-2(July)	0	2,268	-	5.6	5.6	2,400	-
b2))	Dry(Feb.)	0	1,886	-	0	0	0	-

D2.5.3 Water Balance in the Moung Russey River Basin

(1) Moung Russey Sub River Basin

For Moung Russey (Dauntri) Sub river basin, a "Reservoir rehabilitation project" in the "Bassac irrigation system" has been planned by MOWRAM since Oct. 2005, and it was approved by Japanese Government in early 2007 for implementation in 2007-8. Therefore, case (a) Without Bassac Reservoir was conducted for comparison and water potential was determined and evaluated by case (b) With Bassac Reservoir.

(a) Without Rehabilitation of Bassac Reservoir

For the Moung Russey (Dauntri) Sub River Basin, results without reservoir were as follows:

Estimation of Sub River Basin –wise Water Potential in Moung Russey RB without Bassac Reservoir

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Require. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Moung Russey RB	Wet-1(May)	660	3,562	2.35	2.7	0.4	750	1.14
(Moung Russey	Wet-2(July)	1,060	1,871	1.98	4.9	2.7	2,600	2.45
SRB c))	Dry(Feb.)	450	1,674	0.75	0	(-0.8)	0	0

- Wet-1 (May) : d) was 2.7, sufficient for existing 660ha, a potential for 750 ha.
- Wet-2 (July) : d) was 4.9, sufficient for existing 1,060ha, a potential for 2,600 ha.
- Dry (Feb.) : d) was 0 ((q_{ms} + q_e) > (q_0)), insufficient to feed the existing area

(b) With Rehabilitation of Bassac Reservoir

Water balance study on Bassac Reservoir was conducted with 80% dependability river discharge. The document "Project Proposal for Basac Reservoir Rehabilitaion Project in Battambang Province, MOWRAM, Oct. 2005", was referred to collect essential data, such as dimension, condition and related project of Bassac Reservoir as follows:

Reservoir related data

- catchment area : 598km^2
- Effective storage capacity : 32 MCM
- Design maximum height : 10.55m (FWL)
- Approximate reservoir area : maximum: 500 ha. minimum: 12 ha.

Assumptions and condition

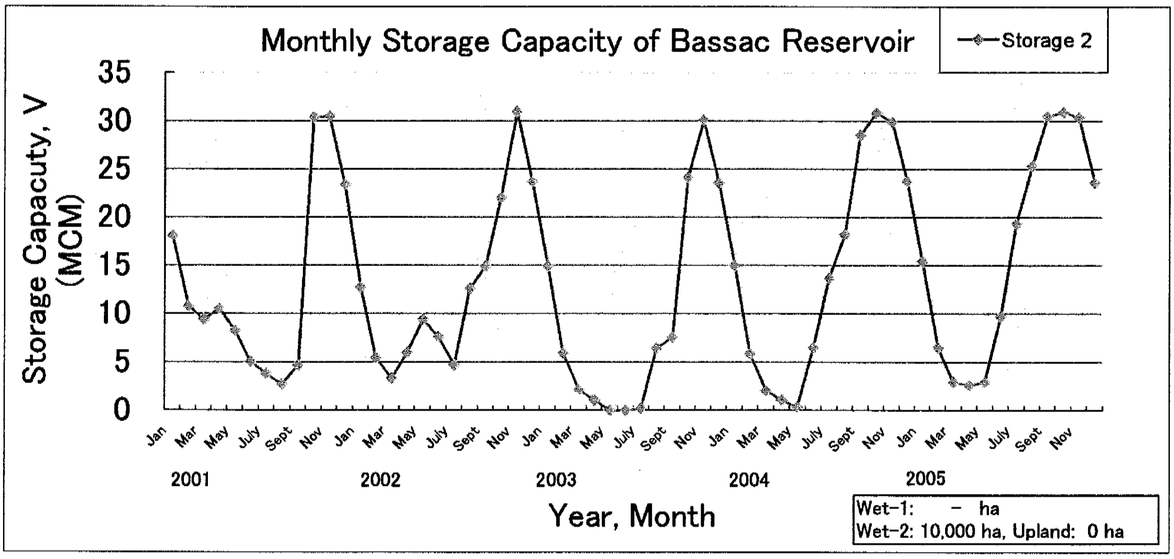
- River Discharge : 80% dependability monthly discharge data estimated for Moung Russey (Dauntri) River for over 5 years: Shown in Annex
- Seepage loss of reserver : 0.05% of Total Storage Volume per day
- Evaporation from reserver : refer to Section 5.2.3 Irrigation water demand

Data on related Project

- Irrigation water Requirement : refer to Section 5.2.3 Irrigation water demand
- Design irrigation target area : Trial

Result of Water balance study: As shown in figure below, it was estimated that maximum of

10,000 ha of medium paddy (or "Wet-2") could be irrigable by Bassac Reservoir based on 80% dependability discharge of Moung Russey River. Therefore, with the reservoir, maximum irrigable area for Moung Russey Sub River Basin would be increased by more than 3 times.



Monthly Water Balance of Bassac Reservoir

Estimation of Sub River Basin –wise Water Potential in Moung Russey SRB with Basssac Resevoir

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	Existing Area (ha)	Unit Irrigation Requir. (m³/ha)	Total Irrigation Water July (MCM)	Proposed Irrigation Potential Area (ha)	Potential / Existing Ratio	Potential / Without Resevoir Ratio
Moung Russey RB (SRB c))	Wet-2(July)	1,060	1,871	1.98	10,000	9.43	3.85

(2) Svay Don Keo Sub River Basin

For Svay Don Keo Sub river basin, results were as follows:

Estimation of Sub River Basin –wise Water Potential in Svay Don Keo SRB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m³/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Moung Russey River Basin (Svay Don Keo SRB d1))	Wet-1(May)	907	3,562	3.23	2.4	(-0.8)	600	0.66
	Wet-2(July)	1,804	1,871	3.38	4.5	0.9	2,400	1.33
	Dry(Feb.)	843	1,674	1.41	0	(-1.4)	0	0

- Wet-1 (May) : d) was 2.4, insufficient for existing 907ha, a potential for 660 ha.
- Wet-2 (July) : d) was 4.5, sufficient for existing 1,804ha, a potential for 2,400 ha.
- Dry (Feb.) : d) was 0 ((q_{ms} + q_e) > (q_0)), insufficient to feed the existing area

(3) Residual Sub River Basin in Moung Russey River Basin

For the residual Sub River Basin in Moung Russey River Basin, results were as follows:

Estimation of Sub River Basin –wise Water Potential in Residual SRB in Moung Russey RB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Moung Russey RiverBasin (ResidualSRB d2))	Wet-1(May)	0	3,562	0	0.9	0.9	200	-
	Wet-2(July)	0	1,871	0	1.6	1.6	800	-
	Dry(Feb.)	0	1,674	0	0	(-0.1)	0	-
Moung Russey RiverBasin (ResidualSRB d3)	Wet-1(May)	0	3,562	0	1.2	1.2	300	-
	Wet-2(July)	0	1,871	0	2.2	2.2	1,100	-
	Dry(Feb.)	0	1,674	0	0	(-0.1)	0	-

(a) Residual SRB d2:

- Wet-1 (May) : d) was 0.9, a potential for 200 ha.
- Wet-2 (July) : d) was 1.6, a potential for 800 ha.
- Dry (Feb.) : d) was 0 ((q_{ms} + q_e) > (q_0)), no potential

(b) Residual SRB d3:

- Wet-1 (May) : d) was 1.2, a potential for 300 ha.
- Wet-2 (July) : d) was 2.2, a potential for 1,100 ha.
- Dry (Feb.) : d) was 0 ((q_{ms} + q_e) > (q_0)), no potential

D2.5.4 Water Balance in the Pursat River Basin

(1) Pursat Sub River Basin

Among 4 River Basins, Pursat Sub river basin has largest catchment area so as to produce about 80 (MCM) in July. The results for Pursat Sub river basin in Pursat River Basin were as follows:

Estimation of Sub River Basin –wise Water Potential in Pursat SRB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Pursat River Basin (Pusat SRB e1))	Wet-1(May)	3,289	3,348	11.00	5.9	(-5.1)	1,700	0.52
	Wet-2(July)	40,599	1,741	70.69	79.5	8.8	45,600	1.12
	Dry(Feb.)	2,212	1,337	2.96	1.2	(-1.7)	900	0.41

- Wet-1 (May) : d) = 5.9, insufficient for existing 3,289ha, a potential for 1,700 ha.
- Wet-2 (July) : d)= 79.5, sufficient for existing 40,600ha, a potential for 45,600 ha.
- Dry (Feb.) : d) = 1.2, insufficient for existing 2,212ha, a potential for 900 ha.

(2) Residual Sub River Basin in Pursat River Basin

For the residual Sub River Basin in Pursat River Basin, results were as follows:

Estimation of Sub River Basin –wise Water Potential in Residual SRB in Pursat RB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Pursat RB (Residual SRB f1))	Wet-1(May)	77	3,348	0.26	0.5	0.3	100	1.30
	Wet-2(July)	566	1,741	0.99	1.1	0.1	600	1.06
	Dry(Feb.)	0	1,337	0	0	(0)	0	-
Pursat RB (Residual SRB f2))	Wet-1(May)	0	3,348	0	1.2	1.2	300	-
	Wet-2(July)	0	1,741	0	2.7	2.7	1,500	-
	Dry(Feb.)	0	1,337	0	0	(0)	0	-

(a) Residual SRB f1 up to NH5:

- Wet-1 (May) : d) = 0.5, sufficient for existing 77ha, a potential for 100 ha.
- Wet-2 (July) : d) = 1.1, sufficient for existing 566ha, a potential for 600 ha.
- Dry (Feb.) : d) = 0 ((q_{ms} + q_e) > (q_0)), no potential

(b) Residual SRB f2 between NH5 and Great Lake:

- Wet-1 (May) : d) = 1.2, a potential for 300 ha.
- Wet-2 (July) : d) = 2.7, a potential for 1,500 ha.
- Dry (Feb.) : d) was 0 ((q_{ms} + q_e) > (q_0)), no potential

D2.5.5 Water Balance in the Boribo River Basin

The results of water balance study for sub river basins in Borio River Basin were as follows.

(1) Bomnak-Thlea Maam and Bomnak-Boribo Sub River Basin

As mentioned in Section 5.2.2, effective catchment area of Bomnak sub river basin was allocated maximum of up to 50% to Bomnak-Thlea Maam (Bomnak-TM) SRB and the rest of 50% or more to Bomnak-Boribo SRB. The results for 2 Sub River Basins were as follows:

Estimation of Sub River Basin –wise Water Potential in Bomnak-Thlea Maam SRB and Bomnak-Boribo SRB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Boribo RB (Bomnak-TM SRB g1)+g2))	Wet-1(May)	600	3,321	1.99	2.9	0.9	870	1.45
	Wet-2(July)	2,253	1,768	3.98	6.1	2.1	3,400	1.51
	Dry(Feb.)	440	1,331	0.58	0.7	0.1	520	1.18
Boribo RB (Bomnak-Boribo SRB g1)+g4))	Wet-1(May)	0	3,321	0	2.9	2.9	870	-
	Wet-2(July)	7,945	1,768	14.04	6.6	(-7.4)	3,700	0.47
	Dry(Feb.)	1,535	1,331	2.04	1.5	(-0.5)	1,120	0.73

(a) Bomnak-Thlea Maam SRB:

- Wet-1 (May) : d) = 2.8, sufficient for existing 600ha, a potential for 870 ha.

- Wet-2 (July) : d) = 6.1, sufficient for existing 2,253ha, a potential for 3,400 ha.
- Dry (Feb.) : d) = 0.6, sufficient for existing 440ha, a potential for 520 ha.

(b) Bomnak-Boribo SRB:

- Wet-1 (May) : d) = 2.9, a potential for 870 ha.
- Wet-2 (July) : d) = 6.6, insufficient for existing 7,945ha, a potential for 3,700 ha.
- Dry (Feb.) : d) = 1.5, insufficient for existing 1,535ha, a potential for 1,200 ha.

(c) Residuals:

- Residual catchment area of Sub river basins g3), g5) between National Road No.5 and Great Lake were so small and only yielded very little amount, therefore, neglected.

As shown in Section 5.2.6, Moung Russey River Basin "with Bassac Reservoir", by having an adequate reservoir, irrigable area will be remarkably increased for the above two sub river basins.

(2) Boribo-North Sub River Basin and Boribo-Middle North Sub River Basin

For Boribo-North (BOR-N) and Boribo-Middle North (BOR-MN) SRB's, the results for 2 Sub River Basins were as follows:

Estimation of Sub River Basin –wise Water Potential in Boribo-North SRB and Boribo-Middle North SRB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Boribo RB	Wet-1(May)	300	3,321	1.00	2.6	1.6	780	2.60
(Boribo-North	Wet-2(July)	4,942	1,768	8.74	1.6	(-7.2)	900	0.18
SRB h1))	Dry(Feb.)	0	1,331	0	0	0	0	-
Boribo RB	Wet-1(May)	0	3,321	0	3.0	3.0	900	-
(Boribo-MN	Wet-2(July)	2,395	1,768	4.23	4.1	(-0.1)	2,320	0.97
SRB i1))	Dry(Feb.)	965	1,331	1.28	0	(-1.3)	0	-
Boribo RB	Wet-1(May)	-	3,321	-	1.4	1.4	420	-
(N, MN Residual	Wet-2(July)	-	1,768	-	1.9	1.9	1,070	-
SRB h2)+i2))	Dry(Feb.)	-	1,331	-	0	0	0	-

(a) Boribo -North SRB:

- Wet-1 (May) : d) = 2.6, sufficient for existing 300ha, a potential for 780 ha.
- Wet-2 (July) : d) = 1.6, insufficient for existing 4,942ha, a potential for 900 ha.
- Dry (Feb.) : d) = 0

(b) Boribo-Middle North SRB:

- Wet-1 (May) : d) = 3.0, a potential for 800 ha.
- Wet-2 (July) : d) = 4.1, almost sufficient for exist. 2,395ha, a potential for 2,320 ha.

- Dry (Feb.) : d) = 0, insufficient for existing 965ha,

(c) Boribo-North , Middle North, SRB Residual:

- Wet-1 (May) : d) = 1.4, a potential for 420 ha.
- Wet-2 (July) : d) = 1.9, a potential for 1,070 ha.
- Dry (Feb.) : d) = 0.

(3) Boribo- Middle South Sub River Basin and Boribo-South Sub River Basin

For Boribo- Middle South (BOR-MS) and Boribo-South (BOR-S) SRB's, the results of water balance for 2 Sub River Basins were as follows:

Estimation of Sub River Basin –wise Water Potential in Boribo- Middle South SRB and Boribo-South SRB

River Basin(RB) (Sub River Basin(SRB))	Cropping Season (Critical month)	a) Existing Area (ha)	b) Unit Irrigation Requir. (m^3/ha)	c) Total Irrigation Water May (MCM)	d) Available Water for Irrigation (MCM)	e) Water Surplus (Deficit) (MCM)	f) Approx. Irrigable Potential Area (ha)	g) Potential / Existing Ratio
Boribo RB	Wet-1(May)	150	3,321	0.50	2.4	1.9	720	4.80
(Boribo-MS	Wet-2(July)	19,693	1,768	34.81	6.1	(-28.7)	3,400	0.17
SRB j1))	Dry(Feb.)	1,245	1,331	1.66	0	(-1.7)	0	-
Boribo RB	Wet-1(May)	0	3,616	0	1.6	1.6	440	-
(Boribo-South	Wet-2(July)	8,744	2,062	18.03	2.7	(-0.1)	1,300	0.15
SRB k1))	Dry(Feb.)	120	1,331	0.16	0	(-0.2)	0	-
Boribo RB	Wet-1(May)	-	3,321	-	0.4	0.4	120	-
(MS,S Residual	Wet-2(July)	-	1,768	-	1.1	1.1	600	-
j2)+k2))	Dry(Feb.)	-	1,331	-	0	(-0.2)	0	-

(a) Boribo-Middle South SRB:

- Wet-1 (May) : d) = 2.4, sufficient for existing 150ha, a potential for 720 ha.
- Wet-2 (July) : d) = 6.1, insufficient for existing 19,693ha, a potential for 3,400 ha.
- Dry (Feb.) : d) = 0

(b) Boribo-South SRB:

- Wet-1 (May) : d) = 1.6, a potential for 440 ha.
- Wet-2 (July) : d) = 2.7, insufficient for existing 8,744ha, a potential for 1,300 ha.
- Dry (Feb.) : d) = 0, insufficient for existing 120ha,

(c) Boribo-Middle South, South SRB Residual:

- Wet-1 (May) : d) = 0.4, a potential for 120 ha.
- Wet-2 (July) : d) = 1.1, a potential for 600 ha.
- Dry (Feb.) : d) = 0.