

### 3 RESERVOIR AND HYDROPOWER DATA

#### 3.1 Reservoirs in Lancang, Yunnan

Based on data from “Sustainable development of Lancang–Mekong” by He Damming [1], the energy production and resulting outflow of 8 of the largest hydropower plants in Lancang (Upper Mekong), Yunnan, have been simulated. The location of the projects are presented in a map in *Figure 3-1*. Because the average flow is known but not the flow variation, the inflow has been estimated by using the monthly inflow data from the gauge station just downstream at Chiang Saen and Luang Prabang in the period 1951-2001 and 1966-2002, respectively. The total energy production based on He Damming is 74 060 GWh/year, whereas the calculated energy production based on the record from Chiang Saen and Luang Prabang is 76 284 and 75 611 GWh/year, respectively. The calculation is based on the data presented in *Table 3-1*.

*Table 3-1 Hydropower projects in Lancang, Yunnan (projects in bold are included in the 2010-scenario).*

Reference No. In Map		1	2	3	4	5	6	7	8	
Power plant		<b>Manwan</b>	<b>Dachaosh Xiaowan</b>	<b>Gonguoqia Xiaowan</b>	Gonguoqia Jinghong	Nuozhadu	Mengsong	Ganlanba		SUM
Completed	year	<b>1993-1996</b>	<b>2001-2003</b>	<b>2010-2012</b>	2011	2013	2014	before 2025		
Average inflow	m <sup>3</sup> /sec	1230	1340	1220	985	1840	1750	2020	1880	
Total storage	Mm <sup>3</sup>	920	933	14560	510	1233	22400	0.9	0.2	40 557
Active storage	Mm <sup>3</sup>	257	367	9900	120	249	12300			23 193
Full Supply Level	m a.s.l.	994	906	1236	1319	602	807	519	533	
Min. Operation Level	m a.s.l.	982	860	1162	1311	595	756	518	532	
Surface at FSL	km <sup>2</sup>	4.2	8.3	37.1	3.4	5.1	45.1	0.9	0.18	104
Net Head <sup>1)</sup>	m	89	80	248	77	67	205	28	10	804
Dam height	m	126	110	300	130	118	254			
Plant capacity <sup>1)</sup>	MW	1500	1350	4200	750	1500	5500	600	150	15 550
No. of turbines		6	6	6	3	5	10	4	4	44
Energy	GWh	7870	7090	18540	4670	8470	22670	3740	1010	74 060
Sim. energy <sup>2)</sup> , Chiang Saen	GWh	8209	6898	19121	4062	8528	24304	4085	1077	76 284
Sim. energy <sup>3)</sup> , Luang Prabang	GWh	8115	6787	18987	3936	8488	24200	4031	1066	75 611
Resettlement	persons	3513	6054	32737	4596	2264	23826	258	71	73 319
Reservoir-%		0.7 %	0.9 %	25.7 %	0.4 %	0.4 %	22.3 %	0.0 %	0.0 %	
Reservoir-% ref. Mengsong		0.4 %	0.6 %	15.5 %	0.2 %	0.4 %	19.3 %	0.0 %	0.0 %	36.4 %

1) Efficiency curve is estimated based on expected normal values. Based on Net head and general layout the head losses and tailwater level is generated thereafter.

2) Inflow record is based on monthly flow at Chiang Saen, 1951-2001. All u/s hydropower are developed.

3) Inflow record is based on monthly flow at Luang Prabang gauge station, 1966-2002. All u/s hydropower are developed.

Ref. Water Resources and Hydropower - Policies and Strategies for the Sustainable Development of the Lancang River Basin, by Prof He Daming and Dr David Plinston, Sep-99.

Since two of the projects already exist (Manwan and Dachaoshan) and construction of third project has started, three projects are included in the “2010”-scenario whereas the other five projects are scheduled between 2010 and 2025.

The present impact of existing regulations in Yunnan is small. The storage of the existing projects is only 1% of the total annual inflow (ref. Mengsong), but the construction of Xiaowan HPP would increase the regulation to 17% in 2010-12. Two of the future projects, the Nuozhadu HPP and Xiaowan HPP, would be able to store (active) almost 35 % of the total inflow (ref. Mengsong).

*Figure 3-1. Location of large existing and planned reservoirs for hydropower and irrigation.*

Dr Adamson has analysed the impact of hydropower development in Yunnan on the Lower Mekong [3]. He refer to the impact of 10% and 20% regulation. However, the “2010”-scenario would provide a regulation of 17%, whereas the “2025”-scenario would imply a regulation of 36 %. In addition, the paper do only present the monthly mean flow and do not present the variation in monthly flows.

Figure 3-2 shows the water flow downstream Mengsong before (Natural Inflow – mean average) and after the scheduled hydropower development in the year 2025 (50% percentile – approx. mean average)

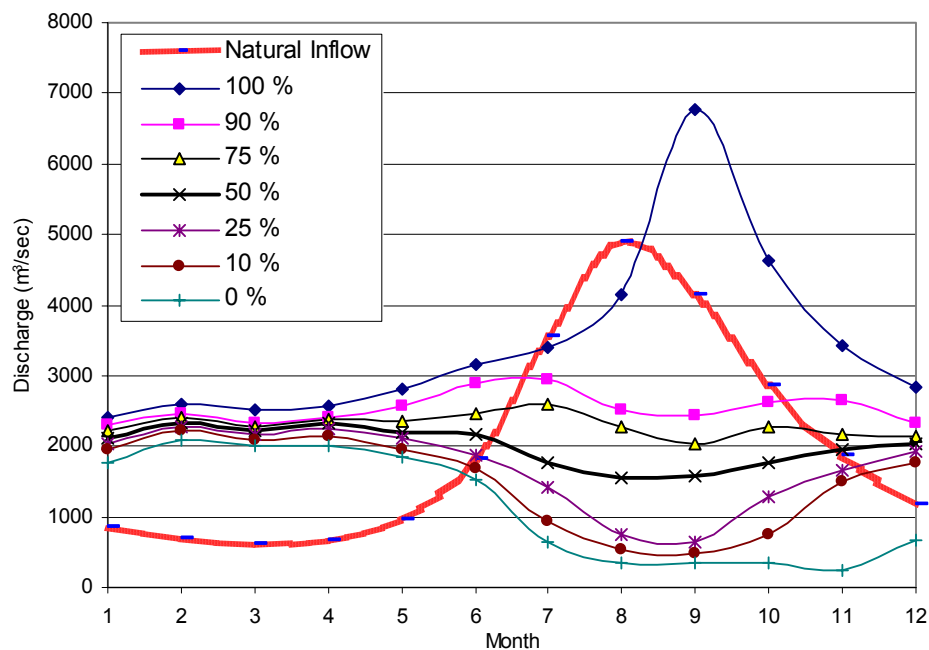


Figure 3-2. Monthly river flow at border to Lao PDR before (natural) and after construction (in percentiles) of planned hydropower projects in Yunnan.

In the 2025-scenario there will be insignificant difference between dry season and wet season flow. In fact, in some years the low flow may occur in July to October if the value of energy is higher during winter.

The trend in the 2010-scenario will be the same, although the period with highest flow in Lancang will still be during the normal “wet season”.

Irrigation

According to [2] the agriculture cultivation in Yunnan is mainly carried out in small valley areas along the middle and lower stretch of Lancang. The total of the major irrigation area is about 151 000 ha (1500 km<sup>2</sup>) in the lower mainstream. Based on [1] there is 550 000 ha farmland in Yunnan within the Lancang basin among which paddy field account for 39%. From the reservoir at Manwan HPP the amount of water has capacity for irrigating 161 300 ha. By assuming an average consumption of 1.5-2 l/s per ha, the total consumption may be estimated. However, much water is returning either as surface run-off/drainage or fed to the groundwater. By assuming an annual evaporation of 1000 mm/year from paddy fields the water loss is 0.3 l/s per ha. However, there was evapotranspiration from

the area before the paddies were established. This might have been the same rate (depending on type of original vegetation cover).

Assuming dry season irrigation of paddy the water loss in existing paddies would represent  $0.39 \times 550.000 \times 0.3 / 1000 \text{ m}^3/\text{sec} = 64 \text{ m}^3/\text{sec}$ .

Planned irrigation of 161300 ha by diverting water from Manwan would in the same way imply a water loss of about  $48 \text{ m}^3/\text{sec}$ . This number is, however, not included in the simulation because the natural/original evapotranspiration is unknown.

### 3.2 Reservoirs in Lao PDR

In Lao PDR there are a large number potential hydropower sites on Mekong tributaries. Based on EdL power development plan 20 projects have been selected [4]. The location of the projects are presented in Figure 3.1. Because the average flow is known but not the variation in inflow the variation has been estimated by using the monthly inflow data from the "Inflow Nam Ngum"-record and the flow at Ban Signo gauge station (Nam Theun 2). The Nam Ngum record has been extrapolated to be used in the period 1951-2001. In Se Kong a hydrological record has been generated by using the monthly inflow data from the Ban Signo gauge station and correlating this record with the monthly distribution in Se Kong given in [6].

Based on trend analysis, see Annex 2, all inflow records in Lao PDR have been reduced by 8%. In spite of this, the simulated basin-wise sum of energy becomes slightly higher than the energy production figures given in the project documents. (Nam Ngum and Nam Theun). The main reason is probably that reservoirs have secondary benefits for all downstream projects.

The calculations of hydrological inflow to Mekong is based on the data in Table 3-2, Table 3-3 and Table 3-4 referring to Nam Ngum basin, Nam Theun basin and Se Kong basin, respectively.

Table 3-2. Storage hydropower projects in Nam Ngum, Lao PDR (projects in bold are included in the 2010-scenario).

Reference No. In Map		10	11	12	13	14	15	17	18	20	
Power plant		<b>N Ngum</b>	<b>N Leuk</b>	<b>N Song</b>	<b>N Lik</b>	N Ngum 3f	N Ngum 2f	N Ngum 5	N Ngum 4f	N Bak 2B	SUM
Completed	year	<b>1972-78</b>	<b>2000</b>	<b>2000</b>	<b>2007</b>						
Average inflow	m <sup>3</sup> /sec	305.9	11.2	65.5	89	106	189	23	27	15	
Total storage	Mm <sup>3</sup>	7010	154		1095	1320			443	186	10 208
Active storage	Mm <sup>3</sup>	4714	123		826	983	150	252	337	119	7 664
Full Supply Level	m a.s.l.	212	405		300	720	280	1100	1040	1030	
Min. Operation Level	m a.s.l.	196	388		270	660			1010	1000	
Surface at FSL	km <sup>2</sup>	370	12.8		42.2	25.6	7.5	14.6	14.5	4.8	502
Net Head <sup>1)</sup>	m	45.5	183.0		80.8	322	65.8	292.5	158.0	624.0	
Dam height	m	55	45.5		63	217	90	97	65	77	
Plant capacity	MW	150	60		100	580	183	90	55	116	1 432
No. of turbines		5	2		2	6			2	3	
Energy	GWh	1018	230		390	2654	830	430	250	563	6 816
Sim. energy <sup>2)</sup>	GWh	1013	143		417	2360	725	439	264	569	6 945
Resettlement	persons				2264	>500	1000	300-500	1470	1552	6 286
Reservoir-%		<b>48.9 %</b>	<b>34.8 %</b>		<b>29 %</b>	<b>29.4 %</b>	<b>2.5 %</b>	<b>34.7 %</b>	<b>39.6 %</b>	<b>25.2 %</b>	<b>79.4 %</b>

Ref. Power Sector Strategy Study, by Electrowatt-Ekono and PA Consulting Group, Sep.-02.

Ref. Nam Ngum 1 Hydropower Station Extension, by Lahmeyer and Worley, Aug. -95.

1) Efficiency curve is estimated based on expected normal values. Based on Net head and general layout the head losses and tailwater level is generated thereafter.

2) Given inflow. Inflow record is based on monthly flow at Nam Ngum 1, 1951-2001, correlated by Ban Signo and later reduced by 8%.

3) EdL is referring the alternative Nam Ngum 3B (690 MW). In the reference list data [5] NN3 and NN3E is available, but the active storage is the same. NN3E (588 MW) is used.

*Table 3-3 Storage hydropower projects in Nam Theun, Lao PDR (projects in bold are included in the 2010-scenario).*

Reference No. In Map		21	23	
Power plant		<b>N Theun 2</b>	<b>TH. Ext</b>	SUM
Completed	year	<b>2009</b>	<b>2009</b>	
Average inflow <sup>2)</sup>	m <sup>3</sup> /sec	240	110	
Total storage	Mm <sup>3</sup>	3910	4870	9 895
Active storage	Mm <sup>3</sup>	3530	2870	6 460
Full Supply Level	m a.s.l.	538	540	
Min. Operation Level	m a.s.l.	525.5	510	
Surface at FSL	km <sup>2</sup>	450	126	592
Net Head <sup>1)</sup>	m	341		
Dam height	m	48	119	
Plant capacity	MW	1074	105	1 424
No. of turbines		6	1	
Energy	GWh	5936	908	8 338
Sim. energy <sup>2)</sup>	GWh	5490	1283	8 664
Resettlement	persons	4800	1220	6 020
Reservoir-%		47 %	83 %	

Ref. Power Sector Strategy Study, by Electrowatt-Ekono and PA Consulting Group, Sep.-02.

Ref. NT2. Environmental Assessment & Management Plan, October 2003.

1) Efficiency curve is estimated based on expected normal values etc.

2) Given inflow. The inflow record is based on monthly flow at Ban Signo, 1951-200,1and later re

*Table 3-4 Storage hydropower projects in Se Kong, Lao PDR (projects in bold are included in the 2010-scenario).*

Reference No. In Map		24	25	26	27	28	29	31	
Power plant		<b>Huoay Ho Xepon</b>		X Kaman 3	X Kaman 1	X Kong 5	N Kong 3	Xe Xou	SUM
Completed	year	<b>1999</b>	<b>2008</b>						
Average inflow	m <sup>3</sup> /sec	10.4	17	35	161	86	34	77	
Total storage	Mm <sup>3</sup>	596	405		6112	4750	320	2750	14 337
Active storage	Mm <sup>3</sup>	480	361	108	3340	2210	299	1710	8 579
Full Supply Level	m a.s.l.	883	580	960	280	500	540	180	
Min. Operation Level	m a.s.l.	861	560		250	470	520		
Surface at FSL	km <sup>2</sup>	38	29.5	5.2	222.0	27.5	37.0	112.9	440
Net Head <sup>1)</sup>	m	763	272.5	568.0	170.1	195.2	77.5	58.0	
Dam height	m	77	36	99	184	205	62	62	
Plant capacity	MW	150	74	250	468	248	25	59	1 162
No. of turbines		2	4	3	4	3	1		
Energy	GWh	556	301	1349	1925	1183	142	277	5 274
Sim. energy <sup>2)</sup>	GWh	531	311	1306	1575	1107	130	269	4 699
Resettlement	persons		1500		>800	5870	1550	500	9 420
Reservoir-%			67 %	10 %	66 %	81 %	28 %	70 %	

Ref. Power Sector Strategy Study, by Electrowatt-Ekono and PA Consulting Group, Sep.-02. X Kaman 3: Vietnamese study in 2004

1) Efficiency curve is estimated based on expected normal values. Based on Net head and general layout the head losses and tailwater level is generated thereafter.

2) Given inflow. Inflow record is based on monthly flow at Se Kong outlet and later reduced by 8%.

### 3.3 Reservoirs in Thailand

Nine projects with reservoirs of significant storage exist in Thailand, see *Table 3-5*.

Six of these projects are combined multipurpose projects, used for irrigation, hydropower and water supply. No plans exist for new large reservoirs projects) for the next 20 years. Hence, the present situation is expected to be the same as in 2010 and 2025.

Table 3-5. Existing reservoirs in Thailand.

Reference No. In Map		47	48	49	50	51	52	53	54	55	56	SUM
Power plant		Nam Pung	Ubol Ratana	Sirinhorn	Huai Kum	Chulabhor	Lam Phra	Nam Pao	Huai Luang	Nam Oon	Lam Takhon	
Completed	year	1965	1966	1971	1980	1972	1967	1971	1984	1973	2002	
Average inflow	m <sup>3</sup> /sec					188					320 / 10	
Total storage	Mm <sup>3</sup>	150	2010	1966		145	145	1260	113	475	290	5 529
Active storage	Mm <sup>3</sup>	122	1695	1191	22	145	145	1260	113	475	290	5 529
Full Supply Level	m a.s.l.											
Min. Operation Level	m a.s.l.											
Surface at FSL	km <sup>2</sup>	21		288		12.0					0.3	306
Net Head <sup>1)</sup>	m										350.0	
Dam height	m	40	35	42	36	70					40	
Plant capacity <sup>1)</sup>	MW	6.3	25	36	1	40					500	640
No. of turbines		2	3	3	1	2					2	
Energy	GWh	17	56	90		59					400 (?)	302
Sim. energy <sup>2)</sup>	GWh											
Irrigation	Hectare	32 000	40 700	24 000		9 600	10 097	50 416	12 800	29 728	22 000	199 341

Ref. EGAT website and JICA/MRC- Paper IV [9]

Pump storage

### 3.4 Reservoirs in Vietnam

In Vietnam there are two existing and many planned power stations on Se San, see Table 3-6. The hydropower projects have been selected based on the preliminary National Hydropower Plan [10]. There exist only two hydropower power station in the basin within Vietnam, the large Yali HPP and Dray Linh. In addition there are two projects under construction; Se San 3 and Se San 3A, However, only Yali has an active storage above 100 mill.m<sup>3</sup>. The other project is not included in the analyses. In addition, there exist several small reservoirs for irrigation purpose which in total has a capacity of approx. 100 mill.m<sup>3</sup>.

Because the average flow is known but not the variation in inflow the variation has been estimated by using the monthly inflow data from the Ban Signo gauge station, but each month is correlated by monthly distribution in Se San given in [6].

Table 3-6 Storage Hydropower projects in Se San and Sre Pok, Vietnam (projects in bold are included in the 2010-scenario). PS! The sum includes the other smaller projects (active storage less than 100 mill.m<sup>3</sup>)

		Se San:				Sre Pok:			
Reference No. In Map		38	39	40	41	42	43	SUM	
Power plant		Yali	U. Kontum	Pleikrong	Se San 4	D. Xuyen	B. Tou Srah		
Completed	year	1999							
Average inflow	m <sup>3</sup> /sec	251	15.1	126	326	39.1	102		
Total storage	Mm <sup>3</sup>		174	1344	893	1811	787	5 576	
Active storage	Mm <sup>3</sup>	779	123	1022	470	484	483	3 589	
Full Supply Level	m a.s.l.	515	1170	575	215	570	488		
Min. Operation Level	m a.s.l.	490	1146	550	205	563	468		
Surface at FSL	km <sup>2</sup>			8.6	64.6	58.4	81.2	37.1	313
Net Head <sup>1)</sup>	m	198	855.6	60.0	65.8	121.2	47		
Dam height	m	77	76	72	75	84/72	83		
Plant capacity <sup>1)</sup>	MW	720	220	110	330	100	84	2 461	
No. of turbines		4	4	3	1	2	2		
Energy	GWh	3500	301	1349	142	334	358	11 783	
Sim. energy <sup>2)</sup>	GWh	2784	822	396	443	329	209	7 315	
Resettlement	persons		1500		1550	755	2012	15 041	
Reservoir-%			26 %	26 %	5 %	39 %	15 %		

Ref. Power Sector Strategy Study, by Electrowatt-Ekono and PA Consulting Group, Sep.-02.

Ref. National Master Plan, 2004 and Se Kong - Se San and Nam Theun River Basins Hydropower Study, by Halcrow, Jan.-98.

1) Efficiency curve is estimated based on expected normal values. Based on Net head and general layout the head losses and tailwater level is generated

2) Given inflow. Inflow record is based on monthly flow at Se Kong outlet and later reduced by 8%.

### 3.5 Reservoirs in Cambodia

In Cambodia there are at present no existing large reservoirs. The construction of Prek Thnot multipurpose dam has been interrupted since 1973 due to the political unrest in the country as well as the financial situation. Kirirom I (12 MW) is the only hydropower plant in operation at present, but the station is a run-of-river project. On Se San and Sre Pok there are several plans, see Table 3-7. Because the average flow is known but not the variation in inflow the variation has been estimated by using the monthly inflow data from the Ban Signo gauge station, but each month is correlated by monthly distribution in Se San given in [6].

*Table 3-7 Storage Hydropower projects in Se San and Sre Pok, Cambodia. (no projects are included in the 2010-scenario).*

Reference No. In Map		44	45	46	
Power plant		L. Se San L	L. Se San U	L. Sre Pok	SUM
Completed	year				
Average inflow	m <sup>3</sup> /sec	408	367	307	
Total storage	Mm <sup>3</sup>				
Active storage	Mm <sup>3</sup>				
Full Supply Level	m a.s.l.	80	120	70	
Min. Operation Level	m a.s.l.				
Surface at FSL	km <sup>2</sup>		6.4		6
Net Head <sup>1)</sup>	m	18	25.0	18.0	61
Dam height	m	30	35	30	95
Plant capacity <sup>1)</sup>	MW	185	153	205	543
No. of turbines		4	3	4	11
Energy	GWh	921	800	1153	2 874
Sim. energy <sup>2)</sup>	GWh	425	443	212	1 081
Resettlement	persons			2676	2 676
Reservoir-%					

Ref. Report analysis of Sub-Area 7V, BDP, July 2003

"L"=Lower, "U"=Upper

### 3.6 Summary of reservoirs in Mekong

The sum of active storage in each country and in total for all countries are presented in Table 3-8.

*Table 3-8. Active storage in the Mekong basin.*

	China	Laos	Thailand	Cambodia	Vietnam	SUM	NT2-portion
Present	257	5 194	5 529	N/A	888	11 868	
2010	10 524	12 949	5 529	N/A	921	29 923	12 %
2025	23 193	22 608	5 529	N/A	3 589	54 919	6 %

JICA [9] has summarised the present total (active?) capacity of large –scale reservoirs in the entire Mekong Basin to 12,147 mill.m<sup>3</sup>. Average annual flow volume of the entire Mekong basin is 475,000 mill.m<sup>3</sup>.

The active storage created by other water users than hydropower is small. An exception is the reservoirs in Thailand of which 2000 mill.m<sup>3</sup> is storage made with the only purpose of irrigating paddies. The remaining 3500 mill.m<sup>3</sup> are used both for hydropower and irrigation.

The extractions of surface water by pumping stations are comparable small. In sum, only 18 m<sup>3</sup>/sec and 1.5 m<sup>3</sup>/sec are withdrawn from Mekong in Thailand and Lao PDR, respectively. [9].