6. TECHNICAL STUDY OF 10 PRIORITY PROJECTS

6.1 REVIEW OF EXISTING REPORTS

Of the selected 10 priority projects, the study team reviewed the existing reports. The review results were reflected to hydrological analysis and project planning works. Table 6.1.1 shows the available existing reports.

Table 6.1.1 Existing Reports on Selected Ten Projects

No.	Project name	Abbreviation	Name of existing report
7&8	Lower Se San 2 + Lower Sre Pok 2	LL2	COMPREHENSIVE DEVELOPMENT OF HYDROPOWER IN SE SAN RIVER BASIN IN CAMBODIA VOLUME 1 SUMMARY REPORT VOLUME 2 MAIN REPORT VOLUME 3 APPENDIX OCTOBER 2006 POWER ENGINEERING CONSULTING COMPANY 1 (PECC1), ELECTRICITY OF VIET NAM (EVN)
12	Prek Liang 1	PL1	
14	Prek Liang 2	PL2	
22	Stung Kep 2	KP2	FEASIBILITY STUDY REPORT OF STUNG TATAY HYDROELECTRIC PROJECT DECEMBER 2007 CHINA NATIONAL HEAVY MACHINERY CORPORATION, NORTHWEST HYDRO CONSULTING ENGINEERS
29	Bokor Plateau	BP	BOKOR HYDROPOWER PROJECT IN CAMBODIA PRELIMINARY STUDY REPORT NOVEMBER 2007 IDICO VIET NAM URBAN AND INDUSTRIAL ZONE DEVELOPMENTINVESTMENT CORPORATION

6.2 TOPOGRAPHY

6.2.1 Preparation of topographic map by sublet works

Of the selected ten priority projects, topographic maps with 1:10,000 scales were prepared for the following six projects using the existing aerophotographs. The works were sublet to a local company from the study team.

① #12 Prek Liang I ② #13 Prek Liang IA ③ #14 Prek Liang II ④ #20 Stung Metoek II ⑤ #22 Stung Kep II ⑥ #29 Bokor Plateau

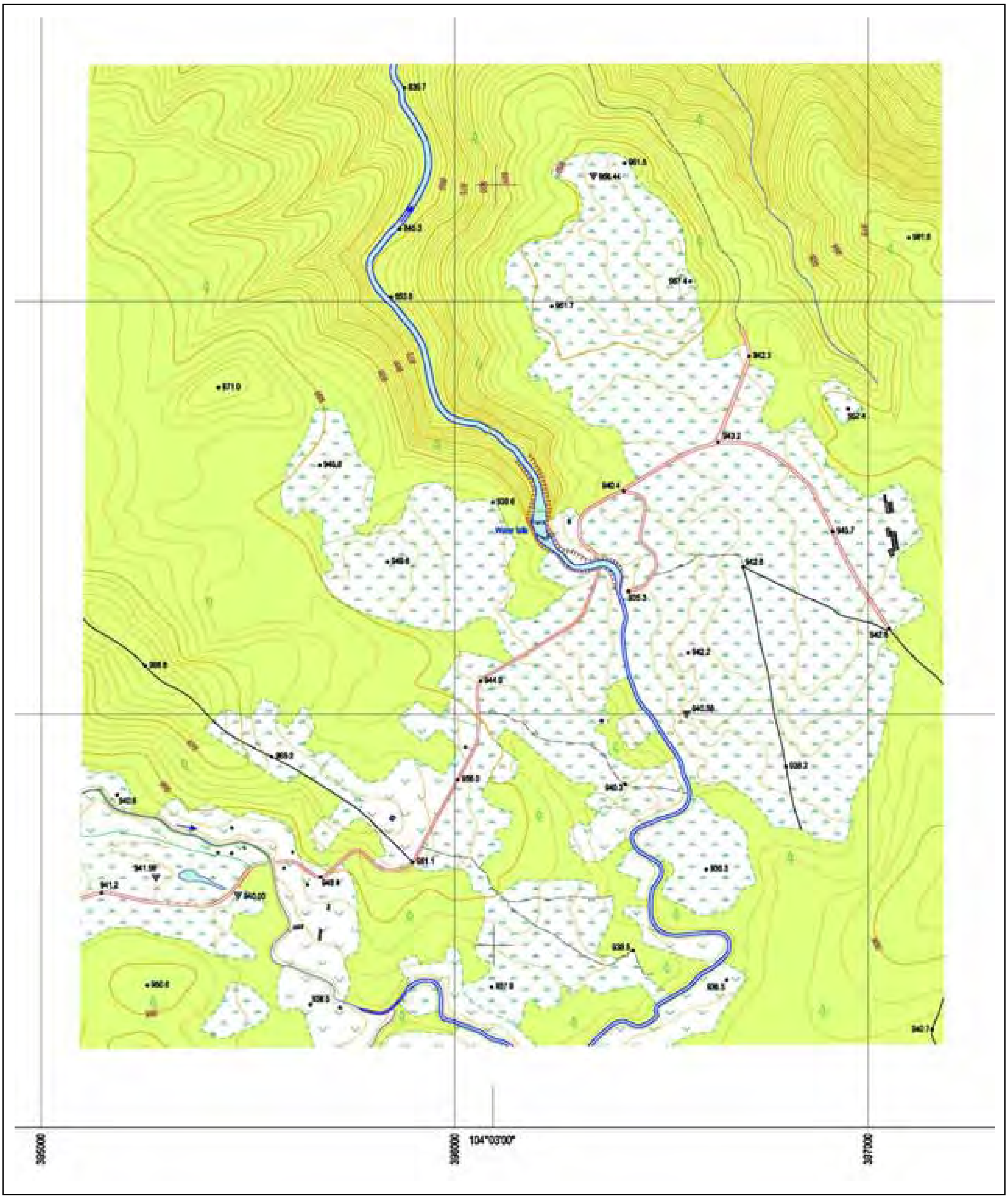
During the course of ground control point (GCP) survey, it was realized that the GCP survey was not possible for the locations of ① to ③ above, because the target area was covered with dense forest and identification of control points were hardly possible. Under such situation, the local company in charge of the work proposed a map preparation works using laser profiler. The study team examined the proposal of the company and discussed with the company in detail. As a result the study team accepted that the proposed method could obtain the same results as the original method in terms of budget, schedule and quality of the output. Thus the study team approved to apply the laser profiler to the ① to ③ locations above.

For the remaining locations of ④ to ⑥, maps were prepared by aerial mapping of aerophotographs. Table 6.2.1 shows the list of aerophotographs used for the map preparation works.

Table 6.2.1 List of Photographs used for Aerophotogrammetry

Site No.	Site Name	Area (km^2)	Used Aerial Photographs
20	Stung Metoek II	42	1/25,000, Feb. 1993 C5506813958, C5506813957 C5506913959, C5506913960, C5506913961, C5506913962 C5607014073, C5607014072 1/40,000, Jan. 2003 40A_1823, 40A_1822, 40A_1821 41A_1541, 41A_1542
22	Stung Kep II	87	1/40,000, Dec. 2001 49_0973, 49_0972, 49_0971 49_0970, 49_0969 50_0918, 50_0919, 50_0920 50_0921, 50_0922
29	Bokor Plateau	4	1/25,000, Dec. 1994 C6410915999, C6410915998 C6410915997, C6410915996
Total Area		182	27 photos

Of the prepared topographic maps, the following is a sample map of Bokor Plateau site:



Source: Study Team

Figure 6.2.1 A Sample Map prepared using Aerophotogrammetry – Bokor Plateau Site

6.3 HYDRO-METEOROLOGY

6.3.1 Hydro-Meteorological Observation System in Cambodia

Hydrological and meteorological observation in Cambodia has been managed by the Ministry of Water Resources and Meteorology (MOWRAM). In MOWRAM, the Department of Hydrology and River Works (DHRW) is in charge of hydrological observation and the Department of Meteorology (DOM) is responsible for meteorological observation. The observed data are sent from branch offices of MOWRAM to the head office and compiled in the data base (HYMOS).

In addition, the hydrological and meteorological data provided by the Mekong River Commission (MRC)[1] are sourced as the observed data of MOWRAM.

6.3.2 Hydrological and Rainfall Station

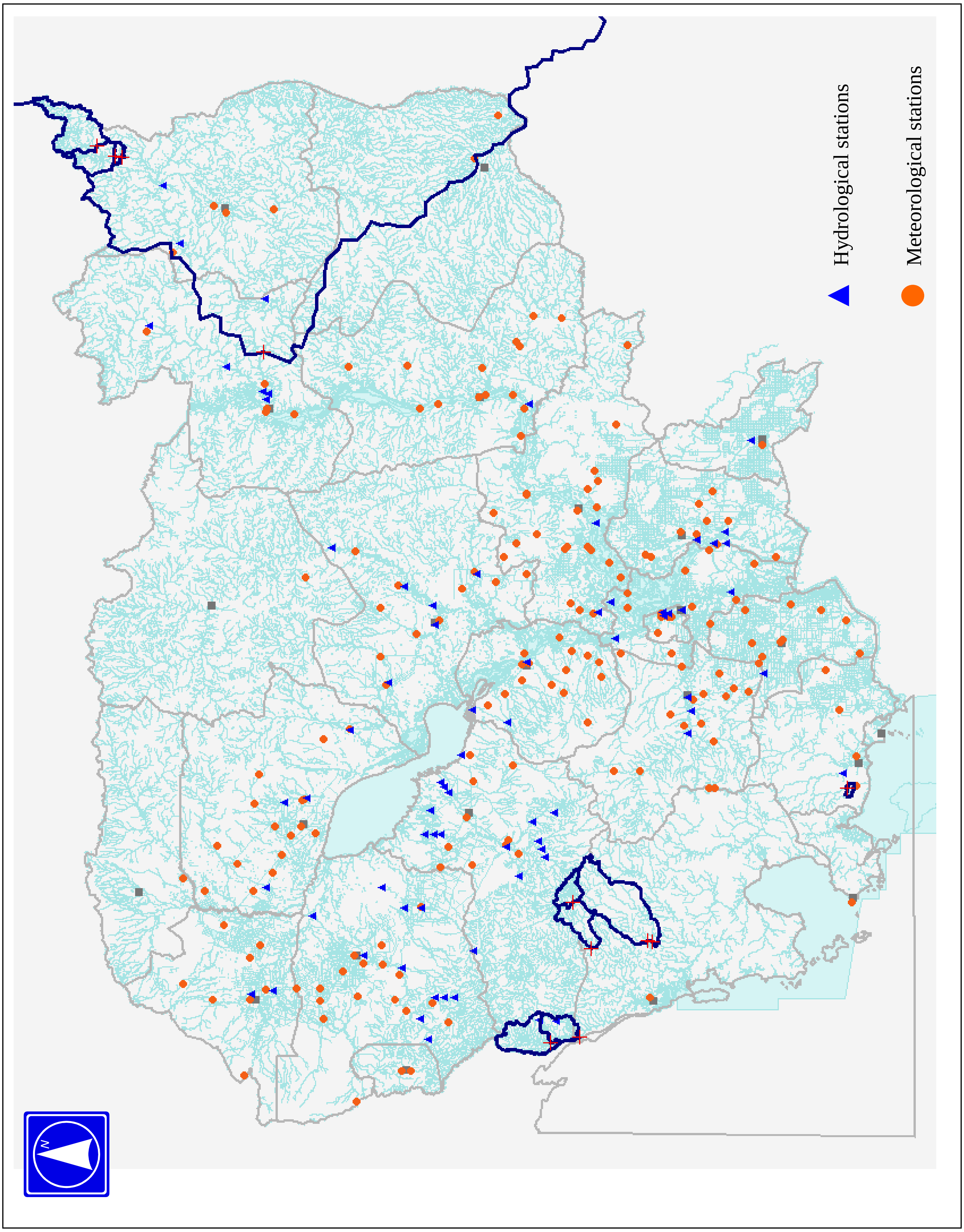
In accordance with the hydro-meteorological data base (HYMOS) managed by MOWRAM, there are 73 hydrological stations[2] and 221 rainfall stations[3] in Cambodia. Location of the stations in the data base is shown in Figure 6.3.1.

Most of the stations are located around Phnom Penh, Tonle Sap and Mekong Mainstream. There are only limited observation stations in Koh Kong and Ratanak Kiri Province, the area for the 10 priority projects in the Study.

1 In the data list of MRC (as of December 2005), there are 72 hydrological stations (35 stations have discharge data and the remaining stations have only water level data), 24 meteorological stations and 204 rainfall stations.

2 Of the 73 stations, 35 stations have discharge data and the remaining stations have only water level data.

3 Of the 221 stations, 21 stations have meteorological data including rainfall and 32 stations have no location data (coordination data).



Source: Study Team

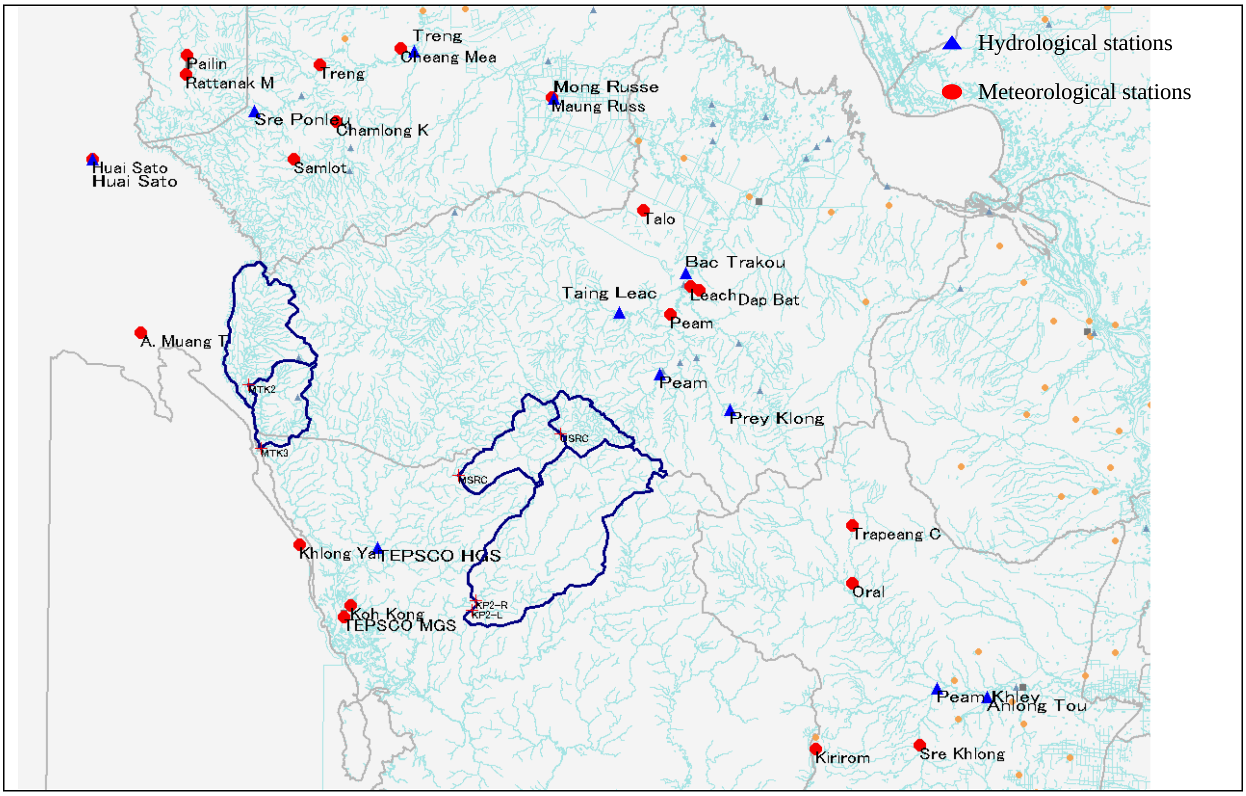
*) Location of the observation stations is plotted based on the coordination data of HYMOS.

Figure 6.3.1 Location of Hydrological/Meteorological Stations in Cambodia and Catchment Area of Priority Projects

6.3.3 Rainfall and Discharge Data at Existing Observation Station Related to 10 Priority Projects

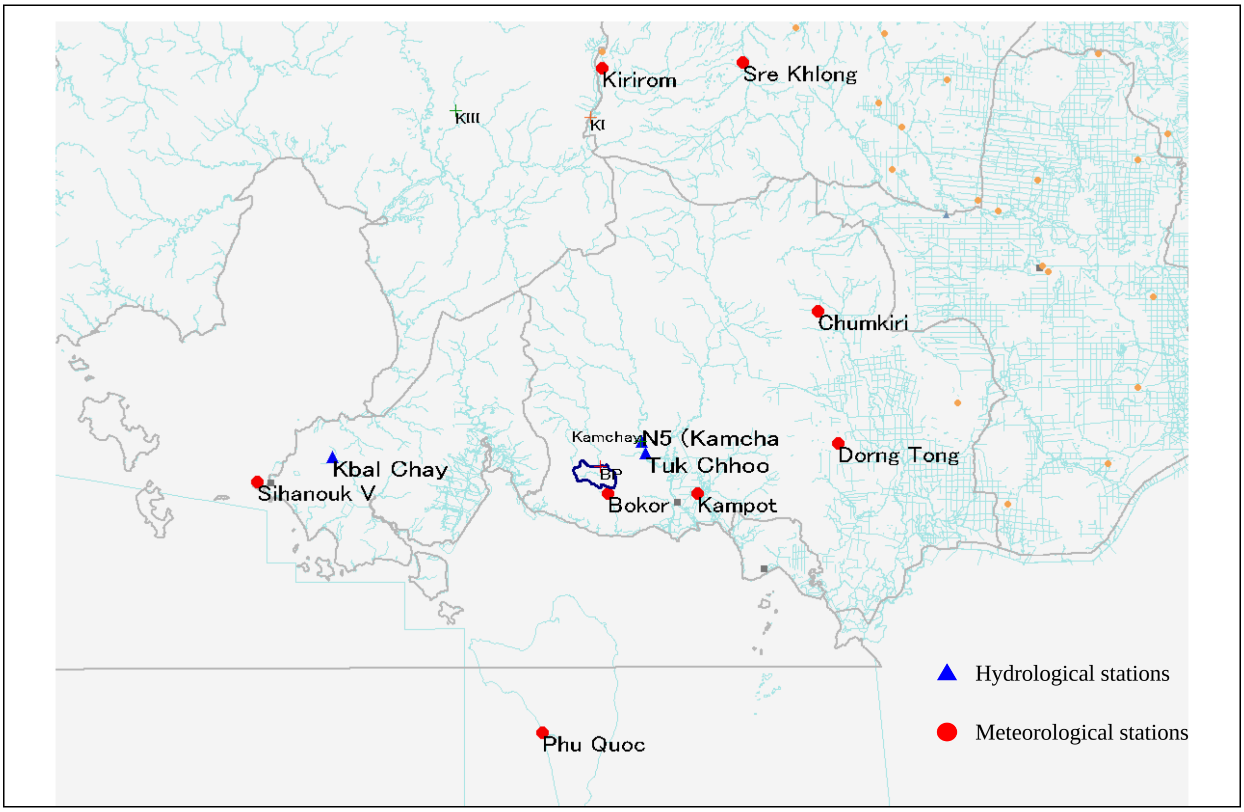
Existing rainfall and discharge data related to the 10 priority projects are limited. Consequently, rainfall and discharge data related to the 10 priority projects are collected and compiled as much as possible referring to data from MOWRAM, related existing studies and data in Vietnam.

Figures 6.3.2 - 6.3.4 show location of the projects and rainfall/hydrological stations, and Tables 6.3.1 - 6.3.2 show representative data of the stations.



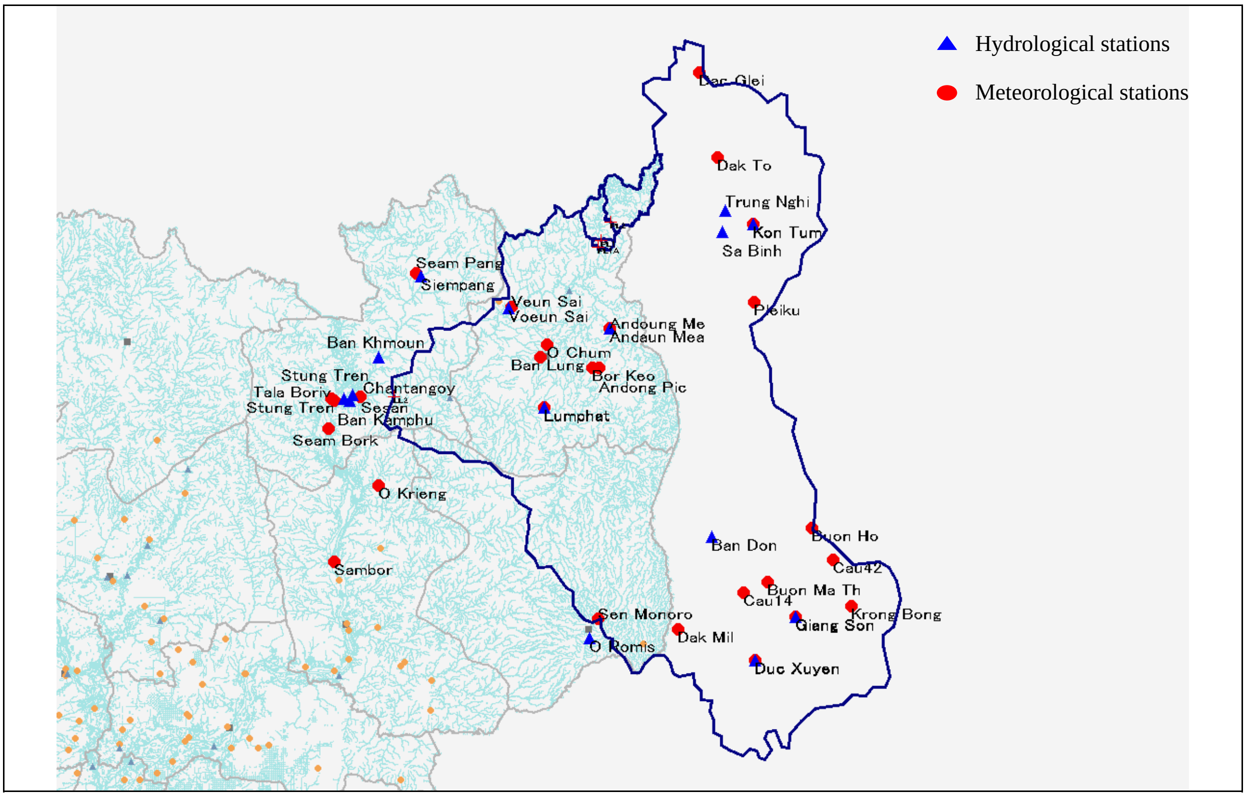
Source: Study Team

Figure 6.3.2 5 Projects in the Southwest Area and Hydrological/Meteorological Stations



Source: Study Team

Figure 6.3.3 Bokor Plateau Project in the Central Mountainous Area and Hydrological/Meteorological Stations



Source: Study Team

Figure 6.3.4 4 Projects in the Northeast Area and Hydrological/Meteorological Stations

Table 6.3.1 Rainfall Stations Related to 10 Priority Projects

Related Project	Rainfall Station	Province	Observation Period* (years)	Mean Annual Rainfall (mm)
5 projects in the southwest area	Koh Kong	Koh Kong	15	**3,690**
– MSRC	TEPSCO MGS	Koh Kong	2	**4,570**
– MTK2	Huai Sato	(Thai)	27	**3,080**
– MTK3	A. Muang Trat	(Thai)	25	**3,590**
– KP2	Khlong Yai	(Thai)	24	**4,780**
– USRC	Leach	Pursat	19	1,560
	Dap Bat	Pursat	20	1,280
	Peam	Pursat	4	1,130
	Talo	Pursat	9	1,190
	Treng	Battambang	8	1,270
	Chamlong Kuoy	Battambang	8	1,150
	Samlot	Battambang	3	1,790
	Cheang Meanchey	Battambang	3	1,260
	Maung Russey	Battambang	26	1,170
	Pailin	Pailin	18	1,230
	Rattanak Mondol	Pailin	3	1,020
	Kirirom	Kampong Speu	8	1,650
	Trapeang Chor	Kampong Speu	4	1,180
	Oral	Kampong Speu	8	1,200
BP	Kampot	Kampot	54	1,940
	Bokor	Kampot	6	**4,920**
	Sihanouk Ville	Sihanouk Ville	41	**3,390**
	Phu Quoc	(Vietnam)	42	**3,000**
	Dorng Tong	Kampot	3	1,200
	Chumkiri	Kampot	3	1,230
	Kirirom	Kampong Speu	8	1,650
	Sre Khlong	Kampong Speu	4	1,240
4 projects in the northeast area	Stung Treng	Stung Treng	46	1,760
– LL2	O Krieng	Kratie	8	1,730
– PL1	Sambor	Kratie	18	1,650
– PL1A	Ban Lung	Ratanak Kiri	10	2,480
– PL2	Veun Sai	Ratanak Kiri	22	2,330
	Andoung Meas	Ratanak Kiri	5	1,790
	Dac Glei	(Vietnam)	21	1,520
	Dak To	(Vietnam)	24	1,860
	Kon Tum	(Vietnam)	25	1,760
	Pleiku	(Vietnam)	25	2,260
	Lumphat	Ratanak Kiri	10	1,700
	Buon Ho	(Vietnam)	24	1,600
	Krong Bong	(Vietnam)	18	1,580
	Duc Xuyen	(Vietnam)	23	1,940
	Dak Mil	(Vietnam)	20	1,790
	Sen Monorom	Mondul Kiri	3	1,810

*) incl. data missing periods
Source: Study Team

The high rainfall areas in south-western and central mountain regions with annual rainfall of more than 3,000 mm shown in boldface in Table 6.3.1 are noticeable.

Table 6.3.2 Hydrological Stations Related to 10 Priority Projects

Related Project	Hydrological Station	River Basin	Catchment Area (km²)	Observation Period* (years)	Mean Annual Discharge (m³/s)	Mean Annual Run-off (mm)
5 projects in the southwest area – MSRC – MTK2 – MTK3 – KP2 – USRC	TEPSCO HGS	SRC+Touch	2292**	2	98.4	1,350
	Huai Sato	(Thai)	190	26	10.1	1,670
	Taing Leach	Pursat	2,011	50	31.3	490
	Bac Trakoun	Pursat	4,245	9	82.5	613
	Peam	Pursat	243	8	16.7	2,170
	Prey Klong (down)	Pursat	421	10	14.4	1,080
	Sre Ponleu	Battambang	566	65	23.4	1,310
	Treng	Battambang	2,225	44	69.7	989
	Mong Russey	Battambang (St.Dauntri)	1,214	2	2.9	77
	Peam Khley	Prek Thnot	3,662	10	40.1	346
	Anlong Touk	Prek Thnot	3,650	50	39.4	340
BP	Tuk Chhuu	Kamchay	745**	5	60.1	2,540
	N5 (Kamchay)	Kamchay	710	1	50.5	2,240
	Kbal Chay	Prek Tuek sub river	52.5	2	4.1	2,450
4 projects in the northeast area – LL2 – PL1 – PL1A – PL2	Stung Treng	Mekong	635,000	81	13,200	654
	Ban Kamphun (daily)	Se San & Sre Pok	49,500	7	1,600	1,020
	Ban Kamphun (monthly)	Se San & Sre Pok	49,500	79	1,570	1,000
	Voeun Sai	Se San	16,300	11	674	1,300
	Andaung Meas	Se San	11,779**	6	521	1,400
	Kon Tum	Se San (Vietnam)	3,056	23	99.4	1,030
	Trung Nghia	Se San (Vietnam)	3,320	8	136	1,290
	Sa Binh	Se San (Vietnam)	6,732	9	234	1,100
	Lumphat (daily)	Sre Pok	25,600	6	664	818
	Lumphat (monthly)	Sre Pok	25,600	56	922	1,140
	Giang Son	Sre Pok (Vietnam)	3,180	25	73.9	733
	Ban Don	Sre Pok (Vietnam)	10,700	24	271	799
	Duc Xuyen	Sre Pok (Vietnam)	3,080	23	109	1,110
	Ban Khmoun	Se Kong	29,600	65	1,380	1,470
	Siempang	Se Kong	23,500	50	911	1,220
	O Romis	O Romis	38	3	1.6	1,310

*) incl. data missing periods
**) measured by Study Team on GIS
Source: Study Team

In the table above, there are four hydrological stations with annual runoff over 2,000 mm. Of these, at Peam, the annual rainfall amounts to 1,130 mm. The annual rainfall increases in the upper reach, as the area comes closer to the sea, however, it is necessary to confirm the reliability of annual runoff value of 2,170 mm through actual measurement. Annual runoff values of 2,240 to 2,540 mm in Bokor Plateau area, such as Kamchay hydrological station, may be possible considering:

(1) the data of the three stations are consistent to each other, and

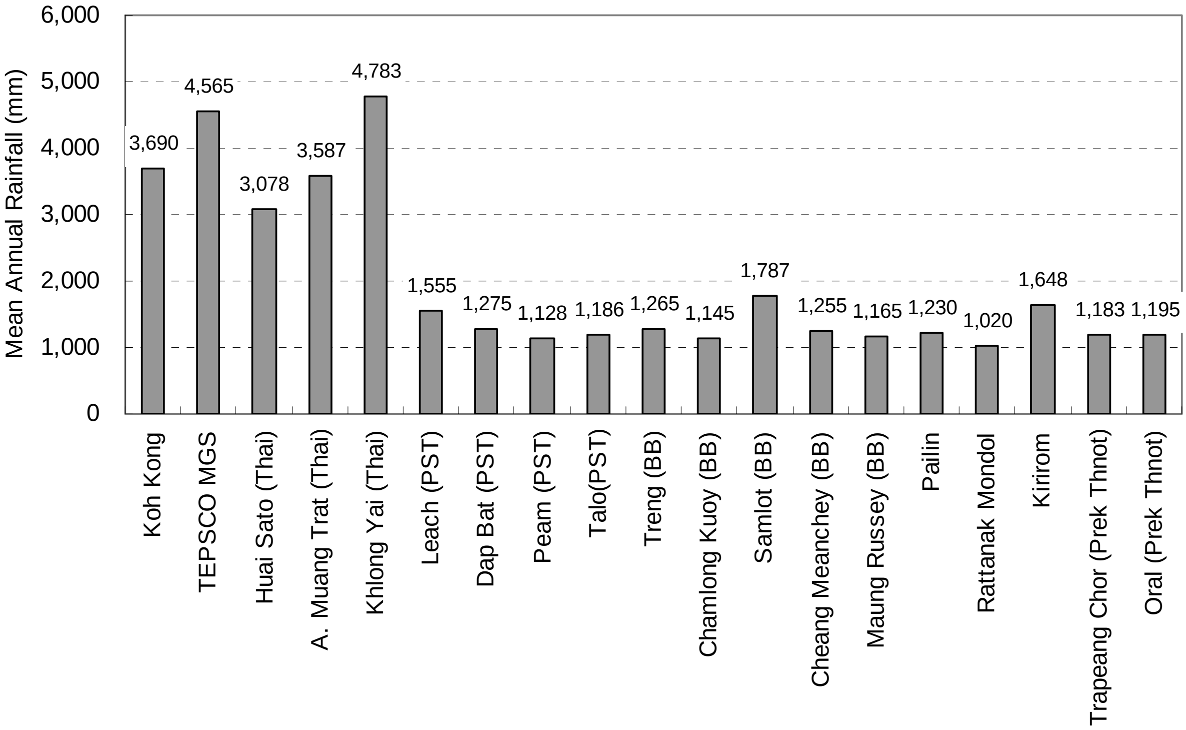
(2) the stations are located in the pluvious Bokor plateau with annual rainfall of over 4,000 mm.

6.3.4 Characteristics of Rainfall and Discharge Related to 10 Priority Projects

(1) Southwest Area

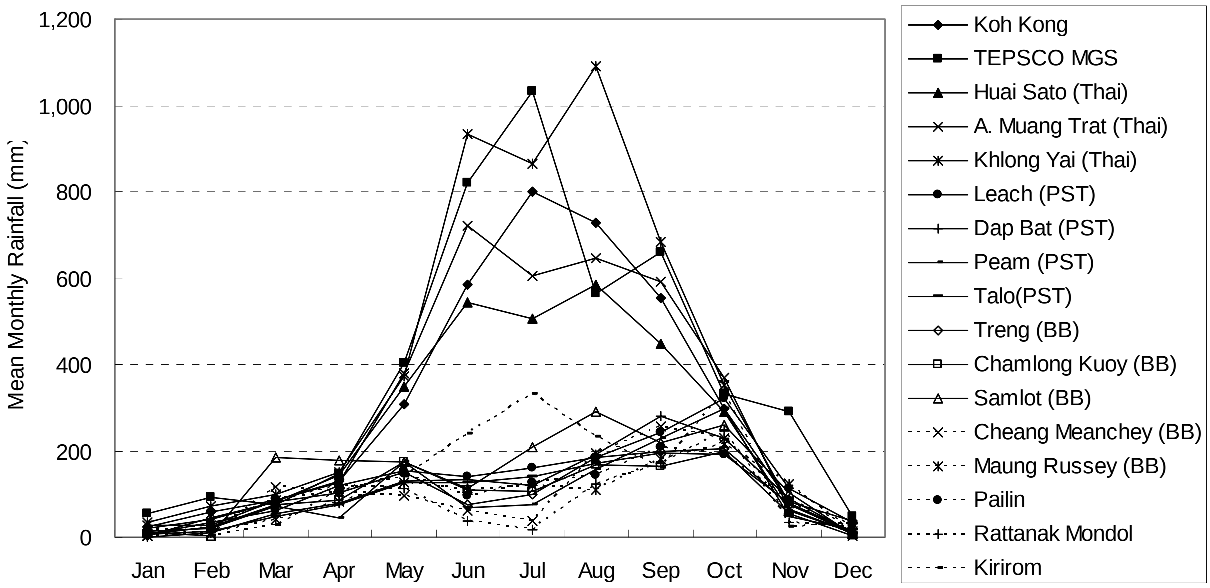
Characteristics of rainfall and discharge related to 5 projects (MSRC, MTK2, MTK3, USRC, KP2) in the southwest area are shown in Figures 6.3.5 - 6.3.8.

Koh Kong, TEPSCO MGS and stations in Thailand, located in the west of the Cardamon Mountains, have a lot of rainfall. With regard to annual run-off, TEPSCO HGS and Huai Sato, located in the Cardamon Mountains, and Peam in the most upstream of Pursat show high value.



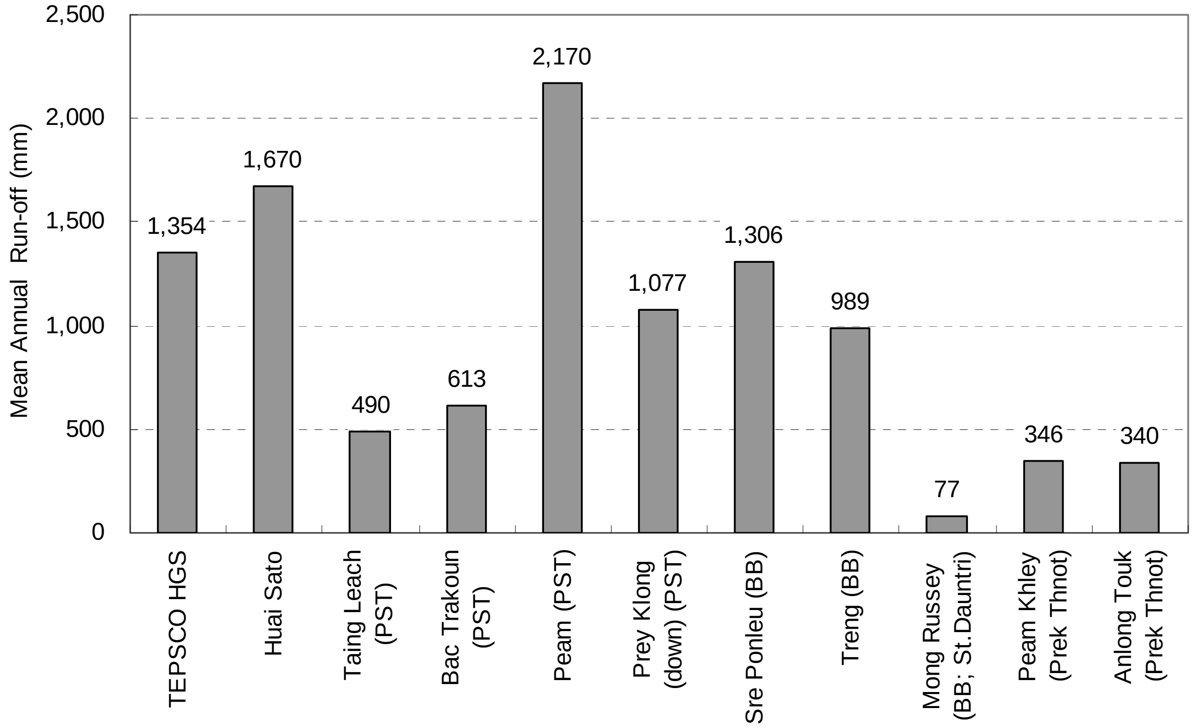
Source: Study Team

Figure 6.3.5 Mean Annual Rainfall in the Southwest Area



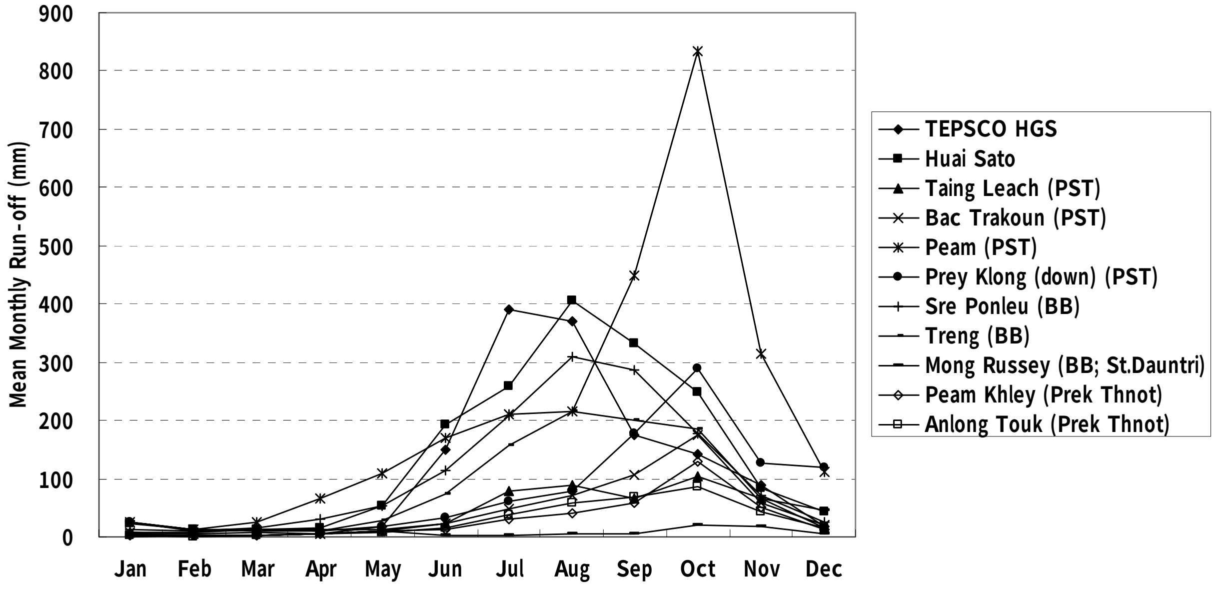
Source: Study Team

Figure 6.3.6 Mean Monthly Rainfall in Southwest Area



Source: Study Team

Figure 6.3.7 Mean Annual Run-off in the Southwest Area



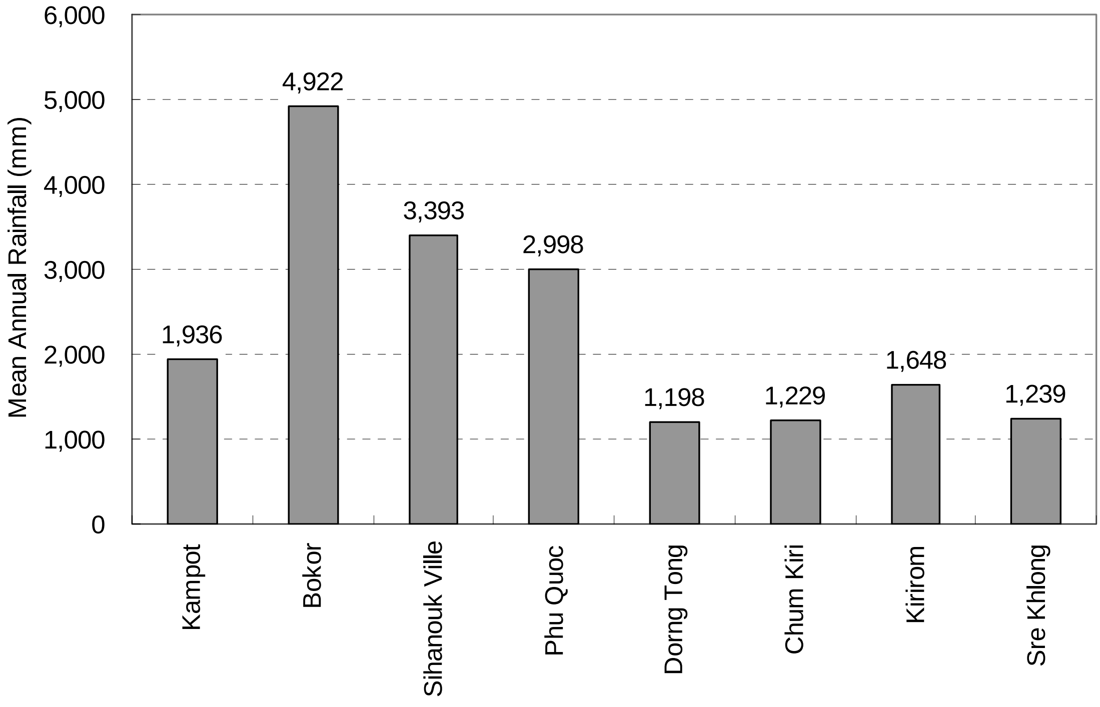
Source: Study Team

Figure 6.3.8 Mean Monthly Run-off in the Southwest Area

(2) Central Mountainous Area

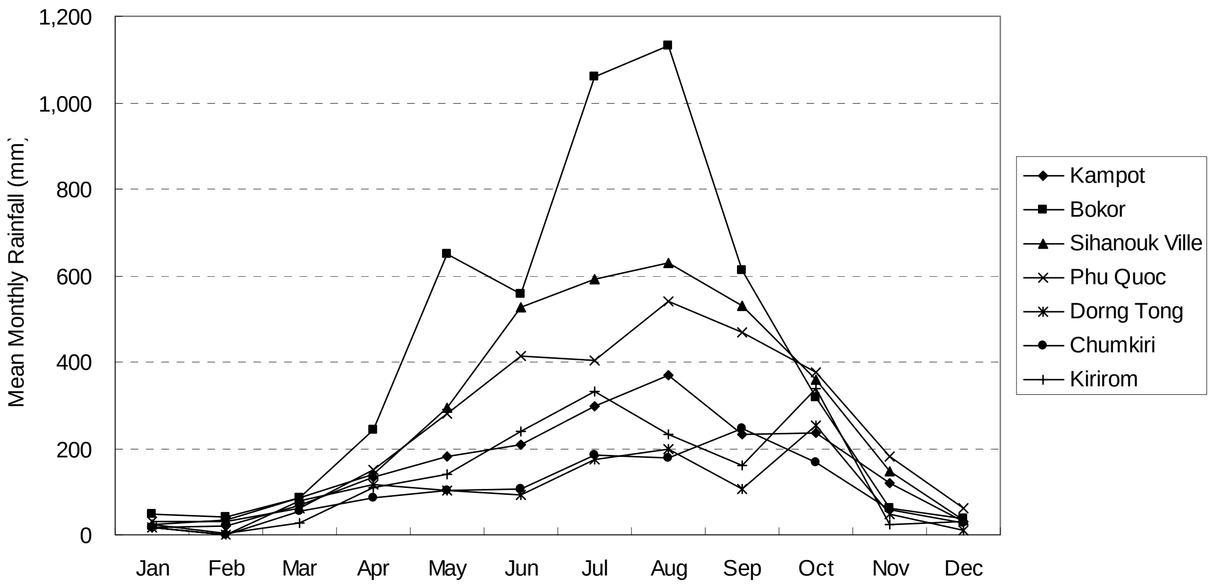
Characteristics of rainfall and discharge related to #29 Bokor Plateau (BP) Project in the central mountainous area are shown in Figures 6.3.9 - 6.3.12.

Annual rainfall at Bokor is remarkably high. The reason seems that Bokor station is located in the west of the Bokor Cliff and regional rainfall due to the southwest monsoon directly influences rainfall at the station.



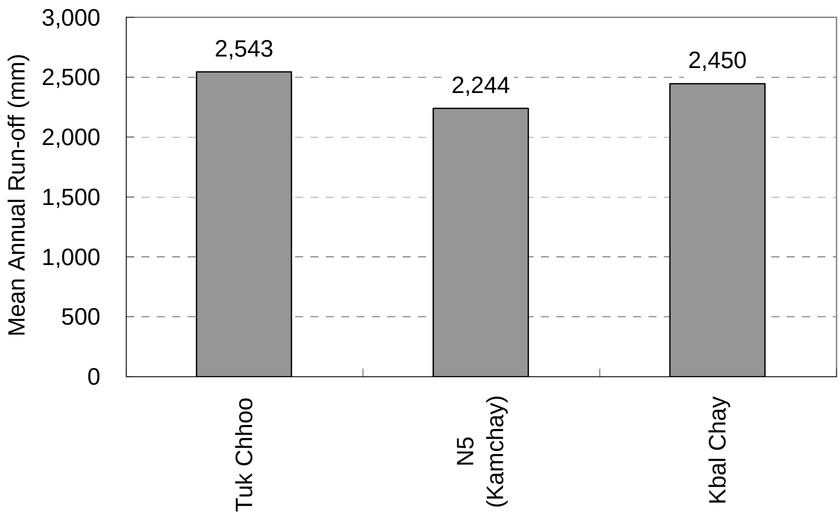
Source: Study Team

Figure 6.3.9 Mean Annual Rainfall in the Central Mountainous Area



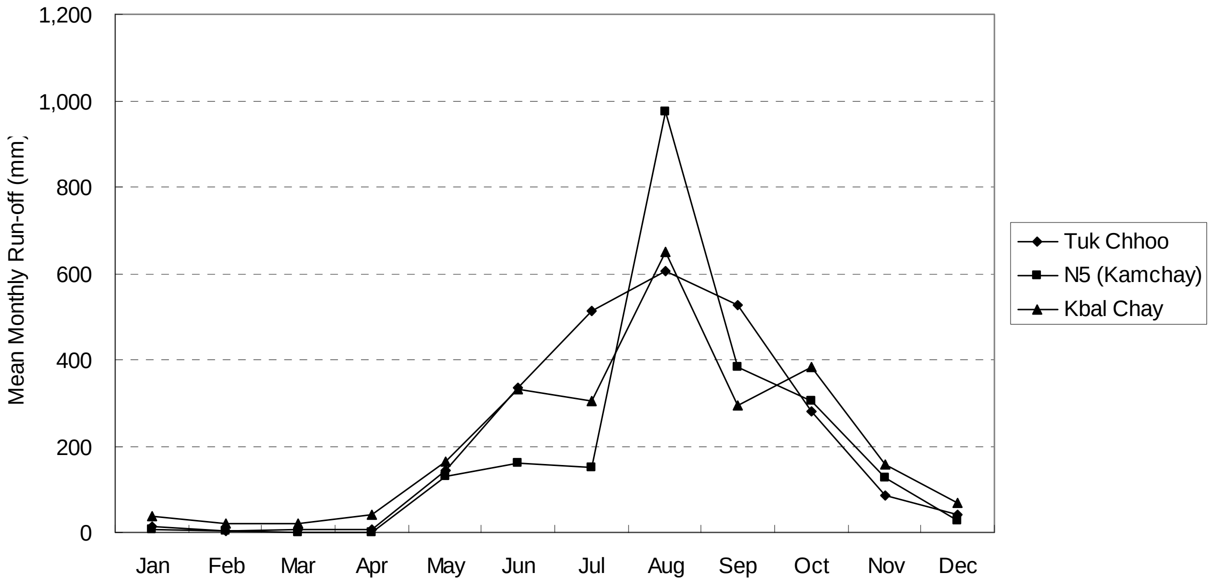
Source: Study Team

Figure 6.3.10 Mean Monthly Rainfall in the Central Mountainous Area



Source: Study Team

Figure 6.3.11 Mean Annual Run-off in the Central Mountainous Area

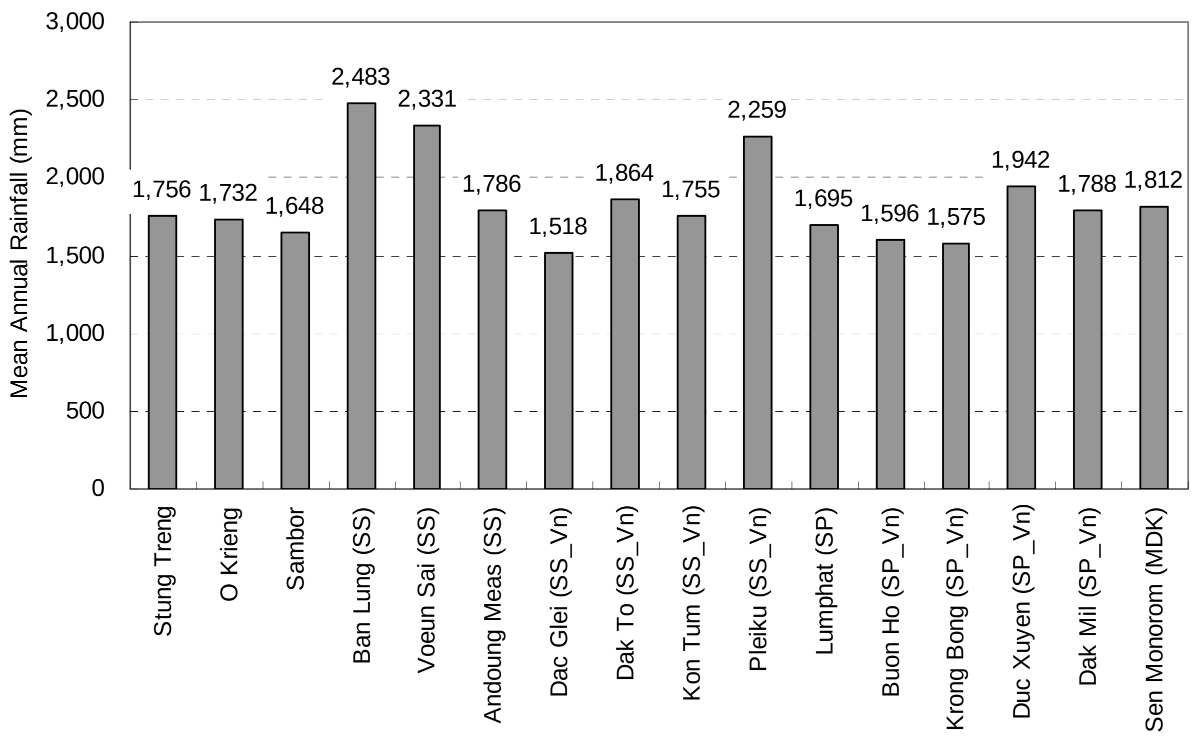


Source: Study Team

Figure 6.3.12 Mean Monthly Run-off in the Central Mountainous Area

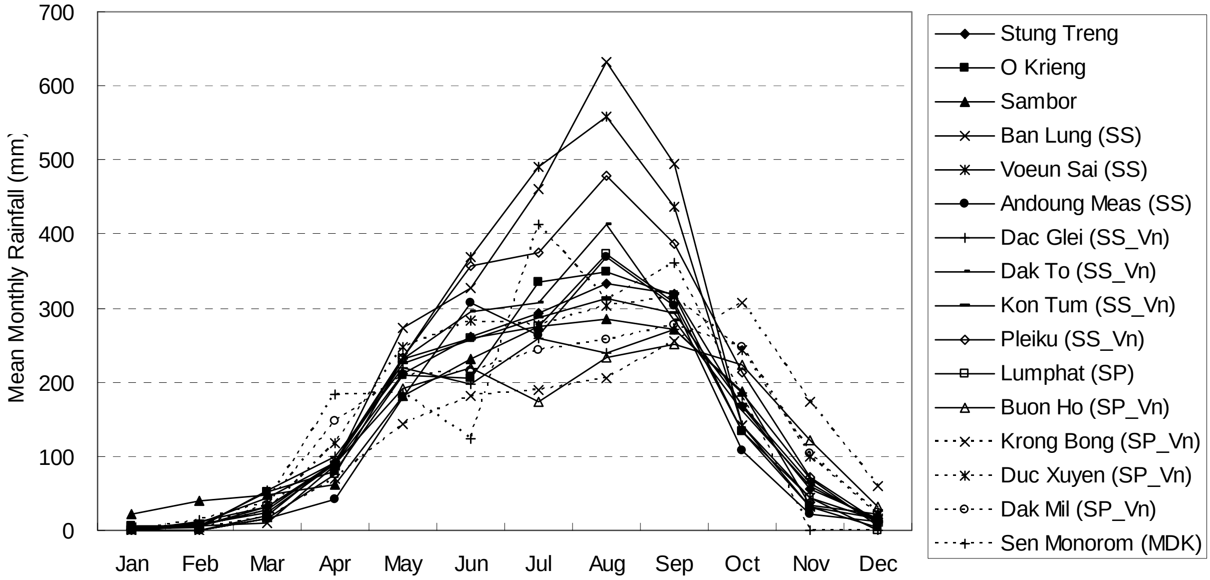
(3) Northeast Area

Characteristics of rainfall and discharge related to 4 projects (#7&8 LL2, #12 PL1, #13 PL1A, #14 PL2) in the northeast area are shown in Figures 6.3.13 - 6.3.16.



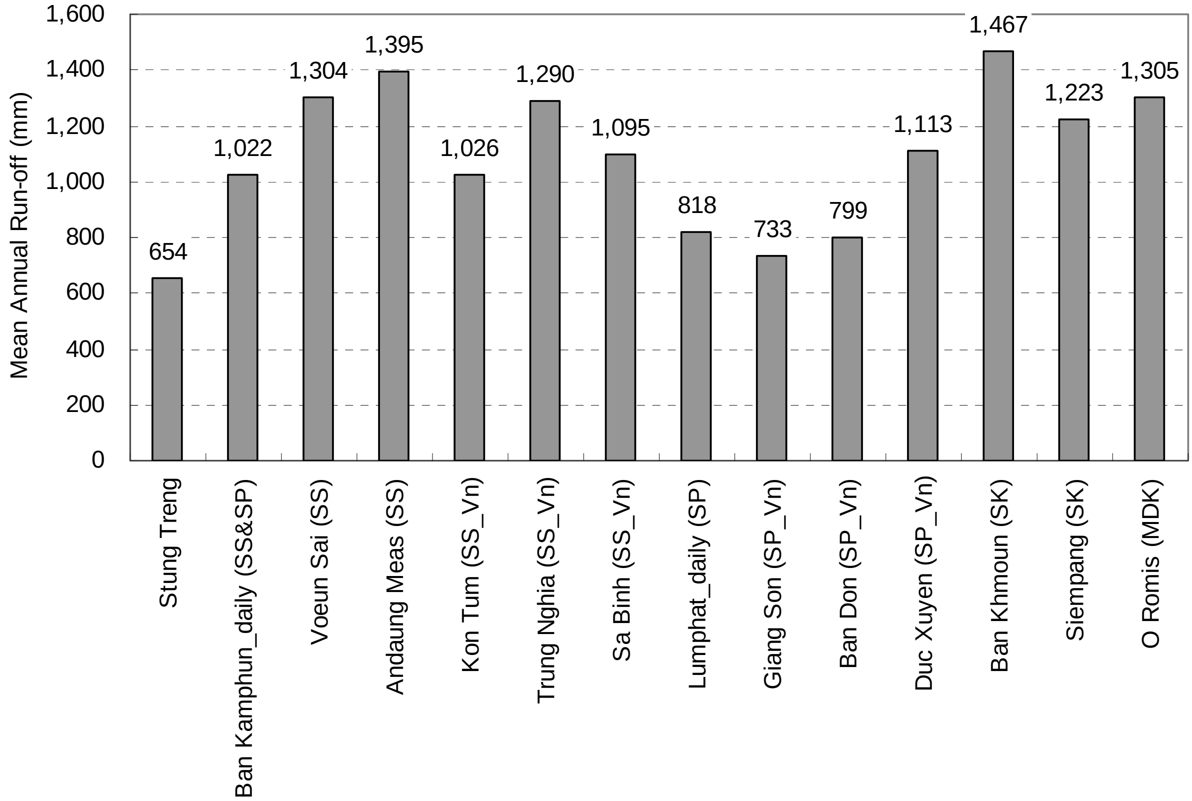
Source: Study Team

Figure 6.3.13 Mean Annual Rainfall in the Northeast Area



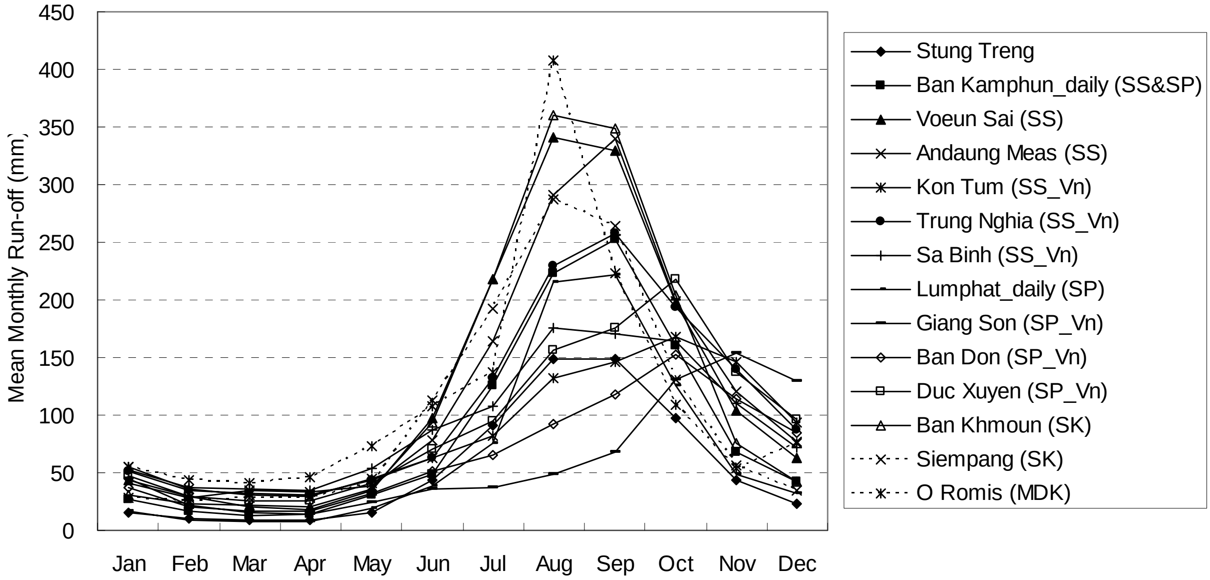
Source: Study Team

Figure 6.3.14 Mean Monthly Rainfall in the Northeast Area



Source: Study Team

Figure 6.3.15 Mean Annual Run-off in the Northeast Area



Source: Study Team

Figure 6.3.16 Mean Annual Run-off in the Northeast Area

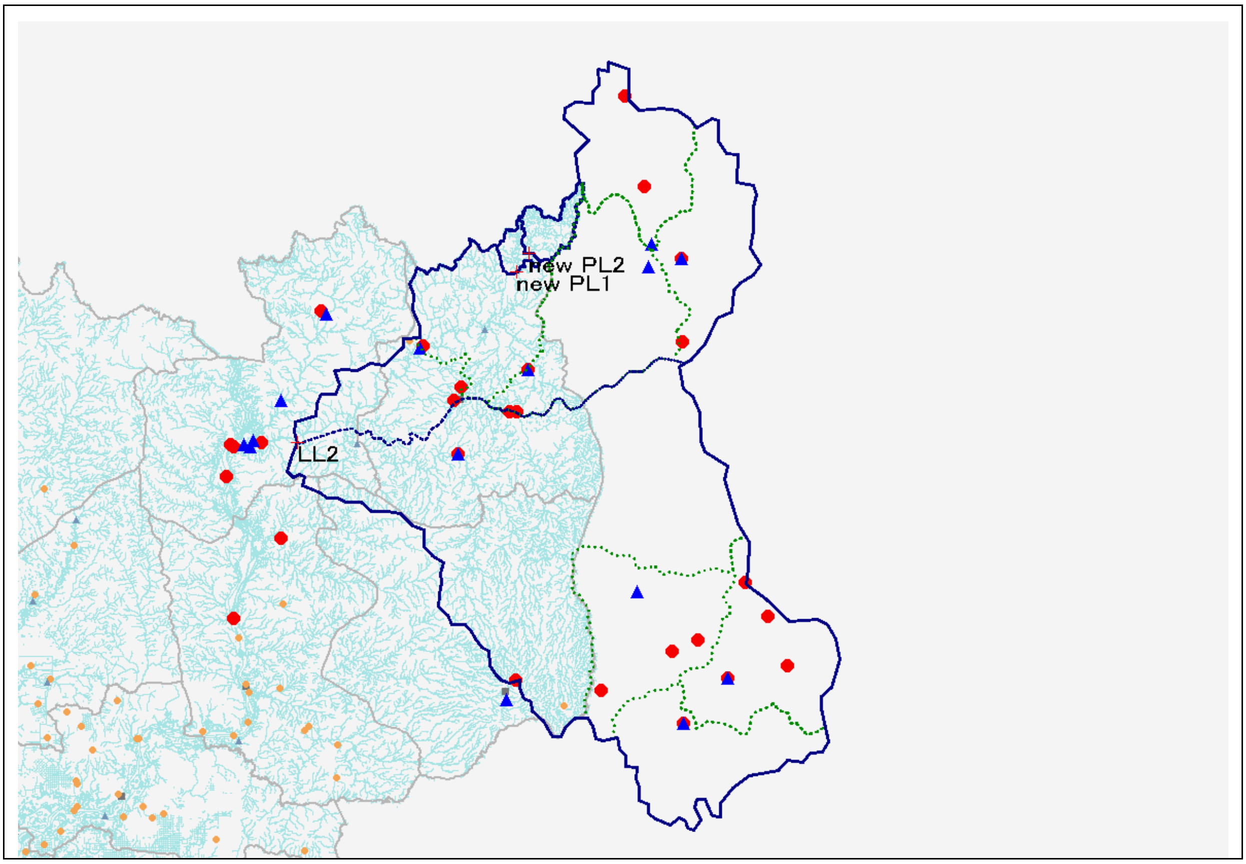
6.3.5 Catchment Area

Catchment areas and boundaries of the 10 priority projects are shown in Table 6.3.3 and Figures 6.3.17 - 6.3.20.

Table 6.3.3 Catchment Area of 10 Priority Projects

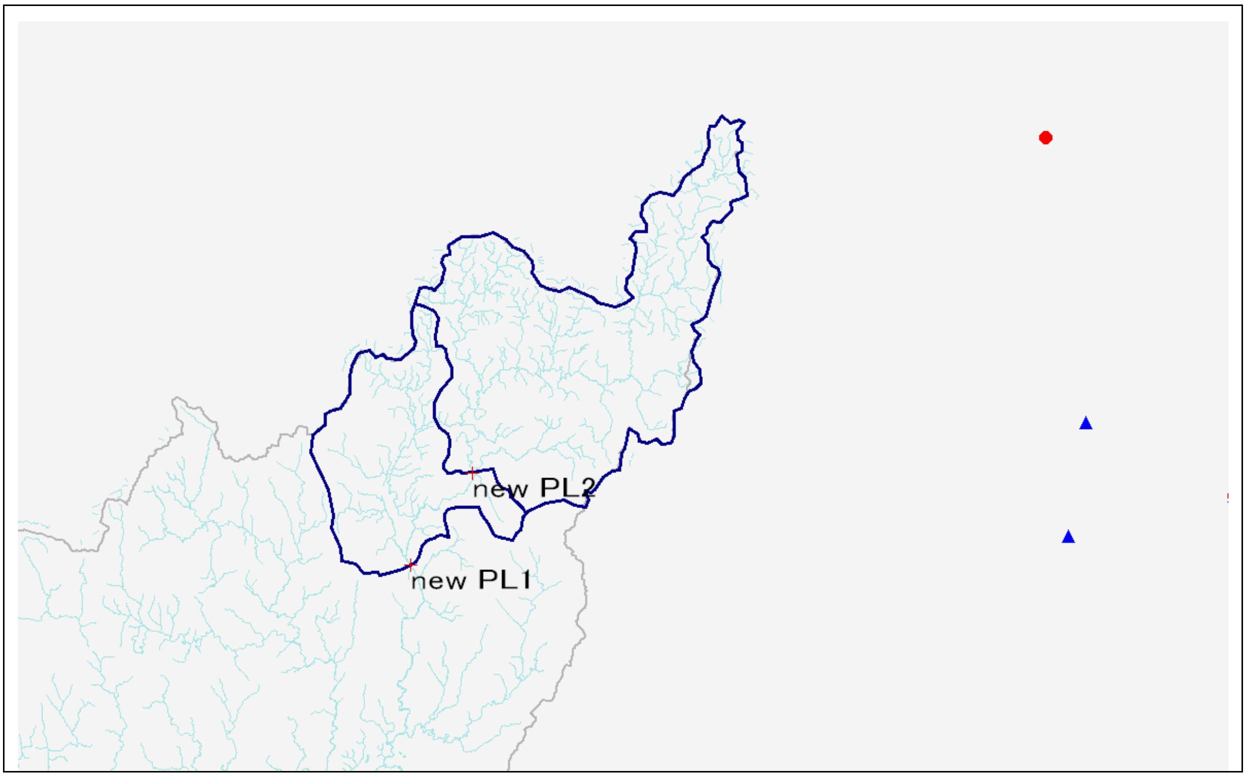
	PJT No.	Project	Catchment Area (km^2)
1	7&8	Lower Sre Pok II + Lower Se San II	49,200
2	12	Prek Liang I*	883 => 839
3	13	Prek Liang IA**	943 => combined with Prek Liang I
4	14	Prek Liang II*	595 => 575
5	16	Middle St. Russey Chrum	461
6	20	Stung Metoek II	416
7	21	Stung Metoek III	656
8	22	Stung Kep II	1,060
9	23	Upper St. Russey Chrum	163
10	29	Bokor Plateau	24.5

*) Based on the new topographic maps with a scale of 1:10,000, the dam sites are shifted upstream.
**) Prek Liang IA was combined with Prek Liang I.
Source: Study Team



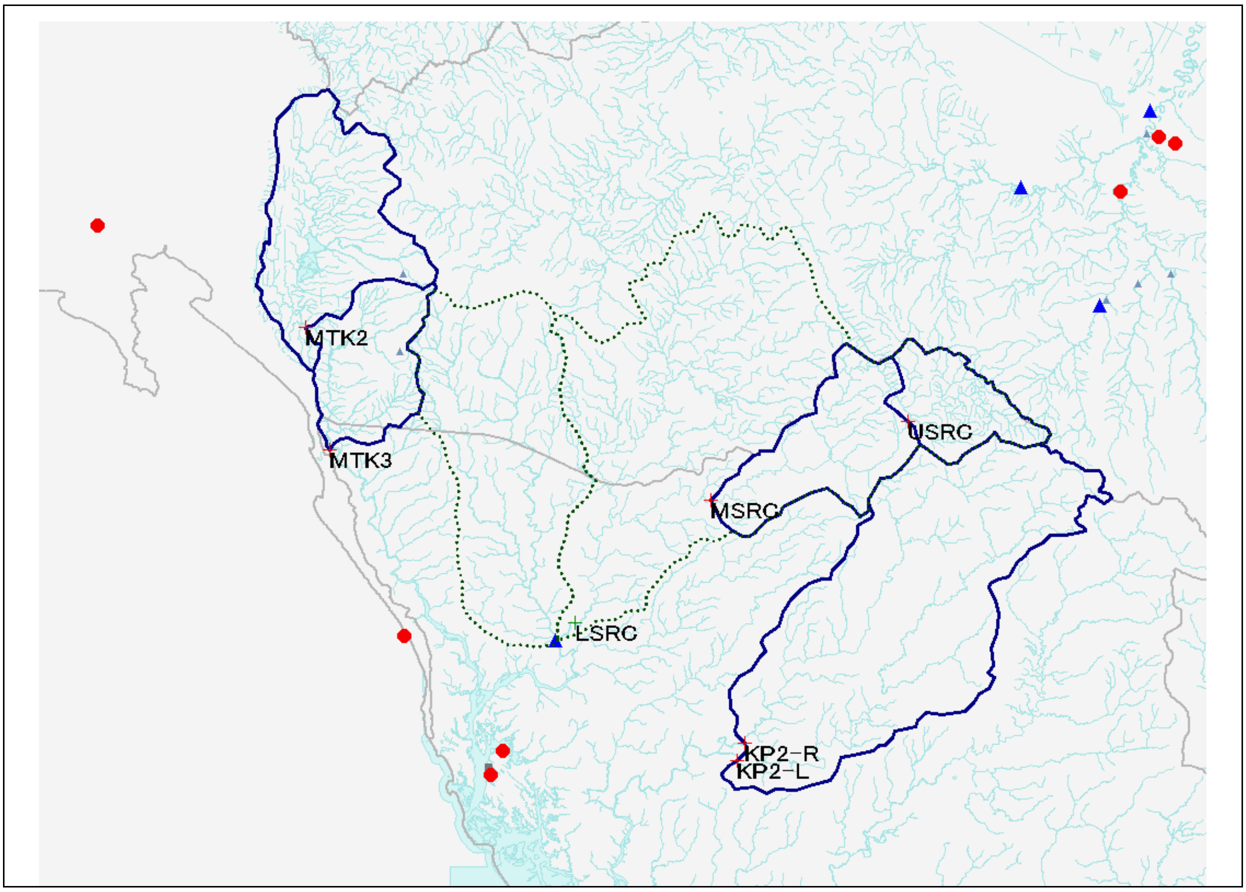
Source: Study Team

Figure 6.3.17 Catchment Boundary of 3 Projects in the Northeast Area



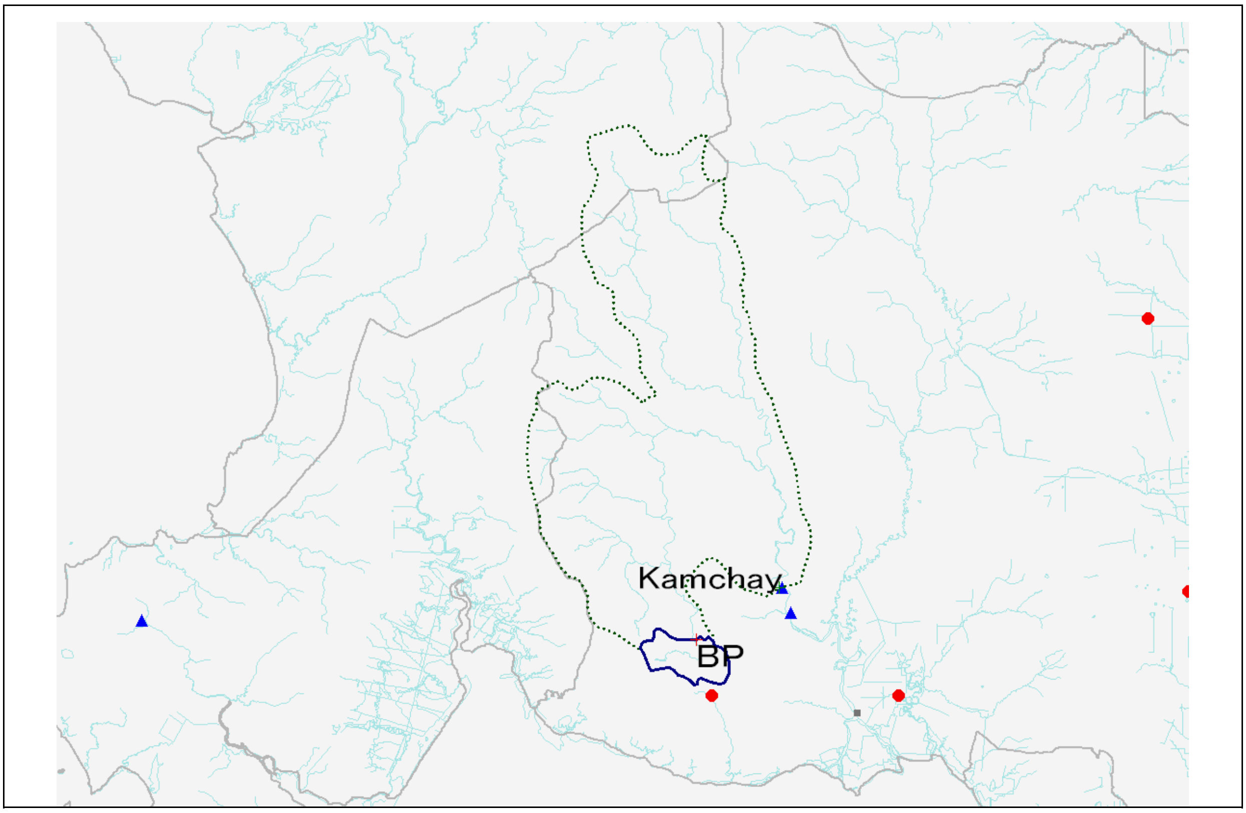
Source: Study Team

Figure 6.3.18 Catchment Boundary of Prek Liang 2 Projects in the Northeast Area



Source: Study Team

Figure 6.3.19 Catchment Boundary of 5 Projects in the Southwest Area



Source: Study Team

Figure 6.3.20 Catchment Boundary of BP and Kamchay Project in the Central Mountainous Area

6.3.6 Basin Rainfalls

Estimated basin rainfalls of the 9 priority projects are shown in Table 6.3.4.

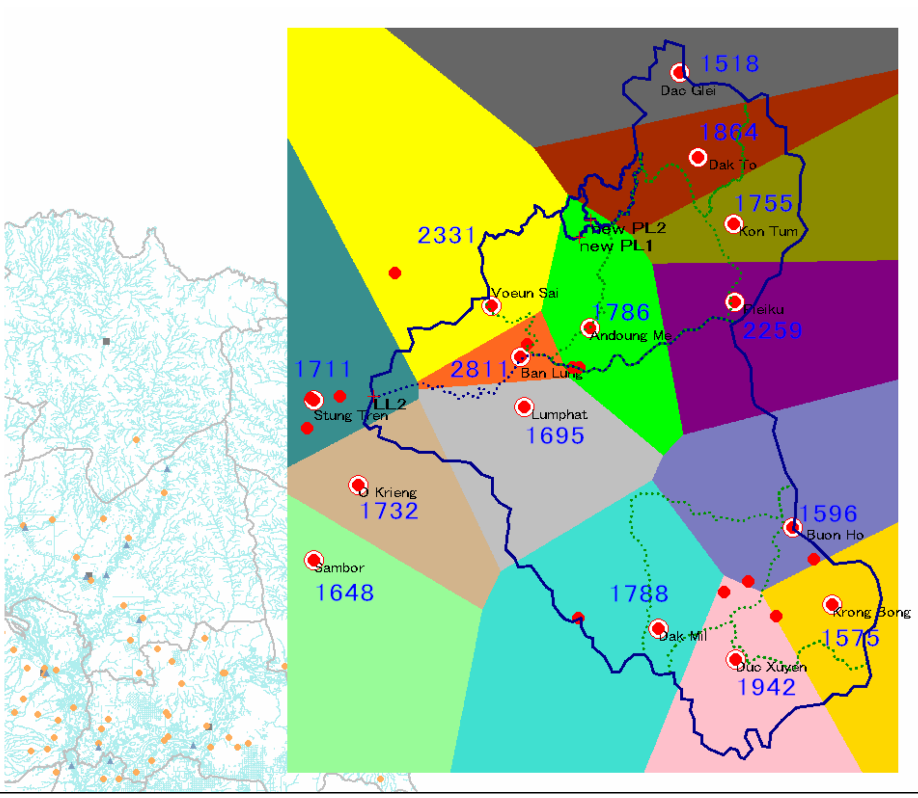
Basin rainfalls of the projects in the northeast area were derived by the Thiessen method. Basin rainfalls of the projects in the southwest area were estimated based on an isohyet map of the area because there are few referable rainfall stations. Because of the same reason as the projects in the southwest area, #29 BP in the central mountainous area was also estimated from an isohyet map of the area.

Table 6.3.4 Basin Rainfalls of Priority Projects

	PJT No.	Project Name	Basin Rainfall (mm/yr)	Estimation Method
1	7&8	Lower Sre Pok II + Lower Se San II	1,840	Thiessen method
2	12	new Prek Liang I	1,840	Thiessen method
3	14	new Prek Liang II	1,850	Thiessen method
4	16	Middle St. Russey Chrum	2,620	Isohyetal method
5	20	Stung Metoek II	3,010	Isohyetal method
6	21	Stung Metoek III	3,100	Isohyetal method
7	22	Stung Kep II	2,690	Isohyetal method
8	23	Upper St. Russey Chrum	2,420	Isohyetal method
9	29	Bokor Plateau	4,630	Isohyetal method

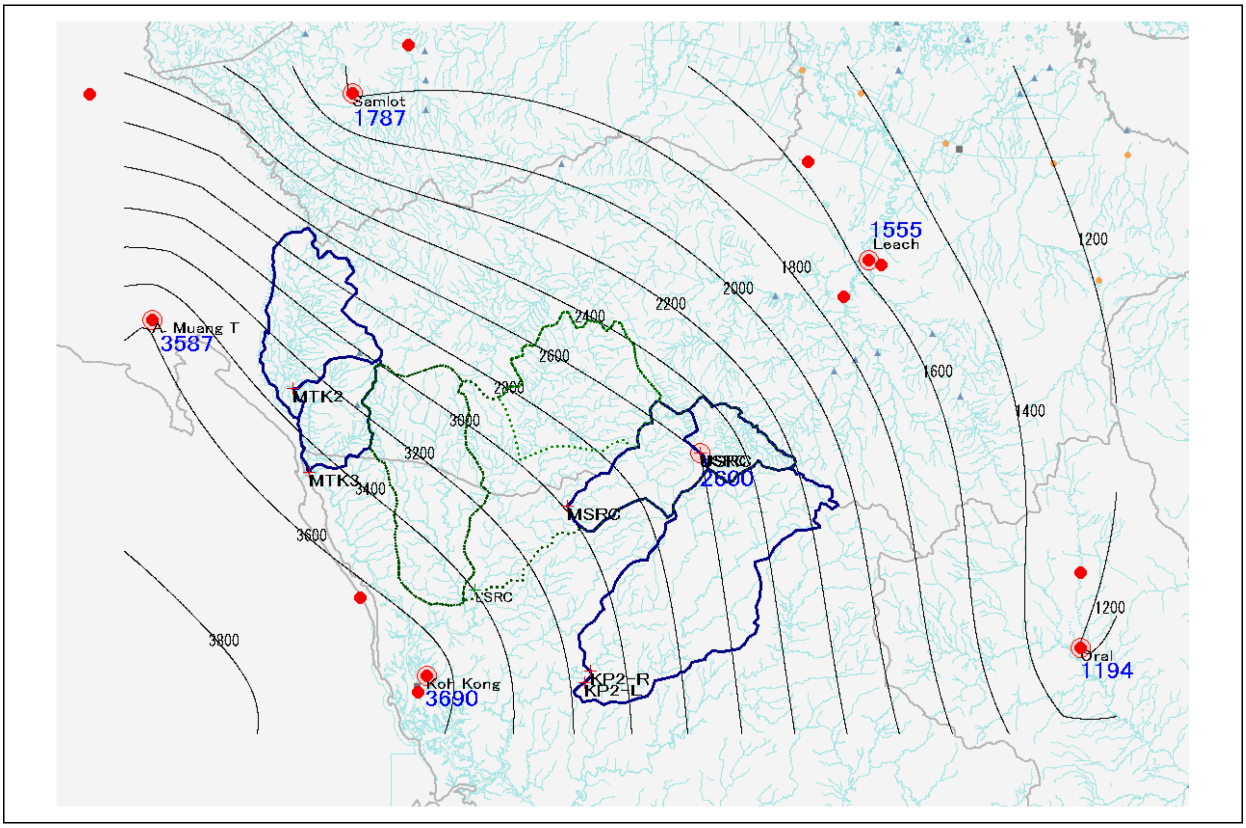
Source: Study Team

Thiessen polygons and isohyets used in the estimates above are shown in Figures 6.3.21 - 6.3.23.



Source: Study Team

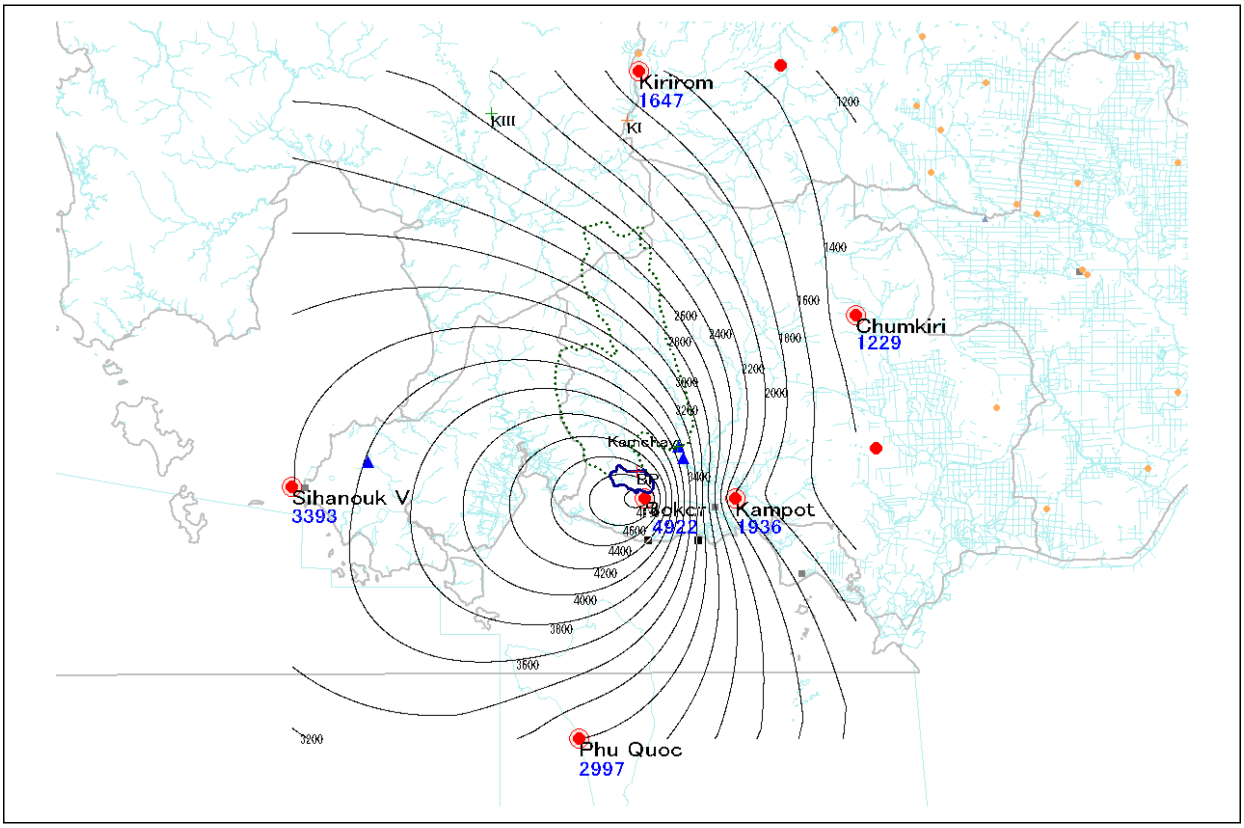
Figure 6.3.21 Thiessen Polygon Related to 3 Projects in the Northeast Area



Remarks) In order to consider the influence due to the Cardamon Mountains, an annual rainfall at USRC was assumed at 2,600mm.

Source: Study Team

Figure 6.3.22 Isohyets Related to 5 Projects in the Southwest Area



Source: Study Team

Figure 6.3.23 Isohyets Related to BP Project in the Central Mountainous Area

6.3.7 Estimation Method of Discharge Data for Power Generation Planning

Existing rainfall and discharge data related to the priority projects are limited. In addition, volume and quality of the data differ by projects. With regard to estimation of the discharge for power generation planning (mean discharge and dry season discharge), suitable estimation methods for each project were applied considering referable data. Estimation methods of long-term mean discharge for each project are summarized in the following table:

Table 6.3.5 Estimation Method of Long Term Mean Discharge for Each Project

<table>
<tr><th></th><th>PJT No.</th><th>Project</th><th>Estimation Method of Mean Discharge</th></tr>
<tr><td>1</td><td>7&8</td><td>Lower Sre Pok II + Lower Se San II</td><td>Estimated from run-off characteristics of whole Se San and Sre Pok basin</td></tr>
<tr><td>2</td><td>12</td><td>Prek Liang I</td><td rowspan="2">Examined run-off characteristics of Se San upstream basin, and then estimated from value of neighbouring similar basin</td></tr>
<tr><td>3</td><td>14</td><td>Prek Liang II</td></tr>
<tr><td>4</td><td>16</td><td>Middle St. Russey Chrum</td><td rowspan="5">Examined long-term mean discharge at neighbouring stations referring to observed discharge for 1 year and long-term rainfall, and then estimated from the discharge at neighbouring stations, ratio of basin rainfall and ratio of catchment area</td></tr>
<tr><td>5</td><td>20</td><td>Stung Metoek II</td></tr>
<tr><td>6</td><td>21</td><td>Stung Metoek III</td></tr>
<tr><td>7</td><td>22</td><td>Stung Kep II</td></tr>
<tr><td>8</td><td>23</td><td>Upper St. Russey Chrum</td></tr>
<tr><td>9</td><td>29</td><td>Bokor Plateau</td><td>Estimated from neighbouring observed discharge and ratio of catchment area</td></tr>
</table>

Source: Study Team

Estimations of long-term mean discharge for each project are explained hereinafter.

6.3.8 Estimation of Long-Term Mean Discharge for 5 Projects in the Southwest Area

Long-term mean discharges for 5 projects in the southwest area were estimated as follows:

(1) Referable Hydrological Station

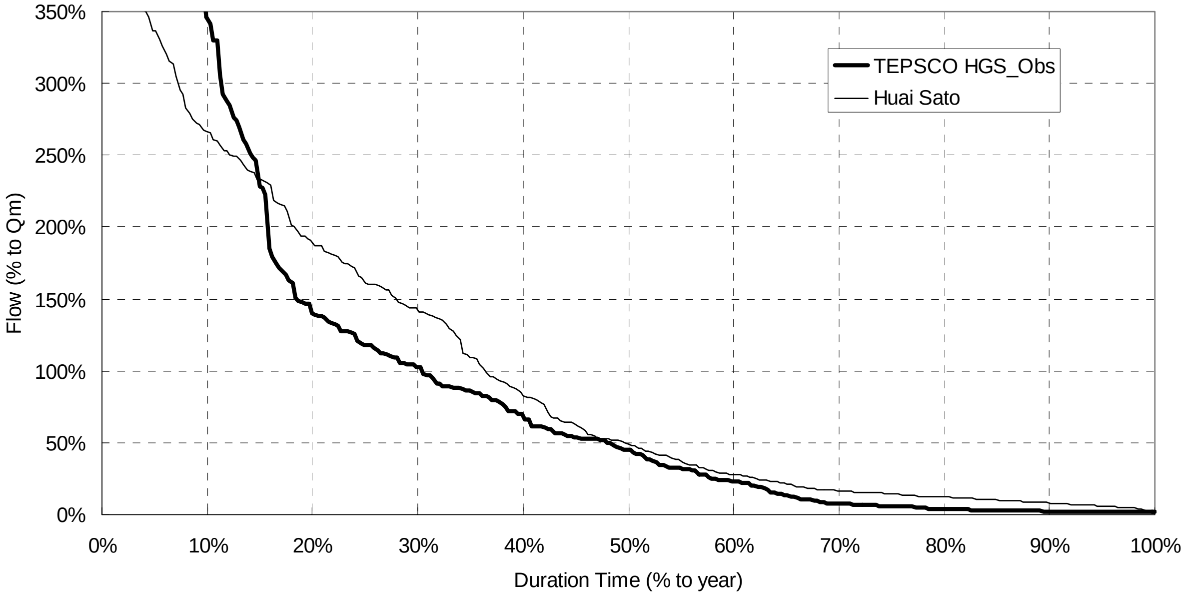
Existing hydrological stations in the west of the Cardamon Mountains and the southwest area are only the following 2:

Table 6.3.6 Existing Hydrological Station Related to 5 Projects in the Southwest Area

<table>
<tr><th rowspan="2">Hydrological Station</th><th rowspan="2">Catchment Area (km^2)</th><th colspan="2">Annual Mean Discharge Qm</th><th rowspan="2">Dry Season Discharge Q_{90} (m^3/s/100km^2)</th><th rowspan="2">Remarks</th></tr>
<tr><th>Annual Run-off (mm/yr)</th><th>Specific Discharge (m^3/s/100km^2)</th></tr>
<tr><td>TEPSCO HGS</td><td>2,292*</td><td>1,550</td><td>4.91</td><td>0.11</td><td>in Koh Kong, daily, 321 days (2005/3/27 - 2006/2/10)</td></tr>
<tr><td>Huai Sato</td><td>190</td><td>1,670</td><td>5.29</td><td>0.43</td><td>in Thai, monthly, 26 years (1971 - 1996)</td></tr>
</table>

*) measured by JICA Study Team on GIS
Source: Study Team

Dimensionless flow duration curves of observed discharge at the stations above are shown in the following figure:



Source: Study Team

Figure 6.3.24 Dimensionless Flow Duration Curve of Observed Discharge at Existing Hydrological Station in the Southwest Area

Even though Huai Sato has long-term data, it is located slightly away from the project area and in Thailand. In addition, only monthly data are available for Huai Sato. At the beginning of examination, discharge at Huai Sato could not be judged as reliable enough because its mean dry season discharge for the initial 6 years of the 26 years appeared over-rated.

Observed discharge at TEPSCO HGS is only for 1 year, and its flow duration curve is not smooth. However, TEPSCO HGS is the nearest station and only the station in the southwest area in Cambodia. Consequently, discharge at TEPSCO HGS was examined more in detail as follows:

(2) Reliability of Observed Discharge at TEPSCO HGS

Based on the catchment area and mean discharge, annual run-off at TEPSCO HGS is calculated at 1,550 mm. Besides, basin rainfall of TEPSCO HGS is estimated at 2,920 mm/yr referring to isohyets in the southwest area (refer to Figure 6.3.22).

Basin rainfall of TEPSCO HGS for the observed period (2005.3 - 2006.2) is estimated at 3,230 mm/yr referring to rainfall at Koh Kong. That is, (Rainfall at Koh Kong for TEPSCO HGS observation period: 4,087 mm) x (Basin Rainfall of TEPSCO HGS: 2,920 mm) / (Long-term Mean Annual Rainfall at Koh Kong: 3,690 mm).

Consequently, the run-off at TEPSCO HGS for the observed period (1,550 mm) was 48% of the rainfall 3,230 mm at TEPSCO HGS for the same period (3,230 mm), that is, run-off coefficient at TEPSCO HGS is estimated at 48%.

This value seems to be appropriate considering related existing study results (run-off coefficient at SRC/Atay in LSRC-F/S: 51%) and data at Huai Sato (ratio of discharge and rainfall at Huai Sato: 54%).

(3) Estimation of Long-term Mean Discharge at TEPSCO HGS

Based on the equation derived from correlation between observed discharge at TEPSCO HGS and rainfall at Koh Kong (monthly data for 15 years, 180 data), long-term time series of monthly discharge at TEPSCO HGS was estimated. Long-term mean discharge/dry season discharge and dimensionless flow duration curve estimated at TEPSCO HGS are shown in Table 6.3.7 and Figure 6.3.25.

Table 6.3.7 Estimated Long-term Mean and Dry Season Discharges at TEPSCO HGS

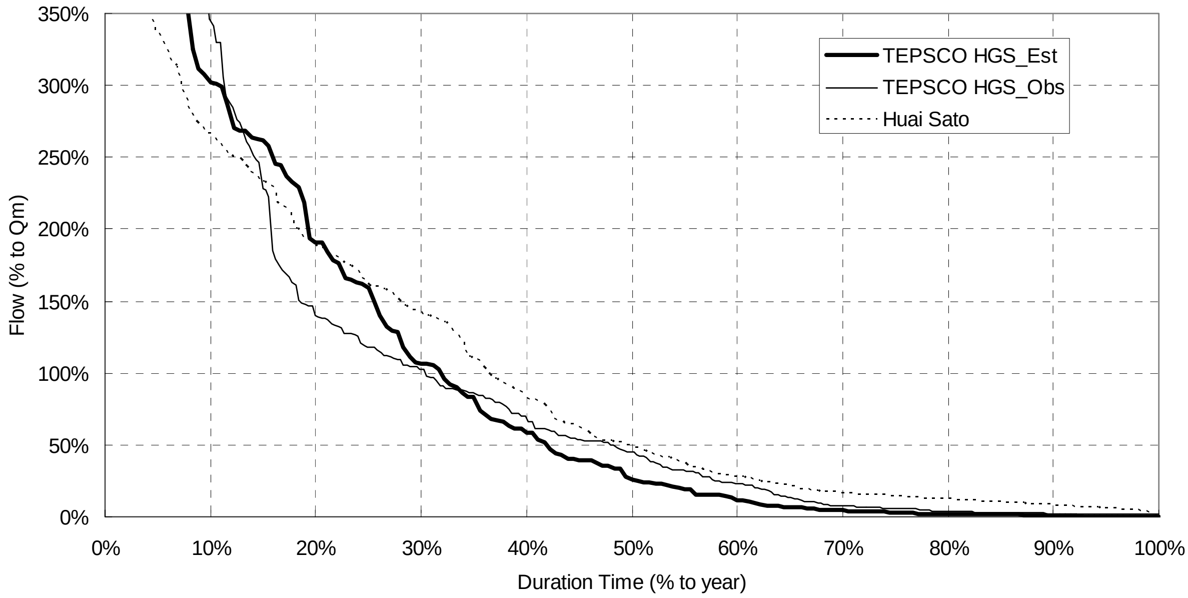
Discharge Data	C.A.	Basin Mean Rainfall	Annual Mean Discharge Qm		Run-off Coeff.	Dry Season Discharge Q_{90}		
	km^2	mm	m^3/s mm/yr	m^3/s/100km^2	%	m^3/s	m^3/s/100km^2	% to Qm
Estimated Long-term Discharge at TEPSCO HGS	2,292	2,920*	90.8 1,250	3.96	43	0.75	0.03	0.8
Observed Short-term Discharge at TEPSCO HGS	2,292	3,230*	113 1,550	4.91	48	2.50	0.11	2.2
Observed Discharge at Huai Sato	190	3,078**	10.1 1,670	5.29	54	0.81	0.43	8.1

*) estimated from isohyet (refer to Figure 6.3.22)
**) Mean annual rainfall at Huai Sato
Source: Study Team

As shown in the table above, long-term annual run-off height was estimated at 1,250 mm against 1,550 mm of the observed annual run-off for 1 year. It could be inferred that the estimated annual run-off was 81% (=1,250mm / 1,550 mm) of the observed annual run-off because the observed year had higher rainfall than the other years. According to the rainfall records at Koh Kong, the rainfall at Koh Kong for the observation period (1 year) of TEPSCO HGS was 4,087 mm. This is 111% of the long-term mean annual rainfall at Koh Kong (3,690 mm), suggesting that the period was actually rich in rainfall.

The long-term rainfall is 90% of the rainfall for TEPSCO HGS observation period, and it exceeds the 81% above for long-term annual run-off by 9%. For estimation of long-term average inflow, the reduction by 19% from the estimate for the one year may suggest an underestimate of the runoff height if compared with the reduction at 10% from the observed rainfall for the same year.

Considering such general hydrological characteristics that annual run-off coefficient also lowers when annual rainfall lowers, it can be a conservative estimate to avoid over-estimate of long-term mean run-off.



Source: Study Team

Figure 6.3.25 Dimensionless Flow Duration Curve of Estimated Discharge at TEPSCO HGS

(4) Estimation of Long-term Mean Discharge for 5 Projects in the Southwest Area

Based on the estimated mean discharge at TEPSCO HGS, mean discharge and dry season discharge for 5 projects in the southwest area were estimated using the following equation:

Long-term Mean/Dry Season Discharge $_{PROJECT}$ = Estimated Long-term Mean/Dry Season Discharge $_{TEPSCO\ HGS}$ x Basin Rainfall Ratio x Catchment Area Ratio

Where,

Basin Rainfall Ratio = Basin Average Rainfall $_{PROJECT}$ / Basin Average Rainfall $_{TEPSCO\ HGS}$ (=2,920 mm)

Catchment Area Ratio = Catchment Area $_{PROJECT}$ / Catchment Area $_{TEPSCO\ HGS}$ (=2,292 km^2)

Estimated long-term mean discharge and dry season discharge for the projects are shown in Table 6.3.8.

Table 6.3.8 Estimated Long-term Mean Discharge and Dry Season Discharge for 5 Projects in the Southwest Area

Project	Catchment Area	Basin Average Rainfall	Annual Mean Discharge Qm		Run-off Coeff.	Dry Season Discharge Q_{90}		
	km^2	mm	m^3/s mm/yr	$m^3/s/100km^2$	%	m^3/s	$m^3/s/100km^2$	% to Qm
MSRC	461	2,620	16.4 1,120	3.55	43	0.14	0.03	0.8
MTK2	416	3,010	17.0 1,290	4.09	43	0.14	0.03	0.8
MTK3	656	3,100	27.7 1,330	4.22	43	0.23	0.03	0.8
KP2	1,060	2,690	38.7 1,150	3.65	43	0.32	0.03	0.8
USRC	163	2,420	5.4 1,040	3.30	43	0.04	0.03	0.8

Source: Study Team

(5) Verification of Estimated Dry Season Discharge for 5 Projects in the Southwest Area

- Dry season discharges for 5 projects in the southwest area were estimated at 0.8% of Qm. It means that discharge drastically falls down in the dry season. This coincides with the fact that the discharge of rivers in the southwest area much differ between the rainy and dry seasons and the rivers often almost dry up in the dry season.
- In accordance with the observed discharge by the Study Team in February 2008 (dry season), discharge at #16 MSRC, #22 KP2 and Tatay were 0.1, 0.1 and 0.5 m^3/s, respectively. These observed discharges were in agreement with the estimated dry season discharges.

6.3.9 Estimation of Long-term Mean Discharge for Bokor Plateau Project

(1) Referable Hydrological Station

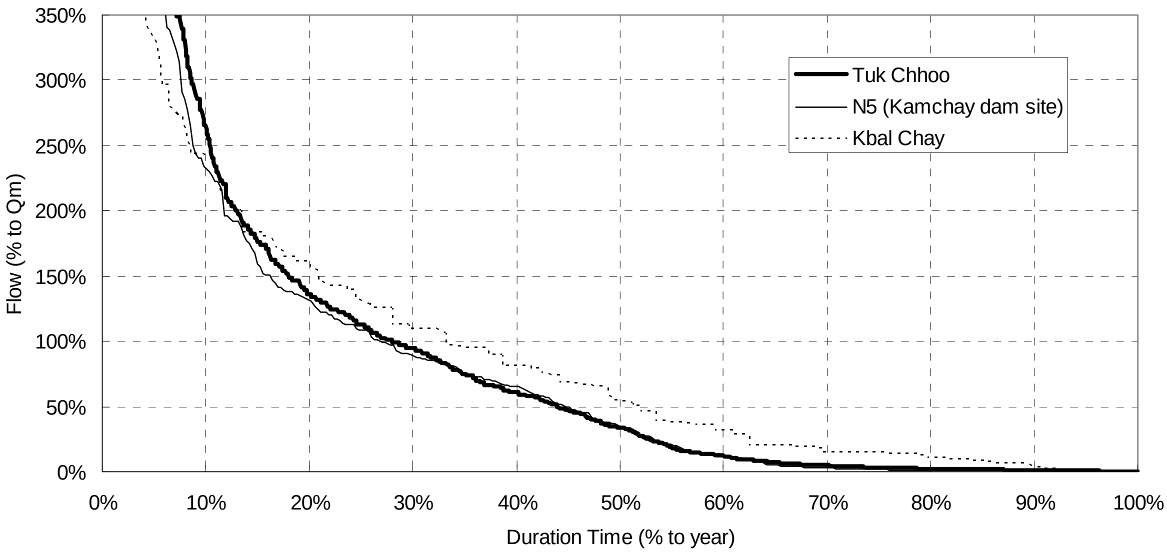
Existing hydrological stations around #29 Bokor Plateau (BP) Project are the following 3:

Table 6.3.9 Existing Hydrological Stations Related to BP

Hydrological Station	Catchment Area (km²)	Annual Mean Discharge Qm		Dry Season Discharge Q90 (m³/s/100km²)	Remarks
		Annual Run-off (mm/yr)	Specific Discharge (m³/s/100km²)		
Tuk Chhoo	745*	2,560	8.11	0.10	in Kamchay River basin, daily, 5 years (2001 - 2005)**
N5 (Kamchay dam site)	710	2,260	7.16	0.04	in Kamchay River basin, daily, 1 year (1964)
Kbal Chay	52.5	2,640***	8.38***	0.29***	in Sihanouk Ville (Prek Tuek sub river), daily, 1.5 years (2001/2/16 - 2002/8/31)

*) measured by JICA Study Team on GIS
**) converted from water level data of MOWRAM and H-Q curve in Kamchay-F/S (June 2002, EXPERCO)
***) derived from 1 year data (2001/3/1 - 2002/2/28)
Source: Study Team

Dimensionless flow duration curves of observed discharge at the stations above are shown in the following figure:



Source: Study Team

Figure 6.3.26 Dimensionless Flow Duration Curves of Observed Discharges at Existing Hydrological Stations Related to BP

(2) Estimation of Long-term Mean Discharge at N5 (Kamchay dam site)

Between the Tuk Chhoo and N5 stations, N5 station was examined more in detail because of the lower annual run-off recorded at N5.

- N5 data was observed in 1964, and its annual run-off is 2,260 mm.

- In accordance with rainfall data at Phu Quoc for 40 years, rainfall in 1964 was 96.5% (2,892 mm) for mean annual rainfall (3,000 mm).

Assuming that annual run-off at N5 in 1965 was 96.5% of the long-term average following the rainfall variation above at Phu Quoc, long-term annual run-off at N5 is estimated at 2,340 mm (= 2,260 / 0.965). In addition, the dry season discharge at N5 was estimated as 0.6% of Qm referring to the dry season discharge of observed discharge at N5.

Table 6.3.10 Estimated Long-term Mean Discharge and Dry Season Discharge at N5 (Kamchay dam site)

Discharge Data	C.A.	Basin Mean Rainfall	Annual Mean Discharge Qm		Run-off Coeff.	Dry Season Discharge Q_{90}		
	km^2	mm	m^3/s mm/yr	$m^3/s/100km^2$	%	m^3/s	km^2	mm
Estimated Long Term Discharge at N5	710	3,800*	52.7 <u>2,340</u>	7.42	62	0.31	0.04	<u>0.6</u>
Observed Discharge at N5	710	3,800*	50.9 2,260	7.16	59	0.30	0.04	<u>0.6</u>

*) assumed at average of annual rainfall at Bokor (4,922 mm), Sihanouk Ville (3,393 mm) and Phu Quoc (2,998 mm) = 3,771 mm -> 3,800 mm; annual rainfall at Kampot (1,939 mm) was not referred considering hydrological characteristics in the area

Source: Study Team

(3) Estimation of Long-term Mean Discharge for BP

Referable hydrological data for #29 BP is limited. Besides, basin rainfall of BP seems to be higher than that of Kamchay referring to isohyets in Figure 6.3.23. Consequently, it is conservative to apply the estimated run-off height at N5 (Kamchay dam site) to BP without rainfall adjustment. In addition, observed discharge at BP site by the Study Team in February 2008, 0.0013 m^3/s (2008.2.29), was assumed to be representative and applied to estimate of the dry season discharge of BP.

Estimated long-term mean discharge and dry season discharge for BP are shown in Table 6.3.11.

Table 6.3.11 Estimated Long-term Mean Discharge and Dry Season Discharge for BP

Project	Catchment Area	Basin Average Rainfall	Annual Mean Discharge		Run-off Coeff.	Dry Season Discharge Q_{90}		
	km^2	mm	m^3/s mm	$m^3/s/100km^2$	%	m^3/s	$m^3/s/100km^2$	% to Qm
BP	24.5	4,630	1.8 <u>2,340</u>	7.42	51	<u>0.0013</u>	0.01	0.1

Source: Study Team

(4) Verification of Estimated Discharge for BP

- Annual run-off at Kamchay dam site estimated in the Kamchay-FS (Jun. 2002, EXPERCO) is 2,450 mm (710 km^2, 55.2 m^3/s). This value is 5% higher than the value estimated by the Study Team (2,340 mm).
- Dry season discharge for #29 BP was estimated at 0.1% of Qm. It shows that discharge drastically falls down in the dry season. This coincides with the fact that rivers in central mountainous area often almost dry up in the dry season like rivers in the southwest area. Observed minimum daily discharge at Tuk Chhoo, N5 and Kbal Chay are 0.17, 0.10 and 0.0002 m^3/s, respectively.

6.3.10 Estimation of Long-term Mean Discharge for Lower Sre Pok II + Lower Se San II (LL2)

(1) Referable Hydrological Station

The following table shows existing hydrological stations in Se San and Sre Pok basins related to #7&8 LL2 Project.

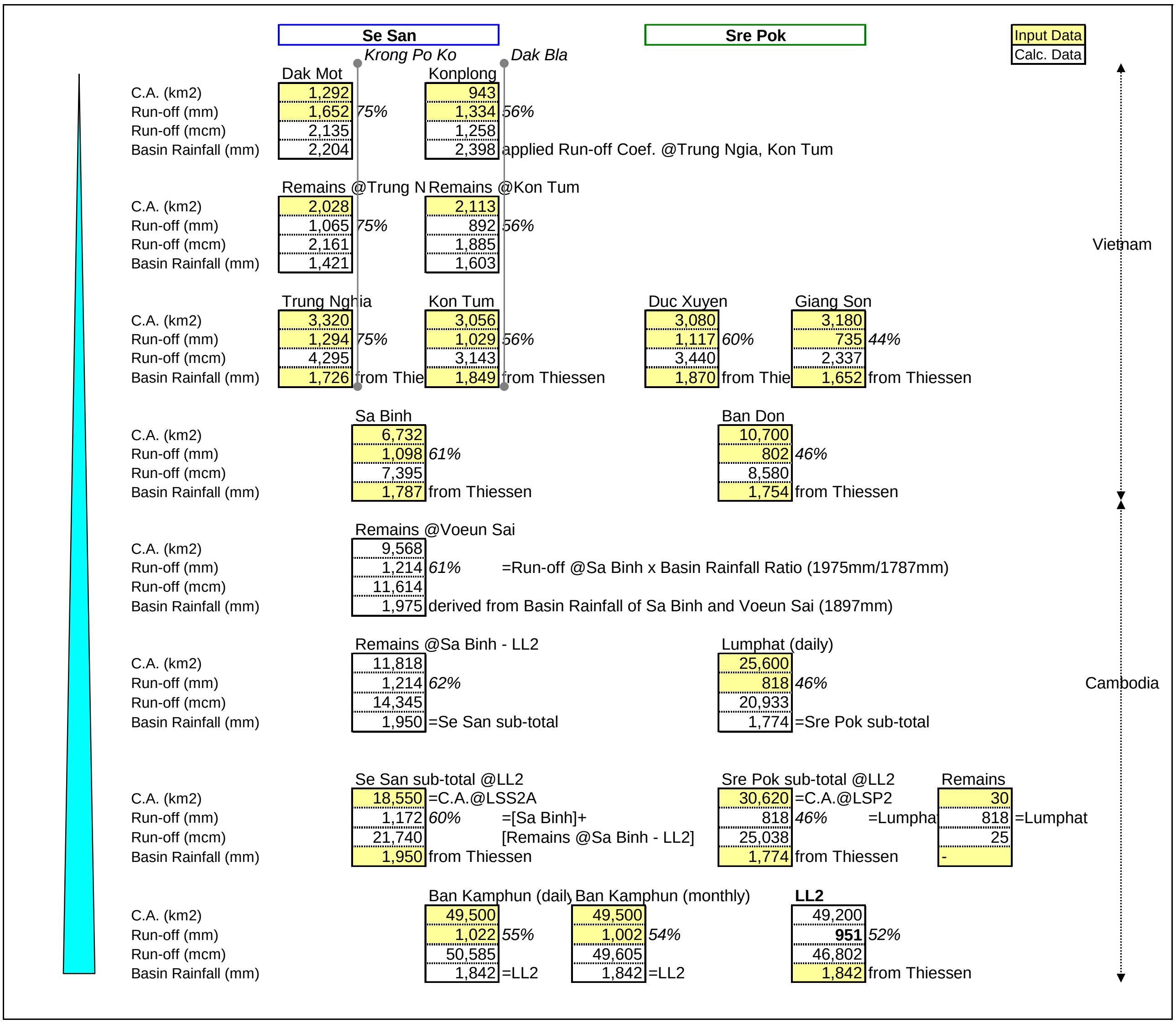
Table 6.3.12 Existing Hydrological Station Related to LL2

Hydrological Station	Catchment Area (km^2)	Annual Mean Discharge Qm		Dry Season Discharge Q_{90} ($m^3/s/100km^2$)	Remarks
		Annual Run-off (mm/yr)	Specific Discharge ($m^3/s/100km^2$)		
Ban Kamphun	49,500	1,020	3.24	0.50	daily, 7 years (1961 - 63, 66 - 69)
		1,000	3.18	0.58	monthly, 65 years (1926 - 90)
Voeun Sai	16,300	1,310	4.15	0.75	SS, daily, 1 year (1965)
Andaung Meas	11,779*	1,400	4.44	0.71	SS, daily, 2 yeas (2002, 2005)
Kon Tum*	3,056	1,030	3.26	1.00	SS, daily, 23 years (1978 - 2000)
Trung Ngia*	3,320	1,290	4.10	1.00	SS, daily, 8 years (1990 - 1997)
Sa Binh*	6,732	1,100	3.48	1.28	SS, daily, 9 years (1982 - 1990)
Dak Mot**	1,292	1,650	5.24	-	SS
Konplong**	943	1,330	4.23	-	SS
Lumphat	25,600	818	2.59	0.21	SP, daily, 6 years (69, 01 - 03, 05 - 06)
		1,140	3.60	0.63	SP, monthly, 54 years (42 - 90, 01 - 03, 05 - 06)
Giang Son*	3,180	735	2.33	0.37	SP, daily, 24 years (1977 - 2000)
Ban Don*	10,700	802	2.54	0.52	SP, daily, 24 years (1977 - 2000)
Duc Xuyen*	3,080	1,120	3.54	0.80	SP, daily, 23 years (1978 - 2000)

*) data from Study on Nationwide Water Resources Development and Management in the Socialist Republic of Vietnam (JICA, Sep. 2003)
**) data from Comprehensive Development Study of Hydropower in Se San River Basin in Cambodia (PECC1, Oct. 2006)
Source: Study Team

(2) Run-off Characteristics of Se San and Sre Pok Basin

The following figure shows run-off characteristics of Se San and Sre Pok basins based on the above discharge data:



Remarks) Voeun Sai and Andaung Meas were excluded in the above water balance due to short observation period and uncertainty.
Source: Study Team

Figure 6.3.27 Run-off Characteristics of Se San, Sre Pok Basin

(3) Estimation of Long-term Mean Discharge for LL2 Project

Annual run-off at #7&8 LL2 was estimated at 951 mm based on Figure 6.3.27. Dry season discharge at LL2 was estimated at 15% of Qm referring to the dry season discharge observed at Ban Kamphun. Estimated mean discharge and dry season discharge for LL2 are shown in Table 6.3.13.

Table 6.3.13 Estimated Long-term Mean Discharge and Dry Season Discharge for LL2

Project	Catchment Area	Basin Average Rainfall	Annual Mean Discharge Qm		Run-off Coeff.	Dry Season Discharge Q_{90}		
	km^2	mm	m^3/s mm	$m^3/s/100km^2$	%	m^3/s	$m^3/s/100km^2$	% to Qm
LL2	49,200	1,842	1,483.7 951	3.02	52	222.6	0.45	15

Source: Study Team

(4) Verification of Estimated Discharge for LL2 Project

- Annual run-off observed at Ban Kamphun is 1,020 mm based on the daily data and 1,000 mm based on the monthly data. Besides, annual run-off at #7&8 LL2 estimated in the PECC1 study is 858 mm (49,200 km^2, 1,340 m^3/s). The estimated value of the Study Team at 951 mm is between the two estimates.
- Dry season discharge at Ban Khmon (downstream of Se Kong), which is near the site and has a large catchment, is about 15% of Qm.

6.3.11 Estimation of Long-term Mean Discharge for Prek Liang Projects

(1) Referable Hydrological Station

The following table shows existing hydrological stations in the Se San basin (LL2) related to Prek Liang (PL) Projects.

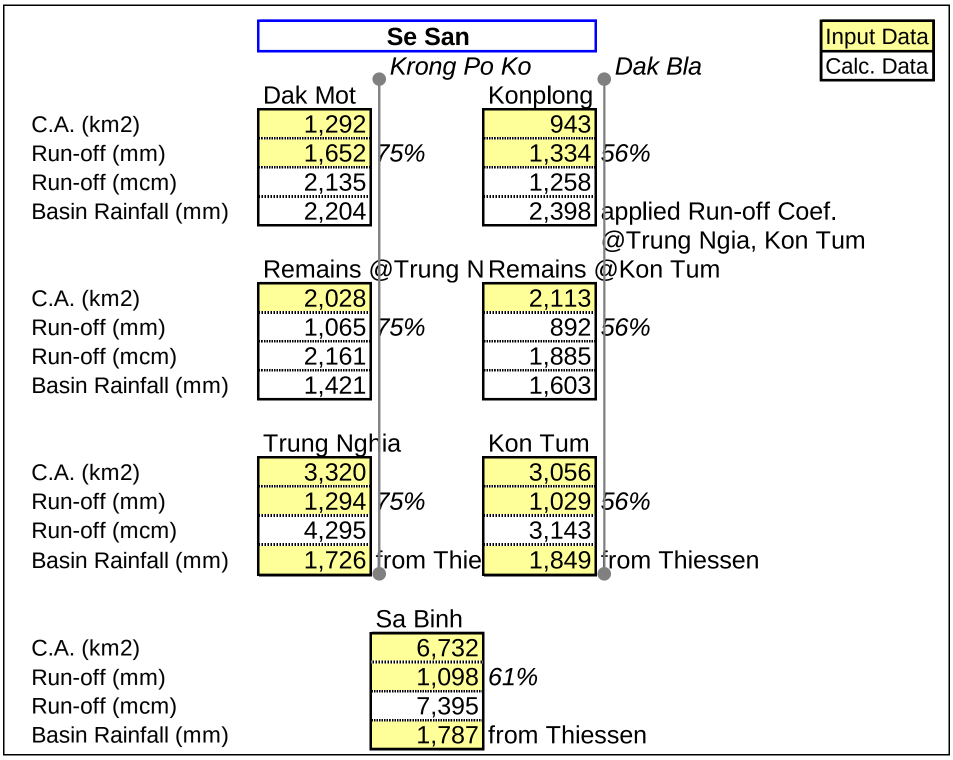
Table 6.3.14 Existing Hydrological Stations Related to PL

Hydrological Station	Catchment Area (km^2)	Annual Mean Discharge Qm		Dry Season Discharge Q90 ($m^3/s/100km^2$)	Remarks
		Annual Run-off (mm/yr)	Annual Run-off (mm/yr)		
Voeun Sai	16,300	1,310	4.15	0.75	SS, daily, 1 year (1965)
Andaung Meas	11,779*	1,400	4.44	0.71	SS, daily, 2 yeas (2002, 2005)
Kon Tum*	3,056	1,030	3.26	1.00	SS, daily, 23 years (1978 - 2000)
Trung Ngia*	3,320	1,290	4.10	1.00	SS, daily, 8 years (1990 - 1997)
Sa Binh*	6,732	1,100	3.48	1.28	SS, daily, 9 years (1982 - 1990)
Dak Mot**	1,292	1,650	5.24	-	SS
Konplong**	943	1,330	4.23	-	SS

*) data from Study on Nationwide Water Resources Development and Management in the Socialist Republic of Vietnam (JICA, Sep. 2003)
**) data from Comprehensive Development Study of Hydropower in Se San River Basin in Cambodia (PECC1, Oct. 2006)
Source: Study Team

(2) Run-off Characteristics of Se San Upstream Basin

The following figure shows run-off characteristics of the Se San upstream basin based on discharge data above.



Source: Study Team

Figure 6.3.28 Run-off Characteristics of Se San Upstream Basin

(3) Estimation of Long-term Mean Discharge for PL Projects

Among annual run-off data in the figure above, referable values for PL Projects are: (1) 1,070 mm at Krong Poko downstream basin; (2) 1,030 mm at Kon Tum basin (whole Dak Bla basin); and (3) 1,100 mm at Sa Binh basin (Krong Poko + Dak Bla basin) considering the basin directions and elevations against monsoons.

Of the three data above, (1) 1,070 mm at Krong Poko downstream basin was applied to estimating annual run-off of PL projects, since it is adjacent to the project area, the catchment area is similar, and topographic and geographic conditions toward two monsoons are comparable.

With regard to the dry season discharge, Trung Nha basin is 24% of Qm, Kon Tun basin is 31% of Qm, Sa Binh basin is 37% of Qm, and O Ronis basin in Mondul Kiri Province, which is expected to be similarly affected by the two monsoons, is 32% of Qm. The value of Sa Binh basin may not be referable because it is affected by existing Yali hydropower. Consequently, an average of remaining three values, 30%, was applied to the dry season discharge of PL projects.

Estimated long-term mean discharge and dry season discharge of PL projects are shown in Table 6.3.15.

Table 6.3.15 Estimated Long-term Mean Discharge and Dry Season Discharge for PL Projects

Project	Catchment Area	Basin Average Rainfall	Annual Mean Discharge Qm		Run-off Coeff.	Dry Season Discharge Q90		
	km^2	mm	m^3/s mm	$m^3/s/100km^2$	%	m^3/s	$m^3/s/100km^2$	% to Qm
new PL1	839	1,840	28.5 1,070	3.39	58	8.5	1.02	30
new PL2	575	1,850	19.5 1,070	3.39	58	5.9	1.02	30

Source: Study Team

(4) Verification of Estimated Discharge for PL Projects

- In accordance with the discharge measurement by the Study Team made once in February 2008 (dry season), the discharge downstream of the PL1 outfall site (catchment area is about 1,000 km^2) was 13.4 m^3/s (1.34 $m^3/s/100km^2$). The observed specific discharge shows similar level to the specific discharge of the estimated dry season discharge (1.02 $m^3/s/100km^2$).
- Annual run-off height of PL1 and PL2 estimated in the PECC1 study were 1,260 mm (883 km^2, 35.4 m^3/s) and 1,270 mm (595 km^2, 23.9 m^3/s) respectively, and those are 18% higher than the estimates of the Study Team (1,070 mm). Comparing to annual run-off of the Se San upstream basin shown in Figure 6.3.25, 1,260 mm of the estimate of PECC1 seems rather high. On the other hand, 1,070 mm of the estimate of the Study Team may possibly be conservative. It is needed to confirm the discharge by actual measurements in the following stage of these projects.
- The estimated dry season discharge of PL projects is 30% of Qm. This is double the value (15%) of

Ban Kamphun (confluence of Se San and Sre Pok). The discharge condition is preferable and it is considered because of the two monsoons.

6.3.12 An overview of runoff characteristics of basins in Cambodia

The Study Team estimated the long term annual discharge, the runoff coefficient, and the rate of decrease of dry season discharge against annual average discharge for each hydropower project site, based on 1) the existing reports, 2) analysis on hydrological records, and 3) actual discharge measurement by the Study Team itself. Table 6.3.16 shows the summary of hydrological characteristics for each hydropower potential region. Table 6.3.17 shows the estimated hydrological values for each hydropower project site.

The hydropower potentials in Cambodia are available in the three areas: the South-western Region centering at Koh Kong Province, Central Mountain over Kampot and Kampong Speu Provinces, and North-eastern Region of Ratanak Kiri and Mondul Kiri Provinces. Rain-gauges and stream gauging stations existing in these 3 regions are limited only to the North-eastern Region. Even if we view over whole Cambodia, the observatories and gauges are concentrated to the Tonle Sap Region and along the mainstream of Mekong, which are apart from the hydropower potential regions and are different in hydro-meteorological conditions. Accordingly, it would incur significant errors if we base our hydropower planning on the rainfall and runoff records of these observatories and gauges. This absolute limitation in the hydro-meteorological data available for development planning is one of the greatest issues in developing the hydropower potentials in Cambodia.

Table 6.3.16 Runoff Features by Region of Hydropower Potentials in Cambodia

No.	Item	Symbol	Unit	North-eastern Region	Central Mountain	South-western Region
1.	Annual basin rainfall	Ra	mm	around 1,800	3,800-4,600	2,500-3,100
2.	Annual runoff height	Qa	mm	900-1,100	2,350-	1,000-1,300
3.	Annual runoff coefficient	Ca	-	0.50-0.60	0.51-0.62	around 0.43
4.	Ration of Dry season flow against Annual mean flow	Qd/Qa	%	15-30	0.1-0.6	0.8

Source: Study Team

In the present Hydropower Master Plan Study, we had a chance to review and compare the runoff features of the hydropower potentials all over the country from the macroscopic viewpoint based on the rain-gauges and stream gauging stations available in Cambodia. Then, the runoff features have been clarified as summarized in the above table. Appropriate estimate of the annual runoff height will directly result in assessment of annual energy generation, which would further control the dependability of operating revenue of power sales and financial viability of each project.

Table 6.3.17 Summary of Estimated Runoff Features of Existing and Priority Projects

No.	Project	Source	Basin Area (km²)	Basin Rainfall (mm/yr)	Runoff Height (mm/yr)	Annual Runoff Coefficient	Average Discharge Q_m (m³/s)	Q_{90} or Qd (m³/s)	Q_{90}/Q_m	Remarks
Estimates by past studies and existing plans										
1	Kamchay	EXPERCO -JST	710	**3,800**	**2,350**	**0.62**	52.9	0.30	0.006	FS by EXPERCO 2002, basin rain & Q_{90}
2	Kirirom 3	CEPT	105	**2,600**	**1,240**	**0.48**	4.1	-	-	Fs by CEPT 2005
4	Lower Stung Russey Chrum	Tepsco	1,550	**2,690**	**1,380**	**0.51**	67.8	-	-	FS by TEPSCO 2006
3	Stung Atay	KFIC	567	**3,026**	**2,280**	**0.75**	41	-	-	FS by KFIC Feb. 2006
		Tepsco	550	**2,390**	**1,220**	**0.51**	21.3	-	-	p. 4-29, TEPSCO 2006
4	New Tatay (same as Kep II)	CNHMC	1,073	**2,850**	**2,030**	**0.71**	69.1	-	-	FS by CNHMC Dec. 2007
5	Bokor Plateau	IDICO	25	**3,100**	-	-	2.4	-	-	FS by IDICO
6	LL2	PECC1	49,200	**1,840**	**852**	**0.46**	1,330	246	0.185	FS by PECC1, basin rain by JST
7	O Romis, Mondol Kiri	JICA	38	**1,810**	**1,370**	**0.76**	1.7	0.52	0.306	JICA BD report, possibility of higher basin rainfall?
Estimates by JICA Study Team										
North-eastern Region										
8	Prek Liang I	JST	839	*1,790*	**1,070**	**0.60**	28.5	8.55	**0.300**	Measured at 13.4 m³/s d/s of PL1 outfall on 2008.2.5
9	Prek Liang II	JST	575	*1,840*	**1,070**	**0.58**	19.5	5.85	**0.300**	
10	LL2	JST	48,200	1,840	**951**	**0.52**	1,450	218	**0.150**	
Central Mountains										
11	Bokor Plateau	JST	23.8	4,630	**2,350**	**0.51**	1.8	0.0013	**0.001**	Measured at 0.0013 m³/s on 2008.2.29
South-western Region										
12	Stung Kep II (new Tatay of CNHMC)	JST	**1,085**	**2,690**	**1,150**	**0.43**	**39.6**	**0.33**	**0.008**	Measured at 0.58 m³/s on 2008.2.14-15
13	Upper Stung Russey Chrum	JST	**170**	**2,420**	**1,040**	**0.43**	**5.6**	**0.05**	**0.009**	
14	Middle Stung Russey Chrum	JST	**473**	**2,620**	**1,120**	**0.43**	**16.8**	**0.14**	**0.008**	Measured at 0.1 m³/s on 2008.2.22
15	Stung Metoek II	JST	**432**	**3,010**	**1,290**	**0.43**	**17.7**	**0.15**	**0.008**	
16	Stung Metoek III	JST	**673**	**3,100**	**1,330**	**0.43**	**28.4**	**0.24**	**0.008**	

Source: Study Team

The following runoff features of hydropower potentials in Cambodia may be derived from Tables 1.2.1 and 1.2.2:

(1) The highest basin rainfall of around 4,000 mm/yr is observed at Central Mountains that soars high for more than 1,000 m facing the Gulf of Thailand to the northwest of Kampot. The next high rainfalls of 2,500-3,100 mm are observed in the South-western Region around Koh Kong Province also facing the Gulf of Thailand. The North-eastern Region of Ratanak Kiri Province is situated far from the Gulf and has relatively low rainfalls of around 1,800 mm. The rainfalls in Pursat Province, which is situated on the southern shore of Tonle Sap behind the Cardamom

Mountains looking from the Gulf of Thailand, is the lowest at 1,100-1,600 mm being about one half of that in the coastal areas.

(2) In terms of annual runoff height, the Central Mountain has the highest rainfall outstanding at 2,350 mm in Cambodia. It is estimated to lower to about one half of it or 1,000-1,300 mm in the South-western Region, and 900-1,100 mm in the North-eastern Region. The annual runoff height is in proportion to the annual basin rainfall, and about one half of the annual rainfall would come out to and runs down the river courses.

(3) In terms of annual runoff coefficient, it is the highest at 0.62 in the Central Mountain[4] while low at about 0.43 in the South-western Region. In the North-eastern Region where the basin rainfall is lowest among the three hydropower potential regions, the runoff coefficient is estimated to be relatively high at 0.50-0.60[5].

(4) In the Central Mountains and South-western Region the dry season runoff drops distinctly. It dropped on the Kamchay river in March to April 1964 to 0.6% of the annual mean of 1964. On the contrary, in the North-eastern Region the dry season runoff is remarkably high at 15-30% of the annual mean. As noted in the right-hand-most column of Table 6.3.17, this high dry season runoff in the North-eastern Region was supported by the discharge measurements made by the Study Team in February 2008.

(5) In the North-eastern Region, there is the second small rainy season from November to January next year being affected by the Northeast Monsoon, which results in relatively limited drops in the dry season runoff in that Region. On the contrary, because of almost no rainfalls in the Central Mountains and South-western Region from November through to April next year, the rivers mostly dry up in February onward. Thus the North-eastern Monsoon creates the distinct difference in the hydrology between the two Regions.

(6) Similarly, the reason for relatively high annual runoff coefficient in the North-eastern Region is: 1) as a result of the rainfalls continuing up to January owing to the Northeast Monsoon, and 2) the Southwest Monsoon will start from May before the basin has become fully dry. On the contrary, the runoff coefficient of the South-west Region, which is featured by the distinct dry season, is

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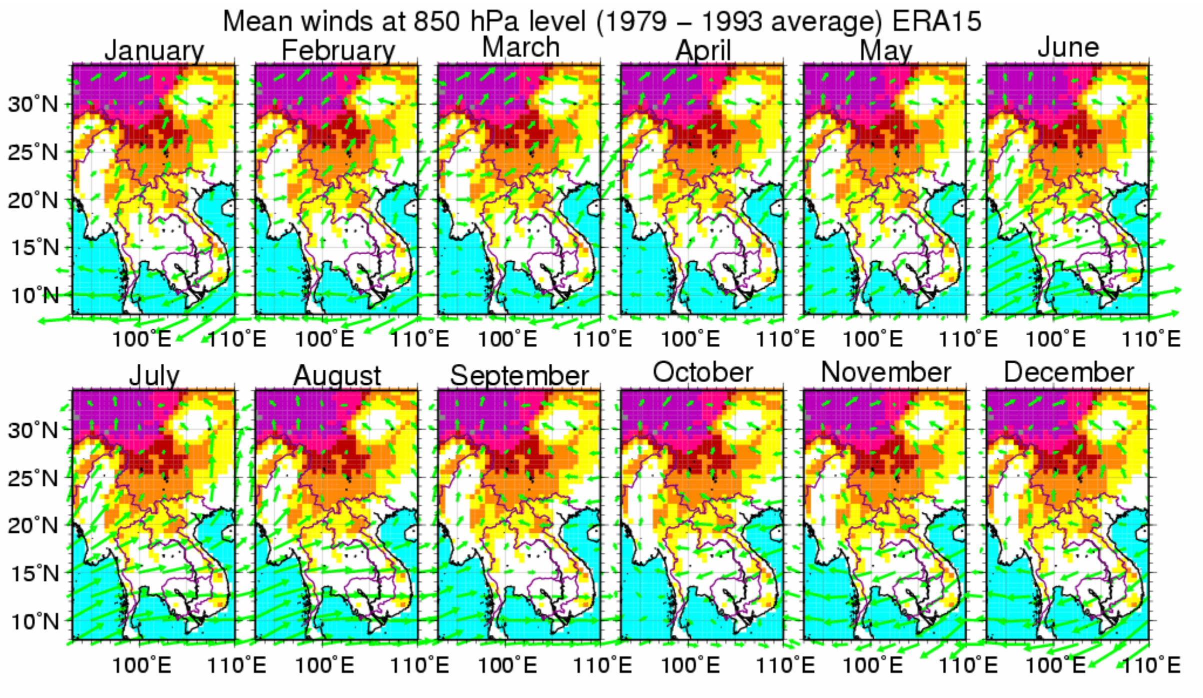
[4] The annual runoff coefficient of Bokor Plateau project may be obtained as 0.51. However, such calculation is based on the rainfall records of only one gauge and no stream gauging records at all. Accordingly, it was assumed to be on conservative side that the annual runoff height was the same with that of Kamchay project. There remains a possibility that the coefficient might be high at around 0.6 like at Kamchay.

[5] The runoff coefficients in Cambodia are 27-32% in the Pursat basins, 46-51% in the Lower Stung Russey Chrum basin, 52% at Huai Sato, Thailand, 57% at Kirirom III project site, 57% at Khlong Yai river basin, Thailand. It is in a general range of 27-57%. The coefficient of 0.62 at Kamchay is outstanding. One at O Romis is further high at 0.76. However, it would need checking of a possibility of underestimate of the basin rainfalls.

The specific runoff is very high at 5.29 $m^3/s/100\ km^2$ (=1,670 mm/yr) at Huai Sato, Thailand located adjacent to the South-western Region. On the contrary the specific runoff is very low at 1.28 $m^3/s/100\ km^2$ (=404 mm/yr) in the Pursat basins situated on the northern slopes of the Cardamon Mountains, which is about one fourth of Huai Sato. It is estimated that (1) Annual rainfall (R) is about double at Huai Sato being 3,000 mm against 1,400 mm in Pursat basins; (2) as a result of this great difference in the annual rainfalls and slopes of riverbed, annual runoff coefficient (C) is also about double at Huai Sato being at 52%+ against 27-32% in Pursat basins; (3) As a results, specific runoff may be expressed as $Q_{SW} = R_{SW} \times C_{SW}$ $2R_{pr} \times 2C_{pr}$ $4Q_{pr}$. It is estimated thus the great difference has been observed in the annual runoff height of about four times in the two adjacent basins.

estimated to be around 0.5 or lower. It further lowers in the Pursat and Kampong Speu Provinces which are located in the inland with less annual rainfalls.

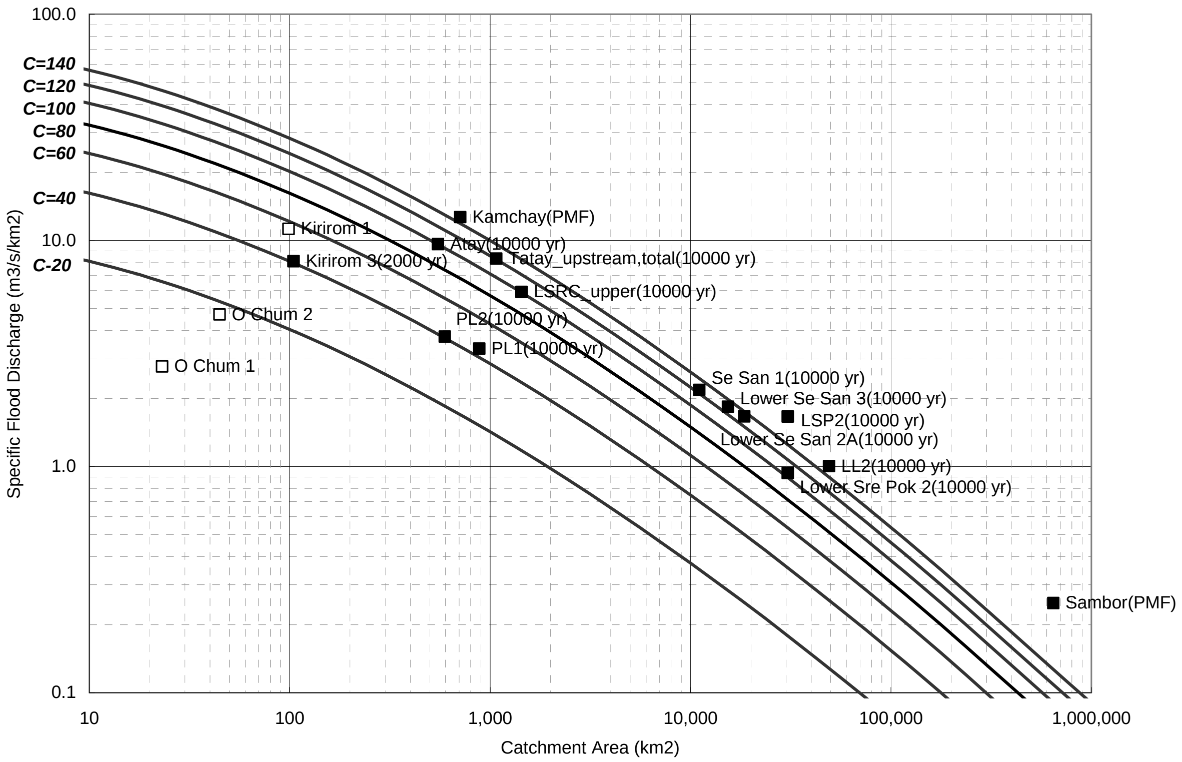


Source: ERA15 (European Centre for Medium-Range Weather Forecasts (ECMWF), 15-year Re-Analysis) data set, Kouichi Masuda

Figure 6.3.29 Seasonal Variation of Monsoon Directions

6.3.13 Flood Discharge

Figure 6.3.30 shows design flood discharges of existing hydropower plans and Creager's Curve.



		km2	m3/s	m3/s/km2		
Existing	Kirirom 1	98.8	1,110.0	11.2		
	O Chum 1	23.1	64.0	2.8		
	O Chum 2	44.7	210.0	4.7		
Kamchay-F	Kamchay	710.0	9,000.0	12.7	PMF	
CETIC	Kirirom 3	104.6	524.0	5.0	100 yr	
		104.6	845.0	8.1	2000 yr	
Chugoku El	LSP2	30,620.0	51,000.0	1.7	10000 yr	
KEPCO		29,490.0	51,000.0	1.7	10000 yr	
Mekong Se	Sambor	646,000.0	161,000.0	0.2	PMF	
LSRC-F/S	LSRC (upper)	1,437.0	8,500.0	5.9	10000 yr	C=100
(TEPSCO)	LSRC (lower)	1,550.0	8,800.0	5.7	10000 yr	C=100
	Atay	550.0	5,300.0	9.6	10000 yr	C=100
PECC1	Se San 1	11,070.0	24,163.0	2.2	10000 yr	
	Lower Se San 3	15,400.0	28,312.0	1.8	10000 yr	
	Lower Se San 2A	18,550.0	30,957.0	1.7	10000 yr	
	Lower Sre Pok 2	30,620.0	28,666.0	0.9	10000 yr	
	LL2	49,200.0	49,443.0	1.0	10000 yr	
	PL1	883.0	2,934.0	3.3	10000 yr	
	PL2	595.0	2,234.0	3.8	10000 yr	
Tatay-F/S	Tatay (upstream, nor	529.0	4,390.0	8.3	10000 yr	
(CHMC)	Tatay (upstream, sou	544.0	4,520.0	8.3	10000 yr	
	Tatay (upstream, tota	1,073.0	8,910.0	8.3	10000 yr	
	Tatay (downstream)	1,088.0	9,030.0	8.3	10000 yr	
	Tatay (plant site)	1,143.0	9,500.0	8.3	10000 yr	

- □ Kirirom 1
- □ O Chum 1
- □ O Chum 2
- ■ Kamchay(PMF)
- ■ Kirirom 3(2000 yr)
- ■ LSP2(10000 yr)
- ■ Sambor(PMF)
- ■ LSRC_upper(10000 yr)
- ■ Atay(10000 yr)
- ■ Se San 1(10000 yr)
- ■ Lower Se San 3(10000 yr)
- ■ Lower Se San 2A(10000 yr)
- ■ Lower Sre Pok 2(10000 yr)
- ■ LL2(10000 yr)
- ■ PL1(10000 yr)
- ■ PL2(10000 yr)
- ■ Tatay_upstream,total(10000 yr)

Source: Study Team

Figure 6.3.30 Design Flood Discharge of Existing Hydropower Plan and Creager's Curve

According to the figure above, most of the design flood discharges with 1/10,000 probability are ranged between C=100 to C=140.

For the cases of C=100, C=120, and C=140, flood discharge of priority projects are estimated as below:

Table 6.3.18 Flood Discharge of Priority Projects for Creager's C = 100, 120, 140

	PJT No.	Project	Flood Discharge (m^3/s)		
			C=100	C=120	C=140
1	7&8	Lower Sre Pok II + Lower Se San II	31,500	37,800	44,140
2	12	new Prek Liang I	6,540	7,850	9,150
3	14	new Prek Liang II	5,410	6,490	7,580
4	16	Middle St. Russey Chrum	4,830	5,790	6,760
5	20	Stung Metoek II	4,570	5,490	6,400
6	21	Stung Metoek III	5,790	6,940	8,100
7	22	Stung Kep II	7,320	8,780	10,200
8	23	Upper St. Russey Chrum	2,710	3,250	3,800
9	29	Bokor Plateau	791	949	1,110

Source: Study Team

6.3.14 Sediment Transport

With regard to issues of the sediment transport, MOWRAM has conducted observation of the total suspended solid (TSS) as part of monthly observation of river water quality. Table 6.3.17 shows average TSS of each river from January 2005 to December 2006.

Table 6.3.19 Total Suspended Solid (TSS) of Each River

Station ID	Station Name	River	Catchment Area	Mean Discharge	Average TSS	
			CA km^2	Qm m^3/s	mg/l*	m^3/km^2/yr**
H014501	Stung Treng	Mekong	635,000	13,200	64.7	33
H020107	Backprea	Battambang	514	9.0	126.3	54
H440103	Andoung Meas	Se San	11,779	523	32.2	35
H450101	Lumphat	Sre Pok	25,600	664	34.6	22
H430102	Siempang	Se Kong	23,500	911	49.6	47

*) observed data
**) derived from C.A. and Qm
Source: Study Team

The table above shows that the specific Total Suspended Solid (TSS) values of Se San and Sre Pok are around one half of the values of Battambang and Se Kong.

The following table summaries the data of sediment transport estimated in the existing studies.

Table 6.3.20 Sediment Transports by Existing Studies

No.	Project	Sediment Production* ($m^3/km^2/yr$)
1	Nam Theun 1	142
2	Se Kong 4	135
3	Se Kong 5	143
4	Xe Kaman 3	277
5	Nam Kong 1	170
6	Houay Lamphan Gnai	236
7	Lower Sre Pok 2	36
8	Lower Se San 2	36
9	Se San 3	260
10	Se San 4	378
11	Upper Kontum	244
12	LSRC Upper	460
13	LSRC Lower	549

*) #1 - 11: data from Se Kong - Se San and Nam Thuen River Basins Hydropower Study (ADB/Halcrow, Jul. 1999), #12 & 13: data from Lower Stung Russey Chrum Hydropower Project (TEPSCO, Aug. 2006)
Source: Study Team

Assuming that sediment transport for the priority project is 200 m^3/km^2/year, sediment volumes of each project for 100 years are tentatively assumed at this MP stage as follows:

Table 6.3.21 Sediment Volume assumed for Priority Projects for 100 Year

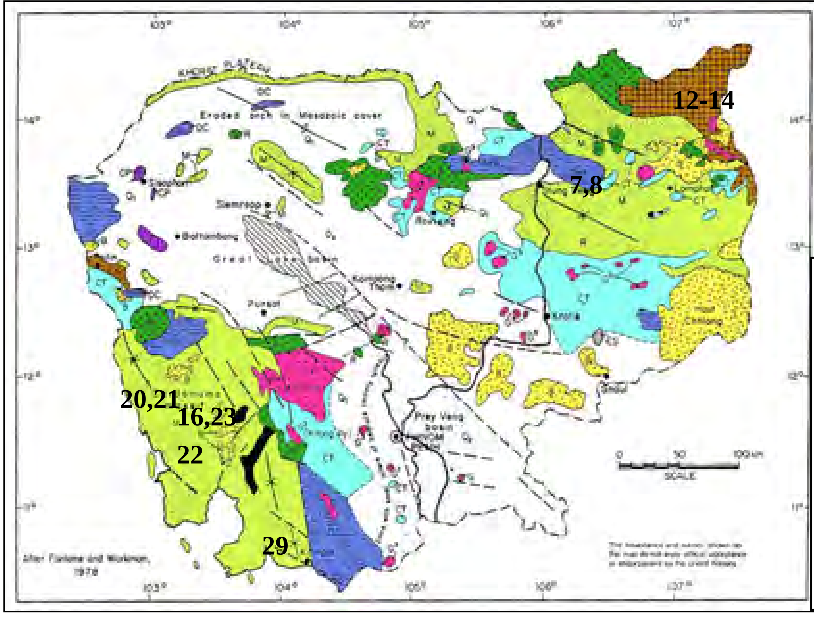
	PJT No.	Project	Catchment Area	Sediment Volume
			km^2	mcm/100yr
1	7&8	Lower Sre Pok II + Lower Se San II	49,200	984
2	12	new Prek Liang I	839	16.8
3	14	new Prek Liang II	575	11.5
4	16	Middle St. Russey Chrum	461	9.2
5	20	Stung Metoek II	416	8.3
6	21	Stung Metoek III	656	13.1
7	22	Stung Kep II	1,060	21.2
8	23	Upper St. Russey Chrum	163	3.3
9	29	Bokor Plateau	24.5	0.5

Source: Study Team

6.4 GEOLOGY

6.4.1 Regional Geology

Geological features of Cambodia vary. It consists of sedimentary, metamorphic, and igneous rocks extending from the Precambrian through Quaternary geologic age, as summarized in the geological map from an ESCAP report[*6] (see Figure 6.4.1). According to said report, Cambodia territory is classified into geologic units as shown in Table 6.4.1.



Source: ESCAP report

Figure 6.4.1 Geological Map of Cambodia

Table 6.4.1 Geologic Units of Cambodia

Exposed basement of the Kontum Massif		
(brown)	PC	Precambrian – Early Palaeozoic granites and high grade metamorphics
Zones of Indosinian folding		
(blue)	DC	Anticlinorial zones
(cyan)	CT	Synclinorial zones
Undeformed or gently folded cover strata		
(purple)	C-P	Paleozoic sedimentary units
(dark green)	A, R	Volcano-sedimentary units
(light green)	M	Mesozoic sedimentary units
(yellow)	B	Neogene – Quaternary platform basaltic rocks
	Q	Quaternary sedimentary rocks and unconsolidated sediments
Intrusive rock groups		
(magenta)	G	Pre-Carboniferous to Cretaceous intrusives

Source: ESCAP report

As shown in Figure 6.4.1, surface geology in Cambodia can be divided into unconsolidated sediments in the Quaternary lying on the northwest, central, to southeast of the territory and the rocks lying on the northeastern and southeastern parts.

*6 UNITED NATIONS (1993): Atlas of Mineral Resources of the ESCAP Region, Vol. 10, CAMBODIA, Explanatory Brochure

The unconsolidated sediments are formed by the slight subsidence of the broad area along the northwest-southeast axes of the Quaternary. The great basin of Tonle Sap lies at the center of the subsided area. Topography of the area ranges from very gentle to flat due to the gentle subsidence and filling of depression parts with unconsolidated sediments.

The areas underlain by rocks can be divided into two geologic groups, and further subdivided into four subgroups in terms of lithfacies (geologic component) and geo-tectonic evolution as summarized below:

(1) Old and hard rocks

An intense geotectonic event (the Indosinian orogeny) occurred on a wide area of Cambodia and its surrounding areas, marked by a strong folding that began in the late Permian age, and culminated in the middle Triassic age. Old rocks from Pre-Cambrian to Permian age consist of hard rocks, originating from marine deposits, which were folded and faulted by the geotectonic activities. Very roughly speaking, general features of the rocks can be summarized as follows:

1) The oldest subgroup
- Age: Pre-Cambodian
- Main components: Granite and high-grade metamorphic rocks (Gneiss, Amphibolite, etc)
- Original features: Very stiff and relatively coarse grained
- Deformation features: The adverse influence of tectonic activities such as crushing and shearing is not so remarkable at an outcrop scale.

2) Old subgroup
- Age: Cambrian to middle Carboniferous
- Main components: Low- to medium-grade metamorphic rocks, shale, cherty shale, sandstones, marl, silicified shale
- Original features: Relatively stiff and fine to medium grained
- Deformation features: The adverse influence of tectonic activities such as crushing and shearing is remarkable at an outcrop scale.

3) Middle subgroup
- Age: Upper Carboniferous to Permian
- Main components: Limestone
- Original features: Stiff and massive
- Deformation features: The adverse influence of tectonic activities such as crushing and shearing is not remarkable at an outcrop scale.

(2) Young and moderately hard rocks

Younger rocks of the Triassic and later in geologic age are moderately hard rocks of continental, littoral, or lacustrine origin. Since geotectonic activity was not so intense after the Triassic age, the rocks are not so mechanically disturbed. The general features of the rocks are as follows.

4) Young subgroup
- Age: Triassic to Cretaceous
- Main components: Relatively coarse grained clastic rocks such as sandstone, conglomerate, siltstone, and volcani-clastic rocks
- Original features: Moderately hard to slightly soft and relatively coarse grained
- Deformation features: The adverse influence of tectonic activities is not remarkable.

6.4.2 Dam site geology

The selected ten sites are located in mountainous areas with accessibility problems. Geological features at remote country areas, especially the Prek Liang and Russey Churum sites, remain unknown due to the difficulty in conducting geological investigation. As shown in Table 6.4.1, existing geological maps show different geological features.

As presented in the itinerary below, reconnaissance of selected dam sites was carried out by the JICA-MIME Joint Research Team for purposes of obtaining geotechnical assessment. However, investigation of sites #14 and No.23, Prek Liang II and Upper Russey Chrum respectively, were not performed due to accessibility problems mentioned above.

The site reconnaissance focused in particular on the dam site geology, which was vital in determining the feasibility of the project, considering that the time and available data are limited for carrying out the study.

No.	Date	Site Reconnaissance Area
1st	27/10/2007-30/10/2007	Ratanak Kiri, Stung Treng and Kraite
2nd	02/11/2007-03/11/2007	Bokor Plateau
3rd	09/11/2007-13/11/2007	Stung Kep II, Stung Metoek III
4th	15/11/2007-17/11/2007	Stung Metoek II
5th	08/02/2008-08/02/2008	Prek Liang
6th	12/02/2008-16/02/2008	Stung Kep II
7th	21/02/2008-25/02/2008	Middle Russey Chrum
8th	27/02/2008-28/02/2008	Bokor Plateau

Based on the results of the site reconnaissance, no serious geological concerns were identified in any of the surveyed sites. The results of site reconnaissance at the selected dam sites are summarized in Table 6.4.3 to Table 6.4.9.

However, it is noted that since all the sites remain geologically unknown as mentioned earlier, detailed geological investigations are still necessary to realistically assess the feasibility of the selected sites.

Table 6.4.2 Geologic Units of Selected 10 Sites

Site		Reference 1	Reference 2
7&8	Lower Sre Pok II + Lower Se San II (LL2)	Unknown geologic era: No classified rock	Devono-Carboniferous: silicified shale, green phtanite, blue-grey calcareous sandstone, covered by relatively thick old alluvium
12	Prek Liang I (PLI)	Unknown geologic era: Crystallized indeterminable rocks	Undifferenciated crystalline rock
13	Prek Liang IA (PLIA)	Unknown geologic era: Crystallized indeterminable rocks	Undifferenciated crystalline rock
14	Prek Liang II (PLII)	Quaternary: Volcanic deposits	Cambrian-Silurian and Precambrian indeterminated rock type
16	Middle St. Russey Chrum (M.RC)	Unknown geologic era: No classified rock	Middle Jurassic to Lower Cretaceous: Upper Sandstone, covered by relatively thick recent alluvium or indifferenciates
20	Stung Metoek II (SMII)	Middle Jurassic – Early Cretaceous: Sandstone	Middle Jurassic to Lower Cretaceous: Upper Sandstone
21	Stung Metoek III	Middle Jurassic – Early	Middle Jurassic to Lower Cretaceous: Upper

Site		Reference 1	Reference 2
	(SMIII)	Cretaceous: Sandstone	Sandstone
22	Stung Kep II (SKII)	Middle Jurassic – Early Cretaceous: Sandstone	Middle Jurassic to Lower Cretaceous: Upper Sandstone
23	Upper St. Russey Chrum (U.RC)	Middle Jurassic – Early Cretaceous: Sandstone	Middle Jurassic to Lower Cretaceous: Upper Sandstone, covered by relatively thick recent alluvium or indifferenciates
29	Bokor Plateau (BP)	Middle Jurassic – Early Cretaceous: Sandstone	Middle Jurassic to Lower Cretaceous: Upper Sandstone

Reference 1: Geological map by Department of Geology, General Department of Mining Resources
Reference 2: Geological of Cambodia in the ESCAP report

Table 6.4.3 Summary of Geological Assessment for #7&8 LL2

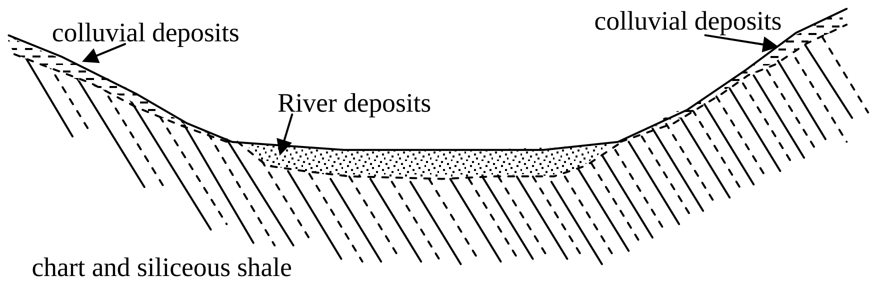
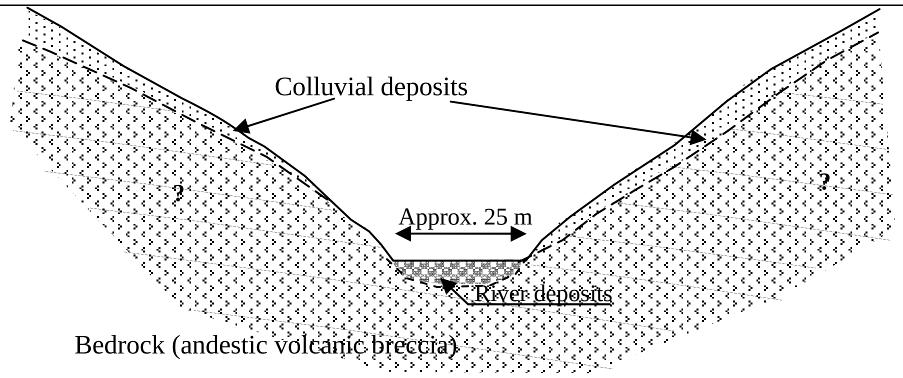
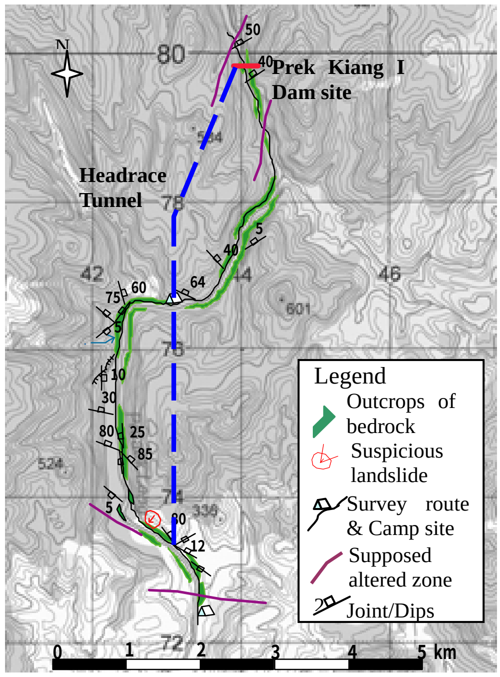
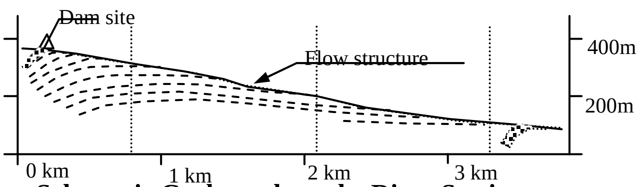
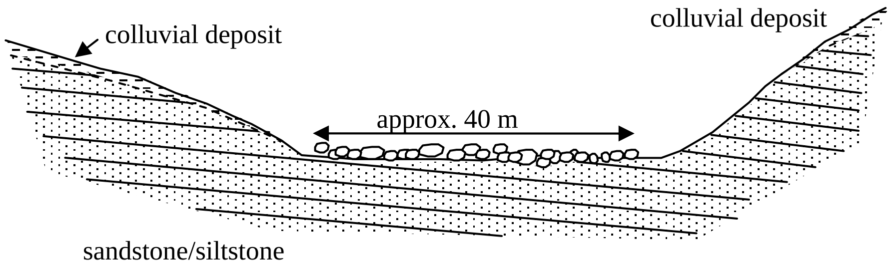
Site No.	#7&8 LL2
1. General Geology	Devono-Carboniferous: silicified shale, green phtanite, blue-grey calcareous sandstone, covered by relatively thick old alluvium
2. Dam site	
Schematic Geological Section along dam axis	
Topography	Tonle Sap River, forming relatively broad valley, meanders through gentle hills to the west.
Geology	Observation area in the reconnaissance was limited to the riverside of the dam site, due to difficult access. **Bedrock** Although no outcrops of bedrocks were observed at the dam site, fairly stiff bedrocks composed of bedded chart and siliceous shale are exposed on the riverbed, about 2 km downstream of the dam site. The dam site is possibly underlain by similar bedded chart and siliceous shale dipping steeply to the northeast. **Unconsolidated deposits** The riverbed is covered mainly with relatively thick silty river deposits. **Engineering Assessment** During the observation of the outcrops about 2 km downstream of the dam site, an estimated unconfined compressive strength of about 50 MPa, was determined by hammering pieces of sound rocks, Accordingly, the sound rocks are probably suitable for dam foundation.

Table 6.4.4 Summary of Geological Assessment for #12 & 13 Prek Liang 1 & 1A

Site No.	#12,13 Prek Liang 1 & 1A
1. General Geology	Because of difficult accessibility, detailed geological investigation has not been carried out yet. According to existing geological maps, this site is underlain by crystallized rocks (of Precambrian age based on the Geology of Cambodia in the ESCAP report) and volcanic rocks covering the upstream area of the reservoir. Site reconnaissance revealed that the area from the dam site to the powerhouse is underlain by andestic rocks with rock facies possibly originating from the Tertiary age. Many small hills in the upstream area of the reservoir, with elevation of about 500-600 m, indicate that this area is covered with gentle dipping stratum of sedimentary rocks, including volcanic rocks.
2. Dam site	
Schematic Geological Section along dam axis	
Topography	Prek Liang River forms 30-40 degrees V-shape valley with about 25 m wide riverbed. A NNE-SSW oriented lineament, which is a possible weak belt, obliquely crosses the river at about 150 m upstream of the dam site.
Geology	**Bedrock** The dam site is covered with crystallized welded tuff and volcanic breccia. Hard andestic rocks are exposed on the left bank of the riverbed, while it intermittently crops out on the right bank. **Unconsolidated Sediment** River deposits are composed of gravelly sand/silt, including boulders of about 2 m in diameter. Its thickness is expected to be about 5 m based on site reconnaissance. Relatively thick colluvial deposits (about 10-15 m in thickness) cover the right bank. **Structure** Gently dipping upstream-ward in general, but inclination of beds increase toward the upstream to the dam site, with an immediate dipping of about 40 degrees.  **Alteration** No significant alteration was detected. A NNE-SSW oriented hydrothermal altered zone with about 20 m in thickness, soften and bleached, are observed at about 500 m downstream of the dam site. NNE-SSW oriented valleys at about 150 m upstream of the dam site also indicate some weak zones. **Weathering** Fresh and sound rocks are expected in the shallow area  **Schematic Geology along the River Section**

	on the riverbed. However, upper slope portions are still unknown. The right bank seems to be relatively deep. **Engineering Assessment** Hard andestic rocks exposed on both banks along the river are expected to be suitable for the foundation of 70-80 m class concrete gravity dam. Estimated unconfined compressive strengths obtained by hammering sound rock pieces is about 80-100 MPa. Cohesion and internal friction angle in the shear strength of the sound rocks are expected to be 25-30 MPa and 40-45 degrees, respectively. Relatively gentle slope features on the right bank indicate that sound rock surface on the right bank would be relatively deep.
2. Reservoir	
Water tightness	According to the existing geological map and topographic inspection conducted, the reservoir area is underlain by crystallized rocks and Quaternary volcanic deposits with gentle to almost flat strata covering the upstream area. Accordingly, the geological boundary and pervious layers intercalated in volcanic deposits, in addition to faults and altered zones, should be considered for the leakage risk analysis of the reservoir However, in the case of FSL of 340 m, the pass seems to be long enough as required, since the smallest pass exceeds 4 km, although geological investigation including ground mapping of the reservoir area is still necessary to determine the final conclusion
Landslide	On the basis of topographic interpretation using 1:100,000 scale maps, significant landslides are foreseen in the reservoir area.
3. Material Resources	Andestic rocks exposed along the river would be suitable as concrete aggregates, although quality check remains necessary, since the rocks have been subjected to regional acid alternation which may contain minerals harmful to concrete. According to results of site reconnaissance, the distribution of terrace deposits or talus deposits is limited and no good borrow area for earth materials is available within the surveyed vicinity.
4. Other Related Structure	**Headrace Tunnel** **<u>Portal area</u>** No significant landslide in this area. The portal area is covered with colluvial deposits, which needs to be excavated. A NNE-SSW lineament should be noted during the geological investigation of this area. **<u>Tunnel Alignment</u>** Tunnel alignment will penetrate andestic welded tuff and volcanic breccia with almost flat structure. Based on site reconnaissance the rock mass behavior of most sections of the connection tunnel is expected to be governed by stable rock mass, although some faults or local discontinuities may cause overbreak. Some NNE-SSW lineaments, which are possible weak belts, cross the tunnel alignment. Tunnel alignment is recommended to minimize the geological risk by crossing the lineament at right angles, if unavoidable. The high potential sections of water inflow include some lineaments, faults, flow units with columnar joints and geological boundary of flow units. **Powerhouse** Based on site reconnaissance along the main river, powerhouse site can be expected to be underlain by very stiff and wide joint spacing andestic welded tuff or volcanic breccia. It is preferable in the layout arrangement of the powerhouse cabin that lineaments indicating faults or alteration, identified from topographic interpretation and ground mapping, are avoided to reduce geological risks. Additionally, geological investigation including detailed ground mapping and core drilling is necessary to assess the feasibility of the powerhouse.

Table 6.4.5 Summary of Geological Assessment for #16 Middle Russey Chrum

Site No.	#16 Middle Russey Chrum
1. General Geology	Middle Russey Chrum Dam site is underlain mainly by sandstone of Middle Jurassic to Lower Cretaceous age. Neogene to Quaternary platform basaltic rocks are distributed along the river.
2. Dam site	
Schematic Geological Section along dam axis	
Topography	Stung Russey Chrum sharply denudes a plateau of Middle Jurassic to Lower Cretaceous sandstone, meanderingly flows westward at the Middle Russey Chrum dam site, and flows southward after the confluence of A Kay River approximately 15 km west of the dam site. Bedded sandstone crops out on the riverbed and the right bank. The river forms asymmetric valley with a riverbed of about 40 m in width. The right bank has a relatively steep slope of about 30 degrees, while its left bank has a relatively narrow ridge with a gentle slope of 10-15 degrees.
Geology	**Bedrock** Middle Jurassic to Lower Cretaceous consist of alternate layers of sandstone (expected unconfined compressive strength, UCS: 30-50 MPa) and siltstone (expected UCS 10-20 MPa). The components are dominated by medium to fine grained arkosic sandstone with cross-bedding. According to the existing information from the drilling survey carried out by TEPSCO in 2006 at the Lower Russey Chrum Site, geological structure is almost flat and mudstone dominates below EL. 100 m. **Unconsolidated Sediment** Bedded sandstone strata are exposed on most of the riverbed. River deposits consist of gravelly sand including boulders of about 3 m in diameter. Small terraces covered with 1 m - 3 m thick fine sand are distributed on the left bank. Depth of colluvial deposits is estimated to be about 10 m -15 m on the left bank and 2 m - 3 m on the right bank (probably thicker on the upper slope). **Structure** Gently dipping northwest ward (to the right bank). **Fault** No faults were observed. **Joint** Not significant, but N-S and E-W joint sets are dominated **Alteration** None, but the basaltic rock at about 700 m downstream of the dam site possibly might have weakened sandstone at the contact zone. **Weathering** Bedrocks on the riverbed, consisting of hard sandstone, with varying color shades of yellow to red due to weathering. The pieces of surface rock sample show relatively high water absorption and low bulk density. **Engineering Assessment** Hard sandstone exposed on the riverbed has enough bearing capacity for a 40 m class dam foundation. However, sheeting joints in weathered sandstone are expected beneath the riverbed while relatively soft siltstone layers might be intercalated in the sandstone. Accordingly, its suitability as dam foundation in terms of strength and water tightness should be assessed carefully by means of core drilling survey, etc. Estimated unconfined compressive strength of about 30-50 MPa is obtained by hammering

	sound rock pieces. Cohesion and internal friction angle in the shear strength of the sound rocks are expected to be 15 MPa and 40-45 degrees respectively. Low permeability of the foundation are expected based on the data of Low Russey Churum investigation (TEPSCO, 2006). However, some bedrocks on the riverbed seem to be pervious due to the sheeting joints. Groundwater level of the both banks might be low. It is noted that water tightness of the relatively thin left abutment of the dam site needs to be further assessed.
2. Reservoir	
Water tightness	The reservoir area is underlain mainly by alternative strata of sandstone and siltstone. According to existing information from geological investigation carried out in geologically similar sites such as Lower Russey Chrum or St. Kep II, sufficient water tightness of bedrocks in the reservoir can be expected. However, water tightness should be assessed carefully especially in the following sites. - The narrow ridge of the left bank of dam site - Basaltic rocks distributed area on the riverbed
Landslide	No significant landslides were observed, according to site reconnaissance. Some relatively gentle slopes beneath the cliffs are covered with colluvial deposits, which might be eroded and become unstable due to impounded water, eventually causing collapses.
3. Material Resources	**For Rock material** Thick bedded sandstone is available as rock materials. **For Earth material** Good resources of earth materials could not be found near the dam site. **For Concrete Aggregates** Basaltic rocks will be suitable in quality but limited in quantity. Sandstone rocks occur widely in the reservoir area, but seemed to be severely weathered and low quality in general
4. Other Related Structure	**Headrace Tunnel** **<u>Portal</u>** Covered with colluvial deposits of 5 m -10 m in thickness. The portal area will require some excavation works. No significant landslides were detected at the portal site. **<u>Tunnel</u>** Tunnel alignment will penetrate alternate layers of hard sandstone and relatively soft siltstone, with an almost flat structure. The rock mass behavior of most sections of the connection tunnel is expected to be governed by stable rock mass, although some minor faults or local discontinuities may cause overbreak. Necessary tunnel supports should be provided due to geological conditions. Particularly, relatively soft siltstone dominated sections or weathered portions may require tunnel supports such as rock bolts, steel rib support and concrete lining. The potential of water inflow will be low in general, except for faults or geological boundaries. **<u>Powerhouse</u>** According to the interpretation of the existing geological map, the powerhouse site is underlain by alternate layers of hard sandstone and relatively soft siltstone with an almost flat structure.

Table 6.4.6 Summary of Geological Assessment #20 Stung Metoek II

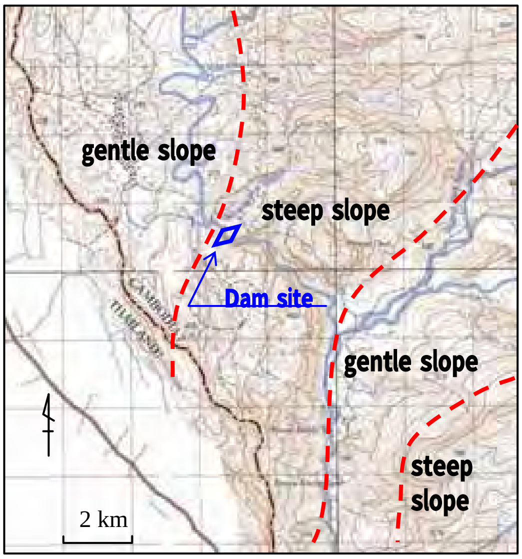
Site No.	#20 Stung Metoek II
1. General Geology	Stung Metoek II Dam site is underlain by alternate layers of hard sandstone and relatively soft siltstone with an almost flat structure of Middle Jurassic to Lower Cretaceous age. Outcrops of sandstone is originally grey in color, but yellowish due to weathering, with some softened in the surface zone of about 5 m in thickness, and relatively massive/jointed at 15 cm -200 cm intervals. Outcrops of siltstone-mudstone, greenish, reddish grey, or dark grey in color, is also weathered and softened.
2. Dam site	
Topography	According to topographic interpretation using 1:100,000 scale maps, this area shows cuesta feature reflecting alternate layers of hard sandstone and weak siltstone. The dam site seems to be located in sandstone dominated hilly area as shown in the following Figure, although this could not be confirmed since the actual dam site is inaccessible as it is located in a minefield area. According to site reconnaissance, actual valley shape is steeper and different from the indications in the 1:100,000 topographic map images. Thus, it might be preferable to shift somewhat to the upstream, Evaluation of dam site using detailed map is recommendable. 
Geology	As mentioned above, actual condition could not be confirmed due to accessibility issue. St. Metoek II Dam site could be underlain by alternate layers of hard sandstone and relatively soft siltstone with an almost flat structure of Middle Jurassic to Lower Cretaceous age. These should have sufficient bearing capacity for the dam's foundation. It should be noted that weathering of surface zone of the dam abutment and siltstone seems to be relatively intense and softened.

Table 6.4.7 Summary of Geological Assessment for #21 Stung Metoek III

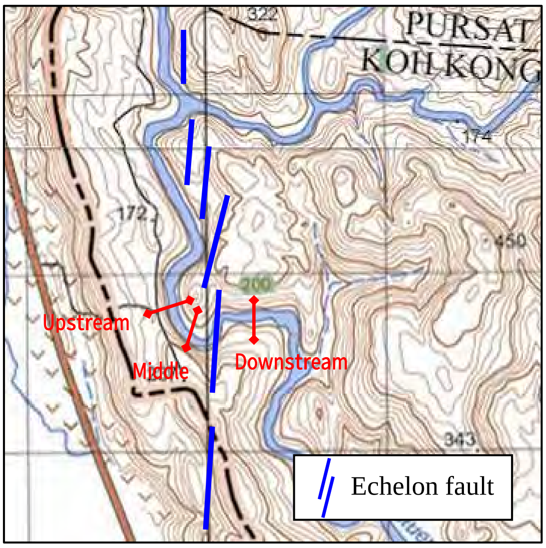
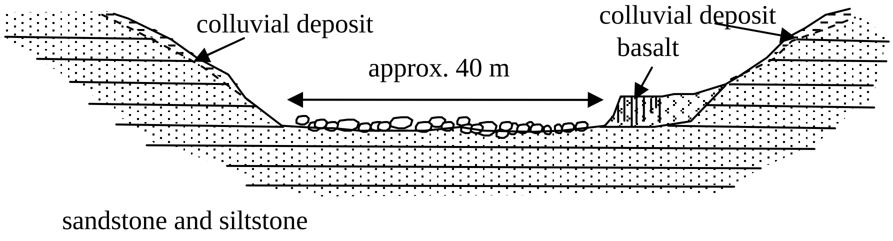
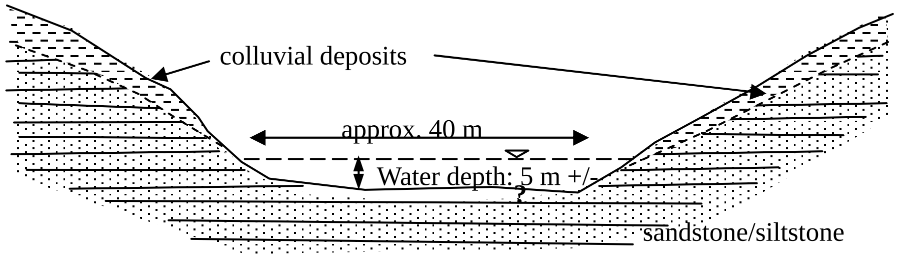
Site No.	#21 Stung Metoek III
1. General Geology	Stung Metoek III Dam site is underlain by alternate layers of hard sandstone and relatively soft siltstone with an almost flat structure of Middle Jurassic to Lower Cretaceous age.
2. Dam site	
Topography	 Three alternative dam sites with almost similar dam crest lengths are topographically suitable as discussed below. **1. Upstream site** Left bank: Relatively narrow ridge with isolated hill of about 80 m high above the riverbed on the map (possibly 50 m long based on site inspection). Additionally, the slope on the downstream side is deeply denuded by a small stream, which is a disadvantage in terms of water tightness. There is an existing terrace of about 100 m wide. Riverbed: 30 m- 40 m in width. The depth of the bedrock surface is probably 5 m or deeper. Right bank: Relatively gentle up to 200 m in elevation except at the riverside. A small stream runs parallel to the main river around the dam crest. **2. Middle site** Left bank: Similar to Upper site. The existing terrace is relatively wider. Riverbed: Similar to Upper site. Bedrocks are exposed on some riverbed. Right bank: Relatively steep up to 200 m in elevation. It appears to be a stable slope. **3. Downstream site** Left bank: Relatively gentle slope. Colluvial deposits are not thick with a probable stable slope. Detailed condition however is not yet confirmed. Riverbed: Sound sandstone is exposed. The downstream portion of this site becomes steeper. Right bank: Relatively gentle slope. Colluvial deposits might be relatively thick and slope appears stable. Detailed condition however is not yet confirmed.
Geology	**Bedrock** Middle Jurassic to Lower Cretaceous alternate layers of sandstone (expected UCS: 30-50 MPa) and siltstone (expected UCS 10-20 MPa). Medium to fine grained arkosic sandstone with cross-bedding seems to occur around the riverbed and cliffs, with siltstone layers intercalated. **Unconsolidated deposits** Unconsolidated deposits are thin in general. Bedrocks are exposed on some portions. Relatively thick colluvial deposits occur beneath the cliffs. **Structure** Almost flat **Fault** N-S oriented echelon faults are suspected according to topographic interpretation of the satellite image shown in the figure. Upstream site and middle site has risks of water leakage through the faults. **Engineering Assessment** Downstream site seems to be suitable from geological aspects. Additionally, downstream site can shorten the tunnel length and reduce the backwater effects from the spill gate.

Table 6.4.8 Summary of Geological Assessment for #22 St. Kep II

Site No.	#20 Stung Kep II
1. General Geology	Stung Kep II Dam site is underlain mainly by sandstone of Middle Jurassic to Lower Cretaceous age. Neogene to Quaternary platform basaltic rocks are distributed along the Tatay River.
2. 1 Dam site 1	Tatay dam site
Schematic Geological Section along dam axis	
Topography	Stung Tatay River sharply denudes a plateau of sandstone, meanderingly flows westward. Riverbed of the dam site is about 40m wide. Slope on both banks varies from 20 degrees - 40 degrees with cliffs beneath the plateau. Small terraces of basaltic lava with 3-5 m high above the riverbed are scattered along the river.
Geology	**Bedrock** Middle Jurassic to Lower Cretaceous alternate layers of sandstone (expected UCS: 30-50 MPa) and siltstone (expected UCS 10-20 MPa). The components are dominated by medium to fine grained arkosic sandstone with cross-bedding. Some riverbed is covered with Neogene – Quaternary platform basaltic rocks with columnar joints of about 5 m in thickness. According to the existing data from the drilling survey carried out by CHMC, geological structure is almost flat and mudstone dominates below elevation EL. 110 m. **Unconsolidated Deposits** River deposits are composed of gravelly sand/silt including boulders of about 1 m in diameter. Its thickness is expected to be about 2-3 m according to site reconnaissance. According to aerial photo interpretation, relatively thick colluvial deposits are detected on both banks beneath the cliffs. **Structure** Generally flat with gentle dipping downstream-ward and upstream towards the dam site **Fault** No significant faults were observed. **Joint** Not significant, but N-S and E-W oriented joint sets dominated **Alteration** Locally, some altered and softened portions especially beneath basaltic rocks were observed along the river bed. **Weathering** Bedrocks on the riverbed, consisted of hard sandstone have color shades varying from yellow to red due to weathering. **Engineering Assessment** Hard sandstone exposed on the riverbed are suitable for the foundation of a rockfill type dam, while relatively soft siltstone layers intercalated in sandstone might be disadvantageous for a gravity type dam. Estimated unconfined compressive strength obtained by hammering of sound rock pieces is about 30-50 MPa. The cohesion and internal friction angle in shear strength of the sound rocks is expected to be 15 MPa and 40-45 degrees, respectively. Since sheeting joints in weathered sandstone are expected beneath the riverbed, suitability for the foundation both in terms of strength and water tightness should be assessed by core drilling survey, etc. Furthermore, basaltic rocks on the right bank are probably highly pervious due to columnar joints which have leakage risks. In case of low groutability, these

	high pervious rocks would need to be removed. Low permeability of the foundation of about 20 m-25 m below ground surface can be expected based on the geological investigations carried out by CHMC near the dam site. However, groundwater level of both banks might be low.
2.2 Dam site 2	Stung Kep dam site
Schematic Geological Section along dam axis	
Topography	Stung Kep River sharply denudes a plateau of Middle Jurassic to Lower Cretaceous sandstone, meanderingly flows westward. Width of riverbed in the project area ranges between 40 m to 120 m. Slope on both banks are varies from about 20 degrees to 40 degrees, with cliffs beneath the plateau. The dam axis may need to be shifted based on detailed topographical maps, since bedrocks are exposed at about 200 m upstream of the planned dam axis.
Geology	**Bedrock** Middle Jurassic to Lower Cretaceous alternate layers (about 50 cm in thickness) of sandstone (expected UCS: 30 MPa - 50 MPa) and siltstone (expected UCS 10-20 MPa). The components are dominated with medium to fine grained arkosic sandstone with cross-bedding. **Unconsolidated Sediment** Based on site reconnaissance river deposits are composed of gravelly sand/silt including boulders of about 1 m in diameter, and its thickness is expected to be about 2 m - 3 m. Both abutments are covered with 10 m - 15 m thick colluvial deposits. **Structure** Almost flat - gently dipping upstream-ward to the dam site **Fault** No significant faults were observed. **Joint** Not significant, but N-S and E-W oriented joint sets dominated **Alteration** Locally, some were altered and softened **Weathering** Bedrocks on the riverbed are stained to pale yellow or pale red due to weathering. **Engineering Assessment** Geologically similar to Stung Tatay site.
2. Reservoir	
Water tightness	The reservoir area is underlain mainly by alternate strata of sandstone and siltstone. According to existing information obtained from geological investigation carried out in geologically similar sites such as Lower Russey Chrum or St. Kep II, sufficient water tightness of bedrocks in the reservoir can be expected. Leakage risk to another river system will be low.
Landslide	No significant landslides were observed, according to site reconnaissance. Some relatively gentle slopes beneath cliffs are covered with colluvial deposits, which might be eroded and become unstable due to impounded water, eventually causing collapse.
3. Material Resources	**For Rock material** Thick bedded sandstone is available as rock materials. **For Earth material** Good resources of earth materials could not be found near the dam site. **For Concrete Aggregates** Basaltic rocks will be suitable in quality but limited in quantity. Sandstone rocks occur widely in the reservoir area, but they seemed to be severely weathered and generally low in quality.

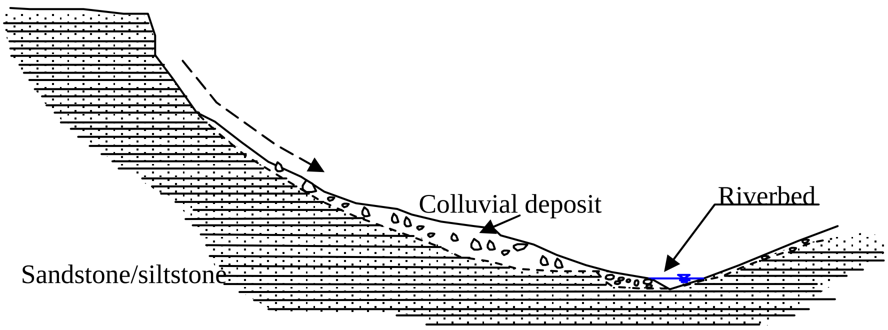
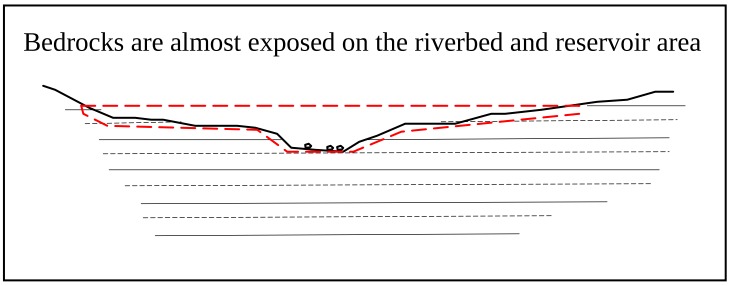
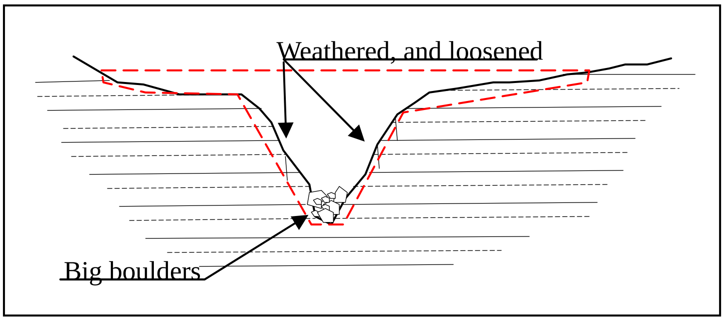
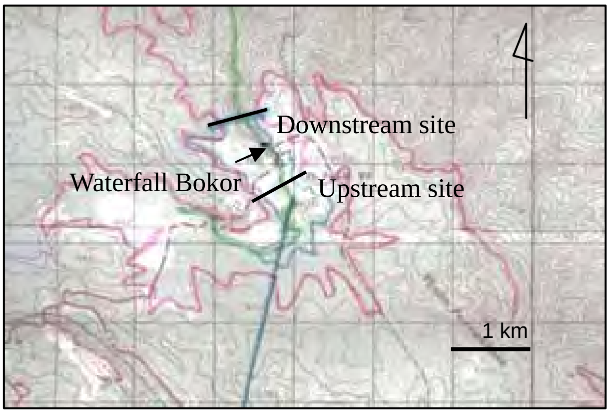
4. Other Related Structure	**Connection Tunnel** **<u>Portal</u>** Covered with colluvial deposits of 5 m-10 m in thickness. The portal area will require some excavation works. No significant landslides were identified at the portal site. The section from the portal of Stung Kep side to about 2 km might be softened due to weathering. **<u>Tunnel</u>** Tunnel alignment will penetrate alternate layers of hard sandstone and relatively soft siltstone with an almost flat structure. The rock mass behavior of most sections of the connection tunnel is expected to be governed by stable rock mass, although some minor faults or local discontinuities may cause overbreak. Necessary tunnel supports should be provided due to geological conditions. Particularly, relatively soft siltstone dominated sections or weathered portions may require tunnel supports such as rock bolts, steel rib support and concrete lining. The potential of water inflow will be low in general except for faults or geological boundaries. **Headrace Tunnel** Tunnel alignment will penetrate alternate layers of hard sandstone and relatively soft siltstone with an almost flat structure. Although geological information is limited, the rock mass behavior of most sections of the connection tunnel is expected to be governed by stable rock mass, although some minor faults or local discontinuities may cause overbreak. Necessary tunnel supports should be applied based on the geological condition. Particularly, relatively soft siltstone dominated sections or weathered portions may require tunnel supports such as rock bolts, steel rib support and concrete lining. The potential of water inflow will be low in general except for faults or geological boundaries. **<u>Powerhouse</u>** The powerhouse site is underlain by alternate layers of hard sandstone and relatively soft siltstone with an almost flat structure. According to topographic interpretations, the slope of the tailrace portal site seems to be covered with relatively thick colluvial deposits as shown in the figure below.  **<u>Schematic geological profile of the slope near the tailrace</u>**

Table 6.4.9 Summary of Geological Assessment for #29 Bokor Plateau

Site No.	#29 Bokor Plateau
1. General	Bokor Plateau Dam site is underlain mainly by sandstone of Middle Jurassic to Lower Cretaceous age.
2. Dam site	
Schematic Geological Section along dam axis	 Schematic Geological Section along Dam axis of Upstream Site  Schematic Geological Section along Dam axis of Downstream Site
Topography	Bokor River sharply denudes a plateau of Middle Jurassic to Lower Cretaceous sandstone. The dam site is planned at the upstream reach of the river. Two alternative dam sites are shown in the Figure. Downstream site is situated on a steep and narrow valley at about 300 m downstream of the fall. Upstream site is situated on a plateau of hard sandstone at about 700 m upstream of the fall.
Geology	**Bedrock** Middle Jurassic to Lower Cretaceous alternate layers of sandstone (expected UCS: 30-50 MPa) and siltstone (expected UCS 10-20 MPa). The components are dominated with medium to fine grained arkosic sandstone with cross-bedding.  **Unconsolidated Sediment** Downstream site Boulders of more than 10 m in diameter cover the riverbed. Upstream site Very thin gravely sand. Colluvial deposits are less than 1 m in thickness in general. Sandstone bedrocks are exposed on some portions in the reservoir area. **Structure** Almost flat. **Fault** No significant faults were observed.

	Joint Not significant, but sheeting joints are developed in the weathered sandstone.. **Alteration** No significant alteration **Weathering** Bedrocks on the riverbed are stained to pale yellow or pale red due to weathering. **Engineering Assessment** Upstream site can reduce the required dam height and volume, although the catchment area of 2 km decreases. Additionally, upstream site is more preferable than the downstream site, in terms of workability and accessibility.
2. Reservoir	
Water tightness	Reservoir area is situated on Bokor Plateau of 930-950 m in elevation. Residual soil and colluvial deposits are almost negligible. Good water tightness of bedrock in the reservoir can be expected. Impact to forest environment by impending water is not significant.
Landslide	No significant landslides.

6.4.3 Seismic risk

(1) Data collection of existing seismic data

Based previous on survey or available data on earthquakes, no active faults or active structures have been identified in the selected sites.

No significant earthquakes exceeding magnitude 6 were recorded in the study area, as shown in Figure 6.4.2.

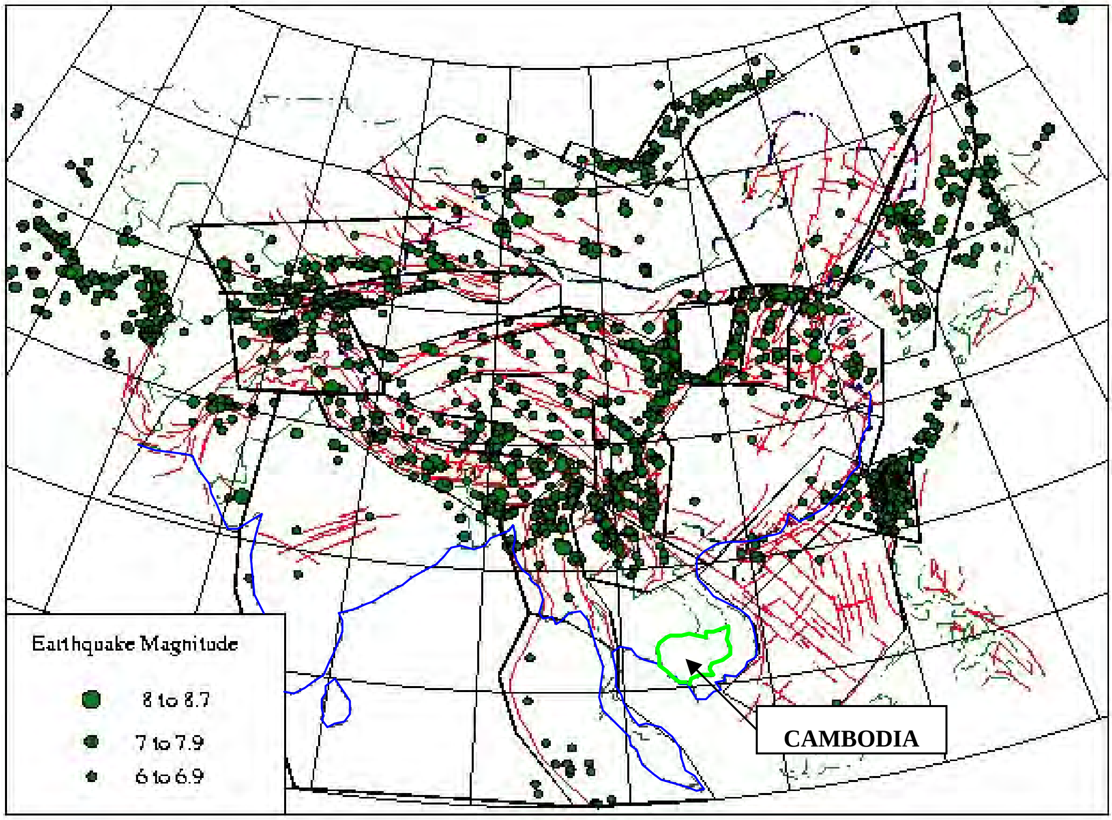


Figure 6.4.2 Seismotectonic Map of Continental Asia.

Source: Hazard map –Eastern Asia, The Global Seismic Hazard Assessment Program (GSHAP), a demonstration project of the UN/International Decade of Natural Disaster Reduction,1998

Note: Thick lines indicate active faults. Solid dots indicate earthquakes with ,magnitudes of equal or greater than 6.0

According to "Hazard map –Eastern Asia" prepared by The Global Seismic Hazard Assessment Program (GSHAP), the peak ground acceleration at the study sites ranges between 0.2 m/s^2 - 0.4 m/s^2 (0.02g-0.04g), as shown in Figure 6.4.3.

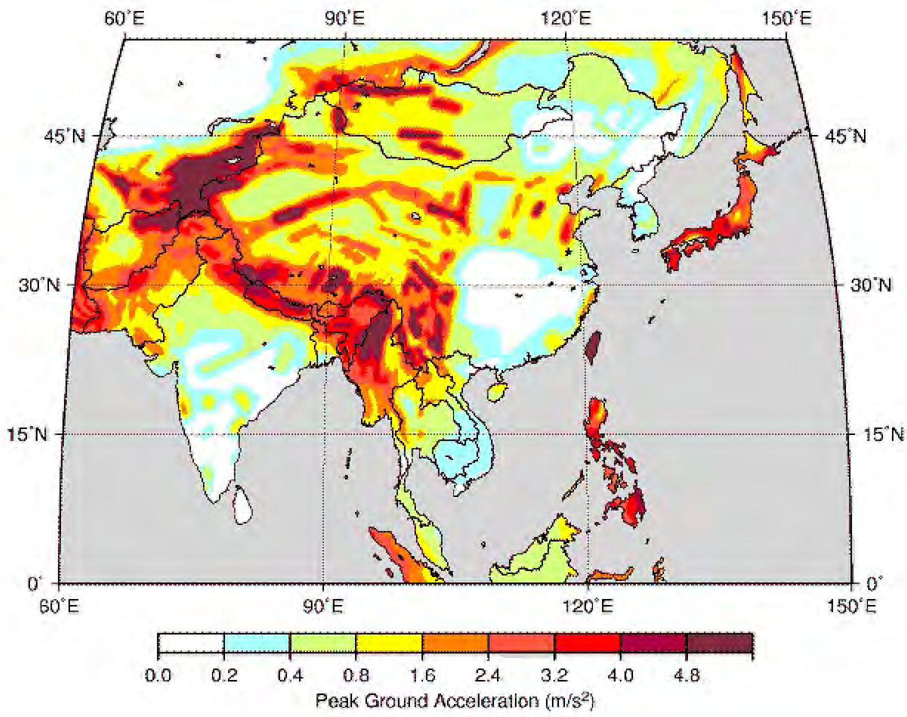


Figure 6.4.3 Peak Ground Acceleration of Eastern Asia

Source: Hazard map –Eastern Asia, The Global Seismic Hazard Assessment Program (GSHAP), a demonstration project of the UN/International Decade of Natural Disaster Reduction,1998.

Note: The GSHAP Global Seismic Hazard Map has been compiled by merging the regional maps produced for different GSHAP regions and test areas. It depicts the global seismic hazard as peak ground acceleration (pga) with a 10% chance of exceedance in 50 years, corresponding to a return period of 475 years.

(2) Estimation of Design Seismicity

The probable maximum peak accelerations of both edges of Cambodia (Prek Liang site near the northeast edge and Stung Metoek site near the southwest edge) were estimated based on the existing seismic record (1973-Present) issued by US Geological Survey as shown in Figure 6.6.4.

The biggest earthquakes within the 500 km radius since 1973 were recorded at magnitude 5.3 and magnitude 5.0, which occurred at remote areas located at 453 km from Prek Liang site and 280 km from St. Metoek site respectively. No earthquakes greater than magnitude 4.0 has occurred within a 200 km radius from any of the selected sites.

The probable maximum peak accelerations for 100-year return period are:

Prek Liang site: 2.9 gal =0.003g

St. Metoek site: 5.0 gal =0.005g

The probable maximum peak accelerations for 200-year return period are:

Prek Liang site: 5.7 gal =0.006g

St. Metoek site: 9.9 gal =0.010g

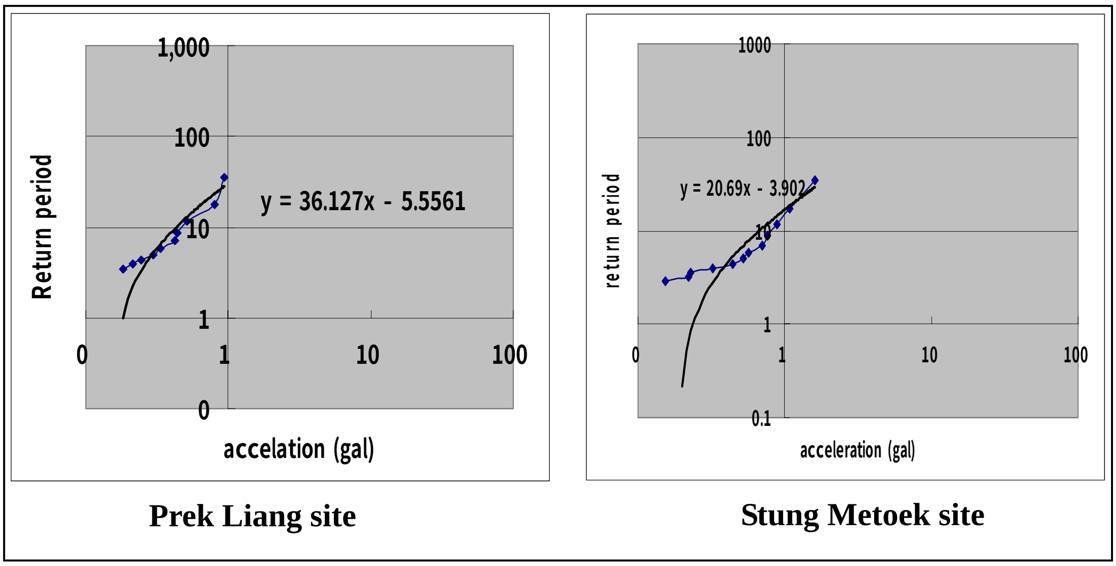


Figure 6.4.4 Acceleration vs Return Period

(3) Design Seismicity of Dam Sites on Similar Geo-tectonic Region (Experiences from Dam sites in Middle to South Vietnam)

For the Ham Thuan – Da Mi Project, the estimated values of design seismic acceleration is 0.035g for rock-based structures and 0.07g for earth-based structures. Meanwhile, for Dai Ninh and Dong Nai projects, a value of 0.1g is taken as a conservative minimum value for design.

It can be concluded that although all selected sites are situated in low earthquake zones, design seismic acceleration values estimated as 0.1g (horizontal) and 0.05g (vertical), are considered to be on the safe side.

6.5 HYDROPOWER DEVELOPMENT PLAN

6.5.1 Layout, Access Road and Transmission Lines for Hydropower Development

During the first screening stage, the study team examined the layout of each project using the existing maps with 1:100,000 and 1:50,000 to estimate the aggregate cost and to examine the economic viability of each project. For the selected ten projects in the first screening, the study team conducted field surveys during the second stage. Of the ten projects, topographic maps with scales of 1:10,000 were prepared for the six projects through interpretation of aerophotographs which were procured for the project. Prepared maps were used for the project planning purpose.

Outline routes for the access road were prepared based on the field surveys conducted and by referring to the existing road maps, 1:100,000 topographic maps, and aerophotographs. The access road costs were estimated for the major three categories, i.e., the sections passing flat lands, mountainous sections, and sections for rehabilitation of the existing roads.

Necessary transmission line length was estimated by assuming that the line was supposed to be connected to the EDC national grid at the grid substation (GS) located in the nearest provincial capital. In case any other power development/power transmission plans existed, the transmission line was assumed to be connected to the national grid at the nearest substation.

The layout of each hydropower development plan and outline route for the access roads are presented in the Appendix-A. The explanation on each development plan is given in sub-section "6.5.6 Points to consider for each hydropower development."

6.5.2 Hydropower Development Plan

Based on the result of field surveys and the result of hydrological analysis, hydropower development plans were prepared with the following manners:

(1) Preparation of reservoir area and storage capacity curve

Reservoir area and storage capacity curve of each project site was prepared to determine the storage capacity of the reservoir considering the hydrological characteristics of the site, and the ratio of reservoir storage capacity against annual inflow (Capacity Inflow Ratio : CIR).

The target CIR was set at 20% for the projects located in the north-eastern part of Cambodia, which has relatively stable flow regime. While the target CIR was set at 30% for the projects located in the south-western part, as such area has drastic drawdown of the river discharge during the dry season.

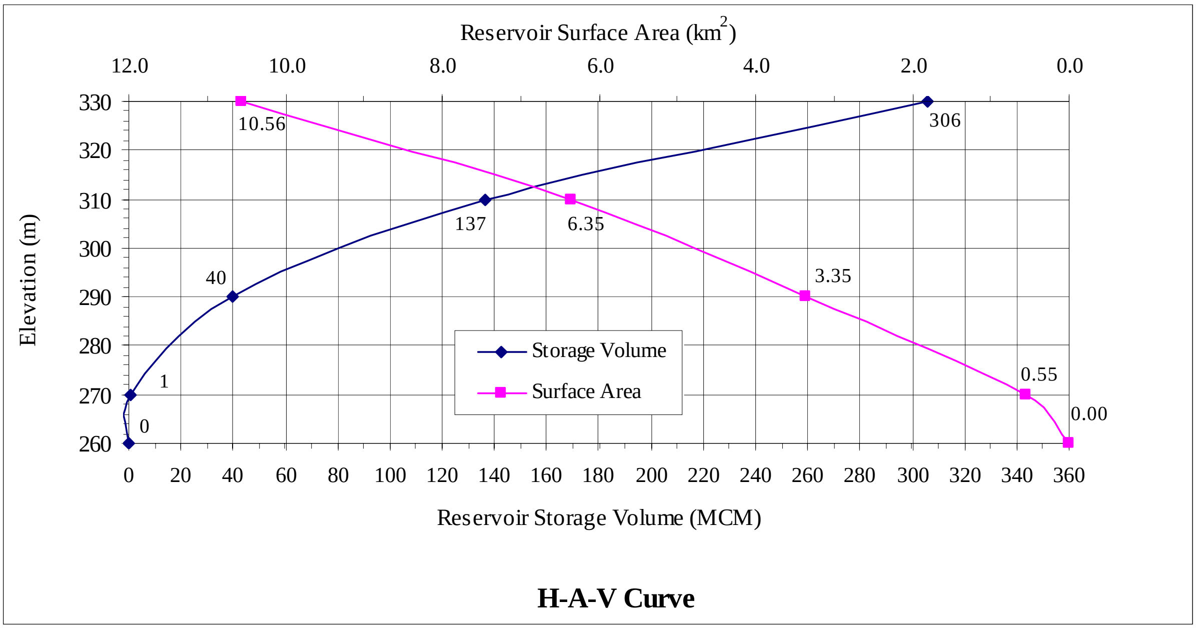


Figure 6.5.1 An Example of Reservoir Area and Storage Capacity Curve

(2) Setting of full supply level (FSL), minimum operation level (MOL), and dead water level (DWL)

Based on the assumed 100 year sediment volume, sedimentation level (dead water level: DWL) was determined. The height of inlet and the diameter of headrace tunnel were designed from the maximum plant discharge to determine the minimum operation level (MOL).

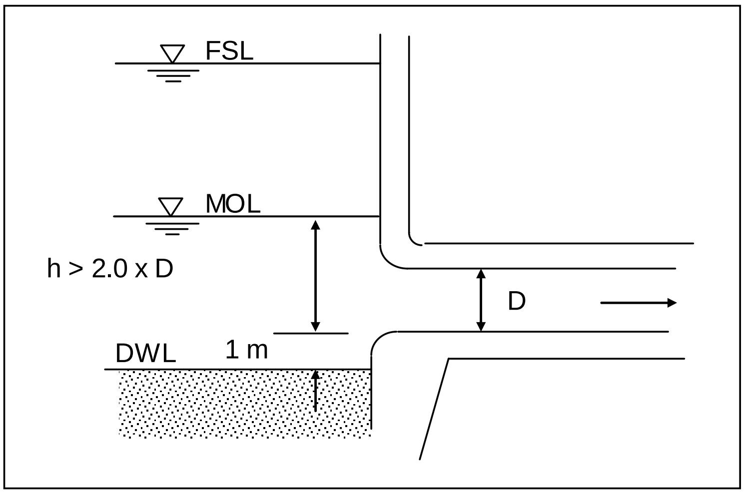


Figure 6.5.2 Determination of Minimum Operation Level (MOL)

(3) Planning of overall layout of the hydropower development plan

Based on the available topographic maps and the results of field surveys, the study team examined and planned the overall layout of each hydropower project. With due considerations to geological and topographic conditions, the location of the dam, powerhouse and outfall was selected to decide the route of the waterway. The layouts are shown in Appendix-A.

6.5.3 Power Generation Planning

Based on the selected layouts, the study team simulated power generation with reservoir operation model, selected the installed capacity with a target plant factor at 40%, and estimated annual power generation, etc.

(1) Inflow data

In and around the target project area, the existing gauging station was selected which had similar hydrological and meteorological characteristics with the selected project. Monthly inflow data of the target project site was prepared by multiplying the ratio of long-term annual runoff of the planned site and the selected gauging station, which were estimated separately (refer to sub-chapter 6.3). Prepared data was used for the reservoir operation simulation.

The target project site and referred data are as follows:

Target project site	Referred data
#7&8 LL2	Seven year monthly discharge data of Ban Kamphun gauging station located right downstream of the project site
#12 PL1, #14 PL2	23 year monthly discharge data of Kontum gauging station located upstream basin of Se San river
#16 MSRC, #20 MTK2, #21 MTK3, #22 KP2, #23 USRC, #29 BP	After examination of Huai Sato gauging station (Thailand)'s 26 year monthly data, the first six year data seemed to have overestimated dry season discharge. Therefore, 20 year monthly discharge data of Huai Sato was applied by abandoning the suspicious data of the first six years.

(2) Evaporation from the reservoir surface

Evaporation from the reservoir surface was assumed at 700 mm/year. This value was derived by assuming the average pan evaporation in Cambodia as 1,000 mm/year, and by multiplying the conversion factor of 0.7 to get the reservoir surface evaporation.

(3) River maintenance flow to the downstream of the dam

River maintenance flow is necessary to maintain the river environment between the proposed dam site and the tailrace outlet (outfall). With reference to the Japanese standard, river maintenance flow for each project was estimated as 0.2 m^3/sec/100 km^2.

(4) Reservoir operation simulation

Long-term monthly inflow data was assumed for each target project to simulate reservoir operation. The firm discharge (Qf) was calculated as the highest one which enables the reservoir operation without lowering the reservoir water level below the minimum operation level (MOL). The maximum plant discharge and the installed capacity were determined aiming at plant factor of 40% with six hour daily peak operation. The followings are the result of reservoir operation simulation results:

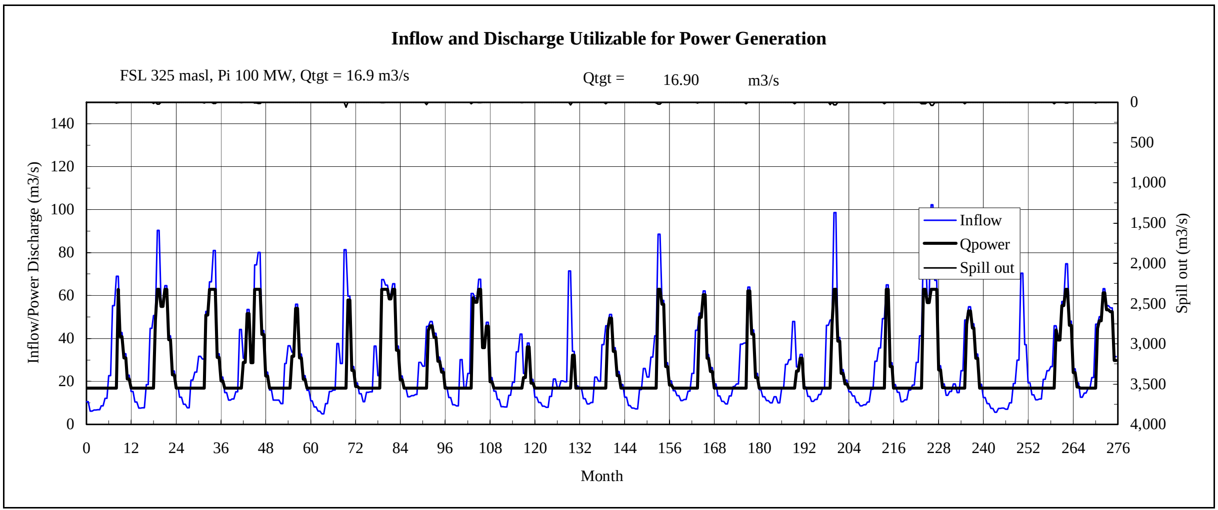


Figure 6.5.3 Result of Reservoir Operation Simulation (1)
Relationship between Inflow and Average discharge for power generation (Qpower)

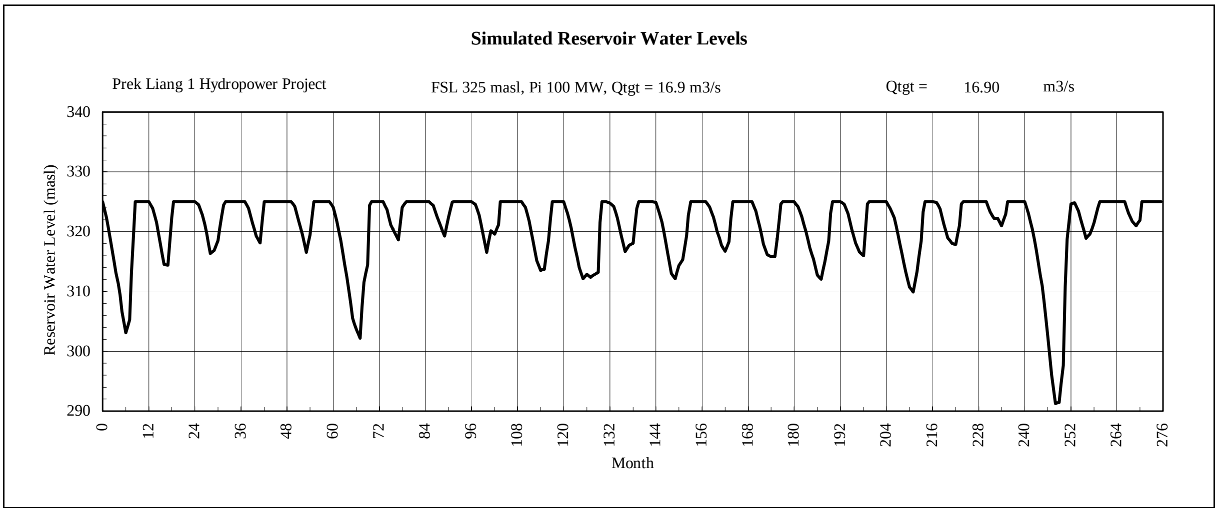


Figure 6.5.4 Result of Reservoir Operation Simulation (2)
Fluctuation of reservoir water level (FSL 325 m, MOL 290 m)

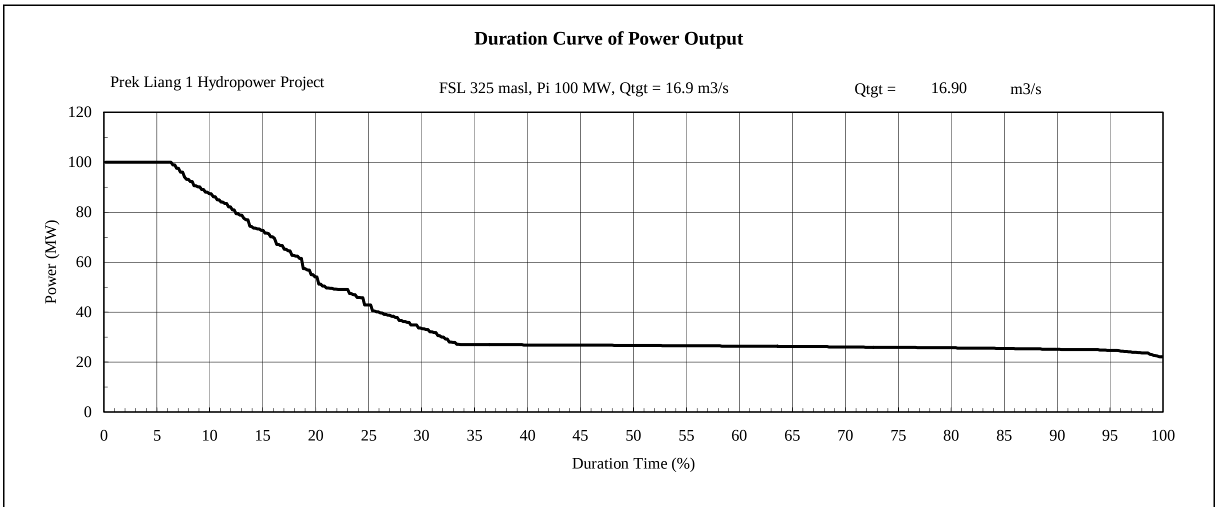


Figure 6.5.5 Result of Reservoir Operation Simulation (3)
Duration curve for 24 hour continuous power output

Preliminary design and cost estimate

Quantities for construction works were estimated based on the hydropower development layout and features for each structure prepared by power generation planning. By referring to the "Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Projects" prepared by New Energy Foundation (Tokyo, Japan 1996), simple empirical equations were applied to estimating the work quantity. Major features for work quantity estimate are as follows:

<Major features for quantity estimate>

1) Dam height, 2) Crest length, 3) Dam volume, 4) Spillway (from flood discharge and dam height), 5) Intake facility (from available depth, maximum plant discharge, and intake diameter), 6) Headrace tunnel (from inner diameter, lining thickness, and tunnel length), 7) Surgetank (from maximum plant discharge and length of head race tunnel) 8) Penstock, 9) Powerhouse, 10) Tailrace, 11) Access road, 12) Others.

<Unit price>

Information on construction unit price was collected for Cambodia, Laos, Viet Nam and neighbouring countries and adjusted by eliminating the extreme values, to estimate standard unit prices as of September 2007.

Major unit prices are shown in Table 6.5.1.

Table 6.5.1 Major Unit Price

No.	Item	Unit Pride	Unit
1	Excavation (common)	3.0	$/m^3$
2	Excavation (rock)	10.2	$/m^3$
3	Excavation (tunnel)	47.5	$/m^3$
4	Embankment (rock material)	8.8	$/m^3$
5	Embankment (random material)	7.1	$/m^3$
6	Concrete for open structures	76.0	$/m^3$
7	Concrete for tunnel	142.0	$/m^3$
8	Mass concrete	70.0	$/m^3$
9	Reinforcement bar	1,124	$/ton
10	Steel gate	5,000	$/ton
11	Steel pipe	3,500	$/ton

Source: Study Team

<Environmental mitigation cost and compensation cost>

Three percent of total civil construction cost was allocated as reservoir area development and environmental conservation costs for each project. Resettlement cost was estimated at $3,500 per household[7], and $11,204 per hectare for farm lands[8]. For #7&8 LL2 project, additional compensation cost at $500 per hectare of inundated land, which PECC1 applied to their feasibility study, was adopted.

7 Power Transmission Project in Cambodia, ADB June 2007

Unit generation cost

Unit generation cost was calculated based on the estimated construction cost for each project with annual power generation figure. With such figure, economic analysis and financial analysis were conducted. The results are shown below:

Name of Project	#7&8 LL2	#12 PL1	#14 PL2	#16 MSRC	#20 MTK2	#21 MTK3	#22 KP2	#23 USRC	#29 BP
Installed Capacity (MW)	420	100	56	28	25	26	116	28	26
Annual Power Generation (GWh)	1,725	348	198	96	86	90	407	98	91
Construction Cost (mil. USD)	623	162	70	85	71	72	314	124	55
Unit Generation Cost (USCent/kWh)	4.76	6.13	4.64	11.52	10.77	10.41	9.98	16.41	9.19
EIRR (%)	18.2	18.2	21.7	10.1	10.7	11.2	10.7	6.4	13.4
FIRR (%)	16.5	13.1	16.8	6.4	7.0	7.3	7.8	3.5	8.6

Source: Study Team

For the economic and financial analysis of selected projects, the following adjustment was made from the assumptions adopted during the first screening stage.

1) Calculation of the Economic Benefit of CO_2 Emission Reduction

More than 90% of electricity generation in Cambodia are by fossil fuel-fired thermal power plants. Hydropower development is expected to contribute to reducing emission of CO_2. On the other hand, certain amount of CO_2 will be emitted also from reservoirs constructed for the hydropower projects due to the decomposition of leaves, twigs and other rapidly degradable biomass. In addition, certain area of forest, which may absorb CO_2, will be submerged in the reservoir.

Taking above factors into consideration, amount of CO_2 emission reduction (increase) of each project was calculated in Section 6.3 of this report. Monetary value of CO_2 reduction was assumed as $27.5 per CO_2 -ton, based on actual average transaction price of CER (Certified Emission Reductions) in ECX, biggest CDM credit exchange market in Europe, for the period from March to June 2008.

If CDM is applied to the certain hydropower project, amount of CER will be additional revenue of the project. However, it is not very sure whether the project can get the CER or not. Accordingly benefit of CO_2 reduction was counted as economic benefit but not as financial revenue.

2) Administration and Engineering Cost

Administration and engineering costs were assumed at 7 to 10% of the total civil construction cost and electrical and mechanical equipment cost. Administration and engineering costs were assumed at 10% when the total cost of civil, electrical and mechanical, and land compensation and resettlement was less than $200 million. When the same total cost was more than $500 million, the value was set at 7%.

[8] Resettlement Plan for GMS Road Improvement Project in Cambodia, Royal Government of Cambodia/Ministry of Public Works and Transport, August 2002. The price was adjusted to 2007 level using the conversion factor of consumer price index of 1.1204.

Points to consider for each hydropower development

#7&8 Lower Sre Pok 2 + Lower Se San 2 (LL2) Project

Detailed study was conducted by Electricity of Viet Nam (EVN), Power Engineering Consulting Company 1 (PECC1) for the period from May 2005 to May 2006. Related reports were obtained and reviewed during the first screening stage. As there was no significant differences between the JICA study team's review and EVN's development plan, the installed capacity was adopted after the EVN-PECC1's plan at 420 MW. However, the energy generation was newly estimated by the study team. The layout shown in Appendix-A is the abstract from the PECC1's report.

#12 Prek Liang 1 (PL1) Project

During the first screening stage, there were #12 Prek Liang 1 and #13 Prek Liang 1A schemes which were separately planned. In view of economic viability and nature conservation, these two schemes were combined and reformulated as #12 Prek Liang 1 Project. As the project is located in the national park, and due to the topographical constraint, the waterway and the powerhouse were planned as underground type aiming at the mitigation of the environmental impacts. As a result of re-examination of the layout using newly prepared 1:10,000 maps, it was considered appropriate to shift the previous dam site by about two kilo meters upstream. With this shifting, dam height could be lowered and thereby the dam volume and construction cost was reduced. Reduced head by lowering dam height can be developed by extending the headrace tunnel by two kilometers more with less cost. With such re-layout, the power generation benefit remains the same. It was noticed that there were about 30 m elevation differences between the existing 1:100,000 maps and newly prepared maps at a scale of 1:10,000. Project features and relevant water levels were determined based on the elevations from newly prepared maps[9]. This plan generates 100 MW electricity with gross head of 200 m. As this project is located inside the national park, it is of the top priority issue to harmonize "hydropower development" and "environment conservation" when the Ministry of Environment (MOE) and the Ministry of Industry, Mines and Energy (MIME) discuss on the issues of the national park zonings, as well as to build national consensus for the national interest of Cambodia.

#14 Prek Liang 2 (PL2) Project

As a result of re-examination on the newly prepared maps, original dam site was shifted upstream to reduce the dam height and volume. It was realized that there was about 20 m height difference between the newly prepared maps and the existing 1:100,000 maps. Project features and relevant water levels were determined based on the elevations from newly prepared maps. In view of the access road preparation, implementation sequence should be #12 PL1 first followed by #14 PL2.

[9] The new maps for Prek Liang sites with 1:10,000 scale were prepared using laser profile survey with helicopter. As the laser profile survey can calibrate the tree height, it was possible that there were differences from the previous survey from aerophtographs.

#16 Middle Stung Russey Chrum (MSRC) Project

At the MSRC project site, there is an 18 km straight river reach between riverbed contour lines of EL. 340 m and EL. 360 m. This means that it is possible to create the necessary reservoir capacity by a relatively low dam. Such flat and long valley topography is efficient in obtaining required reservoir capacity. The dam height was set at 45 m and the full supply level (FSL) was set at 380 masl.

It is probable that the full supply level (FSL) of the Lower Stung Russey Chrum (LSRC) project, which was committed in May 2008 to develop, may affect the tail water level (TWL) of #16 MSRC project. For details, it is necessary to confirm the concession agreement between MIME and the developers, however, the study team examined and prepared the most probable two alternatives. One is the original plan examined during the first screening stage, i.e., to set the TWL at EL. 120 m, which is the FSL of LSRC Lower Scheme (TWL 120 alternative). The other one is the alternative plan to set the TWL at EL. 260 m, which is the FSL of LSRC Upper Scheme (TWL 260 alternative). The gross head of MSRC's TWL 260 alternative is 120 m, which is the half of TWL 120 alternative, therefore, TWL 260 alternative has lower economic and financial viability. Further, as the power density goes below 4 MW/km^2, simplified reservoir emission of greenhouse gas at 90 g/kWh cannot be applied. As a result of river discharge measurement during the field survey, it was realized that the drop in the river discharge during the dry season was quite significant. Taking such results into consideration, the study team reviewed the hydrological indices to reflect to the planning.

During the third field investigation, the Study Team got information that LSRC's concession agreement was concluded in May 2008. In that agreement, LSRC included both lower and upper schemes for development. Therefore, MSRC's TWL was determined to be 260 masl.

#20 Stung Metoek 2 (MTK2) Project

As this project is located in the south-western part of Cambodia, which has significantly small dry season discharge, the target capacity inflow ratio (CIR) was set at 30% in formulating power generation plan[10]. By checking on the newly prepared 1:10,000 maps, the elevations around powerhouse were about 20 m higher compared with the existing 1:100,000 maps.

Two alternatives were examined considering the topography. One is to extend the waterway down to EL. 144 m (on the 1:10,000 map) for power generation (upstream powerhouse alternative). The other one is to extend the waterway down to EL. 141 m (downstream powerhouse alternative). The downstream powerhouse alternative can gain the head three meter more than the upstream powerhouse alternative, but the waterway length will be 900 m longer.

The riverbed elevation at the tailrace outlet of the downstream powerhouse alternative at 141 masl is shown as 120 masl in the existing 1:100,000 map. Full supply level (FSL) of #21 MTK3 project located downstream of #20 MTK2 will be planned with 1:100,000 map at 120 masl, as the available maps for #21

[10] During the feasibility study in the future, in case the scheme is developed as multipurpose development project including the water supply to Koh Kong city and Thailand, the CIR value of 30% should be reexamined to determine the optimum development scale. In addition, care should be taken on too large value of CIR, as such large value of CIR will decrease the ratio of water rotation in the reservoir, which may badly affect to the deterioration of water quality. Generally speaking, more than 40% CIR will hardly contribute to the improvement of regulating capacity of the reservoir.

MTK3 project is only 1:100,000 maps[11]. In a practical sense, TWL of #20 MTK2 and FSL of #21 MTK3 will be set at the same elevation, therefore, there will be no head which remains undeveloped.

#21 Stung Metoek 3 (MTK3) Project

As described in the #20 MTK2 project, FSL was set at 120 masl in the 1:100,000 map. As described in Section 6.4 Geology, there are three alternative dam axes (upper, middle, lower). The lower dam axis is geotechnically the most advantageous. The dam was planned as 44 m high concrete gravity type with the riverbed elevation at 81 masl at the lower dam axis. The tailwater level could be identified down to EL. 60 m with the existing 1:100,000 maps. With satellite images, it could be assumed that there was further 5 m head at the minimum on the downstream 500 m river section. Thus, the powerhouse location was selected 500 m further downstream from the 60 masl contour line location to assume the tailwater level at 55 masl.

As for the implementation sequence, #20 MTK2 may preferably be implemented first followed by #21 MTK3, in view of the diversion convenience for #21 MTK3 during the construction works and flow regulation effect to #21 MTK3.

#22 New Tatay (Stung Kep 2, KP2) Project

During the first screening stage, two alternatives were examined. One is to construct a dam at the confluence of Kep and Tatay rivers (one dam alternative). The other one is to construct dams on Kep river and Tatay river and to connect both reservoirs with tunnel (two dam alternative). The two dam alternative was examined thereafter, as this alternative had the higher economic performance.

In December 2007, after completion of the first screening, the following were noticed:

- A Chinese private company, CHMC who obtained the MOU of #18 Tatay Project located upstream, moved the dam site to the area adjacent to #22 Stung Kep 2 (KP2) proposed by the study team in August 2007, by about 1.5 km downstream.
- CHMC referred the moved dam site as Tatay Project to continue their study.
- For this "#22 New Tatay Project", the concession agreement was concluded with the Government in May 2008 toward implementation.

Therefore, in this Master Plan Study, this "#22 New Tatay Project" is treated as the committed project for implementation from now on.

#23 Upper Stung Russey Chrum (USRC) Project

As this project is located in the south-western part of Cambodia, which has significantly small dry season discharge, the target capacity inflow ratio (CIR) was set at 30% in formulating power generation plan. By using the existing 1:100,000 maps, the dam axis was set at riverbed elevation around 680 masl, and the FSL was set at 760 masl. There continues the steep terrain from the proposed dam site toward

[11] MTK3 project site is located at the border area with Thailand. A part of necessary aerophotographs for topographic mapping was not available. Therefore, 1:10,000 maps for MTK3 was not prepared. Instead, such maps were prepared for other sites.

upstream. Therefore, to obtain enough storage capacity, the dam height becomes as high as 75 m. From the result of discharge measurement during the field survey for MSRC project, hydrological features were reviewed. From the review result, it was supposed that there could be the significant decrease of dry season discharge. By reflecting such results to the power generation planning, economic index went down significantly. Even with CDM benefit taken into consideration, EIRR was below 10%.

#29 Bokor Plateau (BP) Project

This project will construct a 22 m high earthfill dam on the river located at 900 – 1,000 masl highland to divert 3.5 m^3/sec discharge at the maximum to the sea side. The tailwater level is 40 masl, total head is around 900 m. The catchment area is as small as 24.5 km^2, and the drop in the river discharge during the dry season is significant.

A Vietnamese company IDICO has conducted a preliminary study. With IDICO's idea, river water will be diverted to the downstream area of the planned Kamchay dam site at 75 masl with steel penstock with about 7 km for power generation. The preliminary study was prepared based on the limited available material. IDICO's study has significant differences from the JICA study team's plan in terms of layout and energy generation.

In addition, the catchment area of #29 BP project is located inside the basin of the Kamchay hydropower project which is under construction. #29 BP project's catchment area is 24.5 km^2, which stays at 3.5% of the Kamchay catchment area of 710 km^2. By diverting 1.4 m^3/sec discharge on average for #29 BP project, Kamchay project's annual power generation will decrease by about 13 GWh/year. This decreased amount is 2.8% of the annual average power generation of Kamchay project at 460 GWh. As #29 BP project will slightly decrease the annual energy generation of Kamchay project, it will be necessary to compensate for the reduction in the energy generation. Though #29 BP project may decrease the Kamchay energy, the total power benefit will be maximized by the implementation of both projects owing to the high head of #29 BP at about 900 m.

Table 6.5.2 shows the principal features of the priority projects.

Table 6.5.2 Principal Features of Priority Projects

No.			7 & 8	12	15	16	20	21b	22	23	29b
Project Name			Lower Sre Pok II + Lower Se San II *	Prek Liang I	Prek Liang II	Middle St. Russey Chrum *	Stung Metoek II	Stung Metoek III	Stung Kep II	Upper St. Russey Chrum *	Bokor Plateao
Abbreviation			LL2	PL1	PL2	MSRC	MTK2	MTK3	KP2	USRC	BP
1. Basin and Discharge	Symbol	Unit									
Location			Stung Treng	Ratanak Kiri	Ratanak Kiri	Koh Kong	Pursat	Koh Kong	Koh Kong	Pursat	Kampot
Name of River			Se San	Prekliang	Prekliang	Stung Russey	Stung Metoek	Stung Metoek	Stung Kep	Stung Russey	
Catchment Area	A	km^2	49,200	839	575	461	416	656	1060	163	24.5
Anuual Run-off	Qa	mcm	46,800	899	615	517	536	851	1,220	170	57
Average Discharge	Qm	m^3/sec	1480	28.5	19.5	16.4	17.0	27.0	38.7	5.4	1.8
Specific Discharge	qa	$m^3/s/100km^2$	3.01	3.40	3.39	3.56	4.09	4.12	3.65	3.31	7.35
2. Reservoir											
Surface Area	Ar	km^2	394	9.5	9.3	13.1	14.1	11.4	10.5	2	3.2
Gross Capacity	Sg	mcm	2,772	264	157	234	227	186	268	57	22.0
Sediment Volume	Ssd	mcm	984	16.78	11.5	9.22	8.32	13.12	21.2	3.26	0.49
Effective Capacity	Se	mcm	331	219	110	180	188	116	239	50	18
Ratio (Se/Qa)	CIR	%	0.71%	24.36%	17.89%	34.82%	35.07%	13.63%	19.59%	29.41%	31.58%
3. Power Plan											
Power System			Dam type	Dam waterway	Dam waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway
Maximum Plant discharge	Qmax	m^3/sec	1948	67.2	42.1	32.8	34.9	56.1	73.9	10.3	3.5
Firm discharge	Qf	m^3/sec	92.0	16.9	9.6	9.2	9.7	15.6	15.6	2.87	1.0
		% to Qm	6%	59%	49%	56%	57%	58%	40%	53%	56%
Average Discharge for Power Generation	Qp	m^3/sec	898	25.3	17.1	12.4	13.1	21.1	27.8	4	1.38
		% to Qm	60.7%	88.8%	87.7%	75.6%	77.1%	78.1%	71.8%	74.1%	76.7%
Full supply level	FSL	EL.m	75.0	325.0	490.0	380.0	245.0	120.0	215.0	760.0	947.0
Minimum operating level	MOL	EL.m	74.0	291.0	475.0	360.0	225.0	105.0	174.0	720.0	940.0
Dead water level	DWL	EL.m	65.2	281.0	465.0	344.0	215.0	97.0	165.0	710.0	935.0
Tail water level	TWL	EL.m	47.9	125.0	325.0	260.0	144.0	55.0	0.0	380.0	40.0
Intake Diameter	ID	m	10.4	5.4	4.6	4.2	4.2	5.0	5.6	2.6	2.6
Effective Head	He	m	25.9	178.8	153.9	102.4	86.1	55.7	188.6	325.7	899.8
Installed Capacity	Pi	MW	420	100	54	28	25	26	116	28	26
Dependable Peak Power	Pd	MW	220	100	48	28	25	26	92	28	26
Annual Energy Production	Ea	GWh/yr	1,725	348	198	96	86	90	407	98	91
Firm Energy Production	Ef	GWh/yr	480	217	107	64	58	58	205	66	65
4. Structures											
1) Dam Type			Earthfill	Concrete	Concrete	Concrete	Concrete	Concrete	Rockfill x 2	Rockfill	Earthfill
Crest Length x Height		m	7,750 x 32	325.7 x 55	189 x 47	320 x 45	172 x 46	361 x 44	847 x 97, 599 x 62.5	516 x 75	1,162 x22
Dam Volume	V	mcm	4.43	0.158	0.067	0.175	0.076	0.189	6.7	2.23	0.49
Design Flood	IDF	m^3/sec	49,400	2,930	2,230	2,900	2,740	3,470	5,270	1,960	569
2) Waterway											
Type			-	Tunnel	Tunnel	Tunnel	Tunnel	Tunnel	Tunnel	Tunnel	Tunnel
Dimension x Length		D x L (m)		5.4 x 5,000 (HRT) 5.4 x 3,800 (TRT)	4.6 x 4,600	4.2 x 9,300	4.2 x 4,000	5.0 x 2,300	5.6 x 10,800 (HRT), 5.6 x 1,000 (TRT)	2.6 x 8,000	2.6 x 3,200
Penstock pipe		d x L (m)	9.0 x 40	3.8 x 147.5	3.0 x 134	2.6 x 215	2.7 x 406	3.4 x 203	4.0 x 147	1.5 x 1,730	1.3 x 4,000
3) Powerhouse											
Generator Type			Kaplan	Francis	Francis	Francis	Francis	Francis	Francis	Pelton	Pelton
Capacity x Units		MW x nos	84.0 x 5	50.0 x 2	27.0 x 2	14.0 x 2	12.5 x 2	13.0 x 2	58.0 x 2	14.0 x 2	13.0 x 2
4) Transmission Line											
Voltage (kV) x Circuit x Length (km)		kV x cct x km	230 x 2 x 40 (St.Treng)	115 x 2 x 83 (Banlung)	115 x 2 x 13 (Banlung)	115 x 10 (Atay SW)	115 x 60 (Koh Kong)	115 x 5 (Koh Kong)	230 x 2 x 5 (R48 JCT)	115 x 37 (Atay SW)	115 x 22 (Kampot)
5) Access Road	L	km	10	72	92	25	23	46.5	9	31	9
5. Construction Cost (incl. Resettlement cost)	C	mil.$	623.1	162.4	70.2	85.2	71.0	71.8	314.2	124.2	55.2
6. Economic											
Cost for kW (excl. Resettlement cost)	UCC	$/kW	1,348	1,605	1,284	2,992	2,463	2,721	2,659	4,366	2,432
Cost for kWh	UGC	¢/kWh	4.76	6.13	4.64	11.52	10.77	10.41	9.98	16.41	9.19
7. Resettlement											
Number of Households		hh	1,224	0	0	0	168	0	0	0	0

Source: Study Team

6.6 TRANSMISSION LINES FOR THE PRIORITY PROJECTS

Main purpose of the transmission line to be constructed for new development of generating power station is to transmit electric power generated by the said power plant to the power grid. Therefore the consideration and design of such line shall be made with different point of view for the transmission lines for the extension and/or reinforcement of the power grid in order to save its construction cost.

In the case of the extension and/or reinforcement of the power grid, it is the most important to supply stably and continuously electric power to the customers. Therefore, necessary countermeasures shall be considered to avoid any obstructions to continuous power supply when the transmission line is stopped by force due to faults and/or damage of the facilities. In general, however necessary countermeasures will be limited in the preset acceptable range in order to suppress construction cost and tariff increase. For example, the (N-1) contingency criterion is normally adopted for the transmission systems having not so dense, for minimizing forced-outage due to faults and suppressing their construction costs. (N-1) contingency means to establish a system keeping stable power supply under any case where any one circuit of transmission line or a transformer bank is out of service.

On the other hand, forced outage due to fault of the transmission line for transmitting generated power to the grid (hereinafter called as Power Source Line) does not mean “supply obstruction of the specific area and/or to customers” from the viewpoint of power system operation. It means “drop-out of generating plant from the system (deficiency of power supply capacity)”, because the generating plant sending out power through the Power Source Line will be obliged to stop its operation due to the fault of the line. Namely, for continuing system operation in stable manner, necessary measures for compensating the shortage of power supply capacity of the system shall be taken. For compensating the shortage of supply capacity, it will be taken as the first step to increase the output of the remaining generating plants in operation, followed by starting-up of stand-by plants such as hydropower, gas turbine, diesel generators, etc., and then to start-up thermal power plants, etc. depending on the capacity dropped-out from the power system.

In general, drop-out of generating plants from the system including above-mentioned cases have been usually considered not only in the generation expansion plan but also in the daily operation plan in the economically acceptable level as a reserve capacity. Therefore, if the capacity of drop-out of plant from the system is within the estimated range, no hindrance of power supply will be occurred. However, there are some differences of an incremental operation expense of the system between the drop-out of hydropower plant and thermal as explained hereunder.

For the thermal power plant, fuel cost shares the biggest portion of the generating cost, followed by depreciation cost of the plant, operation cost of auxiliary equipment, personnel cost of operators, maintenance cost, etc. Therefore, incremental expense due to a shift from the said thermal power plant to others will be minimized, because the difference of fuel cost of the both power plants will be additionally required.

For the hydropower plant, depreciation cost shares the biggest portion of the generating cost, followed by personnel cost of operators, maintenance cost, operation cost of auxiliary equipment, etc. No fuel cost is required. It means that expense for maintaining hydropower station during standstill of its operation is similar to the expense during operation. Therefore, all generating expense including fuel cost of power plant operated for compensating power deficiency due to drop-out of the said hydropower plant from the system will be surely required as increment cost.

In addition to the above incremental cost differences, normally a big part of the transmission line for a hydropower plant will be constructed in mountain range where access to the tower sites is difficult. Therefore, the restoration work period of the damaged Power Source Line for the hydropower plant will be longer than that for the thermal power plant, because of the difficulty of not only transportation of materials for the restoration but also works for the restoration like tower erection, paying-out of conductors, stringing conductors, etc.

6.6.1 Transmission Line of Each Selected Project

From the above-mentioned points of view, main features of transmission line for the selected priority projects are determined on the following criteria which are similar to the criteria for the extension of the national grid. The results are summarized in Table 6.6.1.

(1) A steel lattice tower is used as support structure for the all transmission lines.

(2) The voltage of the nearest substation will be adopted as a transmission line voltage for establishing simple system configuration when technically applicable.

(3) Kind of conductor shall be ACSR. The minimum size of conductor is 95 mm^2 (max. transmission capacity: 50 MW/cct) for 115 kV and 400 mm^2 (max. transmission capacity: 250 MW/cct) for 230 kV for using single conductor per phase from the technical viewpoint of corona phenomena.

(4) Double circuit line will be considered for the maximum output of the plant more than 60 MW for 115 kV line and 160 MW for 230 kV line.

Table 6.6.1 Main Features of Transmission Lines

Project	LL2	PL1	PL2	BP	MSRC	MTK2	MTK3
Max Output (MW)	420	100	54	26	28	25	26
Nearest Substation							
- Name	St. Treng	Ratanak Kiri	PL1	Kampot	Ou Saom	Koh Kong	MTK2
- Voltage	230/115	115	115	230	230	230	230
Transmission Line							
- Length (km)	32	83	13	32	10	45	15
- Voltage (kV)	230	115	115	230	230	230	230
- Circuit	2	2	1	1	1	1	1
- Conductor	2x330	2x200	1x200	1x400	1x400	1x400	1x400

Source: Study Team

7. ECONOMIC AND FINANCIAL ASPECTS OF PRIORITY PROJECTS

7.1 ECONOMIC EVALUATION FROM THE VIEWPOINT OF NATIONAL ECONOMY OF CAMBODIA

7.1.1 General Assumptions for the Economic Analysis

Economic evaluations were made for the 8 priority projects[1]. Economic evaluation aims at measuring the "economic" impact on the country by implementing a project from a viewpoint of national economy.

The EIRR calculation is based on the following assumptions: 1) all revenues and costs are in 2007 constant prices and are expressed in US dollar ($); (2) assessment period are assumed at 30-year after the completion of the projects*2; 3) project costs exclude tax, nonphysical contingencies, interest during construction, and other financing costs; and 4) operating costs exclude depreciation and debt servicing.

7.1.2 Economic Costs of the Priority Projects

Market values are usually distorted with transfer payments within Cambodia such as taxes and subsidies. These payments are transferred to the Government that acts on behalf of the nation. Then, these should not be treated as costs of the national economy. These have to be excluded from the market values of cost and benefits as a whole. Following the principles, tax and price contingency were excluded from the market cost, also the local portion of the every project cost estimated was converted to border price applying a conversion factor of 0.90, which is commonly adopted in economic analysis in Cambodia.

(1) Capital Cost

The financial cost of the priority projects were estimated at $52.2 million (#29 Bokor Plateau) to 623.1 million (#7&8 Lower Sre Pok II + Lower Se San II) in "5. Technical Review of 10 Priority Projects, (4) Hydropower Planning, 4) Cost estimate", including 1) civil work cost, 2) generating equipment cost, 3) transmission and substation cost, 4) land acquisition and compensation cost, 5) administration and construction supervision cost, and 6) value added tax. Unit construction cost, excluding land acquisition and compensation cost, of the priority projects varied from $1,348 per kW (#7&8 Lower Sre Pok II + Lower Se San II) to $4,366 per kW (#23 Upper Stung Russey Chrum).

After deducting price contingency and taxes and applying standard conversion factor of 0.90 to the local cost portion, the economic cost of the priority projects was calculated at $47.7 million (#29 Bokor Plateau) to $546.1 million (#7&8 Lower Sre Pok II + Lower Se San II).

1 In Chapter 5, 10 priority hydropower projects were selected. Of which, 2 projects (Prek Liang 1 and Prek Liang 1A) were merged to form one project (Prek Liang 1) after the site investigation survey. In addition, concession agreement of Stung Kep II (New Tatay) project was concluded between Cambodian government and Chinese contractor in May 2008. Thus, economic and financial analyses in this chapter targeted for the remaining 8 projects.

2 With referring to the concession period of the existing contract agreement between CETIC and MIME for the Kirirom III Hydropower Station, commercial operation period of the priority hydropower project was assumed 30 years.

These capital costs were assumed to be disbursed during the construction period of 5 years (1st year: 5%, 2nd: 10%, 3rd: 30%, 4th: 35%, and 5th: 20%) for all the projects.

Table 7.1.1 Cost of the Priority Projects (Financial, Economic Cost and Cost per kW)

	Name of the Project	Installed Capacity (MW)	Financial Cost		Economic Cost
			$1,000	$ per kW	$1,000
7&8	Lower Sre Pok II + Lower Se San II	420	623,068	1,348	546,078
12	Prek Liang I	100	162,445	1,605	140,908
14	Prek Liang II	54	70,158	1,284	60,874
16	Middle Stung Russey Chrum	28	85,231	2,992	73,556
20	Stung Metoek II	25	70,985	2,463	62,101
21	Stung Metoek III	26	71,757	2,721	62,202
23	Upper Stung Russey Chrum	28	124,161	4,366	107,036
29	Bokor Plateau	26	55,169	2,432	47,738

Source: Study Team

(2) Fixed Operation and Maintenance Cost

The fixed operation and maintenance (O&M) cost is required annually during the economic life of the project. The fixed O&M cost includes daily operation and maintenance activities as well as semi-overhauling executed every 6 years of operation, and was assumed at 0.5% for civil and metal works and 1.5% for electro-mechanical equipment, and transmission related facilities. Estimated fixed O&M costs were varied from $0.33 million/year to $4.52 million/year.

(3) Variable Operation and Maintenance Cost

Variable O&M cost includes only the cost for lubricant. In Cambodia, water charge/tax is not levied on the project operating entities. Cost of lubricant was assumed at 0.0151 ¢/kWh, based on actual average expenditure for lubricant at the hydropower stations in Indonesia in 2006. Based on these assumptions, variable O&M cost was computed for all the projects.

7.1.3 Economic Benefits of the Priority Projects

(1) Selection of the Candidates of the Alternative Energy Source (First Screening)

The economic benefit can be calculated as a sum of avoided costs of Alternative Thermal Power Plant (ATPP). Avoided costs can be divided into two components, one is construction and fixed O&M cost of firm peak capacity of the hydropower project, and the other consists of fuel cost and variable O&M cost saving of energy generation. The former benefit is called a “capacity benefit” and the latter is known as “energy benefit”.

In calculating economic benefit of a hydropower project, type of alternative thermal power station to be used for calculation should be the lowest among various types of generating plants, and also should be feasible option in terms of fuel supply and technical aspects.

In order to determine alternative thermal plant, five types of generation plants, namely coal fired steam turbine, gas fired combined cycle, HFO fired medium speed and low speed diesel generator, and energy import from neighboring countries were selected.

As a result of the first screening, of the five alternatives as examined below, energy import was excluded from the candidate alternative while the other four generating plants (combined cycle, coal steam, and low/medium speed diesel) are considered to be suitable option in terms of fuel supply and technical feasibility.

Gas Combined Cycle Power Plant

At present in Cambodia, there is neither gas-fired power station nor facilities for importing gas, such as pipeline and LNG terminal. While technical feasibility of the combined cycle power station using domestic natural gas was confirmed by a JICA study in 2001[*3], availability of gas from domestic gas fields is still not clear.

Currently, Cambodia has six potential oil and gas fields in off-shore Sihanoukville. Only one of these has so far been explored, the so-called Block A. The Block A drillings, conducted by a foreign consortium led by Chevron including GS Caltex of South Korea and Japan's Mitsui Oil. Chevron confirmed "significant finds" from its initial exploration in 2005 and then more test drills were conducted. However, they have not published any figure about deposit yet. As such, technical and financial viability of the gas/oil fields are not confirmed yet. Given conditions, according to the Power Supply Development Plan from 2007 to 2020[*4], development of the first gas combined cycle power plant was planned not in the near future but in 2020 (450 MW), and next to 2022 (450 MW). Judging from these circumstances, while combined cycle power station seems unrealistic option in short/middle term, it is still possible option in long-term. And thus, combined cycle power station was selected as the candidate of alternative thermal unit,

Coal-fired Steam Power Plant

At present there is no coal-fired power station in Cambodia. Currently, coal fired power plant in Sihanoukville with installed capacity of 200 MW (100 MW x 2 units) and related transmission facilities are being planned. MIME and EDC already selected concessionaire, joint venture of Malaysian company and Cambodian company, for this BOO (Built Own Operate) project. The negotiation will be concluded within a few months, and the power plant is expected to start commercial operation in 2010.

Construction cost was estimated at about $350 million, including jetty and tugboat for importing coal. Concessionaire intends to import coal from Indonesia.

In addition to this 200 MW power plant, the Power Supply Development Plan from 2007 to 2020 includes BOO based 400 MW coal fired power plant in Sihanoukville in 2013. Given the situation, coal-fired power station was judged reasonable candidate for alternative to hydropower.

Diesel Power Plants

Diesel power plants occupied more than 95% of the electric power generation in Cambodia in 2006. There are three types of diesel engine, namely high speed, medium speed and low speed. Since the high speed diesel engine has very small capacity, it was excluded from the candidate of alternative. Low

[3] Feasibility Study on the Sihanoukville Combined Cycle Power Development Project in Cambodia, Oct 2001, JICA/ NEWJEC

[4] Source: Report on Power Sector of the Kingdom of Cambodia for the year 2006, June 2007, EAC

speed diesel engine has higher thermal efficiency but is more expensive in the capital cost. Middle speed diesel engine is commonly used in Cambodia.

EDC's power purchase price from the diesel IPPs has increased rapidly particularly following the rapid rise in the international crude oil price since 2003. In December 2006, unit purchase prices from IPPs of the EDC Phnom Penh Branch were ranged between 12 and 16 ¢/kWh. Given the situation, while diesel power plants have high generation cost, there are no technical issues, and thus diesel power plants were selected as the candidate alternative for hydropower.

Energy import from neighboring countries

According to the power development plan, MIME intends to import energy from Vietnam (200 MW), Laos (20 MW), and Thailand (80 MW) by 2012. Such energy import at a total of 320 MW will cover about 49% of forecast peak demand (652 MW) of the EDC grid in 2012[*5]. Taking energy security of the country into consideration, further dependence on the energy import should be avoided. For this reason, energy import is excluded from alternative energy source of hydropower development.

(2) Determination of the Alternative Thermal Power Plant (Second Screening)

With reference to the various reports and interviews to concerned persons, general features of selected alternatives were assumed as follows:

Table 7.1.2 Major Assumptions for Calculating Levelized Cost of Generation of ATPPs

	Gas Combined Cycle Plant	Coal-fired Steam Turbine	Medium Speed Diesel Generator	Low Speed Diesel Generator
Capital Cost ($/kW)	870[*2]	1,700[*3]	1,370[*1]	2,020[*1]
Construction Period (year)	3	3	2	2
Disbursement	30%, 50% and 20%	30%, 50% and 20%	40% and 60%	40% and 60%
Type of Fuel	Natural Gas	Coal	Heavy Fuel Oil	Heavy Fuel Oil
Heat Rate (kcal/kWh)	1,592[*2]	2,324[*3]	1,988[*1]	1,761[*1]
Price of Fuel ($)	8.44 /MMBtu[*5]	62.70 /ton[*6]	59.35 /barrel[*4]	59.35 /barrel[*4]
Calorific Value of Fuel (kcal)	-	5,800 /ton[*6]	1,584,425 /barrel[*5]	1,584,425 /barrel[*5]
Project Life (years)	25[*1]	20[*1]	25[*1]	25[*1]
Annual O&M Cost	3.0% of capital cost[*1]	5.0% of capital cost[*1]	5.5% of capital cost[*1]	5.5% of capital cost[*1]

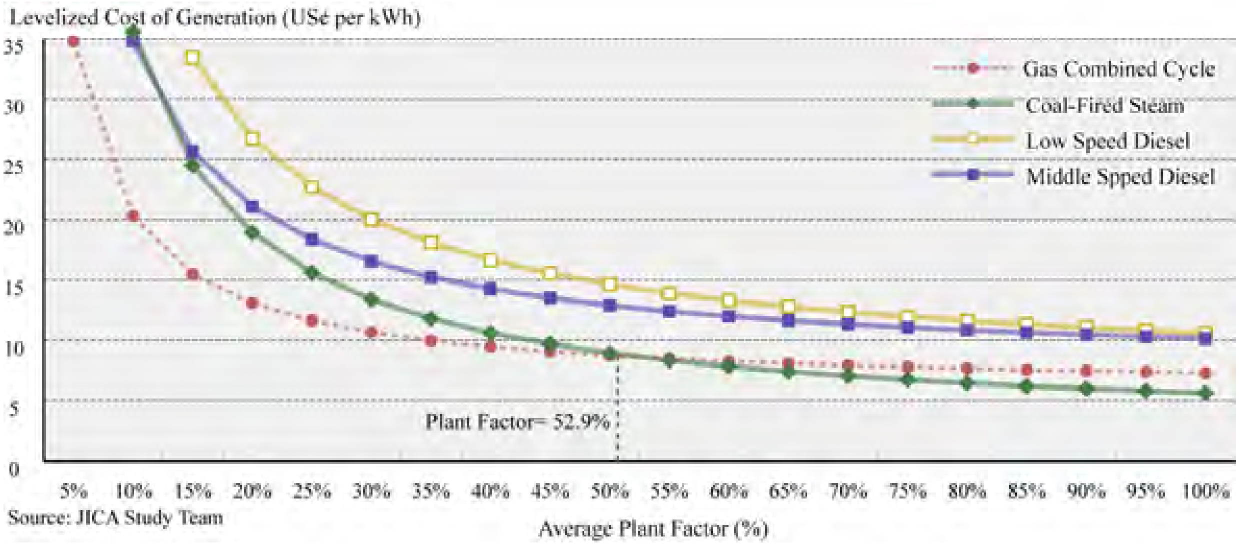
Source: *1: Generation Expansion Plan of Cambodia p 3-39 (World Bank/KOICA, December 2006),
*2: The Sihanoukville Combined Cycle Power Development Project, JICA/NEWJEC, Oct. 2001,
*3: Feasibility Study on the Sihanoukville Coal-fired Power Station, MIME
*4: Financial Statements for the year ended 31 December 2005, EDC Phnom Penh Operation,
*5: EIA Annual Energy Outlook 2007, Coal price for electric generation (average during 2006-2007: $37.05/ton) + transportation cost (generation expansion plan of Cambodia page 3-41, World Bank/KOICA, assumed as same as sea freight cost of oil: $25.0/ton)
*6: EIA Annual Energy Outlook 2007, Gas price for power generation (average during 2006-2007: $7.40/MMBTU) + (sea freight cost: $0.5/MMBTU, liquefaction cost: $1.0/MMBTU, re-gasification cost: $0.4 /MMBTU)

Figure 7.1.1 illustrates levelized cost of generation for each alternative thermal by plant factor (PF)[*6]. The figure shows that the levelized costs of generation become lower along with the increase in the PF,

5 Source: Power Development Master Plan, Final Report, December 2006, Korea Electric Power Corporation/ World Bank, Base Case Demand Forecast

6 Plant Factor = The ratio of the electrical energy produced by a generating unit(s) for certain time period (a year for example) to the electrical energy that could have been produced at continuous full-power operation during the same period.

and the least cost alternative changes depending on PF. When PF is lower than 52.9%, gas-fired combined cycle is the least cost alternative while when PF is higher than 52.9% coal-fired steam turbine is the least cost alternative.



Source: JICA Study Team

Figure 7.1.1 Comparison of Levelized Generation Cost of Alternative Thermal Power Plant

Gas-fired combined cycle power plant was selected as the least cost alternative thermal power plant since the 8 priority projects had been planned with target PF at 40% being lower than 52.9%.

(3) Calculation of Economic Benefits

<u>Calculation of the kW Adjustment Factor and the kWh Adjustment Factor</u>

Generally speaking, a hydropower is normally more mechanically reliable than a thermal. Also, a hydropower has more flexibility in terms of fast-start capability and quick response to changing loads. In order to reflect these characteristics, an adjustment is applied to reflect the higher capacity value of the hydropower project. This higher value is given because somewhat more thermal capacity would be required than hydro capacity to firmly respond to changes in the system peak load. Power benefit can be calculated by multiplying firm peak capacity of hydropower station, kW adjustment factor and kW value. Also energy benefit will be worked out by multiplying energy production of hydropower project, kWh adjustment factor and kWh value.

The following formula and assumptions were used for calculating the kW and kWh adjustment factors.

The kW adjustment factor was estimated to be 1.220 and the kWh adjustment factor at 1.026.

$$\text{kW Adjustment Factor} = \frac{(1 - \text{AxR of HPP}) \times (1 - \text{AvF of HPP}) \times (1 - \text{T/L loss of HPP})}{(1 - \text{AxR of ATPP}) \times (1 - \text{AvF of ATPP}) \times (1 - \text{T/L loss of ATPP})}$$

$$\text{kWh adjustment factor} = \frac{(1 - \text{AxR of HPP}) \times (1 - \text{T/L loss of HPP})}{(1 - \text{AxR of ATPP}) \times (1 - \text{T/L loss of ATPP})}$$

* AxR= Auxiliary Use Rate, T/L loss= Transmission loss, HPP: Hydropower plant, ATPP: Alternative thermal power plant
AvF= Availability factor: operating hours- duration planned outage- duration of forced outage)/total time of a year

Table 7.1.3 Assumptions for Calculating Adjustment Factors

Alternative Thermal Power (Gas CCPP)		Priority Hydroelectric Power	
- Station Use	2.80%	- Station Use	0.30%
- Forced Outage	8.00%	- Forced Outage	0.50%
- Planned Outage	11.00%	- Planned Outage	3.15%
- Transmission Loss	2.00%	- Transmission Loss	2.00%

Source: Study Team

Power Benefit

The 8 priority hydropower projects are planed to have a firm peak capacity of 25 MW ~ 220 MW. Thus, installed capacity of the alternative thermal power station needs 31 MW ~ 268 MW (Firm Peak Capacity × kW adjustment factor). On the other hand, the kW value or the annualized fixed cost of alternative power station is calculated at $133.7 per kW (kW construction cost × capital recovery factor @12% of discount rate + fixed annual O&M cost). Using the following assumptions, power benefit is worked out at $3.34~29.42 million/year (installed capacity of ATTP × kW value, refer to Figure 7.1.2 and Table 7.1.4).

Table 7.1.4 Power Benefit of the Priority Projects

Variable O&M Cost*b (¢/kWh)	0.122	Fixed O&M Cost*b ($/kW/yr)	2.49
Installed Capacity of ATPP (MW)	31 ~ 268	kW-Value ($/kW/yr)	133.7
Capital Recovery Factor*a	0.1241	Power Benefit ($ mil./yr)	3.34 ~ 29.42

Source: Study Team

Note: *a: Capacity Recovery factor= $i*(1+i)^n / \{(1+i)^n-1\}$, where: n= service life, and i= discount rate of 12%

*b: Quoted form the final report of "Electricity Network Master Plan in Cambodia, Volume 1: Generation Expansion Plan, Appendix 4, page 10, October 2006, EGAT"

Energy Benefit

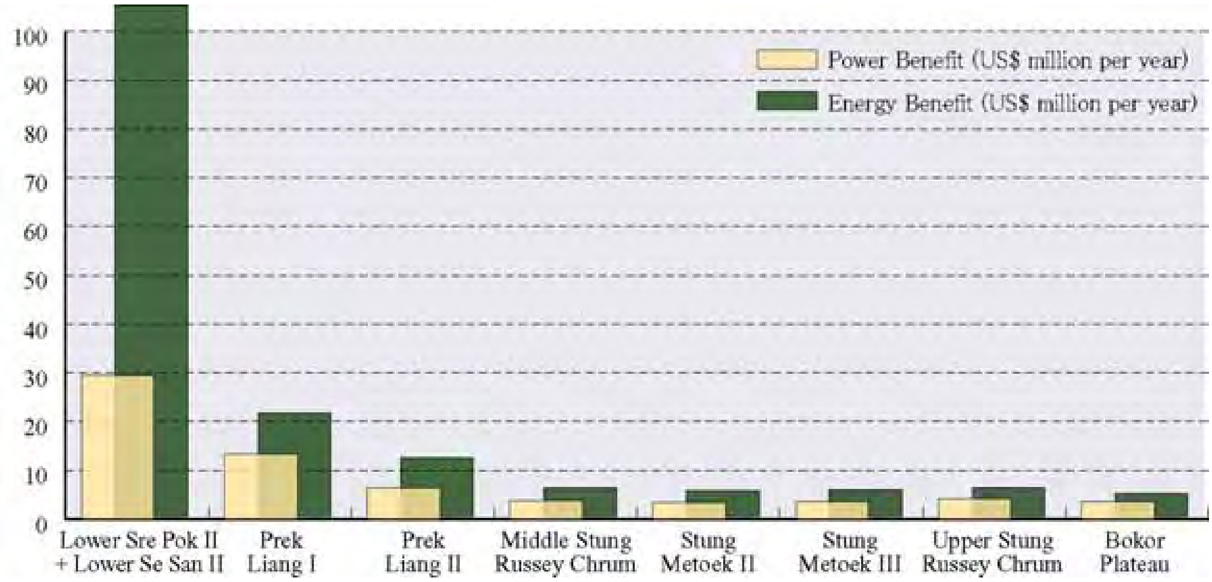
The priority projects are planed to generate 78 ~ 1,725 GWh of energy per annum. Taking auxiliary loss and transmission loss of hydro and alternative thermal into consideration, alternative thermal power station needs to generate 80 ~ 1,770 GWh per annum on an average (annual generation of hydropower projects × kWh adjustment factor). Using the following assumptions, the kWh value and energy benefit were calculated at6.07 ¢/kWh and energy benefit at $4.8 ~ 104.8 million/year (adjusted energy production of ATTP × kWh value, refer to Figure 7.1.2 and Table 7.1.5).

Table 7.1.5 Energy Benefit of the Priority Projects

Unit Cost of Fuel (¢/ kWh)	5.87	Variable O&M Cost*a (¢/kWh)	0.122
kWh-Value (¢/kWh)	6.07	Generation of ATPP (GWh)	80 ~ 1,770
Energy Benefit ($ mil/yr.)	4.8 ~ 104.8		

Source: Study Team

Note: *a=Quoted form the final report of "Electricity Network Master Plan in Cambodia, Volume 1: Generation Expansion Plan, Appendix 4, page 10, October 2006, EGAT"

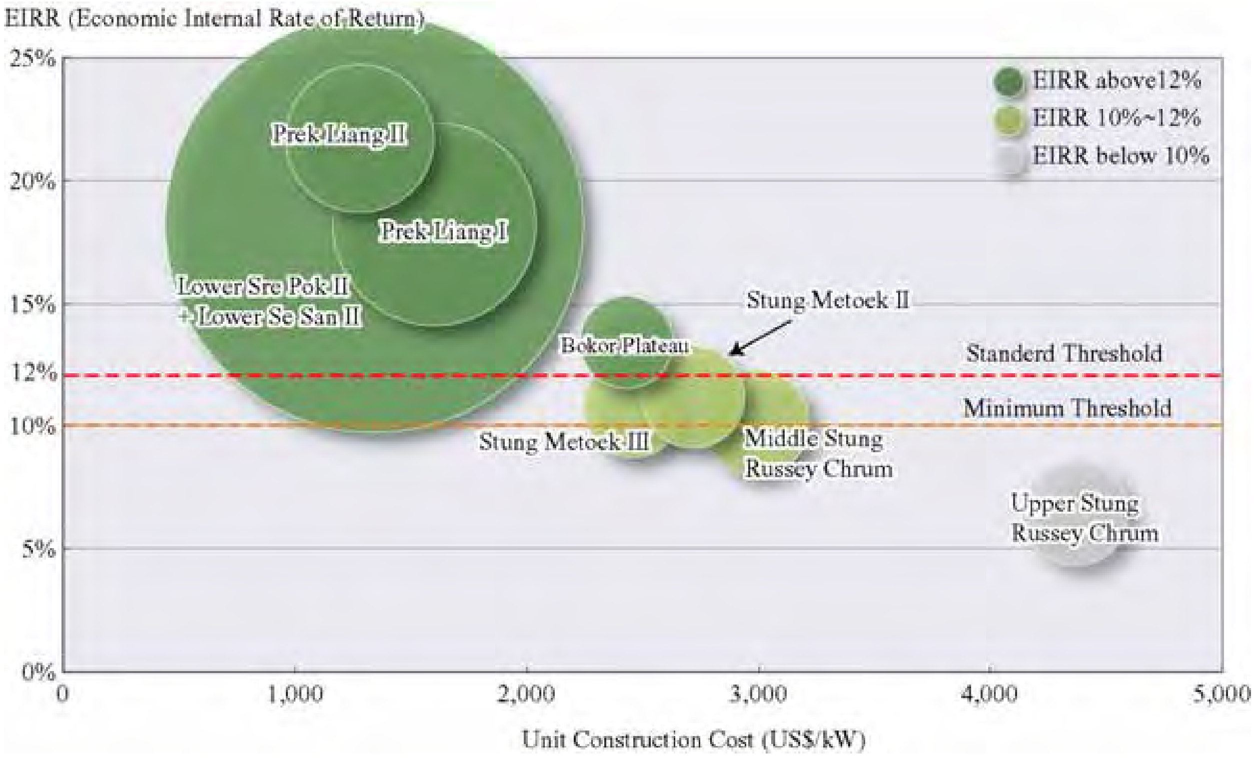


Source: Study Team

Figure 7.1.2 Summary of Power Benefit and Energy Benefit of the Priority Projects

7.1.4 Results of the Economic Analysis

Figure 7.1.3 shows the relation among the calculated EIRR, unit construction cost in US$ per kW, and installed capacities of the 8 priority projects. Generally, the lower unit construction costs would have the higher EIRR of the projects.



Source: Study Team Note: Size of circles indicate relative scale of installed capacity of each project

Figure 7.1.3 Relation among the Calculated EIRR, Unit Construction Costs and Installed Capacities of the Priority Projects

Generally speaking, EIRR of the projects should exceed the Cambodia's economic opportunity cost of capital of 12%. In addition, the Study team adopted more relaxed threshold of 10% as the minimum threshold for the master plan level study.

Of the 8 priority projects, the EIRR of the 4 projects exceed standard threshold of 12%. With regard to the EIRR of the 3 projects, the EIRR varied between the minimum threshold of 10% and standard threshold of 12%. However, EIRR of #23 Upper Stung Russey Chrum (8.0%) is lower than the minimum threshold of 10% (refer to Table 7.1.6), and thus is deemed not economically feasible from viewpoint of the national economy.

Table 7.1.6 Summary of Economic Analysis of the Priority Projects

No.	Name of the Project	Installed Capacity (MW)	Firm Peak Capacity (MW)	Energy Production (GWh/yr.)	Power Benefit ($ 1,000/yr.)	Energy Benefit ($ 1,000 yr.)	EIRR (%)
7&8	Lower Sre Pok II + Lower Se San II	420	220	1,725	29,418	104,788	18.2%
12	Prek Liang I	100	100	348	13,372	21,140	18.2%
14	Prek Liang II	54	48	198	6,418	12,028	21.7%
16	Middle St. Russey Chrum	28	28	96	3,744	5,832	10.1%
20	Stung Metoek II	25	25	86	3,343	5,224	10.7%
21	Stung Metoek III	26	26	90	3,477	5,467	11.2%
23	Upper St. Russey Chrum	28	27	98	3,610	5,935	8.0%
29	Bokor Plateau	22.3	26	78.2	3,477	4,750	13.4%

Source: Study Team

7.2 FINANCIAL EVALUATION FROM THE VIEWPOINT OF PROFITABILITY OF PROJECT OPERATING ENTITY

7.2.1 General Assumptions for the Financial Analysis

The financial analysis of a project examines the adequacy of returns to the project-operating entity, whereas economic analysis measures the effect of the project on the national economy, as a whole.

Being the same as economic evaluation, the cash flow for financial evaluation of the project was prepared in real terms using constant 2007 prices. All prices and costs are expressed in US dollar ($). With reference to the existing contract between EDC and Hydropower IPPs, assessment period of the priority hydropower stations was assumed as 30 years.

Since the large and medium scale hydropower development in Cambodia has been and will be made by IPP basis in principle, in this financial analysis, the project operating entities of priority projects were assumed to be private investors. Accordingly project cost includes the power station as well as transmission line to the nearest substation, and the benefit was revenue from sales of electricity to EDC at the substation.

7.2.2 Financial Costs of the Priority Projects

Financial costs of the priority projects include physical contingency and various taxes, but exclude nonphysical contingencies, interest during construction, other financing costs, depreciation and debt servicing. Financial costs can be divided into 1) capital cost, 2) fixed O&M costs, and variable O&M costs.

(1) Capital Cost

The financial cost of the 8 priority projects was estimated at $55.2 million (#29 Bokor Plateau) to 623.1 million (#7&8 Lower Sre Pok II + Lower Se San II), refer to Table 7.2.1. These capital costs were assumed to be disbursed during the construction period of 5 years (1st year: 5%, 2nd: 10%, 3rd: 30%, 4th: 35%, and 5th: 20%) for all the projects.

(2) Fixed Operation and Maintenance Cost

The fixed operation and maintenance (O&M) cost is required annually during the economic life of the project. The fixed O&M cost includes daily operation and maintenance activities as well as semi-overhauling executed every 6 years of operation, and was assumed at 0.5% for civil and metal works and 1.5% for electro-mechanical equipment, and transmission related facilities. Estimated fixed O&M costs varied from $0.33 million/year to $4.52 million/year.

(3) Variable Operation and Maintenance Cost

Variable O&M cost includes only the cost for lubricant. In Cambodia, water charge/tax is not levied on the project operating entities. Cost of lubricant was assumed at 0.0151 ¢/kWh, based on actual average expenditure for lubricant at the hydropower stations in Indonesia[*] in 2006. Based on these assumptions, variable O&M cost was computed for all the projects.

7.2.3 Financial Benefits of the Priority Projects

(1) Revenue from Sale of Electricity

Financial benefit was measured as the revenue from sales of electricity received from EDC. Generated energy was assumed to be sold to EDC at the nearest substation (delivery point). Sales revenue can be measured as the products of average sales price of electricity, and sales volume of electricity at delivery point. Sales volume of energy was calculated by deducting auxiliary loss at the power station and transmission loss from annual generation volume. Auxiliary loss of 0.3% and transmission loss between the power stations to the substations of 1.0% were used in calculating sales volume of energy at the delivery point.

According to the EAC and EDC, power purchase prices from the IPP hydropower stations are as follows:

Table 7.2.1 Unit Sales Price of Electricity from the Hydro IPPs to EDC

Name of Power Station	Operator	Installed Capacity	Start of Operation	Price of Electricity
Kirirom I	CEPTC (China Electric Power Technology Import and Export Corporation)	12 MW	2002	7.00 ¢/kWh
Kirirom III	CEPTC (China Electric Power Technology Import and Export Corporation)	18 MW	2010 (Plan)	8.10 ¢/kWh
Kamchay	SINOHYDRO	193 MW	2010 (Plan)	8.08 ¢/kWh
Stung Atay	CYC (China Yunnan Corporation)	120 MW	2012 (Plan)	5.81 ¢/kWh

Note: Power purchase price data is provisional figure, except for Kirirom I
Source: MIME, EAC, and EDC

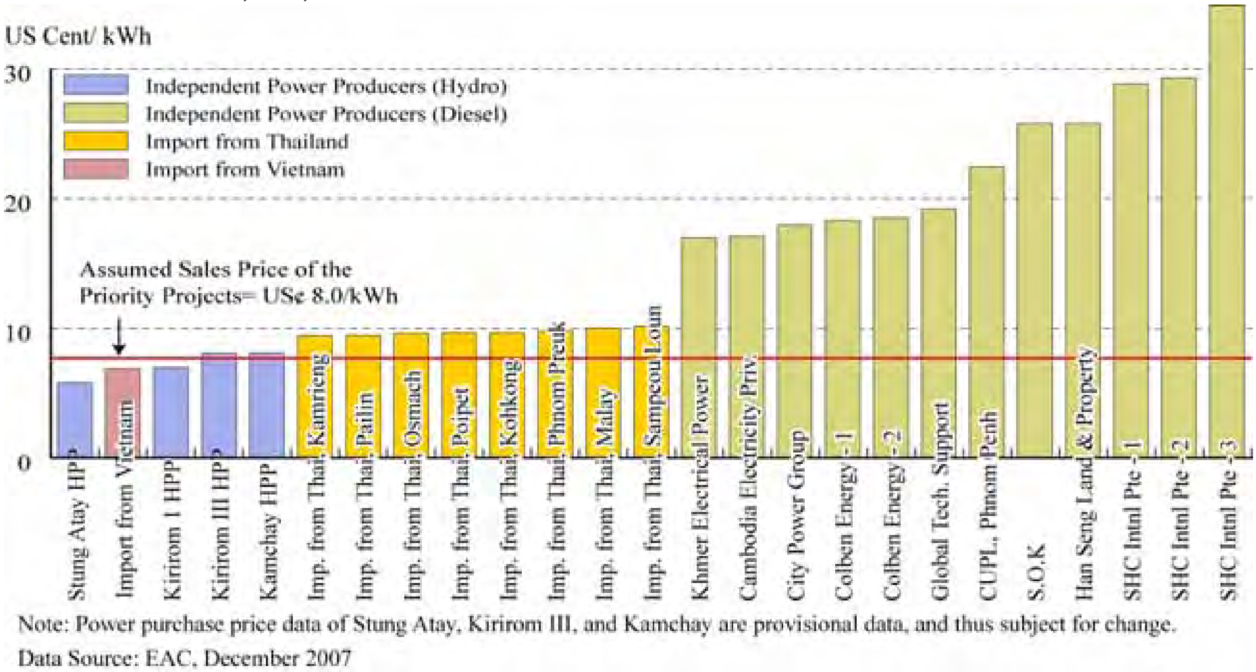


Figure 7.2.1 Comparison of Sales Price to EDC between the Priority Hydro and Others

In this financial analysis, whole sale price of 8.0 ¢/kWh was assumed for all the priority projects. As shown in the figure above, the assumed whole sale prices of the priority hydropower projects at 8.0 ¢/kWh is slightly higher than the price of Kirirom I (7.0 ¢/kWh), Stung Atay (5.8 ¢/kWh) and import energy from Vietnam (6.90¢/kWh in December 2007). But it is slightly lower than Kirirom III

(8.10 ¢/kWh), Kamchay (8.08 ¢/kWh), and imports from Thailand (8.49 ~ 9.37 ¢/kWh in December 2007)[*7]. Also, 8.00 ¢/kWh is lower than one half of the purchase price from diesel based IPPs (16.96 ~ 34.90 ¢/kWh in December 2007)[*8]

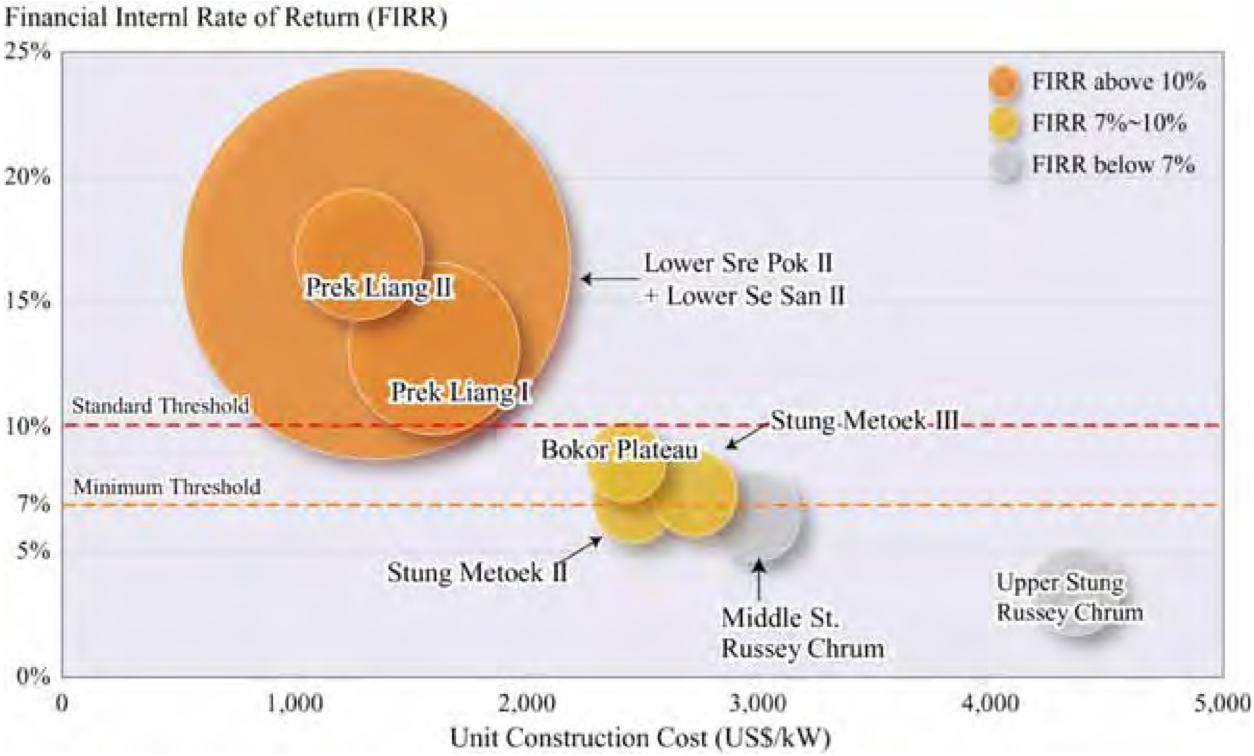
7.2.4 Results of the Financial Analysis

Figure 7.2.2 shows the relation among the calculated FIRR, unit construction cost in $ per kW and annual energy productions of the priority projects. Generally, the lower unit construction costs would have the higher FIRR of the projects.

Generally speaking in Cambodia, FIRR of the projects should exceed 10%. In addition, the Study Team adopted more relaxed threshold of 7% as the minimum threshold for the master plan level study.

Of the 8 priority projects, the FIRR of the 3 projects are more than 10%, FIRR of 3 projects are distributed between 7% and 10%. However, FIRR of the remaining 2 project (#16 Middle Stung Russey Chrum and #23 Upper Stung Russey Chrum) was below the minimum threshold of 7.0% (refer to Table 7.2.2). In implementing these 2 projects, selling price of electricity would need a tariff higher than 8 cent per kWh.

In the case of #23 Upper Stung Russey Chrum project, the project has a quite low financial viability (FIRR= 3.5%). In addition, the project was judged to be unfeasible from the viewpoint of national economy (refer to 7.1.4), and thus the project is discarded from the further study.



Source: Study Team Note: Size of circles indicate relative scale of installed capacity of each project

Figure 7.2.2 Relation among the Calculated FIRR, Unit Construction Costs and Annual Energy Productions of the 8 Priority Projects

7 Thai Bath 2.99 ~ 3.30 /kWh (Source: Report on Power Sector of the Kingdom of Cambodia for the year 2006, EAC, June 2007), Exchange rate used: 1 Bath= $0.0284 as of 15 December 2006

8 Source: Report on Power Sector of the Kingdom of Cambodia for the year 2006, EAC, June 2007

On the other hand, #14 Prek Liang II shows the highest FIRR of 16.8%, followed by #7&8 Lower Sre Pok II + Lower Se San II (16.5%), and #12 Prek Liang I (13.1%).

Table 7.2.2 Summary of Financial Analysis of the Priority Projects

No.	Name of the Project	Energy Production (GWh/year)	Plant Factor (%)	Total Project Cost ($1,000)	Unit Cost of Construction ($/kW)	Financial Cost of Generation* (¢/kWh)	FIRR (%)
7 & 8	Lower Sre Pok II + Lower Se San II	1,725	46.9%	623,068	1,348.1	4.76	16.5%
12	Prek Liang I	348	39.7%	162,445	1,605.3	6.13	13.1%
14	Prek Liang II	198	41.9%	70,158	1,283.6	4.64	16.8%
16	Middle St. Russey Chrum	96	39.1%	85,231	2,991.8	11.52	6.4%
20	Stung Metoek II	86	39.3%	70,985	2,463.1	10.77	7.0%
21	Stung Metoek IIII	90	39.5%	71,757	2,721.3	10.41	7.34%
23	Upper St. Russey Chrum	98	40.0%	5,953	4,365.6	16.41	3.5%
29	Bokor Plateau	78.2	40.0%	55,169	2,432.3	9.19	8.6%

Source: Study Team
Note: Financial cost of generation was calculated using 10% of discount rate

8. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS OF 10 PRIORITY PROJECTS

8.1 SOCIAL CONSIDERATIONS

8.1.1 Interview Survey of People in and around the Project Site

(1) Purpose of the Study

The Study Team grasped the outline of the socio-economic conditions of 29 nominated potential sites by reviewing the existing data such as Rural Development Database. 10 priority projects sites were selected by the multi-criteria analysis based on the technical, environmental and economical indicators, as described in Chapter 5. The household survey targeting the selected sites was conducted by the Study Team in order to compare more detail of socio-economic conditions. By understanding the tendency of their awareness and mindset on modernization, electricity and so on, the assessment of priority projects were tuned up.

This socio-economic survey is not a complete census but sample survey because it is a baseline survey. The survey results show the present livelihood in the target sites.

(2) Methodology

An interview survey was conducted in and around the prioritized hydropower project sites. The target villages for the interview survey were selected based on the conditions listed below:

1) The ten project sites are located within the six basins, therefore the target villages for the interview survey were selected in these same basins.
   - Projects #12-14 Prek Liang I, IA and II are located in the same basin and the inhabitants only living downstream are common for all three projects (100 samples in total commonly for the three projects).
   - Projects #16 Middle St. Russey Chrum and #23 Upper St. Russey Chrum, are in the same basin, therefore some inhabitants may get some common impacts (100 samples in total commonly for the two projects). A 100 samples were taken from Srae Kor commune in the planed site of Project #7&8 (LL2) along the Se San River, a 100 samples from Kbal Romeas commune for the same project area along the Sre Pok River, another 100 samples from Hot Pak commune in upper stream of LL2 plus Ta Lat commune and Phluk commune on downstream reaches of LL2.
   - Projects #20 St. Metoek II and #21 St. Metoek III, are in the same basin (100 samples for two projects).

2) In principle, the number of samples was set at 100 for one basin.

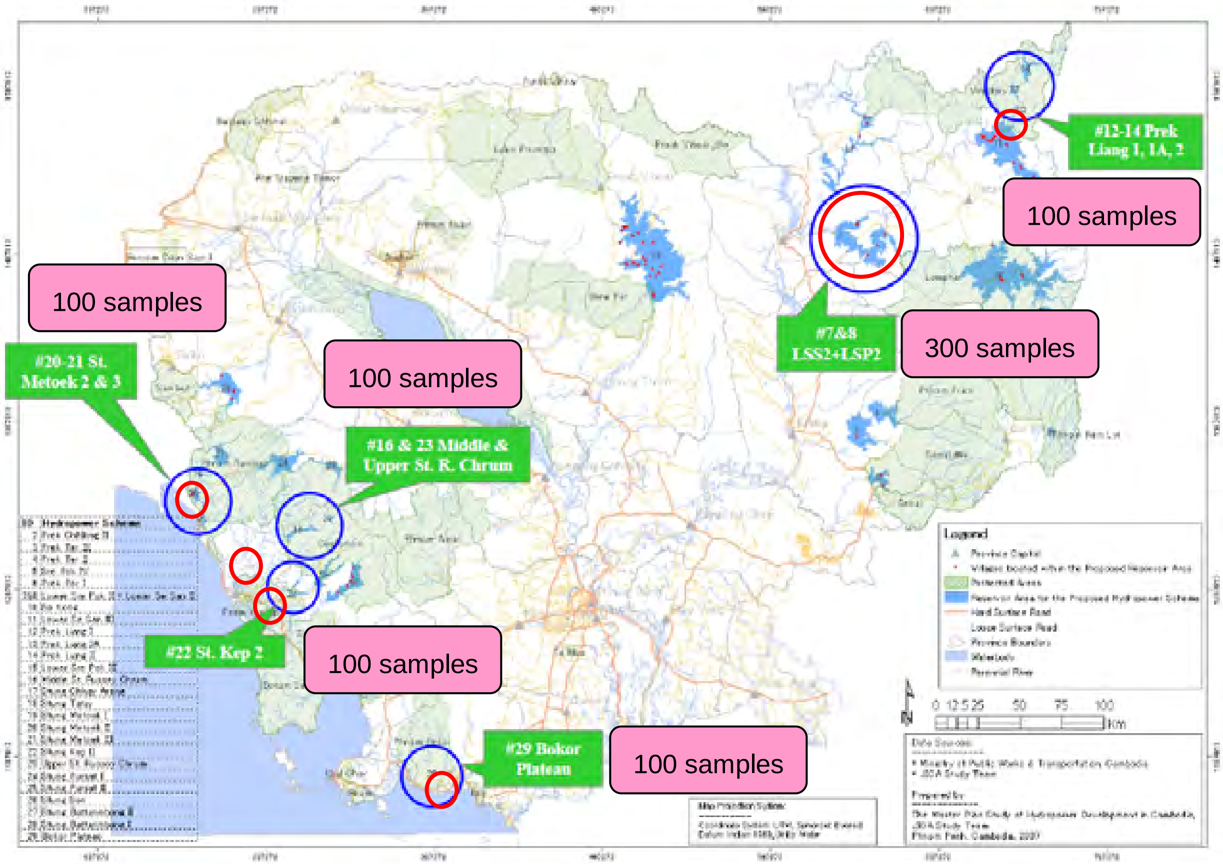
3) Since #7&8 Lower Sre Pok II + Lower Se San II project covers a wide area ranging over two

rivers and its reservoir scale is wide compared to the other projects, 200 samples were added to make a total 300 samples for this project.

4) Consequently, the total number of samples was set at 800.

(2) Target Sites

A location map of the target villages is shown in Figure 8.1.1. The target village names and corresponding number of households are presented in Table 8.1.1. Most of the target respondents for the interview survey are residing outside the envisaged reservoir areas. Some target villages are more than 50 km away from the project sites because the project sites are situated deep in the remote mountains. Of the ten projects, only two include residential area and farmlands within the planned reservoir areas.



Source: Study Team

Figure 8.1.1 Target Sites of the Interview Survey

Table 8.1.1 Target Villages and Number of Households

No	Project Name	Province	District	Commune	Village	Families	Population	Sample
12	Prek Liang I	Ratanak Kiri	Ta Veaeng	Taveaeng Leu	Bangket	56	264	100
13	Prek Liang IA				Ta Bouk	88	424	
14	Prek Liang II				Ta Veaeng	123	904	
7&8	Lower Sre Pok II+Lower Se san II (LL2)	Ratanak Kiri	Veun Sai	Hot Pak	Hot Pak	149	867	50
					Veun Hay	59	335	
		Stung Treng	Sesan	Kbal Romeas	Kbal Romeas	97	432	100
					Krabei Chrum	146	696	
					Srae Sranok	91	426	
				Srae Kor	Phum Muoy	156	658	100
					Phum Pir	134	602	
				Ta Lat	Rumpoat	39	188	50
					Ta Lat	59	311	
				Phluk	Ban Bung	52	173	
					Phluk	173	749	
29	Bokor Plateau	Kampot	Kampot	Kaoh Touch	Kandal	139	721	100
					Preaek Ampil	232	1541	
					Preaek Chek	100	493	
22	Stung Kep II (New Tatay)	Koh Kong	Kaoh Kong	Ta Tai Kraom	Anlong Vak	134	590	100
					Kaoh Andaet	73	346	
16 23	Middle St. Russey Chrum Upper St. Russey Chrum	Koh Kong	Mondol Seima	Bak Khlang	Kaoh Pao	88	389	100
			Smach Mean Chay	Dang Tong	Phum Ti Buon	1450	6949	
					Phum Ti Pir	452	2134	
20 21	St. Metoek II St. Metoek III	Pursat	Veal Veaeng	Thma Da	Aekakpheap	50	239	100
					Kandal	77	322	
					Sangkom Thmei	41	174	
								800

Source: Study Team

Concurrently with the household interview survey using questionnaires, key informant interviews were conducted by experts of the Study Team in order to understand the background of the villagers' lives from the socio-economic and historical viewpoints. Environmental issues relative to the villagers' lives were reviewed as well.

8.1.2 Analysis of the Interview Survey

(1) Background Information of the Respondents

The characteristics of the target villages were analyzed from various viewpoints such as culture, economics and environment. First, the baseline information was compared among the target villages to grasp the people’s characteristics.

1) Head of Household

Table 8.1.2 shows the sex and age of heads of households in each target village. In Cambodia, as in the other Asian countries, elder men would generally be heads of their respective households. When husbands pass away, the widows take over the headship. In case of divorce, women look after the children in most cases.

Table 8.1.2 Sex and Age of Head of Household

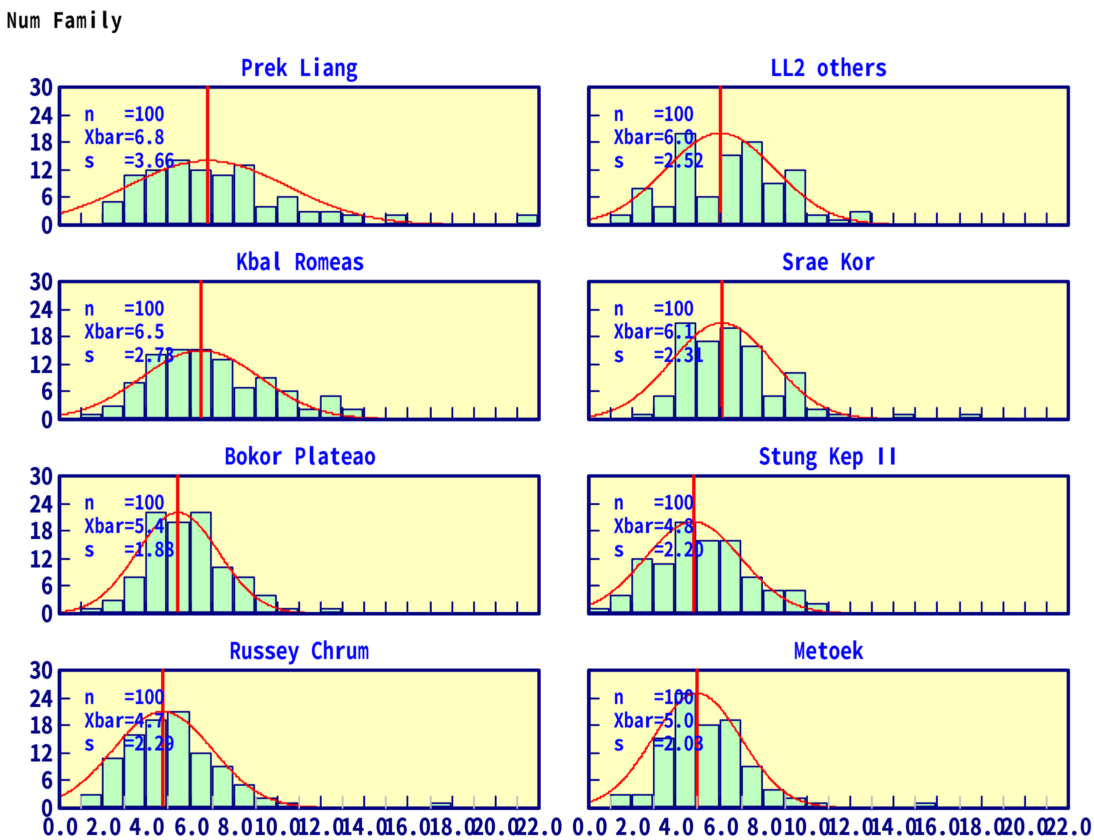
	Sex of Head of Household			Age of Head of Household		
	Male	Female	Total	Male	Female	Average
Prek Liang	95	5	100	44.3	46.0	44.4
LL2 others	79	21	100	45.5	48.1	46.0
Kbal Romeas	83	17	100	44.2	51.8	45.5
Srae Kor	88	12	100	43.9	44.2	43.9
Bokor Plateau	84	16	100	44.2	52.8	45.6
Stung Kep II	76	24	100	46.3	48.5	46.8
Russey Chrum	82	18	100	42.9	46.1	43.5
Metoek	89	11	100	42.1	42.1	42.1
Overall	676	124	800	44.1	48.0	44.7

Source: Study Team

2) Number of Household Members

The average size of households in Cambodia in 2004 was 5.1 persons. There was a tendency that the sizes of households were greater in rural areas than in urban areas. In the target villages of the interview survey, the same tendencies were observed. The target villages in the northeast region were much isolated compared to those in the southwest region. Accordingly, the average size of households in the northeast region was greater.

Figure 8.1.2 illustrates the frequency distribution of household sizes in the target villages.

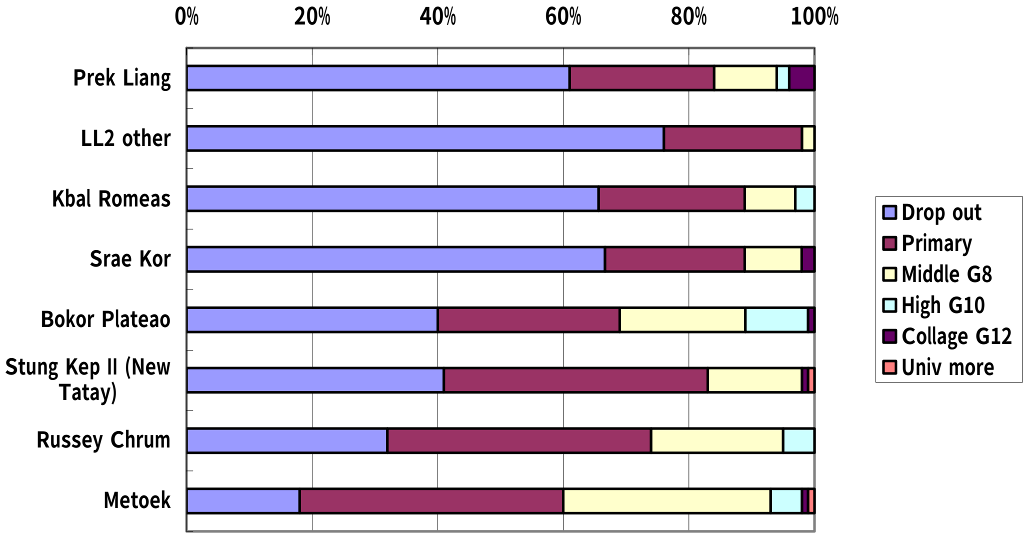


Source: Study Team

Figure 8.1.2 Frequency Distribution of Household Sizes

3) Educational Level

Figure 8.1.3 illustrates the educational level of the heads of households. The educational level of target villages in the northeast region was rather low in comparison with those of the southwest region. The reasons for the low education in the northeast were not only because of the disadvantageous isolated location but also because of ethnicity. Most of the inhabitants of the Ratanak Kiri Province were Lao. There were some other tribal ethnic groups as well. They don't speak the Cambodian language and had less opportunity to get an education.



Source: Study Team

Figure 8.1.3 Educational Background of Heads of Households

4) Religion

The majority of Cambodia, i.e. 95% of the population, believes in Buddhism. The second largest population is Islamic which accounts for 4% of the population. Respondents were asked about their religious beliefs for reference in order to understand their lifestyles. Table 8.1.3 shows the various religions of the target villages.

It is said that Cambodian Muslims tend to live along the river. In the household interview survey, some families living in the downstream villages of Russey Chrum River were recognized as Muslim as well. Most of the Muslim families, 18 respondents out of 30, were engaged in fishing activities as their primary occupation.

As mentioned in Table 4.6.3 "Populations of Minority Groups", 79.5% of the population in Ratanak Kiri Province is regarded as an ethnic minority. Some ethnic groups believe in animism or shamanism, maintaining their traditions. The majority of respondents, living far downstream of the Prek Liang hydropower project site in Ratanak Kiri Province, are minority ethnic groups and believe in animism as shown in Table 8.1.3.

Table 8.1.3 Religious Backgrounds of the Respondents

	Buddhism	Christianity	Islam	Animism or Shamanism	No religion	Total
Prek Liang	31	4		65		100
LL2 others	91			7	2	100
Kbal Romeas	91			9		100
Srae Kor	98	1			1	100
Bokor Plateau	99			1		100
Stung Kep II	100					100
Russey Chrum	70		30			100
Metoek	100					100
Total	680	5	30	82	3	800

Source: Study Team

(2) Economic Activities and Living Standards

1) Primary Occupation

Table 8.1.4 shows the respondents' answers concerning their primary occupation. Although the questionnaire asked only for one main job, some of the interviewers allowed multiple answers when interviewees wished so. As a result, the total number of the answers exceeded the total number of respondents. Some characteristics can be pointed out below by analyzing the table:

- 530 respondents out of 800 were owner-cultivators, and in particular, more than 90% of respondents in #12-14 Prek Liang, LL2, Kbal Romeas and Srae Kor were engaged in cultivating their own farmlands.
- Fishing was the second most important economic activity as replied by 249 out of 800 respondents living along the rivers,.
- In some parts of the target villages for Prek Liang and LL2 projects, some respondents are still active in hunting.
- Respondents in the northeast region were engaged in various economic activities. They were not engaged in a monopolized system but kept a recycle-oriented lifestyle.
- Downstream of Russey Chrum River and close to the sea was a rather urbanized area so that the majority of respondents were engaged in fishing but not in farming.
- Of the respondents of Bokor Plateau and Stung Russey Chrum, about one half selected “others” referring to being company staff. The respondents of Metoek were engaged in timber logging.

Table 8.1.4 Main Job of Head of Household

	Owner cultivator	Farm labor	Breeder	Fisherman	Hunter	Self-employed	Company executives/ Investor	Govt. employee/ teacher	Not working/R etired	Others (staff, log., etc.)	Total
Prek Liang	91	0	0	37	8	6	1	25	2	10	180
LL2 others	94	0	4	45	10	4	0	3	4	27	191
Kbal Romeas	99	1	12	55	5	3	0	7	4	9	195
Srae Kor	98	0	0	1	0	1	0	0	0	0	100
Bokor Plateau	52	2	0	36	0	15	1	8	0	30	144
Stung Kep II (New Tatay)	43	1	0	18	0	7	1	5	0	31	106
Russey Chrum	6	2	0	54	0	4	2	10	0	22	100
Metoek	47	3	0	3	0	3	0	13	1	34	104
Total	530	9	16	249	23	43	5	71	11	163	1120

Note: Total number of jobs exceeded the total number of interviewees because of multiple answers.
Source: Study Team

2) Income and Expenditure

The total sample being valid for both expenditure and income was 786. As shown in Table 8.1.5, the overall average of expenditure per capita per year was $270.86 and that of income was $306.43.

Table 8.1.5 Expenditure and Income of Household

	per household per year ($)		per capita per year ($)	
	Expenditure	Income	Expenditure	Income
Prek Liang	593	714	110	136
LL2 others	942	1,210	168	199
Kbal Romeas	1,047	1,191	206	229
Srae Kor	1,736	1,834	326	339
Bokor Plateau	1,291	1,907	252	375
Stung Kep II (New Tatay)	1,084	1,295	270	322
Russey Chrum	1,744	1,723	433	422
Metoek	1,639	1,760	398	425
Overall average	1,260	1,457	271	306

Source: Study Team

Comparing the target villages, the following tendencies and characteristics were found out:

- The income level in the northeast region was lower than that of the southwest region.
- The income level of Srae Kor was highest among the four northeast villages. This may be due to a newly rehabilitated community road.
- The income level of the Thma Da Commune along the Metoek River was the highest among the eight target villages although it was situated in an isolated remote area. People there mainly earned cash income by logging and selling open land in recent years. A border gate to Thailand was opened in April 2007 and brought benefits to the villagers.
- Dang Tong Commune which was located downstream of Russey Chrum River had been developing in recent years with the construction of road networks from Sihanoukville to the Thai border. People tend to invest, while borrowing, for the procurement of motorcycles etc.
- 247 respondents out of 786 valid answers said that their income was less than their

expenditure. In terms of the consideration how to cope with the deficit, the 275 respondents answered including the respondents who are not deficit this target year. Table 8.1.6 indicates the answers to the question “If the income is less than expenditure, please tell the reasons, whether you have debt or remittance from families.” Deficit was mostly covered by debt or remittance from family members living abroad.

- Ethnic groups in the northeast region maintained their traditional ways of life but they were no longer able to live without cash earnings. More than 20% of the respondents borrowed money from others.

Table 8.1.6 Management of Deficit

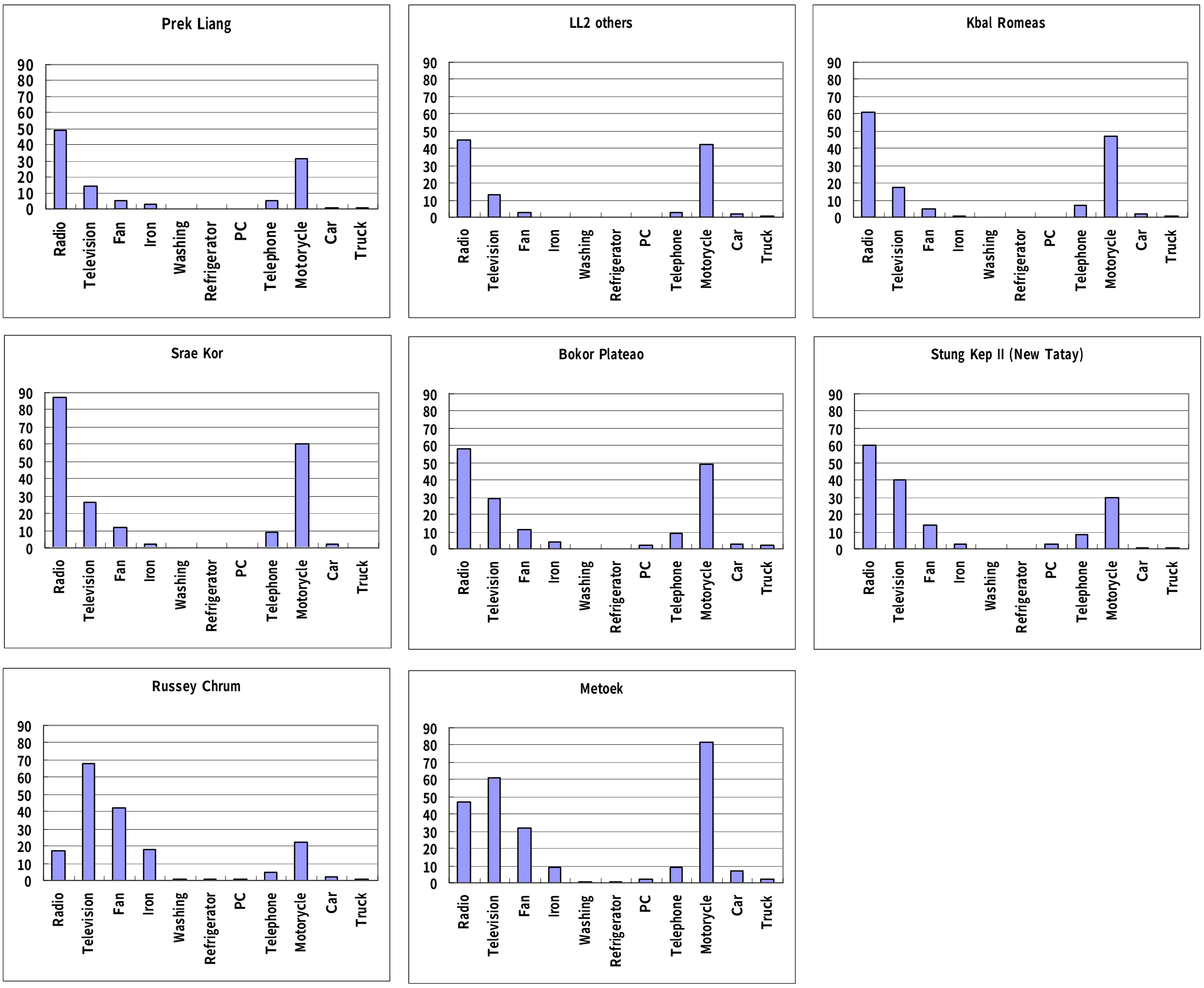
	1. NA	2. Debt	3. Remittance	4. Saving	5. Others	2&3	2&4	2&5	3&4	3&5	Total
Prek Liang	58	21	13		5	1		1		1	100
LL2 others	64	23	7	1	3			2			100
Kbal Romeas	59	23	7		11						100
Srae Kor	62	16	5		17						100
Bokor Plateau	70	9	5	1	4	2	1	6	1	1	100
Stung Kep II (New Tatay)	73	11	5		8						97
Russey Chrum	63	19	6		11						99
Metoek	62	5		1	20			2			90
Total	511	127	48	3	79	3	1	11	1	2	786

Source: Study Team
1. Not applicable (Income is more than expenditure)
2. Debt
3. Remittance from families
4. Withdraw money from saving accounts
5. Other reasons (specify___________________________)

3) Assets

In order to figure out the degree of modernization and affordability of people’s livelihood, the kinds of typical assets held by respondents were surveyed. Figure 8.1.4 illustrates the number of households which have assets listed in the questionnaire. The features of each village are stated below:

- The majority of respondents had radios which were one of the important tools to access information.
- The household ratio with TV sets was still low. However, more than 50% of the respondents of Russey Chrum and Metoek enjoyed watching TV. In Metoek, TV programs were broadcast from Thailand.
- Most of the villages were not covered by mobile phone services. Respondents who had mobile phones used them only when they traveled into the service area.
- The distribution ratio of motorcycles was higher than expected, particularly in Metoek. Opening the border once a week might have encouraged the villagers to buy motorcycles as business investments for border trading.



Source: Study Team

Figure 8.1.4 Assets of Households

(3) Electrification

1) Lighting Cost

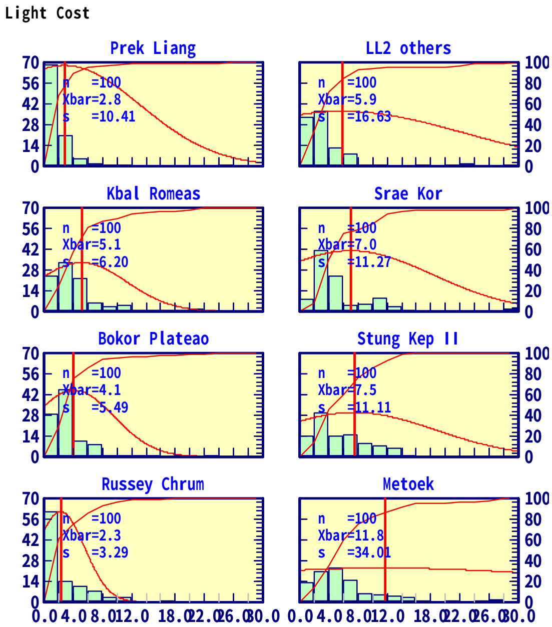
Most of the target villages have no connection to distribution lines of the rural electricity enterprises (REE) including EDC. People had been using kerosene lamps and candles as well as flashlights or engine generators. The unit cost of lighting in rural areas was reportedly much higher than that in urban areas where mini-grids distribute electricity. The results of the household interview survey are shown in Table 8.1.7.

The average lighting cost was calculated, including replies of zero payment, among the 132 respondents. As shown in Table 8.1.8, the standard deviation was very large. The average could be influenced by the outstanding high values. Monthly lighting costs below $5.00 were paid by 67.8% of the respondents.

Table 8.1.7 Lighting Cost (/month/household)

	Size n	Min ($)	Max ($)	Average ($)	St.dv
Prek Liang	99	0	25	1.8	3.07
LLS others	99	0	58	4.5	8.08
Kbal Romeas	100	0	40	5.1	6.20
Srae Kor	100	0	79	7.0	11.27
Bokor Plateau	100	0	46	4.1	5.49
Stung Kep II (New Tatay)	100	0	82	7.5	11.11
Russey Chrum	100	0	17	2.3	3.29
Metoek	98	0	45	7.5	7.97
Overall	796	0	82	5.0	7.90

Source: Study Team
* $0 is included
* 4 samples over $100 per month are excluded as outliers.
* cumulative frequency curve and theoretical distribution curve are shown in the figure.



Source: Study Team

Figure 8.1.5 Lighting Cost

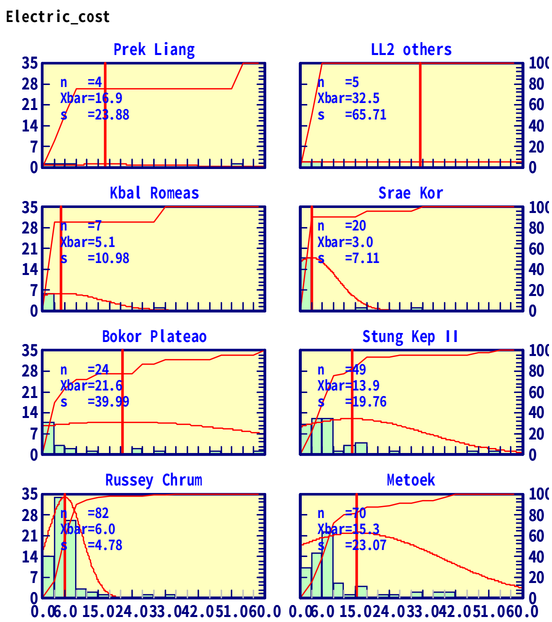
2) Electricity Cost

Focusing on the monthly electricity cost per household, excluding the other lighting costs such as kerosene and candle, there were 261 respondents who were paying electricity tariff. The overall average was $21.93 per household per month. Some of the respondents were using electricity, not only for household use, but also for business by operating one engine generator. Accordingly, the average became high. In the case of using a generator, the electricity cost meant the cost of petrol. The following were found as reference information:

Table 8.1.8 Electricity Cost ($/month/household)

	n	Min ($)	Max ($)	Average ($)	St.dv
Prek Liang	4	3	53	16.9	23.88
LLS others	5	2	150	32.5	65.71
Kbal Romeas	7	1	30	5.1	10.98
Srae Kor	20	1	30	3.0	7.11
Bokor Plateau	24	1	166	21.6	39.99
Stung Kep II (New Tatay)	49	2	75	13.9	19.76
Russey Chrum	82	1	34	6.0	4.78
Metoek	70	1	113	15.3	23.07
Overall	261	1	166	11.8	21.93

* Cases indicating $0 are excluded.
Source: Study Team



Source: Study Team

Figure 8.1.6 Electricity Cost

- Villages located far downstream of the Prek Liang project site had no electricity. Only a few restaurants or offices were using electricity.
- Communes downstream of Russey Chrum River enjoyed electricity which was supplied by private REE. Therefore the distribution level of electrical goods was relatively high, i.e. TV at 68%, electric fan 42% and electric iron 18%.
- Villagers in the Thma Da Commune along the Metoek River used their own generators for electricity. Since the price of petrol increased, the production cost of electricity increased. They used electricity not only for lighting but also for TV (61%), fan (32%) and iron (9%).
- Unit costs of electricity differed among villages. Isolated rural areas where distribution lines hardly arrive have a disadvantage in unit cost of electricity.
- Exceptionally, people in Kbal Romeas Commune and Srae Kor Commune that would be affected by the Lower Se San II + Lower Sre Pok II project enjoyed free electricity services for one year from a private company which was running a business in the forest of the Economic Land Concession nearby.

Table 8.1.9 shows number of households and monthly average expenditures in the cross table indicating battery light users, generator users and electricity supply by private REEs. The monthly average expenditure for battery light users is $5.63, and that of the grid electricity users is $9.02. There are 117 households using both electricity sources of battery and grid electricity, of which the monthly average expenditure is $12.32.

Table 8.1.9 Status of Grid Electrification and Utilization of Battery Lighting

		Number of grid electrified/non-electrified household ( ): Average amount of payment ($/month)*					
		Non-electrified		Electrified		Total	
Number of household of battery users	Non-user	299	(0.00)	194	(7.04)	493	(2.77)
	User	190	(1.51)	117	(12.32)	307	(5.63)
	Total	489	(0.59)	311	(9.02)	800	(3.87)

Source: Study Team
* $0 is inclusively calculated

Table 8.1.10 presents the survey results on electrified households in the target project areas. Electrification ratio on Prek Liang site is the lowest in progress and the LL2 site is the second lowest. In Srae Kor village, a private company has started electricity supply to the community free of charge since 2007 for one year and most of the house holds in the village has been connected to generator. A part of villages in Kbal Romeas has also been electrified by private companies with relatively low tariffs. Reasons for such free/low cost electricity supply are not clear. The free services of the electricity had been finished after one year. After socio-economic survey, the Study Team visited Srae Kor again, August 2008, and realized the villagers there stopped using the donated generator and distribution lines since they didn’t reach the consensus of operating system by themselves.

Table 8.1.10 Household Electrification Status by Target Areas

Area/Plan	Non-electrified household	Electrified household	Total
Prek Liang	85	15	100
LL2 others	67	33	100
Kbal Romeas	48	52	100
Srae Kor	8	92	100
Bokor Plateau	29	71	100
Stung Kep II (New Tatay)	26	74	100
Russey Chrum	12	88	100
Metoek	24	76	100
Total	299	501	800

Source: Study Team

Table 8.1.11 indicates replies to the question "Do you want to use electricity even if it is a pay service?" and "If yes, how much can you pay for electricity per month?" About 84.4% of the respondents, which was 675 out of 800, answered that they wished to have electricity even if it was a pay service. An overall average of willingness to pay (WTP) was $3.73 per month. However, averages of the target villages had a wide range of difference from each other depending on the current conditions of electrification. Respondents who were enjoying free electric services, i.e. in Srae Kor, had a low WTP. On the other hand, respondents of Metoek who were spending a high electricity cost for their own generators replied that they wished to have integrated distribution lines that they expected to realize lower costs than what they spent.

Table 8.1.11 Willingness to Pay

	Do you want to use electricity even if it is a pay service?		If yes, how much can you pay for electricity per month?		
	No need	If tariff is acceptable, yes	No need	Acceptable cost per month ($)	Average ($)
Prek Liang	10	90	0.00	2.52	2.52
LL2 others	38	62	0.00	1.91	1.91
Kbal Romeas	28	72	0.00	1.15	1.15
Srae Kor	35	65	0.00	1.30	1.30
Bokor Plateau	3	97	0.00	4.99	4.99
Stung Kep II (New Tatay)	6	94	3.75	5.44	5.42
Russey Chrum	3	97	1.25	4.55	4.51
Metoek	2	98	5.00	6.38	6.37
Total / average	125	675	3.33	3.73	3.73

Source Study Team

(4) Water and Hygiene

1) Water Utilization

Cambodia has a tropical rainforest climate with high rainfall over 1000 mm/year to 4000 mm/year. However, water management had not been effective enough to improve the people's livelihoods. Utilities of drinking water supply had not been well established. Therefore, people in rural areas were taking water directly from rivers or ponds, or storing rainwater from roofs to tanks. International donors supported groundwater well drilling but arsenic was reportedly detected in some of the wells.

In the target villages of the questionnaire survey, the respondents in the northeast region mainly use river water and well water whereas the respondents in the southeast region depend on rainwater. There were 47 households using piped water in urban areas downstream of the Russey Chrum River. Sixty seven respondents in the Thma Da commune answered that they took flowing water from the channel or tributary which the Pol Pot party built.

Table 8.1.12 Drinking Water

	Piped water			Private well			Public well			Flowing water in channel / tributary		
	No use	Sub	Main	No use	Sub	Main	No use	Sub	Main	No use	Sub	Main
Prek Liang	100	0	0	74	5	21	68	2	30	84	7	9
LL2 others	99	0	1	94	3	3	67	11	22	99	1	0
Kbal Romeas	98	0	2	98	0	2	47	13	40	100	0	0
Srae Kor	100	0	0	96	0	4	59	15	26	100	0	0
Bokor Plateau	88	0	12	34	3	63	77	1	22	100	0	0
Stung Kep II	100	0	0	35	4	61	89	2	9	78	2	20
Russey Chrum	52	1	47	70	2	28	91	0	9	96	1	3
Metoek	96	1	3	98	1	1	99	0	1	29	4	67
Overall	733	2	65	599	18	183	597	44	159	686	15	99
Overall (%)	91.6%	0.3%	8.1%	74.9%	2.3%	22.9%	74.6%	5.5%	19.9%	85.8%	1.9%	12.4%

	Well of landlord			River or pond			Rainwater			Bottled water		
	No use	Sub	Main	No use	Sub	Main	No use	Sub	Main	No use	Sub	Main
Prek Liang	95	2	3	28	19	53	10	86	4	97	2	1
LL2 others	100	0	0	4	8	88	5	91	4	100	0	0
Kbal Romeas	99	0	1	2	6	92	8	91	1	100	0	0
Srae Kor	98	0	2	1	6	93	4	85	11	99	1	0
Bokor Plateau	98	0	2	98	2	0	17	80	3	100	0	0
Stung Kep II	91	1	8	79	9	12	7	6	87	87	7	6
Russey Chrum	91	1	8	95	2	3	11	6	83	75	3	22
Metoek	100	0	0	75	4	21	11	28	61	81	2	17
Overall	772	4	24	382	56	362	73	473	254	739	15	46
Overall (%)	96.5%	0.5%	3.0%	47.8%	7.0%	45.3%	9.1%	59.1%	31.8%	92.4%	1.9%	5.8%

Source: Study Team

2) Cost of Water Management

Most respondents in the northeast region did not pay for drinking water while the ratio who bought drinking water was high in the southwest region. The total number of respondents who bought drinking water was 208 and their average cost of drinking water was 36,012 Riel ($9.00) per month.

Since irrigation systems are not popular in the target villages, most respondents did not pay for irrigation. The total number of respondents who paid for irrigation was 60 and their average cost was 39,845 Riel ($9.96) per month.

Table 8.1.13 Cost of Water Management

	Drinking Water		Irrigation Water	
	Respondents who pay	Cost /month (Riel)	Respondents who pay	Cost / month (Riel)
Prek Liang	6	31,417	0	-
LL2 others	1	54,000	0	-
Kbal Romeas	4	13,375	1	5,800
Srae Kor	1	10,000	0	-
Bokor Plateau	15	50,583	11	17,582
Stung Kep II (New Tatay)	25	46,180	3	115,000
Russey Chrum	73	19,730	3	28,335
Metoek	83	46,157	42	41,940
Overall	208	36,012	60	39,845

Source: Study Team

3) Toilet

Figure 8.1.7 illustrates the types of toilet. About 68.3% of the respondents did not have a toilet at home. However, some used huts as toilets, which was built along the rivers apart from the residential areas.

Code1	Pit latrine	Flush toilet	No toilet	Total
Prek Liang	22	1	77	100
LL2 others	1	1	98	100
Kbal Romeas	5	12	83	100
Srae Kor	37	19	44	100
Bokor Plateau	6	64	30	100
Stung Kep II] (New Tatay)	10	9	81	100
Russey Chrum	3	27	70	100
Metoek	13	24	63	100
Overall	97	157	546	800
Overall(%)	12.1	19.6	68.3	100

Source: Study Team

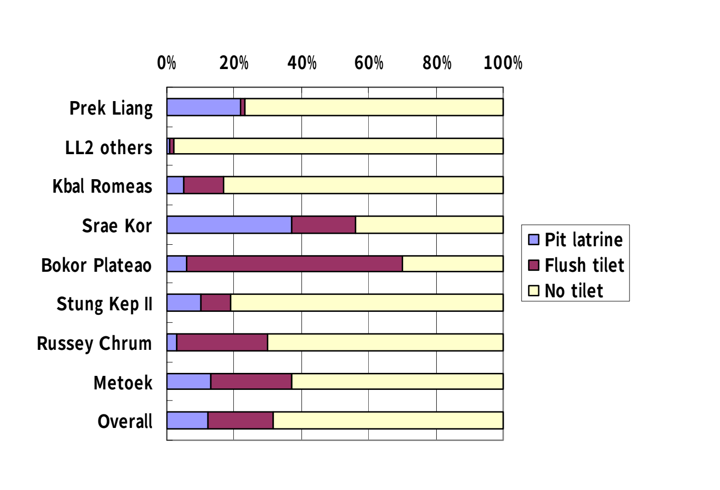
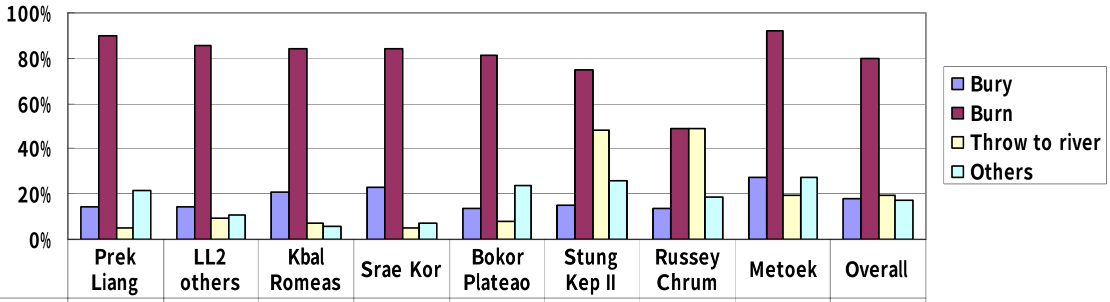


Figure 8.1.7 Type of Toilet

4) Waste Disposal

Most respondents burn their wastes beside houses. Wastes could often be used as fuel. About 64.25% of the respondents answered that they used twigs, husks and/or stems of crops as cooking fuel. Some of the respondents, especially those living downstream of the Stung Kep and Russey Chrum, threw wastes into rivers. “Others” include disposal in forests or somewhere near their houses. A few respondents answered that they made compost for agriculture. There were some respondents who answered that waste was used for feeding animals.



	Prek Liang	LL2 others	Kbal Romeas	Srae Kor	Bokor Plateao	Stung Kep II	Russey Chrum	Metoek	Overall
Bury	14%	14%	21%	23%	13%	15%	14%	27%	18%
Burn	90%	86%	84%	84%	81%	75%	49%	92%	80%
Throw to river	5%	9%	7%	5%	8%	48%	49%	19%	19%
Others	21%	11%	6%	7%	24%	26%	19%	27%	18%

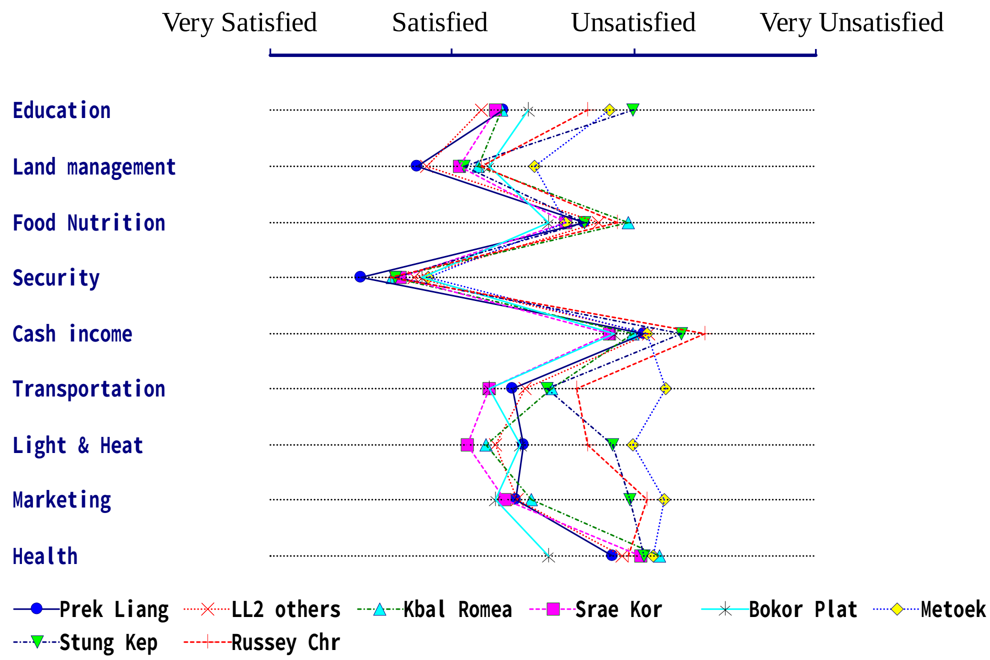
Source: Study Team

Figure 8.1.8 Waste Disposal

(5) Awareness and Mind-Set about Lifestyle

1) Degree of Livelihood Satisfaction and Complaint

Degrees of livelihood satisfaction were asked for each item as shown below in Figure 8.1.9. No security issues were observed among the eight target villages. On the other hand, cash income had a low satisfaction rating among the respondents Health care was a big concern of most of the respondents. However, health conditions of the target village of Bokor Plateau project were better than the others.



Source: Study Team

Figure 8.1.9 Degree of Livelihood Satisfaction

2) Problems of Concern

Table 8.1.14 shows the ratings in terms of problems being faced by respondents. Respondents rated the degree of difficulty from no problem (1) to big problem (5).

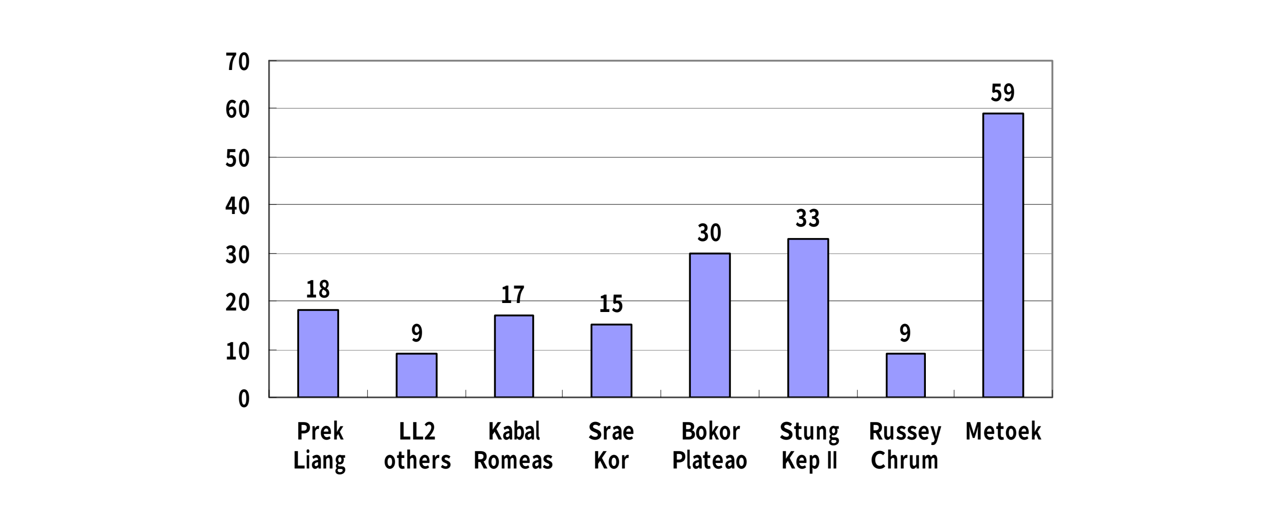
Table 8.1.14 Problems Being Faced by Respondents (Average Score)

	Prek Liang	LL2 others	Kbal Romeas	Srae Kor	Bokor Plateau	Stung Kep II (New Tatay)	Russey Chrum	Metoek	Overall
Shortage of education opportunities	2.23	2.06	2.40	2.32	2.41	2.76	2.47	2.88	2.44
High cost of education	2.08	1.97	2.22	2.20	2.63	2.90	2.86	3.14	2.50
Children's low motivation in study	1.84	1.60	1.86	1.72	1.88	2.61	2.37	2.48	2.05
Having trouble with land ownership	1.41	1.32	1.91	1.88	1.63	1.98	1.76	2.28	1.77
Registration of land	1.53	1.55	2.07	2.11	1.77	1.94	1.66	2.15	1.85
Low land quality and low yield	3.00	2.53	3.00	2.28	2.40	2.86	2.38	2.48	2.62
Insufficient irrigation systems	2.05	2.00	2.28	2.21	2.09	2.79	2.18	2.65	2.28
Shortage of labor	2.40	2.16	2.22	2.11	2.15	3.09	2.74	2.95	2.48
Shortage of business opportunities	1.64	1.54	1.48	1.62	1.78	2.87	2.86	2.77	2.07
Inaccessibility of electricity	2.46	1.91	1.89	1.77	2.36	3.45	2.65	3.42	2.49
High living expenses	3.43	3.21	3.43	3.15	3.28	3.87	4.09	3.96	3.55
Inaccessibility of information	2.17	1.80	1.76	1.78	1.95	2.68	2.11	2.98	2.15
Security problems	1.25	1.65	1.52	1.79	1.39	1.79	1.74	1.95	1.64
Inaccessibility of health care services	2.89	3.11	3.18	3.03	2.38	3.08	2.51	3.28	2.93
Shortage of transportation means	2.41	2.37	2.31	2.16	1.61	2.49	2.52	3.61	2.44
Insufficient road conditions	2.77	2.55	2.55	2.48	1.57	2.35	2.83	4.15	2.66
Low selling price of products	2.77	2.32	2.52	2.41	2.71	3.10	3.26	3.11	2.78
Broken family network due to immigration	1.51	1.33	1.47	1.45	1.46	1.33	1.21	1.44	1.40
Less collaboration with neighbors	1.36	1.34	1.38	1.50	1.17	1.73	1.58	1.59	1.46
Inaccessibility of micro credit	1.31	1.23	1.21	1.34	1.29	1.65	1.73	1.83	1.45

Source: Study Team

3) Conflict of Land Ownership

Figure 8.1.10 illustrates replies to the question “Have you ever heard about troubles concerning land ownership of neighbors?” About 59 respondents in the Metoek area answered “yes”. A legal land registration system had not been introduced in the Thma Da Commune. Many land investors came to buy land expecting price hikes because of the proximity of the Thma Da Commune to the Thai Border. Land speculation was booming in Cambodia and some of the potential lands for development would be targeted by outsiders. The number of respondents shown in the figure represents not that of conflicts but that of those who heard of land conflicts.



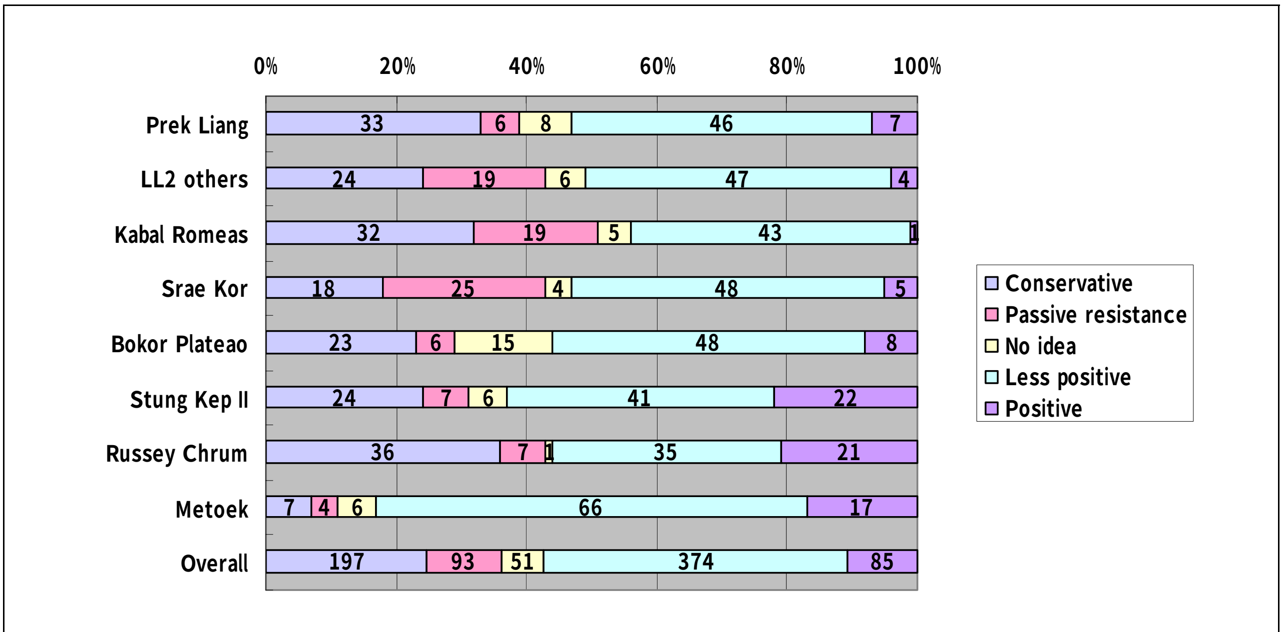
Source: Study Team

Figure 8.1.10 Respondents Who Heard of Land Conflicts inside Villages

4) Mind-Set Concerning Modernization and Development

It is important to understand the respondents' ways of thinking about modernization and development for assessment of maturity for development. The following alternative replies were presented to the interviewees and the most appropriate was selected by respondents. The results are illustrated in Figure 8.1.11.

1. Strongly keep traditional lifestyle (conservative)
2. Change of traditional activities is not desirable (passive resistance to modernization)
3. Anything will do. No idea.
4. Change of some traditional activities is acceptable (a bit positive for modernization)
5. Willing to modernize the villages (positive for modernization)



Source: Study Team

Figure 8.1.11 Mind-Set Concerning Modernization

(6) Hydropower and Dam Construction

Opinion Concerning Hydropower Development

General opinions concerning hydropower development were asked during the questionnaire survey. Conditions were not the same among the target villages whether these would be submerged in the planned reservoir or not. Table 8.1.15 summarizes the replies of the respondents to hydropower development.

Intermediate value of score is 3 which means agree and oppose is half-and-half. It was obvious that the respondents in the Kbal Romeas and Srae Kor Communes strongly opposed the hydropower dam construction because their villages would be submerged and they would have to resettle. They worried about their properties such as houses and paddy fields. In addition, the elderly people love villages that had long histories since the 1920s.

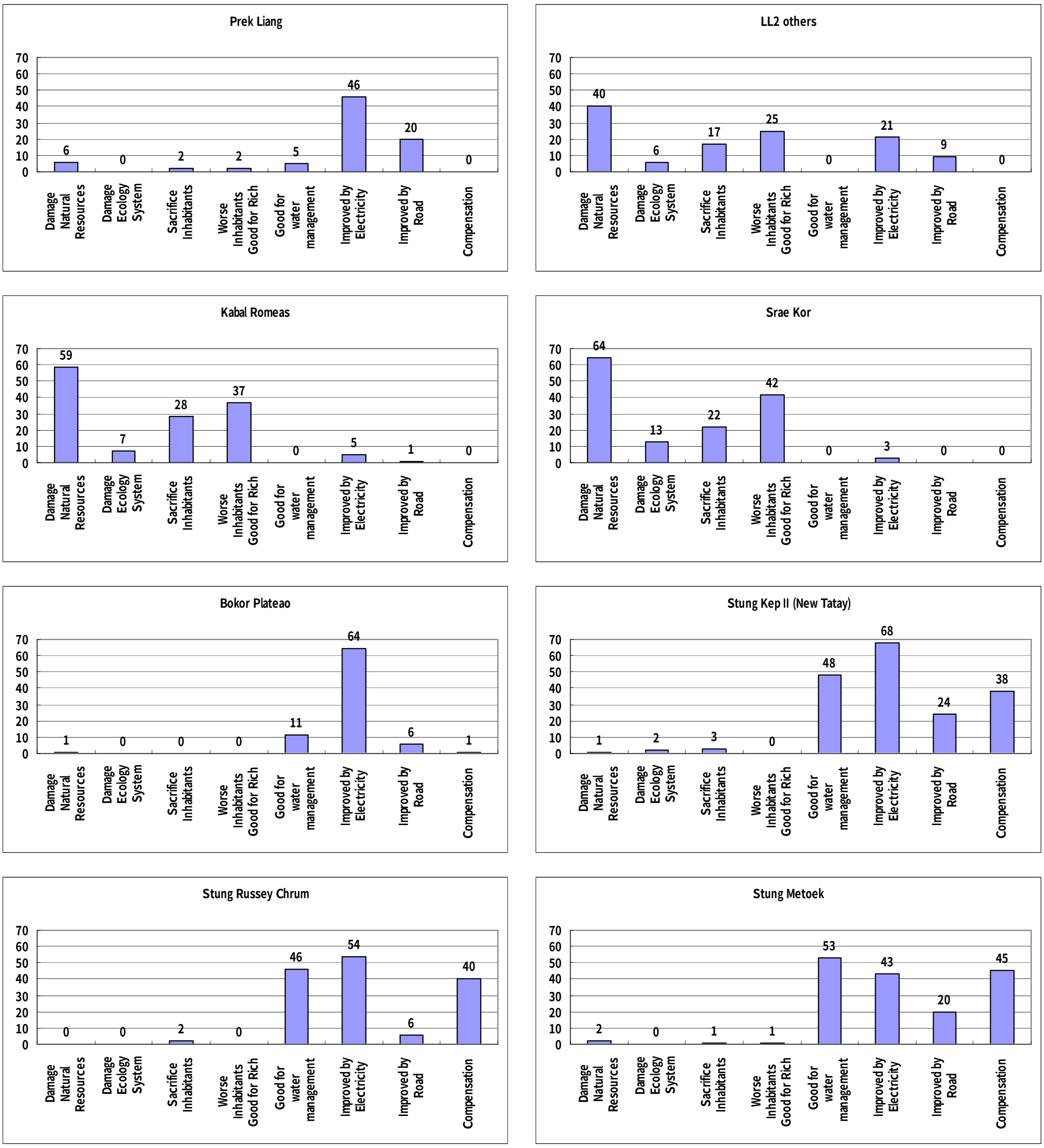
Table 8.1.15 Villagers' Position to Hydropower Development

	1	2	3	4	5	
	Strongly oppose	Not like	No idea	Passively accept	Positively accept	Average of score
Prek Liang	2	6	22	28	42	4.02
LL2 others	28	38	6	13	15	2.49
Kbal Romeas	53	39	1		6	1.66
Srae Kor	49	46	1	1	3	1.63
Bokor Plateau	1		18	31	50	4.29
Stung Kep II (New Tatay)	1	4	8	32	55	4.36
Russey Chrum	3		7	39	51	4.35
Metoek	1	2	4	47	46	4.35
Overall	138	135	67	191	268	3.40

Source: Study Team

"Damage to environmental resources" was the most significant reason for opposing the projects as stated by 173 respondents. The second largest reason was "Worse for Inhabitants, Good for the Rich" as indicated by 107 respondents. Particularly, in the case of the integrated hydropower project of Lower Sre Pok II + Lower Se San II, the generated power would be exported to Vietnam and therefore the inhabitants there complained "the project would sacrifice Cambodians to benefit non-Cambodians."

Meanwhile, those inhabitants who reside in the envisaged reservoir area of the Metoek II project were positive about dam construction. The history of their villages is short and most inhabitants moved there from different parts of the country. They lived close to the border of Thailand, a country that was already developed, and were stimulated by modern technology. Due to landmines, the farmlands were limited. Therefore, people expected a large scale of economic development which would support them in order to catch up with their neighbors. Since they were facing water shortages, the degree of expectation for sustainable water management was high.



Source: Study Team

Figure 8.1.12 Opinions about Hydropower Development

Table 8.1.16 indicates the opinions concerning resettlement caused by dam construction. Inhabitants in the target villages of the interview survey other than in Kbal Romeas, Srae Kor and Metoek do not need to resettle but they were also interviewed for reference. Since the inhabitants would not be directly affected by these projects, they were quick to answer “yes”. However, those inhabitants subject to resettlement answered “no”.

A notable feature was found in the responses of the inhabitants in Metoek. They did not have a very negative image on dam construction.

Table 8.1.16 Opinions about Resettlement

	1	2	3	4	5	
Code	No	No, principle	No idea	Conditional Yes	Positively Yes	Average of score
Prek Liang	14	6	5	44	31	3.72
LL2 others	45	12	3	13	27	2.65
Kbal Romeas	37	30	2	13	18	2.45
Srae Kor	49	12	1	8	30	2.58
Bokor Plateau	1	6	8	57	28	4.05
Stung Kep II	15	10	12	38	25	3.48
Russey Chrum	12	7	21	37	23	3.52
Metoek	4	10	3	57	26	3.91
Overall	177	93	55	267	208	3.30

Source: Study Team

8.1.3 Findings

The study team subcontracted a questionnaire interview survey of households. At the same time, the village profiles were compiled through the key-informant interviews and observation trips. After analyzing the abovementioned quantitative data and integrating it with qualitative information, the findings are summarized below:

(1) Target Villages Located in Planned Reservoir

1) Integrated Project of #7&8 Lower Se San II + Lower Sre Pok II

Kbal Romeas Village, Krabei Chrum Village and Srae Srannok Village along the Sre Pok River in Kbal Romeas Commune will be submerged according to the design of the Lower Se San II + Lower Sre Pok II integrated hydropower project.

Phum Muoy village and Phum Pir village in the Sre Kor Commune are located on the opposite banks of the Se San River. Two of them will be submerged together with the Kbal Romeas Commune.

The notable features of the two communes are listed below:

- Most inhabitants are Lao ethnics speaking the Lao language,
- They believe in Buddha,
- Customs, behavior and culture are very similar to Khmer,
- Road accesses to Krabei Chrum and Srae Sranok of Kbal Romeas is not year-round,
- Life is simple and abstemious with expenditures below $1 per person per day,
- Wealth in community prosperity,
- Generator and distribution lines were donated by private companies, while in some parts, electricity was free of charge for one year.
- Since the cost of fuel is required, some of the communities left generators and distribution lines,
- Almost satisfied with their traditional lifestyle,
- Long village history since 1920s makes inhabitants stick to original home land,

- They are confused by unclear information about hydropower projects,
- They are upset about being sacrificed for electricity supply to Vietnam,
- Almost all of them opposed the project and refused to move.

2) #20&21 Metoek II and Metoek III

The Metoek II project is located upstream of the Metoek River while the Metoek III is downstream. The Thma Da Commune is located in and around the Metoek II reservoir area. Part of the commune would be submerged depending on the full supply level (FSL) of the Metoek II reservoir. Features of the commune are listed below:

- The first people moved into this place in 1979, and the village was officially registered in 1998.
- Most inhabitants were former supporters of the Pol Pot Party who came from all over Cambodia.
- Road conditions were much improved in recent years.
- After opening the border to Thailand, their lifestyles changed dramatically.
- Land prices were increasing by speculation and logging was booming for clearing of open land.
- Landmine accidents were increasing because people go to clear forests in order to make a sizable sum of money.
- The majority of inhabitants already used electricity to enjoy lighting and watching TV.
- Most commodities were purchased from Thailand.
- The image of hydropower for generating electricity and for managing water with electric pumps was good,.
- People were willing to move their houses, if necessary.
- An army camp with 400 soldiers is located along the border.
- Private investors had a joint venture with a Malaysian company to construct roads and a hospital.

(2) Target Villages for Interview Survey Outside Planned Reservoir Areas

1) Integrated Project of #7&8 Lower Se San II + Lower Sre Pok II (villages outside the planned reservoir area)

The Hot Pak Commune is located upstream of the Lower Se San reservoir area. Since the feasibility study was under implementation by EVN and the design features were not clear, it was unknown whether the Hot Pak Commune will be submerged or not. The Ta Lat Commune is located upstream of the Sre Pok River, and the Phluk Commune is located downstream of the power plant site.

- These communes are located in very isolated and remote areas.
- Villagers are Lao Buddhists.
- Hunting in the forest is still one of the main jobs.
- Income is very low and it is rather a self-supplying economy.
- Number of debtors is increasing.
- Majority of households are non-electrified and willing to have electricity even if they have to pay for the services.

2) #12-14 Prek Liang I, IA and II (villages are far downstream of power station site)

Taveaeng Leu Commune is the closest commune to but is about 15 km downstream of the outfall site of the Prek Liang I project.

- Ethnic minority believe in traditional animism.
- Cash income is the lowest among the target villages of the questionnaire survey
- They live in a self-supply economy.
- Some of them depend on debt and remittance, which means that their lifestyle is no longer cashless.
- Most households are non-electrified and are willing to have electricity even if they have to pay for the services.
- People are positive about the hydropower project which would supply electricity provided that they do not need resettlement.

3) #29 Bokor Plateau (villages downstream of the planned reservoir area, being to the south of the Plateau)

The Kandal village, Preaek Ampil village and Preaek Chek village belong to the Kaoh Touch Commune. The project site is the nearest to Phnom Penh among the 10 priority project sites.

- There are advantages in the access to Phnom Penh.
- Looking from the villages, the river flows towards the opposite side of the mountain.
- The river water would be diverted when hydropower is constructed.
- Since villages face the sea, many inhabitants are engaged in fishing.
- Majority have private wells and toilets.
- Inhabitants have accepted recent modernization that had taken place along with the development of tourist spots in the Bokor national park.
- Inhabitants were not informed of dam construction. Therefore many answered as “no idea” but their image on hydropower was positive.

4) #22 Stung Kep II (New Tatay) (villages outside the planned reservoir area)

The Anlong Vak village and the Kaoh Andaet village in Ta Tai Kraom Commune are located downstream of the Stung Kep River.

- People are engaged in agriculture and fishing.
- Road conditions were improved in recent years.
- Lighting costs including electricity is very high.
- They are willing to have electricity at reasonable tariff.
- Majority have private wells for drinking water.
- People are positive on hydropower development for water management and electricity generation.
- Few people were concerned about potential impacts on the downstream mangroves which provide habitats for fish. Such impacts may result from potential changes in the flow regime due to flood regulation by reservoir.

5) #16 Middle St. Russey Chrum and #23 Upper St. Russey Chrum (villages outside the planned reservoir area)

The Kaoh Pao Village belongs to the Bak Khlang Commune in Mondol Seima District and the Phum Ti Buon village and Phum Ti Pir Village belong to Dang Tong Commune in Smach Mean Chay District.

- Dang Tong Commune is regarded in the Seila village database as an urbanized area.
- There are residential areas of Muslim families in the Phum Ti Buon village.
- Many people are not engaged in agriculture.
- Fishing is popular since the sea is very close.
- Most households already have electricity.
- Household ratio with TV sets is very high.
- The electricity cost is at a reasonable level compared with the other target villages.
- Habit of waste disposal to the river is not appropriate.
- People are positive on hydropower project.
- People are not aware of the natural environment.

8.2 ENVIRONMENTAL CONSIDERATIONS

Environmental aspects of the potential hydropower sites were analyzed using two approaches: 1) questionnaire survey to sample households and 2) GIS-based analysis using relevant geospatial data. For the first approach, questions related to environmental aspects were also included and the results are presented in Section 8.1. Section 8.2 presents the GIS-based geospatial analysis along with some inputs from the field observation and study on existing documents and information.

8.2.1 Protected Areas

(1) Introduction

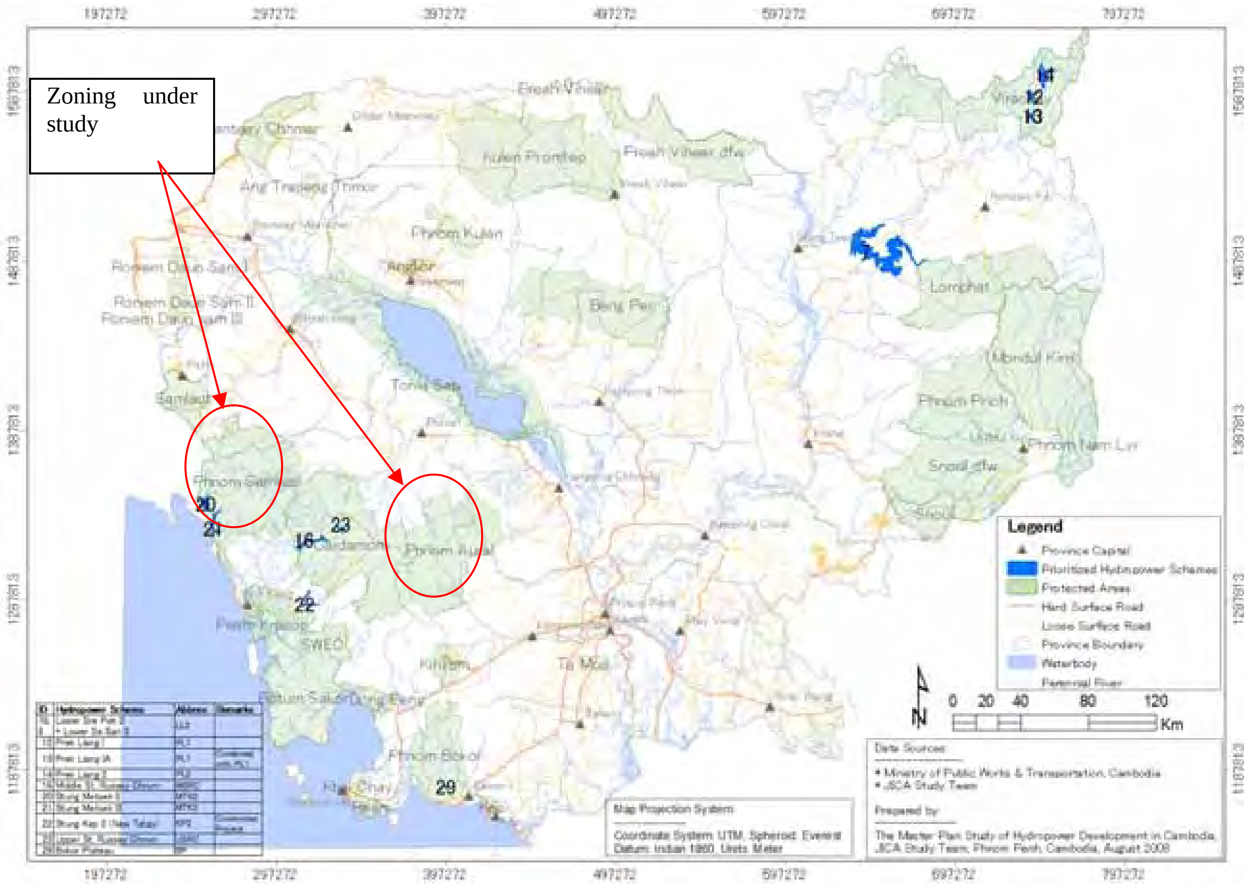
All, but one, promising hydropower sites selected during this study were concentrated in the northeast and southwest region of the country. These regions present mountainous topography with considerable amount of rainfall, both of which are essential conditions for hydropower. Again, being mountainous, most of the protected areas and wildlife sanctuaries in Cambodia are also concentrated in these regions (Figure 8.2.1). Thus, there is a natural conflict of interest between the development of hydropower resources and environmental conservation of the protected areas. In this connection an attempt was made to analyze the extent of such environmental impacts and possible mitigation options and plans.

(2) Present Situation

There are 33 different types of protected areas (Table 8.2.1) proclaimed in the country. The total area amounts to 46,560 km^2, which is approximately 25.72% of the total area of Cambodia (181,035 sq. km.[1]). Having this large share of the protected areas, it reflects a promising situation for the protection of flora

[1] http://www.cambodia.gov.kh/unisql1/egov/english/home.view.html

and fauna and is very beneficial for the environmental protection of the country. Furthermore, official figures show that the country has 53% of its area under forest classification[1] and most of the protected areas (except a few such as Tonle Sap) are part of it. Thus, proclaiming these protected areas had much favorable impact in conserving the natural environment. However, there is a considerable degree of work to be done to enforce such proclamation. In the recent past, after achieving political stability in the country, efforts had been made through national and international collaboration in this field, specifically through the Ministry of Environment (MOE). According to the MOE, the main achievements are a formulation of the 1) zoning concept and 2) laws and regulations for the protection of proclaimed protected areas. Although certain progress had been made, implementation and enforcement of such activities were not easy.



Source: Study Team

Figure 8.2.1 Distribution of Protected Areas and Potential Hydropower Sites

A law for the protection and utilization of natural resources available in such protected areas was passed at the national assembly in December 2007. The MOE is now preparing the strategies and other necessary measures to enforce these laws. One of the most demanding work is the zoning of the protected area. The MOE had already defined such zoning along with preliminary demarcations of some areas. There are four categories of zoning defined for the protected areas as listed below:

- Core zone (Strict): Core area to be maintained for the health of the protected area

- Conservation zone: Second tier sensitive area. Proper environmental assessment is required before any change in the existing landscape and land cover

- Sustainable use zone (Development): Area can be used for development but with due consideration and respect to the existing surrounding environment. This zone is also termed as CPA (Community Protected Area).

- Community zone (Local Community): the zone is used by the local community based on their judgment that best serves the community as well as the protected area.

According to the MOE, due to the financial constraints, there was no clear schedule to zone all the protected areas. With some support from donor agencies and some international NGOs, zoning of a few protected areas had been studied recently. Among the protected areas, the National Parks and Wildlife Conservation areas had been given more priority for the zoning. For example, two wildlife conversation areas, Phnom Samkos and Phnom Aural (marked in Figure 8.2.1) had been studied for zoning, under the "Cardamom Mountain Wildlife Sanctuary Project" jointly by the MIS-GIS office and FFI (Fauna and Flora International). It had been learned that there were 6 to 12 other protected areas where some level of zoning study had been done. However, these areas had not been officially published since the necessary law/sub-decree had not been enacted yet. The law/sub-decree is still under consideration by the authorities concerned. Zoning is crucial in taking any decision on development projects located inside or on the border of the protected areas, such as hydropower.

Table 8.2.1 Types and Area of Protected Areas in Cambodia

S. No.	Name	Status (Type)	Area (ha.)	S. No.	Name	Status (Type)	Area (ha.)
1	Ang Trapeng Thmor	10	12,905.81	18	Phnom Nam Lyr	12	53,832.51
2	Angkor	13	13,518.11	19	Phnom Prich	12	221,818.39
3	Banteay Chhmar	13	81,897.05	20	Phnom Samkos	12	330,793.37
4	Beng Per	12	249,407.59	21	Preah Vihear	13	4,844.61
5	Botum Sakor	11	182,584.96	22	Preah Vihear_dfw	9	190,028.48
6	Cardamom	8	401,310.81	23	Ream	11	14,676.48
7	Dong Peng	14	28,968.27	24	Roniem Daun Sam I	12	16,565.75
8	Kbal Chay	8	6,356.07	25	Roniem Daun Sam II	12	21,268.25
9	Kep	11	6,663.96	26	Roniem Daun sam III	12	2,100.00
10	Kirirom	11	28,374.69	27	Samlaut	14	59,916.48
11	Kulen Promtep	12	406,759.25	28	Snoul	12	74,360.89
12	Lomphat	12	251,468.06	29	Snoul_dfw	9	297,915.80
13	Mondul Kirri	9	429,437.24	30	SWEC	6	144,275.21
14	Peam Krasop	12	24,590.55	31	Ta Moa	7	2,384.47
15	Phnom Aural	12	256,737.06	32	Tonle Sap	14	322,269.64
16	Phnom Bokor	11	142,316.56	33	Virachey	11	338,056.65
17	Phnom Kulen	11	37,608.17	Total			4,656,011.19
Protected Areas Status Description							
6: South West Elephant Corridor (SWEC), 7: Zoo, 8: Watersheds Protection, 9: Bio-Diversity Conservation, 10: Water Birds Conservation, 11: National Park, 12: Wildlife Conservation, 13: Protected Landscape, 14: Multiple Purpose							

Source: Study Team

Besides the questionnaire survey, the study team (which included various experts such as a civil engineer, hydrologist, geologist, sociologist, GIS/natural environmentalist and others) had several multipurpose field visits to observe the present site conditions of the forests and protected areas in and around potential hydropower sites, along with the primary objective of formulation of a hydropower master plan. Specifically, a team composed of a sociologist and a GIS/natural environmentalist visited potential hydropower sites such as Stung Metoek II (Project Site #20) that lies inside the Wildlife Conservation “Phnom Samkos” Protected Area, and Bokor Plateau (Project Site #29) that lies inside National Park “Phnom Bokor” Protected Area. Based on these two ground observations and information from questionnaires survey, the following can be summarized with viewpoints of observation of general landscape, general socioeconomic activities related to environment, and general environmental issues, with the perspective of the development of a hydropower project:

- In general, exploitation activities of agricultural land along with deforestation can be observed at several places including those around and inside defined protected areas and national parks. However, the degrees of such activities vary from mild to severe. For example, Bokor Plateau (Site #29) can be categorized as mild while that of Stung Metoek II (site #20) is severe.

- Tree trimming is going on in many areas in Pursat Province, which holds several potential hydropower sites. It can be inferred that inappropriate use of natural resources and mismanagement of cleared land were widespread.

- Slash and burn agricultural activities, specifically for growing rainfed paddies, are still being practiced in and around Stung Metoek II (site #20).

- In some cases like Bokor Plateau (Site #29), there were signs of forest regeneration but most of it were natural forest without any re-plantation. Most of the deforested areas were invaded by shrubs and grasses.

- There were active infrastructure developments and restoration activities going on around the country including the area with hydropower potential.

- It had been observed that there was plenty of water during the rainy season, but in the dry season, many rivulets and rivers went dry. Such situation comes from the climate conditions in the southwest region where only one rainy season is created by southwest monsoon. Dry season starts from November and continues until next April, resulting decreased or dried river conditions. It had been reported that some communes (Thma Da for example) experienced flash floods during the rainy season but people had to expend considerable time to fetch water during the dry season.

- It had been learned that RGC is not fully aware of integrated watershed management.

- Government agencies responsible for agriculture, forestry and environment should advise and educate the people on the sustainable use of natural resources. The presence of the Ministry of Environment at some places, however, was not effective as it should be.

- Hunting of wildlife, specifically wild deer, wild boars and monkeys, was observed in some areas such as Thma Da commune of #20 Stung Metoek II. Unwise fishing, for example, electric fishing, was also found.

- Some of the area needs active reforestation

(3) Possible Impacts from Hydropower Development

As explained before, the ten prioritized hydropower project sites fall inside the six basins. Most of them are inside the protected areas, partially or fully (Figure 8.2.1). It was obvious that there will be some degree of adverse impacts as well as beneficial impacts on the protected areas. Some of the issues are summarized below:

- According to the land use map, almost all potential hydropower sites are dominated with land cover types of forest, shrubland, and grassland. However, in reality, things are a bit different. For example, most of the envisaged reservoir areas of sites #20 (Stung Metoek II) and #29 (Bokor Plateau) had already been deforested. Furthermore, deforested lands in site #20 are in fact mostly dominated by slash and burn type of agriculture with temporary land rights (lease for 5 years).

- It can be said that most of the proposed reservoir area is dominated by bushes and grass, thus environmental damage will be minimal.
- Riverine forests along several small channels will be under water if the project pushes through.
- The reservoir will have water for the survival of aquatic life as well as wild animals and birds from the surrounding reserves and national parks. However, it will alter the downstream river flow, which might have some degree of adverse impact on aquatic life.
- Some forest areas will be submerged in the reservoir, displacing the flora and fauna.
- Although it was not confirmed, some endangered species might be in the area and need to be checked and verified by the authorities concerned.

(4) Possible Mitigation

The nine prioritized project sites namely Prek Liang I and II, Middle St. Russey Chrum, Upper St. Russey Chrum, St. Metoek II, St. Metoek III, Lower Sre Pok II + Lower Se San II, and Bokor Plateau are located in the six basins as mentioned earlier. Prior to the examination of the mitigation plans, it was necessary to see their geophysical location and their area extent with respect to the protected areas. Table 8.2.2 shows the extent (area) of reservoir of the potential hydropower sites situated inside the protected areas. The bold characters indicate the selected seven master plan projects. It can be seen that of the ten prioritized sites, all are inside the protected area except for #7&8 Lower Sre Pok II + Lower Se San II, which is almost completely outside (only 0.6% are inside).

Table 8.2.2 Geophysical Location and Area Extent of Potential Hydropower Sites in Relation of Protected Areas.

Potential Hydropower			Protected Areas				
IDs	Name	Total Reservoir Area (sq. km.)	Name	Status (Type)	Reservoir Area Inside Reserve (ha)	Total Reservoir Area Inside Reserve (ha)	% of Reservoir Area Inside Reserve
2	Prek Chhlong II	58.12	Snoul	12	142.45	5,721.46	98.4
			Snoul_dfw	9	5,579.00		
3	Prek Ter III	178.79	-	-	-	-	-
4	Prek Ter II	101.55	Phnom Prich	12	1,901.61	1,901.61	18.7
5	Sre Pok IV	52.62	Mondul Kirri	9	5,242.70	5,242.70	99.6
6	Prek Por I	11.51	Phnom Nam Lyr	12	0.71	1,151.26	100.0
			Mondul Kirri	9	1,150.55		
7	**Lower Sre Pok II + Lower Se San**	**355.14**	**Lomphat**	**12**	**210.68**	**210.68**	**0.6**
10	Se Kong	117.11	Virachey	11	495.57	495.57	4.2
11	Lower Se San III	460.68	Virachey	11	1,527.06	1,527.06	3.3
12	**Prek Liang I**	**7.15**	**Virachey**	**11**	**715.39**	**715.39**	**100.0**
14	**Prek Liang II**	**14.16**	**Virachey**	**11**	**1,415.82**	**1,415.82**	**100.0**
15	Lower Sre Pok III	709.78	Lomphat	12	43,243.49	64,699.01	91.2
			Mondul Kirri	9	21,455.52		
16	**Middle St. Russey Chrum**	**22.59**	**Cardamom**	**8**	**2,258.87**	**2,258.87**	**100.0**
17	Stung Chhay Areng	135.10	Cardamom	8	4,754.16	4,754.16	35.2
18	Stung Tatay	47.06	Cardamom	8	2,909.72	2,909.72	61.8
19	Stung Metoek I	4.60	Phnom Samkos	12	460.23	460.23	100.0
20	**Stung Metoek II**	**20.22**	**Phnom Samkos**	**12**	**2,021.68**	**2,021.68**	**100.0**
21	**Stung Metoek III**	**11.20**	**Phnom Samkos**	**12**	**1,120.13**	**1,120.13**	**100.0**
22	Stung Kep II-B	5.23	SWEC	6	347.98	390.94	51.8
	Stung Kep II-A	2.32	SWEC	6	42.95		
23	Upper St. Russey Chrum	4.45	Cardamom	8	445.28	445.28	100.0
24	Stung Pursat I	101.54	Phnom Samkos	12	6,448.08	6,531.84	64.3
			Cardamom	8	83.76		
25	Stung Pursat II	24.75	Cardamom	8	1,426.89	1,426.89	57.7
26	Stung Sen	939.40	Beng Per	12	2,105.11	2,105.11	2.2
27	Stung Battanmbang II	39.67	Phnom Samkos	12	3,967.49	3,967.49	100.0
28	Stung Battanmbang I	132.30	Phnom Samkos	12	96.73	96.73	0.7
29	**Bokor Plateao**	**1.84**	**Phnom Bokor**	**11**	**184.37**	**193.50**	**100.0**
	Bokor Plateao-B	**0.09**	**Phnom Bokor**	**11**	**9.13**		
Protected Areas Status Description							
6: South West Elephant Corridor (SWEC), 7: Zoo, 8: Watersheds Protection, 9: Bio-Diversity Conservation, 10: Water Birds Conservation, 11: National Park, 12: Wildlife Conservation, 13: Protected Landscape, 14: Multiple Purpose							
Project Site # 13 "Prek Liang IA" is runoff type, thus there in no reservoir							

Source: Study Team

The simple illustration presented above of the area extent of hydropower projects shows a gloomy picture, but there is another side of the story. If the area extent of potential hydropower and protected area of Table 8.2.2 are swapped, Table 8.2.3 will result, showing that the extended protected areas will be under the reservoir, in the case that all 29 projects push through. The bold characters indicate the selected seven master plan projects. In such a case, only less than 5% (in aggregated form) of the protected areas will be affected except for two cases: Lomphat and Mondul Kiri. In the case of implementing only the ten prioritized projects, then these two areas will also be under less than 5%.

Table 8.2.3 Geophysical Location and Area Extent of Protected Areas in Relation of Potential Hydropower Sites

Protected Areas			Potential Hydropower		Reservoir Area Inside Reserve (ha)	Total Reserve Area Inside Reservoir (ha)	% of Reserve Area Inside Reservoir
Name	Status (Type)	Total Reserve Area (ha)	IDs	Name			
-	-		3	Prek Ter III	-	-	
Beng Per	12	249,407.59	26	Stung Sen	2,105.11	2,105.11	0.84
Cardamom	8	401,310.81	16	Middle St. Russey Chrum	2,258.87	11,878.67	2.96
			17	Stung Chhay Areng	4,754.16		
			18	Stung Tatay	2,909.72		
			23	Upper St. Russey Chrum	445.28		
			24	Stung Pursat I	83.76		
			25	Stung Pursat II	1,426.89		
Lomphat	12	251,468.06	**7**	**Lower Sre Pok II + Lower Se San II**	**210.68**	43,454.17	17.28
			15	Lower Sre Pok III	43,243.49		
Mondul Kirri	9	429,437.24	5	Sre Pok IV	5,242.70	27,848.77	6.48
			6	Prek Por I	1,150.55		
			15	Lower Sre Pok III	21,455.52		
Phnom Bokor	11	142,316.56	**29**	**Bokor Plateao**	**184.37**	193.50	0.14
				Bokor Plateao-B	**9.13**		
Phnom Nam Lyr	12	53,832.51	6	Prek Por I	0.71	0.71	0.00
Phnom Prich	12	221,818.39	4	Prek Ter II	1,901.61	1,901.61	0.86
Phnom Samkos	12	330,793.37	19	Stung Metoek I	460.23	14,114.34	4.27
			20	**Stung Metoek II**	**2,021.68**		
			21	**Stung Metoek III**	**1,120.13**		
			24	Stung Pursat I	6,448.08		
			27	Stung Battanmbang II	3,967.49		
			28	Stung Battanmbang I	96.73		
Snoul	12	74,360.89	2	Prek Chhlong II	142.45	142.45	0.19
Snoul_dfw	9	297,915.80	2	Prek Chhlong II	5,579.00	5,579.00	1.87
SWEC	6	144,275.21	22	Stung Kep II-B	347.98	390.94	0.27
				Stung Kep II-A	42.95		
Virachey	11	338,056.65	10	Se Kong	495.57	4,153.85	1.23
			11	Lower Se San III	1,527.06		
			12	**Prek Liang I**	**715.39**		
			14	**Prek Liang II**	**1,415.82**		
Protected Areas Status Description							
6: South West Elephant Corridor (SWEC), 7: Zoo, 8: Watersheds Protection, 9: Bio-Diversity Conservation, 10: Water Birds Conservation, 11: National Park, 12: Wildlife Conservation, 13: Protected Landscape, 14: Multiple							
Project Site # 13 "Prek Liang IA" is runoff type, thus there in no reservoir							

Source: Study Team

This analysis shows that the adverse impact is not very severe unless a reservoir falls inside the "core zone" and "ecologically sensitive" areas. To see such impact, zoning of the protected areas is essential.

As an example, an environmental and socioeconomic damage mitigation plan was formulated for Site No. 7 & 8. At the full supply level, the total size of the reservoir will be 355.14 km^2, which comprises the categories of land use/land cover as shown in Tables 8.2.4 and 8.2.5. These land uses/covers may have adverse impacts on the socio-economy (agricultural lands) and natural environment (forest).

Table 8.2.4 Types of Land Use/Land Cover Considered for Mitigation Plan

1	Forest	Deciduous forest
		Evergreen broad leafed forest
		Mixed forest from evergreen and deciduous species
		Riparian forest

Source: Study Team

Based on the table above on the land use/land cover definition, the total area of forest land is 284.86 km^2. In order to compensate or substitute the CO_2 sink capacity of the forest submerged, it would be required to make reforestation by planting trees for pulp etc. in an area corresponding to about 22%[2] or 6.270 ha. After reviewing the available land use/land cover categories, the following types enumerated in Table 8.2.6 can be taken as candidates for such replacement.

Table 8.2.5 Potential Land Use/Land Cover Categories for Reforestation

Land use Categories Used for Available Land for Replacement or Substiturion	
1	Swidden agriculture (Slash and burn)
2	Bamboo and Secondary forests
3	Dry Deciduous (Open) forest
4	Grassland (undifferentiated)
5	Woodland and scattered trees (C < 10%)
6	Barren land
7	Grass Savannah
8	Shrubland (undifferentiated)

Source: Study Team

In order to find the suitable land area for reforestation, a buffer zone was drawn around the reservoir. The area of buffer zone by distance from the reservoir edge is presented in Table 8.2.7. After evaluating the land use/land cover types of each buffer zone, the available land area, which is suitable for reforestation was calculated and is presented in Table 8.2.8.

[2] The unit CO_2 sink capacity of tropical rainforest in Cambodia is estimated at 5.19 トン-CO_2/ha/yr. On the other hand, the unit production of pulp tree or fuel tree for biomass gasification is estimated at 10 dry ton/ha/yr. Its CO_2-fixing capacity will then be calculated as 10 x 1.37 (adjustment for biomass belowground) x 0.47 (Carbon content) x (44/12) = 23.6 ton-CO_2/ha/yr。 Accordingly, the required land area for reforestation will be 5.19 / 23.6 = 1 / 4.55 = 22%. That is, if we plant pulp tress on the land corresponding to 22% of the forest land submerged, we can substitute the CO_2-sink capacity of the forest.

Table 8.2.6 Land Area of Buffer Zone

S.No.	Distance (km)	Area (sq.km.)
1	Reservoir	355.14
2	Reservoir Edge to 2.5	605.56
3	2.5 to 5	443.25
4	5 to 10	843.72
5	10 to 15	981.55
6	15 to 20	1,133.00
7	20 to 25	1,287.22
8	25 to 30	1,442.75

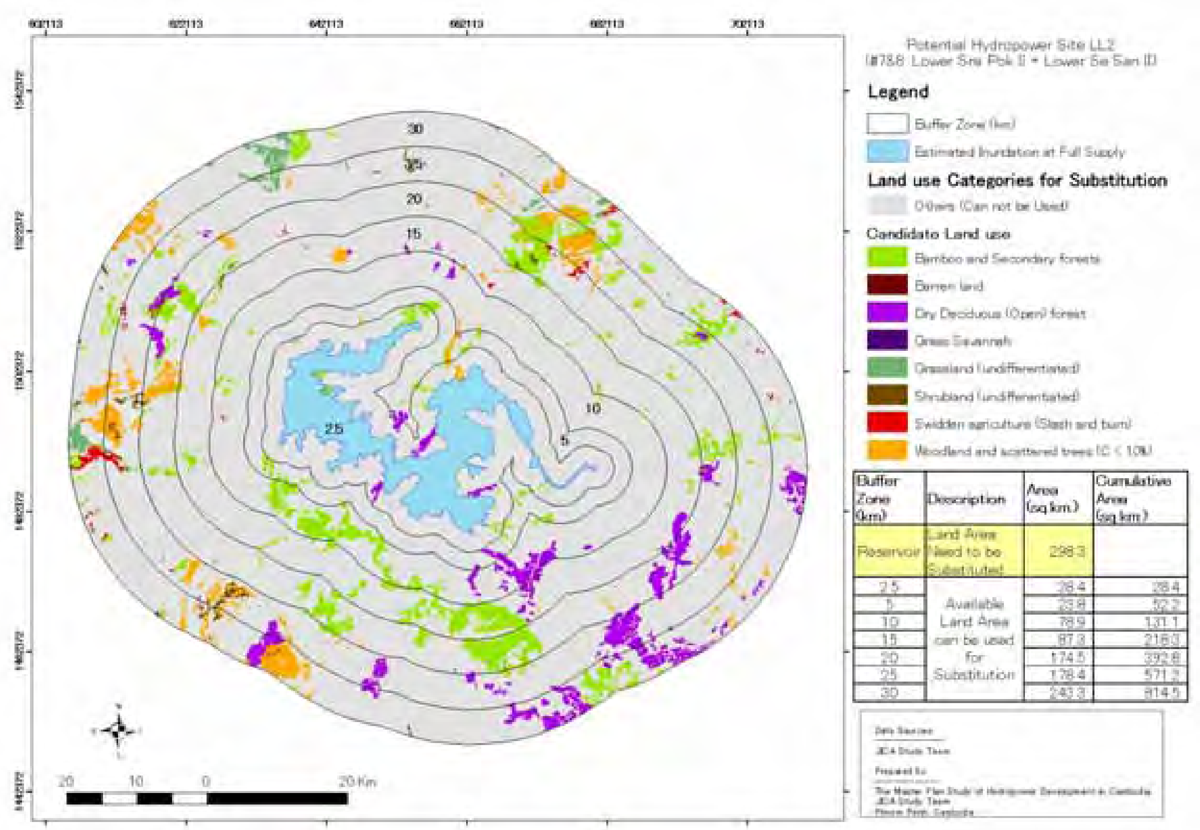
Source: Study Team

Table 8.2.7 Available Land for Reforestation

Buffer Zone (km)	Description	Area (km^2.)	Cumulative Area (sq.km.)
Reservoir	Land area to be reforested	**62.7**	
2.5	Available land area for reforestation	28.4	28.4
5		23.8	52.2
10		78.9	131.1
15		87.3	218.3
20		174.5	392.8
25		178.4	571.2
30		243.3	814.5

Source: Study Team

The distribution of such land is illustrated in Figure 8.2.2.



Source: Study Team

Figure 8.2.2 Buffer Zone and Distribution of Potential Lands for Proposed Reforestation

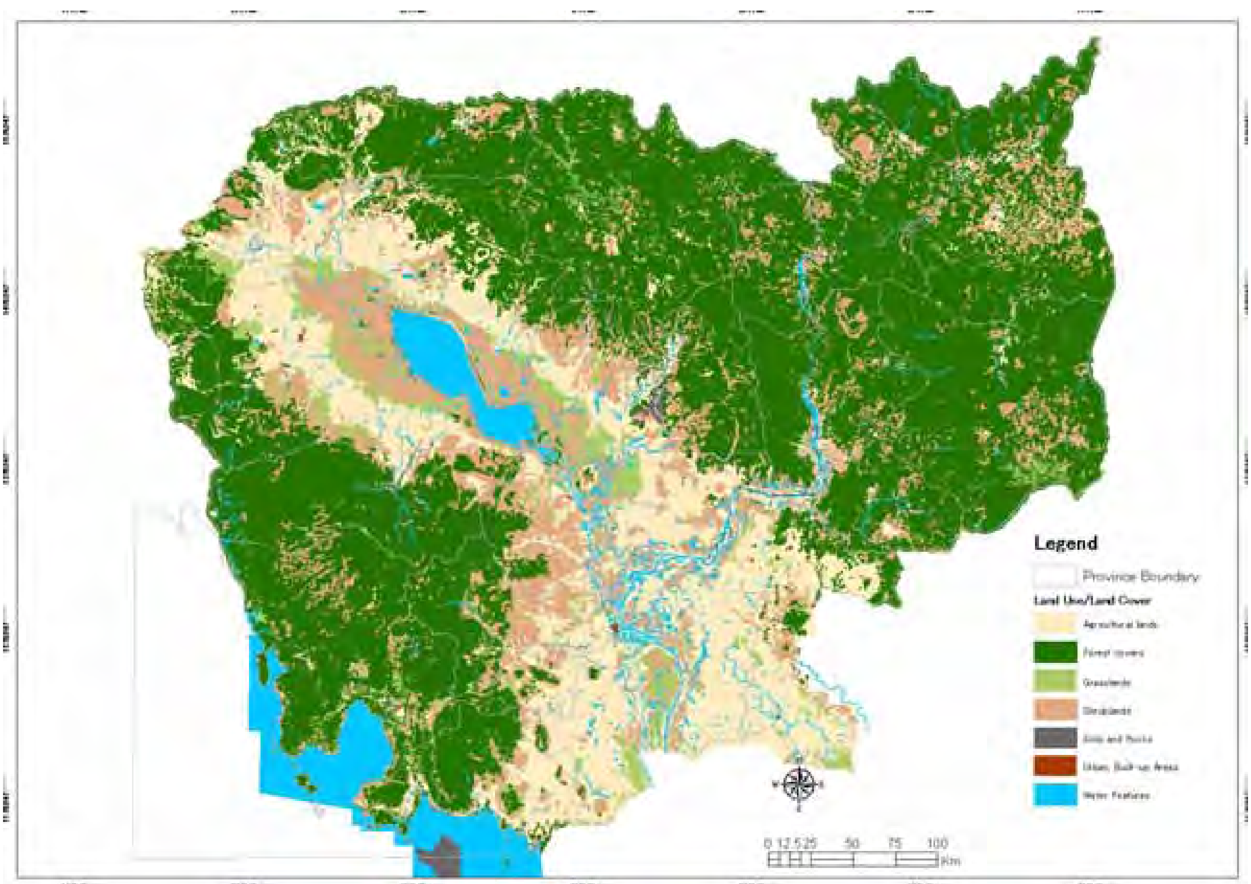
8.2.2 Forest and Biodiversity

(1) Forest

According to the land use/land cover map prepared in 2002 (extracting and compiling land use from various data starting as early as 1992 to 2002), forest covers more than 53% of the total land area of Cambodia followed by agricultural lands with nearly 23%. Figure 8.2.3 shows the land use/land cover distribution in Cambodia. It may be observed that most of the forests are found in the northeast and southwest of the country where most of the potential hydropower sites are located.

There is a difference between the officially proclaimed forest area and actual forest area measured by the Study Team on digital maps. It is a well known fact that Cambodia has one of the worst deforestation rates, which are still going on in one form or the other. The forest cover map presented earlier does not precisely show the actual forest area but rather the official figures. The dense or primary forest is much less, probably it does not reach double digit percentage figure, and most of the areas are either open forest or shrubs and bushes. Furthermore, some of the highlands and plateaus are covered with savanna type grasses.

Cambodia has a tropical monsoon climate, which, along with local geophysical conditions, determines the type of forest in the country. The densest rainforests are found in the mountains and along the southwestern areas, while highlands and plateaus contain savanna type grasses. In qualitative forest type terms, Cambodian forests may be classified as 1) evergreen forest, 2) deciduous forest, 3) hill evergreen forest, and 4) swamp forest. The evergreen forest can be further divided into two sub-types: i) dry evergreen forest, and ii) secondary evergreen forest. Similarly, the deciduous forest can be divided into i) deciduous dipterocarp forest, and ii) a mixed deciduous forest. There are some pine trees found mixed with other types of forests in higher altitude areas.



Source: MOPWT

Figure 8.2.3 Major Land Use/Land Cover Distribution in Cambodia

(2) Biodiversity

Sitting in the tropical monsoon climatic zone, Cambodia has a rich biodiversity with several indigenous flora and fauna. For many species, Cambodia might reportedly be the last refuge. Of these, there are several kinds of plant and animal species. The wild animals would include large mammals such as elephants, deer, wild oxen, panthers, bears, and tigers; several types of birds that includes cormorants, cranes, parrots, pheasants, and wild ducks; reptiles such as numerous poisonous snakes, frogs, turtles; several kinds of fishes and insects.

As mentioned earlier, ten prioritized potential hydropower sites lie in two prominent regions; northeast and southwest of the country. For example, Cardamom mountain forest (southwest region) hosts prioritized project sites of Middle and Upper Stung Russey Chrum, Stung Metoek II and III, and Stung Kep II (New Tatay). In the other region, Prek Liang I, II sites lie in Virachey National Park forest (northeast region). The flora and fauna of Cambodia as a whole have more or less many similarities and are found in respective regions. However, there are some degrees of different types in the northeast and southwest regions. Thus, it would be appropriate to summarize the biodiversity on these two representative forests/natural reserves.

(3) Virachey National Park (Prek Liang I, II)

The Virachey National Park (VNP) and surrounding forests are located near the border of Lao, Viet Nam and Cambodia. The high altitude and rugged terrain make accessibility for human activities somewhat difficult, which in return, become a favorable condition for flora and fauna. It is still very common to find some of the undisturbed natural forest covers in the area. Mountainous topography and wet climate (due to the two rainy seasons in these areas) give favorable environment for many species of plants and mammals, birds, reptiles and insects. Furthermore, the relatively dense network of perennial rivers and rivulets is favorable for several kinds of fish and amphibious animals. Geophysical conditions of the area are suitable, thus provide breeding ground for several species. Given the conditions of appropriate protection and scientifically devised sustainable use of the forest resources of the area, it could become one of the valuable areas for the protection of several endangered species of flora and fauna.

Realizing the importance of the forest resources of the area, the government of Cambodia had created VNP under the Royal Decree for creation and designation of the Protected Areas, enforced on 1st November 1993. VNP is managed by the Ministry of Environment. VNP would be one of the top priority areas for conservation in Southeast Asia. The streams from the mountains of Virachey National Park contribute to the low flow of the Mekong River during the dry season, being blessed by the northwest monsoon that prevails in the northeast of Cambodia and adjacent Vietnam from November to January.

Since 2000, the World Bank finances "Biodiversity and Protected Area Management Project (BPAMP)" within the Virachey National Park. This project aims at improving the capabilities of staff in the Ministry of Environment to plan, implement and effectively monitor the protected areas. This includes developing and testing proactive measures in order to minimize unsustainable exploitation and degradation of the biodiversity of national and global significance in the Virachey National Park. There are four components: 1) national policy and capacity building, 2) park protection and management, 3) community development, and 4) project management. The extension of this conservation project (2008-2012) will soon be approved by the World Bank.

1) Major Type of Fauna

There had been some studies in the past about the fauna of the VNP, which however may not be claimed as systematic. Previous surveys and studies indicate that there may be as many as 156 vertebrate species in the park area. Of these, 43 are of international significance. Some of the bovids, cats, small carnivores and primates are listed as endangered. Globally threatened primate species can be found in the Virachey National Park. These include slow loris, pygmy loris, pig-tailed macaque, long-tailed macaque, douc langur and yellow-cheeked crested gibbon. Key species of particular concern include elephant, tiger, gaur and banteng (BPAMP, 2007).

It is estimated that as many as 100 bird species of international significance are present in VNP and surrounding forest areas. This area is one of the two areas in Cambodia known to support Germain's Peacock Pheasant, a restricted-range species. In addition, the park is refuge to a number of globally threatened and near-threatened species, including Siamese sireback, red-collared woodpecker and great hornbill (BPAMP, 2005). A number of significant records had been found (Mlicovsky, 1999), including three species recorded for the first time in Cambodia: White browed Piculet Sasia ochracea, Eurasian Woodcock Scolopax rusticola, and Japanese Paradise-flycatcher Terpsiphone atrocaudata.

The aquatic environment in the Virachey National Park is a suitable place for fresh water crocodile, otters, and freshwater tortoise. Some fish species are of conservation significance. As an example, Emmett (Emmett, 2006) surveyed some rivers in the area in 2006 and listed about 30 fish species. These include among others *Osphronemus exodon, Raiamas guttatus, Xenentodon cancila, Barbodes schwanefeldi, Hypsibarbus sp. Cf. vernayi, Parambassis apogonoides, Annamia normani, Mystus albolineatus.*

2) Major Type of Flora

Dense semi-evergreen lowland and montane (low mountain) forests, upland savannahs, bamboo thickets and occasional patches of mixed deciduous forests dominate the vegetation of forests in and around Virachey National Park. Hills and low mountains dominate the topography of the area, with most areas lying higher than 400 masl, and elevations reaching over 1,500 masl along the borders of Lao and Vietnam. Grassland and scrubland formations are found in isolated areas and marshes as well.

The literature describes two broad vegetation formations for Virachey National Park. Two vegetation formations are found in seven landscapes, each with its own predominant vegetation (BPAMP, 2005):

- Humid medium elevation formations (above 600 masl) with montane slopes and montane peneplain

- Humid low elevation formations with middle valley reaches, valley floors, western lowland, isolated granite outcrops and wetlands

The indigenous local community collects forest products for self-consumption and for selling as well. Among the commercial/human consumption value, more than 60 species of wild edible vegetable, 30 species of wild edible fruits, 3 kinds of dry and oil resin, rattan and bamboo can be listed (BPAMP, 2000).

(4) Cardamom Mountain Forest and Protected Areas (Middle Stung Russey Chrum, Upper Stung Russey Chrum, Stung Metoek II, Stung Metoek III, New Tatay)

Cardamom mountain is one of the important rainforest areas of the country, hosting three protected areas adjacent to each other, namely Phnom Samkos, Central Cardamom and Phnom Aural. The Cardamom protected area was gazetted in 2002 and had a formally demarcated boundary. It is managed by the Cardamoms Conservation Program, which is a partnership between Conservation International (CI) and the Forestry Administration (FA) of RGC. The area has now been designated as 'protected forest' and all logging concessions have been cancelled within its boundaries. The area is covered with evergreen forest, dry dipterocarp forest, pine forest, grasslands, and wetland habitats, with an elevation range of approximately 50–1,500 masl. This area contains a wide variety of lowland and mid-altitude habitats surrounding a core central plateau, of which about 60,000 hectares have an elevation over 1,000 masl (Emmett and Olson, 2005).

The area has been recognized as an internationally important region for biodiversity conservation. With limited resources and technical know-how, but with collaboration from conservation organizations, studies and biological surveys have been conducted in southwest Cambodia including the following five:

- A preliminary wildlife survey in the Cardamom mountains region of southwest Cambodia – FFI, 1999
- Cardamom Mountains Biodiversity Survey – FFI, 2000
- Social and Ecological Surveys of Phnom Aural Wildlife Sanctuary – FFI, 2002
- Mini-RAP Assessment of the Silver Road Logging Concession, Cardamom Mountain Area, Cambodia – CI, 2003
- Biodiversity Assessment of the Southern Cardamoms and Botum-Sakor Peninsular – WildAid, 2003

These study reports can be used as references for the details of the biodiversity of the area. For an overview, a brief introduction on flora and fauna is presented below:

1) Major Type of Fauna

The areas surveyed by CI in 2004 were found to contain a high diversity and abundance of threatened species. With the CI survey, twelve mammal species, two birds, seven reptiles, one amphibian, and one fish were classified as 'globally threatened', and many others were classified as 'near threatened' or 'data deficient.' Potentially undescribed species were discovered, including a rodent (Rattus sp), at least one species of shrew (Crocidura sp), a snake (Oligodon sp), several frogs (e.g., Philautus sp and Polypedates sp), a skink (Scincella sp), and a caecilian (Ichthyophis sp) (Emmett and Olson, 2005).

Mammal Species

In total, approximately 79 mammal species were recorded in the Cardamom area (Emmett and Olson, 2005). Of these, twelve were classified as 'globally threatened.' Species such as fishing cats and otters are identified in the area and are dependant on wetland habitats which provide fishes as their main food. However, their number is dwindling dangerously. Some of the surveys show the presence of mammals like Eurasian otter Lutra lutra, Smooth-coated otter Lutrogale perspicillata, Asian small-clawed otter Aonyx cinerea, and the Hairy-nosed otter Lutra sumatrana (Daltry & Traeholt, 2003).

Wild cattle tracks were identified on the upland plateau in the pine forest, montane evergreen forest, and grassland. The gaur is vulnerable and these identifications and records are important and positive signs for the need of conservation of this specie. Elephant dung was identified in and around a large cave in the Knorgl Strol mountain area. Two species of bear inhabit this region: the Malayan Sun bear Helarctos malayanus, and the Asiatic black bear Ursus thibethanus. Both bear species are widespread in Asia, but both are threatened due to hunting and habitat loss throughout their range (Emmett and Olson, 2005) .

Large cat scats were identified in the Russey Chrum Valley. The size and consistency of the scats indicate either a leopard or a tiger. The survival of these species in the region is dependent on high levels of direct protection and improved enforcement of wildlife laws within Cambodia's justice system. Asian golden cat and clouded leopard (vulnerable species) were recorded in fairly low numbers in the area (Emmett and Olson, 2005) .

The CI's 2004 survey recorded two species of tree shrew, and at least eight rodents and two insectivore species. Of these, ten species are new records for the Cardamom Mountains, and six species are new records for Cambodia. Some of the rats and shrews appear to be morphologically distinct from known species and may be new to science. Several voucher specimens from the rodent genera Maxomys and Niviventer were externally different to previously recorded species for the country and may be new records for Cambodia, or even new to science. Eleven species of bats were recorded during this survey. Two species, Myotis horsfieldi and Rhinolophus lepidus, are new records for Cambodia. Both species are found throughout the Cardamom region. Another species, Rhinolophus shameli, is listed as near threatened on the IUCN list (Emmett and Olson, 2005) .

Bird Species

A total of 93 bird species were recorded in and around the Cardamom region (Emmett and Olson, 2005). Fifteen of the species represent new records for the region. Three of these represent specifically the Cardamom Mountains. The new species for the Cardamom Mountains are the Black-browed Reed Warbler, Chinese Sparrowhawk, and Common Moorhen. Additional new species for the region are the

Lesser Fish Eagle, Oriental Bay Owl, Black-headed Bulbul, Changeable Hawk Eagle, Common Tailorbird, Oriental Darter, Long-tailed Broadbill, Osprey, Rackettailed Treepie, Cattle Egret, Oriental Reed Warbler, and Green Imperial Pigeon. However, it is yet to be confirmed that the potential record of the White-crowned Hornbill would represent an expansion of the known distribution of this globally 'near-threatened' species.

Reptile and Amphibian Species

The CI's survey in 2004 recorded at least 55 reptile and 29 amphibian species (Emmett and Olson, 2005) A large number of the reptile species identified in the region were classified as 'globally threatened.' The Siamese crocodile, *Crocodylus siamensis*, is critically endangered. The elongated tortoise, *Indotestudo elongate*, is endangered. The Asiatic softshell turtle, *Amyda cartilaginea*, Asian giant pond turtle, *Heosemys grandis*, black marsh turtle, *Siebenrockiella crassicollis*, impressed tortoise, *Manouria impressa*, and the Asian box turtle, *Cuora alboinensi*s, are identified in the area and classified as 'vulnerable.' The Asian leaf turtle, *Cyclemys atripons*, is 'near threatened.' One of the amphibian species, the spiny-breasted giant frog, *Paa fasciculispina*, is classified as 'vulnerable', and Mortensen's frog, *Rana mortenseni*, is 'near threatened.' (Emmett and Olson, 2005) .

Fish Species

Forty-three species of fish from the 14 families (five Orders) were identified, 33 of which were newly recorded for the Cardamom Mountains. These results bring the total number of fish species recorded from drainage basin originating in the Cardamom Mountains to 54. The family Cyprinidae (carps, minnows and barbs) dominated the collections with 20 species, more than three times as many species as the next most abundant group, Balitoridae (hill stream loaches). Three or fewer species were observed in the other 12 families, with six families being represented by only one species (Anabantidae, Cobitidae, Gobiidae, Osteoglossidae, Pristolepididae, and Sisoridae). The highest priority for freshwater fish conservation in the region, and indeed in southwest Cambodia, is the endangered Asian arowana or dragon fish, *Scleropages formosus*, and Blackfish, *Tor sp*. (Emmett and Olson, 2005).

2) Major Type of Flora

The Cardamom mountain area forest and protected areas contain some of the most important hill river systems and swathes of contiguous evergreen forest in Cambodia. Deforestation in this region is occurring at a comparatively low rate and the evergreen forests appear to be in good condition. It is under favorable conditions for the other several plant species. Some of the 'globally threatened' plant species such as the endangered agar wood Aquilaria crassna are identified in the area (Emmett and Olson, 2005).

The lowland wetlands on the eastern side of the Areng valley and the upland marshes to the east and north of O'Som represent a significant still-water bodies in the region, both in terms of size and biological importance. These wetlands are home to the world's largest known wild populations of critically endangered species. The wetlands biodiversity (both flora and fauna) within the Areng Valley are threatened by over-fishing and conversion to agriculture. However, the upland marshes around O'Som show fewer signs of disturbance (Emmett and Olson, 2005).

(5) Overview on Envisaged Impacts on the Ecosystem

Table 8.2.8 shows the extent of reservoir areas of the selected seven potential hydropower sites falling inside the protected areas. #7&8 Lower Sre Pok II + Lower Se San II project hardly falls inside the protected areas (only 0.6% of the reservoir area located inside the protected areas). For other six projects, the whole reservoir area (100%) of each project is located inside the protected areas.

Table 8.2.8 Area Extent of Selected 7 Potential Hydropower Sites in Relation of Protected Areas

Potential Hydropower			Protected Areas		Reservoir Area Inside Reserve (ha)	Total (ha)	% of Reservoir Area Inside Reserve
ID	Name	Total Reservoir Area (km^2)	Name	Status (Type)			
7	Lower Sre Pok II + Lower Se Sa	355.14	Lomphat	12	210.68	210.68	0.6
12	Prek Liang I	7.15	Virachey	11	715.39	715.39	100.0
14	Prek Liang II	14.16	Virachey	11	1,415.82	1,415.82	100.0
16	Middle St. Russey Chrum	22.59	Cardamom	8	2,258.87	2,258.87	100.0
20	Stung Metoek II	20.22	Phnom Samkos	12	2,021.68	2,021.68	100.0
21	Stung Metoek III	11.20	Phnom Samkos	12	1,120.13	1,120.13	100.0
29	Bokor Plateao	1.84	Phnom Bokor	11	184.37	193.50	100.0
	Bokor Plateao-B	0.09	Phnom Bokor	11	9.13		
Protected Areas Status Description							
6: South West Elephant Corridor (SWEC), 7: Zoo, 8: Watersheds Protection, 9: Bio-Diversity Conservation, 10: Water Birds Conservation, 11: National Park, 12: Wildlife Conservation, 13: Protected Landscape, 14: Multiple Purpose							

Source: Study Team

Table 8.2.9 shows the ratio of inundated area against total area of protected areas. In all protected areas, inundated area against the total area of protected area is less than 1%. This fact suggests that in case the reservoir area does not fall inside the "core zone" or "conservation zone" in the protected areas, it is possible to accept the environmental impacts by inundation. In order to evaluate the environmental impacts in more detail, zoning of the protected area is more important.

In chapter 1, Table 1.1.3 shows the area of primary forest in the envisaged reservoirs. Table 1.2.5 shows the details of land use in the envisaged reservoirs. By assuming the inundated areas of primary forest to be indices of impacts to the ecosystem, impacts are relatively high in #7&8 LL2, #16 MSRC, #20 Stung Metoek II, which have more than 1,000 ha of primary forest inundation in the reservoir. Further, by assuming the share of primary forest in the inundated area as magnitude of impacts, i.e., if the share is nearly 100%, the reservoir is located in the primary forest, and if the share is low, it means that the reservoir is situated in between the border of primary and secondary forests. It is assumed that #12 Prek Liang 1, #16 MSRC, and #23 USRC with more than 90% share are considered to be situated in the primary forest region. On the other hand, shares for #29 Bokor Plateau, #20 Stung Metoek 2, and #21 Stung Metoek 3 stays around 50%, which means that the reservoir of these projects may be situated in the mixed forest of primary and secondary forests.

It is not possible to identify the existence and magnitude of impacts on individual ecosystem in this Master Plan Study. The necessary items and check points for EIA in the next stage may be referred to the EIA guidelines which are introduced in sub-clause 9.4.2.

Table 8.2.9 Inundated Areas for Ongoing and MP Projects against Total Area of Protected Areas

Protected Area			Candidate Project Site		Reservoir Area Inside Reserve (ha)	Total Reserve Area Inside Reserve (ha)	% of Inundation Area against Total Rserve Area
Name	Status (Type)	Total Reserve Area (ha)	ID	Name			
Cardamom	8	401310.81	**16**	**Middle St. Russey Chrum**	**2258.87**	2258.87	0.56
			17	Stung Chhay Areng	-		
			18	Stung Tatay	-		
			23	Upper St. Russey Chrum	-		
			24	Stung Pursat I	-		
			25	Stung Pursat II	-		
Lomphat	12	251468.06	**7**	**Lower Sre Pok II + Lower Se Sa**	**210.68**	210.68	0.08
			15	Lower Sre Pok III	-		
Mondul Kirri	9	429437.24	5	Sre Pok IV	-	0.00	0.00
			6	Prek Por I	-		
			15	Lower Sre Pok III	-		
Phnom Bokor	11	142316.56	**29**	**Bokor Plateao**	**184.37**	193.50	0.14
				Bokor Plateao-B	**9.13**		
Phnom Nam Lyr	12	53832.51	6	Prek Por I	-	0.00	0.00
Phnom Prich	12	221818.39	4	Prek Ter II	-	0.00	0.00
Phnom Samkos	12	330793.37	19	Stung Metoek I	-	3141.81	0.95
			20	**Stung Metoek II**	**2021.68**		
			21	**Stung Metoek III**	**1120.13**		
			24	Stung Pursat I	-		
			27	Stung Battanmbang II	-		
			28	Stung Battanmbang I	-		
Snoul	12	74360.89	2	Prek Chhlong II	-	0.00	0.00
Snoul_dfw	9	297915.80	2	Prek Chhlong II	-	0.00	0.00
SWEC	6	144275.21	22	**Stung Kep II-B**	347.98	390.94	0.27
				Stung Kep II-A	42.95		
Virachey	11	338056.65	10	Se Kong	-	2131.21	0.63
			11	Lower Se San III	-		
			12	**Prek Liang I**	**715.39**		
			14	**Prek Liang II**	**1415.82**		
Protected Areas Status Description							
6: South West Elephant Corridor (SWEC), 7: Zoo, 8: Watersheds Protection, 9: Bio-Diversity Conservation, 10: Water Birds Conservation, 11: National Park, 12: Wildlife Conservation, 13: Protected Landscape, 14: Multiple Purpose							

Source: Study Team

8.2.3 River Discharge

All the seven MP projects are planned with dam and reservoir.

Of these, #7&8 LL2 project located in northeastern part is a dam type hydropower development, of which power house is located just downstream of the dam. Therefore there is no river section which would have less or no flow during the power generation. In addition, though LL2 project has a wide reservoir area, the project is of run-of-river type in view of the flow regulating function. In principle, LL2 project releases the inflow as flows in, toward downstream. Therefore there would be hardly changes on the flow regime on the downstream river reaches. Warning on the water release would be required if daily peak operation causes unacceptable water level fluctuations in the downstream. The need for the warning system depends on the speed of water level fluctuation. It is necessary to examine such needs during the feasibility study. LL2 project may block the migration routes of fish, and would require mitigation measures (see No. 6 of Table 9.4.2 and sub-clause 9.4.2 (7) 3)). However, the flow regime would hardly change.

As for Prek Liang 1 and 2 in the northeastern part, three projects in the southwestern part (Middle Stung Russey Chrum, Stung Metoek 2 and 3), and Bokor Plateau project in the central mountains, it is expected that social impacts in downstream areas of these projects are relatively small. For the six MP projects except LL2 project, river sections between the dam and the power house will be the depleted section. As most of these depleted sections are located in the remote mountain area, there would be no social impacts expected.

8.2.4 Sediment Transport

It is needed to consider impacts on sediment transport and downstream environment. In particular, impacts such as river bank erosion due to sediment trap and reduction of agricultural production due to decrease of nutrient supply should be considered.

In this study, from a view point of Strategic Environmental Assessment (SEA), Mekong Mainstream projects with unconfirmed technical feasibility on sand flushing from the reservoir, were excluded from the list of MP projects in the preliminary examination stage. LL2 project would trap the transported sediment in the reservoir, and would cause downstream impacts. It is necessary to take care of these impacts during the feasibility study stage.

For 3 projects in the southwest area and BP in the central mountains, volume of sediment transport may remarkably change due to dam construction. This is because those areas have relatively steep topography with a lot of rainfall and thus sediment production in the areas would be high. On the other hand, it is considered that unit sediment production in the basin of three projects in the northeast area may not be so high because the rainfall in the areas is not as high as in the southwest coastal area and the central mountains.

In conducting EIA as a next step, general countermeasures against rather large amount of trapped sediment are as follows:

- Sand flushing through sand gate
- Dredging/sand removal from the reservoir
- Bypassing sand through tunnel/channel

9. MASTER PLAN OF HYDROPOWER DEVELOPMENT IN CAMBODIA

9.1 PRIORITY RANKING FOR THE SELECTED 10 PROJECTS

(1) Priority Ranking

On the 10 priority projects selected in Chapter 5, hydropower development plan was formulated through field investigations and technical assessment in Chapter 6. Economic and financial analysis was made in Chapter 7, and social and natural environmental impacts were overviewed in Chapter 8. As a result of field surveys, #12 Prek Liang 1 and #13 Prek Liang 1A, which had been separately re-formulated during the first screening stage, were combined as single Prek Liang 1 project from the economic point of view. A concession agreement on the #22 New Tatay project was concluded between the government and a Chinese developer in May 2008. Therefore, the MP Study treats #22 New Tatay project as committed one hereinafter. Accordingly, the number of priority projects decreased to eight.

Of the MP candidate projects, priority ranking was made with the same manner as the first screening as described in Chapter 5, by the following five aspects comprehensive assessment. The ranking of the selected projects are shown in Table 9.1.1 with the principal features (detailed classification by aspect with rating scale and units of elements are given in Chapter 5, Table 5.2.2.)

<Technical and Economic Aspects>

1) Technical aspect
2) Economic and financial aspects

<Environmental Aspects and Speed>

3) Socioeconomic aspect
4) Environmental aspect
5) Speed of implementation

The score and ranking of each project evaluated only with Technical and Economic Aspects are shown on the first line of Table 9.1.1. In addition, the result of Five Aspects Comprehensive Assessment (FACA) including Social and Natural Environmental Aspects are shown several lines below it. Taking into account of Environmental Aspects, #20&21 Stung Metoek II & III with rather large area of reservoir goes one rank down, #16 MSRC goes two ranks up, and #29 Bokor Plateau goes one rank up. Since these projects were once selected through the first screening by FACA, there are no significant differences observed between “Technical and Economic Assessment” and “FACA”.

Table 9.1.1 Priority Ranking of the Candidate Hydropower Projects

	Unit	7 & 8	12	14	16	20	21	22	23	29
		Lower Sre Pok II + Lower Se San II *	Prek Liang I	Prek Liang II	Middle St. Russey Chrum *	Stung Metoek II	Stung Metoek III	Stung Kep II	Upper St. Russey Chrum *	Bokor Plateau
Abbreviation		LL2	PL1	PL2	MSRC	MTK2	MTK3	KP2	USRC	BP
Total score of technical and economic evaluation		47.6	38.1	40.9	9.5	11.8	11.4	18.7	8.5	16.8
Rank		**1**	**3**	**2**	**8**	**6**	**7**	**4**	**9**	**5**
EIRR required for MP candidate projects: 10%		18.2%	18.2%	21.7%	10.1%	10.7%	11.2%	10.7%	6.4%	13.4%
EIRR value considering CDM benefit		21.6%	21.6%	25.3%	12.1%	12.8%	13.3%	13.4%	8.0%	15.7%
Five aspect comprehensive assessment (FACA)		67.9	64.3	66.8	48.2	43.8	42.0	55.6		58.5
Rank		**1**	**3**	**2**	**6**	**7**	**8**	**5**		**4**
Power Generation Features and Economic Viability	Unit									
Installed Capacity	MW	420.0	100.0	54.0	28.0	25.0	26.0	116.0	28.0	26.0
Annual energy generation	GWh	1,725	348	198	96	86	90	407	98	91
Unit generation cost	Cent/kWh	4.76	6.13	4.64	11.52	10.77	10.41	9.98	16.41	9.19
FIRR	%	16.5	13.1	16.8	6.4	7.0	7.3	7.8	3.5	8.6
Main Environmental Impacts										
CO_2 Emission Reduction ($t\text{-}CO_2/km^2$)	$t\text{-}CO_2/km^2$	2,859	30,368	15,484	5,053	4,262	5,588	32,181	31,650	17,375
Reservoir surface area more than 100 km^2 indicated as **bold**	km^2	**394**	10	9	13	14	11	11	2	3
Households to be resettled more than 1,000 households indicated as **bold**	hh	**1,224**	0	0	0	168	0	0	0	0
Farmlands innundated more than 1,000 ha indicated as **bold**	ha	**1,347**	0	0	9	724	0	0	0	0

Source: Study Team

First of all, as a result of technical and economic evaluation, it was realized that EIRR of #23 USRC project was 6.4% at the level of MP study. Even taking account of CDM benefit, EIRR still remains at 8.0%. This value is below the opportunity cost of capital at 10% in Cambodia. The investment on this project could not be justified from the national economic point of view. Therefore, #23 USRC project is excluded from the subjects of the Master Plan Study to 2024.

(2) Updating of Scoring of FACA at Second Screening

After the first screening, the ratings of each evaluation item were updated for hydrology, geology, and environment, based on the result of the field survey.

The following geological values of evaluation were changed:

#7&8 LL2 Project: During the first screening, it was pointed out that there may be a possibility of limestone distributions in the project area. After the field survey, it appeared that the possibility of limestone distributions was low.

#29 BP Project: During the first screening, it was pointed out that there may be thick overburden distributed on a part of the potential site. After the field survey, it was considered that the possibility of thick overburden distribution was low.

Apart from the above, changes in project features due to minor modifications on dam site locations or layout were reflected to the evaluation values. Further, installed capacity, firm power output, and economic evaluation index are also tuned up for priority ranking.

As a result of the priority ranking, #7&8 LL2 project is top ranked at the level of technical and economic evaluation as well as at the level of FACA.

(3) Breakdown of Scores by Five Aspects

Figure 9.1.1 shows the detailed scores by five aspects. All of the top ranked three projects (#7&8 LL2, #14 PL2, #12 PL1) gain high scores in both "Technical" and "Economic and Financial" aspects. Two projects of #22 KP2 and #29 BP get evenly distributed scores for each category, and ranked at fourth and fifth. Remaining three projects (#16 MSRC, #20 MTK2, and #21 MTK3) have less scores in both "Technical" and "Economic and Financial" aspects. However, #20 MTK2, and #21 MTK3 are located in the border area with Thailand where chronic water shortage has been suffered. As both projects would jointly provide abundant water resources of 15.6 m^3/s even during the dry season, it will be necessary to consider these projects as a multipurpose project jointly with water resource development.

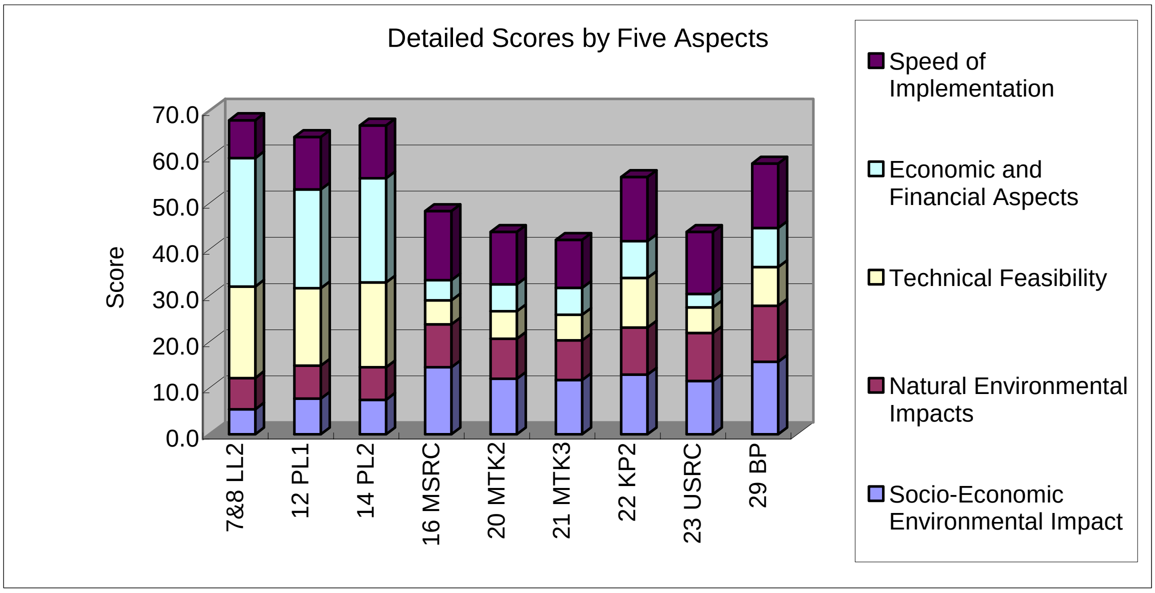


Figure 9.1.1 Detailed Scores by Five Aspects

(4) Existing, Committed and New Projects for Hydropower MP of Cambodia

As a result of comparisons and examinations above, seven new projects were selected as shown in Table 9.1.2 together with two existing projects and five committed projects, as the subjects for the Hydropower Master Plan toward 2024.

Table 9.1.2 Existing, Committed and Newly Selected Hydropower Projects of Cambodia

Priority Rank	Project	Province	Source	Basin Area (km^2)	Annual Runoff (m^3/s)	Effective Head (m)	Installed Capcity (MW)	Annual Energy (GWh)	Plant Factor -	Remarks
Existing hydropower stations										
-	Kirirom 1	Kampong Speu, Koh Kong	EAC	99		373.5	12.0	48	0.46	
-	O Chum	Ratanak Kiri	EAC	23		31.0	1.0	3	0.36	
	Sub-total 1			122	-	-	13.0	51	0.46	
Committed projects for implementation (excluded from Master Plan Study)										
-	Kamchay	Kampot	MIME	710	54	122.0	193.2	498	0.30	Under construction by Sinohydro, China
-	Stung Atay	Pursat	MIME	590+567	79.2+77	181+35	120.0	572	0.55	Under construction by CYC, China
-	Kirirom III	Koh Kong	MIME	105	4	271.0	18.0	73	0.47	CETIC, China, PPA under negotiation
-	Lower St. Russey Chrum	Koh Kong	MIME	1,020	57	103.0	338.0	1,019	0.35	CA with Michelle to build until 2015 with $495.7 m.
-	#22 New Tatay (former Stung Kep II)	Koh Kong	CHMC	1,144	69.2	185.5	246.0	858	0.40	CA with CHMC to build until 2014 with $540 m.
	Sub-total 2			2,979	-	-	915.2	3,020	0.38	
Priority projects for Hydropower Master Plan										
1	#7&8 Lower Srepok II + Lower Sesan II	Stung Treng	**JST**	**48,200**	**1,480**	**25.9**	**420.0**	**1,725**	**0.48**	Under FS by EVN, Vietnam
2	#14 Prek Liang II	Ratnak Kiri	**JST**	**575**	**19.5**	**150.8**	**54.0**	**198**	**0.42**	-
3	#12 Prek Liang I	Ratnak Kiri	**JST**	**839**	**28.5**	**178.4**	**100.0**	**348**	**0.40**	-
4	#29 Bokor Plateau	Kampot	**JST**	**24.5**	**1.80**	**911.7**	**26.0**	**91**	**0.41**	
5	#16 Middle St. Russey Chrum	Koh Kong	**JST**	**461**	**16.4**	**224.0**	**28.0**	**96**	**0.40**	LOP on Pre-FS with KTC, Korea
6	#20 Stung Metoek II	Koh Kong	**JST**	**416**	**17.0**	**88.1**	**25.0**	**86**	**0.40**	-
7	#21 Stung Metoek III	Koh Kong	**JST**	**656**	**27.7**	**55.7**	**26.0**	**90**	**0.40**	-
	Sub-total 3			51,172	-	-	679	2,634	0.45	
	Total			54,272	-	-	1,607.2	5,705	0.41	

Source: Study Team

The seven projects have a total installed capacity of 679 MW and a total annual energy of 2,634 GWh.

(5) Economic Performance of MP Projects

Table 9.1.3 presents principal features of power generation and economic indicators of the seven priority projects of the Hydropower Master Plan. The total construction costs of the seven projects are estimated at $1,138 million. Weighted average of kW construction cost is $1,680 and weighted average of kWh cost is 7.26 cent.

Table 9.1.3 Economy of Hydropower MP Projects

No.	Project	Installed Capcity (MW)	Annual Energy (GWh)	Annual reduction of CO_2 (1000 t-CO_2)	Construc-tion Cost ($ m)	kW Cost ($/kW)	kWh Cost (c/kWh)	EIRR (%)	FIRR (%)	EIRR with CDM (%)
1	#7&8 Lower Sre Pok II + Lower Se San II (LL2)	*420.0*	*1,725*	*1,127*	*623*	*1,480*	*4.76*	*18.2*	*16.5*	-
2	#14 Prek Liang II (PL2)	54.0	198	146	70	*1,300*	4.64	21.7	16.8	25.3
3	#12 Prek Liang I (PL1)	100.0	348	289	162	*1,620*	6.13	18.2	13.1	21.6
4	#29 Bokor Plateau (BP)	*26.0*	*91*	*57*	*55*	*2,120*	*9.19*	*13.4*	*8.6*	*15.7*
5	#16 Middle St. Russey Chrum (MSRC)	28.0	96	66	85	*3,040*	11.52	10.1	6.4	-
6	#20 Stung Metoek II (MTK2)	25.0	86	60	71	*2,840*	10.77	10.7	7.0	-
7	#21 Stung Metoek III (MTK3)	26.0	90	64	72	*2,770*	10.41	11.2	7.3	-
Total/Arithmetic Average		679	2,634	1,809	1,138	2,170	8.20	14.8	10.8	20.9
Weighted Average						1,680	7.26			
8	#23 Upper St. Russey Chrum (USRC)	28.0	98	63	124	*4,430*	16.41	5.9	2.7	-

Note: CDM effect was provisionally accounted only for those having *Power Density* > 4 MW/km^2.

Source: Study Team

(6) Overview of Foreseen Environmental Impacts of MP Projects

Of the selected seven MP projects, resettlement and inundation of farmland would take place only in #7&8 Lower Sre Pok II + Lower Se San II (LL2) project and the #20 Stung Metoek II project. As for #7&8 LL2 project, an IPP is preparing resettlement plans as part of FS-EIA after exchanging MOU with MIME. According to the hearing survey to the villagers made under the Study, villagers said “There were explanations on the dam development and resettlement from the developers, but there was no explanation from the government.” It is important for RGC to provide information on the power policy of the government, needs of the project and resettlement, planned implementation by private finance, and basic policy of the government for the resettlement compensation. As for #20 Stung Metoek II, there has been no action by the private developer since July 2007.

Four results of the preliminary study are presented below in relation to the environmental impacts of the selected seven MP projects:

- Impacts on the life of rare species: No specific information was obtained from villagers on the seasonal migration of wild elephants.

- Existence of heritage, nature, topography inside the proposed reservoir: There was no particular report on the heritage obtained from the hearing survey made through the sub-contractor.

- Impacts of seasonal flow regulation by the reservoir on the downstream reaches: Particular impacts not foreseen (#7&8 LL2 project has small regulating capacity compared with the annual inflow. Other projects do not have villages downstream of the intake. All the projects were formulated and assessed taking into consideration the flow release for environmental management.)

- Possibility of riverbed lowering in the downstream riverbed: There may be such possibility in #7&8 LL2 project.

#7&8 LL2 project will create a wide reservoir in the gently sloped hilly topography. It is required to carefully study and prepare mitigation measures of environmental impacts including the following:

- The project is located downstream-most of hydropower stations existing on the Se San River and Sre Pok River. Its reservoir capacity is small compared with its annual inflow and, therefore, the LL2 reservoir would be operated as run-of-river scheme in principle. If hourly output control is required for semi-peak load operation, the power station would be operated in accordance with the *hourly scheduled load*. It is desirable to limit the semi-peak load operation to an extent that the rising speed of the downstream river water level would remain within 30 cm in 30 minutes. In case the water level rising speed exceeds the said limit by all means, it will be required to install a discharge warning system to the river stretches where such water level rising speed is forecast. The system is to avoid water related casualties to the people who may be along the river shore.
- If the spillway of the project is of gated overflow type, it would inevitably incur certain risk of mal-operation of gates. If it is of non-gated free overflow type, the said risk of mal-operation can be fully avoided, however, it will require a surcharge depth above the Full Supply Level (FSL) and the reservoir would expand its area during the flooding period due to the higher flood water level. Examinations are required on the optimum type of spillway, including the combination of gated overflow and non-gated free overflow types, which can avoid the rapid fluctuation of river water level on the downstream reaches and limit the expansion of reservoir area during the flood.
- If power generation of #7&8 LL2 project is stopped probably during the off-peak night time, it will be required to release 96 m^3/s from the dam during the shutdown period of power generation if Japanese standard rate of environmental flow release (EFR) at 0.2 $m^3/s/100km^2$ is adopted. This amount of flow release is equivalent to about 20% of the single turbine discharge. Therefore it will be difficult to release such discharge through turbine. Accordingly, it will be important to study the required and sufficient amount of EFR and study on the need to add a small turbine generator to facilitate such EFR through turbine.

9.2 EXISTING GENERATION EXPANSION PLAN

As explained in the Sub-section 4.5.1, a current generation expansion plan has been formulated in the Master Plan 2006 (MP 2006). The MP 2006 aims at effective use of the renewable energy in Cambodia and the major hydropower projects, of which potential was verified through desk study, reconnaissance survey, or pre-feasibility study, were taken into the Expansion Plan with a priority. As a result of the study for the normal demand growth scenario, 13 hydropower projects having a total output of 1,985 MW and 5 coal-fired thermal and gas-fired combined-cycle power plants having a total output of 1,500 MW are recommended to be developed up to the year 2024. The peak demand, installed (name plate) capacity and supply capacity in the dry season of the Base Case Scenario are given in Figure 9.2.1.

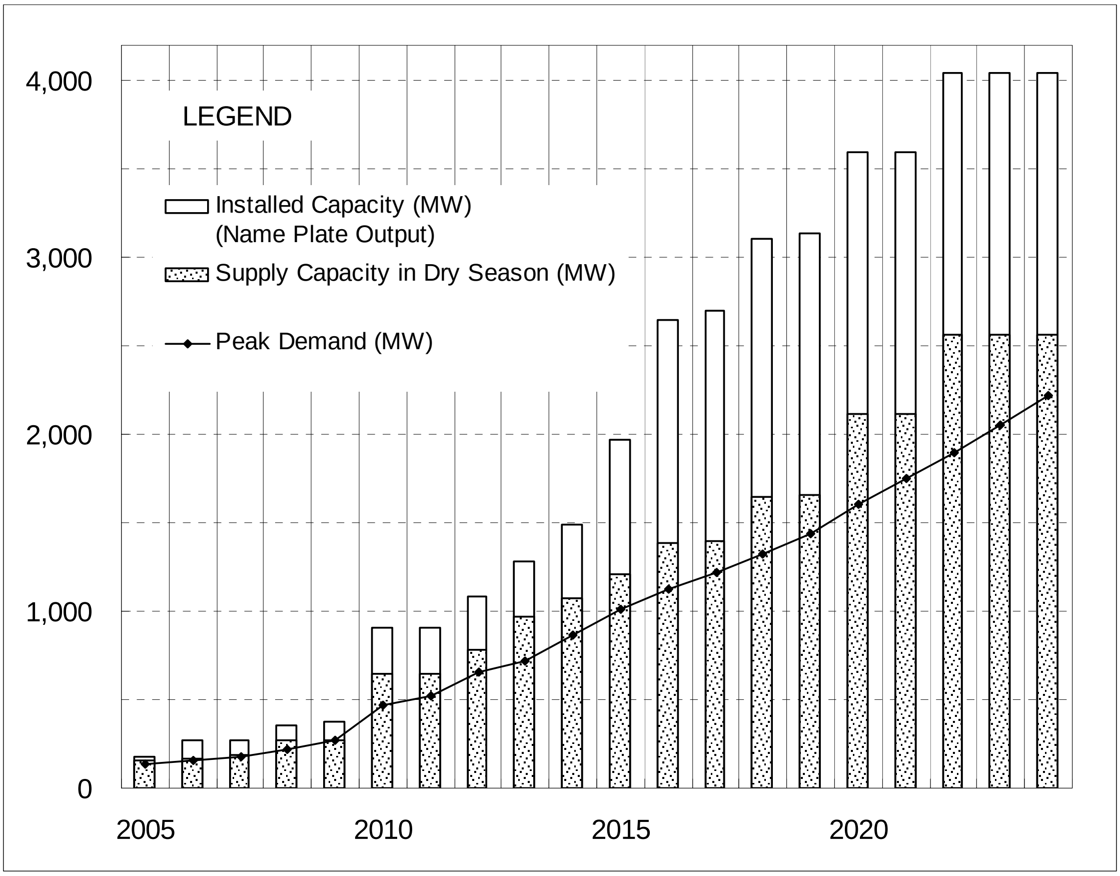


Figure 9.2.1 Current Generation Expansion Plan (Master Plan 2006)

Furthermore, the generation expansion plan of the MP 2006 has been reviewed by the Government and the result has been introduced in the EAC Annual Report 2006. The implementation timing and planned output of the hydropower projects in the EAC Annual Report 2006 are almost the same with the MP 2006. However, the implementation of the thermal power projects has been slightly changed:

MP 2006	EAC Annual Report 2006
coal-fired plant #1 (200 MW)	coal-fired plant#1 (200 MW)
combined cycle gas turbine (CCGT) #1 (200 MW)	coal-fired plant#2 (400 MW)
CCGT#2 (200 MW)	CCGT#1 (450 MW)
CCGT#3 (450 MW)	CCGT#2 (450 MW)
CCGT#4 (450 MW)	

As given in Figure 9.2.1, the difference between the planned installed capacity and its expected supply capacity of the system seems to be big because of the inappropriate assessment of the possible output of hydropower plants in the dry season. Most of the proposed hydropower projects are planned as reservoir type in the present Study. In these cases, higher output in the dry season than planned in the MP 2006 will be expected, depending on the type of inflow duration curve and CIR (ratio between the reservoir capacity and annual inflow). Therefore, it is recommended to review the Generation Expansion Plan from time to time, not only based on the price trend of oil resources but also based on the more in-depth study of these hydropower projects, for the least cost combination of hydropower and thermal plants to achieve economic operation of the power supply system.

The following projects out of those taken up in the MP 2006 have been proposed by the private firms and already approved by the Government by August 2008:

1) Kirirom III Hydro (18 MW, 2010)
2) Kamchay Hydro (193 MW, 2010)
3) Coal-fired Thermal Plant #1 (100 MW, 2011)
4) Stung Atay Hydro (120 MW, 2012)
5) Coal-fired Thermal Plant #2 (100 MW, 2012)
6) Lower Russey Chrum Hydro (235 MW, 2013)
7) #22 New Tatay Hydro (246 MW, 2013)

Therefore, the 7 priority projects explained in Sub-section 9.1 will be best fit to the Generation Expansion Plan, fixing the committed projects above.

9.3 HYDROPOWER EXPANSION PLAN

9.3.1 Introduction

As explained in Chapter 2, the ultimate purpose of the Study is to review and update the Generation Expansion Plan prepared in the MP 2006 with the priority projects finally selected in Sub-section 9.1. The committed hydropower projects will be constructed as scheduled according to the agreement of the Government and IPP. The demand forecasts were worked out in the MP 2006 and were the base of the existing Generation Expansion Plan. The same demand forecasts were used for updating the Generation Expansion Plan under the Study because it is very important to harmonize with the existing Expansion Plan. However, only Base and High Demand Scenarios were used in the Study because the difference between Low Demand Scenario and the actual records after preparation of the MP 2006 has become significant.

Almost all the hydropower projects in the existing Generation Expansion Plan except for the above-mentioned committed ones were also reviewed and modified and/or excluded from the candidate projects for the Study through the selection study of the priority projects due to 1) the technical difficulty not yet resolved, 2) overlapping with the other project areas, 3) low economic performance, etc. Of the projects recommended for development in the MP 2006, except for the five hydropower projects committed or under construction (as described in Section 9.1), all the projects were reviewed. Finally, the seven projects have been selected as the candidates for the Master Plan formulation.

In addition to using the same demand forecasts for the Study, those assumptions, conditions, criteria, etc. adopted in formulating the existing Generation Expansion Plan of the MP 2006 were also used for the Study except for the items discussed hereinafter. These common bases will be more convenient for the Cambodian side to compare the results of the two Generation Expansion Plans as well as to revise and integrate into the Generation Development Plans.

9.3.2 Dependable Output of Hydropower Stations

The purpose of formulating the Generation Expansion Plan is to make clear the need of generation development in the future in order to supply stable and dependable electricity to the customers. In general, the thermal power plants are expected to be able to provide supply capacity to the power system at its rated output throughout the year as far as enough fuel is stored, except for the period of forced outage due to faults of machines, scheduled outage for overhaul of machines or repair of the faults. On the other hand, supply capacity of the hydropower stations depends on the usable amount of water which has large seasonal fluctuation in general unless flow is seasonally regulated by reservoir. Therefore, it is a normal practice to treat the supply capacity in the driest season of the year as the dependable power of hydros which can be stably supplied throughout the year. Particularly for hydropower development with significant difference in the inflow between the rainy and dry seasons like in Cambodia, it is necessary to severely estimate the dependable output during the dry season being supported by reservoir operation, to enable stable supply of electricity to users throughout the year.

In the MP 2006, however, supply capacity of hydropower plants in the dry season were simply assumed at “26.1% of the nominal capacity” as explained in the table 3-15 and in page 3-53 of the report, and were commonly applied to all the hydropower candidates. As explained above, dependable output in the dry season depends on the dry season inflow for the run-of-river scheme, and effective storage volume of reservoir against annual inflow to the reservoir (capacity inflow ratio; CIR) for the reservoir type development, i.e., it largely depends on the regulating capacity of the reservoir. By applying reservoir operation simulation using inflow data and effective storage of the reservoir, it is possible to estimate the dependable output during the dry season with some extent of accuracy.

In the Study, the primary energy (firm energy) is used for calculation of dependable output in the dry season, which is generated throughout the year by output having 95% of probability and is usually indicated in the study reports on hydropower projects. The output having 95% of supply probability throughout the year is calculated from the annual inflow duration curve for a run-of-river type and from the results of reservoir operation simulation study for a reservoir type. For the committed hydropower projects, as far as the primary energy or dependable output in the dry season is clearly mentioned in the reference report such value was adopted.

Installed capacity, annual energy, firm energy and available energy in the dry season of hydropower projects are summarized in Table 9.3.1 for formulating Generation Expansion Plan in the Study. The available energy in the dry season is used for verifying the energy balance of the power supply system in the dry season after formulation of the Generation Expansion Plan.

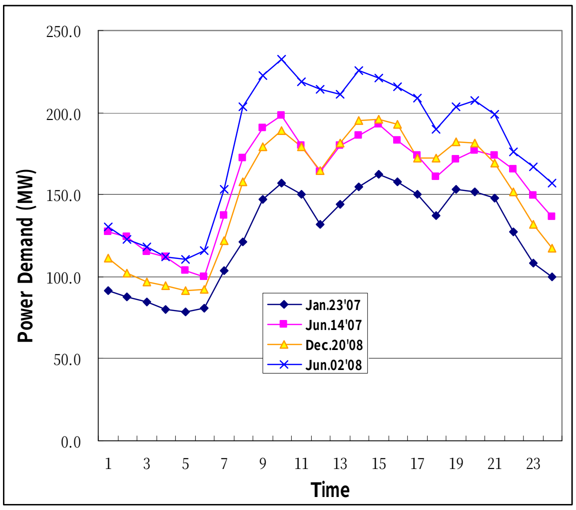
Table 9.3.1 Installed Capacity and Generated Energy of Hydropower Projects

	Hydropower Projects	Installed Capacity (MW)	Annual Energy (GWh)	Firm Energy (GWh)	In Dry Season (GWh)
Committed Projects					
1	Kamchay	193	498	n.a	n.a
2	Kirirom III	18	76	n.a	n.a
3	Stung Atay	120	306	186	108
4	Lower Russei Chrum	235	805	449	n.a
5	New Tatay	246	858	333	n.a
	Total	812	2,543	-	-
Priority Projects selected under the Study					
1	Lower Se San & Sre Pok 2	420	1,725	480	231
2	Prek Liang 1	100	348	217	112
3	Prek Liang 2	54	198	107	54
4	Bokor Plateau	26	91	65	32
5	Stung Metoek II	25	86	58	30
6	Stung Metoek III	26	90	58	30
7	Lower Stung Russei Chrum	28	96	64	33
	Total	679	2,634	1,049	522

Source: Study Team

Typical daily load curves of the Phnom Penh system are given on Figure 9.3.1 of which original hourly outputs of power plants including those of IPP have been recorded by the Load Dispatching Center of EDC. Each daily load curve is of the day when monthly maximum peak demand was recorded. As shown on the figure, it is clear that the former night peak type has been shifted to the day peak type. In future, day time demand will increase at higher speed than that of the night time demand. It is expected that the day time peak will become more sharp. The trend of daily load curve having day peak will be not affected, even though the Grid is extended along with the transmission extension and presently isolated power supply systems are integrated to the Grid, because the demand of Phnom Penh areas is much bigger than those of the isolated systems.

The priority hydropower projects selected under the Study will be commissioned and available for the power system operation only after 2015 because of the lead time for feasibility study, detailed design, tendering, and construction. The day time demand is supposed to become more sharp by that time. Therefore, the supply capacity in the dry season of each hydropower project is calculated and applied to the formulation of the Generation Expansion Plan in the Study under the assumption of 9.6 hours operation per day (40% of a day) by using available water in the dry season (firm energy in the dry season). For the committed hydropower projects, as far as a firm energy is presented in their related survey and/or study reports, the same criterion is applied. The same criteria of the MP 2006, 26.1% of the nominal output of power plant is applied when no certain information on the firm energy is available.



Source: Study Team

Figure 9.3.1 Typical Load Curves

9.3.3 Thermal Power Plants

As explained in Sub-section 9.2, the thermal power plants are recommended in the MP 2006 for implementation up to 2024 for the Base Demand Scenario as shown below. Another thermal development plan is presented in the EAC Annual Report 2006. In addition to these two development plans, the development order of the thermal power plants has been revised by MIME in their revised Generation Development Plan which was handed over to the Study Team in August 2008.

MP 2006	EAC Annual Report 2006	MIME Revision 2008
coal-fired plant #1 (200 MW)	coal-fired plant#1 (200 MW)	coal-fired plant #1 (2x100 MW)
combined cycle gas turbine (CCGT) #1 (200 MW)	coal-fired plant#2 (400 MW)	coal-fired plant #2 (5x100 + 1x200 MW)
CCGT#2 (200 MW)	CCGT#1 (450 MW)	
CCGT#3 (450 MW)	CCGT#2 (450 MW)	
CCGT#4 (450 MW)		

In general, efficiency of the generating machine having bigger unit capacity is higher than that of smaller unit and the unit generating cost can also be kept at a lower level. On the other hand, bigger reserve capacity of the system should be required and considered to minimize the system disturbance due to forced outage of the unit not only in the planning of generation expansion but also in the daily operation of the power supply system. Adoption of bigger unit capacity may increase the reserve capacity of the comparatively small system. It will increase the total operation cost.

In the Study, unit capacity of the thermal plat is set at 100 – 200 – 400 MW, because a plant having 100 MW unit has been committed and it is assumed that the other bigger unit will commence its operation in the power supply system when the required reserve capacity (15% of the forecasted peak demand) of the system becomes similar to the unit capacity (200 MW, and then 400 MW). The same capacity with the unit capacity is considered as the required reserve capacity when the unit capacity is bigger than the 15% of the system peak demand.

9.3.4 Formulation of Generation Expansion Plan

The generation expansion plan is formulated based on the power balance and energy balance in the dry season when the dependable output will remarkably decrease. To enable stable power supply, it is necessary to consider the reserve capacity. To secure the reserve, it is considered in the Study to input the optimum candidate power plants into the power system one by one including thermal power plants. In inputting candidate power plants into the system, care should be taken to avoid excessive reserve capacity, i.e., to minimize the prior investment for the power system, and decide the candidates to input year by year.

The generation expansion plans for the Base and High Demand Scenarios worked out in the MP 2006 are formulated by using the candidate projects including the committed hydropower projects, the priority projects selected in the Study and above-mentioned thermal plants. The results are given in Tables 9.3.2

and 9.3.3, and Figures 9.3.2 and 9.3.3. It is noted that the projects selected in the Study are put into the power system with priority to minimize a surplus reserve capacity of the system, because their economic superiority has been proven in the prior stage of the Study by economic comparison study with the alternative thermal plants.

In the Mater Plan 2006, total installed capacity of hydropower plants of 1,985 MW has been recommended to be developed till 2024 for the both of Base and High Demand Scenarios, and development of thermal plants is 1,500 MW for the Base Demand Scenario, and 2,400 MW for the High Scenario. In the present Study, total capacity of hydropower projects to be developed is 1,491 MW for both Demand Scenarios and thermal plants to be developed are 1,500 MW for the Base Scenario and 2,300 MW for the High Scenario. For the both Master Plans, total capacity of hydropower plants to be developed is almost the same, but there is a difference of 494 MW of hydropower development between the two Generation Expansion Plans. This is because of 1) exclusion of the Sambor project from the candidate hydropower projects for its technical feasibility of sand flushing unsolved yet, and 2) even without having the Sambor on the expansion sequence of hydros, the Grid will not require an increase of thermal plants in the present Study to offset the reduction of total capacity of hydros by 494 MW and the required power supply capacity is secured also in the dry season because of the enhanced dry season outputs of hydros achieved through the planning of reservoir projects with target CIR at 20-30%.

According to the Generation Expansion Plan optimized in the present Study, the completion year of Stung Atay, Lower Stung Russey Chrum and New Tatay may be possible to put off by one year in comparison with the existing Development Plan, if the future power demand is similar to the Base Demand Scenario. Even for the High Demand Scenario, the completion time of New Tatay project is supposed to be put off by one year.

Energy balance in the dry season is examined against the above-mentioned Generation Expansion Plan and the results of the examination are given in Tables 9.3.4 and 9.3.5. As shown in these tables, no shortage of energy supply in the dry season occurs throughout the study horizon. Available energy of diesel and thermal power plants are calculated on the basis of spinning reserve margin, forced-outage rate, maintenance period, etc, as assumed in the MP 2006. As for the imported energy, contracted capacity and annual load factor of the Phnom Penh system in 2007 are used for calculating available energy in the dry season.

Table 9.3.2 Generation Expansion Plan for Base Demand Scenario

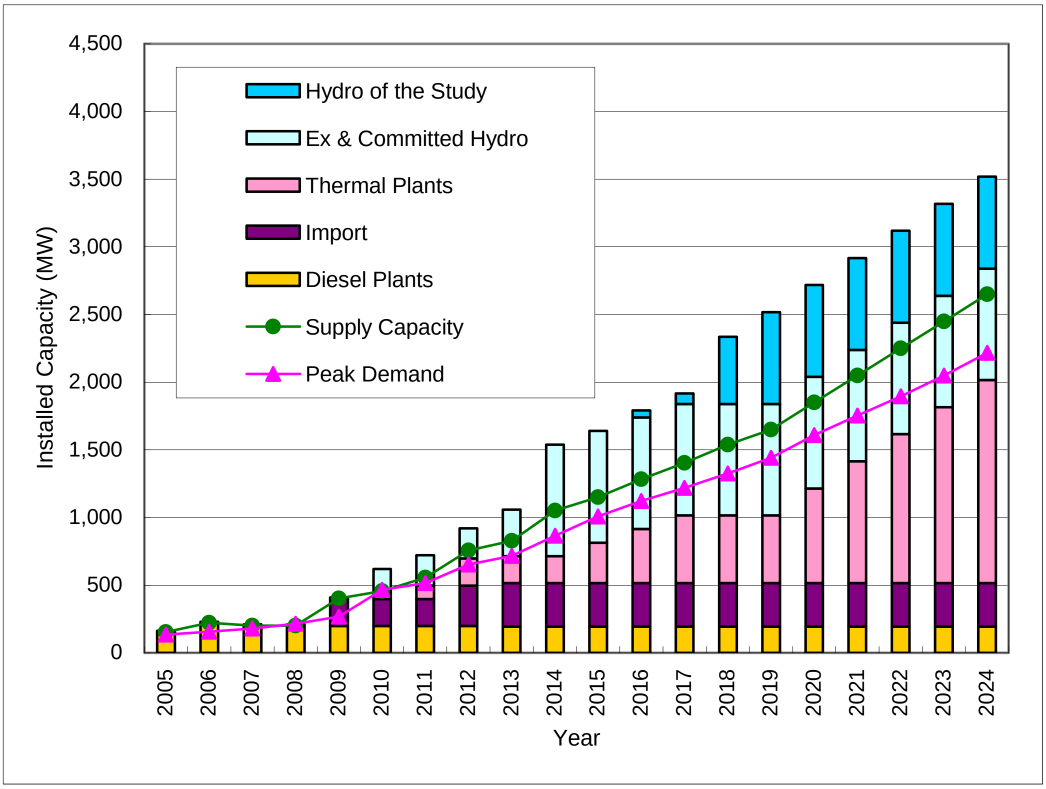
Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Peak Demand : Base Case (MW) of Master Plan 2006						**134**	**156**	**180**	**215**	**268**	**467**	**516**	**652**	**717**	**866**	**1,008**	**1,122**	**1,219**	**1,325**	**1,440**	**1,610**	**1,752**	**1,894**	**2,048**	**2,216**
I. Existing Diesel Plants																									
Available Total Output (MW)						**150**	**218**	**198**	**198**	**198**	**198**	**198**	**198**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**
			Max MW																						
II. Import	Yr to Grid		Contract																						
1 Thailand by 115kV line	2012		20/80				(20)	(20)	(20)	(80)	(80)	(80)	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
2 Vietnam by 230kV line	2009		80/200							200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
3 Vietnam by 115kV line	2012		20							(20)	(20)	(20)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
4 Laos by 115kV line	2013		20							(20)	(20)	(20)	(20)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Total Imported Power for the National Grid in Dry Season (MW)							**0**	**0**	**0**	**200**	**200**	**200**	**300**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**
III. Hydropower Development		Inst MW	Unit Cap	Firm En	MWinDry																				
Existing : Kirirm I	2001	12.0	6.0	14.3	4.1	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Committed Hydro Plants																									
1 Kamchay	2010	193.2	64.4	n.a	50.4						50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4
2 Kirirom III	2010	18.0	7.5	n.a	4.7						4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
3 Stung Atay	2012	120.0	50.0	186.0	53.1									53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1
4 Lower Russey Chrum	2013	235.0	64.0	449.0	128.1										128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1
5 New Tatay	2013	246.0	82.0	333.0	95.0										95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
		812.2			331.4																				
Total of Committed Hydro Plants											**55.1**	**55.1**	**55.1**	**108.2**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**
Master Plan		Inst Cap	Unit Cap	Firm En.	MWinDry																				
1 LSP2 + LSS2	2016-18	420.0	70.0	480.0	137.0														137.0	137.0	137.0	137.0	137.0	137.0	137.0
2 Prek Liang 1		100.0	33.4	217.0	61.9															61.9	61.9	61.9	61.9	61.9	61.9
3 Prek Liang 2		54.0	27.0	107.0	30.5															30.5	30.5	30.5	30.5	30.5	30.5
4 Bokor Plateau		26.0	13.0	65.0	18.6													18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
5 Stung Metoek II		25.0	12.5	58.0	16.6												16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
6 Stung Metoek III		26.0	13.0	58.0	16.6												16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
7 Middle St. Russei Chrum		28.0	14.0	64.0	18.3															18.3	18.3	18.3	18.3	18.3	18.3
		679.0		1,049.0	299.4																				
Total of Hydro Plants for the Master Plan																**0.0**	**33.1**	**51.7**	**188.6**	**299.4**	**299.4**	**299.4**	**299.4**	**299.4**	**299.4**
IV. Thermal Plants to be Developed																									
1 Coal-fired plant #1	200	100										100.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
2 Coal-fired plant #2	700	100/200														100.0	200.0	300.0	300.0	300.0	500.0	700.0	700.0	700.0	700.0
3 Coal-fired plant #3	1000	200																					200.0	400.0	600.0
4 Coal or gas-fired plant	1600	400																							
Total of Thermal Plants to be Developed											**0**	**100**	**200**	**200**	**200**	**300**	**400**	**500**	**500**	**500**	**700**	**900**	**1,100**	**1,300**	**1,500**
V. Total Supply Capacity						**154**	**222**	**202**	**202**	**402**	**457**	**557**	**757**	**827**	**1,050**	**1,150**	**1,283**	**1,402**	**1,539**	**1,650**	**1,850**	**2,050**	**2,250**	**2,450**	**2,650**
VI. Reserve Margin																									
15 % of Peak Demand						20.1	23.4	27.0	32.3	40.2	70.1	77.4	97.8	107.6	129.9	151.2	168.3	182.9	198.8	216.0	241.5	262.8	284.1	307.2	332.4
Maximum Unit Capacity						6.5	6.5	6.5	6.5	6.5	64.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	200.0	200.0	200.0	200.0	200.0
Required Margin in MW						**20.1**	**23.4**	**27.0**	**32.3**	**40.2**	**70.1**	**100.0**	**100.0**	**107.6**	**129.9**	**151.2**	**168.3**	**182.9**	**198.8**	**216.0**	**241.5**	**262.8**	**284.1**	**307.2**	**332.4**
Margin against Peak Demand		in MW				**20.5**	**66.5**	**22.0**	**-13.0**	**134.0**	**-9.9**	**41.1**	**105.1**	**110.2**	**184.3**	**142.3**	**161.4**	**183.0**	**214.0**	**209.7**	**239.7**	**297.7**	**355.7**	**401.7**	**433.7**
		in %				15.3%	42.6%	12.2%	-6.1%	50.0%	-2.1%	8.0%	16.1%	15.4%	21.3%	14.1%	14.4%	15.0%	16.1%	14.6%	14.9%	17.0%	18.8%	19.6%	19.6%
Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

Source: Study Team

Table 9.3.3 Generation Expansion Plan for High Demand Scenario

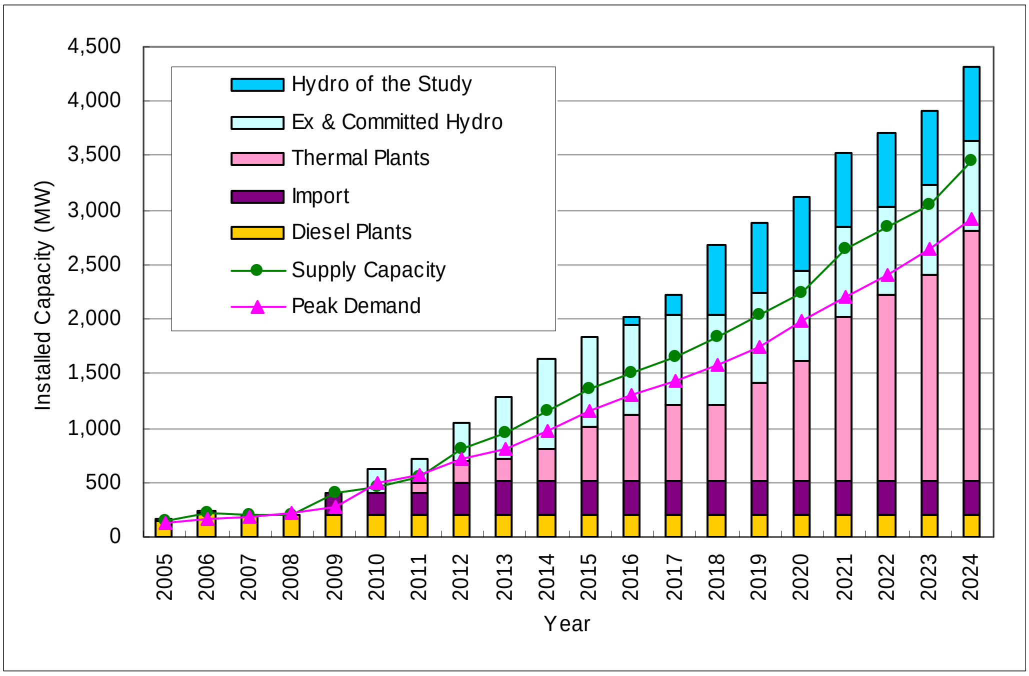
Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Peak Demand : High Case (MW) of Master Plan 2006						**134**	**159**	**186**	**225**	**271**	**502**	**561**	**719**	**800**	**979**	**1,155**	**1,302**	**1,435**	**1,582**	**1,746**	**1,985**	**2,195**	**2,409**	**2,647**	**2,912**
I. Existing Diesel Plants																									
Available Total Output (MW)						**150**	**218**	**198**	**198**	**198**	**198**	**198**	**198**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**
			Max MW																						
II. Import	Yr to Grid		Contract																						
1 Thailand by 115kV line	2012		20/80				(20)	(20)	(20)	(80)	(80)	(80)	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
2 Vietnam by 230kV line	2009		80/200							200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
3 Vietnam by 115kV line	2012		20							(20)	(20)	(20)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
4 Laos by 115kV line	2013		20							(20)	(20)	(20)	(20)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Total Imported Power for the National Grid in Dry Season (MW)							**0**	**0**	**0**	**200**	**200**	**200**	**300**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**	**320**
III. Hydropower Development		Inst MW	Unit MW	Firm En	MWinDry																				
Existing : Kirirm I	2001	12.0	6.0	14.3	4.1	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Committed Hydro Plants																									
1 Kamchay	2010	193.2	64.4	n.a	50.4						50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4
2 Kirirom III	2010	18.0	7.5	n.a	4.7						4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
3 Stung Atay	2012	120.0	50.0	186.0	53.1								53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1
4 Lower Russey Chrum	2013	235.0	64.0	449.0	128.1									128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1	128.1
5 New Tatay	2013	246.0	82.0	333.0	95.0										95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
		812.2			331.4																				
Total of Committed Hydro Plants											**55.1**	**55.1**	**108.2**	**236.3**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**	**331.4**
Master Plan		Inst Cap	Unit Cap	Firm En.	MWinDry																				
1 LSP2 + LSS2		420.0	70.0	480.0	137.0														137.0	137.0	137.0	137.0	137.0	137.0	137.0
2 Prek Liang 1		100.0	33.4	217.0	61.9													61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9
3 Prek Liang 2		54.0	27.0	107.0	30.5												30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
4 Bokor Plateau		26.0	13.0	65.0	18.6														18.6	18.6	18.6	18.6	18.6	18.6	18.6
5 Stung Metoek II		25.0	12.5	58.0	16.6														16.6	16.6	16.6	16.6	16.6	16.6	16.6
6 Stung Metoek III		26.0	13.0	58.0	16.6												16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
7 Middle St. Russei Chrum		28.0	14.0	64.0	18.3																18.3	18.3	18.3	18.3	18.3
		679.0		1,049.0	299.4																				
Total of Hydro Plants for the Master Plan																	**47.1**	**109.0**	**281.1**	**281.1**	**299.4**	**299.4**	**299.4**	**299.4**	**299.4**
IV. Thermal Plants to be Developed																									
1 Coal-fired plant #1	200	100										100	200	200	200	200	200	200	200	200	200	200	200	200	200
2 Coal-fired plant #2	700	100/200													100	300	400	500	500	700	700	700	700	700	700
3 Coal-fired plant #3	1000	200																			200	600	800	1,000	1,000
4 Coal or gas-fired plant	1600	400																							400
Total of Thermal Plants to be Developed								**0**	**0**	**0**	**0**	**100**	**200**	**200**	**300**	**500**	**600**	**700**	**700**	**900**	**1,100**	**1,500**	**1,700**	**1,900**	**2,300**
V. Total Supply Capacity						**154**	**222**	**202**	**202**	**402**	**457**	**557**	**810**	**955**	**1,150**	**1,350**	**1,497**	**1,659**	**1,831**	**2,031**	**2,250**	**2,650**	**2,850**	**3,050**	**3,450**
VI. Reserve Margin																									
15 % of Peak Demand						20.1	23.9	27.9	33.8	40.7	75.3	84.2	107.9	120.0	146.9	173.3	195.3	215.3	237.3	261.9	297.8	329.3	361.4	397.1	436.8
Maximum Unit Capacity						6.5	6.5	6.5	6.5	6.5	64.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	200.0	200.0	200.0	200.0	200.0	400.0
Required Margin in MW						**20.1**	**23.9**	**27.9**	**33.8**	**40.7**	**75.3**	**100.0**	**107.9**	**120.0**	**146.9**	**173.3**	**195.3**	**215.3**	**237.3**	**261.9**	**297.8**	**329.3**	**361.4**	**397.1**	**436.8**
Margin against Available Output		in MW				**20.5**	**63.5**	**16.0**	**-23.0**	**131.0**	**-44.9**	**-3.9**	**91.2**	**155.3**	**171.3**	**195.3**	**195.4**	**224.4**	**249.4**	**285.4**	**264.7**	**454.7**	**440.7**	**402.7**	**537.7**
		in %				15.3%	39.9%	8.6%	-10.2%	48.3%	-8.9%	-0.7%	12.7%	19.4%	17.5%	16.9%	15.0%	15.6%	15.8%	16.3%	13.3%	20.7%	18.3%	15.2%	18.5%
Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

Source: Study Team



Source: Study Team

Figure 9.3.2 Generation Expansion Plan for Base Demand Scenario



Source: Study Team

Figure 9.3.3 Generation Expansion Plan for High Demand Scenario

Table 9.3.4 Energy Balance for Base Demand Scenario

Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Annual Energy Demand (GWH) of Master Plan 2006						764	887	1,020	1,271	1,472	2,574	2,891	3,750	4,188	4,728	5,250	5,869	6,408	7,000	7,646	8,550	9,330	10,111	10,958	11,879
Energy Demand in Dry Seasons (for 6 months) : Base Case (GWh)						**382**	**444**	**510**	**636**	**736**	**1,287**	**1,446**	**1,875**	**2,094**	**2,364**	**2,625**	**2,935**	**3,204**	**3,500**	**3,823**	**4,275**	**4,665**	**5,056**	**5,479**	**5,940**
I. Existing Diesel Plants																									
Available Total Output (MW)						150	218	198	198	198	198	198	198	195	195	195	195	195	195	195	195	195	195	195	195
Available Max. Energy in Dry Season (GWh)						**524**	**760**	**689**	**689**	**689**	**689**	**689**	**689**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**
			Max MW	Energy in Dry																					
II. Import	To Grid		Contract	GWh	In future																				
1 Thailand by 115kV line	2012		20/80	55.2	220.8		(55.2)	(55.2)	(55.2)	(220.8)	(220.8)	(220.8)	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8
2 Vietnam by 230kV line	2009		80/200	220.8	551.9					551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9
3 Vietnam by 115kV line	2013		20	55.2	55.2					(55.2)	(55.2)	(55.2)	(55.2)	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2
4 Laos by 115kV line	2013		20	55.2	55.2					(55.2)	(55.2)	(55.2)	(55.2)	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2
Available Total Energy for National Network in Dry Season (GWh)							**0**	**0**	**0**	**552**	**552**	**552**	**773**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**
III. Hydropower Development		Inst MW	Y.GWh	Firm En	GWhinDry																				
Existing : Kirirm I	**2001**	**12.0**	**46.9**	**n.a**	7.2	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**
Committed Hydro Plants																									
1 Kamchay	2010	193.2	498.0	n.a	130.0						130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
2 Kirirom III	2010	15.0	76.0	n.a	19.8						19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
3 Stung Atay	2012	120.0	306.0	186.0	108.0									108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0
4 Lower Russey Chrum	2014	235.0	805.0	449.0	224.5										224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5
5 New Tatay	2015	246.0	858.0	333.0	166.5										166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5
	Total	809.2	2,543.0		648.8																				
Total of Committed Hydro Plants											**150**	**150**	**150**	**258**	**482**	**649**	**649**	**649**	**649**	**649**	**649**	**649**	**649**	**649**	**649**
Master Plan		Inst Cap	Y.GWh	Firm En.	in Dry																				
1 LSP2 + LSS2		420.0	1725.0	480.0	231.0														231.0	231.0	231.0	231.0	231.0	231.0	231.0
2 Prek Liang 1		100.0	348.0	217.0	112.0															112.0	112.0	112.0	112.0	112.0	112.0
3 Prek Liang 2		54.0	198.0	107.0	54.0															54.0	54.0	54.0	54.0	54.0	54.0
4 Bokor Plateau		26.0	91.0	65.0	32.0													32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0
5 Stung Metoek II		25.0	86.0	58.0	30.0												30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
6 Stung Metoek III		26.0	90.0	58.0	30.0												30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7 Middle St. Russei Chrum		28.0	96.0	64.0	33.0															33.0	33.0	33.0	33.0	33.0	33.0
	Total	679.0	2,634.0	1,049.0	522.0																				
Total of Hydro for Master Plan																	**60**	**92**	**323**	**522**	**522**	**522**	**522**	**522**	**522**
IV. Thermal Power Development																									
Thermal Plants																									
	Plant	Unit	Nos		GWh/unit *1																				
1 Coal-fired plant #1	200	100	2		348.2							348.2	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4
2 Coal-fired plant #2	400	100/200	6		348.2	696.4										348.2	696.4	1,044.6	1,044.6	1,044.6	1,741.1	2,437.5	2,437.5	2,437.5	2,437.5
3 Coal-fired plant #3	1000	200	5		696.4																		696.4	1,392.8	2,089.3
4 Coal or gas-fired plant	1600	400	4		1,392.8																				
Total of Thermal Plants												**348**	**696**	**696**	**696**	**1,045**	**1,393**	**1,741**	**1,741**	**1,741**	**2,437**	**3,134**	**3,830**	**4,527**	**5,223**
V. Total Available Energy in Dry Season (GWh)						**531**	**768**	**696**	**696**	**1,248**	**1,398**	**1,746**	**2,315**	**2,523**	**2,748**	**3,262**	**3,670**	**4,051**	**4,282**	**4,481**	**5,177**	**5,874**	**6,570**	**7,266**	**7,963**
VI. Surplus Energy (GWh)						**149**	**324**	**186**	**61**	**512**	**111**	**301**	**440**	**429**	**384**	**637**	**736**	**847**	**782**	**658**	**902**	**1,209**	**1,514**	**1,787**	**2,023**
% of Required Energy						39.0%	73.1%	36.5%	9.6%	69.6%	8.6%	20.8%	23.5%	20.5%	16.2%	24.3%	25.1%	26.4%	22.3%	17.2%	21.1%	25.9%	30.0%	32.6%	34.1%
Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

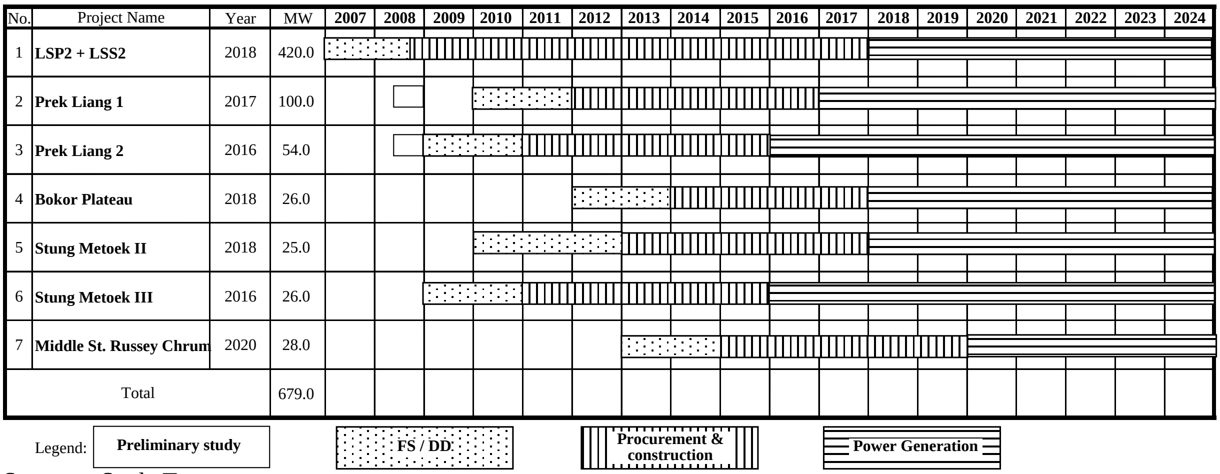
Source: Study Team

Table 9.3.5 Energy Balance for High Demand Scenario

Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Annual Energy Demand (GWH) of Master Plan 2006						764	901	1,051	1,328	1,560	2,766	3,147	4,133	4,677	5,351	6,022	6,809	7,553	8,369	9,278	10,548	11,691	12,863	14,160	15,599
Energy Demand in Dry Seasons (for 6 months) : High Case (GWh)						**382**	**451**	**526**	**664**	**780**	**1,383**	**1,574**	**2,067**	**2,339**	**2,676**	**3,011**	**3,405**	**3,777**	**4,185**	**4,639**	**5,274**	**5,846**	**6,432**	**7,080**	**7,800**
I. Existing Diesel Plants																									
Available Total Output (MW)						150	218	198	198	198	198	198	198	195	195	195	195	195	195	195	195	195	195	195	195
Available Max. Energy in Dry Season (GWh)						**524**	**760**	**689**	**689**	**689**	**689**	**689**	**689**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**	**679**
			Max MW	Energy in Dry																					
II. Import	To Grid		Contract	GWh	In future																				
1 Thailand by 115kV line	2012		20/80	55.2	220.8		(55.2)	(55.2)	(55.2)	(220.8)	(220.8)	(220.8)	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8	220.8
2 Vietnam by 230kV line	2009		80/200	220.8	551.9					551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9	551.9
3 Vietnam by 115kV line	2013		20	55.2	55.2					(55.2)	(55.2)	(55.2)	(55.2)	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2
4 Laos by 115kV line	2013		20	55.2	55.2					(55.2)	(55.2)	(55.2)	(55.2)	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2
Available Total Energy for National Network in Dry Season (GWh)							**0**	**0**	**0**	**552**	**552**	**552**	**773**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**	**883**
III. Hydropower Development		Inst MW	Y.GWh	Firm En	GWhinDry																				
Existing : Kirirm I	2001	12.0	46.9	n.a	7.2	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**
Committed Hydro Plants																									
1 Kamchay	2010	193.2	498.0	n.a	130.0						130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
2 Kirirom III	2010	15.0	76.0	n.a	19.8						19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8
3 Stung Atay	2012	120.0	306.0	186.0	108.0								108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0
4 Lower Russey Chrum	2014	235.0	805.0	449.0	224.5									224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5
5 New Tatay	2015	246.0	858.0	333.0	166.5										166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5	166.5
	Total	809.2	2,543.0		648.8																				
Total of Committed Hydro Plants											**150**	**150**	**258**	**482**	**482**	**649**	**649**	**649**	**649**	**649**	**649**	**649**	**649**	**649**	**649**
Master Plan		Inst Cap	Y.GWh	Firm En.	in Dry																				
1 LSP2 + LSS2		420.0	1725.0	480.0	231.0														231.0	231.0	231.0	231.0	231.0	231.0	231.0
2 Prek Liang 1		100.0	348.0	217.0	112.0													112.0	112.0	112.0	112.0	112.0	112.0	112.0	112.0
3 Prek Liang 2		54.0	198.0	107.0	54.0												54.0	54.0	54.0	54.0	54.0	54.0	54.0	54.0	54.0
4 Bokor Plateau		26.0	91.0	65.0	32.0														32.0	32.0	32.0	32.0	32.0	32.0	32.0
5 Stung Metoek II		25.0	86.0	58.0	30.0														30.0	30.0	30.0	30.0	30.0	30.0	30.0
6 Stung Metoek III		26.0	90.0	58.0	30.0												30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7 Middle St. Russei Chrum		28.0	96.0	64.0	33.0																33.0	33.0	33.0	33.0	33.0
	Total	679.0	2,634.0	1,049.0	522.0																				
Total of Hydro for Master Plan																	**84**	**196**	**489**	**489**	**522**	**522**	**522**	**522**	**522**
IV. Thermal Power Development																									
Thermal Plants																									
	Plant	Unit	Nos		GWh/unit																				
1 Coal-fired plant #1	200	100	2		348.2							348.2	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4	696.4
2 Coal-fired plant #2	400	100/200	6		348.2	696.4									348.2	1,044.6	1,392.8	1,741.1	1,741.1	2,437.5	2,437.5	2,437.5	2,437.5	2,437.5	2,437.5
3 Coal-fired plant #3	1000	200	5		696.4																696.4	2,089.3	2,785.7	3,482.1	3,482.1
4 Coal or gas-fired plant	1600	400	4		1,392.8																				1,392.8
Total of Thermal Plants												**348**	**696**	**696**	**1,045**	**1,741**	**2,089**	**2,437**	**2,437**	**3,134**	**3,830**	**5,223**	**5,920**	**6,616**	**8,009**
V. Total Available Energy in Dry Season (GWh)						**531**	**768**	**696**	**696**	**1,248**	**1,398**	**1,746**	**2,423**	**2,748**	**3,096**	**3,959**	**4,391**	**4,851**	**5,144**	**5,841**	**6,570**	**7,963**	**8,659**	**9,356**	**10,748**
VI. Surplus Energy (GWh)						**149**	**317**	**171**	**32**	**468**	**15**	**173**	**357**	**409**	**420**	**948**	**986**	**1,075**	**960**	**1,202**	**1,296**	**2,117**	**2,228**	**2,276**	**2,949**
% of Required Energy in Dry Season						39.0%	70.4%	32.5%	4.9%	60.0%	1.1%	11.0%	17.3%	17.5%	15.7%	31.5%	29.0%	28.5%	22.9%	25.9%	24.6%	36.2%	34.6%	32.1%	37.8%
Year						2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

Source: Study Team

The required input years of the seven MP projects are shown in Figure 9.3.4 for high demand scenario including required timing of preceding feasibility study, detailed design, and procurement & construction.



Source: Study Team

Figure 9.3.4 Implementation Schedule of Seven MP Projects, High Demand Scenario

9.3.5 Technical Remarks on Generation Expansion Plan

Explanation of the concerns on the aforementioned generation expansion plan is given below:

(1) Supply Capacity Deficit of the Year 2008, 2010 and 2011

As indicated in Tables 9.3.2 and 9.3.3, supply capacity deficits appear in the year 2008, 2010 and 2011 for both Base and High Demand Scenarios. Especially, the maximum power demand of 239 MW was recorded on May 27, 2008 which was higher than that of the High Demand Forecast value. For such extreme demand increase, necessary countermeasures such as load shedding, additional power purchase from IPP, etc. are considered to be taken by the Government.

On the other hand, supply capacity deficits of the year 2010 and 2011 are considered to be caused by over estimate of the demand in Kampot area in the MP 2006. Namely, a cement factory having its production capacity of 1 million ton per annum had been constructed in the area at the time when the MP 2006 was formulated and its power demand from the Grid had been over-estimated. The over-estimated demand of Kampot area is scheduled to be integrated into the Grid in 2010 by the extension of 230 kV transmission line from Takeo and the peak demand of the Grid of 268 MW in 2009 is rocketed to 467 MW (in the Base Demand Scenario). According to the EAC Annual Report 2006, Kampot Power Plant Co., Ltd. (IPP, license No. 142L) aiming at power supply to the cement factory has been established and power plant was constructed in the same site and its operation has already been started. In this power plant, the total installed capacity of generating machines is 2,316 kW. The supply capacity deficits in the year 2010 and 2011 may be solved, if the demand forecast of Kampot area is reviewed based on the certain information on their power demand from the Grid to be collected from the related staff of the factory.

(2) Cascade Development of Hydropower Projects

It is noted that annual generated energy of the priority projects given in Table 9.3.1 has been basically calculated as single project by the simulation study of single reservoir even hydropower projects are located in cascade on the same river such as Prek Liang, Stung Metoek, because all candidate projects stand on the same base and independent from each other in formulation of the Generation Expansion Plan in the Study. In general, if some hydropower plants are cascaded on the same river, available water for generation in the dry season for the plant located downstream will increase due to an increase in the dry season inflow to the reservoir. As a result of the increase in the dry season inflow, the firm energy of the downstream plant will be increased and its dependable output in the dry season also be increased.

It is recommended to review in more detail the annual firm energy and dependable output in the dry season of the project by simulation study of combined reservoir operation in the feasibility study stage which is the next step following this Study and to reflect to the review study of the Generation Expansion Plan. However, it is noted that total annual generated energy will not be changed so much and the change in the annual energy will be limited to the energy increase due to decrease of spilled water from reservoirs by appropriate operation, because of no change in the total rainfall in the catchment area.

(3) Operation of Hydropower Plants through the Year

Actual monthly generated energy of Kirirom I Hydropower Station in the past 4 years is given in Table 9.3.6. The Load Dispatching center of EDC has recorded hourly output of each power plant of the Phnom Penh power supply system including these of IPP. Monthly operation days of Kirirom I power plant were examined from the actual hourly operation records from January 2007 to July 2008 and given in the same table. It is clearly understood that operation of Kirirom I plant is concentrated on the period from July to November in the rainy season and a little less than 80% of annual energy is generated in the period on an average of the 4 years. Furthermore, there are so many days not operated in the dry season and it is considered that scheduled operation to meet the power system requirement has not been made up to the present.

Frankly speaking, it is noted that the supply capacity of Kirirom I in the dry season would not be expected not only in formulating Generation Expansion Plan but also in daily operation. It is considered that there is some difficulty for proper operation of the reservoir through the year, because of size of its catchment and effective reservoir capacity. However, it is strongly recommended that usable discharge for power generation through the year should be analyzed by using actual operation records, fluctuation records of reservoir water level, inflow to the reservoir, spilled water from the reservoir, etc., and optimum operation rule of reservoir should be established to meet the power system requirement in the dry season.

Table 9.3.6 Actual Monthly Operation Records of Kirirom I

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Generated Energy in MWh													
2004	524	247	95	431	1,790	1,544	3,270	3,510	5,303	5,148	5,114	49	27,024
2005	961	82	510	319	476	926	1,462	8,237	8,143	7,853	7,859	4,055	40,882
2006	2,045	1,530	1,054	1,600	1,606	4,301	6,115	8,270	8,196	8,030	4,357	582	47,686
2007	725	1,013	1,001	797	2,412	2,050	7,283	8,035	7,984	7,866	5,857	1,507	46,531
Average	1,064	718	665	787	1,571	2,205	4,533	7,013	7,406	7,224	5,797	1,548	40,531
Operated Days in 2007													
Nos of Day	6	8	9	7	9	13	31	31	30	31	25	8	208
Ratio (%)	19.4	28.6	29.0	23.3	29.0	43.3	100.0	100.0	100.0	100.0	83.3	25.8	57.0

Source: EDC

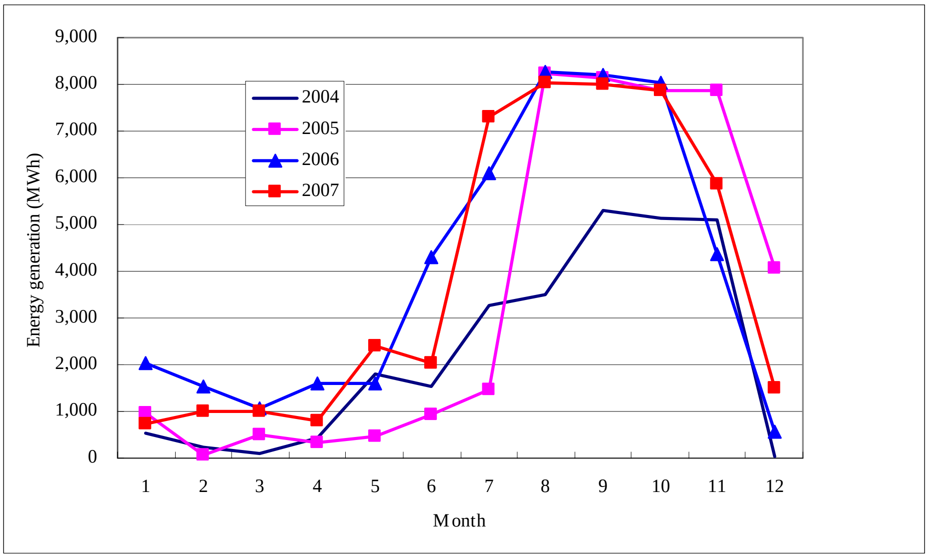


Figure 9.3.5 Actual Monthly Operation Records of Kirirom I

9.4 ISSUES OF MANAGEMENT OF PROJECT IMPLEMENTATION AND MONITORING

9.4.1 Implementing Organization/Investment and Project Operation

(1) Implementing Organization for Generation Expansion

Present Situation as of 2008

Upon promulgation of the Electricity Law of Cambodia in 2001, the power sector has been liberalized and opened to the electricity service providers of the private sector. EDC is one of the electricity service providers but owns a Complex License that enables EDC to undertake generation, transmission, and distribution. The Transmission License is to undertake planning, erection, operation, and management of the countrywide transmission network and is issued only to EDC. Generation License permits EDC to build, own and operate power plants either as EDC's own asset or as the Government project. In order to secure the stable power supply, the Government recognizes the importance that EDC build, own and operate certain ratio of the generation capacity.

However, since 1) in Cambodia where various infrastructures are in shortage, the financing needs of the public works are competing to each other, 2) since it would take 3-5 years until the Government can use soft loans from MDB/ODA, it has become common way for the government to depend on the private sector in implementing the Generation Expansion Plan which consists of profitable projects and can attract investors.

The World Bank financed the Private Power Policy Study in 2001. However, the procurement method recommended in the study report has not been approved by the Government.

The selection method of developers (IPP) practiced in the power sector of Cambodia as of 2008 is outlined below:

An IPP who is interested in implementation of certain hydropower project will first submit a proposal for pre-feasibility study or feasibility study to the Minister of MIME. The Minister will call for evaluation of the proposal and views of the Hydroelectricity Department under General Department of Energy. If the view of the Hydroelectricity Department is positive, Letter of Permission（LOP）will be issued to permit the pre-feasibility study and MOU（Memorandum of Understanding）will be exchanged to permit the feasibility study. MOU may include the following:

1) MOU will be exchanged between MIME and the developer (IPP).
2) The validity period of MOU may be two years from the date of signing and can be extended by mutual agreement. If IPP does not start the field survey within 90 days from the date of MOU, the MOU will be invalid.
3) MOU is to give the right to undertake a feasibility study on condition that IPP should bear all the costs. MIME will make necessary arrangements for IPP to get necessary data and access to relevant ministry/agency. It includes EIA and will assess environmental impacts including construction sites and people residing in and around the proposed reservoir areas and power station site. MOU also requires IPP to identify, as part of the study, the procurement method of finance and investors.
4) Upon completion of the study, IPP will submit reports and one set of data to MIME.
5) The study results will not be opened to the third party without the mutual agreement.
6) Upon completion of the Study, MIME will invite IPP or its agent and discuss on the project implementation. However, in case no mutual agreement has been achieved within six months, MIME has the right to invite a third party for negotiation and to conclude a contract on the project implementation.

MIME, EAC and EDC will jointly review the study outputs. MIME will review mainly the technical and environmental aspects, EAC cost aspect, and EDC operation and maintenance aspect. Although tendering is a normal process to select developer after the feasibility study, direct negotiation and appoint method may be taken where only one or two bidders are expected. Upon mutual agreement between the Government and IPP on the project implementation, it will be reported to the Prime Minister in writing, the Government will provide concession, and EAC will issue License for Generation. In the negotiation of Power Purchase Agreement (PPA), a committee will be organized by MEF, MIME, EAC, and EDC and will be chaired by MIME. The committee will be organized for every project to appraise the implementation agreement and PPA. After finalizing the PPA and obtaining the approval of EAC, EDC who is the off-taker of the electricity generated will sign the PPA. A sample form prepared by UK consultant (Mott MacDonald) in 2001 is used for PPA. There are two sample forms, one for large project and the other for small. After starting the power generation, EAC as Regulator will monitor the management of the electricity services in accordance with the implementation agreement.

Future Issues

After launching those hydropower projects that are under negotiation, the following would be the issues of the power sector:

- Aiming at energy security and long-term lowering of the unit generation costs of the entire Grid, it is desirable, although it may take certain time, for the Government to get soft loan and implement generation projects so that EDC will own certain share of generation capacities and operate these[1]. As to the EDC share of the Grid generation capacity, EDC should target at 15% at the minimum which is the reserve capacity and could hardly be owned by the private sector as it will not generate electricity.
- In the process of selecting the priority projects, some projects were excluded for their low power density, low economic performance, etc. Of these there might be some projects that would become feasible if developed for multipurpose. For example, a hydropower project located in such region as has strong demand for water supply or irrigation, or a hydropower project that has high firming up effects of the dry season outputs of the downstream projects although the economy of itself may be low, these projects could hardly be developed by IPP of the private sector whose objective is the sales revenue of electricity. Development of this type of projects should be implemented by the Cambodian side although it may take long time. A careful operation and management of reservoirs will be needed not only for the needs of the power grid but also for the water supply and irrigation. To this end, a development model that facilitates operation and management by the Cambodia side will be needed.
- As far as the projects EDC will implement, contractors will be selected through competitive bidding in principle.

(2) Priority Implementation of Master Plan Projects

The demand forecast used in the formulation of the MP 2006 had been developed for the present electrification situation such as non-existence of National Grid, scattering of regional load centers countrywide and isolated and independent to each other. Also adopted in the forecast were various and challenging assumptions. As pointed out in the present Report, it should be noted that some deviations from the forecast are becoming apparent. Accordingly, when the MP 2006 is reviewed, the countrywide

[1] It would also be effective for long-term lowering of grid generation costs to expand transmission and substation network with soft loans, although it is not generation projects.

perspective of the power demand growth should be studied, theoretical appropriateness of the basic demand forecast be examined, and then the MP 2006 and the succeeding program of RGC should be updated. As already described in the selection of the priority hydropower projects of the Master Plan Study, the Generation Expansion Plan to follow the ongoing implementation of the committed hydros including thermal plants was prepared, in order to maintain consistency with the MP 2006, adopting not only the demand forecasts but also the conditions and assumptions employed in formulating the MP 2006. In general, generation projects need long time from planning to commissioning of operation. Accordingly it is recommended that RGC aggressively tackle the feasibility study of the Master Plan projects selected in the Study.

(3) Establishment and Operation of Hydro-meteorological Observation System

Hydro-meteorological observatories, that is, the stream gauging stations and rain-gauges among others existing in Cambodia are concentrated on Phnom Penh, Tonle Sap, and Mekong Mainstream basins. In those hydropower potential areas of North-eastern Region (Ratanak Kiri, Stung Treng) and South-western Region (Koh Kong, Pursat), the number of gauging stations are quite limited (refer to Chapter 6 for details). In those project basins situated in the South-western Region and Prek Liang basins in the North-eastern Region, there is neither stream gauging station equipped with discharge measuring facilities nor rain-gauge except for temporary staff gauges. Hydrological data necessary for hydropower development could not be collected and accumulated if we simply depend only on the observation network of MOWRAM. In general, a 30 year hydro-meteorological data are required for hydropower planning and operation and a 10 year data are desired at the minimum. The shorter the available period of hydro-meteorological data, the greater the hydrological risks such as power sales revenue falls in short of the planned level, floods exceeding the design flood would take place to cause flood damage to the project facilities. It is recommended that as to the five committed projects and the seven MP projects, MIME conclude contracts with respective developers requiring the developers to install staff gauges and rain-gauge, build facilities for discharge measurements, provide current meters for low flow and high flow measurements, execute discharge measurements, and to submit copy of the observation and measurement data including annual report and analysis of H-Q curve and so forth. As to those projects of which developer has not been selected, it will be required that the Hydro-electricity Department of MIME undertake the observation and arrange the budget therefore.

Some examples of observation process and actual stream gauging conducted as part of the present Master Plan Study are given below:

1) Water Level Observation on Staff Gauges

Staff gauges will be installed nearby the project site to observe the river water level thereon. The developer given with the right of pre-FS or FS should employ an observer to read water levels twice a day (morning and evening). The observation should be started upon onset of the pre-FS or FS. Copy of the observed data should be submitted to MIME. The observation should be continued also after completion of the Study. If the contract negotiation for implementation is failed or when the contract period of BOT is completed, MIME should succeed the observation. It is the principle of hydro-meteorological observation to continue without interruption.

2) Discharge Measurements

Discharge measurements should be executed once a month at the minimum, once a week in principle. The measurement should be made using a current meter except for high flood flow measurements in which float may be used depending on the conditions. Several 10s of discharge measurements will be required to develop H-Q curve for a wide range from low flow to high flood flow. Since the measurement of flood flows incur safety risk, special facilities such as spanning of a cable over the river for velocity measurement will be required. Copy of the measurements and its graphical distribution and updated H-Q curve should also be submitted to MIME.

The costs for these facilities and measurements should be borne by respective developers.

Under the present Master Plan Study, staff gauges were installed on the Prek Liang River in Ratanak Kiri and Stung Metoek River in Koh Kong. Gauge height reading was continued since then by local observers (see pictures below). Throughout the study period, technology transfer to the counterpart staff was conducted at the time of field reconnaissance. Of the staff of Hydro-electricity Department of MIME, four engineers have practiced and learnt the discharge measurement using a current meter. It is expected the technology acquired through the present Master Plan Study contribute to implementing the hydropower development in Cambodia.

Installation of staff gauge in Yon Village, on the right bank of the Prek Liang River

Staff gauge and local observer who receives instructions on gauge height reading and daily logging

Figure 9.4.1 Installation of Gauging Staff and Training of Gauge Reading

Record of Water Level at Yon village

JICA TEAM

Name of Gauge Reader:

Month: [illegible] (4) 2008

Tel: [illegible]

Days	7:00AM	5:00PM	Average	Weather	Remark
1	24	25		[illegible]	Sunny
2	26	24		[illegible]	—
3	23	20		[illegible]	—
4	20	30		[illegible]	Raining
5	26	22		[illegible]	Sunny
6	30	24		[illegible]	Raining
7	30	25		[illegible]	Sunny
8	20	19		[illegible]	—
9	19	18		[illegible]	—
10	18	16		[illegible]	—
11	16	15		[illegible]	—
12	16	15		[illegible]	—
13	18	17		[illegible]	—
14	19	16		[illegible]	—
15	16	14		[illegible]	—
16	14	12		[illegible]	—
17	13	12		[illegible]	—
18	12	11		[illegible]	—
19	11	10		[illegible]	—
20	11	11		[illegible]	—
21	14	11		[illegible]	—
22	11	10		[illegible]	—
23	10	8		[illegible]	—
24	9	7		[illegible]	—
25	7	6		[illegible]	—
26	8	7		[illegible]	—
27	7	5		[illegible]	—
28	8	20		[illegible]	Raining.
29	11	10			
30	10 cm	9 cm			
31					

Figure 9.4.2 Sample Monthly Sheet of Daily Gauge Height Records

Evaluation Criteria of Newly Proposed Projects

When a new hydropower project is identified and or proposed, its preliminary evaluation will be required:

1) Of the social and environmental impacts of a reservoir, judgment of the project implementation be suspended if there are such cases:

   - It incurs some issues of which technical feasibility for mitigation measures have not been clarified like sand flushing of Sambor reservoir situated in the flat region;
   - Existence of an endangered species or historical remains has been identified but its countermeasure has not been prepared.

2) It is recommended that the power density of a single purpose project for hydropower generation be checked at the initial stage of project planning except when EIA has been executed to confirm the project acceptability. If the power density is lower than 0.5 MW/km^2, it is a precaution and suggests the project would have significant environmental impacts and would need a careful EIA (refer to Section 9.4.2, paragraph (1), item 3)). A multi-purpose project will require a separate study.

3) Those hydropower projects situated inside the Mekong River Basin need notice to MRC as shown below:

Water use in the dry season	Mekong Mainstream Projects	Tributary Projects
Development and utilization inside the basin	Prior consultation aiming at achieving an agreement at Joint Committee of MRC	Notification
Development and utilization by inter-basin water transfer	To be agreed by Joint Committee of MRC, through specific agreement for each project	Notification

4) Economic Performances

It is recommended that the following be used as the standard level of project requirements. Since FIRR and ROE depend on the power purchase tariff, these are reference indicator for the preliminary evaluation. Whether we should implement a hydropower project or not in view of the national economic interest of Cambodia, that is whether the project is in superior to alternative thermal projects can be judged by EIRR. If EIRR is assessed to exceed 10% as a result of the feasibility study after clearing the technical feasibility and environmental and social considerations, the project should be implemented.

- EIRR > 10%
- FIRR > 10%
- A standard ROE = 15%

However, EIRR assessed at master plan study or pre-FS may include significant error. Therefore, EIRR is not an absolute indicator. When there are needs other than for hydropower development such as for flood control and water resources development (irrigation, water supply), a plan should be prepared for multi-purpose development and EIRR be assessed accordingly.

5) Operation Management by IPP

Upon completion of the construction works, IPP will undertake the operation management of the electricity business. After expiry of the BOT contract period, the generation facilities and the operation will be handed over to EDC.

Notes on Operation of Hydropower Stations

One of the great differences between hydropower and thermal power from the viewpoint of grid management is while thermal plants can artificially adjust its operation throughout the year, hydropower stations will strongly receive influences of nature and, therefore, cannot adjust its operation independently from the nature. Under the situation that generation equipment has no mechanical problem and fuel stock is secured, thermal plants can respond to any supply demand of the grid. On the other hand, hydropower stations, even if having a great reservoir capacity, can hardly respond to the generation demand from the grid once the reservoir becomes empty no longer to have water storage for power generation. Accordingly, in the hydropower stations it will be important to manage the water storage in the reservoir so that the station can respond to the scheduled power generation.

On the other hand, in the case of IPP project of which PPA is based on the energy output, such operation as to maximize the annual energy output is the most desirable and, therefore, the power discharge will be maximized. In other words, the spill out from the reservoir will be minimized, that is, the reservoir water level will be maintained as low as possible to avoid spilling of the reservoir inflow. The past reservoir operation described in Section 9.4.5 is a typical case. In particular, a fluctuation in the reservoir water levels will not affect much the gross head of a dam-waterway type project. As a result, the operation in Kirirom I has been practiced. However, in the case of dam type hydropower project, the fluctuation in the reservoir water levels will much affect the gross head. In this case, an optimum target level of reservoir exists. A reservoir will be operated to maintain the reservoir level high around the target level (often referred to as High Reservoir Level Operation), to maximize the energy output. A reservoir operation study should be executed carefully before commissioning of the project. It is important to manage the reservoir operation in response to the changes in the grid situation of available power.

Present Operation of Existing Hydro and Issue

As may be inferred from the background described above, there is an issue in the operation management of a hydropower station. The operator will release the reservoir inflow as much as possible during the rainy season in order to maximize the energy generation. There is no incentive to store water in the reservoir. As a result, the reservoir will become almost empty in the dry season and the adequate power generation will not be possible. New hydropower projects will be commissioned one after another in the future, maximization of the energy generation, that is, maximization of the dry season power output of the hydropower stations should be achieved by providing appropriate conditions and incentive measures in PPA and monitoring of reservoir operation to issue timely instructions to hydropower stations.

Upon putting the many large scale hydros into operation in the grid, it will be required to strengthen the Load Dispatching Center (LDC) for monitoring the available storage in each reservoir and issuing instructions on daily energy generation at each hydro station. In order to facilitate such judgment and instruction, hydro-meteorological observatory system as described in Section 9.4.1 paragraph (3) should be established by respective developers as early as possible and rainfall and hydrological data should be accumulated. These data will contribute to optimum operation of reservoir groups. Investments on the hydro-meteorological system will return in many folds finally as the maximized generation and power outputs of hydropower station group.

9.4.2 Environmental and Social Considerations

(1) EIA Guidelines

The Law on the Environmental Protection and Natural Resources Management and Sub-Decree on Environmental Impact Assessment Process, August 11, 1999 of RGC as well as the environmental guidelines of the World Bank, ADB, and JICA (including the former JBIC) can be downloaded from respective URLs below:

Table 9.4.1 EIA Guidelines for Reference

No.	Environmental Guidelines	URL
1.	**RGC**: Sub-Decree on Environmental Impact Assessment Process, August 11, 1999, to the Law on the Environmental Protection and Natural Resources Management, 1996. Protected Area Law was promulgated in January 2008 on the Protected Areas which were defined by the Law above. However, the Protected Area Law has not been available on the web sites.	http://www.camnet.com.kh/moe/EnvironmentLow.htm http://siteresources.worldbank.org/INTEAPREGTOPENVIRONMENT/Resources/Cambodia_EIA_Sub_Decree_1999.doc
2.	**The World Bank**: The World Bank's New Operational Manual, OP 4.01 January 1999	http://www.env.go.jp/earth/coop/coop/materials/10-eiae/10-eiae-7.pdf
3.	**ADB**: Environmental Impact Assessment for Developing Countries in Asia, December 1997	http://www.adb.org/Documents/Books/Environment_Impact/#contents
4.	**New JICA**: Guidelines for Environmental and Social Considerations are under study for integration of the two between former JICA and former JBIC.	-
5.	**Former JBIC**: "JBIC Guidelines for Environmental and Social Considerations", April 2002, in Japanese "Environmental Checklist of Dam/Reservoir Projects" in Japanese	http://www.jica.go.jp/environment/guideline/archives/jbic/guideline/pdf/kankyou_GL.pdf http://www.jica.go.jp/environment/guideline/archives/jbic/guideline/docs/check_12.xls
6.	**Former JICA**: Existing Guidelines are "JICA Guidelines for Environmental and Social Considerations", April 2004	http://www.jica.go.jp/environment/guideline/archives/jica/pdf/guideline_eng.pdf

Source: The study team

(2) Envisaged Environmental Impacts and Possible Mitigation Measures

Based on the available information and analysis, the following can be considered in order to mitigate the possible environmental damages:

Table 9.4.2 Envisaged Environmental Impacts and Possible Mitigation Measures

No.	Envisaged Environmental Impacts	Possible Mitigation Measures
1.	Resettlement	■ Compensation for houses (monetary compensation, compensation in kind) ■ Tentative monetary compensation to secure livelihood at the initial stage of resettlement ■ Measures for improvement of livelihood: Fish farming using the reservoir surface, small scale pumped irrigation using reservoir water, etc. ■ Measures for regional development/improvement: Rural electrification, improvement of farm road, water supply, community facilities
2.	Inundated farmland	■ Monetary compensation or provision of alternative farmland and alternative livelihood including job training
3.	Inundated road	■ Construction of relocation road
4.	Inundation of forest etc.	■ Take precaution by Power Density at initial stage of project planning ■ Tree felling and taking out before impounding ■ Tree planting: Tree planting in the shrublands and grasslands around the reservoir area to mitigate loss in the CO_2 fixing sink capacity of the inundated primary forest.
5.	Transportation by boat	■ Navigation lock: Installation of navigation lock where there is the navigation demand by boat. However, if modal shift from boat to truck transportation in the future with road construction, such navigation lock may become unnecessary. Monetary compensation may also be considered depending on the demand scale.
6.	Fish migration	■ Installation of fish pass ■ Nursing and release of fish juvenile ■ Fish farming using the reservoir surface: There are successful examples in Indonesia and Nepal. WWF warns that the risk of Mekong River is triggered by overcatch of the fish resources. Further, it would be difficult to continue the way of fishing style practiced since the ancient era also in the 21st Century. It is considered necessary in the future on the Lake Tonle Sap and Mekong River to promote fish farming regardless of dam construction.
7.	River section between intake and outfall (outlet of power discharge)	■ Environmental Flow Release: To support the water use and ecosystem in the river section, certain discharge will be released for such section, e.g. at 0.20 m^3/s in 100 km^2 of the catchment area. ■ Warning for water release: Warning system for water release should be installed if it is judged necessary for power generation and release of flood. In Japan, warning system will be installed if the water level rising speed is faster than 30 cm in 30 minutes.
8.	Protected Areas	■ To classify the Protected Area into four zones, and officially announce by Sub-decree of the Environmental Law.

No.	Envisaged Environmental Impacts	Possible Mitigation Measures
		■ Access control: To install check gates on the access road, which would be constructed for construction works and operation & maintenance activities. This is to prevent uncontrolled entrance to the Protected Area for illegal activities like tree felling, opening of farmland, and hunting. Access control should be made based on the Environmental Law. ■ Financial and technical assistances for the management of the Protected Areas and National Parks ■ Environmental education：To provide chances to the people for experiencing walk and life in natural environment ■ Watershed management of the upstream area: afforestation, soil conservation (sand retention forest, check dams, contour-line farming) ■ Surveys on endangered species whether such species live in the proposed reservoir area or not. This will be as part of EIA survey to be conducted during the feasibility study stage. In case specific species are identified, appropriate countermeasures should be taken in a sustainable manner. For the seven MP project areas existing information on the endangered species of fauna and flora are introduced in Table 4.8.2, Sub-Sections 4.8.3 and 8.2.2. These are summarized below by project: ➢ #7&8 LL2: The upstream part of the reservoir area or its 0.6% belong to the Lomphat wildlife reserve (Table 8.2.8). There is a report that wild elephants seasonally migrate in the reserve (Table 4.8.2). The study team got no such information in the course of the hearing survey made on the natural and social environment. ➢ #12&14 PL1-PL2: Virachey National Park is situated on the north bank of the Se San River. The reservoirs of these projects are located within the Park. There is a report that the Park provides habitats for several endangered species including tigers, elephants, douc langur (Table 4.8.2 and paragraph (3) of Sub-Section 8.2.2). ➢ #29 Bokor Plateau: The project site is located in the Phnom Bokor National Park where tigers, elephants, sun bears reportedly inhabit (Table 4.8.2). The reservoir area is located to the north of the past summer resort on the plateau. As of 2008, the resort was under planning for rehabilitation. ➢ #16 MSRC: The project site is located in the western part of the Cardamon Protected Area. According to the CI survey made in 2004, twelve mammal species, two birds, seven reptiles, one amphibian, and one fish were classified as 'globally threatened'. CI views the Stung Chhay Areng basin located in the eastern part of the Cardamon is of particular significance in terms of biodiversity. ➢ #20&21 Stung Metoek 2&3: The project sites are

No.	Envisaged Environmental Impacts	Possible Mitigation Measures
		located inside the valley of Stung Metoek River which belongs to Phnom Samkos wildlife reserve. The reserve includes high mountains and is reported to provide habitats for birds of endangered species (Table 4.8.2).
9.	Widening of gaps	■ Establishment and operation, by the Government, of Social and Environmental Fund (SEF) through Cross Subsidy by the grid users, implementation of the Project Area Development by IPP and communities with subsidy from SEF, and implementation of the Livelihood Improvement Program with contribution from IPP. ■ Dissemination activities by the related authorities on education and agriculture extension services to promote: 1) environment conservation, 2) agro-forestry, and 3) ecotourism

Source: Study Team

(3) Aiming at Socioeconomic Development in harmony with Environment

The Chairman of Parliament singed the Protected Area Law (PAL) in January 2008. PAL stipulates that the Protected Area will be grouped into 4 zones. In the two upper zones (Core Zone and Conservation Zone) development of infrastructure is prohibited. Zoning of the Protected Area will be studied one after another and will be defined by the Sub-decree to PAL. It is required at the zoning, without bias neither to environmental conservation nor to resources development, to pursue development and harnessing of the hydropower, water resources, mineral resources, and so forth for the national interests while conserving the environment of the country. It would be necessary and effective for RGC repeatedly to explain to the public on the basic policy of the Government regarding the environment and development.

The Law on the Environmental Protection and Natural Resources Management, 1996 prescribes the objectives in its Chapter 1, Article 1 as follows:

- To protect {and} promote environmental quality and public health through the prevention, reduction, and control of pollution
- To assess the environmental impacts of all proposed projects prior to the issuance of the decision by the Royal Government
- <u>To ensure the rational and sustainable conservation, development, management, and use of the natural resources of the Kingdom of Cambodia</u>
- To encourage and enable the public to participate in environmental protection and natural resource management
- To suppress any acts that cause harm to the environment

In order to promote sustainable development of hydropower resources while conserving the environment, it is recommended to execute a series of campaign for achieving national consensus. The campaign may include the following:

- To create a catch copy like "***Socio-economic Development in Harmony with Environment***";

  The Government should explain to and deepen the understanding of the urban residents in particular on the fact 1) why they can enjoy the life with electricity but without power plants inside the urban areas and 2) the need of *Cross Subsidy* among the Grid users as the thanks to those people who have accepted resettlement and or other impacts accompanying to the implementation of hydropower and or thermal power projects. MIME/DIME should hold public meetings to disseminate the project implementation plan and information to the stakeholders concerned preceding the FS-EIA and resettlement planning by private developers so that the people concerned can get advanced proper information from the Government;

- To hold inspection tours of power stations and substations;
- To build and operate such facilities for the people to experience the life in natural environment.

(4) Notes for Resettlement Planning

Figure 9.4.3 presents four compensation items in relation to resettlement. Study on the following matters will be important:[2]

1) Preceding the explanation by foreign developer to the people on the resettlement of hydropower projects in Cambodia, it is important for RGC first to explain to the people about the national policy of energy and electricity, outlines and needs of the project, reason why involuntary resettlement is required, plan for EDC or other private developers to implement the project, and basic approach of the Government for resettlement. According to the hearing survey conducted under the Study, such opinions were taken up "We have not got explanation from the public. Why do we need to resettle for electricity export to foreign country?" The explanation from the Government to the people at the very first stage is an essential requirement in achieving understanding of the people for resettlement.
2) The resettlement plan should be studied and prepared through participatory planning. There is an example that the people once resettled in accordance with the top-down plan returned to the previous place.
3) If more than half of one community is subject for resettlement but some parts of the households do not need resettlement, it should be a principle to resettle the whole community and maintain the community also at the new host land as far as the people wish so.
4) Since alternative farmland would be relatively easy to identify and acquire in the project areas of Cambodia, it should be another principle of resettlement to provide the farmland necessary and sufficient to have agricultural products at the same level or higher than before the resettlement.
5) In selecting the host land, the following should be studied:

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2 Reference materials of the World Bank: Involuntary Resettlement: Comparative Perspectives, World Bank Series on Evaluation and Development, Vol 2), World Bank.

- The location should be selected taking into consideration the convenience for navigation and road transport. It is desirable the host land be close to the lake shore on one hand and close to the main road to the provincial town on the other hand. In view of the electrification by extension of distribution lines from the power station of the project, it is also desirable to be not very far from the station.
- The host land should be appropriate for use as farmland (fertility, flat or hilly land). It should be studied if an irrigation by a low head pump from the lake surface is appropriate for the farming after the relocation. It is also important the required area of land is available within one area (for resettlement by whole community as well as for effective maintenance of farm roads).
- Land for housing and community facilities including community roads should also be acquired. The scenic value of commanding panoramic view of the lake surface would be one of the factors for site selection. Such view may be potential resources for echo-tourism.
- When the host land is adjacent to existing communities, social study should be made in advance not to cause social discord among different communities.
- It will be the best if creek water or groundwater is available for drinking and domestic use throughout the year. However, in Cambodia which has distinct dry season, it would be required to tap the groundwater or pump from the lake surface. Drinking water could be supplied by pumping with appropriate treatment.

6) Monetary compensation will also be planned when necessary to cover transportation costs of movables upon resettlement and compensation for livelihood for the initial period after resettlement. There is an experience that because of delay in the payment of compensation money, people borrowed money of high interest rates and struggled in repayment. Livelihood compensation over long years may be provided on installment basis.

7) In accordance with “Dengen-Sampo (Three Generation Laws)” in Japan since 1974 (refer to paragraph (8) hereof), surcharge tariff has been collected from power companies and provided, in addition to ordinary compensation accompanying to the resettlement, to those rural development projects to be prepared by Prefecture government and implemented by City-Town-Village government covering such projects as improvement of living standards, building of infrastructures, environmental conservation and so forth. Necessary projects have been implemented by obtaining the understanding and cooperation of the people living in the project area through inputs of various efforts extended over long time.

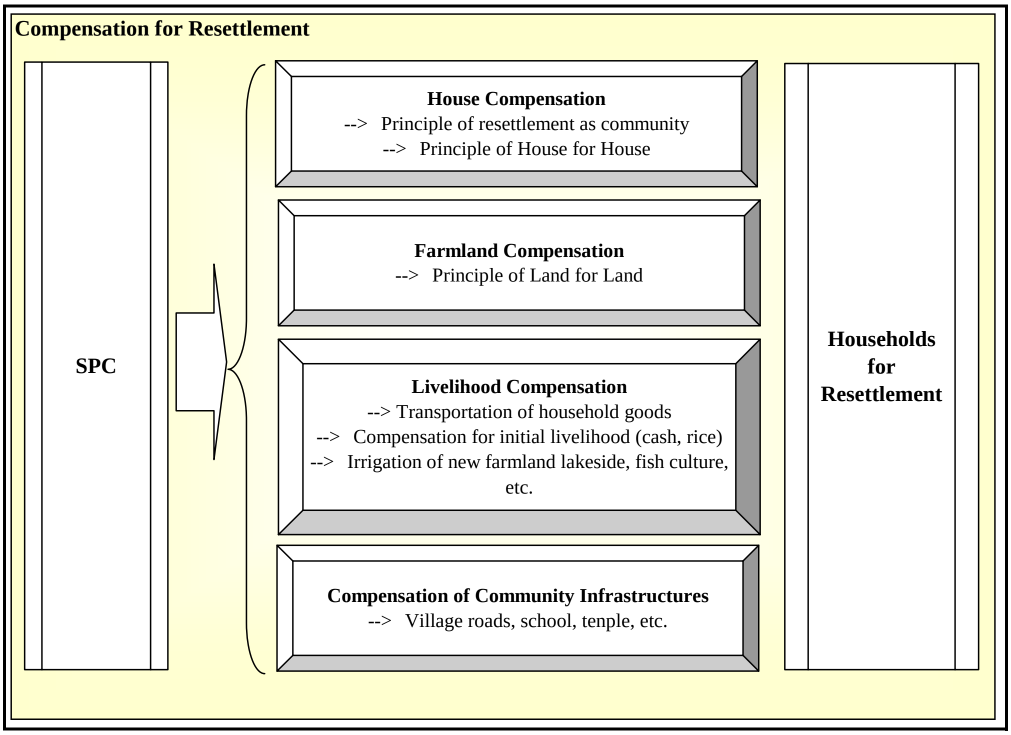


Figure 9.4.3 Items of Resettlement Compensation

(5) Introduction of Power Density (PD)

A concept of PD was introduced into the selection process of 10 priority projects in Stage 1 study as described in Section 5.4.3. The Study Team recommends the Power Density criteria be introduced also in the initial assessment of new projects other than the Master Plan projects.

Figure 9.4.4 shows power density and number of people for resettlement per power output of world hydropower dams. There are five precedents reported in the world that have lower PD than 0.5 MW/km^2. The PD at 0.5 MW/km^2 (red vertical line) is on the left side on the figure, that is, this PD level is at a significantly low level being rather close to the world lows (although it may seem distant on the logarithmic scale). This PD level was selected to meet the growing electricity demand and the need of hydropower development in Cambodia while maintaining the practical balance with the environment (refer to Table 5.4.2 for such balance of hydropower development and environmental).

Although there are 10 projects shown on the left side of PD at 0.5 MW/km^2, 5 had provisional EIRR lower than 5% and 2 were ranked by FACA at or lower than 24th. The rests are #11 LSS3, #15 LSP3, and #24 PST1. At Stage 1 of the present Master Plan Study, #11 LSS3 and #15 LSP3 projects were not retained as subjects for the further selecting study for their low PD and because there were no field survey and EIA that convince the acceptability of their social and environmental impacts. These two projects are shown in the lower left corner of the figure, that is, these would have a wide submerged land and large number of people for resettlement compared to its power output. Although there are some precedents in the world, it may be inferred that these projects have significant impacts both in the area of submerged land and number of people for resettlement.

The last project in Cambodia on the left side of PD line is #24 PST1 which is located on left and upper corner of the figure. It requires no resettlement. If this project is developed for multipurpose for hydropower and irrigation water supply for example, the PD criteria will not be relevant.

For reference, CDM Board accepts use of simplified constant as a unit reservoir emission of CO_2 if PD is greater than 4.0 MW/km^2. This special permission is to encourage development of clean and renewable hydropower resources by reducing the burden to prove the level of reservoir emission when PD is high. If PD is lower than 4.0 MW/km^2 and if they still wish to get Certified Emission Reduction (CER) from CDM Board, applicants to CDM are required to prove the level of reservoir emission.

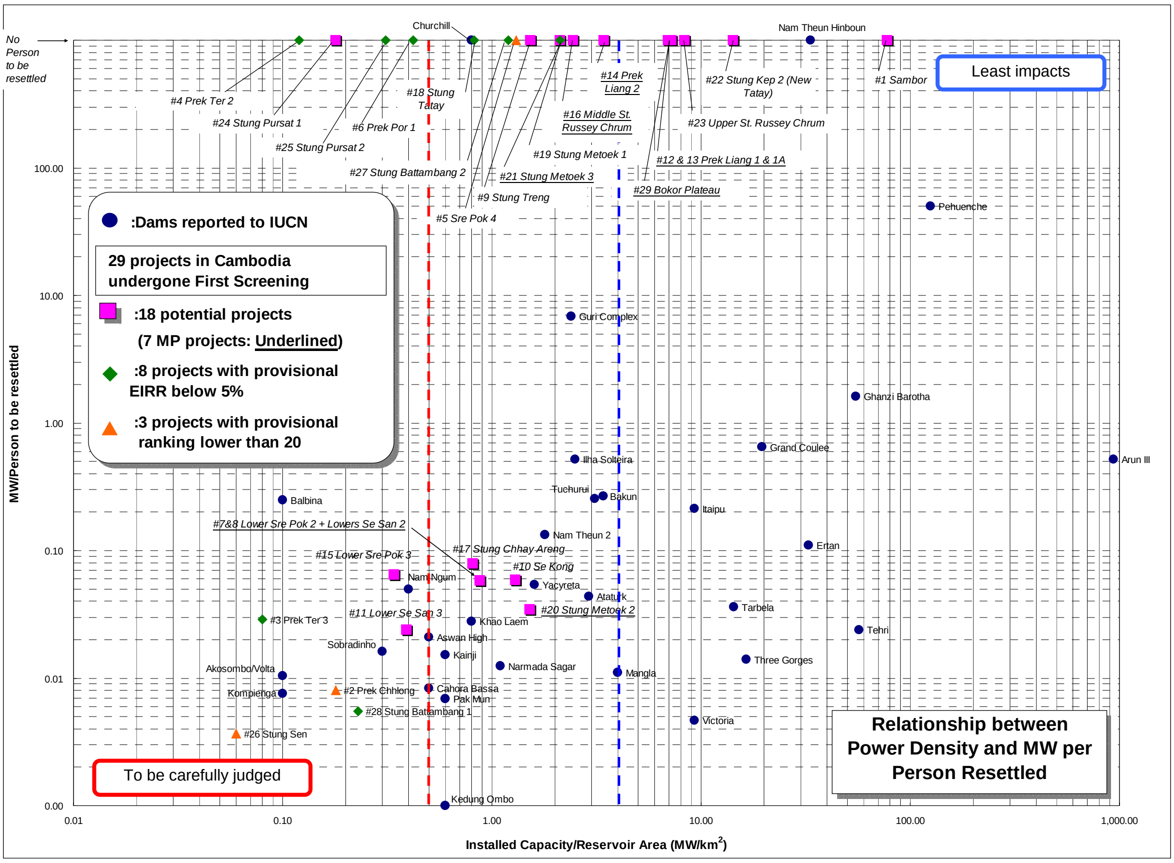
As described below, the PD of 0.5 MW/km^2 may be close to the level that could be achieved by growing sugarcane in the proposed reservoir area and producing bio-ethanol.

According to the sugarcane harvesting in Brazil, bio-ethanol is produced with a unit production at 5.82 kL/ha. Heat rate of bio-ethanol is 5,589 kcal. Assuming the power generation efficiency at 40%, with one liter of bio-ethanol we can generate 2.60 kWh/L, which is equivalent to 15,100 kWh/ha or 1,510,000 kWh/ km^2. Assuming plant factor at 40%, its PD will be 0.43 MW/km^2.

As explained above, if we grow sugarcane in the proposed reservoir areas, there would be a possibility to achieve PD by biomass energy similar to the low PD hydros. It is considered that the PD level at 0.5 MW/km^2 to take precaution against potential environmental impacts is not excessively severe from the viewpoints of land efficiency as well as development of domestic energy resources. The decision maker should well recognize those projects that have PD lower than 0.5 MW/km^2 may incur significant environmental impacts on one hand and low land efficiency in energy production on the other hand. In such case, detailed field survey and EIA should be conducted in sufficient time and should be followed by feasibility study preceding final decision.[3]

It is to be noted that the proposed PD criteria is relevant to a single purpose project for hydropower development. When a reservoir has a flood control effect or when the discharge after power generation will be used for irrigation or municipal water supply, the PD criteria will not be relevant.

[3] There may remain such possibility as to subtract the areas of grassland, shrubland, wasteland from the denominator of PD.



Source: Prepared by Study Team based on the material from World Bank Web Page etc.

Figure 9.4.4 PD and Number of People Resettled per MW of Hydropower Dams

(6) Judgment Whether to Implement Mekong Mainstream Projects in relation to Reservoir Sedimentation

It will be required to clarify and confirm the technical feasibility of sand flushing of sediment deposits to be accumulated in the reservoir bed that will be created on flat region like in Cambodia. For that purpose, it will be required to make field survey and laboratory tests including SS concentration, particle size distribution, mineral components of clay materials, section and profile survey of reservoir area, hydraulic model tests, computer simulation, etc.

The Mekong River has many branch streams in its section between Stung Treng and Sambor dam site. There can be an idea to develop run-of-river scheme utilizing these branch streams[4]. Even if we totally close the Mekong River by a dam (dam type development), the reservoir capacity will be very small compared to the annual inflow and it is, therefore, a run-of-river type in terms of its function to regulate reservoir inflow. Although the power output of a run-of-river type scheme utilizing branch stream will drastically decrease in the rainy season, it is expected that the dry season power output be theoretically the same with that of dam type development.

4 These new hydropower projects are not included in the 29 projects and are not subjects of the present Master Plan Study. "An example of using a part of river course for power generation in the Mekong Mainstream" is shown in Appendix D-3.

(7) Facility Planning in relation to Environmental Conservation

1) Underground structures inside Protected Areas:

By adopting underground layout of headrace and tailrace waterways, power station, the scenery impacts could be mitigated. In general there may be such thinking that underground cavern is more expensive than surface type power house. However, a surface type power station often requires deep setting to found turbine on sound bedrock, which results to require a large slope cutting behind the power house. The underground cavern could shorten the headrace tunnel length, avoid cascade development resulting from technical difficulty of long headrace tunnel, construction cost of tailrace tunnel reduces because of non-pressure type, and so forth. Thus, we should note that gross construction costs could be reduced in some cases.

2) Environmental Maintenance Flow:

The standard in Japan sets the rate of environmental maintenance flow in proportion to the area of basin. The rivers in the South-western Region of Cambodia would almost dry up in the dry season. In the present MP Study the standard in Japan, that is, 0.2 m^3/s/100 km^2 was adopted. As a result, there would be such possibility that a reservoir scheme situated in the Southwestern Region in particular facilitate diversified usage of the water resources in the dry season. The dry season inflow of a run-of-river type hydro will be much below 0.2 m^3/s/100 km^2. Accordingly, this maintenance flow rate should not be applied to a run-of-river scheme in Cambodia if any. It is required to decide the environmental maintenance flow balancing the dry season inflow and the water use and ecology on the downstream river reaches.

3) Fish Pass:

As to the rivers in the North-eastern Region, there is a report that some fishes migrates between Tonle Sap and 3S Rivers (Sre Pok, Se San, and Se Kong). As to the blockage of the migration routes of the fishes, installation of fish pass is one of the options. There remains a possibility of the dam construction affecting the fisher. However, it is difficult to assess the impacts quantitatively. WWF reports that the risk factor of the Mekong River is in over-catch of fishes. It is required to study on the fresh water aquaculture using the lake water surface. It is no longer possible to continue the outdated fishing also in the 21st century like hunting and gathering on the ancient time. It is required to promote freshwater aquaculture as practiced in China at a great scale.

According to the Dam Catalogue 2008 issued by the Japan Congress on Large Dam, there are 15 dams as of 2008 that installed fish pass. Table 9.4.3 lists projects with fish pass in Japan and Figure 9.4.5 shows pictures of fish pass. In planning fish pass of #7&8 LL2 project, a careful comparative study will be required to have the most appropriate type.

Table 9.4.3 Dams with Fish Pass in Japan and Their Feasutes

No.	Name of dam	Feature of Dam		Features of Fish Pass				Characteristics
		Height (m)	Crest Length	Type	Height Differe	Length (m)	Intended Species	
1	Aono	29	286	natural	18	652	Not limited	Minimize the usage of concrete and placed natural stones as much as possible.
2	Arase	25	210.8	folding back ice harbour	16	335	sweetfish, eel, *Rhinogobius brunneus*	
3	Ikeda	24	247	cascade	21		sweetfish, dace, freshwater minnow, carp, catfish, eel	
4	Ohno Headworks	26	66.2		21			Pools at an interval of 10m are provided for the fish to rest
5	Kanna	45	185					Located closer to the river mouth, considerations are made for crabs or shrimps to pass. An example of fish pass installed in relatively high dam
6	Koshido	22.8	120.3				sweetfish	A rare fish pass which can observe the fish very close
7	Samani	44	140	cascade (partially channel)	22	288	white-spotted char, cherry salmon, salmon	Newly installed fish pass to the existing dam
8	Shoukawa-goukuchi	18.5	103.3	cascade				
9	Shiromaru	30.3	61	ice harbour	27	332	seema, cherry salmon, salmon	
10	Setoishi	26.5	139.4	ice harbour		430		Three quarter of the long fish pass (430 m) is tunnel or culvert.
11	Nakaiwa	26.3	107.9		22	332	sweetfish,seema, Japanese dace	
12	Nishidaira	31.5	144.4	cascade				
13	Nibutani	32	550	cascade			cherry salmon	
14	Pirika	40	1480	cascade, natural		2400	cherry salmon	
15	Meboro	40	150	cascade	14	178		Equiped with float type power shute gate.

1) Cascade type fish pass of Nishidaira dam and the powerhouse

2) Cascade type fish pass of Nibutani dam

3) Fish pass of Nakaiwa dam

4) Fish pass of Meboro dam (center) and the whole picture of the dam

Source : 1) Dam's Room http://damsroom.web.infoseek.co.jp/Dam_nishidaira_frame.htm
2) Dam's Room http://damsroom.web.infoseek.co.jp/Dam_nibutani2_frame.htm
3) Dam Roman http://fumu2.jp/damdam/
4) Dam binran(handbook) http://wwwsoc.nii.ac.jp/jdf/Dambinran/binran/All/All_2651.html

Figure 9.4.5 Existing Fish Pass in Japan

4) Navigation Lock:

A navigation lock should be provided where navigation demand is high. However, there may be a case that although the navigation is a major transport means at present, it may be forecast that truck transportation will become the main future means in accordance with the ongoing development of the road networks. In such case, the navigation lock would soon become useless in the future. Depending on the demand forecast, monetary compensation may also be studied as an alternative.

5) Power Station and Dam Discharge Warning:

When it is judged prerequisite for daily operation of power station and or operation of spillway, discharge warning system should be installed. According to a standard in Japan, such warning system is installed when it is forecast that the river water level rises at a rate faster than 30 cm in 30 minutes.

It is required to establish the Operation Rule of power stations in order not to exceed the limit above for the rising speed of downstream water levels. Even if the actual operation is made strictly in accordance with the Operation Rule keeping the limit, there remains a risk of Grid Disturbance breaking out due to incidents of large scale. In order to avoid further extension of such Grid Disturbance even if taken place, there would be a case that a station be obliged to suddenly increase the power output. For those stations that are operated for peak load, the rising speed of downstream river water levels should be simulated and when danger is forecast, necessary countermeasures should be taken. In particular, a large scale power station like #7&8 LL2 has superior capacity for regulating further extension of Grid Disturbance and, therefore, it is essential for RGC to seek for the ultimate safety even in case of emergency discharging operation.

(8) Social and Environmental Fund and Project Area Development

1) Samples of Cross Subsidy

Cross subsidy is a special purpose tax. In order to secure the use of the cross subsidy and to manage the money, a Special Account or Fund should be established by law.

2) Similar Sample in Japan

“Dengen-Sampo (Three Generation Laws)” was enacted in 1974. In order to promote implementation of generation projects, Dengen-Sampo is to contribute and return part of the benefits created by construction of power projects, to the people in the project area. It consist of 1) Tax law for promotion of generation expansion, 2) Special Account law for Generation Expansion, and 3) Law for Regional Development around Generation Facilities. It is prerequisite for implementation of a hydro to have cooperation from the people of the project area. Accordingly, in accordance with these laws, the power company collects cross subsidy from the grid users as surcharge to the power tariff. The cross subsidy collected and reserved in the Special Account of the Central Government is allocated to each City-Town-Village for construction of roads, public facilities, etc. The local government also benefits from the tax on in-movables.

Dengen-Sampo may be outlined as follows:

Tax law for promotion of generation expansion： To collect tax for promotion of generation expansion from power companies at Yen 445 per MWH sold. This corresponds to a surcharge at 0.42 cent/kWh at an exchange rate of August 2008 ($1.00 = Yen 105).

Special Account law for Generation Expansion： From the Special Account for promotion of generation expansion, subsidy is provided at Yen 190 per MWh under Account for Project Acceptance and Yen 255 under Account for Generation Diversification.

Law for Regional Development around Generation Facilities： Prefecture Government prepares Project Area Development Plan and relevant City-Town-Village government will implement it with subsidy from the Special Account.

In 2003, some parts of 2) Special Account law for Generation Expansion and 3) Law for Regional Development around Generation Facilities were amended into “Subsidy for Project Acceptance” to expand the use of the subsidy to promotion of village industry or welfare services. It is also intended to support with priority those generation projects such as nuclear power, hydropower, geothermal, etc. that has low environmental load and can supply stable power.

3) Sample of other sector in Japan -- Universal Service of Telephone

In Japan, a universal tariff system is managed by cross-subsidy, to facilitate universal service for the telecommunication also on isolated islands where special costs is incurred, emergency notices to police and ambulance. As source of the services, a number charge at Yen 6 per telephone number is collected and is allocated to providing such universal services. The number charge is reviewed every six month with reference to the increase or decrease of telephone subscribers.

4) Sample of the Philippines – Internal Subsidy System

The Department of Energy (DOE) imposes universal charge at 0.0373 Peso/kWh (1-3% of the electricity tariff) to all the customers of NPC (grid operator) including domestic, commercial, industrial, and public institutions. DOE entrusts the collection business of universal charges to NPC. DOE manages the money by establishing Special Fund. Small Power Utility Group (SPUG) of NPC, which is an organization for promotion of electrification of off-grid areas, undertakes the transaction of subsidy. The subsidy is allocated to electrification projects of non-electrified villages using renewable energy. Details of the subsidy will be defined in Renewal Energy Act.

5) Sample of Bangladesh -- **2-Step Loan for rural electrification**

The money flow and interest rate are as shown below:

- JBIC→GOB (Ministry of Finance): Interest rate at 1%, repayment period 30 years including grace period of 10 years
- GOB→REB (Rural Electrification Bureau): Interest rate at 2%, repayment period 30 years including grace period of 5 years
- REB→PBSs (Electrification Cooperatives): Interest rate at 3%, repayment period 33 years including grace period of 8 years

The fund is allocated mainly to construction of distribution network. REB is responsible for procurement and construction while PBSs for operation and management after completion. Upon commencement of the operation, PBSs start repayment of the 2-step loans to REB.

6) Sample in Kenya

In Kenya, a 5% surcharge is added to a power tariff and is allocated for promotion of rural electrification projects.

7) Concept of Cross Subsidy among Grid Users and Project Area Development with SPC Contributions

Points of resettlement planning have been described in paragraph (4). It is desired to establish a system that facilitates continuous improvements of the living standard of the people who would live in the remote mountainous areas also after the resettlement. To achieve such system, the following two may be considered based on the background as presented in Figure 9.4.6:

- A certain surcharge will be imposed on the power tariff as cross subsidy of the grid users in Cambodia. The surcharge will be pooled in the Special Account or Fund (Social and Environmental Fund). It will be allocated to financing those projects for Project Area Development including environmental conservation and rural electrification.
- IPP as implementing agency of hydropower projects will be required to raise capitals to SPC for resettlement compensation etc. In addition to the four resettlement compensation, IPP will allocate its stock as thanks to the people for acceptance of the resettlement and will also contribute mitigation costs for environmental impacts. With these funds, IPP will execute resettlement compensation and environmental conservation in the Project area.

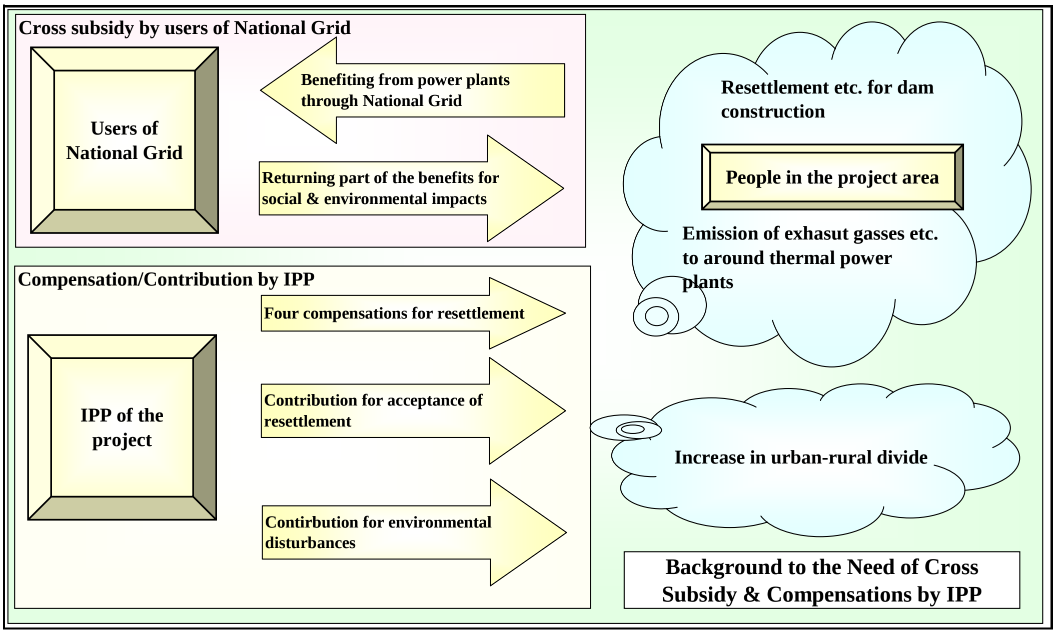


Figure 9.4.6 Background to the Needs of Cross Subsidy and Contribution by IPP

8) An Idea to Support Project Area Development in Cambodia

Figure 9.4.7 presents the concept of SEF for Project Area Development and SPC contributions for compensation. Cross subsidy through SEF is for the whole grid users including corporate users to contribute part of the benefits obtained by using electricity and to return it to the people in the project area. It will be used mainly for Project Area Development in order to improve the living standard there. On the other hand, the IPP contributions will compensate for social and environmental impacts. Such systems are being studied worldwide. However, there is few examples except for compensation for resettlement and submersion of farmland. The dividend to the people resettled is to treat their acceptance of the involuntary resettlement as capital raising to SPC in kind as the people's contribution by accepting move to a new host place leaving the long lived place and the stock of SPC would be issued to the community as a whole. That is, SPC will raise such capital under the name of the community in exchange of the project acceptance. Separately from this, parts of the external non-economy costs of environment will be borne by the developers and will be raised also as capital of SPC for financing those activities of environmental conservation. SPC will undertake Project Area Development and environmental conservation with own capitals and subsidy through SEF. The community resettled will receive dividend from SPC after starting power generation. The dividend may be used as source of micro-credit for continuous improvements of living standards. The communities will participate in the joint activities with SPC and will also monitor such activities.

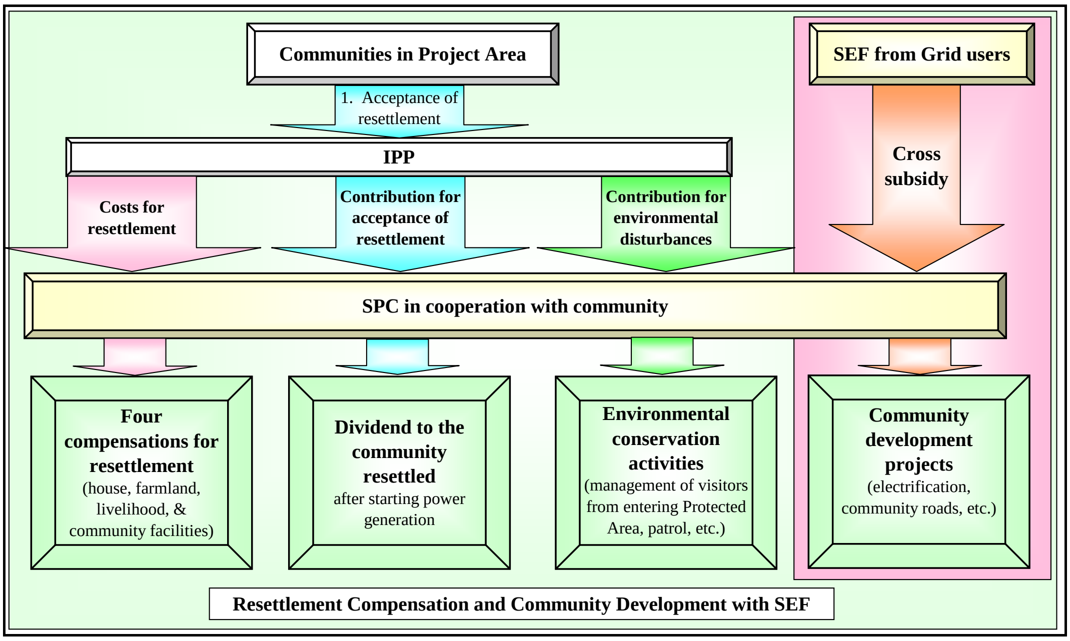


Figure 9.4.7 An Idea of Project Area Development with SEF and Compensation by SPC Contributions

It is desirable that the Project Area Development with SEF subsidy and environmental conservation by SPC capital are implemented under a comprehensive development program include the following:

- Community infrastructures such as village roads, electrification, water supply;
- Livelihood measures such as irrigation and aquaculture;
- BHN facilities like school, heath post;
- Welfare facilities like community hall;
- Environmental education and building and operation of pro-environment facilities like promenade and camping area to experience life in natural environment;
- Environmental conservation activities like checking of illegal access to Protected Area;
- Management of micro-credit.

9.4.3 Procurement Plan of Finance

The basic approach of RGC as of 2008 in relation to the financial arrangement for implementing the Master Plan projects is to Build-Operate-Transfer (BOT) with the private finance. In the case of BOT, the MP projects could be implemented without particular financial inputs by RGC. This is a natural selection of RGC who has the policy obligation to supply electricity to the people of Cambodia under such financing situation that the public financing in cooperation with MDB and ODA would take several years from application to commencement of the loan disbursement. However, if RGC totally depends on the private financing alone, there would be certain adverse effects as examined in Table 9.4.4 below:

Table 9.4.4 Pros and Cons of Generation Expansion with Private Financing

Pros	Cons
■ Financial inputs of RGC are not required. The public debt will not increase.	■ The developer will recover the investments from the future power tariff. The power tariff may become higher. Compared with public loan (some of these include very low interest rate at 0.01% per annum), the interest rates available for the developers would in general be higher and shorter in repayment period, which would lead to a higher tariff.
■ Fast in decision.	■ Since each project is developed by individual developer, combination of these would not necessarily result in an optimum basin development. ■ In place of pursuing the maximum net benefit (B-C) as a development project of natural resources of Cambodia, maximum investment efficiency, that is, the highest FIRR or the maximum benefit-cost ratio (B/C) would be pursued. There may be a possibility that certain potentials of low investment efficiency remain undeveloped. ■ There may be a case that IPP is interested only in a specific project within a basin and is not interested in the maximization of the total benefit of the basin-wide hydropower development. As a result an optimum development plan of individual project would not necessarily form an element of the optimum basin development plan. Also there may be such a case that although one project contributes to the maximization of the entire benefit of the basin development, financial viability of that particular project may be low and no IPP would show interests in its implementation. In such cases, the two issues above could be overcome with the following counter-measures: ➢ MIME should prepare a basin master plan in advance for hydropower development in each basin. It should be followed by implementation of individual projects by IPP. Thus an optimum development of whole the basin potential could be achieved. ➢ The Stung Atay and MSRC projects will significantly augment the dry season power outputs of two dam schemes of the LSRC project located downstream. This is an augmentation effect on the Dry Season Power Outputs to be

	welcomed by the power sector of Cambodia and the people. However, the financial viability of MSRC project itself is rather low. It would be solved either by requiring the IPP of the LSRC project for integrated development of LSRC and MSRC, or by making special consideration in setting power tariff of MSRC from the viewpoint of the augmentation effect on the Dry Season Power Outputs in order to encourage the implementation of MSRC by IPP.
■ RGC can transfer most of the risks to IPP, such as hydrological risk (risk to face low rainfall year), flood risk, landslide risk, subsurface geological risk, risk of price inflation, risk of exchange rates, risk of delay in works completion, and so forth.	■ Power tariff will rise by the risks to be borne by IPP. ■ RGC retains risks of electricity not supplied to the Grid as planned and scheduled.
■ RGC needs neither pre-FS nor FS. ■ What RGC should undertake by the time of construction is evaluation of proposal, pre-FS, FS, concluding contract, and monitoring of implementation.	■ Know-how on the hydropower planning, design, construction supervision will not be accumulated in the staff of RGC.

In order to complement the expected cons above, it is recommended that RGC promotes procurement of public financing in parallel with the ongoing project implementation with Private Finance Initiative (PFI) so as to start the following in a few years:

- MIME/EDC to participate in the project implementation by raising capital to SPC with back finance from MDB;
- MIME/EDC to implement a model project as public works or PPP project with public finance from MDB and ODA.

9.4.4 Human Resources Development

A JICA study program was provided in Tokyo in September 2008 to the three officers participating from MIME with the following seminar programs:

1) Basics of hydropower planning
2) Sedimentation and reservoir operation
3) Cost estimate
4) Economic evaluation and financial analysis
5) Unit generation cost and power tariff
6) Environmental impact assessment
7) Development and resettlement

8) Hydropower development and social environment

9) Inspection tour: Example of hydropower projects in national park, example of environmental consideration in national park by power company

Since MIME has 30 staff in the Hydro-electricity Department, it is desirable to have similar study programs also in the future. Although desk study is also required, it alone will not be sufficient. According to the past experience in other countries, important technology transfer and capacity development could be well achieved through on-the-job training. At the early stage of the nation's development, project implementation as public works with foreign financial supports could engage the staff of RGC directly in the following works to accumulate the experience:

1) Field investigation works such as topographic survey, hydrological observation, geological investigation, and so forth;

2) Hydropower planning, preliminary design, cost estimate, environmental impact assessment, economic evaluation and financial analysis;

3) Design, preparation of tender documents, tender evaluation, contract negotiation;

4) Contract management, quality control, time control, payment management, safety control;

5) Operation, maintenance and replacement of generation facilities.

9.4.5 Cooperation with Relevant Sectors

In order to implement hydropower projects, the following would be needed to have various cooperation from central and local government organizations:

1) Cooperation with MEF towards creation of cross subsidy system for setting up of the proposed Social and Environmental Fund (SEF);

2) Cooperation with MOE in zoning of the Protected Areas;

3) Cooperation with MAFF (FA) for acquisition of forest land to be submerged in reservoir, reforestation program, and fishery, fish pass, etc.

4) Cooperation with MOWRAM in hydrological observation;

5) Cooperation with MOPWT in construction of relocation roads, access roads, and navigation.