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

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LIST OF VOLUMES

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Meteorology and Hydrology

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

FINAL REPORT

APPENDIX-A METEOROLOGY AND HYDROLOGY

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CHAPTER A1 METEO-HYDROLOGICAL CONDITIONS

A1.1 River Basins

A1.1.1 Four River Basins

(1) The Study Area

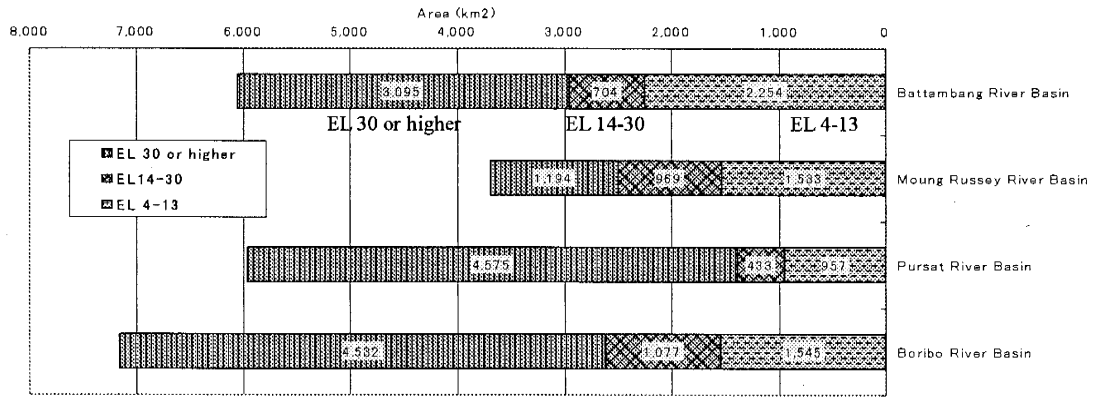
The Basin-wide Basic Irrigation and Drainage Master Plan Study (the Study), covers 22,868 km2 of the south-western part of the Tonle Sap Lake (the Great Lake) Basin. The Study Area consists of four River Basins, namely the Battambang (Sangker), Moung Russey (Dauntri), Pursat and Boribo River Basins as in Figure A.1.1.1. These River Basins are based on the 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 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



Area by Elevation

(2) Battambang River Basin

The Battambang (Sangker) River Basin has an area of 6,053 km2, of 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 the Mongkol Borei river at Bac Prea, about 40 km downstream from the Battambang Town, and the Sreang river at another 10 km downstream, then flows into the Tonle Sap Lake. The Battambang river basin area at Battambang Town is 3,194 km2.

(3) Moung Russey River Basin

The Moung Russey (Dauntri) River Basin has an area of 3,696 km2, of which 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 Russey river and the Svay Don Keo river are main rivers in the River Basin. The Kambot river flows eastern part of the River Basin.

(4) Pursat River Basin

The Pursat River Basin has an area of 5,965 km2, of which the highest elevation is 1,717 m. This River Basin has more 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 river basins, namely the Pursat, Arai (Peam) and Prey Khlong river basins. The Pursat river basin area at Khum Viel in Pursat Town is 4,596 km2.

(5) Boribo River Basin

The Boribo River Basin has an area of 7,154 km2, of which the highest elevation is 1,764 m. Topography of the River Basin is more complicated in the Study Area. This River Basin consists of smaller river basins compared with the Battambang and Pursat River Basins.

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. In addition, remaining area of the Study Area is composed of parts of Pailin, Kompong Speu, Kandal Provinces and Phnom Penh City.

(1) Battambang River Basin

This Basin is mostly of the Battambang Province and two small parts are of 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 formulate 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 includes 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. The northwestern part belongs to the Pursat Province, the southwestern part Kompong Speue Province, and southeastern part 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. There is not available data in recent years.

Also in Pursat station, an automatic observation system was installed but is not functioned completely 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.

A1.2.2 Rainfall Observation

Table A.1.2.2 is a 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, Kompong Chhnang, Pochengton and Kompong Speue stations being among the long term observation stations in Cambodia, have more than 50 years rainfall data.

Under control of or requested by PDWRAM/MOWRAM, local observer 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/MOWRAM staff members collect the recorded sheets and compile data. DOM is responsible for the rainfall observation at present.

A1.2.3 Water Level Observation

Hydrological stations are located as illustrated in Figure A.1.2.7 and available water level data together with discharge data are shown in Figure A.1.2.8. List of the hydrological stations is prepared as in Table A.1.2.3. Of available hydrological data, observation period start 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 the discharge measurement numbers are not enough for periodical rating curve preparation in general. Daily discharge calculation through rating curves is not conducted sufficiently and correctly in recent year.

A1.3 Meteo-Hydrological Conditions

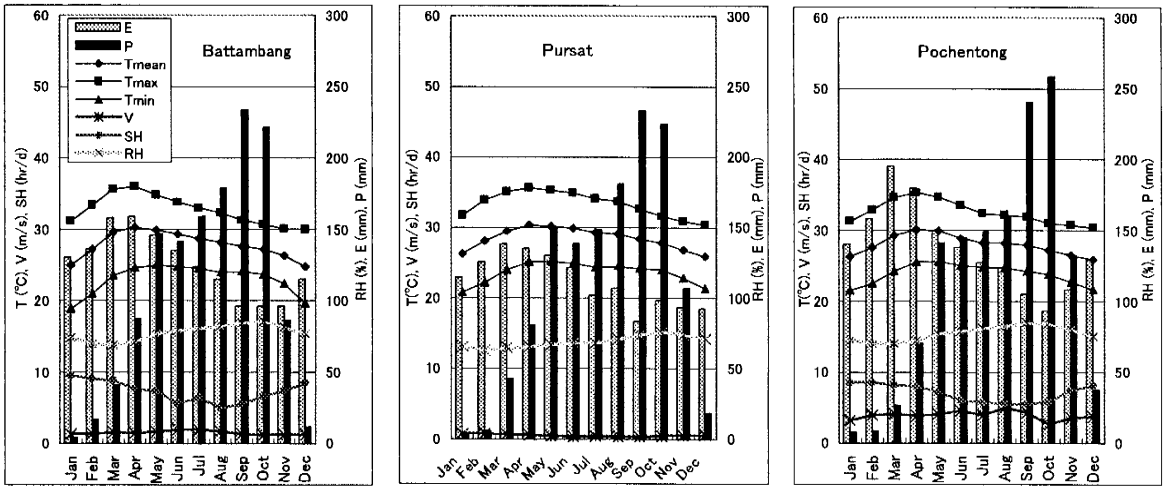
A1.3.1 River System

As presented in Figure A.1.3.1, the Battambang (Sangker) river and the Pursat river are 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, 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

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 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. Average annual rainfalls are between 1100 mm and 1700 mm in the plain as seen in Figure A.1.3.2.

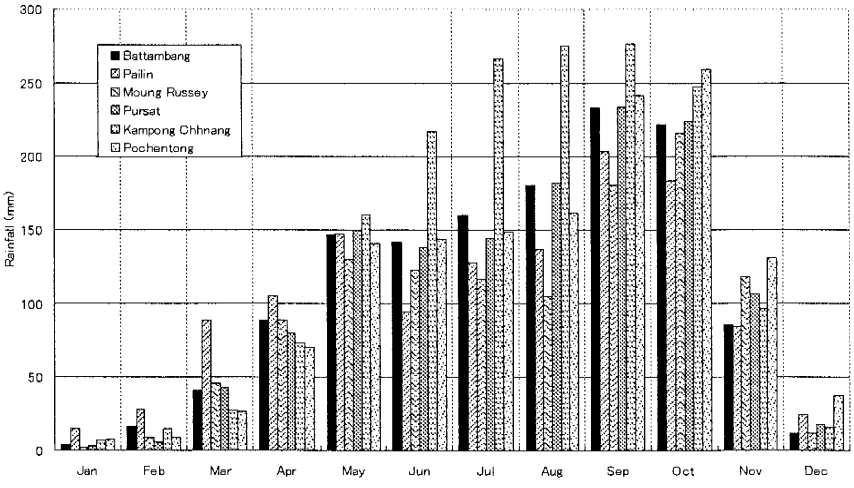
Average Monthly Rainfall

(Unit: mm)

River Basin	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Battambang	Battambang	4	17	41	89	147	142	160	180	233	222	86	11	1331
Mongkol Borey	Pailin	15	28	89	106	148	94	128	137	203	183	84	24	1239
Moung Russey	Moung Russey	2	9	46	89	130	123	117	105	180	216	119	12	1146
Pursat	Pursat	3	6	43	80	150	138	144	182	234	223	107	18	1328
Boribo	Krakor	4	6	30	63	193	188	178	210	241	287	96	21	1517
Boribo	Kampong Chhnang	7	15	27	73	161	217	266	275	277	247	97	16	1677
Prek Thnot	Pochentong	7	9	27	70	141	144	148	161	241	259	131	37	1375

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

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 (1680 mm).

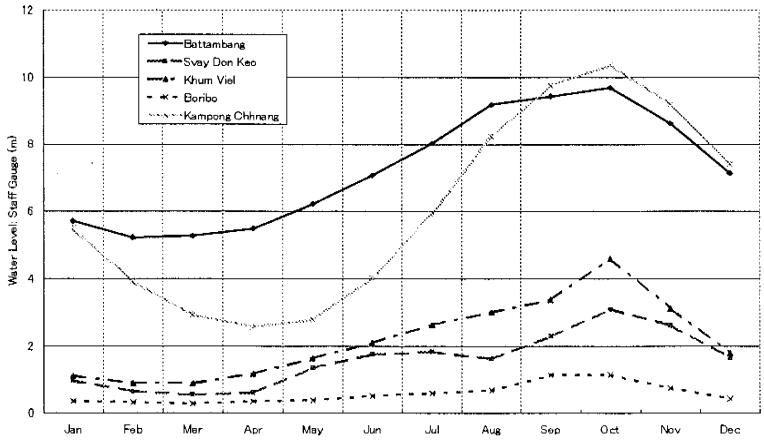


Average Monthly Rainfall

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.



Average Monthly Water Level

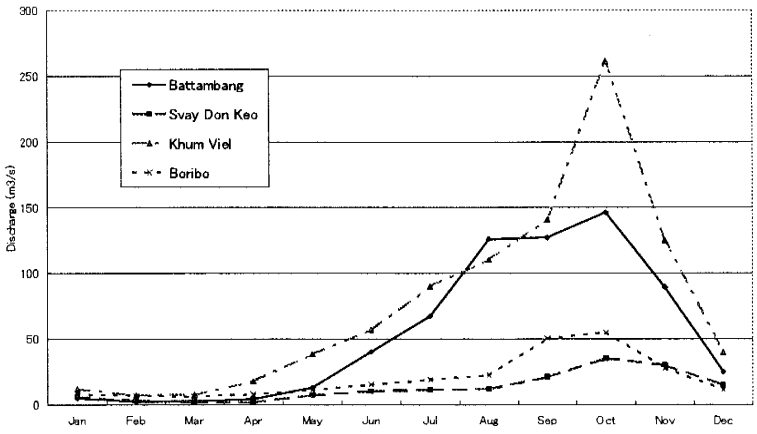
Average Monthly Water Level

(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.



Average Monthly Discharge

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, discharge measurement including low and high flow times must be carried out every year. However, the data seem insufficient in general. Such water level stations that locate near the Tonle Sap Lake, 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 enough, is limited staff in DHRW.

(2) Rating Curve

Preparation of rating curves is quite important and is often difficult work. Improper rating curve leads improper discharges, which sometimes occur. 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

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. Amount of fund from external donors in 2001 and 2002 is 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.

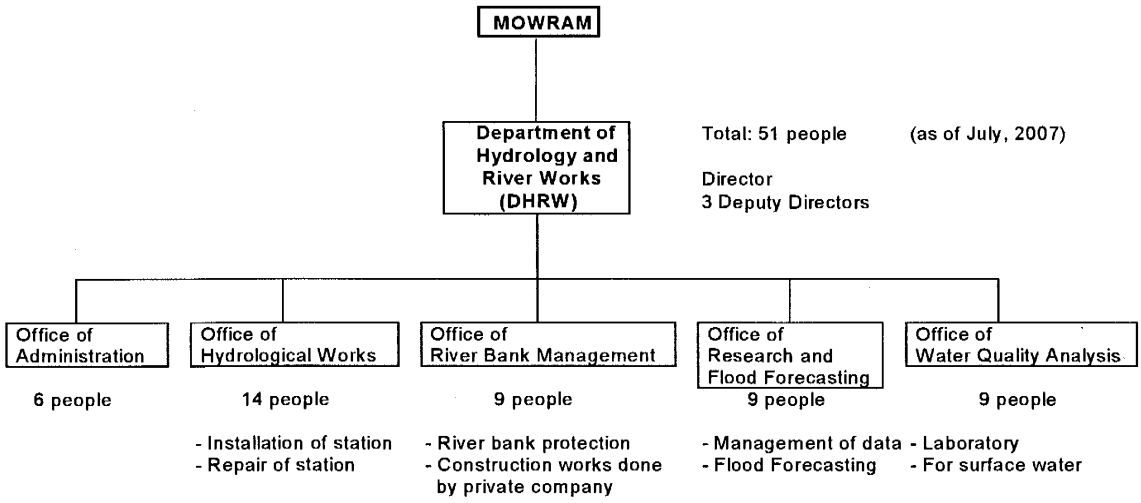
MOWRAM Expenditure (million Riel) **E-Data**

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. 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

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.

(2) Data Compilation

The data are compiled through HYMOS system. However, MOWRAM engineers or technical officers seem not fully employ the system. One of the constraints is insufficient technical level of the staff. Number of specialist for meteorological observation is not enough. There is no college having fixed meteo-hydrological study course. Very few young technical 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 km2, meteo-hydrological observation network is not sufficiently developed and collected data are not enough to make various water related programs, plans and project, including irrigation and drainage sector. Objective of the meteo-hydrological investigation in the Study includes strengthening of the observation system, through equipment installation, following observation and data processing. Installed equipment consists of new rain gauges, staff gauges and automatic water level gauges. The observation includes rainfall, water level and discharge measurement.

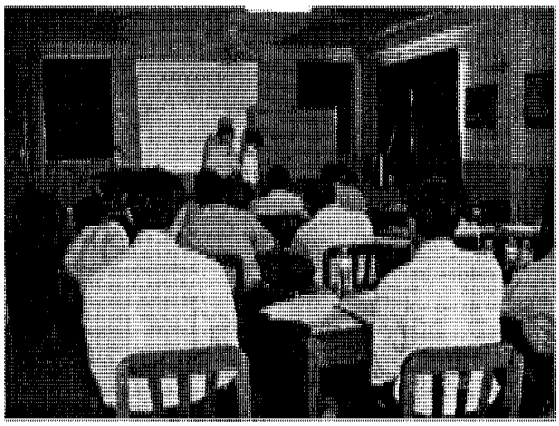
A2.1.2 Scope

In addition to the 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 as in Table A.2.1.1 and Figure A.2.1.1. 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 pressure type, commenced in July 2007. Observation by automatic water level recorder (AWLR) started in August, but lower part structure will be completed after water level drop down to low enough in the dry season. The above meteo-hydrological equipment was supplied by JICA.

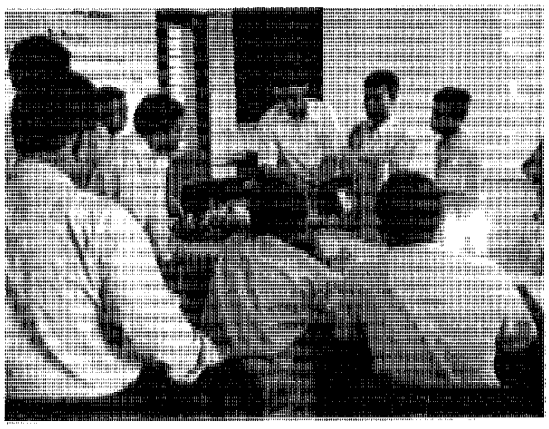
A2.2 Methodology

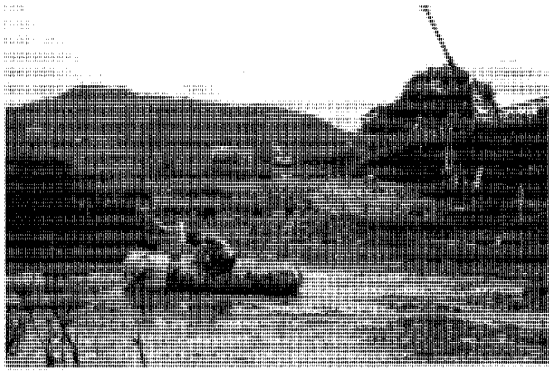
A2.2.1 OJT Technology Transfer and Mini Workshop

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 is going on by the Study Team as a sub-contract works 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 by September 2007. The flow meters and floats were supplied from JICA.

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 Site 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 Commune
R10	Boribo	Police Office
R11	Ta Kab	Beside observer's house
R12	Peam (Krang Ponley River)	Commune land

Two more automatic rain gauges are scheduled to be installed by February 2008. After discussion with MOWRAM/PDWRAM staff, candidate locations are selected at Kompong Tralach and Rolear Phear in Kompong Chhnang Province or Boribo River Basin. Compared with other main Provinces in the Study Area, the Kampong Chhnang Province has less automaric rain gauges and the candidate stations are comparatively longer observation period.

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 is 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 can be 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

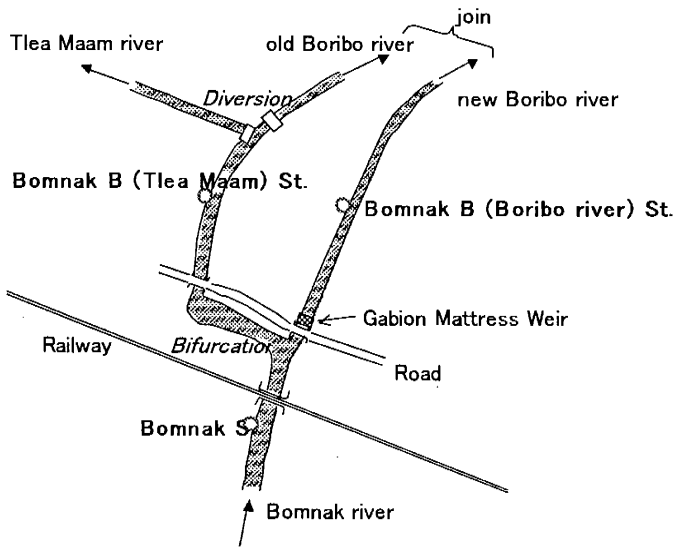
No.	Station	Staff Gauge (m)						Automatic Water Level Recorder
		MOWRAM/ PDWRAM	JICA*1 Preliminal	the Study Team*2 Replace	Install		Length in March*3	
1	Battambang	10	-	4	1	lowest	11	-
2	Dong Tung	-	11	-	1	lowest	12	Pressure type
3	Moung Russey	-	-	-	8	new	8	-
4	Prek Chic (River)	-	7	-	2	low/highest	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 (Tlea Maan)	-	-	-	5	new	5	Float type
10	Bonmak B (Boribo river)	-	-	-	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
	Total	22	27.8	4	44.2		90	

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

(2) Additional Stations around Bomnak Diversion

The reasons why two stations were added to the above list are mentioned here with figure below. The Bomnak river bifurcates to old and new 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 river discharges, two stations were placed on the old and new Boribo rivers. Since the old Boribo river divert its water to the Tlea Maam river, station name near the diversion point is named Bomnak A (Tlea Maam) and the other is named Bomnak B (Boribo river).



Three Water Level Stations near Bomnak Diversion

(3) Automatic Water Level Recorder

Six (6) automatic water level recorders (AWLRs) are to be installed at six (6) stations 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 candidate sites of AWLR installation are selected as follows. Two numbers at Veal Veang (Pursat Province) and Battambang (Battambang Province) are suggested 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 recording to new local observer, before start of the observation.

Since MOWRAM has experience to use the AWLRs, several useful advices were given to the Study Team. For example, double roof of shelter to shut out overheat from sunshine and required height of the shelter to keep space for pulling out inside cylinder of the sensor. Observation interval was set at a half hour so far, which will be adjusted later (one hour, for example) when flood hydrographs can be checked.

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 cannot be collected so far.

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

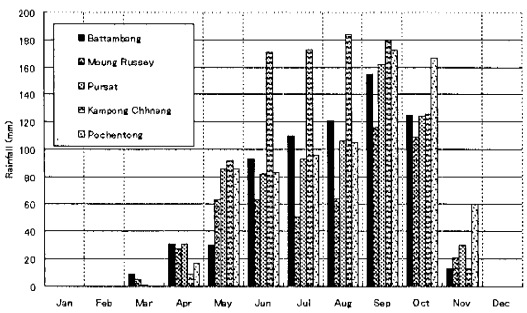
Average monthly meteorological data for each River Basin are estimated as seen in Figure A.3.2.1 from existing data at three stations mentioned in above **A1.3.2**.

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, Kompong 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 a 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 Russey River Basin and Battambang River Baison gains the lowest 5-year dependable annual rainfall from 900 to1100 mm.



80 % Dependable Rainfall

Kompong 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, the rainfall there 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

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

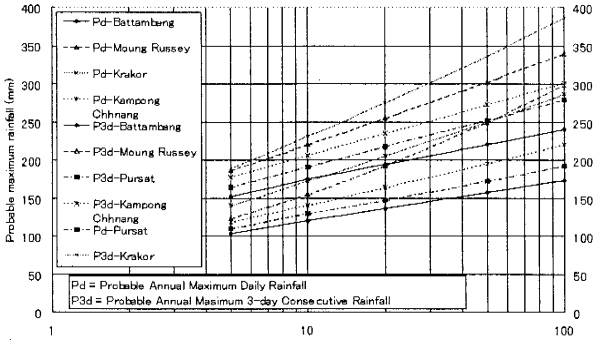


Figure A.3.2.4 Probable Maximum Rainfall

Probable Annual Maximum Rainfall

Return Period	Maximum Daily Rainfall (mm)					Max. Consecutive 3-day Rainfall (mm)					Data
(Year)	5	10	20	50	100	5	10	20	50	100	(year)
Battambang	103	120	136	157	173	152	174	194	220	240	42
Pailin	118	138	156	-	-	180	215	247	-	-	13
Moung Russey	122	155	192	-	-	186	220	255	-	-	12
Pursat	110	129	147	172	192	164	191	217	252	279	54
Krakor	140	172	205	250	-	189	231	274	336	-	30
Kampong Chhnang	118	140	163	195	220	177	206	234	272	301	52
Pochentong	106	125	148	-	-	138	155	172	-	-	14

Note: "-" are not shown due to shorter data period.

A3.3 Low Flow Analysis

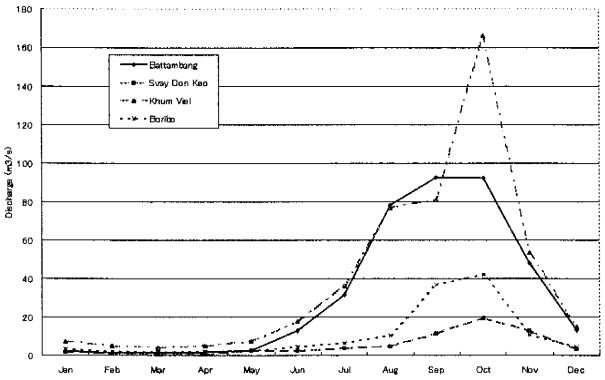
A3.3.1 Hydrological Data Check and Selection

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 Russey 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.



Probable Monthly River Discharge of 80 % Dependability

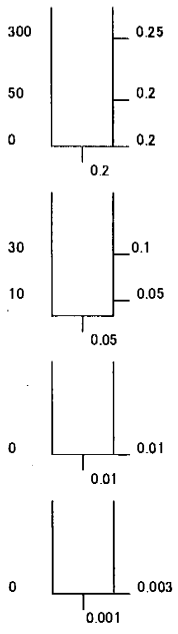
from Main rivers (m3/s)

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

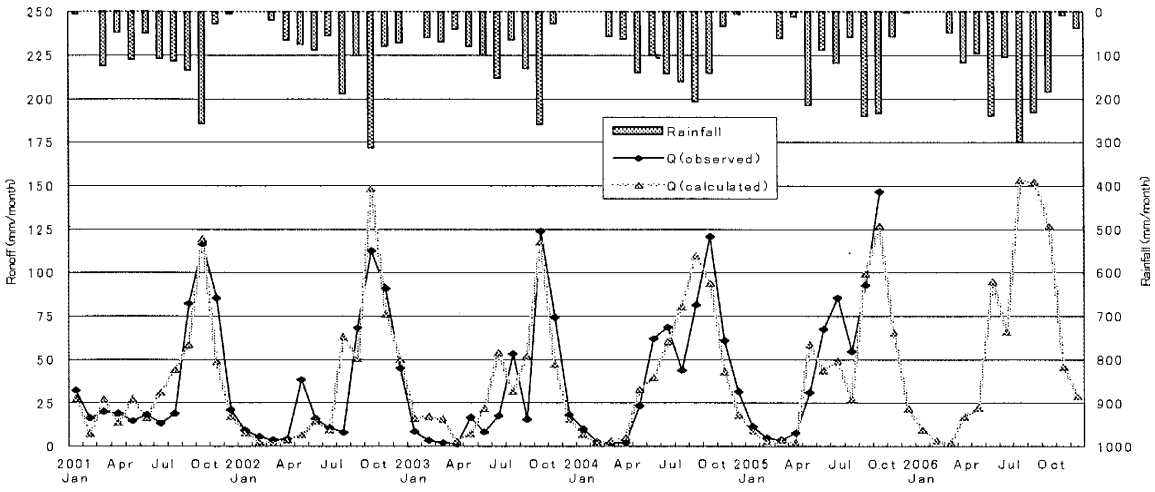
The Battambang river and the Pursat river, being the largest rivers in the Study Area, have available monthly discharge data as abovementioned. The Svay Don Keo river and the Boribo river, which can be classified into middle class in the Study, also have monthly discharge data. In the remaining area, 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.

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.



Tank Model

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



Observed and Calculated Monthly Discharge at Svay Don Keo in mm

A3.3.4 Available Water by Sub-basin

Monthly specific discharges (l/s/km2) 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.

River Basin	Station	Return Period or Recurrence Interval 5	10	20	50	100	Data (year)
Battambang	Battambang	650	750	850	970		17
Battambang	Treng	1130	1310	1480	1700		11
Moung Russey	Svay Don Keo	60	67	74			8
Pursat	Khum Viel	520	550	580			9
Pursat	Bac Trakoun	1000	1200	1390			6
Boribo	Boribo	180	190	210			7

Note: Blank cells are less relaible due to shorter data period.

Probable Maximum Discharge (m3/s)

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 water surface rising of the Tonle Sap Lake is seen in maps of MOWRAM prepared in TSLSP in 2006. Lowland area from National Highway 5 to the lake is widely inundated every year in accordance with the lake water level rising. Of the Tonle Sap river at Kompong 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.

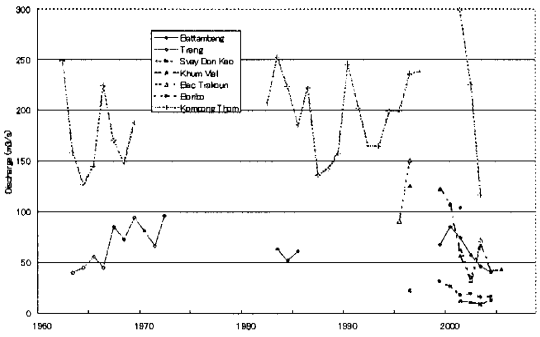
Another type of inundation comes from river flood. There exists only few flood control structure in the Study Area, therefore flood overtopping occurs frequently over the alluvial plain. It seems that for the local people flood and inundation can be acceptable to certain extent as usual natural events,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

A3.5 Long Term Tendency

A3.5.1 Past Trend

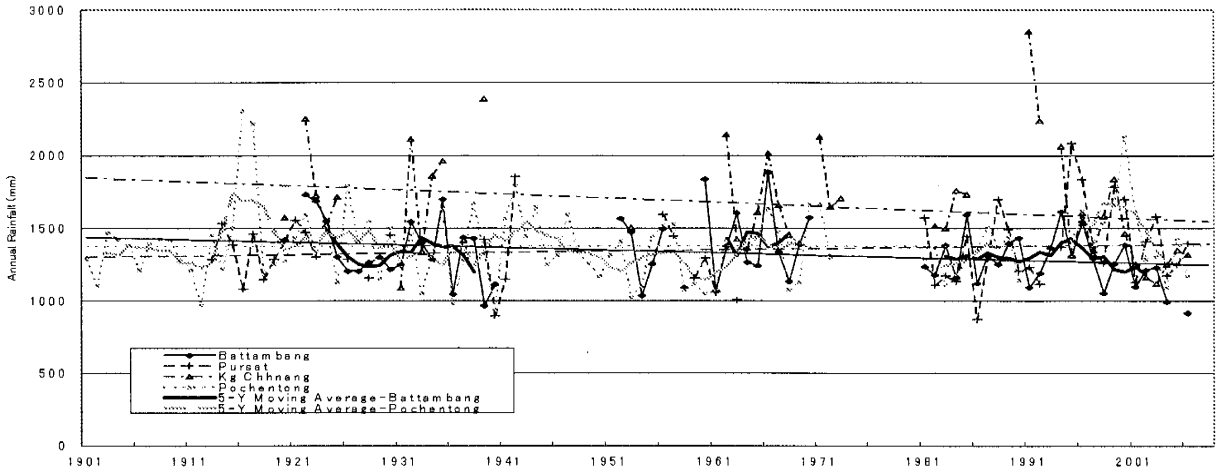
Annual average discharges fluctuate violently as seen in right figure. Long term tendency is not clear.

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 20th century is presented in the following figure.



Annual Discharge Fluctuation

At Battambang and Kompong 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.



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 fund is comparatively high in both MOWRAM and PDWRAM development budgets. 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.

A4.2.2 Technology Education System Support Program

Through exchange of ideas with MOWRAM officers, some projects 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 as in case of the abovementioned data book. The main objective may be technology level up 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, 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 computer.

A4.4 Implementation Plan

A4.4.1 Project Cost

Total of the two project costs is roughly estimated at US$ 2.25 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	2008 JFY 2008 4Q	1Q	2Q	3Q	4Q	2009 JFY 2009 1Q	2Q	3Q	4Q	2010 JFY 2010 1Q	2Q	3Q	4Q	2011 JFY 2011 1Q	2Q	3Q	4Q	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

Tentative Project Implementation Schedule and Cost

A4.4.2 Implementation Schedule

Proposed project implementation schedule is estimated as in the above chart. Tentative program period is 4 years from 2008 to 2012 as in the chart. The period of the Education Support Project is 3 years and that of the Technical Cooperation Project is 3.5 years.

Tables

Table A.1.2.1 List of Meteorological Station

River Basin	Name	Province	Observation Element	Latitude (N)	Longitude (E)
Battambang	Battambang	Battambang	T, RH, SH, Vw, E	13° 05' 60"	103° 12' 00"
Pursat	Pursat	Pursat	T, RH, E	12° 33' 00"	103° 54' 00"
Prek Thnot	Pochentong	Phnom Penh	T, RH, SH, Vw, E	11° 33'	104° 50'

Source: MOWRAM

T: Temperature RH: Relative Humidity SH: Sunshine Hour
Vw: Wind Velocity E: Evaporation

Table A.1.2.2 List of Rainfall Station

ID	Name	Province	Coordinate X	Coordinate Y	Latitude (N)	Longitude (E)
Battambang (Sangker) River Basin						
130301	Banan	Battambang	300,136	1,433,272	12° 57' 41"	103° 09' 13"
130305	Battambang	Battambang	305,278	1,448,570	13° 05' 60"	103° 12' 00"
120205	Chamlong Kuoy	Battambang	278,878	1,405,980	12° 42' 48"	102° 57' 35"
120311	Cheang Meanchey	Battambang	294,728	1,423,962	12° 52' 37"	103° 06' 16"
120305	Raing Kesey	Battambang	310,599	1,433,785	12° 58' 00"	103° 15' 00"
120213	Rattanak Mondol	Battambang*	241,720	1,417,740	12° 49' 00"	102° 37' 00"
130215	Samlot	Battambang	268,329	1,396,781	12° 37' 46"	102° 51' 48"
130406	Tbeng (Sdau)	Battambang	280,939	1,426,413	12° 53' 53"	102° 58' 38"
120206	Treng	Battambang	274,711	1,420,067	12° 50' 25"	102° 55' 13"
Moung Russey (Dauntri) River Basin						
120426	Beoung Khnar	Pursat	364,732	1,396,810	12° 38' 07"	103° 45' 02"
120303	Maung Russey	Battambang	332,167	1,411,952	12° 46' 14"	103° 27' 00"
581102	Svay Donkeo	Pursat	353,555	1,401,224	12° 40' 29"	103° 38' 51"
120309	Talo	Pursat	354,705	1,383,952	12° 31' 07"	103° 39' 32"
Pursat River Basin						
120320	Beoung Kantuot	Pursat	401,213	1,383,543	12° 31' 00"	104° 05' 13"
120304	Dap Bat	Pursat	368,527	1,364,407	12° 20' 33"	103° 47' 13"
120312	Kravanh	Pursat	353,555	1,401,224	12° 40' 29"	103° 38' 51"
120306	Leach	Pursat	366,334	1,365,247	12° 21' 00"	103° 46' 00"
120313	Peam	Pursat	361,461	1,358,235	12° 17' 11"	103° 43' 20"
120302	Pursat	Pursat	380,920	1,387,303	12° 33' 00"	103° 54' 00"
Boribo River Basin						
120406	Bamnak	Pursat	409,815	1,361,396	12° 19' 00"	104° 10' 00"
120410	Baribo	Kampong Chhnang	442,465	1,376,054	12° 27' 00"	104° 28' 00"
110429	Boeung Leach	Kampong Chhnang	466,456	1,314,490	11° 53' 37"	104° 41' 17"
120411	Boeung Por	Kampong Chhnang	467,769	1,330,986	12° 02' 34"	104° 42' 00"
120401	Kompong Chhnang	Kampong Chhnang	464,172	1,352,918	12° 14' 28"	104° 40' 00"
110405	Kompong Tralach	Kampong Chhnang	475,016	1,315,189	11° 54' 00"	104° 46' 00"
120403	Krakor	Pursat	415,376	1,385,212	12° 31' 56"	104° 13' 02"
120419	Krang Tamoung	Kampong Chhnang	454,058	1,340,216	12° 07' 34"	104° 34' 26"
120418	Pong Ro	Kampong Chhnang	456,107	1,356,612	12° 16' 28"	104° 35' 33"
120417	Ponley	Kampong Chhnang	442,942	1,375,290	12° 26' 35"	104° 28' 16"
120416	Rolear Phear	Kampong Chhnang	465,006	1,350,308	12° 13' 03"	104° 40' 28"
110430	Samaki Meanchey	Kampong Chhnang	458,166	1,313,217	11° 52' 55"	104° 36' 43"
120407	Sdoc Ach Romeas	Kampong Chhnang	449,630	1,333,654	12° 04' 00"	104° 31' 60"
120420	Tuk Phos	Kampong Chhnang	449,083	1,332,328	12° 03' 17"	104° 31' 42"
110414	Tuol Khpos	Kampong Chhnang	433,276	1,320,782	11° 57' 00"	104° 22' 60"
120301	Tuol Krous	Kampong Chhnang	448,903	1,366,178	12° 21' 39"	104° 31' 34"
Other Adjacent Stations						
110425	Pochengton	Phnom Penh			11° 33'	104° 50'
110404	Kompong Speue	Kompong Speue			11° 27' **	104° 32' **
130318	Boeung Raing	Battambang	300,841	1,443,833	13° 03' 25"	103° 09' 34"
130208	Bovel	Battambang	270,380	1,465,684	13° 15' 08"	102° 52' 37"
120414	Doun Pean	Kampong Chhnang	480,224	1,335,951	12° 05' 16"	104° 48' 52"
130211	Komping Pouy	Battambang	282,573	1,446,561	13° 04' 49"	102° 59' 27"
120415	Kompong Leang	Kampong Chhnang	471,418	1,355,741	12° 16' 00"	104° 43' 60"
130210	Komrieng	Battambang	225,180	1,447,531	13° 05' 04"	102° 27' 42"
130304	O Taky	Battambang	296,344	1,454,632	13° 09' 15"	103° 07' 02"
120202	Pailin	Pailin	241,915	1,422,376	12° 51' 31"	102° 37' 05"
130212	Roung Chrey	Battambang	280,550	1,467,381	13° 16' 06"	102° 58' 14"
130319	Thmar Kol	Battambang	287,021	1,467,395	13° 16' 08"	103° 01' 49"
130313	Tuol Samraung	Battambang	287,123	1,480,274	13° 23' 07"	103° 01' 49"

Source: MOWRAM and TSLSP * changed by the Study Team ** estimated

Table A.1.2.3 List of Hydrological Station

ID	Name	River	Catchmen (km2)	Coordinate X	Coordinate Y	Latitude (E) ° ′ ″	Longitude (E) ° ′ ″	Remarks
Battambang (Sangker) River Basin								
201107	Bac Prea	Tributary Great Lake		327,465	1,472,023	13° 18′ 47″	103° 24′ 11″	
550101	Treng	Battambang (Sangker)	2,135	298,075	1,423,398	12° 52′ 19″	103° 08′ 06″	
550102	Battambang	Battambang (Sangker)	3,194	305,290	1,448,764	13° 06′ 07″	103° 12′ 00″	
550103	Sre Ponleu	Battambang (Sangker)	566	258,582	1,408,534	12° 44′ 06″	102° 46′ 23″	
Moung Russey (Dauntri) River Basin								
551101	Mong Russey	Moung Russey (Dauntry)	785	332,454	1,411,688	12° 46′ 05″	103° 27′ 11″	
581101	Campang	Moung Russey (Dauntry)*		377,762	1,400,147	12° 39′ 58″	103° 52′ 12″	Location not clear
581102	Svay Don Keo	Svay Don Keo**	805	352,788	1,401,028	12° 40′ 23″	103° 38′ 24″	corrected
581210	Kroch Seuch (up)	Moung Russey (Dauntry)*		381,043	1,405,619	12° 42′ 58″	103° 54′ 00″	Location not clear
581220	Kroch Seuch (down)	Moung Russey (Dauntry)*		384,512	1,407,407	12° 43′ 55″	103° 55′ 55″	Location not clear
Pursat River Basin								
580101	Pursat	Pursat	4,495	382,449	1,384,336	12° 31′ 23″	103° 54′ 50″	
580102	Taing Leach	Pursat	2,011	348,668	1,358,715	12° 17′ 24″	103° 36′ 18″	
580103	Bac Trakoun	Pursat	4,245	365,176	1,368,532	12° 22′ 48″	103° 45′ 22″	
580104	Khum Viel	Pursat	4,596	384,709	1,388,489	12° 33′ 40″	103° 56′ 06″	
580105	Lo Lok Sar	Pursat		381,808	1,382,666	12° 30′ 29″	103° 54′ 29″	
580106	Phum Kos	Pursat	387	365,503	1,350,513	12° 13′ 01″	103° 45′ 36″	
580110	Kbal Hong (up)	Pursat		383,195	1,387,043	12° 32′ 53″	103° 55′ 16″	
580120	Kbal Hong (down)	Pursat		383,367	1,387,307	12° 33′ 00″	103° 55′ 23″	
580201	Peam	Tributary of Pursat	243	358,720	1,343,659	12° 09′ 14″	103° 41′ 53″	
580301	Prey Klong (down)	Tributary of Pursat	421	376,266	1,334,706	12° 04′ 26″	103° 51′ 32″	
580302	Prey Klong (up)	Pursat		390,281	1,324,947	11° 59′ 13″	103° 59′ 17″	
580310	Sanlong (up)	Pursat		371,572	1,410,350	12° 45′ 29″	103° 48′ 47″	
580320	Sanlong (down)	Pursat		371,915	1,406,206	12° 43′ 16″	103° 48′ 58″	
580330	Svay At	Pursat		372,569	1,401,123	12° 40′ 30″	103° 49′ 23″	
581310	Wat Liep (down)	Pursat*		364,558	1,403,730	12° 41′ 53″	103° 44′ 56″	Location not clear
581410	Wat Liep (up)	Pursat*		363,311	1,402,609	12° 41′ 17″	103° 44′ 13″	Location not clear
583020	Tlea Maam (up)	Tributary of Pursat***	322	391,083	1,384,565	12° 31′ 34″	103° 59′ 38″	***
Boribo River Basin								
583010	Tlea Maam (1)	****		414,372	1,389,452	12° 34′ 16″	104° 12′ 29″	Lake side near Krakor
583101	Banteay Krang	Krakor	138	414,213	1,381,888	12° 30′ 07″	104° 12′ 25″	
590101	Boribo	Boribo	803	433,016	1,364,795	12° 20′ 53″	104° 22′ 48″	
20103	Kampong Chhnang	Tonle Sap		465,810	1,355,934	12° 16′ 05″	104° 40′ 55″	

Source: MOWRAM and TSLSP

*** In the Study, the Tlea Maam river is not a tributary of the Pursat river,bu t in the Boribo River Basin.

Table A.1.3.1 River System and Sub-basin Area

River Basin	Sub-basin		Block		(km2)	Main river
Battambang (Sangker)	a	Battambang river (S) at Battambang	a1	Battambang river Hill	2,265	Battambang (Sangker) river (S)
			a2	Battambang river Plain	929	
	b	Battambang Remaining Area	b1	Battambang Plain	883	
6,053 km2			b2	Battambang Lake Side	1,976	
Moung Russey (Dauntri)	c	Moung Russey river (S) at Moung Russey	c	Moung Russey river (S) at Moung Russey	785	Moung Russey (Dauntri) river (S)
	d	Moung Russey Remaining Area	d1	Svay Don Keo river at Svay Don Keo	805	Svay Don Keo river (S)
			d2	Moung Russey Plain	915	Kambot river
3,696 km2			d3	Moung Russey Lake Side	1,191	
Pursat	e	Pursat river (S) at Khum Viel	e1	Pursat river Hill	4,235	Pursat river (S)
			e2	Pursat river Bank	361	
5,965 km2	f	Pursat Remaining Area	f1	Pursat Plain	393	
			f2	Pursat Lake Side	976	
Boribo	g	Bomnak-Boribo (S) -Tlea Maam River Basin	g1	Bomnak river (S)	384	Bomnak river (S)
			g2	Tlea Maam river Up/Middle-stream	468	Tlea Maam river
7,154 km2			g3	Tlea Maam river Lake Side	121	
			g4	Boribo river (S) UP/Middle-stream	419	Boribo river (S)
			g5	Boribo river (S) Lake Side	30	
	h	Boribo North Area	h1	Boribo North Upper Area	559	
			h2	Boribo North Lake Side	266	
	i	Boribo Middle North Area	i1	Boribo Middle North Upper Area	759	
			i2	Boribo Middle North Lake Side	223	
	j	Boribo Middle South Area	j1	Boribo Middle South Upper Area	1,736	Svay Chek river
			j2	Boribo Middle South Lake Side	306	
	k	Boribo South Area	k1	Boribo South Upper Area	1,835	Krang Ponley river
			k2	Boribo South Lake Side	48	

Note: River name with "(S)" indicates the single river of the name, but not the River Basin of the same name.
"Lake Side" area here is an area between the National Highway No.5 and the Tonle Sap Lake (the Great Lake).

Table A.1.3.2 Average Monthly Meteorological Values

Station: Battambang
Province: Battambang

Monthly		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(°C)	25.0	27.2	29.6	30.3	29.9	29.3	28.7	28.2	27.6	27.2	26.3	24.8	27.8
Mean max.	(°C)	31.2	33.4	35.6	36.0	34.8	33.8	33.0	32.3	31.3	30.7	30.1	30.0	36.0
Mean min.	(°C)	18.9	21.0	23.5	24.6	25.0	24.8	24.5	24.0	24.1	23.7	22.4	19.6	18.9
Relative humidity	(%)	74	70	69	71	77	79	80	82	84	85	81	77	78
Wind velocity*	(m/s)	1.3	1.4	1.6	1.5	1.6	2.0	1.9	1.8	1.4	1.2	1.2	1.3	1.5
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)	4.2	4.8	5.1	5.3	4.7	4.5	4.0	3.7	3.2	3.1	3.2	3.7	4.1
	(mm)	130	136	158	159	146	135	124	115	96	96	96	115	1506

* height at 10 m

Station: Pursat
Province: Pursat

Monthly		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(°C)	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.	(°C)	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.	(°C)	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 humidity	(%)	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)	-	-	-	-	-	-	-	-	-	-	-	-	-
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

Station: Pochentong
Province: Phnom Penh

Monthly		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(°C)	26.3	27.6	29.3	30.1	29.9	28.9	28.2	28.2	27.9	27.2	26.5	25.9	28.0
Mean max.	(°C)	31.3	32.9	34.6	35.3	34.7	33.5	32.4	32.2	31.9	31.0	30.7	30.4	35.3
Mean min.	(°C)	21.5	22.5	24.2	25.5	25.6	25.0	24.8	24.7	24.2	23.8	22.7	21.6	21.5
Relative humidity	(%)	73	70	70	72	77	79	81	82	85	84	80	75	77
Wind velocity	(m/s)	3.2	3.9	4.1	3.8	4.1	4.6	3.9	5.0	4.3	2.7	3.6	3.7	3.9
Sunshine hours	(hr/day)	8.5	8.5	8.2	8.0	7.2	6.0	5.7	5.6	5.5	5.8	7.4	8.1	7.0
Evaporation	(mm/day)	4.5	5.6	6.3	6.0	4.8	4.6	4.1	4.0	3.5	3.0	3.6	4.2	4.5
	(mm)	140	158	195	180	150	138	127	124	105	93	108	130	1648

* height at 12 m
Source: MOWRAM

Tmean: Mean Temperature (°C)
Tmax: Max. Temperature (°C)
Tmin: Min. Temperature (°C)
RH: Relative Humidity (%)
V: Wind Velocity (m/s)
SH: Sunshine Hour (hr/day)

Table A.2.1.1 List of Additional Stations

No.	Station Name	River Basin	Province	District	COOR-X	COOR-Y	Remarks
Rainfall Station (Automatic Gauge)							
1	Rattanak Mondol	Battambang	Battambang	Rattanak Mondo	280,470	1,425,751	w/Manual
2	Samlot	Battambang	Battambang	Samlot	267,896	1,395,135	
3	Phnom Proek	Mongkol Borey	Battambang	Phnom Proek	218,362	1,463,038	w/Manual
4	Basak Reservoir	Moung Russey	Battambang	Moung Russey	320,342	1,389,968	
5	Moung Russey	Moung Russey	Battambang	Moung Russey	331,702	1,412,740	
6	Roveang	Pursat	Pursat	Phnom Krovanh	342,385	1,361,942	
7	Svay Don Keo	Moung Russey	Pursat	Svay Don Keo	352,960	1,400,807	
8	Koh Chhom	Boribo	Pursat	Sampov Meas	397,235	1,381,720	
9	Bomnak	Boribo	Pursat	Kra Kor	410,336	1,359,608	
10	Boribo	Boribo	Kompong Chhnang	Boribo	444,613	1,368,895	
11	Takab	Boribo	Kompong Chhnang	Tuek Phos	440,743	1,328,650	
12	Peam	Boribo	Kompong Chhnang	Kampong Tralac	450,721	1,298,030	
Water Level Station (Staff Gauge)							
1	Battambang	Battambang	Battambang	Battambang	305,274	1,447,682	
2	Dong Tung	Battambang	Battambang	Samlot	268,684	1,411,161	w/Auto-Pressure type
3	Moung Russey	Moung Russey	Battambang	Moung Russey	330,388	1,410,310	
4	Prek Chik (River)	Moung Russey	Battambang	Moung Russey	325,645	1,396,938	w/Auto-Pressure type
5	Prek Chik (Canal)	Moung Russey	Battambang	Moung Russey	325,949	1,397,837	
6	Svay Don Keo	Moung Russey	Pursat	Svay Don Keo	352,741	1,400,941	
7	Koh Chhom	Boribo	Pursat	Sampov Meas	397,283	1,381,727	
8	Bomnak	Boribo	Pursat	Kra Kor	410,336	1,359,340	
9	Bomnak-A (Tleam Maam riv	Boribo	Pursat	Kra Kor	410,336	1,359,618	w/Auto-Float type
10	Bomnak-B (Boribo river)	Boribo	Pursat	Kra Kor	410,533	1,359,638	w/Auto-Float type
11	Boribo	Boribo	Kompong Chhnang	Boribo	444,592	1,368,820	
12	Takab	Boribo	Kompong Chhnang	Tuek Phos	440,743	1,328,650	w/Auto-Float type
13	Peam	Boribo	Kompong Chhnang	Kampong Tralac	450,761	1,297,577	w/Auto-Pressure type

Note: Installed or re-installed in the Study

Table A.3.2.1 Meteorological Data by River Basin

Battambang River Basin

Monthly		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(℃)	25.0	27.2	29.6	30.3	29.9	29.3	28.7	28.2	27.6	27.2	26.3	24.8	27.8
Relative humidity	(%)	74	70	69	71	77	79	80	82	84	85	81	77	78
Wind velocity*	(m/s)	1.02	1.07	1.23	1.17	1.27	1.54	1.50	1.37	1.06	0.94	0.94	0.98	1.17
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)	4.2	4.8	5.1	5.3	4.7	4.5	4.0	3.7	3.2	3.1	3.2	3.7	4.1
	(mm)	130	136	158	159	146	135	124	115	96	96	96	115	1506

Note: Data of Battambang Stati * Wind velocity is adjusted to the equivalent one at 2 m height.

Moung Russey River Basin

Monthly		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
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

Note: Data = Average of Battambang and Pursat Stations' data except sunshine hours
Sunshine hours = that of Battambang Sta * Wind velocity is adjusted to the equivalent one at 2 m height.

Pursat River Basin

Monthly		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
Relative humidity	(%)	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

Note: Data of Pursat Stations except sunshine hours
Sunshine hours = that of Battambang Station

Boribo River Basin

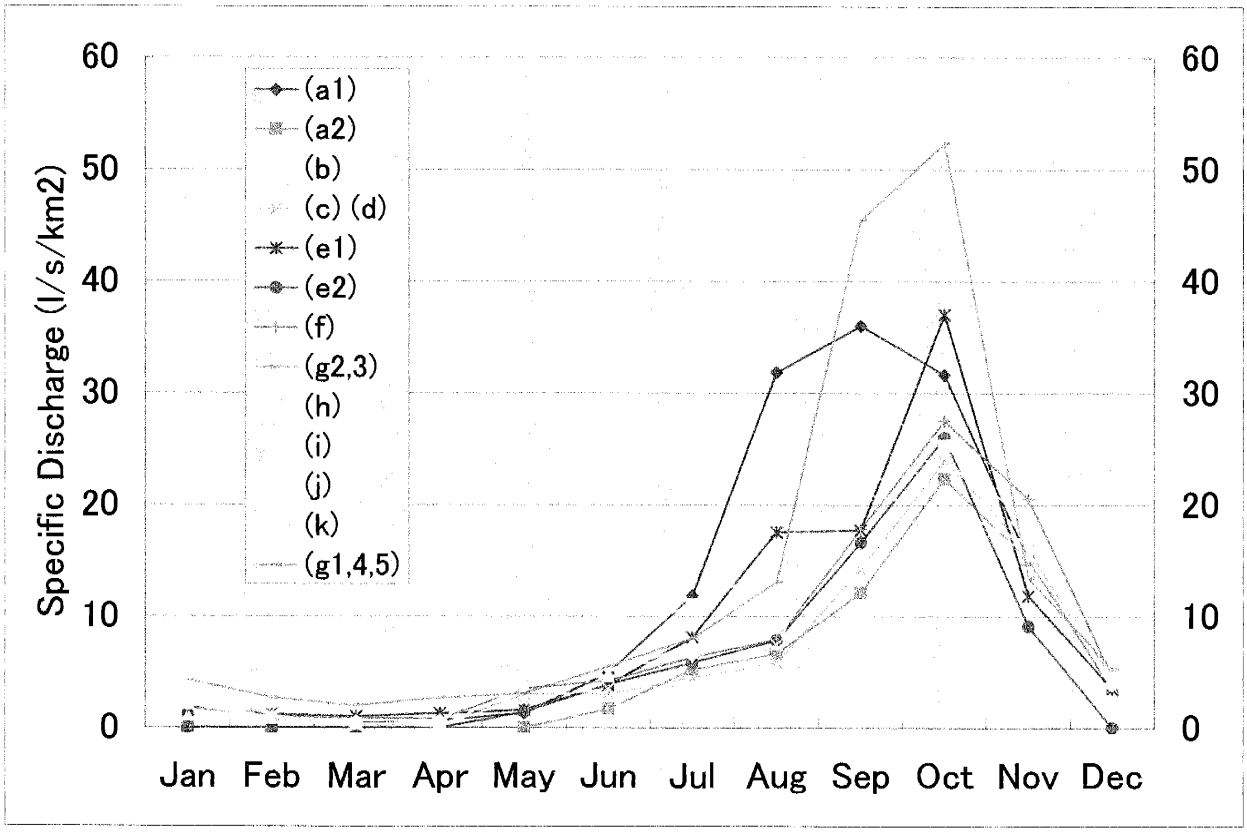
Monthly		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature														
Mean	(℃)	26.4	27.9	29.5	30.4	30.2	29.6	29.0	28.8	28.2	27.6	26.8	26.0	28.3
Relative humidity	(%)	70	67	67	69	72	73	75	76	79	80	77	73	73
Wind velocity	(m/s)	1.65	1.84	1.94	1.80	1.89	2.09	1.85	2.29	1.91	1.39	1.75	1.79	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

Note: Data = Average of Pochentong and Pursat Stations' data except sunshine hours
Sunshine hours = that of Pochentong Station * Wind velocity is adjusted to the equivalent one at 2 m height.

Table A.3.3.1 Available Water by Sub-Basin

from smaller rivers and streams 80 % Dependability (lit/s/km2)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Battambang River Basin													
(a1)	BAT-H: Battambang Hill	1.1	0.6	0.5	0.7	1.3	4.9	11.8	31.8	36.0	31.6	15.1	4.5
(a2)	Battambang River Basin in F	0.0	0.0	0.0	0.0	0.0	1.7	5.2	6.6	12.1	22.3	15.1	3.4
(b)	BAT-P: Battambang Plain	1.1	0.6	0.2	0.7	3.0	4.8	6.5	7.5	14.5	24.9	16.8	3.4
Moung Russey River Basin													
(c)	MR-H: Moung Russey Hill	2.0	0.9	0.4	0.3	3.0	3.0	4.5	5.8	14.2	23.9	16.0	4.0
(d)	MR-P: Moung Russey Plain	2.0	0.9	0.4	0.3	3.0	3.0	4.5	5.8	14.2	23.9	16.0	4.0
Pursat River Basin													
(e1)	PR-H: Pursat Hill	1.8	1.2	1.0	1.3	1.6	3.8	8.1	17.5	17.7	37.0	11.8	3.5
(e2)	Pursat River Basin in Plain	0.0	0.0	0.0	0.0	1.4	3.9	5.8	7.8	16.6	26.0	9.1	0.0
(f)	PR-P: Pursat Plain	1.8	1.0	0.9	0.8	3.5	4.2	6.3	7.9	17.8	27.5	20.5	4.6
Boribo River Basin													
(g1,4,5)	BMN-BOR: Bomnak Boribo	4.3	2.7	2.0	2.7	3.1	5.5	8.0	13.0	45.5	52.3	13.4	5.3
(g2,3)	BMN-BOR: Bomnak Boribo	2.1	0.9	0.6	0.7	5.0	5.3	6.4	9.1	21.0	19.8	16.6	3.8
(h)	BOR-N: Boribo North	2.1	0.9	0.6	0.7	5.0	5.3	6.4	9.1	21.0	19.8	16.6	3.8
(i)	BOR-MN: Boribo Middle Nor	2.1	0.8	0.3	0.4	8.3	8.1	11.0	14.4	29.1	25.3	18.2	4.5
(j)	BOR-MS: Boribo Middle Sou	2.4	0.9	0.4	0.1	3.7	4.6	7.6	11.9	26.7	20.8	15.5	4.1
(k)	BOR-S: Boribo South	3.2	1.1	0.2	0.3	2.6	3.5	3.8	7.4	21.6	24.6	15.2	4.4



Figures

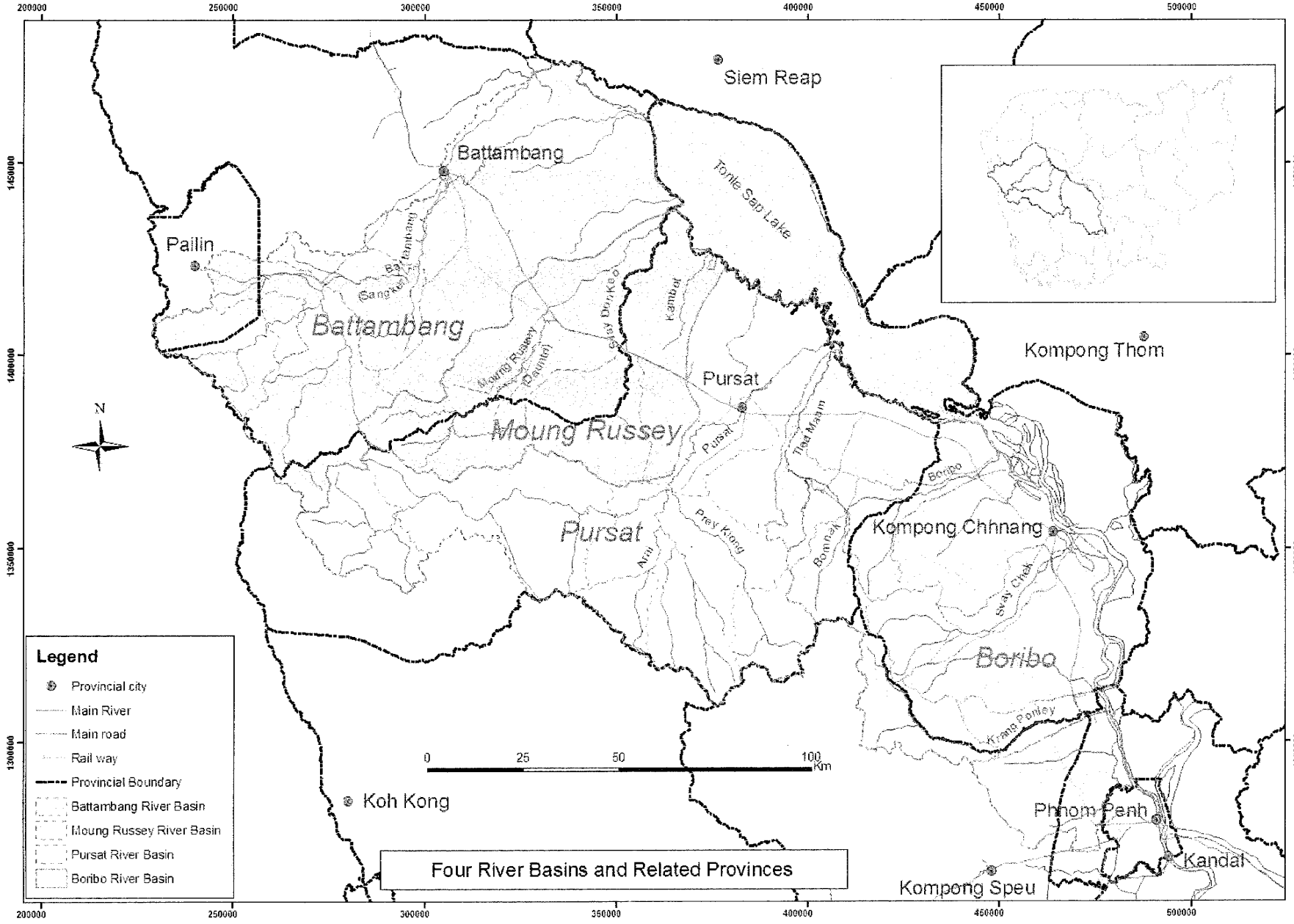


Figure A.1.1.1 Four River Basins and Related Provinces

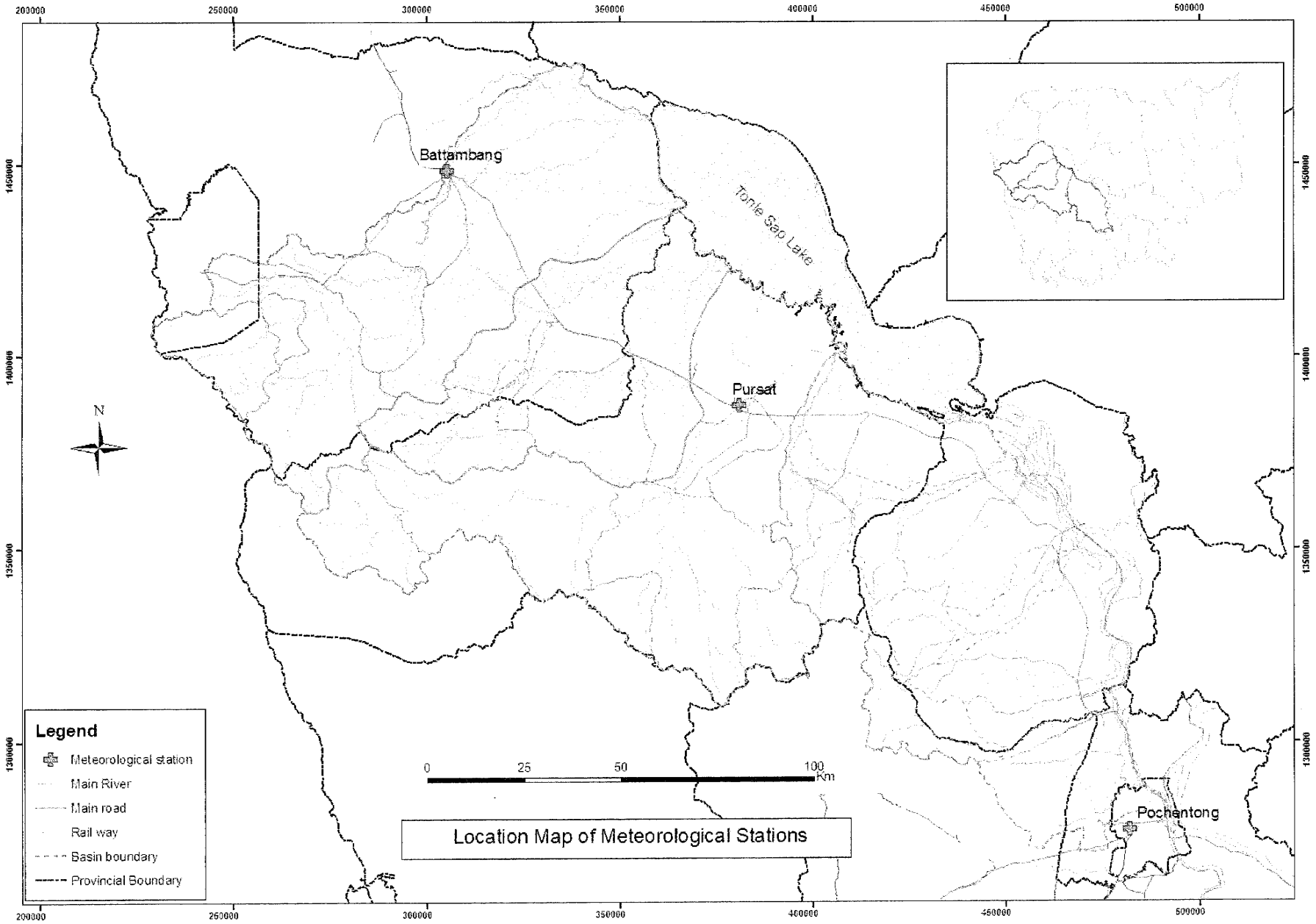


Figure A.1.2.1 Location Map of Meteorological Stations

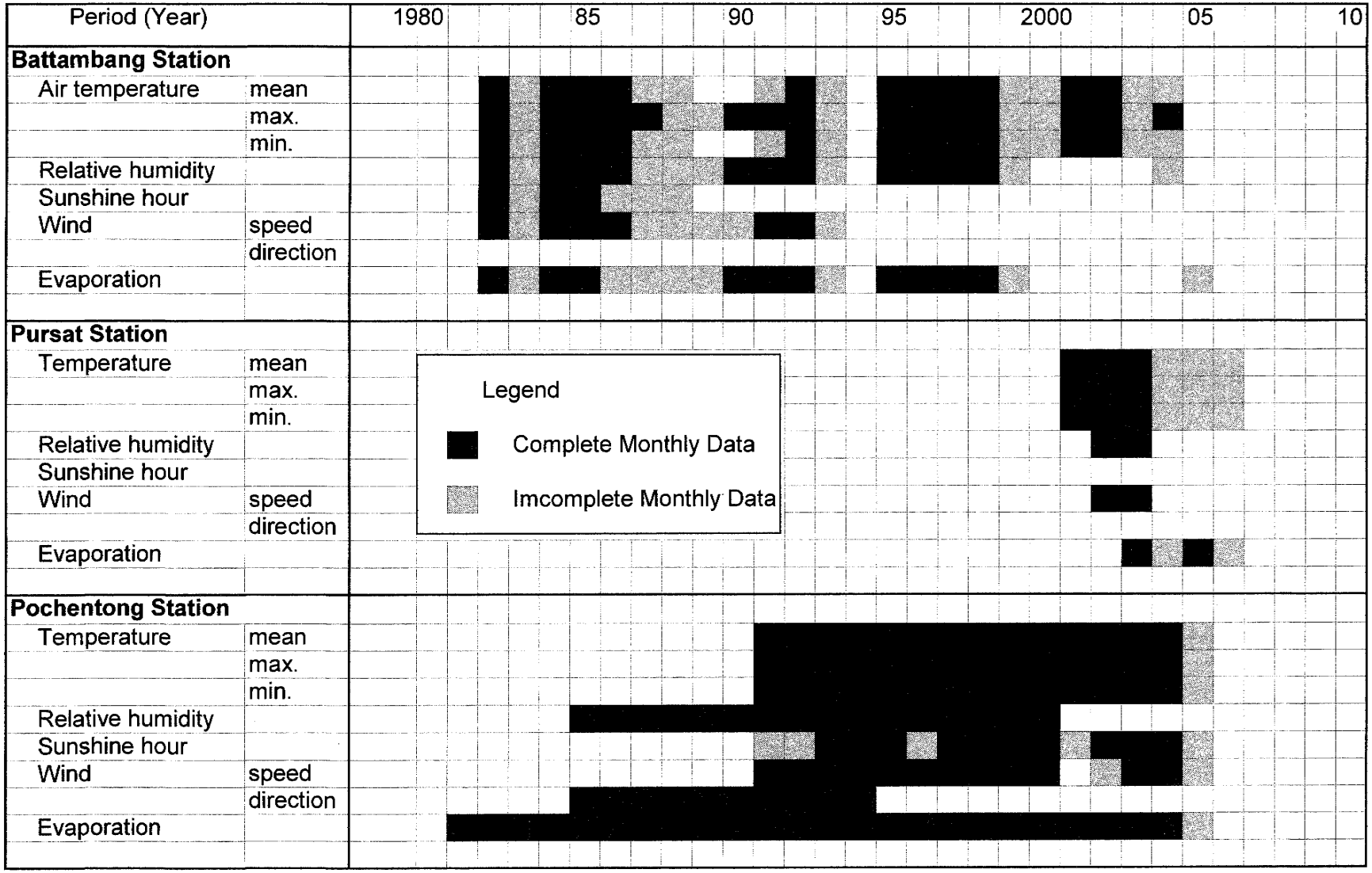


Figure A.1.2.2 Meteorological Data Availability Chart

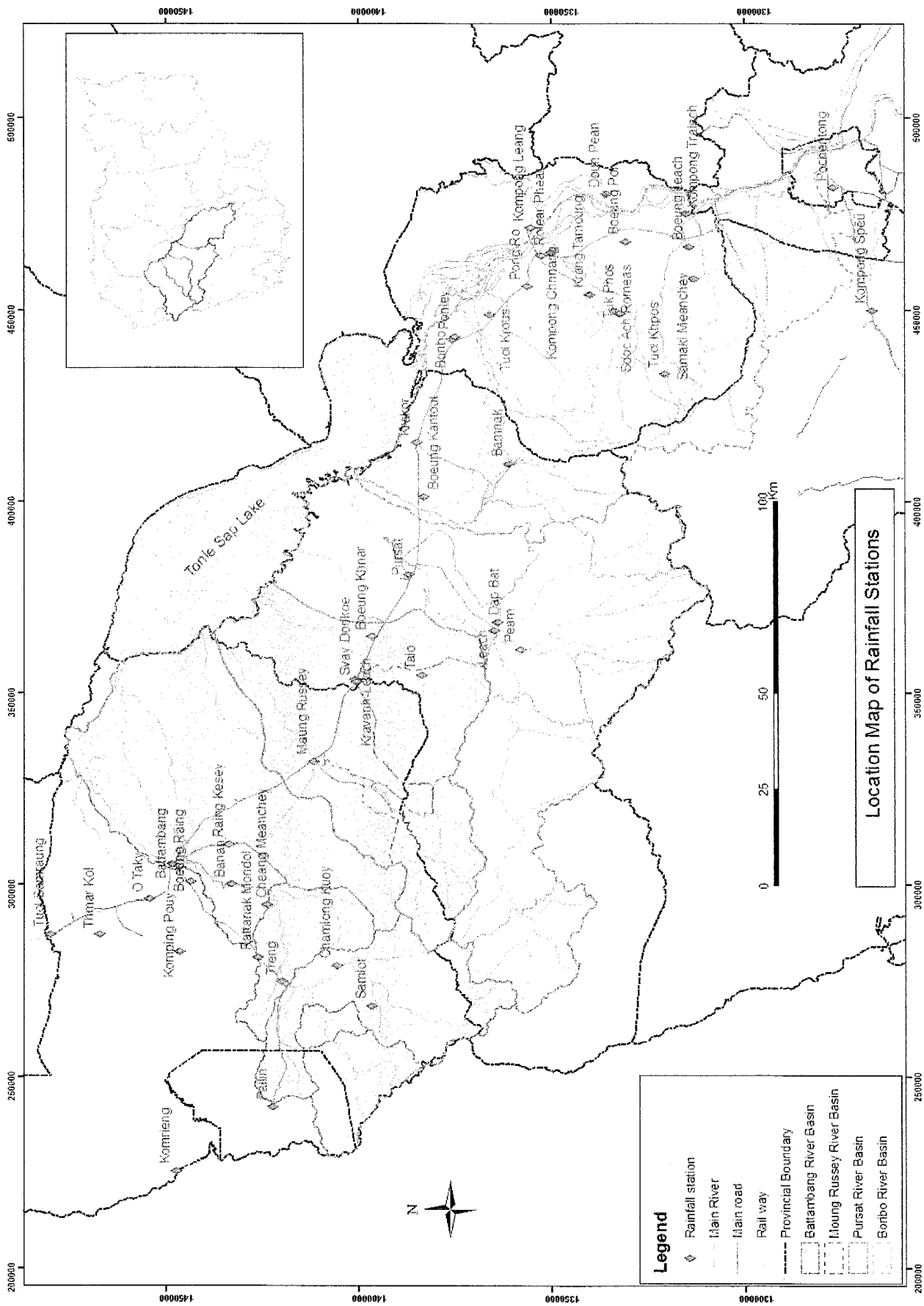


Figure A.1.2.3 Location Map of Rainfall Stations

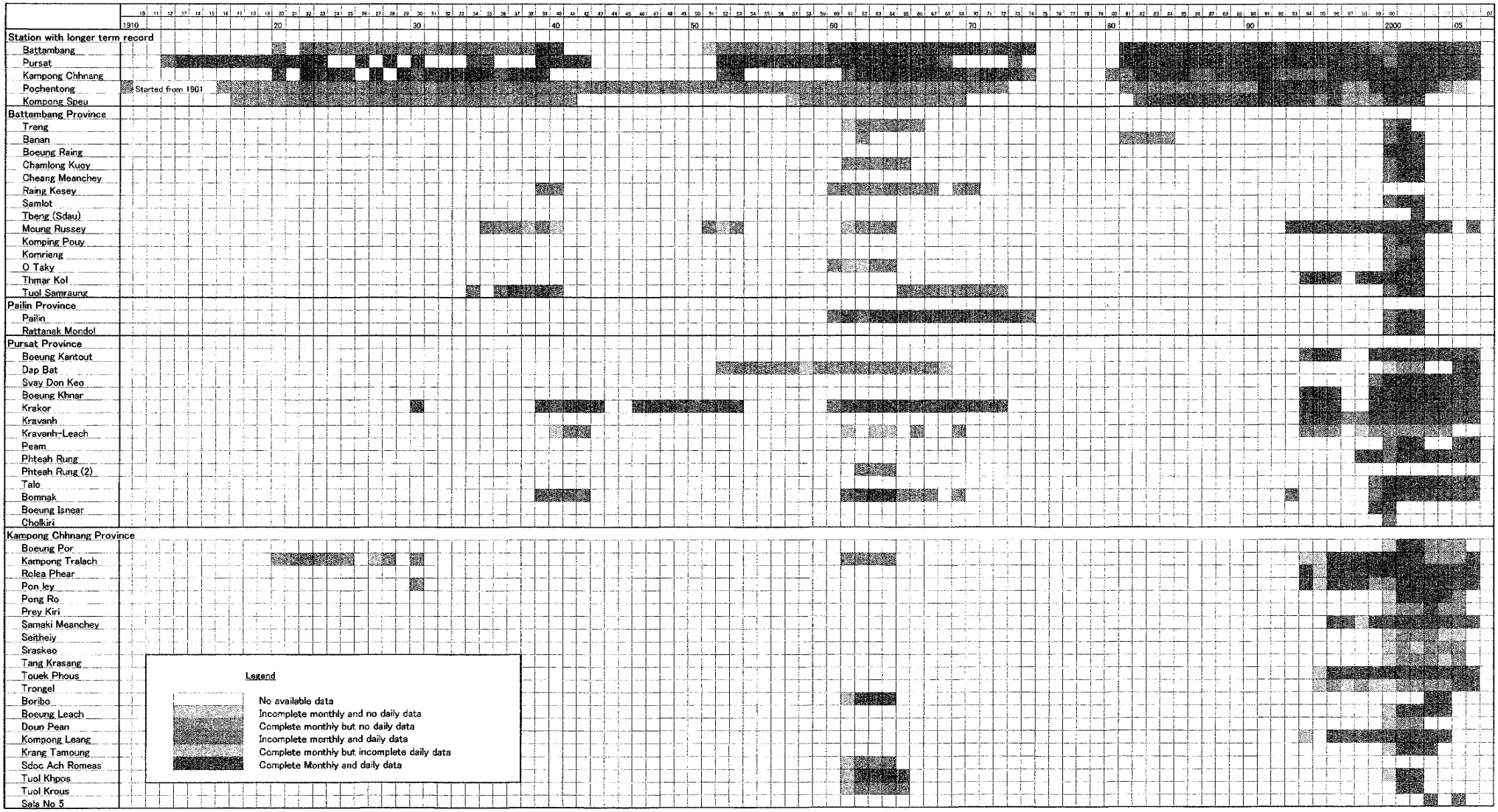


Figure A.1.2.4 Rainfall Data Availability Chart

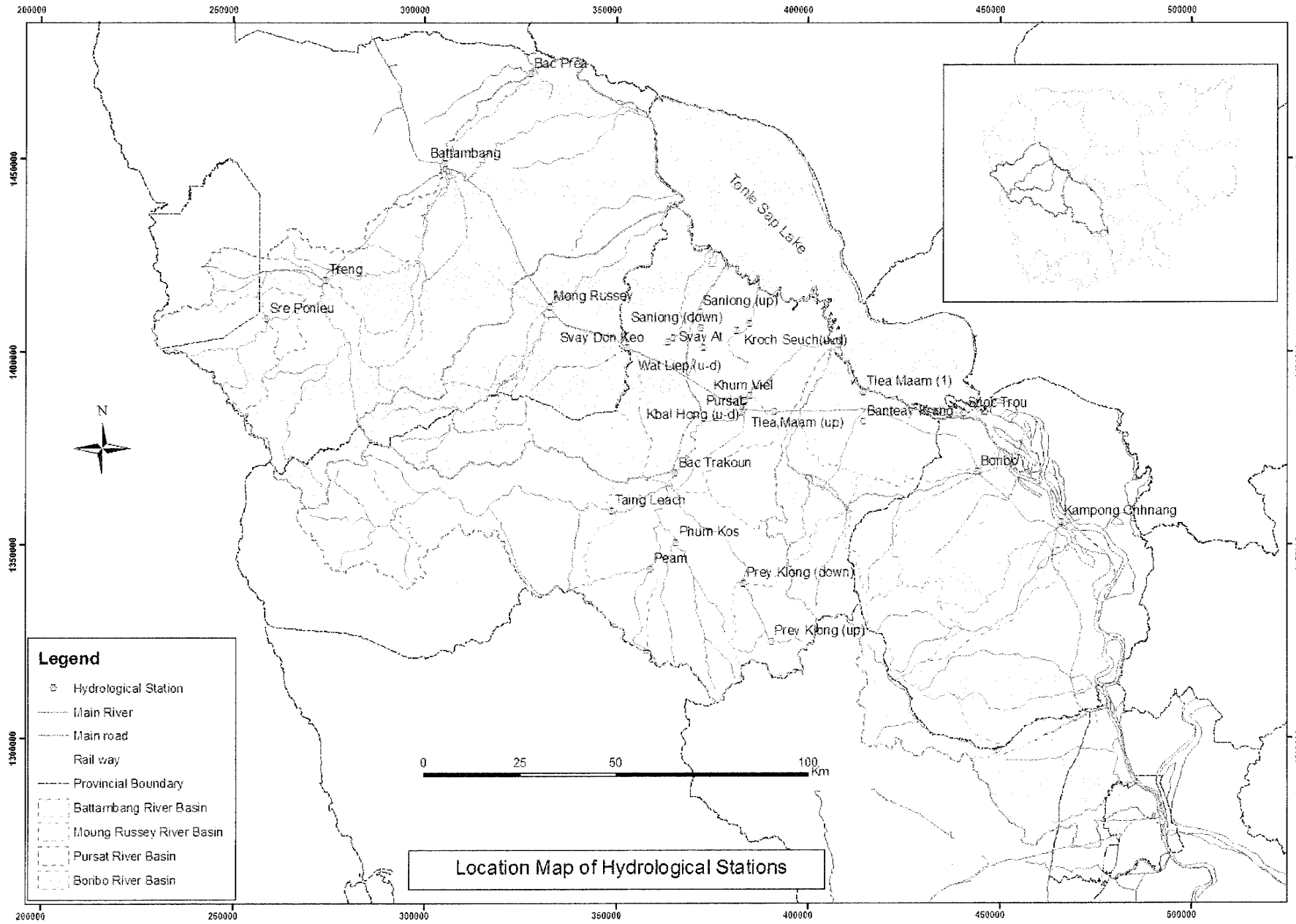


Figure A.1.2.5 Location Map of Hydrological Stations

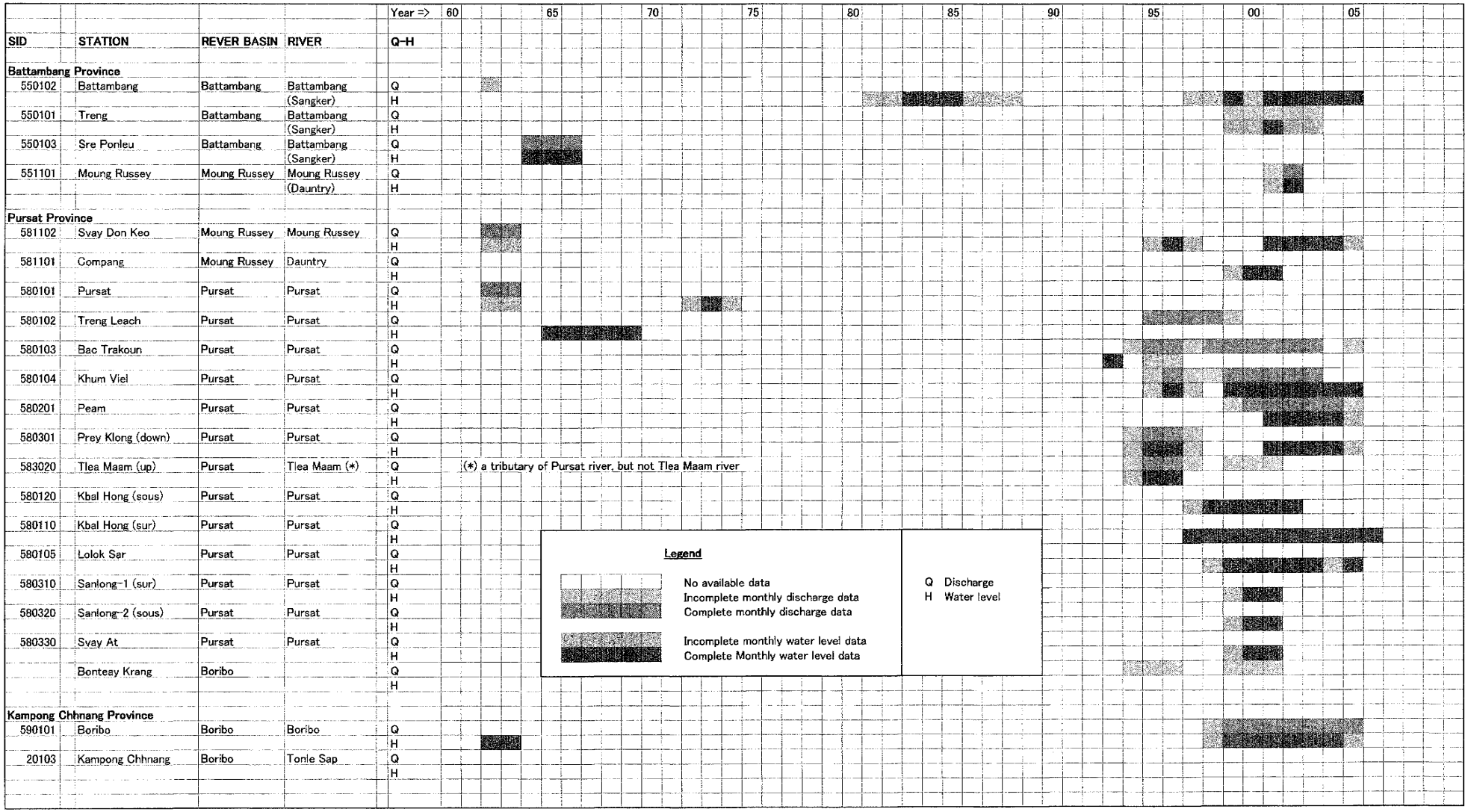


Figure A.1.2.6 Hydrological Data Availability Chart

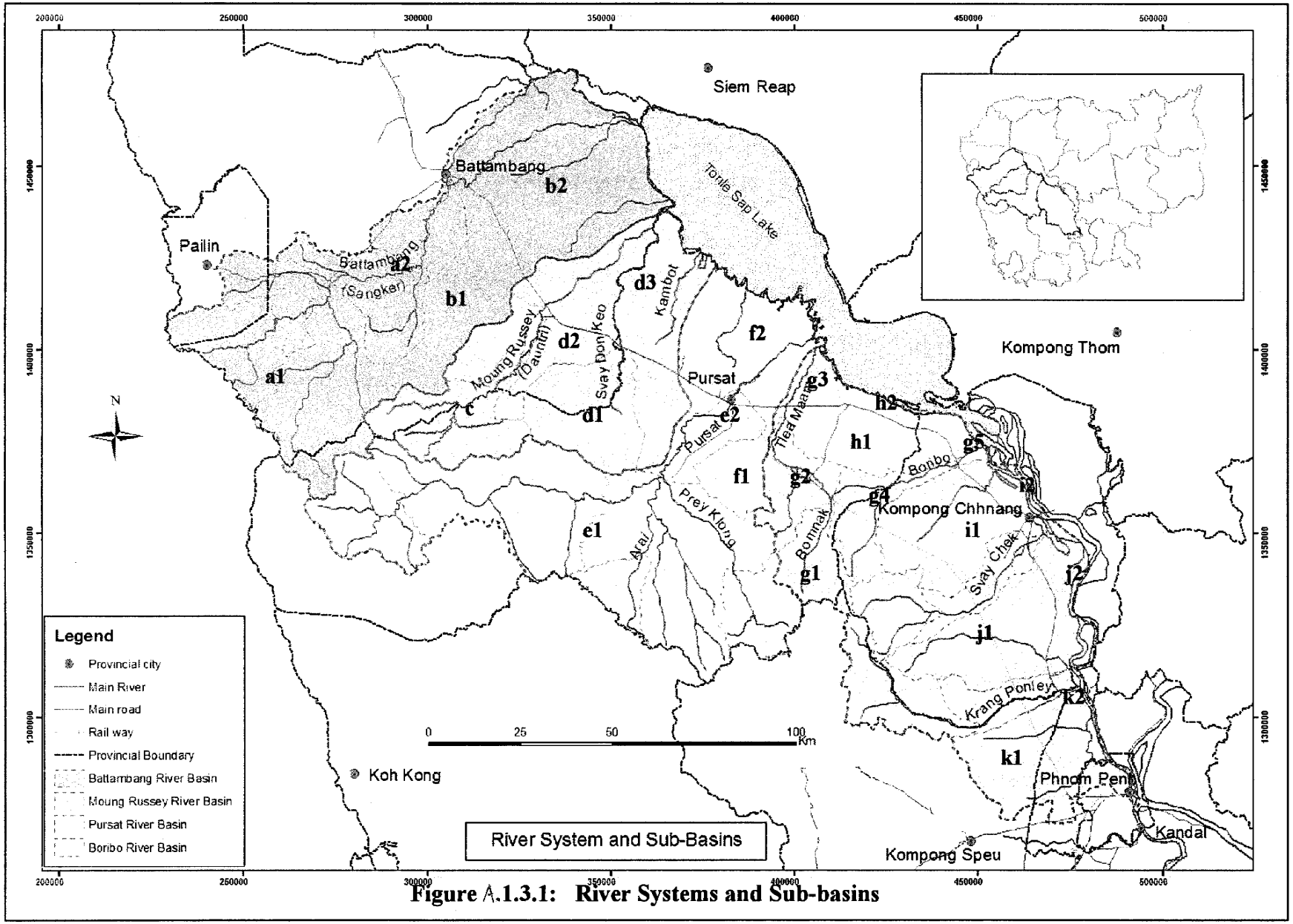


Figure A.1.3.1: River Systems and Sub-basins

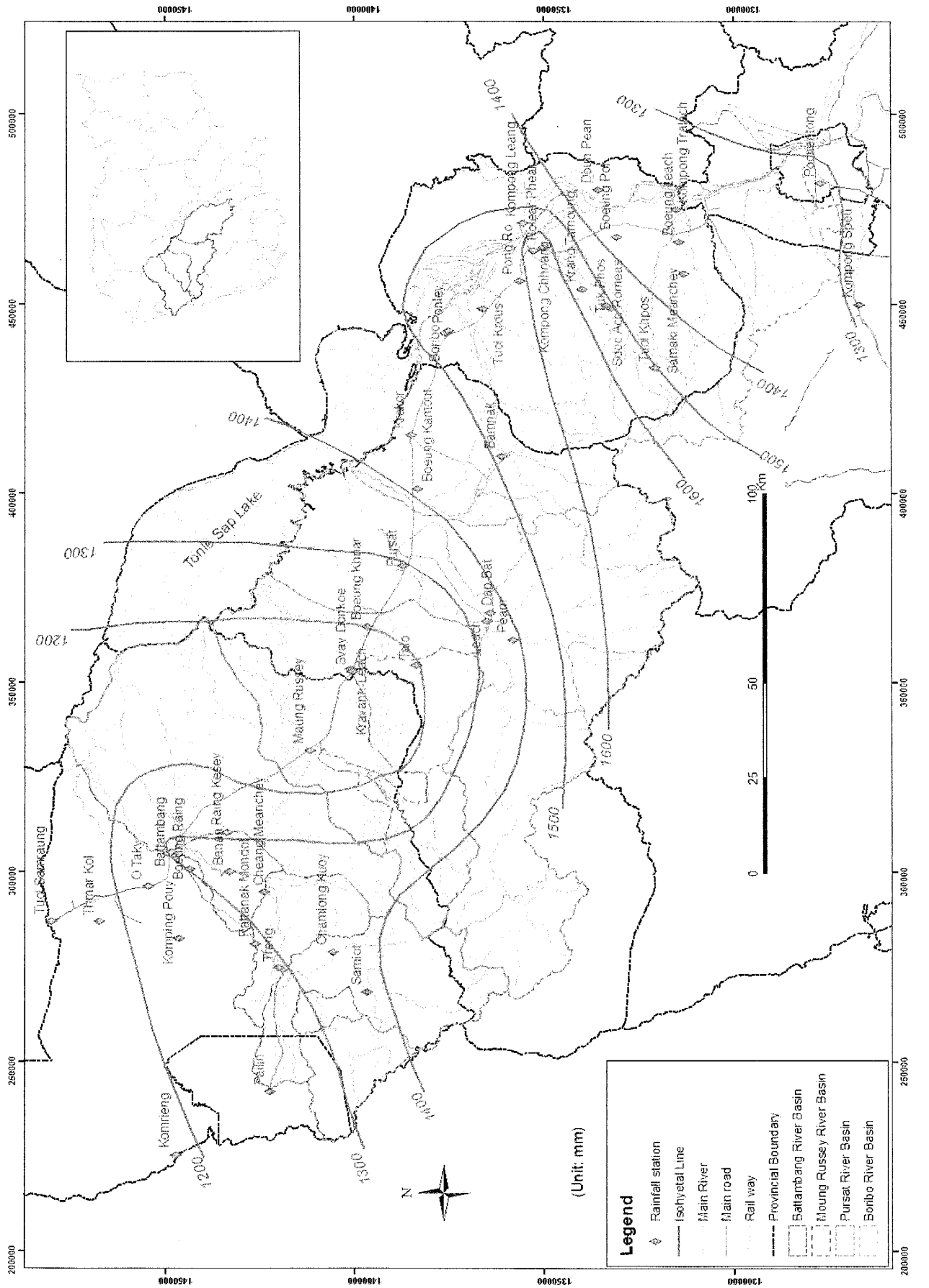
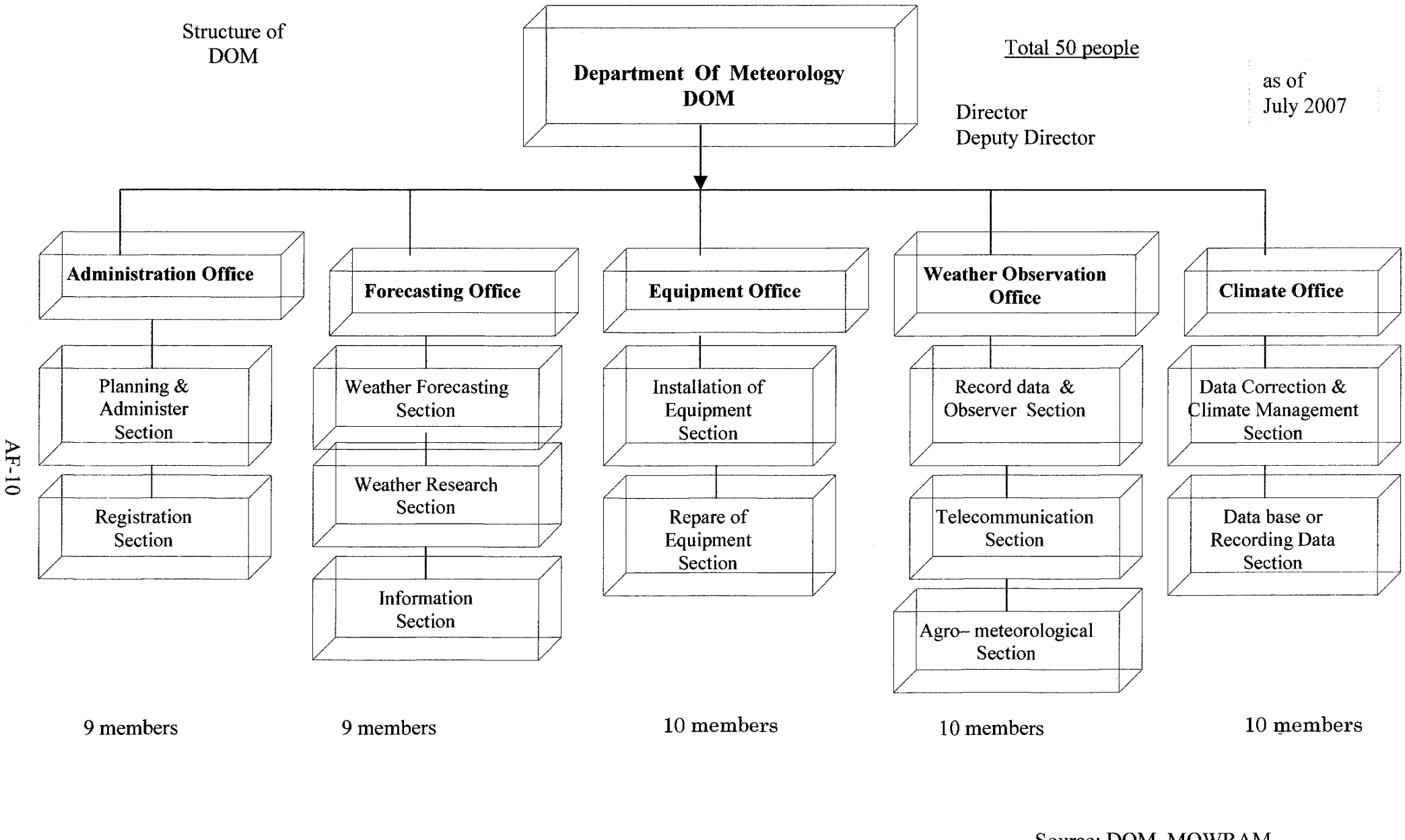


Figure A.1.3.2 Isohyetal Map of Average Annual Rainfall



Source: DOM. MOWRAM

Figure A.1.4.1 Organization Chart of DOM

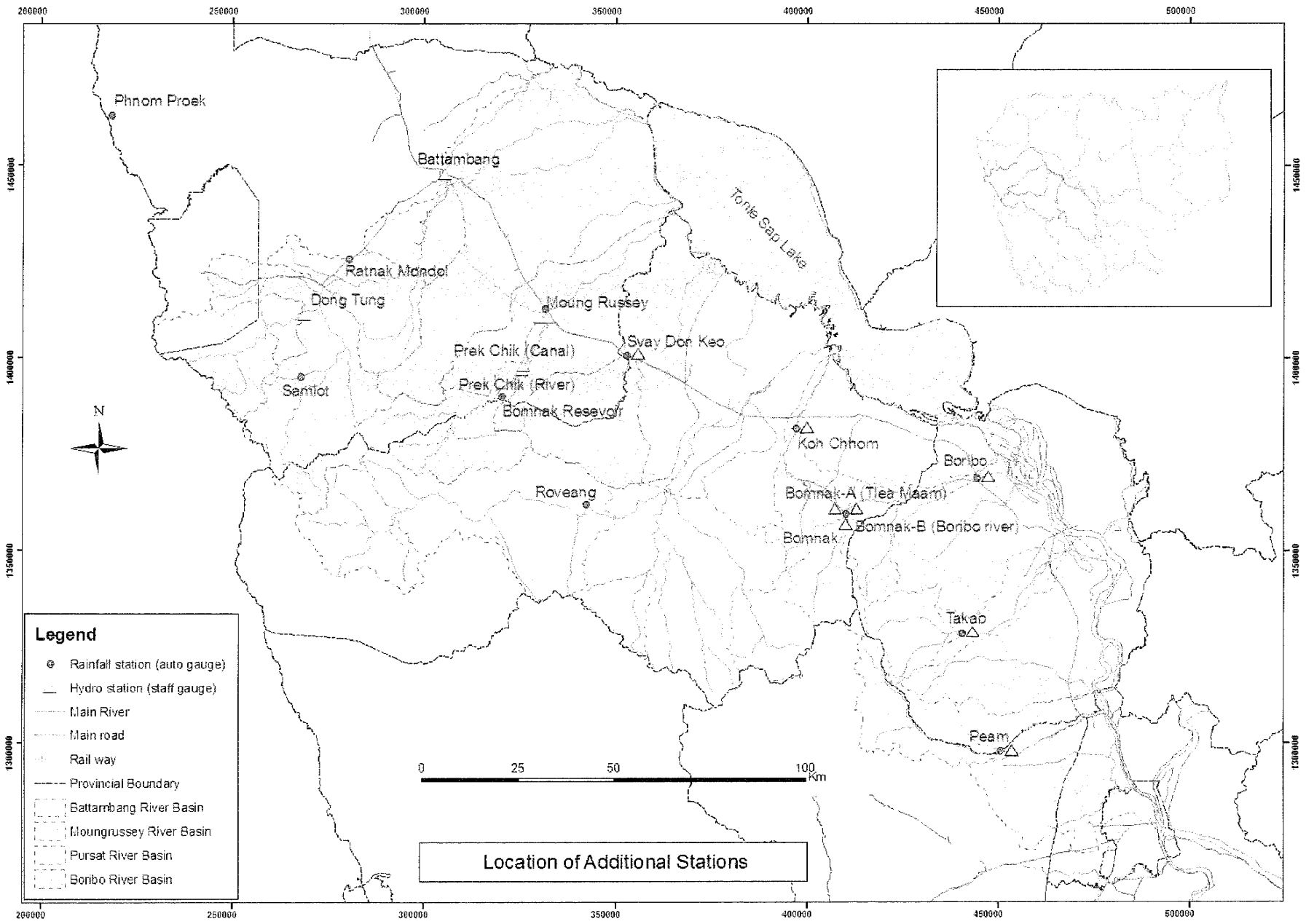


Figure A.2.1.1 Location Map of Additional Stations

Figure A.2.3.1 Rainfall Station

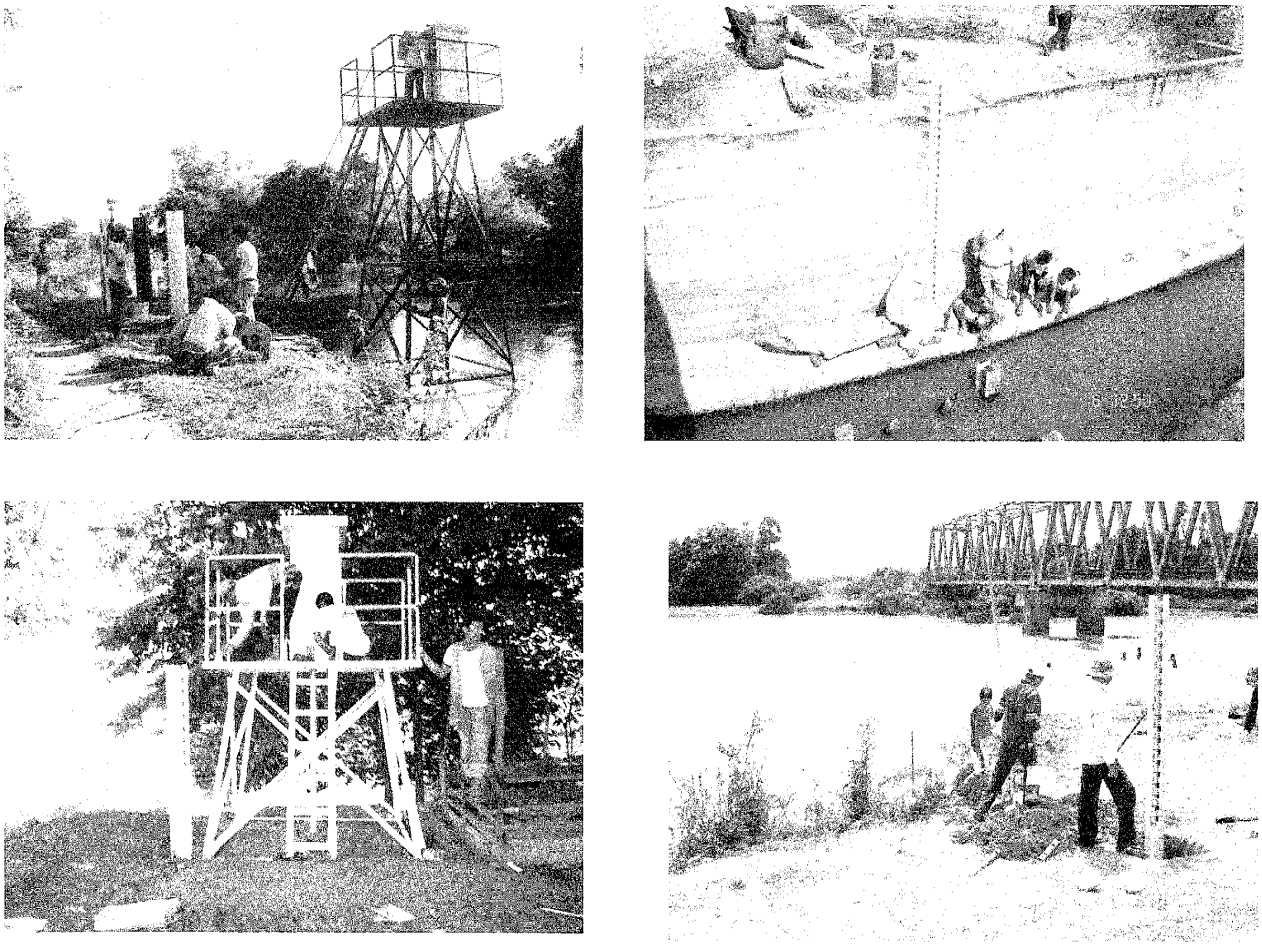


Figure A.2.4.1 Water Level Station

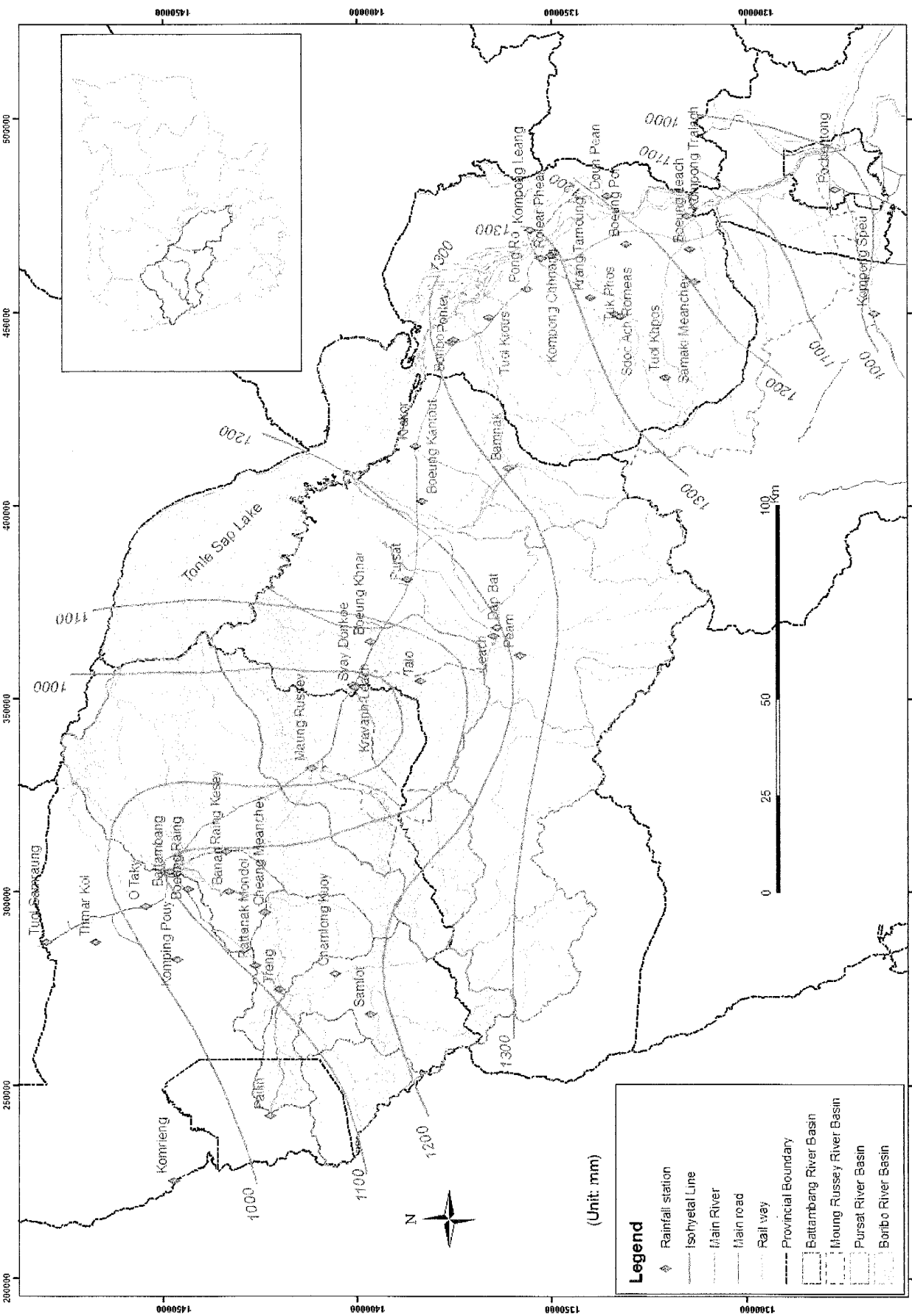


Figure A.3.2.1 Isohyetal Map of Annual Rainfall of 80% Dependability

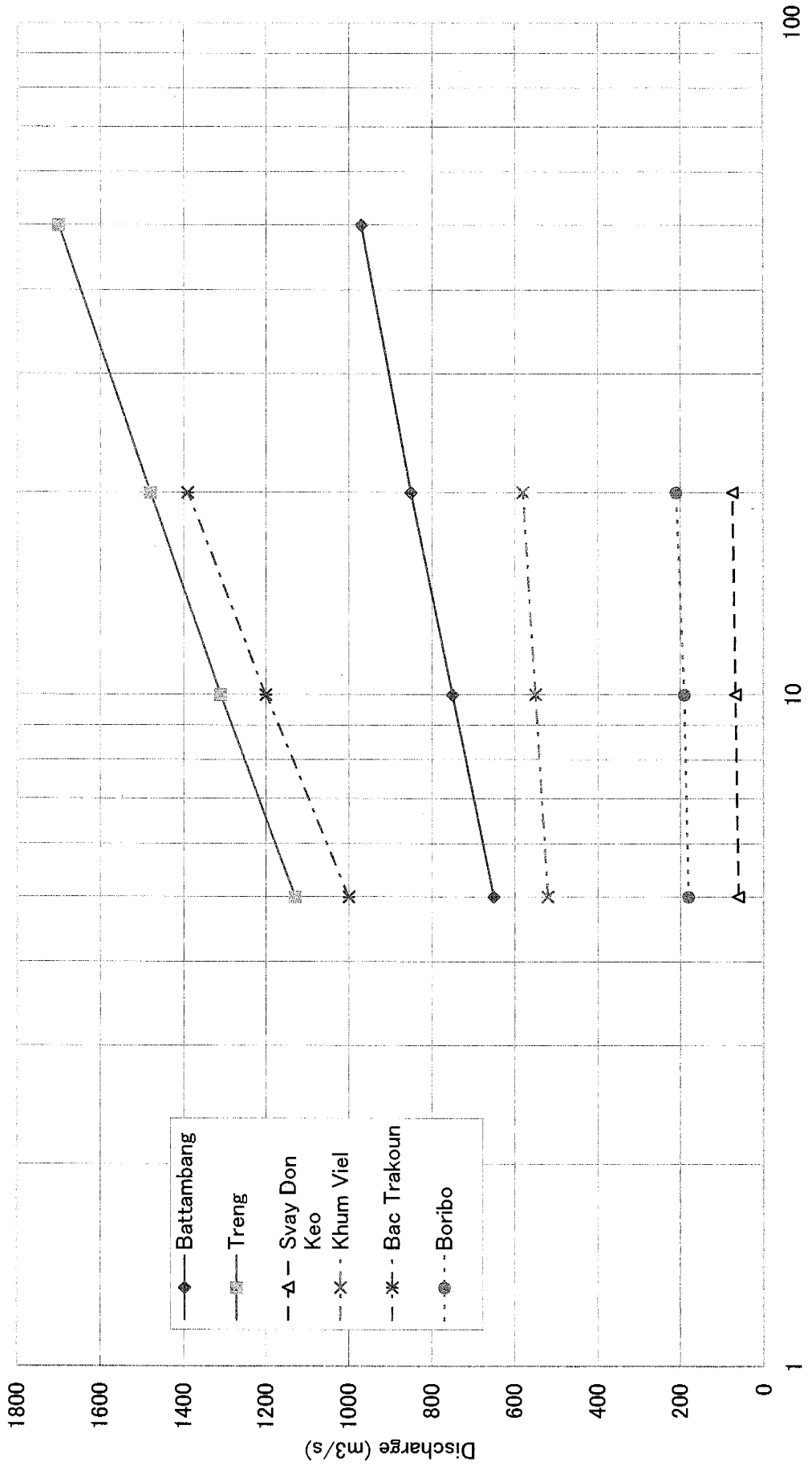


Figure A.3.4.1 Probable Flood Discharge