Ministry of Water Resources and Meteorology,
Ministry of Agriculture, Forestry and Fisheries,
The Kingdom of Cambodia

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

FINAL REPORT

VOLUME-III
APPENDIXES
(PRE-FEASIBILITY STUDY FOR PRIORITY SIX SUB-PROJECTS)
(1/2)

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LIST OF VOLUMES

VOLUME-I **MAIN REPORT**

VOLUME-II **APPENDIXES (MASTER PLAN STUDY FOR FOUR RIVER BASINS)**

Appendix-A: Meteorology and Hydrology

Appendix-B: Rural Socio-Economy

Appendix-C: Agriculture

Appendix-D: Irrigation and Drainage

Appendix-E Cost Estimate

Appendix-F Environment

Appendix-G Project Evaluation

VOLUME-III **APPENDIXES (PRE-FEASIBILITY STUDY FOR PRIORITY SIX SUB-PROJECTS) (1/2)**

Appendix-A: Meteorology and Hydrology

Appendix-B: Agriculture

Appendix-C: Irrigation and Drainage

VOLUME-IV **APPENDIXES (PRE-FEASIBILITY STUDY FOR PRIORITY SIX SUB-PROJECTS) (2/2)**

Appendix-D Design and Cost Estimate

Appendix-E Project Evaluation

Appendix-F Rural Socio-Economy and Environment

Appendix-A

METEOROLOGY AND HYDROLOGY

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

FINAL REPORT

APPENDIX-A METEOROLOGY AND HYDROLOGY

Table of Contents

Page

List of Tables

List of Figures

CHAPTER A1 METEO-HYDROLOGICAL CONDITIONS

A1.1 River Basins

A1.1.1 Four River Basins

(1) The Study Area

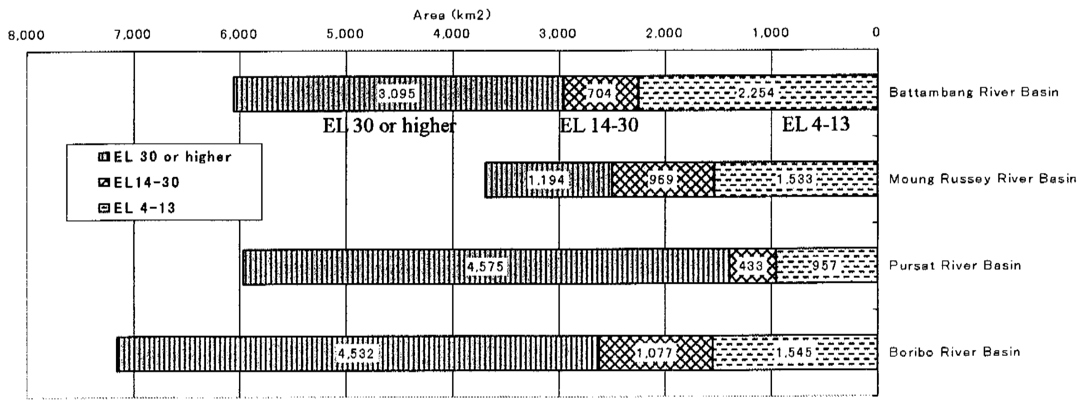
The Basin-wide Basic Irrigation and Drainage Master Plan Study (the Study), covers 22,868 km2 of the south-western part of the Tonle Sap Lake (the Great Lake) Basin. The Study Area consists of four River Basins, namely Battambang (Sangker), Moung Russei (Dauntri), Pursat and Boribo River Basins as in Figure A.1.1.1. These River Basins are defined on the basis of a basin map illustrated in "Irrigation Rehabilitation Study in Cambodia" prepared by Mekong River Commission (MRC) in 1994 and following ADB's "Halcrow Report". Each of the above four River Basins is not a single river basin, but a complex of plural river basins. In the Appendix A, the "River Basin" is regarded as one of the above four River Basins and the "river" or "river basin" indicates the single river itself or single river basin. Major rivers are illustrated in Figure A.1.1.2.

Major dimensions of the River Basins are presented below.

River Basin Dimensions

River Basin	Area*1	Lower area*1				EL 30 or higher		Highest point*3
		EL 4-13		EL14-30				
	(km2)	(km2)	(%)	(km2)	(%)	(km2)	(%)	(m, amsl)
Battambang	6,053	2,254	37	704	12	3,095	51	1,391
Moung Russey	3,696	1,533	42	969	26	1,194	32	1,280
Pursat	5,965	957	16	433	7	4,575	77	1,717
Boribo	7,154	1,545	22	1,077	15	4,532	63	1,764
Total	22,868	6,289	27	3,183	14	13,396	59	1,764

Data source: *1 = MOWRAM and "Tonle Sap Lowland Stabilization Project, Report on Water Availability, Sep., 2006", financed by ADB; Original figures are rounded.
*2 = The Study Team *3 = The Study Team from 1:10,000 scale topographic map



Prepared by JICA Study Team

Area by Elevation

(2) Battambang River Basin

The Battambang (Sangker) River Basin has a catchment area (CA) of 6,053 km^2, in which the highest elevation is 1,391 m. More than one third (1/3) of the River Basin is EL 4 to 13 m. The Battambang River joins with the Mongkol Borei River (CA=10,858 km^2) at Bac Prea, about 40 km downstream from the Battambang Town. The Sreang River (CA=9,933 km^2) joins to the Sangker (Battambang) River at around 10 km downstream from Bac Prea. The Sangker River, consisting of above three rivers, flows into the Lake Tonle Sap. The Battambang River catchment area at Battambang hydrological station in Battambang Town is 3,194 km^2.

(3) Moung Russey River Basin

The Moung Russei (Dauntri) River Basin has an area of 3,696 km^2, where the highest elevation is 1,280 m. More than 40 % of the River Basin is EL 4 to 13 m and less than one third (1/3) of the Basin is EL 30 m or higher. The Moung Russei River and the Svay Don Keo River are main rivers in the River Basin. The Kambot River flows eastern part of the River Basin along one of the old river courses of the Pursat River.

(4) Pursat River Basin

Catchment area of the Pursat River Basin is 5,965 km^2, in which the highest elevation is 1,717 m. This River Basin has comparatively wider hilly area and more than three forth (3/4) of the Basin is EL 30 or higher. The upper Pursat River basin consists of three tributary basins, namely Pursat, Arai (Peam) and Prey Khlong River basins. The Pursat River catchment area at Khum Viel hydrological station in Pursat Town is 4,596 km^2.

(5) Boribo River Basin

The Boribo River Basin has an area of 7,154 km^2, of which the highest elevation is 1,764 m. Topography of the River Basin is relatively complicated in the Study Area. This River Basin consists of smaller river basins compared with the Battambang and Pursat River Basins. Major rivers are Tlea Maam, Bomnak-Boribo, Svay Chek and Krang Ponley Rivers.

A1.1.2 Related Provinces

As seen in Figure A.1.1.1, main provinces in the Study Area are Battambang, Pursat and Kampong Chhnang Provinces. Some parts of the Study Area belong to Pailin, Kompong Speu, Kandal Provinces and Phnom Penh City.

(1) Battambang River Basin

This Basin is mostly covered by the Battambang Province and two small upstream parts are belonging to the Pailin and Pursat Provinces. The northern half of the Battambang Province covers the Mongkol Borey River Basin.

(2) Moung Russey River Basin

The Svay Don Keo river channel formulates a part of the provincial boundary between Battambang and Pursat, the river itself being included in the Pursat River Basin. Southeastern half belongs to the Pursat Province and northwestern half to the Battambang Province.

(3) Pursat River Basin

The Pursat Province covers the whole of the Pursat River Basin. The Pursat River Basin occupies a central part of the Pursat Province.

(4) Boribo River Basin

The largest part of the Boribo River Basin belongs to the Kampong Chhnang Province. Of the River Basin, northwestern part belongs to the Pursat Province, southwestern part to the Kompong Speue Province, and southeastern part to the Kandal Province and Phnom Penh.

A1.2 Existing Conditions of Meteo-Hydrological Observation

A1.2.1 Meteorological Observation

There are three meteorological stations in and around the Study Area as seen in Table A.1.2.1 and Figure A.1.2.1. Collected available data are shown in Figure A.1.2.2.

In Battambang station, an automatic observation system was installed but is almost out of order at present. Available data have not been found for recent years.

Also in Pursat station, an automatic observation system was installed but is not functioning fully at present.

Pochentong meteorological station is located beside the international airport near the office of Department of Meteorology (DOM), MOWRAM in Phnom Penh. It locates near the southern perimeter of the Boribo River Basin.

According to MOWRAM information, Chhnok Trou meteorological station exists at southeastern end of the Lake Tonle Sap or the Tole Sap river head in the Kampong Chhnang Province. Detailed information on the station is not obtained.

A1.2.2 Rainfall Observation

Table A.1.2.2 is list of related rainfall stations. The rainfall stations are located as in Figure A.1.2.3 and period of available rainfall data can be seen in Figure A.1.2.4. Battambang, Pursat, Kampong Chhnang, Pochengton and Kompong Speue stations being among the long term observation stations in Cambodia, have monthly rainfall data of more than 50 years. These stations are placed in each PDWRAM office space.

Under control of or requested by PDWRAM/MOWRAM, local observer living near each local station usually measures or checks rainfall at 7 am in the morning every day and records the observed value on the MOWRAM format sheet. The sheets are three colored, namely white, light blue and light pink and printed in Khmer. In use of carbon papers, three sheets (original and two copies) are to be one set, though it is often not followed. PDWRAM and/or MOWRAM staff members collect the recorded sheets and compile data. DOM is responsible for the rainfall observation in principle at present. Some stations are maintained by DHRW.

A1.2.3 Water Level Observation

Hydrological stations are located as illustrated in Figure A.1.2.5 and available water level data together with discharge data are shown in Figure A.1.2.6. List of the hydrological stations is prepared as in Table A.1.2.3. Of available hydrological data, observation period starts 1962 or later and many are from 1993 or after.

Normal observation has been done through staff gauge reading twice a day (7:00 and 17:00 or 19:00) by local people under control of PDWRAM and/or MOWRAM. The local observers use similar record format sheets as rainfall case. Department of Hydrology and River Works (DHRW), MOWRAM is in charge of the observation.

A1.2.4 Discharge Measurement

Discharge measurement has been carried out intermittently by DHRW. It seems that numbers of the discharge measurement are often not enough for periodical rating curve preparation. Daily discharge calculation through rating curves is sometimes not conducted sufficiently and correctly in recent year.

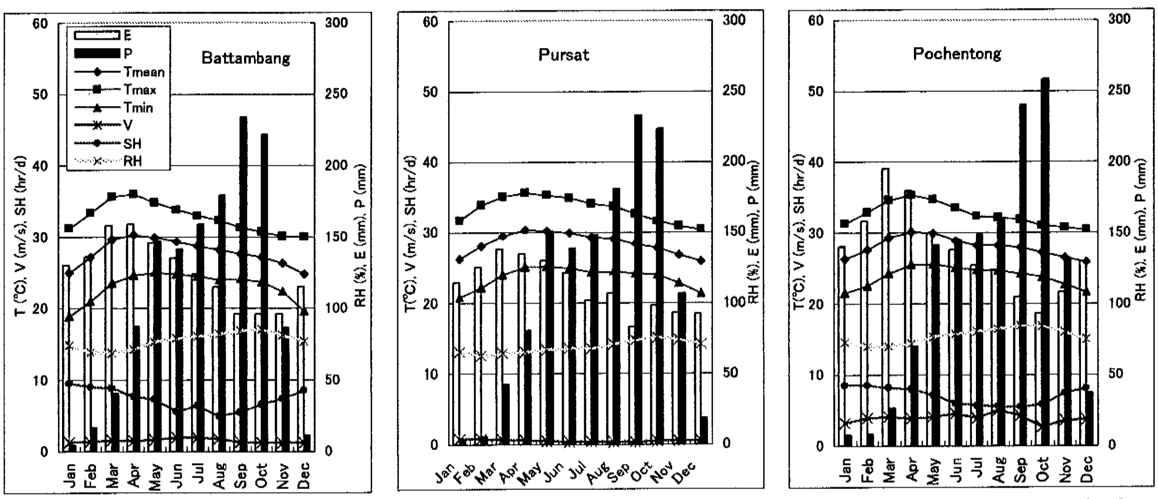
A1.3 Meteo-Hydrological Conditions

A1.3.1 River System

As presented in Figures A.1.3.1 and A.1.1.2, the Battambang (Sangker) river and the Pursat river are of the largest scale in the Study Area. Other major rivers are the Moung Russey (Dauntri) and Svay Don Keo rivers in the Moung Russey River Basin, and the Bomnak-Boribo-Tlea Maam river system, Svay Chek and Krang Ponley rivers in the Boribo River Basins. For hydrological study, the River Basins are divided into sub-basins as in Table A.1.3.1 and Figure A.1.3.1.

A1.3.2 Climate

Climate of the Study Area is classified into tropical monsoon or savanna zone. Meteorological characteristics can be seen in Table A.1.3.2 and figure below.



Wind speed (V) at 10 m above ground surface

Wind speed (V) at 12 m above ground surface

Prepared by JICA Study Team

Meteorological Characteristics

The dry season is from November to April and the wet season is from May to October. Annual mean temperature is estimated at 27.8-28.5℃ and relative humidity is 69-78 % as in the figure above. Annual pan evaporation is around 1340-1650 mm in average.

A1.3.3 Rainfall

Among the rainfall stations in Figure A.1.2.4, several stations have longer term observation data, from which average monthly rainfalls are calculated as below. As an example, monthly discharges at Battambang are shown in Table A.1.3.3. Average annual rainfalls are between 1100 mm and 1700 mm in the plain as seen in Figure A.1.3.2.

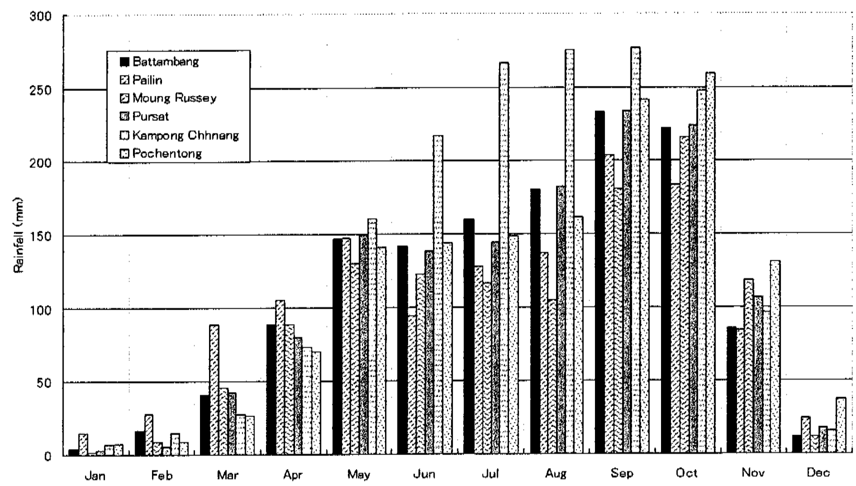
Average Monthly Rainfall

(mm)

River Basin	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Battambang	Battambang	4	17	41	86	148	143	158	178	234	220	87	11	1328
Mongkol Borey	Pailin	15	28	89	106	148	94	128	137	203	183	84	24	1240
Moung Russey	Moung Russey	2	8	48	88	130	127	120	107	179	216	121	12	1156
Pursat	Pursat	3	6	43	81	150	140	142	183	233	223	107	18	1329
Boribo	Krakor	4	6	30	63	193	188	178	210	241	287	96	21	1517
Boribo	Kampong Chhnang	7	15	27	74	163	216	267	272	281	247	96	15	1679
Prek Thnot	Pochentong	7	9	27	70	141	145	148	163	240	259	130	37	1375

Source: MOWRAM and TSLSP   Prepared by JICA Study Team

The monthly rainfall is the least in January and the largest in September/October. Among the stations in the above table and right hand side figure, Moung Russey station gains the least annual rainfall (1150 mm) and Kompong Chhnang is receiving the largest annual rainfall (1680 mm).



Prepared by JICA Study Team

Average Monthly Rainfall

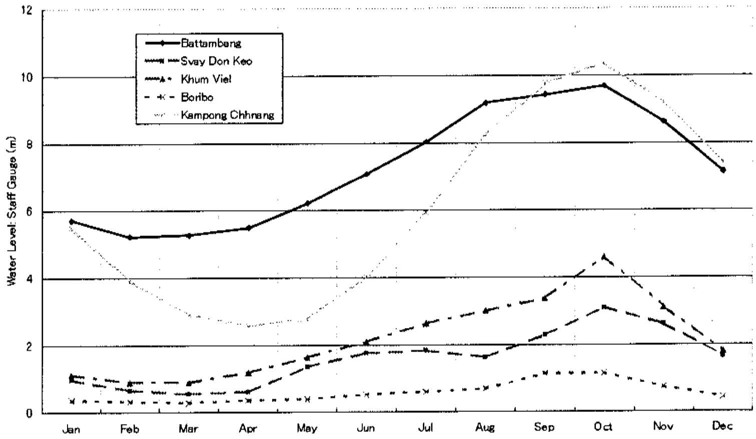
At Moung Russey and Kampong Chhnang rainfall stations, 72% and 86% of annual rainfall concentrate in the rainy season from May to October, respectively. Average rainfall in the dry season from November to April is larger at Moung Russey station (276 mm) than at Kampong Chhnang station (235 mm).

As shown in Table A.1.3.4, mean annual rainy days are 102 and 106 days at Pursat Town and Kampong Chhnang Town, respectively, and 126 days at Moung Russey Town. Therefore, daily rainfall at Moung Russey tends to smaller than that at Kampong Chhnang. In other words, rainfall at Kampong Chhnang generally concentrates to certain shorter days in the rainy season with high intensity compared with relatively milder rainfall at Moung Russey.

A1.3.4 Water Level and Discharge

(1) Water Level

Considering available data quantity and quality, key stations are selected for respective River Basins as presented in the following table. To assess data quality, runoff in height (mm) and shape of hydrograph are carefully checked. The hydrographs are illustrated in the right figure.



Prepared by JICA Study Team

Average Monthly Water Level

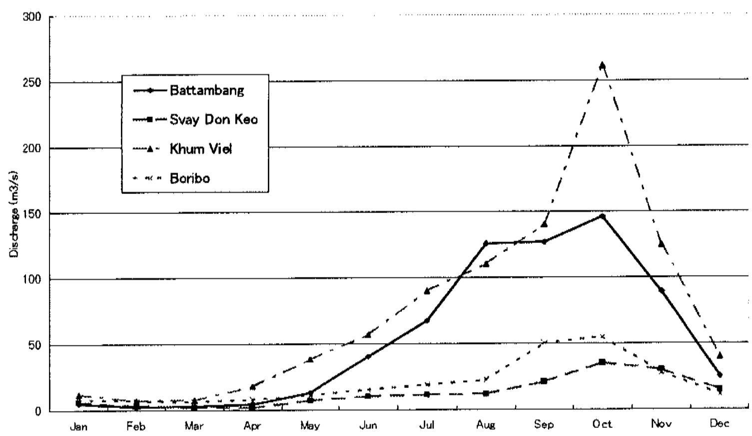
Prepared by JICA Study Team

(m, staff gauge)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Battambang River Basin													
Battambang	5.71	5.23	5.27	5.49	6.22	7.07	8.03	9.18	9.43	9.69	8.62	7.14	7.26
Moung Russey River Basin													
Svay Don Keo	0.96	0.66	0.55	0.62	1.35	1.76	1.82	1.63	2.28	3.10	2.61	1.65	1.58
Pursat River Basin													
Khum Viel	1.12	0.90	0.89	1.19	1.64	2.10	2.64	3.01	3.38	4.60	3.11	1.79	2.20
Boribo River Basin													
Boribo	0.36	0.32	0.28	0.36	0.39	0.52	0.59	0.68	1.13	1.14	0.75	0.44	0.58
Tonle Sap River													
Kampong Chhnang	5.49	3.91	2.92	2.58	2.78	4.02	5.93	8.23	9.75	10.36	9.18	7.42	6.05

(2) Discharge

Hydrographs of average monthly discharge clearly show seasonal runoff pattern as in right hand figure and table below. Discharge becomes the lowest or droughty from February to April and its peak comes out in October. Discharge in December is higher than that in May, which suggests delay or gap between rainfall and runoff patterns.



Prepared by JICA Study Team

Average Monthly Discharge

Average Monthly Discharge (m3/s)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Battambang	4.8	2.2	2.7	4.4	12.9	40.2	67.6	126.1	127.1	146.2	89.5	25.0	54.1
Svay Don Keo	5.9	3.0	1.9	1.7	7.2	10.1	11.3	11.8	21.0	35.2	30.0	14.7	12.8
Khum Viel	11.9	7.1	7.4	17.9	38.3	56.8	90.1	110.4	140.5	261.3	125.1	40.0	75.6
Boribo	8.0	6.7	6.0	7.9	10.8	15.3	18.9	22.4	50.4	54.8	27.6	11.2	20.0

Source: MOWRAM and TSLSP (Tonle Sap Lowland Stabilization Project)

A1.3.5 Discharge Measurement and Rating Curve

(1) Discharge Measurement

Since collected discharge measurement data are limited, it is difficult to review them deeply. To prepare and revise rating curves periodically, discharge measurement including low and high flows must be carried out every year. However, the measurement data seem insufficient in general. Such water level stations that locate near the Tonle Sap Lake, usually do not have discharge measurement record, probably because the objective of them is only gain water level data. One of the reasons why discharge measurement data are not sufficient, is limited budget and staff in DHRW. DHRW is in charge of discharge measurement along the Mekong river system also.

(2) Rating Curve

Preparation of rating curves is quite important and is often difficult work. Improper rating curve leads improper discharges, which sometimes occur. Rating curves must be revised sometimes, at the time of change in river channel condition. During flood river bed and bank often change shape by scouring or sediment. Some of the good rating curves were prepared in MRC-JICA study, "The Study on Hydro-Meteorological Monitoring for Water Quantity Rules in Mekong River Basin", March 2004, CTI and NK.

A1.4 Current Observation System

A1.4.1 Institutional Frame

(1) MOWRAM

Ministry of Water Resources and Meteorology (MOWRAM) is in charge of meteorological and hydrological observation, data processing and analysis. In each province, Provincial Department of Water Resources and Meteorology (PDWRAM) is placed under MOWRAM.

According to Ministry of Economy and Finance (MOEF) of the Government of Cambodia (GOC), the Government budget expenditure for MOWRAM in 2006 is approximately 18.8 billion Riel or US$ 4.6 million as seen in table below. Detailed annual budget is presented in Table 7.5.1 in Main Report. Amounts of fund from external donors in 2001 and 2002 are US$ 5.81 and 5.27 million, respectively, against the government development budget of US$ 0.26 and 0.09 million in 2001 and 2002.

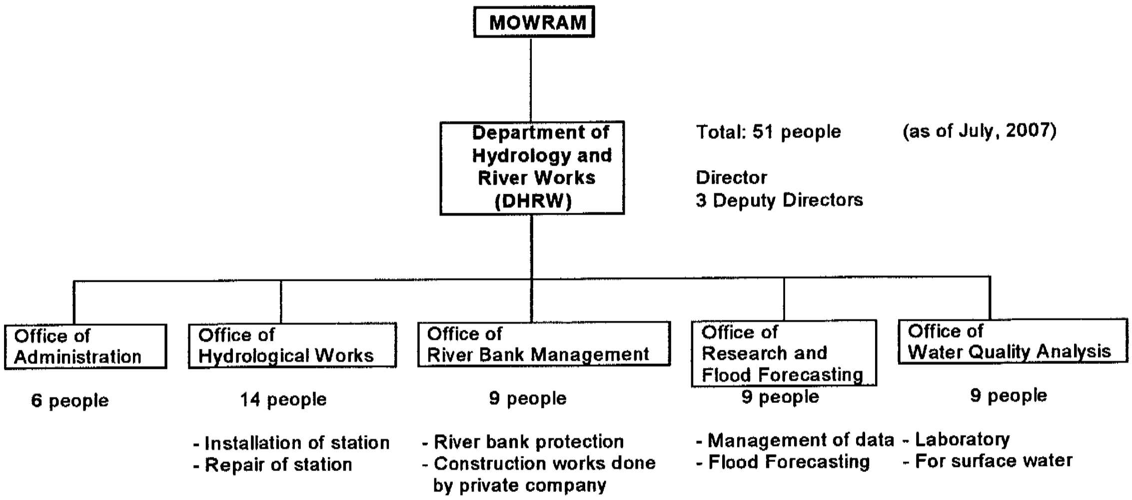
MOWRAM Expenditure (million Riel) E-Data

2000	2001	2002	2003	2004	2005	2006
6,109	8,764	11,861	13,844	14,305	13,765	18,774

Source: MOEF

(2) DHRW, MOWRAM

Department of Hydrology and River Works (DHRW) of 51 people is responsible for hydrological observation and such items as shown in organization chart below. Office of Hydrological Works conducts discharge measurement. Office of Research and Flood Forecasting treat collected data. Development budget of DHRW in 2003 is only US$5,200 as seen in Table 7.5.1 in Main Report.



Organization of DHRW

(3) DOM, MOWRAM

Department of Meteorology (DOM) of 50 people is responsible for meteorological observation including rainfall. One of the duties is meteorological observation for international airport at Pochentong, Phnom Penh. DOM prepared its organization chart as illustrated in Figure A1.4.1. Development budget of DOM in 2003 is only US$ 2,400 as in Table 7.5.1 in Main Report.

(4) PDWRAM

Long term rainfall data of more than 50 years are available at Battambang, Pursat and Kampong Chhnang stations located in PDWRAM office areas.

The development budget from external donors to the three PDWRAMs during a period from 2002 to 2004, is US$ 1.05 in total. Out of that, US$ 0.41 million is for Battambang province, US$ 0.15 million is for Pursat province and US$ 0.49 million is for Kampong Chhnang province as seen in Table 7.5.1 in Main Report.

A1.4.2 Observation and Data Compilation

(1) Observation

As seen in Figures A.1.2.4 and A.1.2.6, most of the rainfall and hydrological stations have only limited observation period, even though number of the stations are not so small. In many cases, observation continues during certain project period, but stops after the end of the project. According to MOWRAM, GOC budget is not sufficient to cover operation and maintenance cost for meteo-hydrological observation.

Another problem is that most of the officers cannot concentrate to his duties in the government offices. Salary level of the officers in Cambodia is very low, around US$ 50/month in average, against reported necessary living cost (in Phnom Penh) of US$200 to 400/month/family. In general, most of the officers come to their offices, confirm that no works on that day and go to side-business. As a result, office works usually concentrate to limited number of higher class officers. Also, new personnel from younger generation is in short.

(2) Data Compilation and Processing

The hydrological data are compiled or processed through HYMOS system. Meteorological and hydrological data observed at main station are compiled and processed as routine work. However, a lot of data seem to be processed mainly through works in respective project. One of the constraints is insufficient personal computers and engineers to use computers, particularly in PDWRAMs. Number of staff with necessary technical level and experience is limited. Number of specialist for meteorological observation is not enough. There is no college having fixed meteo-hydrological study course. Very few young technically trained people joined DHRW recently.

CHAPTER A2 DEVELOPMENT OF METEO-HYDROLOGICAL OBSERVATION SYSTEM

A2.1 Objective and Scope

A2.1.1 Objective

In the Study Area of 22,868 km^2, meteo-hydrological observation network is not sufficiently developed and collected data are not enough to make various water related programs, plans and projects, including irrigation and drainage sector. Objective of the meteo-hydrological investigation in the Study includes strengthening of the observation system, through equipment installation with following observation and data processing. Installed equipment consists of automatic rain gauges, staff gauges and automatic water level gauges. The observation includes rainfall and water level observation, and discharge measurement.

A2.1.2 Scope and Activity

In addition to preliminary installation of staff gauges by JICA Cambodia Office in December 2006, the Study Team installed staff gauges and automatic rain gauges in February and March 2007. In total, 12 automatic rain gauges and 13 staff gauges were placed at site through subcontract by March 2007. Rainfall observation began just after the installation and water level staff reading began after selection of the local observer. Establishment of six automatic water level gauges, of which three are of float type and three are of pressure type, commenced in July 2007 through sub-contract. Observation by automatic water level recorder (AWLR) started in August, but lower part structure was completed later after water level dropped down to low enough in the dry season. Two automatic rain gauges and two pressure type AWLRs were additionally installed by February 2008. Finally, 14 rainfall stations and 14 water level stations were installed or re-installed in the Study as in Table A.2.1.1 and Figure A.2.1.1. The above meteo-hydrological equipment was supplied by JICA.

In cooperation with MOWRAM and three PDWRAMs, the Study Team collected and compiled observed data at abovementioned stations, and carried out discharge measurement and prepared rating curves. The earliest data are from December 2006. Some parts were performed by sub-contractor, including discharge measurement from June 2007 to February 2008. From May to September 2008, the Study Team carried out the data collection and discharge measurement under site control of counterparts of MOWRAM/PDWRAMs. From technical point of view, MOWRAM /PDWRAMs staff have enough capacity to collect data and do discharge measurement, from October 2008.

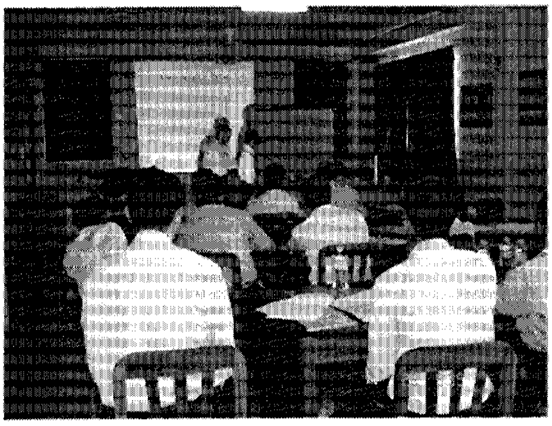
Above observed data in 2007 are used in the Study and the data in 2008 will be utilized in future studies and projects.

A2.2 Methodology

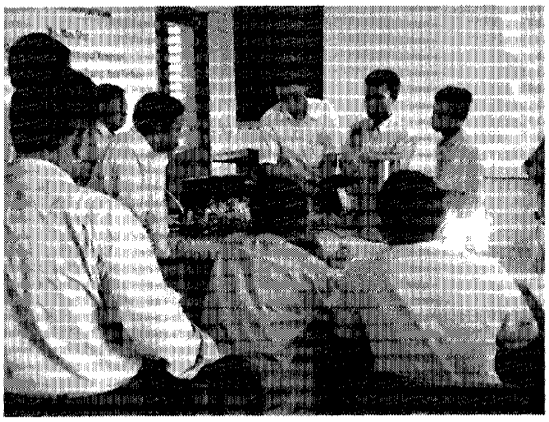
A2.2.1 OJT Technology Transfer and Mini Workshop

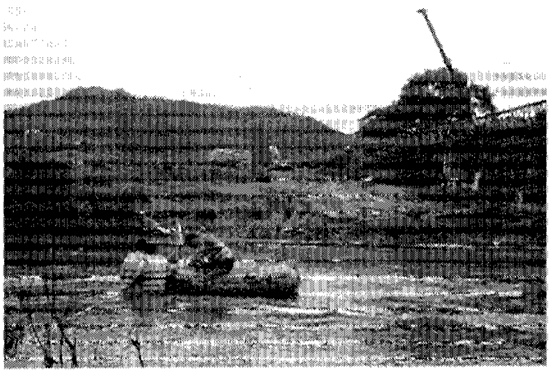
Technology was transferred in all aspects of the study through OJT.

To transfer necessary technology for the discharge measurement and handling of automatic rain gauge, a mini-workshop was held to PDWRAM and MOWRAM staff on 28th and 29th June, 2007 as on-the-job training (OJT). The OJT was composed of indoor and field training, namely explanatory presentation, equipment treatment guidance, and discharge measurement and rain data collection together with maintenance check at site.



Mini-workshop





"River Discharge Measurement Manual (Draft)", presentation materials and equipment manuals were prepared and distributed to the participants.

The Study Team and its counterpart made presentation both in English and in Khmer. The first presentation was on outline of the Study. In the technical subjects, real problems found in the course of data processing were pointed out as examples for easy understanding.

Mini-workshop

A2.2.2 Discharge Measurement and Data Collection

At newly installed or additional water level stations, discharge measurement was conducted 15 times from June 2007 to February 2008 by the Study Team as a sub-contract work in cooperation with MOWRAM/PDWRAM. Out of two sets of flow meter or current meter, one set is used in the field, but no float was thrown into the river during this period. The flow meters and floats were supplied from JICA.

From May to September in 2008, discharge measurement was carried out eight times by the Study Team under control of counterparts of MOWRAM and PDWRAMs.

A2.3 Rainfall Station

A2.3.1 Selection of Location

In consideration of importance and approach easiness, location of twelve (12) rainfall stations were selected during the preliminary survey stage as a result of discussion between JICA Preliminary Survey Team and MOWRAM/PDWRAM as well as field survey. In February 2007 at the beginning of Phase I, the Study Team visited and confirmed all the candidate locations with MOWRAM/PDWRAM counterparts, and finally decided the locations at basically the same points as selected before. Manual rain gauges were already placed at Ratnak Mondol and Phnon Preak stations. In the preliminary survey, Ta Kab station was called Svay Chek, which is about 10 km downstream from the selected point. Ta Kab is village name of the left bank of the Chi Prang river in the Svay Chek river basin.

(refer to Table & Figure A.2.1.1)

There is another older station named Peam in the Pursat river basin. The additional station is named Peam (Krang Ponley river), to distinguish it from the existing station in the Pursat river basin. The station sites are as seen in right table.

Land Ownership of Additional Rainfall Station

No.	Station	Site
R1	Ratnak Mondol	District Office*
R2	Samlot	District Office
R3	Phnom Proek	District Office*
R4	Basak Reservoir	Military Compound
R5	Moung Russey	District Office
R6	Roveang	Temple (Pagoda)
R7	Svay Don Keo	Police Office
R8	Koh Chhom	Village
R9	Bomnak	Private land of Chief of Commur
R10	Boribo	Police Office
R11	Ta Kab	Beside observer's house
R12	Peam (Krang Ponley Rive	Commune land
R13	Kampong Tralach	District Office*
R14	Veal Veang	District Office

Prepared by JICA Study Team

Additional two automatic rain gauges were installed in February 2008. After discussion with MOWRAM/PDWRAM staff, the locations were selected at Kompong Tralach in Kampong Chhnang Province or Boribo River Basin and Veal Veang in Pursat Province or Pursat river basin. The Kompong Tralach station, with longer observation period from 1920, is one of the important stations in the province. The Veal Veang station was selected, because it is located in a less distributed upstream area of observation network and previous rain gauge was broken.

A2.3.2 Rain Gauge

The installed rain gauge example is shown in Figure A.2.3.1. Tipping bucket type automatic rain gauge with small data logger is selected for the Study. The tipping bucket type is broadly used in many countries. The data logger can be contained in the rain gage cylinder cover, so outside logger case is not required. Tipping count is set at 0.5 mm/count. Stored data are withdrawn either by personal computer or data collector.

A2.4 Water Level Station

A2.4.1 Selection of Locations

(1) Staff Gauge

Location of eleven (11) water level stations were selected during the preliminary survey stage as a result of discussion between JICA Preliminary Survey Team and MOWRAM/PDWRAM as well as field survey. In February 2007 at the beginning of Phase I, the Study Team visited and confirmed all the candidate locations with MOWRAM/PDWRAM counterparts, and finally decided the locations at basically the same points as selected before, though two (2) stations were added, location of some stations were slightly moved and some station names were changed. Before the Study Team start field survey, eight (8) staff gauges were already installed, of which seven (7) were done by JICA Cambodia Office and one (1) was by MOWRAM. The Study Team and counterpart MOWRAM/PDWRAM staff checked each location and standing staff gauge carefully, and completed the staff gauge installation as presented in the following table. Two (2) stations were added to original list due to change of conditions at Bomnak as mentioned in **(2)** below. In the preliminary survey, Treng station was listed up. According to MOWRAM, the location was changed to Dong Tung bridge point during the preliminary survey, but the station name remained unchanged. Dong Tung station is more than 10 km upstream from Treng site. Also, as in **A2.3.1**, Ta Kab station was called Svay Chek, which is about 10 km downstream from the selected point. Ta Kab is village name of the left bank of the Chi Prang river in the Svay Chek river basin.

Installation of Staff Gauge and Automatic Water Level Guages

No.	Station	Staff Gauge (m)						Automatic Water Level Recorder
		MOWRAM/ PDWRAM	JICA*1 Preliminal	the Study Team*2			Total Length*3	
				Replace	Install			
1	Battambang	10	-	4	1	lowest	11	-
2	Dong Tung	-	11	-	1	lowest	12	Pressure type
3	Moung Russey	-	-	-	8	new	8	-
4	Prek Chic (River)	-	7	-	2	low/highest	9	Pressure type
5	Prek Chic (Canal)	-	4	-	1	lowest	5	-
6	Svay Don Keo	4	0	-	5	new site	5	-
7	Koh Chhom	-	-	-	6	new	6	-
8	Bomnak	-	4	-	-		4	-
9	Bomnak A (west)	-	-	-	5	new	5	Float type
10	Bonmak B (east)	-	-	-	6	new	6	Float type
11	Boribo	4	0.8	-	1.2	highest	6	-
12	Ta Kab	-	-	-	6	new	6	Float type
13	Peam (Krang Ponley river)	4	1	-	2	highest	7	Pressure type
14	Veal Veang	-	-	-	14	new*4	14	Pressure type
	Total	22	27.8	4	58.2		104	

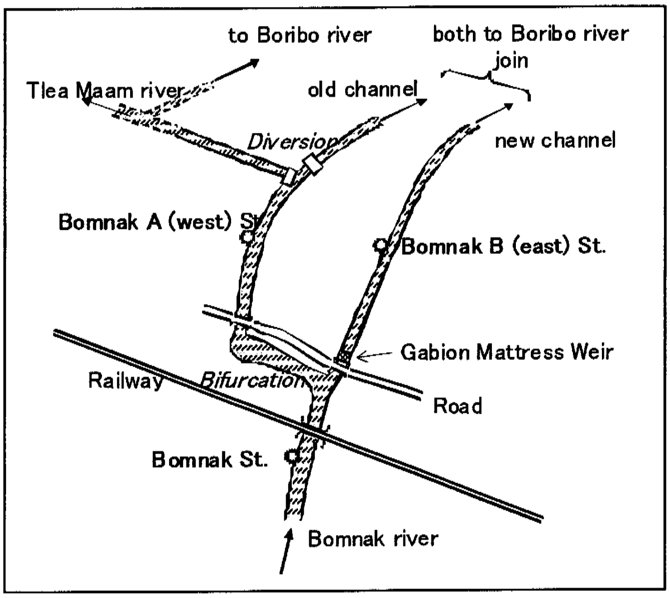
Note *1: Installed in December 2006 by JICA Cambodia Office *2: Installed in February and March 2007
*3: Total length of staff gauge in September, 2008 *4: Installed in February 2008

Prepared by JICA Study Team

(2) Additional Stations around Bomnak Diversion

The reasons why two stations were added to as in the above list are mentioned here with figure below. The Bomnak River bifurcates to old and new channels of the Boribo Rivers at Bomnak at present. In the beginning of February 2007, a simple gabion mattress weir was under construction at the head of the new Boribo River for recovery of old Boribo River flow. As a matter of course, the weir influence river flow conditions.

Upstream Bomnak water level station is affected by back water from the weir. To observe the Bomnak River discharge without backwater effect and those of bifurcated two channel discharges, two stations were placed on the old and new channels. Since the old Boribo River divert its water to the Tlea Maam River direction, station name near the diversion point is named Bomnak A (Tlea Maam) and the other is named Bomnak B (Boribo River).



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Three Water Level Stations near Bomnak Diversion

Note: In the early stage of the Study, it is considered that diverted water from the old Boribo River is sent to the Tlea Maam River, so Bomnak-A station was named with Tlea Maan River. Later it was informed and confirmed in the field that the diverted water is used for irrigation near Bomnak and not small amount of the diverted water is returned to the Boribo River. Therefore, name of the Bomnak-A and B stations are judged better with west and east.

(3) Automatic Water Level Recorder

Six (6) automatic water level recorders (AWLRs) were installed at six (6) stations out of above thirteen (13) water level stations with staff gauge as in above table, Table A.2.1.1 and Figure A.2.1.1. AWLRs are placed at upstream stations to detect sharp flood wave. Considering river cross section, space for the gauge structure and so on, three stations have float type AWLR and other three stations have pressure type AWLR.

The Study Team discussed with MOWRAM and PDWRAM on the strengthening of the meteo-hydrological observation system, and two sites of additional AWLR installation were selected at Veal Veang (Pursat Province) and Battambang (Battambang Province) by the reasons below. Veal Veang is located in the upstream basin of the Pursat River Basin, where no water level station is placed. Water level data of the station together with its rainfall data, will help rainfall runoff analysis around the catchment border. The Battambang water level station is a key station for flood forecast and warning system. The automatically recorded data will contribute to analyze flood conditions and development of the above system

A2.4.2 Water Level Gauge

The staff gauge and AWLR are presented in Figure A.2.3.2. The staff gauge scale is simple for easy reading by observer. To avoid misreading as much as possible, red and black color plates are placed alternately in principle. PDWRAM/MOWRAM staff explained how to read staff scale and how to record observed value in the form to newly assigned local observer, before start of the observation.

Since MOWRAM has experience to use the AWLRs, several useful advices were given to the Study Team, particularly by Department of Meteorology. For example, double roof of shelter to shut out overheat from direct sunshine and sufficient shelter height that is required to keep space for pulling out inside cylinder of the sensor. Observation interval was set at a half hour at first, which was adjusted to one hour at some of the stations in February 2008 after check of flood hydrographs of 2007.

CHAPTER A3 METEO-HYDROLOGICAL ANALYSIS

A3.1 Review of Previous Studies

A3.1.1 Groundwater and Water Quality

As for groundwater in the Study Area, available data were not found.

Water quality issues in the Study Area are discussed in Appendix-F Environment.

A3.1.2 Previously Adopted Models

In the MOWRAM's "North West Irrigation Sector Project" (NWISP) financed by ADB and AFD, PRD Water & Environment and DHI Water & Environment used MIKE Basin Model for Dauntri Sub-basin (= Moung Russey River Basin) and Boribo Sub-basin (= Bomnak-Boribo-Tlea Maam Sub River Basin, a part of Boribo River Basin). The adopted MIKE Basin Model, being one of DHI's water resources soft packages, consists of Water Balance Model, NAM Model as a runoff model and Water Quality (WQ) Model in NWISP.

A3.2 Meteorological and Rainfall Analysis

A3.2.1 Meteorological Data for Estimation of Irrigation Water Requirement

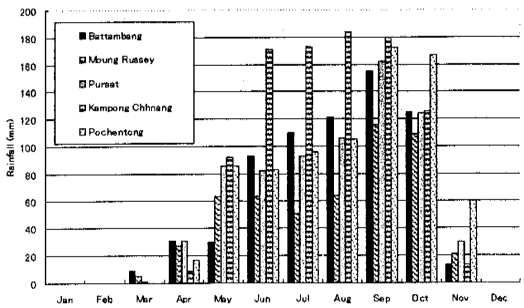
Average monthly meteorological data for each River Basin are estimated as seen in Table A.3.2.1 from existing data at three stations mentioned in above **A1.3.2**.

A3.2.2 Rainfall Data Check and Selection

Existing available rainfall data are being checked mainly through hyetograph of daily rainfall. It was found that "no data" and "no rainfall" are often not distinguished clearly. Some of the daily rainfall hyetographs are unnatural. For example, the hyetographs at Krakor in recent years do not have higher values and rainfall intervals are rather constant. Such rainfall data that were judged not natural, are not used for the Study. Long term observation stations, including Battambang, Pursat, Kampong Chhnang and Pochentong, are selected as main stations for the analysis. Some stations have only a few years' observation data, which were collected only during each project period in many cases.

A3.2.3 Dependable Monthly Rainfall

Of the main stations with long-term data, dependable monthly rainfalls are calculated by Iwai method as in right figure and table below. Isohyetal map of the dependable rainfall are illustrated in Figure A3.2.1. In the plain of the Study Area, Moung Russei River Basin and Battambang River Basin gains the lowest 80% dependable annual rainfall from 900 to1100 mm.



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80 % Dependable Rainfall

Kampong Chhnang Town and adjacent area receives the highest one of 1300 mm or more. From December to February, 80 % dependable rainfall is zero, and in March less than 10 mm. Since there is no available rainfall data, accuracy of the isohyetal map is much lower in the mountainous area. Considering upstream discharge data, rainfall in the mountains is estimated higher than that of the plain.

Probable Monthly Rainfall with 80% Dependability (mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Battambang River Basin													
Battambang	0	0	9	31	30	93	110	121	155	125	13	0	1146
Moung Russey River Basin													
Moung Russey	0	0	5	27	63	63	51	64	116	109	21	0	941
Pursat River Basin													
Pursat	0	0	1	31	86	82	93	106	162	124	30	0	1141
Boribo River Basin													
Kampong Chhnang	0	0	0	9	92	171	173	184	180	126	13	0	1345
Other River Basins													
Pochentong	0	0	0	17	86	83	96	105	172	167	60	0	1173

Prepared by JICA Study Team

A3.2.4 Maximum Rainfall

Probable annual maximum daily rainfall and 3-day consecutive rainfall are calculated by Iwai method as in the following table and right figure. The probable maximum daily and 3-day consecutive rainfalls of 10-year return period are from 120 to 172 mm and from 155 to 231 mm, respectively

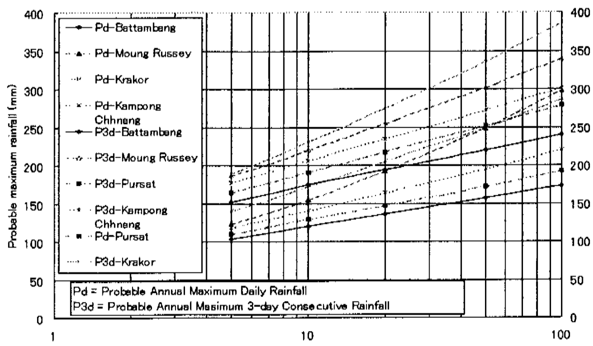


Figure A3.2.4 Probable Maximum Rainfall

Probable Annual Maximum Rainfall

Return Period (Year)	Maximum Daily Rainfall (mm) 2	5	10	20	50	100	Max. Consecutive 3-Day Rainfall (mm) 2	5	10	20	50	100	Data (year)
Battambang	78	103	119	135	156	172	118	151	173	193	219	238	43
Pailin	85	118	138	156	*178*	*195*	126	180	215	247	*289*	*321*	13
Moung Russey	88	130	164	201	*257*	*304*	139	185	218	249	*292*	*326*	13
Pursat	82	109	129	148	175	197	124	163	190	217	253	281	55
Krakor	95	140	172	205	250	*286*	134	189	231	274	336	*386*	30
Kampong Chhnang	89	118	140	162	193	217	137	178	207	235	272	301	53
Pochentong	90	110	128	148	*180*	*207*	118	139	154	169	*189*	*205*	15

Prepared by JICA Study Team

Note: *Italic figures* are less relaible due to shorter data period.

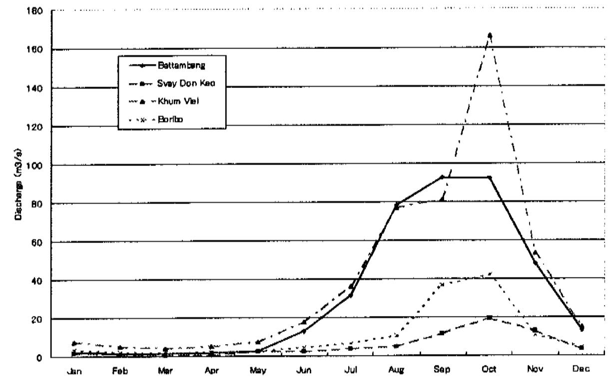
A3.3 Low Flow Analysis

A3.3.1 Hydrological Data Check and Selection

As seen in Figure A.1.2.6, monthly and daily water level and discharge data are available in the Study Area. The monthly discharge data compiled in NWISP, were utilized in principle in the Study. Many of the daily data were not completely compiled, so the Study Team has compiled them in a form of table with hydrograph. Judging from data quantity and quality, or observation period and hydrograph shape, four key hydrological stations are selected. They are Battambang station in Battambang River Basin, Svay Don Keo station in Moung Russei River Basin, Khum Viel station in Pursat River station and Boribo station in Boribo River Basin.

A3.3.2 Dependable Monthly Discharge

Probable monthly river discharges are calculated by Iwai method and those of 80 % dependability are as shown in right figure and table below. From January to May, 80 % dependable discharges are less than 2.9 and 7.6 m3/s at Battambang and Khum Viel, respectively. Those at Svay Don Keo and Boribo are less than 2.4 and 3.4 m3/s, respectively.



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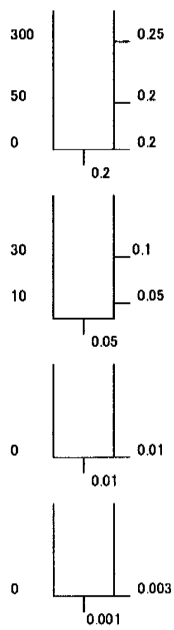
Probable Monthly River Discharge of 80 % Dependability

from Main rivers (m3/s)

River Basin and River	Station	Catchment area (km2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Battambang River Basin														
Battambang (Sangker) River	Battambang	3194	2.4	1.4	1.2	1.5	2.9	12.8	31.5	78.2	92.7	92.3	48.3	13.3
Moung Russey River Basin														
Moung Russey (Dauntry) River	Moung Russey	785	1.6	0.7	0.3	0.3	2.3	2.4	3.5	4.6	11.2	18.8	12.6	3.2
Svay Don Keo River	Svay Don Keo	805	1.6	0.8	0.4	0.3	2.4	2.5	3.6	4.7	11.4	19.2	12.9	3.3
Pursat River Basin														
Pursat River	Khum Viel	4596	7.6	5.0	4.1	5.3	7.3	17.7	36.3	76.8	80.9	166.0	53.3	14.9
Boribo (L) River Basin														
Boribo (S) River	Boribo	803	3.4	2.2	1.6	2.2	2.5	4.4	6.4	10.4	36.5	42.0	10.8	4.3

A3.3.3 Runoff Analysis for Plain

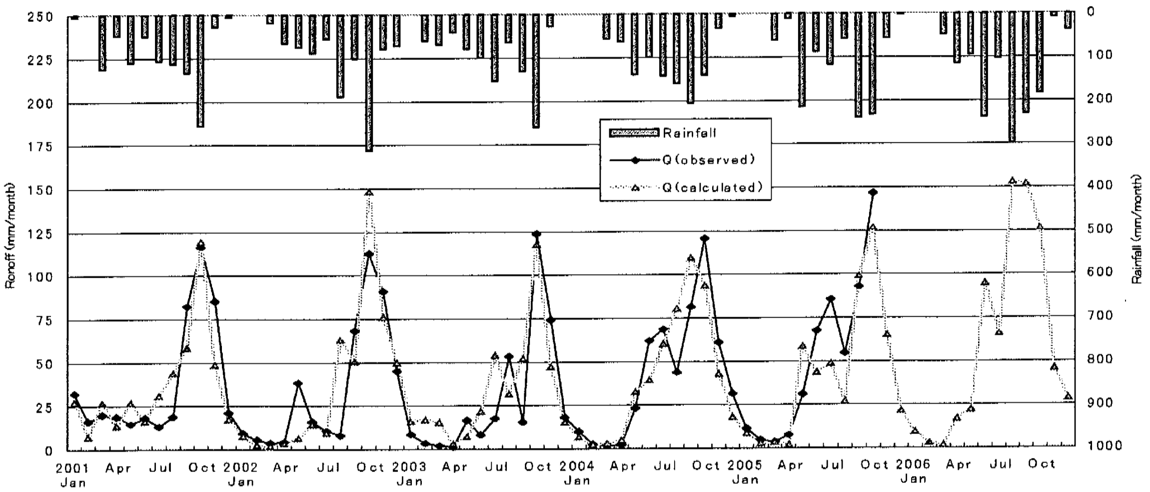
The Battambang river and the Pursat river, being the largest rivers in the Study Area, have available monthly discharge data as abovementioned. The Svay Don Keo river and the Boribo river, which can be classified into middle class in the Study, also have monthly discharge data. In the remaining area, smaller rivers are flowing mostly without available discharge data. For small reservoir irrigation planning, available water in the remaining area or plain area is estimated on the basis of the Svay Don Keo river data that are considered only one available station data in the lowland plain area.



Tank Model

At First, the converted monthly discharge data (in mm) and monthly rainfall data (2001 to 2006) of nearby stations are used to calibrate parameters of Sugawara's tank model. Through trial and error method, the model structure is decided as in right figure. Simulation result can be seen in comparison of observed and calculated discharge hydrographs as shown below.

Then, for other sub-basins, each set of monthly rainfall data is used to calculate monthly discharge by the obtained tank model.



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Observed and Calculated Monthly Discharge at Svay Don Keo in mm

A3.3.4 Available Water by Sub-basin

Monthly specific discharges (l/s/km^2) of each Sub-basin are derived from calculated runoff as summarized in Table A.3.3.1. The Battambang River Basin at Battambang station is divided to two sub-basins, namely upstream hilly area and middle-downstream plain area. The specific discharge is calculated considering discharge data of the three stations on the river. Runoff from the plain area of the Battambang and Pursat Rivers is quite small in the dry season, since water of many of the small streams is mostly utilized locally. Natural levees, being slightly higher than surrounding land, usually do not keep rainwater so much. In case of flood, bank overtop flows occur place to place, resulting in no increase of river discharge along the lower reach. The Pursat River Basin at Khum Viel station is also divided into hilly and plain sub-basins. The river flow capacity is the same level or smaller downstream of the confluence.

A3.4 Flood Analysis

A3.4.1 Flood Water Level

Annual maximum daily water levels for 16 years at Battambang station are in a range from 10.09 to 13.40 m, of which average is 12.55 m with standard deviation of 0.90 m. The peak water level occurred in between June and October, most frequently in August with center of August 5. Those for 7 years at Svay Don Keo station are from 3.17 to 3.96 m, and 3.62 m in average with 0.28 m of standard deviation. With center of October 23, they happened in October except for one year in November. In Pursat River Basin, the peak water levels for 9 years at Khum Viel station are in a scope from 5.47 to 6.72 m, of which average is 6.42 m and standard deviation is 0.38 m. All of them took place in October except for one event in November, of which center of time is October 19. Annual maximum daily water levels for 8 years at Boribo station are from 1.92 to 2.65 m, their average and standard deviation being 2.33 m and 0.25 m, respectively. The events occurred from September to November around the center of October 6.

A3.4.2 Flood Discharge

Probable flood discharges are calculated as seen in Figure 3.4.1 and the table below. Since the available data periods are limited to less than 20 years, 50-year and 100-year probable floods are less reliable.

Probable Annual Maximum Daily Discharge

(m3/s)

River Basin	Station	Return Period or Recurrence Interval (year)						Data
		2	5	10	20	50	100	(year)
Battambang	Battambang	490	650	750	850	970	*1070*	17
Battambang	Treng	850	1130	1310	1480	*1700*	*1870*	11
Moung Russey	Svay Don Keo	50	60	67	74	*83*	*90*	11
Pursat	Khum Viel	460	520	560	590	*630*	*650*	10
Pursat	Bac Trakoun	780	1160	1390	1590	*1850*	*2030*	12
Boribo	Boribo	160	190	210	230	*270*	*310*	9

Prepared by JICA Study Team Note: *Italic figures* are less reliable due to short perioc

Flood water often overtop the river banks after coming out from the mountainous area to the plain, resulting in reduced or the same scale flood discharge along the downstream reach, particularly near the Tonle Sap Lake. Field survey as well as the river channel meandering scale suggests the phenomenon.

A3.4.3 Inundation Conditions

Inundation is mentioned in Appendix F, Environment.

Inundation due to the seasonal rising of water surface of the Lake Tonle Sap, is seen in maps of MOWRAM prepared in TSLSP in 2006. Lowland area from National Road No.5 (NR5, hereinafter) to the lake is widely inundated every year in accordance with rising of the lake water level. Of the Tonle Sap river at Kampong Chhnang station, annual maximum and minimum daily water levels are 10.62 m and 2.29 m in average, of which difference is 8.33 m.

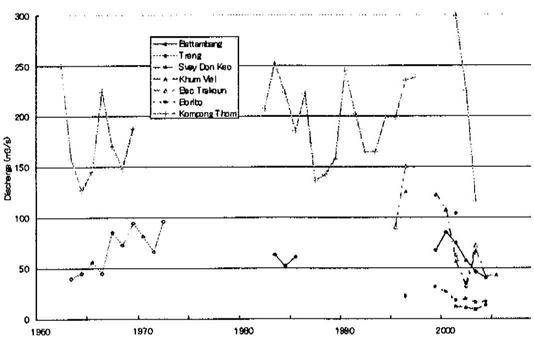
Another type of inundation comes from river flood. There exists only few flood control structure in the Study Area, therefore flood overtopping occurs frequently over the alluvial plain. It seems that for the local people flood and inundation can be acceptable to certain extent as usual natural events, compared with serious water shortage and drought damage.

A3.5 Long Term Tendency

A3.5.1 Past Trend

Annual average discharges fluctuate violently as seen in right figure. Long term tendency is not clear.

Annual rainfalls fluctuate widely and in unstable way in the Study Area. They were mostly in a range between 1000 to 2000 mm. Annual rainfall fluctuation in the 20^{th} century is presented in the following figure.



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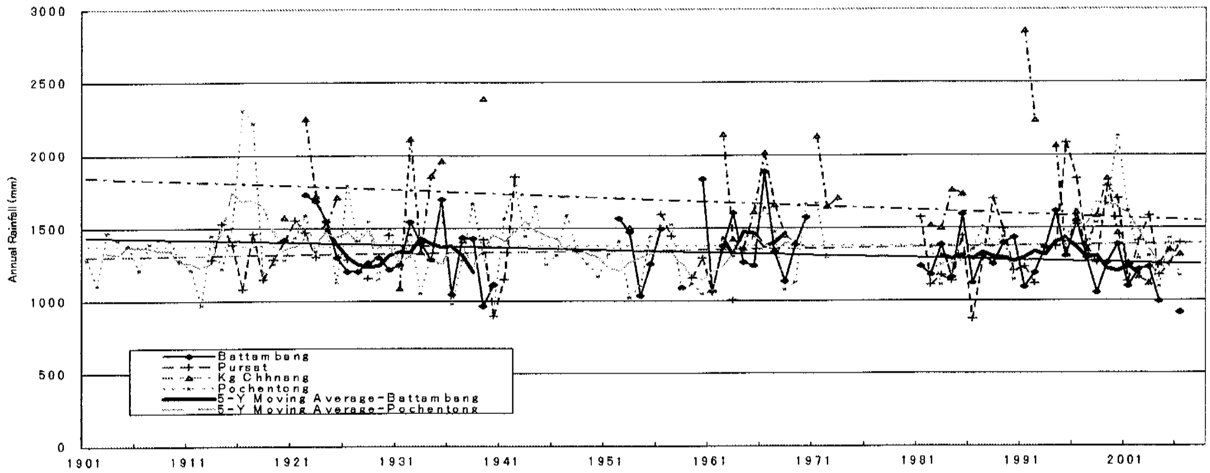
Annual Discharge Fluctuation

At Battambang and Kampong Chhnang stations, the hyetographs have declined trend. At Pursat station on the contrary, increase trend can be seen. Long term rainfall trend shows rather constant at Pochentong.



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Annual Rainfall Fluctuation

A3.5.2 Future Consideration

Both global climate change and local environmental change may influence future meteo-hydrological conditions in the Study Area. Probably large and small scale pumps will be used more widely and groundwater intake will increase. Integrated comprehensive water management will be more required, which needs more accurate and sufficient quantity of meteo-hydrological data.

CHAPTER A4 METEO-HYDROLOGICAL OBSERVATION STRENGTHENING PROGRAM

A4.1 Current Issues

A4.1.1 Institution and Human Resources

As mentioned in A1.4.1, any youth with technological ability has joined the DHWR for years, one is because there is no fixed study course in Cambodia. Also, most of the staff of DHRW and DOM cannot concentrate to official works due to insufficient salaries, and a few higher class officers must treat a lot of official works by themselves.

A4.1.2 Budget

As abovementioned in A1.4.1, the government development budget for DHRW and DOM is rather low level. Development budget from external donor funds is comparatively high in both development budgets of MOWRAM and PDWRAM. These matters often result in stop of observation at the end of a project. Not small number of rainfall and water level stations are standing at present in the Study Area, however many of them are not operational without sufficient budget for running cost, such as maintenance and equipment repair costs.

A4.2 Human Resources Empowerment Program

A4.2.1 On-going and Future Water Resources Project

From practical point of view, it is desirable that all the water resources related projects include meteo-hydrological observation supporting portion. The support should include capacity building of the MOWRAM/PDWRAM staff. In case of implementation of any project from the Study, meteo-hydrological observation strengthening portion should be included.

A4.2.2 Technology Education System Support Program

Through exchange of ideas with MOWRAM officers, projects for education are considered essentially necessary. To educate young students as well as MOWRAM/PDWRAM staff, study course on meteo-hydrological observation and analysis is expected to be set in college and in TSC.

A4.3 Data Accumulation Supporting Program

A4.3.1 Annual Meteo-Hydrological Data Book

To make observed meteo-hydrological data more useful and available, preparation of annual meteo-hydrological data book is proposed. The proposed data book may be as follows. The data book with CD should be published and may be sold at bookshops for help of maintenance cost. In that case, the price should be low or free for Cambodian students. The data book includes daily data table and figure in a form one year per one page. The data are composed of rainfall, water level and discharge, and meteorological elements such as air temperature, humidity, wind speed, sunshine hour, evaporation and so on. It also contains discharge measurement record. The preparation work itself is regarded as on-the-job training.

A4.3.2 Annual Meteo-Hydrological Analysis Report

It is proposed to prepare and publish annual or bi-annual meteo-hydrological analysis report with CD. The report may be sold in the same manner as for the abovementioned data book. The main objective may be level up of technology in short term, and improvement of drought and flood forecast and warning system in long term. Groundwater survey and water quality survey may start, for the purpose of basic data collection for integrated water resources management study. Subject of the analysis can be selected from wide scope. For example, low flow and flood runoff analysis, flooding and inundation analysis, river basin water balance, groundwater balance and so on.

A4.3.3 Technical Cooperation Project

A technical cooperation project is proposed to support abovementioned plans. The proposed project consists of dispatch of a long term expert or senior hydrologist and short term experts as required, training in Japan and seminar/workshop in Cambodia, equipment supply such as observation gauge and personal computer.

A4.3.4 Rural Tourism Project

The first required condition of this project is that MOWRAM basically agree this concept. The second condition is cooperation of some travel agency or NGO. This project may end when required budget be prepared. The idea started from a question that who owe fuel cost for the meteo-hydrological observation, if MOWRAM/PDWRAM cannot. Some of the travelers or tourists may wish to visit rural area. If so, they need vehicle and guide. Being not so easy, both parties may find compromise. As a matter of course, security system will be essentially required for the project.

Among attractive points, followings may be combined to the tour course. (i) Battambang province: Komping Puoy dam and Wat Phnom Sampeau, (ii) Pursat province: Damnak Ampil Weir, and Noodle and sugar palm wine production, (iii) Kampong Chhnang province: 7 th January Canal and Dyke, and local restaurant serving local dishes including ants, and (iv) general: rain water harvest on roof.

Two teams are considered, namely data collection team and discharge measurement team. The data collection team can be formulated with minimum one car, a driver, two collectors from MOWRAM and PDWRAM, and two or three tourists. The discharge measurement team needs at least two cars, two drivers, three or four working members of MOWRAM and PDWRAM, and three or four tourists. Data collection tour is more feasible, because it is not so much different from usual tour if we replace guide with the data collector. If MOWRAM car is available and is used, the tour can be more feasible.

If this idea is supported by MOWRAM, feasibility study is desirable to be conducted. The study period may be one year, including several trial tours. Experts required are considered a hydrologist/coordinator and a tourism specialist.

A4.4 Implementation Plan

A4.4.1 Project Combination

From above Sections A4.2 and A4.3, three projects are formulated for implementation plan as in figure below, namely (i) A4.2.2 → Education Support Project, (ii) A4.3.1 to 3 → Technical Cooperation Project and (iii) A4.3.4 → Rural Tourism Installation Project.

A4.4.2 Project Cost

Total of the two project costs is roughly estimated at US$ 1.24 million as in chart below. The Education Support Project costs US$ 1.01 million and Technical Cooperation Project US$ 1.24 million.

Project and item	Estimated Cost (US 1,000$)	(¥million)
1 Education Support Project		
Long term expert	420	50
Training in TSC	420	50
New course in institute	170	20
Sub-total	1,010	120
2 Technical Cooperation Project		
Long term expert, Sr. Hydrologist	500	60
Short term expert	170	20
Training in Japan	330	40
Equipment supply	80	10
Workshop	80	10
Publication		
Annual Databook	40	5
Annual Analysis Report	40	5
Sub-total	1,240	150
Total	2,250	270

Prepared by JICA Study Team

Tentative Project Implementation Schedule and Cost

A4.4.3 Implementation Schedule

Proposed project implementation schedule is estimated as in the above chart. Tentative program period is to be four years from 2009 to 2013 as in the chart. The period of the Education Support Project is scheduled to be three years and that of the Technical Cooperation Project is three and a half years.

CHAPTER A5 REAM KON AND POR CANAL SUB-PROJECTS IN MOUNG RUSSEI RIVER BASIN

A5.1 Ream Kon and Por Canal Rehabilitation Sub-projects

A5.1.1 Ream Kon Rehabilitation Sub-project

As illustrated in Figure A5.1.1, Ream Kon Rehabilitation Sub-project is located on the right bank of the Moung Russei (Dauntri) River and on the Lake Tonle Sap side of the National Road No.5 (NR5). According to the topographic survey results, ground elevation is mostly between 12 m and 16 m.amsl.

A5.1.2 Por Canal Rehabilitation Sub-project

As seen in Figure A5.1.1, Por Canal Rehabilitation Sub-project locates on the left bank of the Moung Russei River and on the Lake side of NR5. From the topographic map of 1:100,000 scale, ground elevation seems slightly higher than that in the Ream Kon Sub-project area.

A5.2 Meteorology and Rainfall

A5.2.1 Meteorology

For both Ream Kon and Por Canal Sub-projects, meteorological data for Moung Russei River Basin in table below are applicable.

Monthly Meteorological Values for Ream Kon and Por Canal Sub-projects

Element		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(℃)	25.7	27.7	29.6	30.4	30.1	29.6	29.0	28.7	28.0	27.5	26.6	25.4	28.2
Mean max.	(℃)	31.5	33.7	35.4	35.8	35.1	34.4	33.6	33.0	32.0	31.2	30.5	30.2	35.8
Mean min.	(℃)	19.9	21.6	23.8	24.9	25.1	24.9	24.5	24.3	24.2	23.9	22.6	20.5	19.9
Relative humidity	(%)	70	66	67	68	72	73	74	77	79	81	78	74	73
Wind velocity	(m/s)	0.91	0.93	0.96	0.89	0.88	0.96	0.95	0.87	0.69	0.71	0.72	0.78	0.85
Sunshine hours	(hr/day)	9.5	9.0	8.8	7.7	7.3	5.6	6.4	5.0	5.5	6.6	7.4	8.5	7.3
Evaporation	(mm/day)	4.0	4.7	4.8	4.9	4.5	4.3	3.7	3.6	3.0	3.2	3.2	3.4	3.9
	(mm)	122	131	148	147	138	128	113	111	90	97	95	104	1423

Prepared by JICA Study Team Original data source: MOWRAM

Annual mean, mean maximum and mean minimum temperatures are 28.2℃, 33.0℃ and 23.3℃, respectively. Monthly mean temperature is the highest at 30.1℃ in May and the lowest at 25.4℃ in December. Monthly highest mean maximum temperature is 35.8℃ in April and monthly lowest mean minimum temperature is 19.9℃ in January. Annual mean relative humidity is 73%. Monthly mean relative humidity is in a range from 66% in February to 81% in October. Annual mean wind speed at 2 m height is 0.85m/s. Sunshine hours fluctuate between the shortest 5.0 hr/day in August and the longest 9.5 hr/day in January. Annual pan evaporation is 1423 mm in average.

A5.2.2 Annual and Monthly Rainfall

Long term annual and monthly rainfalls at Moung Russey are seen in Table 5.2.1. Annual average rainfall is about 1150 mm and rainy days are 124 days, Monthly rainfalls and rainy days of long term average, and those of 80% and 50% dependability are presented in table below.

Average Monthly Rainfall, Rainy Days and Dependable Rainfall at Moung Russey

Item	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (avrage)	mm	2	8	48	88	130	127	120	107	179	216	121	12	1156
Rainy day	day	1	2	6	8	14	15	17	17	19	16	9	2	124
Dependability (up to 2006 data)														
80% or 5-year P	mm	0	0	5	28	64	66	54	66	116	111	23	0	953
50% or 2-year P	mm	0	0	21	65	106	113	98	93	179	169	65	0	1174

Source: MOWRAM Prepared by JICA Study Team

A5.2.3 Maximum Rainfall

Annual maximum daily and consecutive 3-day rainfalls for 13 years at Moung Russey rainfall station are picked up for probability calculation.

Results of exceedance probability calculation by Iwai Method are as shown in right table. Probable rainfalls of 50 and 100 year return period are less reliable.

Annual Maximum Daily and 3-Day Rainfall at Moung Russey

Period (day)	Return Period (year) 2	5	10	20	50	100
Daily (mm)	88	130	164	201	*257*	*304*
3-Day (mm)	139	185	218	249	*292*	*326*

Note: *Italic figures* are less reliable due to limited number of data,
Prepared by JICA Study Team

A5.3 Moung Russei River

A5.3.1 Hydrological Characteristics

Catchment area of the Moung Russei River basin is 785 km^2 at Moung Russey water level station near the Moung Russey Town, and the area is 598 km^2 at planned Basak Reservoir site. Upstream basin of the river formulates a side wide smaller basin surrounded by boundaries (mostly less than 1000 m in elevation) with Pursat and Battambang river basins. In this relatively shallower and lower hilly basin, rainfall tends to lower than in higher mountainous basins. Flood overbank flow occurs along the lower reach from the Prek Chik as suggested in Figure A.5.3.1. Flow capacity of the river is larger at Prek Chik than at Moung Russey.

A5.3.2 Hydraulic Structure on Moung Russei River

As shown in Figure A.5.3.2, the Basak reservoir is planned to be constructed soon at outlet from upstream basin. Effective capacity of the reservoir is 32 MCM.

A damaged weir and a irrigation main canal exist at Prek Chik, where water level stations were installed in the Study, one at upstream on the river and another on the main canal. In the Prek Chik irrigation main canal, there seems no water flow at least in 2007 at the head of the canal except in flood time.

In the Study of the Ream Kon and Por Canal Rehabilitaation Sub-projects, it is proposed that existing damaged weir be demolished and a new weir named Moung Russey headworks be constructed for irrigation.

A5.4 Low Flow of Moung Russei River

A5.4.1 Methodology

Available discharge data are quite limited along the Moung Russei River. On the contrary, there are more than five years data at Svay Don Keo on the Svay Don Keo river. Of the Moung Russei River, monthly discharges at Moung Russey station are calculated through correlation formula from the Svay Don Keo river monthly discharges, for water balance of the Basak reservoir in Phase I. To calculate 5-day discharges, the same formula is used. For estimation of Basak Reservoir 5-day discharges, newly gained data in 2007 are checked and employed.

A5.4.2 Five-day discharge at Basak Reservoir

Daily discharges at Svay Don Keo are converted to those at Moung Russey through correlation formula, Q (Moung Russey) = 0.216 Q (Svay Don Keo) + 0.58 [m^3/sec], which is derived from 19 monthly data sets. Five-day discharge data are calculated for five years from 2001 to 2005, which is judged a period of more reliable data.

Newly gained data in 2007 at both Moung Russey and Prek Chik (river) stations on the Moung Russei River are compared each other. The data suggest a tendency that river discharges at Prek Chik (river) station are a little smaller in the dry season and slightly larger in the wet season than at Moung Russey station. Along river course between the Basak reservoir and Prek Chik, change of river discharge is judged negligibly small as water coming in and going out is quite limited. Considering these matters as well as safety side standpoint, the Basak reservoir five-day discharges are estimated in use of conversion coefficients of 0.9 (Jan.-Apr.) and 1.0 (May-Dec.) from discharge of Moung Russey station to Basak reservoir site. Discharges from residual area of 187 km^2 between Basak Reservoir and Moung Russey water level station, are calculated by multiplying Q (Basak reservoir) by area ratio of 0.31 (=187/598). In Table 5.4.1, five-day discharges of Basak reservoir and its residual area for five years are presented for water balance of the Basak reservoir. Annual average discharge from 2001 to 2005 is calculated 3.23 m^3/sec or 102 MCM/year at Basak reservoir and 1.00 m^3/sec or 32 MCM/year from residual area between the reservoir and Moung Russey water level station

A5.4.3 Consideration

Both monthly and five-day discharges of Moung Russei River at Moung Russey are calculated based on the correlation with Svay Don Keo discharge. Newly observed data in 2007 suggest the above calculation may be under-estimate as a whole. Hydrograph of the new data shows sharper shape, that is to say higher flood and lower drought. With additional and by sufficient data in near future, which may be with additional a few years data, the calculation method should be reviewed and revised, if necessary.

A5.5 Flood Discharge

A5.5.1 Methodology and Flood

Since available discharge data of the Moung Russei River are quite limited as abovementioned, flood discharges at Moung Russey station is estimated, on the basis of (1) those at Svay Don Keo, (2) the latest data in 2007 on the Moung Russei River and (3) estimated flow capacity of the river for a counter check. Recent annual maximum daily discharges (Qd (max)) are comparatively small at Svay Don Keo or 52 m^3/sec in average. On 21st November, 2007, a flood of 80 m m^3/sec in Qd (max) was observed at Moung Russey station on the Moung Russei River, which is judged middle class flood from local information. Probable flood discharge at Moung Russey is estimated multiplying flood discharge at Svay Don Keo by 1.5 (= 80/52), even though it is quite rough. Obtained discharges are counterchecked with cross-sectional flow capacity. Flood discharge of 100-year return period is estimated from hydraulic calculation with estimated flood height.

As shown in Figure A.5.3.1, a part of flood flow between Prek Chik and Moung Russey stations is diverted to Prek Chik main canal. Not small amount (nearly a half in case of above flood in 2007) of the Prek Chik flood flow is probably bifurcated to right stream at about 6 km south (about 10 km in river channel length) from the Moung Russey station. Peak discharges (Q peak) are calculated by multiplying Qd (max) by ratio 1.2. The ratio (Q peak/Qd (max)) is selected, considering that flood wave shape is milder along downstream reach and the ratio of 1.4 obtained at Prek Chik (river) water level station in 2007.

Tables A.5.5.1 and A.5.5.2 present flood information gained through Household Survey by social and environment sector and interview to village people.

A5.5.2 Probable Flood and Consideration

With return period of probability, flood discharges at Moung Russey station are estimated by Iwai method as presented in Table below. The river flood scale is relatively low, because not small amount of river high water overbank and inundate over paddy fields. Village people accept overbank flood and inundation to certain extent at present. Of the Moung Russei River, flood discharge at Prek Chik is roughly estimated as twice of that at Moung Russey, if required. After around two years, if good flood data are obtained at Prek Chik (river) and Moung Russey stations, more precise flood discharge can be estimated.

It is noted that the presented flood discharges at Moung Russey water level station are usable under present conditions, but not under river trained conditions. Anyway, such river improvement or flood control plans should be studied as a part of integrated water management plan or program.

Flood Discharge of Moung Russei River

T	Moung Russey		Prek Chik (river)	
	Qd(max) (m3/s)	Qpeak (m3/s)	Qd(max) (m3/s)	Qpeak (m3/s)
(year)				
2	80	100	*160*	*220*
5	90	110	*180*	*250*
10	100	120	*200*	*280*
20	110	130	*220*	*310*
50	130	160	*260*	*360*
100	160	190	*320*	*450*

Note: *Q of Prek Chik (river)* is rough estimate.
Prepared by JICA Study Team

If river improvement or training works be implemented along the river in future, when damageable property increase and flood influence become more serious, flood discharge would increase accordingly. In particular, possibility of change of flow capacity of the river at NR5 bridge may be important for planning of the proposed Moung Russei Headworks. The bridge is considered as a bottle neck or control point of the river.

Annual peak discharge (Q peak) is calculated by multiplying annual maximum daily discharge (Qd (max)) by ratio of Q peak/Qd (max). To estimate the ratio, the maximum half hourly discharges and daily discharges are compared at Prek Chik (river) water level station for high water peaks of more than 4 m in October and November 2007. Regarding the maximum half hourly discharge as peak discharge, the ratio of 1.4 is obtained even though available data are quite limited at Prek Chik (river) station, where automatic water level recorder was installed in the Study. At Moung Russey water level station, the ratio is estimated at 1.2 in the middle of 1.4 at Prek Chik and 1.0 of the Lake Tonle Sap. At Moung Russey station, flood wave shape is milder due to overbank flow along downstream reach from Prek Chik and water level fluctuation is negligibly small at the river mouth or in the Great Lake in case of daily base viewpoint.

CHAPTER A6 DAMNAK AMPIL, WAT LOUNG AND WAT CHRE SUB-PROJECTS IN PURSAT RIVER BASIN

A6.1 Damnak Ampil, Wat Loung and Wat Chre Rehabilitation Sub-projects

The three Sub-project areas are in the Pursat Province.

A6.1.1 Damnak Ampil Rehabilitation Sub-project

As illustrated in Figure A.6.1.1, Damnak Ampil Rehabilitation Sub-project is located between the left bank of the Pursat River and right bank of the Svay Don Keo River. Developing in the north side of the main canal, this area is planned to be command area of Damnak Ampil Main Irrigation Canal. According to the 1:100,000 scale topographic maps, its ground elevation is mostly between 10 and 20 m above sea level (masl). Most of the Sub-project area belongs to the Moung Russei River Basin (but not the Moung Russei River Basin).

A6.1.2 Wat Loung Rehabilitation Sub-project

As seen in Figure A.6.1.1, Wat Loung Rehabilitation Sub-project locates on the left bank of the Pursat River and develops between the Damnak Ampil Sub-project and National Road No.5 (NR5). From the topographic map of 1:100,000, ground elevation seems slightly lower than that in the Damnak Ampil Sub-project area. Of the Sub-project area, northeastern part is in the Pursat River Basin and southwestern part is in the Moung Russey River Basin. In the Sub-project area, old river courses of the Pursat River are seen in aero-photo, where inundation may occur frequently.

A6.1.3 Wat Chre Rehabilitation Sub-project

Figure A.6.1.1 shows Wat Chre Rehabilitation Sub-project, which locates on the right and left banks of the Kambot River and in the lake side of NR5. Kbal Hong Canal runs from the Pursat River in parallel with NR5, but it is not connected to upstream part hydraulically now and the flow is cut place to place. From the topographic survey results, ground elevation is mostly between 11 m to 14 masl. This Sub-project area is in the Moung Russei River Basin.

A6.2 Meteorology and Rainfall

A6.2.1 Meteorology

For both Damnak Ampil and Wat Chre Sub-projects, meteorological data for Moung Russei River Basin in table below are applicable. For Wat Loung Sub-project, meteorological data for both/either Pursat and/or Moung Russei River Basins can be used, which are presented in two tables below.

For Moung Russei River Basin, annual mean, mean maximum and mean minimum temperatures are 28.2℃, 33.0℃ and 23.3℃, respectively. Monthly mean temperature is the highest at 30.1℃ in May and the lowest at 25.4℃ in December. Monthly highest mean maximum temperature is 35.8℃ in April and monthly lowest mean minimum temperature is 19.9℃ in January. Annual mean relative humidity is 73%. Monthly mean relative humidity is in a range from 66% in February to 81% in October. Annual mean wind speed at 2 m height is 0.85m/s. Sunshine hours fluctuate between the shortest 5.0 hr/day in August and the longest 9.5 hr/day in January. Annual pan evaporation is 1423 mm in average

Monthly Meteorological Values for Moung Russei River basin

Element		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(℃)	25.7	27.7	29.6	30.4	30.1	29.6	29.0	28.7	28.0	27.5	26.6	25.4	28.2
Mean max.	(℃)	31.5	33.7	35.4	35.8	35.1	34.4	33.6	33.0	32.0	31.2	30.5	30.2	35.8
Mean min.	(℃)	19.9	21.6	23.8	24.9	25.1	24.9	24.5	24.3	24.2	23.9	22.6	20.5	19.9
Relative humidity	(%)	70	66	67	68	72	73	74	77	79	81	78	74	73
Wind velocity	(m/s)	0.91	0.93	0.96	0.89	0.88	0.96	0.95	0.87	0.69	0.71	0.72	0.78	0.85
Sunshine hours	(hr/day)	9.5	9.0	8.8	7.7	7.3	5.6	6.4	5.0	5.5	6.6	7.4	8.5	7.3
Evaporation	(mm/day)	4.0	4.7	4.8	4.9	4.5	4.3	3.7	3.6	3.0	3.2	3.2	3.4	3.9
	(mm)	122	131	148	147	138	128	113	111	90	97	95	104	1423

Prepared by JICA Study Team　　Original data source: MOWRAM

For Pursat River Basin, annual mean, mean maximum and mean minimum temperatures are 28.5℃, 33.3℃ and 23.6℃, respectively. Monthly mean temperature is the highest at 30.4℃ in April and the lowest at 25.9℃ in December. Monthly highest mean maximum temperature is 35.6℃ in April and monthly lowest mean minimum temperature is 20.8℃ in January. Annual mean relative humidity is 69%. Monthly mean relative humidity is in a range from 63% in February to 76% in October. Annual mean wind speed at 2 m height is 0.53m/s. Sunshine hours fluctuate between the shortest 5.0 hr/day in August and the longest 9.5 hr/day in January. Annual pan evaporation is 1340 mm in average

Monthly Meteorological Values for Pursat River basin

Element		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(℃)	26.3	28.1	29.5	30.4	30.2	29.9	29.3	29.1	28.4	27.8	26.8	25.9	28.5
Mean max.	(℃)	31.7	33.9	35.1	35.6	35.3	34.9	34.1	33.7	32.6	31.6	30.9	30.4	35.6
Mean min.	(℃)	20.8	22.2	24.0	25.1	25.2	24.9	24.4	24.5	24.2	24.0	22.8	21.4	20.8
Relative humididy	(%)	66	63	65	66	67	68	68	71	74	76	74	71	69
Wind velocity	(m/s)	0.80	0.78	0.68	0.60	0.48	0.37	0.40	0.37	0.32	0.48	0.50	0.58	0.53
Sunshine hours	(hr/day)	9.5	9.0	8.8	7.7	7.3	5.6	6.4	5.0	5.5	6.6	7.4	8.5	7.3
Evaporation	(mm/day)	3.7	4.5	4.4	4.5	4.2	4.1	3.3	3.5	2.8	3.2	3.1	3.0	3.7
	(mm)	115	126	138	135	130	121	102	107	83	98	93	92	1340

Prepared by JICA Study Team　　Original data source: MOWRAM　　Note: Data of Pursat Stations except sunshine hours
Sunshine hours = that of Battambang Station

A6.2.2 Annual and Monthly Rainfall

Monthly and Annual rainfalls at Pursat are presented in Table A.6.2.1. Annual average rainfall is about 1330 mm and rainy days are 102 days, Monthly rainfalls and rainy days of long term average, and those of 80% and 50% dependability are presented in table below.

Average Monthly Rainfall, Rainy Days and Dependable Rainfall at Pursat

Item	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (avrage)	mm	3	5	43	81	150	140	142	183	233	223	107	18	1329
Rainy day	day	0	1	4	6	12	11	13	15	17	13	8	2	102
Dependability (up to 2006 data)														
80% or 5-year P	mm	0	0	1	31	86	82	93	106	162	124	30	0	1141
50% or 2-year P	mm	0	0	8	64	134	128	141	169	228	198	75	1	1330

Source: MOWRAM　　Prepared by JICA Study Team

A6.2.3 Maximum Rainfall

Annual maximum daily and consecutive 3-day rainfalls are picked up. Results of probability calculation by Iwai Method are shown in table below.

For 10-year probability, maximum daily and 3- day rainfall are 129 mm and 190 mm, respectively.

Annual Maximum Daily and 3-Day Rainfall at Pursat

Period	Return Period (year)					
(day)	2	5	10	20	50	100
Daily (mm)	82	109	129	148	175	197
3-Day (mm)	124	163	190	217	253	281

Prepared by JICA Study Team

A6.3 Pursat River and Kambot River

A6.3.1 Hydrological Characteristics

As shown in Figure 6.1.1, catchment area of the Pursat River is 4,245 km^2 at Bac Trakoun water level station and 4,596 km^2 at Khum Viel water level station. At existing Damnak Ampil weir, the catchment is 4,480 km^2. As abovementioned in A1.1.1 (1), 77% of the Pursat River Basin is covered by hilly or mountainous area with 30 m or higher elevation. The Pursat River basin consists of wide upstream hilly area and narrow middle stream with natural levees. As mentioned below, flow capacity of the river channel decreases downward from the confluence of upper three tributaries. The three Sub-project areas are mostly developed in the flood or alluvial plain of the Pursat River.

The Kambot River is considered one of old Pursat River courses. Natural low flow is quite limited and only high water of the Pursat can come into the Kambot River during flood time.

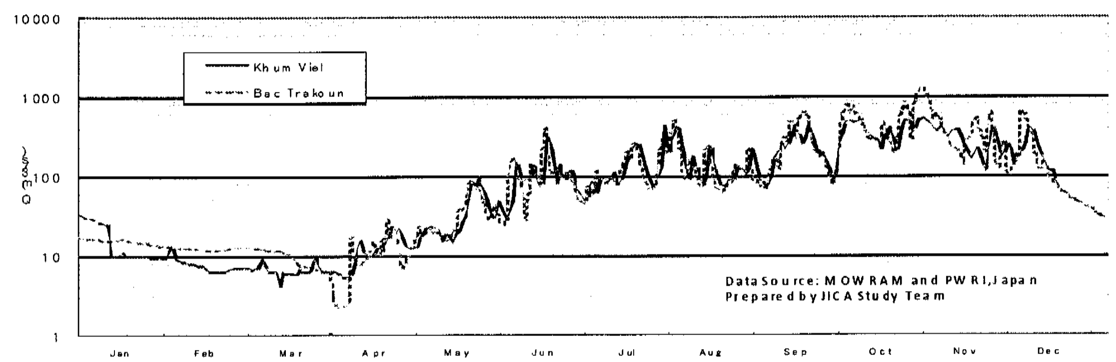
A6.3.2 Hydraulic Structure on Pursat River and Kambot River

Damnak Ampil weir crossing the Pursat River is renewed with automatically movable flap gates in 2006. A broken weir is located at intake of irrigation canal at Wat Loung. On the Kambot River, free intake system is seen for Wat Chre irrigation system. Figure A.6.3.1 shows major existing and proposed hydraulic structures related with three Sub-projects.

A6.4 Low Flow of Pursat River

A6.4.1 Monthly and Daily Discharge

Daily discharge data are available at Khum Viel and Bac Trakoun water level stations for nearly and around 10 years period, respectively. Hydrographs in 1996 are shown below.



Prepared by JICA Study Team

Daily Discharge at Khum Viel and Bac Trakoun in 1996

In use of monthly discharges, correlation of the two stations' discharge is studied and correlation formulae are obtained. To calculate daily discharge at Damnak Ampil, daily discharge data are supplemented for duration of eight month for Khum Viel (KV) and 16 months for Bac Trakoun (BT). As a result, a data set of ten years daily discharges is prepared. Daily discharge (Qd) at Damnak Ampil (DA) is estimated from that of the two stations in consideration of each catchment area and relative location. DA is in the middle of BT and KV. The equation is Qd(DA) = (Qd(BT) + 2 x Qd(KV)) / 3 [m^3/sec]

A6.4.2 Five-day discharge at Damnak Ampil

Table A.6.4.1 presents estimated five day discharge at Damnak Ampil for about ten years. Annual average discharge for about 10 years from 1995 to 2005 except 1997, is calculated 76.4 m^3/sec or 2,426 MCM/year at Damnak Ampil weir. Discharges are ample in the wet season, but discharges in the dry season sometimes fall down to be less than 10 m^3/sec.

Five-day discharges at Svay Don Keo also prepared as in Table A.6.4.2 for irrigation planning. Annual average discharge from 2001 to 2005 is calculated 12.2 m^3/sec or 385 MCM/year at Svay Don Keo water level station on the Svay Don Keo river.

A6.5 Flood Discharge

A6.5.1 Flood

As shown in Table A.6.5.1, "Household Survey" was conducted by social and environment sector, of which results suggest that floods come every year in some parts of Wat Loung area. Lower land such as old river channel/pond is usually water surface, swamp or paddy field, receiving flood water frequently.

From flood interview results in Table A.6.5.2, small floods are often not so damageable. It is found through field reconnaissance that there exists seriously damaged village road in Wat Loung area by probably overtop flow of large scale flood.

According to the information from village people and PDWRAM of Pursat Province, the largest flood in the memory of the people occurred in 1996 as presented in Table A.6.5.2. The 1996 flood, composed of plural flood peaks, caused large scale overbank flow along middle reach from the confluence at Samroang and inundated alluvial plain widely as illustrated in Figure A.6.5.1. The maximum daily discharges in 1996 are 1,330 m^3/sec at Bac Trakoun and 540 m^3/sec at Khum Viel, respectively.

According to the Preliminary Inventory Survey Report by JICA in 2006, it is described in Japanese that overbank flows caused by such floods that occur two or three times per year inundate Pursat town area with several photographs.

River flow capacity at upstream Bac Trakoun is larger than that at downstream Khum Viel. At first, upstream high water to certain extent of scale is absorbed by river channel storage in the plain. Then, rising high water partly flows out of the main channel to old river course such as the Kambot River. When high water rises higher, overbank flow occurs mainly from downstream reach and spreads towards upward.

A6.5.2 Probable Flood

Of Bac Trakoun and Khum Viel water level stations, the annual maximum daily discharges (Qd (max)) with return period of probability, are calculated by Iwai Method. Qd (max) at Damnak Ampil weir is estimated as average of the above two station's values considering location and safety side planning. To estimate ratio of peak discharge (Q peak) by Qd (max), samples are picked up from hourly discharge data in 2005 at Bac Trakoun, which were observed by MOWRAM and Public Works Research Institute (PWRI), Japan. Samples with daily discharge (Qd) of more than 300 m^3/sec are selected and averaged ratio of Qpeak/Qd is calculated 1.2, which is employed to estimate Qpeak at Bac Trakoun. The maximum hourly discharge is regarded as Qpeak in the Study. The ratio at Khum Viel is decided 1.05 taking into consideration that overflow occurs more commonly there and flood wave becomes milder. As presented in table below, Q peak at Damnak Ampil is estimated as an average of the values of the two stations.

Flood Discharge with Probability along the Pursat River

T (year)	Bac Trakoun Qd (max) (m3/s)	Bac Trakoun Qpeak (m3/s)	Damnak Ampil Qd (max) (m3/s)	Damnak Ampil Qpeak (m3/s)	Khum Viel Qd (max) (m3/s)	Khum Viel Qpeak (m3/s)
2	780	940	620	710	460	480
5	1160	1390	840	970	520	550
10	1390	1670	980	1130	560	590
20	1590	1910	1090	1270	590	620
50	1850	2220	1240	1440	630	660
100	2030	2440	1340	1560	650	680

Prepared by JICA Study Team Data source: MOWRAM, ADB and PWRI, Japan

According to information from interview to village people, small floods are often not serious for them as abovementioned and useful in some cases. In this stage, costly river improvement works, which sometimes causes more serious flood in other places, are considered not practical generally now in this area.

There can be seen many sand taking places along the Pursat River from the confluence to NR5 crossing. At Veal Veang, boulders are picked out from the river bed. These activities may cause certain influence to the river flow conditions and river structures. Rating curve tends to change every year, if river bed condition changes rapidly.

As abovementioned, 1996 flood was the largest for recent several decades. However, flood discharge as well as flood water level in 1996 was not the largest or highest at Bac Trakoun. This may be explained that a series of large floods came in 1996 and total flooded water volume was the largest in 1996. The error of prepared rating curves may be sometimes not small, particularly in droughty and higher water scope because of insufficient discharge measurement data.

CHAPTER A7 LUM HACH SUB-PROJECT IN BORIBO RIVER BASIN

A7.1 Lum Hach Rehabilitation Sub-project

A7.1.1 Lum Hach Rehabilitation Sub-project

As illustrated in Figure A.7.1.1, Lum Hach Rehabilitation Sub-project area is located on the right bank of the Boribo River, and between 7 th January Canal and National Road No.5 (NR5). According to the topographic map of 1:100,000 scale, ground elevation is mostly between 15 and 40 m above sea level (masl). On the opposite bank or left bank of the Boribo River, O-Roluss Scheme is located. A reservoir of the scheme was constructed on the old channel of the Boribo River, which was disconnected to upstream by 7 th January Dyke.

A7.1.2 7 th January Canal and Dyke

Description of this term is based on local information from PDWRAM and villagers.

Construction of 7 th January Canal and Dyke started in Pol Pot era. According to PDWRAM personnel, the dyke was planned to be from Lum Hach to approximately 30 km southeastward and to be extended another 13 km long northeastward to Kol Kob, 6 km southwest from Kampong Chhnang Town as on the 1:100,000 topographic map. Water was planned to be stored opposite side or north side along the tail portion. Some parts of the canal and dyke as well as some related structures were constructed then. Eroded dyke, broken intakes, damaged check gates and an incomplete aqueduct were visited at site. One of them is Lum Hach reservoir, consisting of dyke, canal, two gate structures and/or intake structures.

During a period of no authorized power or political confusion, plural floods occurred but the gates were not opened, so flooded water overtopped the dyke. Finally, flood water breached the dyke and storage function was lost. At the time of the breach, large scale flood flowed down, probably resulting in a lot of erosion, scouring, sediments and enlargement of the Boribo River channel.

As illustrated in Figure A.7.1.2, proposed Lum Hach headworks locates in the same area of the reservoir, namely northwest end of 7 th January Canal.

A7.2 Meteorology and Rainfall

A7.2.1 Meteorology

For Lum Hach Sub-project, meteorological data for Boribo River Basin in table below are usable.

For Boribo River Basin, annual mean, mean maximum and mean minimum temperatures are 28.3℃, 32.9℃ and 23.7℃, respectively. Monthly mean temperature is the highest at 30.4℃ in April and the lowest at 26.0℃ in December. Monthly highest mean maximum temperature is 35.5℃ in April and monthly lowest mean minimum temperature is 21.2℃ in January. Annual mean relative humidity is 73%. Monthly mean relative humidity is in a range from 67% in February/March to 80% in October. Annual mean wind speed at 2 m height is 1.80m/s.

Sunshine hours fluctuate between the shortest 5.5 hr/day in September and the longest 8.5 hr/day in January/February. Annual pan evaporation is 1494 mm in average

Monthly Meteorological Values for Boribo River basin

Monthly		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(℃)	26.4	27.9	29.5	30.4	30.2	29.6	29.0	28.8	28.2	27.6	26.8	26.0	28.3
Mean max.	(℃)	31.5	33.4	34.9	35.5	35.0	34.2	33.3	33.0	32.3	31.3	30.8	30.4	35.5
Mean min.	(℃)	21.2	22.4	24.1	25.3	25.4	25.0	24.6	24.6	24.2	23.9	22.8	21.5	21.2
Relative humididy (%)		70	67	67	69	72	73	75	76	79	80	77	73	73
Wind velocity	(m/s)	1.65	1.84	1.94	1.80	1.89	2.09	1.85	2.29	1.91	1.39	1.75	1.79	1.80
Sunshine hours	(hr/day)	8.5	8.5	8.2	8.0	7.2	6.0	5.7	5.6	5.5	5.9	7.5	8.1	7.1
Evaporation	(mm/day)	4.1	5.1	5.4	5.3	4.5	4.4	3.7	3.8	3.2	3.1	3.4	3.6	4.1
	(mm)	127	142	167	158	139	130	115	115	94	96	101	111	1494

Prepared by JICA Study Team Original data source: MOWRAM

A7.2.2 Annual and Monthly Rainfall

Monthly and Annual rainfalls at Kampong Chhnang and Krakor are presented in Table A.7.2.1 and Table A.7.2.2, respectively. Annual average rainfall is about 1680 mm at Kampong Chhnang and 1520 mm at Krakor. Annual average rainy days are 106 days at Kampong Chhnang and 117 days at Ktakor. Monthly rainfalls and rainy days of long term average, and those of 80% and 50% dependability are presented in table below.

Average Monthly Rainfall, Rainy Days and Dependable Rainfall at Kampong Chhnang

Item	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (avrage)	mm	7	15	27	74	163	216	267	272	281	247	96	15	1679
Rainy day	day	1	1	2	4	12	14	16	17	17	15	6	1	106
Dependability (up to 2006 data)														
80% or 5-year P	mm	0	0	0	9	92	126	173	184	180	126	13	0	1345
50% or 2-year P	mm	0	0	1	35	146	193	250	256	258	214	51	1	1618

Source: MOWRAM Prepared by JICA Study Team

Average Monthly Rainfall, Rainy Days and Dependable Rainfall at Krakor

Item	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (avrage)	mm	4	6	29	63	193	188	178	210	241	287	96	21	1517
Rainy day	day	1	1	2	5	14	16	16	18	18	15	8	2	117
Dependability (up to 2006 data)														
80% or 5-year P	mm	0	0	0	18	130	125	136	152	172	170	23	0	1344
50% or 2-year P	mm	0	0	1	46	185	177	172	207	236	259	64	1	1517

Source: MOWRAM Prepared by JICA Study Team

A7.2.3 Maximum Rainfall

Annual maximum daily and 3-day rainfalls are picked up. Results of probability calculation by Iwai Method are shown in table below

Annual maximum daily and 3-day rainfall at Kampong Chhnang and Krakor

Period	Kampong Chhnang						Krakor					
	Return Period (year)						Return Period (year)					
(day)	2	5	10	20	50	100	2	5	10	20	50	100
Daily (mm)	89	118	140	162	193	217	95	140	172	205	250	*286*
3-Day (mm)	137	178	207	235	272	301	134	189	231	274	336	*386*

Note: *Italic figures* are less reliable due to limited number of data, Prepared by JICA Study Team

A7.3 Boribo River

A7.3.1 Hydrological Characteristics

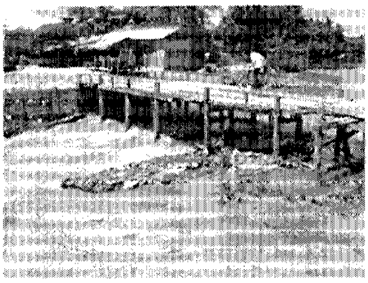
As shown in Figure A.7.1.1, catchment area of the Boribo River is 735 km^2 (=384+351) at proposed Lum Hach headworks. The Boribo River has the largest catchment area among those rivers that flow across 7 th January Dyke/Canal. The Boribo River has relatively steep longitudinal gradient (1/500 – 1/600) in downstream reach at Boribo water level station.

A7.3.2 Bomnak Diversion

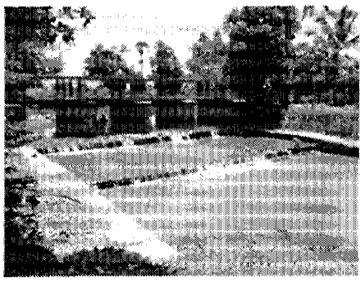
The Bomnak River is main tributary of the Boribo River, as can be seen in Figure A.7.1.1. At Bomnak or somewhere near Bomnak, the Bomnak River changes its name to the Boribo River. The Bomnak River is bifurcated to old and new channels at Bomnak at present as illustrated in Figure A.7.3.1. Old or west channel has deteriorated diversion structures at downstream of a few hundred meters from the bifurcation as shown in Figure A.7.3.2.

According to information from PDWRAM, village people and NWISP report, background and brief history of the Bomnak diversion can be understood as follows.

Before, the Bomnak/Boribo River has only one channel, which is called as old Boribo River (or old Bomnak River) now. In 1950s, diversion structures, probably including a weir, an intake and an irrigation canal at least, were constructed on the river. The weir being damaged by explosion, another weir was constructed just upstream of the old weir in Pol Pot era. The intake was rehabilitated at the same time. The structures are now deteriorated and without gate, manual control is not functional. The weir works as a fixed weir and low water ($H <$ approx. 1.05 m at Bomnak-A station) flows to diversion canal. The diverted water flows towards the Tlea Maam River and used for irrigation in the plain not so far from the diversion point. Out of the diverted water, low water is used for irrigation, and most of the remaining water and returned water comes into a tributary of the Boribo River.



Gabion weir at new channel



New weir at Bomnak diversion

Intake at Bomnak divsersion

New channel came out from the Bomnak River and developed or scoured by floods in 1980s. River water tends to bypass the old channel and diversion canal recently. To lead river flow to old channel, efforts have been made by moving sands on the river bed, but effect was not enough. Then a gabion mattress weir was constructed at the inlet of the new channel and under the bridge in January 2007. In flood season of 2007, flood water eroded side earth of the gabion mattress.

A7.4 Low Flow of Boribo River

A7.4.1 Daily Discharge and Case Setting

Daily discharge data are available at Boribo water level station for 8.5 years period. Daily discharge at Lum Hach is calculated from that at Boribo station together with catchment ratio.

The discharge at Boribo station does not include consumed water for irrigation in between Bomnak and Boribo station. Such discharge quantity and return flow cannot be known at present. Therefore, water that used for irrigation from the Boribo River is neglected in discharge calculation at Lum Hach from safety point of view.

Since water distribution at Bomnak diversion is an important but unclear factor for low flow analysis of the Boribo River, several cases are set for calculation of Lum Hach discharge. Discharge at Bomnak is calculated from that at Boribo station and catchment area ratio. Low water of the Bomnak River can be controlled technically by structures and water management rule, which may sometimes or more or less be decided from political standpoint. As for low flow distribution between (a) upstream of Lum Hach or in Tlea Maam River basin and (b) downstream to Lum Hach or in Boribo River basin, four cases are prepared. Those are (a):(b) of 0:100, 50:50, 75:25 and 100:0.

In future, if the Bomnak River water be used before Lum Hach, other water sources may be required for Lum Hach and downstream irrigation schemes. So, in addition to above cases, further cases in use of adjacent eastern stream flow(s) in other river basin, are considered taking into consideration of advices and suggestion from PDWRAM. Together with high water distribution cases, total eight cases are calculated as follows.

Case Setting of Bomnak Diversion and Calculation Results

Case	Distribution: Boribo river Lum Hach headworks : Tlea Maam river & Bomnak	Qmax from Bomnak to Tlea Maam river (m3/s)	Additional water source from east stream	Result of calculation: Annual average discharge (m3/s)	(MCM)	(mm)	(specific) (lit/s/km2)	Ratio of Case X vs Case 2
0	100 : 0	10	-	19.3	612	833	26.3	1.25
1	50 : 50	5	-	16.3	517	703	22.2	1.06
2	50 : 50	10	-	15.4	487	662	20.9	1.00
3	50 : 50	20	-	14.6	463	630	19.9	0.95
4	25 : 75	10	-	14.2	449	610	19.3	0.92
5	0 : 100	10	-	13.3	421	573	18.1	0.86
6	0 : 100	10	Stream No.1	13.4	423	576	18.2	0.87
7	0 : 100	10	Stream No1&2	14.1	448	609	19.2	0.92

Prepared by JICA Study Team

In case of high flow, followings are considered realistic. (1) High flow (that is not diverted) directly passes old channel. (2) Diverted high flow may partly or mostly return to the Boribo River. (3) High flow needs to be released to new channel, also. (4) Tlea Maam River Basin do not want so much high flow. From above, high flow to the Tlea Maam River Basin is regarded as 10 m^3/sec at most.

A7.4.2 Five-day discharge at Lum Hach

Above table presents setting of eight cases of five day discharge calculation sets at Lum Hach headworks for 8.5 years. Case 2 and Case 7 are recommendable as practical cases from hydrological viewpoint. Tables A.7.4.1 and A.7.4.2 show calculated five-day discharges for

Case 2 and Case 7, respectively.

A7.4.3 Consideration

If observation of water level and discharge measurement at three Bomnak stations and Boribo station will be conducted in order continuously, significant or precious data will be accumulated. Hydrological analysis will be able to be carried out deeply and useful results will be expected to come out. Sand extraction by pump was seen in the old channel, which may affect hydrological observation and hydraulic condition of the river.

A7.5 Flood Discharge

A7.5.1 Flood

As shown in Table A.7.5.1, "Household Survey" was carried out by social and environment sector and flood information was collected as a part. From obtained information, flood seems not serious in Lum Hach area.

According to flood information through interview to village people and PDWRAM as presented in Table A.7.5.2, there was a large flood in 1950s, most probably in 1952 judging from villager's age and rainfall data. On the middle of the left bank between Lum Hach and NR5 of the Boribo River, no other flood was experienced in recent 60 years. On the right bank, it seems that flood from several streams of other river basin sometimes occurs, which means flooded water sometimes come across the low elevated basin boundary.

Overbank flow occurs at Bomnak in flood time almost every year as shown in Figure A.7.5.1, but normal scale flood is not serious. In case of large scale flood, evacuation to hillside is one of countermeasures.

A7.5.2 Probable Flood

The annual maximum daily discharges at Boribo water level station are picked up and probability calculation is done by Iwai Method. Flood discharge with 100-year return period is estimated considering flow capacity of the river. Flood discharge at Lum Hach is regarded as the same discharge as at Boribo station, because it is considered that flood discharge does not increase or decrease considerably between Lum Hach and NR5. Peak discharge is converted from the annual maximum discharge and the ratio of 1.4 obtained from Bomnak-A and B data. It is also taken into consideration that the Boribo station has rather steep river profile slope as abovementioned.

Flood at Lum Hach

T (year)	Qd(max) (m3/s)	Qpeak (m3/s)
2	160	220
5	190	270
10	210	290
20	230	320
50	270	380
100	310	430

Prepared by JICA Study Team

A7.5.3 Consideration

According to information from Household Survey, people in Lum Hach Sub-Projec area do not have much sense or feeling of flood damage. This may come from relatively larger flow capacity of the river due to unnaturally enlarged Boribo River channel and comparatively steep slope of the river.

CHAPTER A8 METEOROLOGICAL AND HYDROLOGICAL OBSERVATION IN THE STUDY

A8.1 Objective and Scope

A8.1.1 Objective

As mentioned in A2.1.1, in the Study Area, meteo-hydrological observation network is not sufficiently developed and available data are not enough. Objective of the meteo-hydrological observation in the Study includes increase of data stock and strengthening of the observation system through installation of equipment, observation and data collection, and data processing.

A8.1.2 Scope and Results

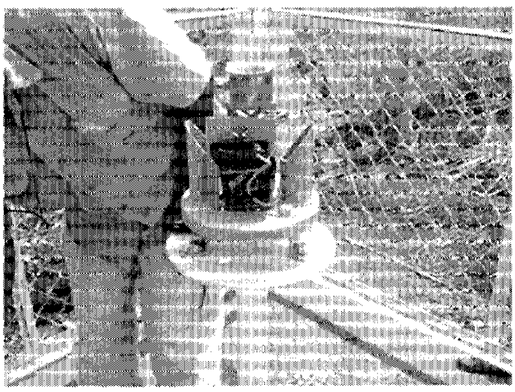
Observation items are rainfall and river water level. In addition, discharge measurement was carried out in two periods from (i) June/July 2007 to January/February 2008 (about 8 months) and (ii) from May 2008 to September 2008 (about 4 months).

The observation data in 2007 are processed and compiled as in Supporting Documents A3. Some of the results are presented in this chapter. Collected observation data are compiled and stored in Meteo-Hydrological Databook.

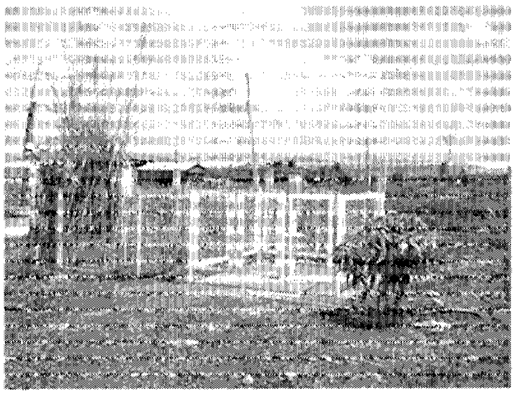
A8.2 Methodology

A8.2.1 Rainfall

As shown in location map of Figure A.2.1.1 and in the station list of Table A.2.1.1, 14 automatic rain gauges were installed, of which observation started in February/March 2007 at 12 sites and in February 2008 at two sites. Available data are as presented in Figure A.8.2.1. At three stations of Ratnak Mondol, Phnom Proek and Kampong Tralach, rainfall is observed also by manual rain gauge on daily base. Automatic and manual rain gauges are shown below.



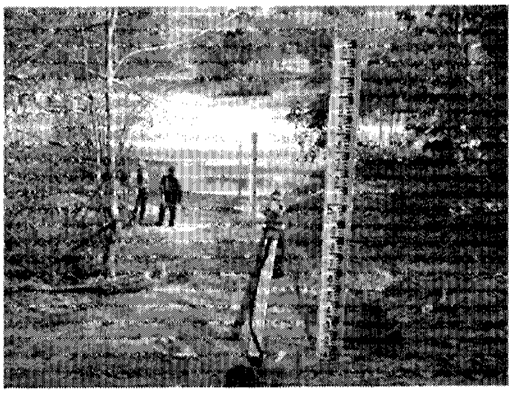
Automatic rain gauge with data logger



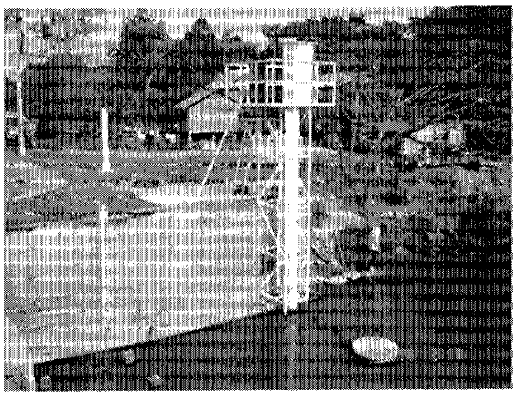
Manual and automatic rain gauge

A8.2.2 Water Level

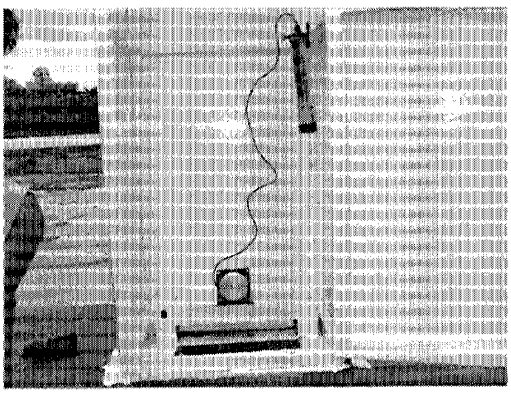
Under the Study, river water level was observed at 14 staff gauges twice per day by local observer. Out of these stations, additional water level observation by automatic water level recorder (AWLR) started at eight stations. As presented in Figure A.8.2.2, six stations started their observation after August 2007 and two stations from February 2008. This observation network is provided with three float type AWLRs and five pressure type AWLRs. Observation interval was set at half hour at the beginning time, and adjusted to 1 hour at some of the stations from February 2008. It is noted that Prek Chik (Canal) station is on an irrigation canal but not on a natural river. Examples of staff gauge and AWLRs are seen below.



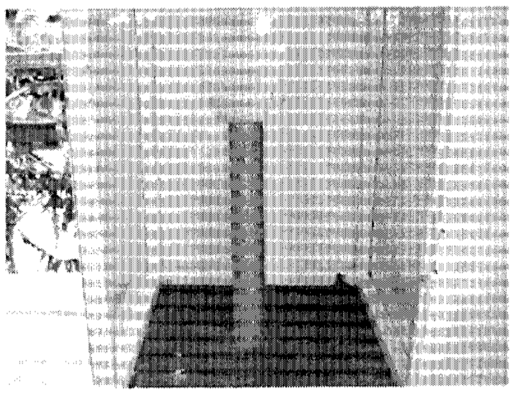
Staff gauge



Staff gauge and AWLR



Float type AWLR

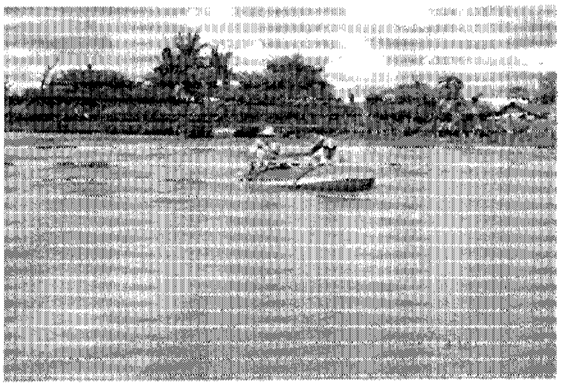


Pressure type AWLR

A8.2.3 Discharge

In corporation with counterparts of MOWRAM and PDWRAM, the Study Team conducted discharge measurement in two series for preparation of rating curves. The first series was carried out through subcontract, and the second was performed by the counterparts. In the first series, the measurement was done around 16 times from June/July 2007 to January/February 2008. In the second series, it was done eight times from May to September 2008. The measurements were done in use of flow meter or current meter. Floats of one and two meter long, being also prepared for flood measurement, were not used during the observation period.

The measurement scenes are shown in the following photographs.



Discharge measurement on boat

Discharge measurement on foot

A8.3 Results of the Observation

A8.3.1 Results in 2007

Meteo-hydrological study was carried out in use of both previous data and newly observed data in the Study. In this chapter, the study results are mainly based on the observed data in 2007. Since the observation is going on, the study herein should be updated with additional data or 2008 data and deeper consideration in the following stage after the Study. The observed data were checked and necessary correction was conducted as much as possible within the available time.

A8.3.2 Rainfall

Daily rainfall data in 2007 at 12 stations installed in the Study, are compiled in Supporting Documents A3. According to the observed data in the Study, annual rainfall in 2007 seems larger than mean value as shown in table below. For calculation of annual rainfall in this table, lack of data in January and February is regarded as no rainfall in the table, because rainfall in January and February is usually little in the dry season.

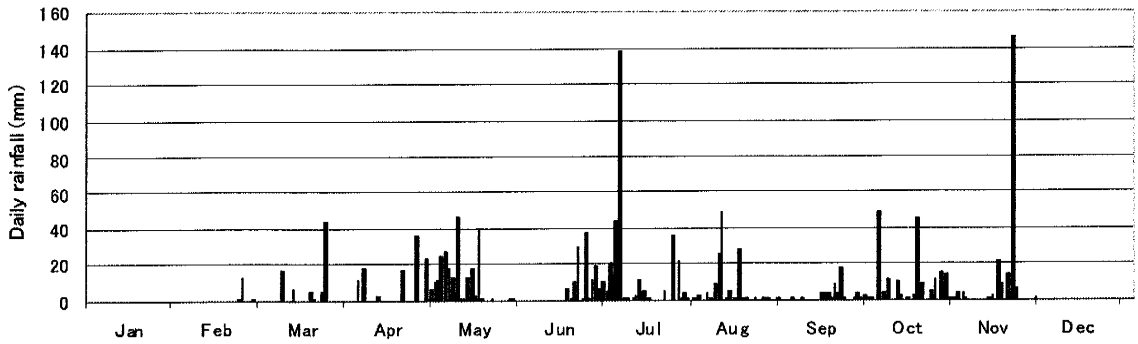
Sample daily base and ten minutes base hyetographs are presented below.

Monthly Rainfall in 2007

(mm)

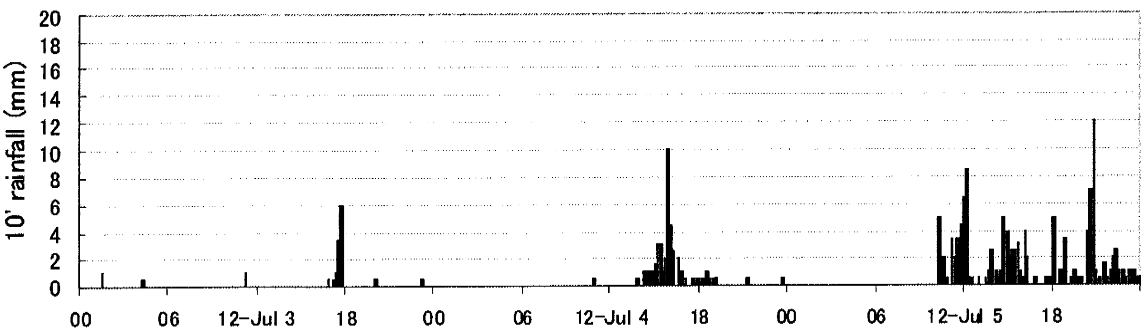
Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ratanak Mondol	-	22	17	78	303	215	145	64	142	162	156	0	1301
Samlot	-	15	78	119	236	139	317	162	52	223	205	0	1544
Phnom Proek	-	-	63	296	345	166	161	188	174	133	92	1	1616
Bassac Reservoir	-	-	88	169	268	206	55	58	305	312	134	0	1592
Moung Russey	-	-	111	85	338	257	55	161	174	259	180	0	1616
Roveang	-	1	159	102	251	292	119	93	345	272	90	0	1721
Svay Don Keo	-	-	84	114	176	205	46	120	270	278	128	0	1419
Koh Chhom	-	1	122	67	266	146	114	177	181	213	86	1	1371
Bomnak	-	-	47	162	266	162	160	250	269	270	85	2	1671
Boribo	-	-	88	64	374	241	245	254	53	243	70	0	1631
Takab	-	-	110	104	282	171	193	312	299	325	78	0	1872
Peam (Krang Ponley)	-	-	88	50	131	202	96	184	289	142	83	0	1263

Data from MOWRAM and the JICA Study Team



Prepared by JICA Study Team

Daily Rainfall in 2007 at Samlot



Prepared by JICA Study Team

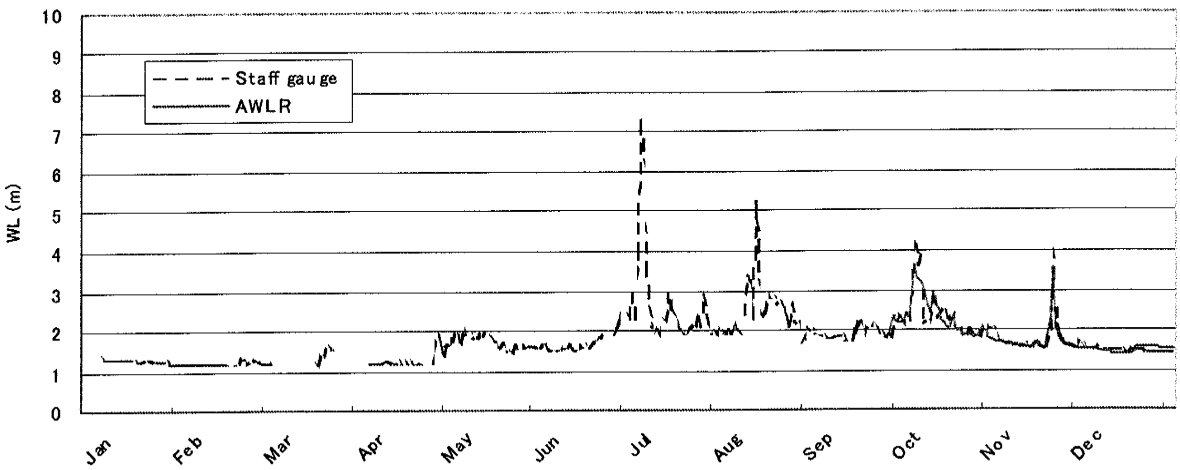
Ten Minutes Rainfall at Samlot: in July 2007

As seen in above figure of 10 minutes rainfall hyetograph for annual maximum 3-day rainfall of 196.5 mm from 3rd to 5th of July 2007 in Samlot, rainfall tends to concentrate in the afternoon. Rainfalls in hour 0-6, 6-12, 12-18 and 18-24 are 1.5 mm (1%), 25.5 mm (13%), 104.0 mm (53%) and 65.5 mm (33%), respectively. Hourly rainfall in July shows similar tendency. However, it is not like this in some other months. Annual maximum rainfall record in 2007 at Samlot was 145.5 mm on 19 November, when remarkable 79.5 mm was recorded for three hours from 0 to 3 hour.

A8.3.3 Water Level

Daily water level data in 2007 at 13 water level stations installed in the Study, are compiled in Supporting Documents A3. Water level hydrographs are prepared and preliminary checked by shape, and judged mostly "not so bad" as illustrated in figure as follows. Comparison between staff gauge read water level and that by AWLR shows generally fair conformity with each other like an example at Dong Tung shown in the following figure.

At the beginning of the AWLR observation, initial setting of the equipment was not done properly at a few stations, so their recorded data could not used as they were, because they were not actual water level. Most of such data were converted or adjusted to actual water level and became useful. In the Databook, original records before adjustment are saved.



Prepared by JICA Study Team

Daily Water Level in 2007 at Dong Tung

A8.3.4 Rating Curve

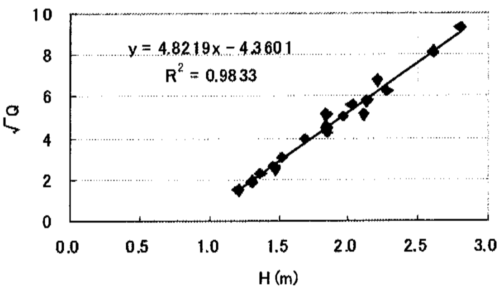
Based on the discharge measurement results, rating curve for respective station is prepared as in Table A.8.3.1 (1/6 - 6/6) and summarized as in following table except Battambang and Prek Chik (Canal) stations. Since Battambang station is under influence of backwater from the Lake Tonle Sap, rating curve was not prepared this time. The curve can be prepared with downstream Bac Prea water level data. Because irrigation water was not supplied to Prek Chik Main Irrigation Canal during most of the observation period except flood time in 2007/2008, rating curve could not be prepared for the station. Though backwater effect comes to Svay Don Keo site sometimes, rating curve was prepared. As an example, estimated rating curve at Dong Tung is shown in figure below.

Estimated Rating Curve for 2007 Water Level Data

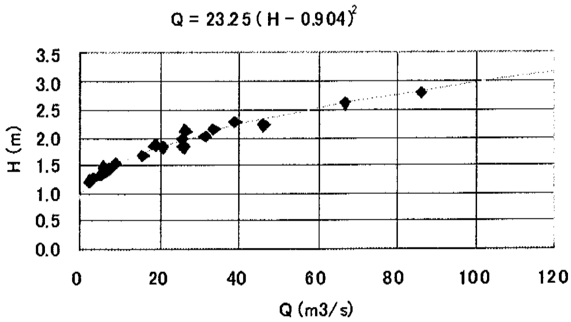
No.	Station	applicable H	Rating Curve Formula
H- 1	Battambang		Bac Prea H data needed
H- 2	Dong Tung	$H \geqq 0.94$	$Q = 24.19 (H - 0.931)^2$
H- 3	Moung Russey H < 1.93m H >= 1.93m	$H \geqq 1.46$	$Q = 22.88 (H - 1.454)^2$ $Q = 3.07 (H - 0.641)^3$
H- 4	Prek Chik (River)	$H \geqq 1.34$	$Q = 12.82 (H - 1.339)^2$
H- 5	Prek Chik (Canal)		No running water observed
H- 6	Svay Don Keo	$H \geqq 1.68$	$Q = 17.68 (H - 1.677)^2$
H- 7	Koh Chhom	$H \geqq 0.06$	$Q = 9.62 (H - 0.054)^2$
H- 8	Bomnak	$H \geqq 0.32$	$Q = 15.57 (H - 0.319)^2$
H- 9	Bomnak-A (Tlea Maam R)	$H \geqq 0.20$	$Q = 11.45 (H - 0.191)^2$
H- 10	Bomnak-B (Boribo R)	$H \geqq 0.28$	$Q = 6.27 (H - 0.275)^2$
H- 11	Boribo	$H \geqq 0.51$	$Q = 24.37 (H - 0.501)^2$
H- 12	Ta Kab	$H \geqq 0.44$	$Q = 13.20 (H - 0.434)^2$
H- 13	Peam (Krang Ponley R)	$H \geqq 0.72$	$Q = 13.42 (H - 0.720)^2$

Prepared by JICA Study Team H: Staff gauge water level (m) Q: Discharge (m3/s)

During field visits, the Study Team sometimes found problematic preparation of rating curves. Therefore, better approach technology to estimate rating curves was transferred to counterparts of MOWRAM and PDWRAM. In use of computer software, calculation of the curves is usually easy and gained correlation coefficient is often quite high. It does not mean easiness of preparation of rating curves. Such curves that have high correlation coefficient of nearly one, are sometimes unreasonable curves. Some example curves produce discharge below zero and others estimate higher discharge from lower water level. Many points must be checked to estimate better curves. Many factors should be taken into consideration for preparation of rating curves and it is not so easy work but difficult work.



H-√Q Plot: Dong Tung 2007



Rating Curve at Dong Tung for 2007

Prepared by JICA Study Team

H/Q Plot and Rating Curve in 2007 at Dong Tung

A8.3.5 Discharge

Daily discharge in 2007 was calculated from observed daily water level and estimated rating curve at 11 stations except for Battambang, Prek Chik (Canal) and Veal Veang stations. Rating curve has not yet prepared at Battambang station. No flow was observed in usual time without flood at Prek Chik (Canal) station. Water level observation started from February 2008 at Veal Veang station. The processed daily discharge data are compiled in Supporting Documents A3. Specific discharges of the stations differ in wide range. Dong Tung on the upper reach of the Battambang (Sangker) River shows relatively larger runoff. Prek Chik (River) and Peam (Krang Ponley River) recorded small runoff in 2007. Monthly discharge and specific discharge in 2007 are presented in the following tables.

Preliminary Estimated Monthly Discharge

(m3/s)

Station name	2007												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Battambang	*	*	*	*	*	*	*	*	*	*	*	*	*
Dong tung	3.85	2.65	3.54	3.78	16.07	16.28	97.79	63.60	26.08	57.57	24.21	8.00	26.95
Moung Russey	-	-	-	-	-	-	6.36	2.98	8.04	14.23	13.12	2.29	-
Prek Chik (River)	0.43	0.19	0.34	0.80	28.99	15.08	5.98	2.32	9.14	13.81	18.77	1.83	8.14
Prek Chik (Canal)	-	-	-	-	-	-	-	-	-	-	-	-	-
Svay Don Keo	0.46	0.03	-	0.00	-	-	5.20	0.57	11.54	22.52	27.59	8.78	-
Koh Chhom	-	-	0.97	0.72	-	-	8.12	10.80	30.40	18.64	5.41	1.56	-
Bomnak	-	-	-	0.59	6.43	9.53	11.51	17.48	29.15	30.96	7.25	3.01	-
Bomnak-A (west)	-	-	0.52	0.57	1.50	5.58	7.31	10.64	15.82	16.15	9.44	4.14	-
Bomnak-B (east)	-	-	0.19	0.22	1.07	-	3.24	7.92	13.43	14.55	3.80	0.81	-
Boribo	1.83	0.83	0.68	0.70	5.27	13.83	17.87	32.19	60.21	72.37	22.68	10.46	19.91
Ta kab	-	-	0.67	1.02	7.54	4.04	6.26	10.99	32.94	34.03	9.55	3.62	-
Peam (Krang Ponley R)	1.07	0.55	0.65	0.79	6.95	4.34	2.92	3.58	20.84	21.73	5.24	2.03	5.89
Veal Veang	------------------------ Installrf in February 2008 ------------------------												-

Prepared by JICA Study Team   * To be estimated later   - No data or no flow

Preliminary Estimated Monthly Specific Discharge

(l/s/km2

Station name	2007 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Battambang	*	*	*	*	*	*	*	*	*	*	*	*	*
Dong tung	5.5	3.8	5.0	5.4	22.9	23.2	139.3	90.6	37.2	82.0	34.5	11.4	38.4
Moung Russey	-	-	-	-	-	-	8.1	3.8	10.2	18.1	16.7	2.9	-
Prek Chik (River)	0.6	0.3	0.5	1.1	40.4	21.0	8.3	3.2	12.8	19.3	26.2	2.6	11.4
Prek Chik (Canal)	-	-	-	-	-	-	-	-	-	-	-	-	-
Svay Don Keo	0.6	0.0	-	0.0	-	-	6.5	0.7	14.3	28.0	34.3	10.9	-
Koh Chhom	-	-	1.6	1.2	-	-	13.2	17.6	49.5	30.4	8.8	2.5	-
Bomnak	-	-	-	1.5	16.7	24.8	30.0	45.5	75.9	80.6	18.9	7.8	-
Bomnak-A (Tlea Maam R)	-	-	2.7	3.0	7.8	29.1	38.1	55.4	82.4	84.1	49.2	21.6	-
Bomnak-B (Boribo R)	-	-	1.0	1.2	5.6	-	16.9	41.3	70.0	75.8	19.8	4.2	-
Boribo	2.9	1.3	1.1	1.1	8.4	22.0	28.5	51.3	95.9	115.2	36.1	16.7	31.7
Ta kab	-	-	1.9	2.8	20.9	11.2	17.4	30.5	91.5	94.5	26.5	10.1	-
Peam (Krang Ponley R)	1.9	1.0	1.2	1.4	12.5	7.8	5.2	6.4	37.4	38.9	9.4	3.6	10.6
Veal Veang	------------ Installrf in February 2008 ------------												-

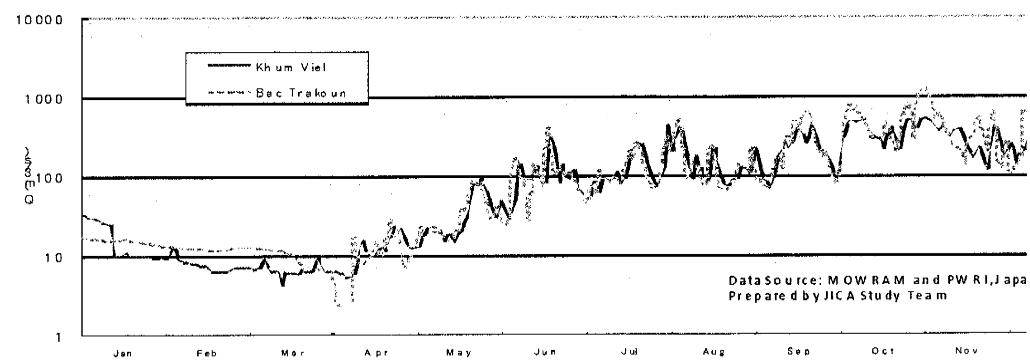
Prepared by the JICA Study Team * Not yet estimated - No data or no flow

A8.4 Consideration

A8.4.1 Flood Characteristics and river flow

The Study Area consists of upper hilly area and lower flat area from topographical point of view. In the hilly area or upper basin, river generally formulates a valley and inundation due to overbank flow is limited within the valley. The river comes out from the hilly area to open low flat land, flood plain or alluvial plain. In the plain, overbank flow occurs frequently, and the river meanders more violently and often formulates natural levee along the bank. In the plain, flow capacity of the river decreases as it goes downward in general. Near the Lake Tonle Sap, the river channel scale becomes slight or insignificant, and fade out into the lake.

In case of larger flood along the Pursat River and the Battambang river, flood discharge of upstream is larger than that of downstream in the plain. For example, in the Pursat River, the mean daily discharge at Bac Trakoun (CA=4,245 km^2) is frequently larger than that at Khum Viel (CA=4,245 km^2) which is located more than 20 km downstream of Bac Trakoun as shown in the following figure.



Prepared by JICA Study Team **Daily Discharge at Khum Viel and Bac Trakoun in 1996**

A8.4.2 Approach for Flood Control

Even though flood and inundation occurs frequently in time and widely in space in the Study Area, a lot of people do not have sense of serious flood damage for small and middle scale of floods. Inundation occurs in large range and intensity is relatively thin. At present and in near future, drastic change of river system by flood control is not considered necessary. Enlargement of flow cross-sectional area of river channel, not only needs considerable cost but also increases downstream flood discharge and sedimentation. Continuous flood dyke also needs a lot of cost and land for high water channel, and increase downstream flood discharge. These flood control approaches are not required now or even harmful.

CHAPTER A9 RECOMMENDATION

A9.1 Observation

A9.1.1 Maintenance of Equipment

To keep better observation through timely check and maintenance, monthly or bimonthly data collection and inspection is recommended. Following possible troubles are expected to be solved through routine periodical inspection. Staff gauge scale plate may be dirty, broken and/or not readable. Like ants, lizards, spiders, etc., small living things often intrude into observation equipment or its shelter. Dust and leaves sometimes choke rain receptor of automatic rain gauges. Battery power may expire before assured time. Float wire may come out from wheel. These should be avoided as much as possible or recovered in order.

A9.1.2 Staff Gauge Reading

Reading water level precisely on staff scale is basic and important matter, however it is sometimes not easy for local observer. It is desirable that personnel or engineer in charge of data collection and processing always check data quality and guide observer how to read the scale, if necessary.

A9.1.3 Rain Gauging and Data Recording

Rain gauging is performed sometimes not precisely, for example, at Krakor station in recent years. Guidance on how to observe and record is desirable, where required.

A9.2 Data Processing

A9.2.1 Rainfall

In the process of daily rainfall data, careful attention is to be paid to distinction of "no rainfall" and "no observation". Also, checking of data through hyetograph was recommended with sample figures. Unnatural hyetograph pattern usually suggest problems in observation or data processing.

A9.2.2 Water Level

It is also strongly recommended to check water level data through hydrograph. Change in river conditions should be carefully noted and necessary countermeasures should be taken in preparation of rating curves. The change includes backwater influence due to downstream weir up, considerable volume of extraction of river bed materials, a lot of sediment by flood, and so on.

A9.2.3 Discharge Measurement and Rating Curve

To prepare better rating curve, discharge measurement should be conducted for wide range of water level. Particularly, the data should include high flow and low flow.

Rating curve should be revised, when discharge measurement data set suggest difference from previous curve on the figure. Rating curve should be a set of plural curves, when single curve cannot represent water level – discharge plotting pattern.

It is recommended to try firstly a formula " $Q = a (H - b)^2$ ", which can be applicable in many of the cases. The formula can be " $\sqrt{Q} = \sqrt{a} (H - b)$ " and usable where $H \geqq b$. In normal condition, $Q \geqq 0$ and as H lowers, so Q lowers. Constants "a" and "b" can be calculated through computer software. The calculation is not so difficult but estimation of good rating curve is not easy. This can be said to preparation of a model also.

A9.2.4 Discharge

In case that discharge measurement data are not well distributed or are concentrated to middle flows, lower and higher discharges are often calculated through extrapolated part of a rating curve. In such a case, accuracy of discharge is often not so high. Therefore, it is recommended to try countercheck for drought or/and flood discharges through estimate flow capacity or other ways.

A9.3 Analysis and Publication

A9.3.1 Meteo-Hydrological Analysis

It seems unfortunately that MOWRAM and PDWRAM staffs have not enough time to analyze processed meteo-hydrological data. However, assigned counterparts to a project may have a chance to analyze data with project members for the project. In that case, the counterpart is recommended to prepare brief report on the works and distribute to MOWRAM and PDWRAM members. By accumulation of experience, it will be easier to understand analysis method. Using a formula without understanding it, often leads unnatural results.

A9.3.2 Databook Publication

It is recommended to publish compiled or processed data as "Meteorological and Hydrological Databook", and analysis results as "Meteorological and Hydrological Analysis Reports". Published documents are expected to be utilized for study by not only MOWRAM and PDWRAM staffs but also students and consulting engineers.