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For sustainable development

Council Study

Hydropower Development Scenarios 2007, 2020 and 2040 and 2040 sub-scenarios

6th RTWG Meeting
Phnom Penh, Cambodia
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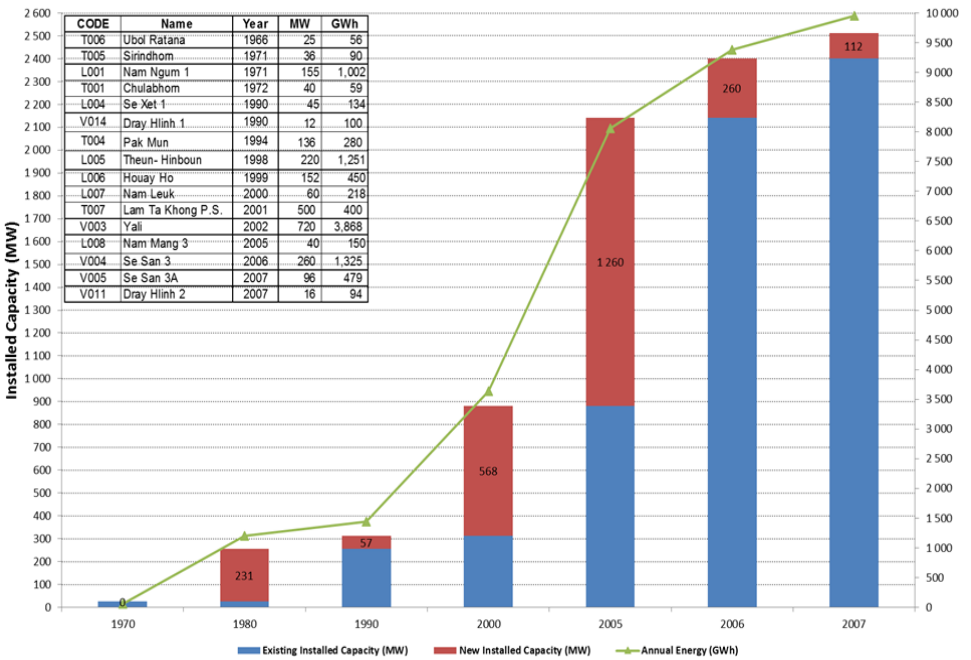
Hydropower Development in LMB Scenario "Early Development 2007"

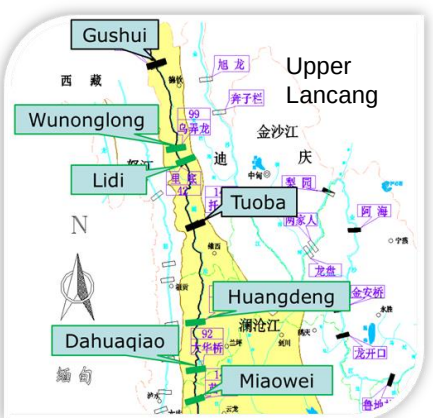
CODE	Name	Year	MW	GWh
T006	Ubol Ratana	1966	25	56
T005	Sirindhorn	1971	36	90
L001	Nam Ngum 1	1971	155	1,002
T001	Chulabhorn	1972	40	59
L004	Se Xet 1	1990	45	134
V014	Dray Hlinh 1	1990	12	100
T004	Pak Mun	1994	136	280
L005	Theun- Hinboun	1998	220	1,251
L006	Houay Ho	1999	152	450
L007	Nam Leuk	2000	60	218
T007	Lam Ta Khong P.S.	2001	500	400
V003	Yali	2002	720	3,868
L008	Nam Mang 3	2005	40	150
V004	Se San 3	2006	260	1,325
V005	Se San 3A	2007	96	479
V011	Dray Hlinh 2	2007	16	94



Map of Hydropower Dam Location in Mekong River Basin "Early Development Scenario 2007"

Hydropower development in UMB / Chinese Dams by 2007

Project name	Commissioning Year	Installed Power (MW)	Average annual generation (GWh)
Manwan	1995	1 670	8 133
Dachaoshan	2003	1 350	7 397
Total		3 020	15 530



Early Development Scenario 2007

Definite Future Scenario 2020

Manwan

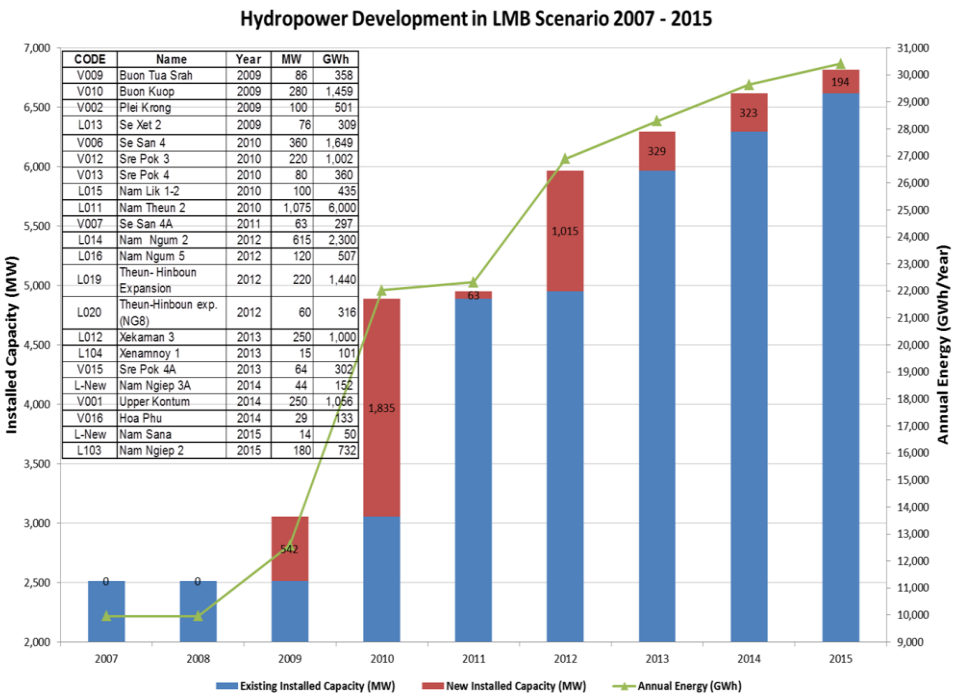
Xiaowan

Development in the period 2020 - 2040

Studied and abandoned project

Gushui

Mengsong



CODE	Name	Year	MW	GWh
V009	Buon Tua Srah	2009	86	358
V010	Buon Kuop	2009	280	1,459
V002	Plei Krong	2009	100	501
L013	Se Xet 2	2009	76	309
V006	Se San 4	2010	360	1,649
V012	Sre Pok 3	2010	220	1,002
V013	Sre Pok 4	2010	80	360
L015	Nam Lik 1-2	2010	100	435
L011	Nam Theun 2	2010	1,075	6,000
V007	Se San 4A	2011	63	297
L014	Nam Ngum 2	2012	615	2,300
L016	Nam Ngum 5	2012	120	507
L019	Theun- Hinboun Expansion	2012	220	1,440
L020	Theun-Hinboun exp. (NG8)	2012	60	316
L012	Xekaman 3	2013	250	1,000
L104	Xenamnoy 1	2013	15	101
V015	Sre Pok 4A	2013	64	302
L-New	Nam Ngiep 3A	2014	44	152
V001	Upper Kontum	2014	250	1,056
V016	Hoa Phu	2014	29	133
L-New	Nam Sana	2015	14	50
L103	Nam Ngiep 2	2015	180	732

Hydropower development in UMB / Chinese Dams by 2015

Project name	Commissioning Year	Installed Power (MW)	Average annual generation (GWh)
Previous table	Until 2007	3 020	15 530
Jinghong	2009	1 750	7 748
Xiaowan	2010	4 200	18 646
Gongguoqiao	2012	900	4 197
Nuozhadu	2014	5 850	23 240
Miaowei	2014	1 400	6 000 1)
Total		17 120	69 361

1) Data Not Found but calculated assuming plant factor about 50%

Definite Future Scenario 2020
Hydropower development in LMB

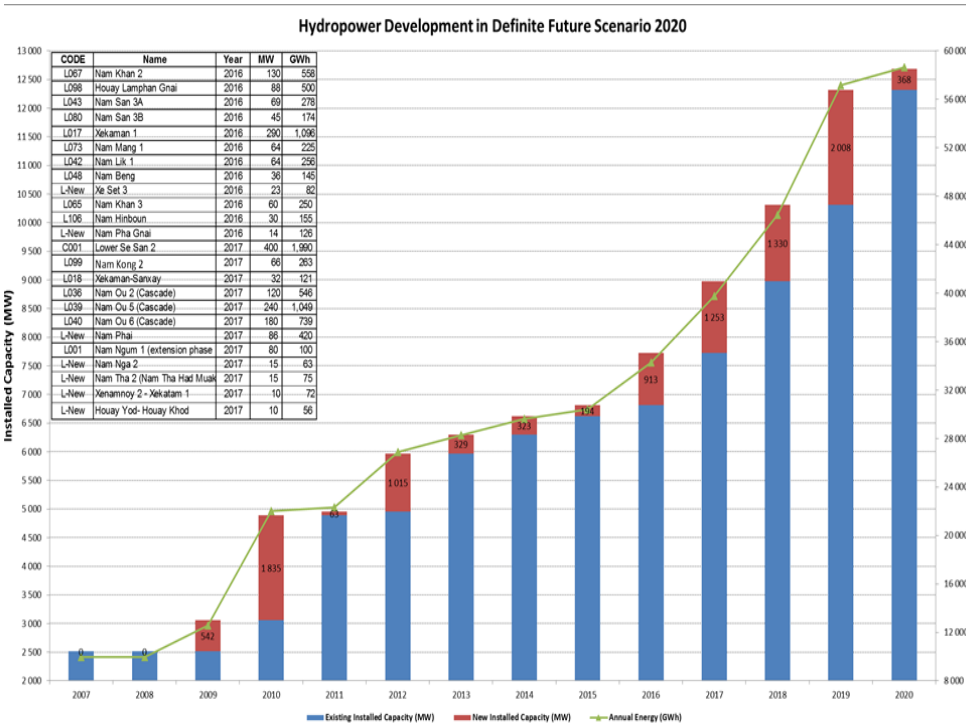
Assumptions and Considerations:

MS Dams

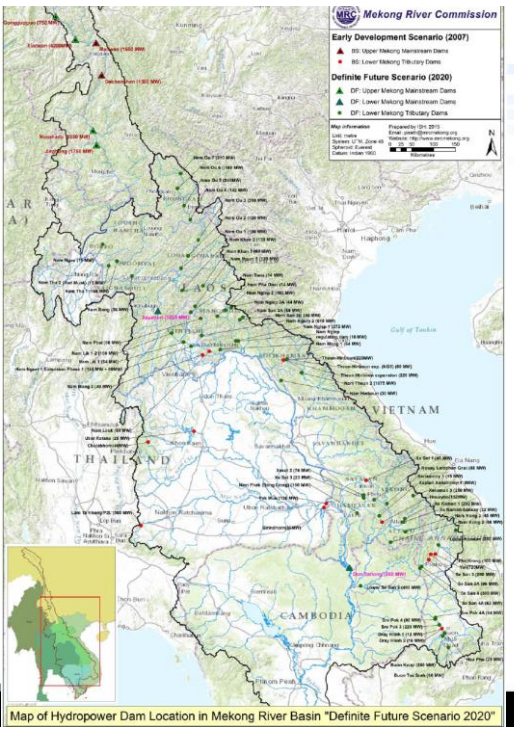
- Xayabury commercial operation is scheduled for 2019 and Don Sahong for 2018
- No other MS Dams before 2020

Tributary projects

- All projects scheduled to 2020 are included
- All Nam Ou projects (1 to 7) are included
- Projects with less than 10 MW not considered



CODE	Name	Year	MW	GWh
L067	Nam Khan 2	2016	130	558
L098	Houay Lamphan Gnai	2016	88	500
L043	Nam San 3A	2016	69	278
L080	Nam San 3B	2016	45	174
L017	Xekaman 1	2016	290	1,096
L073	Nam Mang 1	2016	64	225
L042	Nam Lik 1	2016	64	256
L048	Nam Beng	2016	36	145
L-New	Xe Set 3	2016	23	82
L065	Nam Khan 3	2016	60	250
L106	Nam Hinboun	2016	30	155
L-New	Nam Pha Gnai	2016	14	126
C001	Lower Se San 2	2017	400	1,990
L099	Nam Kong 2	2017	66	263
L018	Xekaman-Sanxay	2017	32	121
L036	Nam Ou 2 (Cascade)	2017	120	546
L039	Nam Ou 5 (Cascade)	2017	240	1,049
L040	Nam Ou 6 (Cascade)	2017	180	739
L-New	Nam Phai	2017	86	420
L001	Nam Ngum 1 (extension phase	2017	80	100
L-New	Nam Nga 2	2017	15	63
L-New	Nam Tha 2 (Nam Tha Had Muak	2017	15	75
L-New	Xenamnoy 2 - Xekatam 1	2017	10	72
L-New	Houay Yod- Houay Khod	2017	10	56



Map of Hydropower Dam Location in Mekong River Basin "Definite Future Scenario 2020"

Hydropower development in UMB / Chinese Dams by 2020

Project name	Commissioning Year	Installed Power (MW)	Average annual generation (GWh)
Previous table	Until 2015	17 120	69 361
Wunonglong	2016 - 2020	1 750	7 748 1)
Lidi	2016 - 2020	4 200	18 646 1)
Huangdeng	2016 - 2020	900	4 197 1)
Dahuaqiao	2016 - 2020	5 850	23 240 1)
Total		21 350	93 761

1) Data Not Found but calculated assuming plant factor about 50%

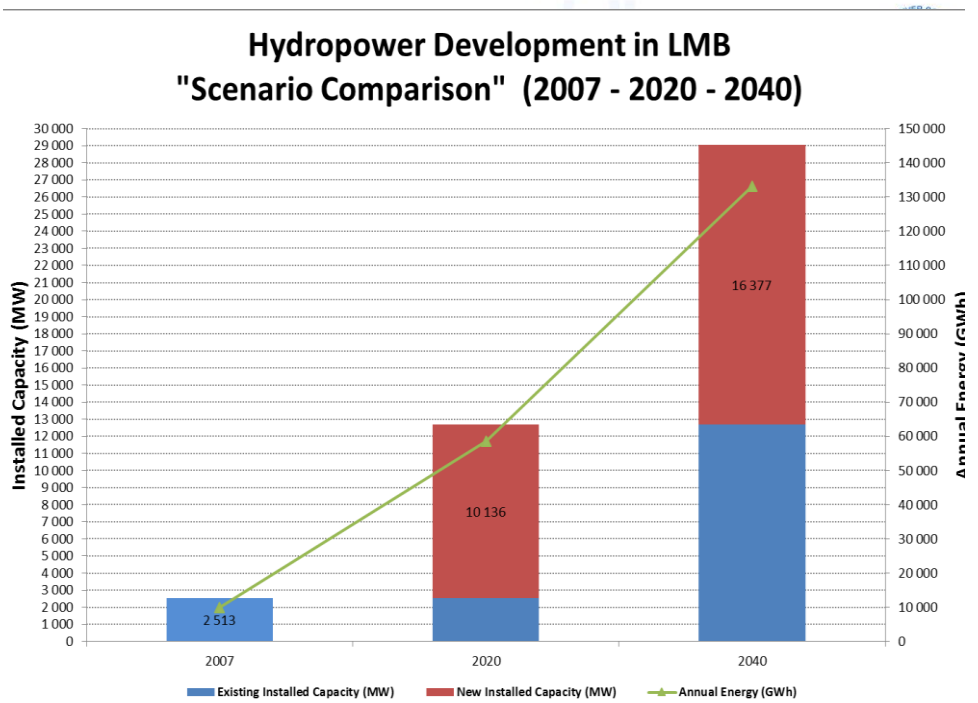
Hydropower Development in the period 2020 - 2040
Hydropower development in LMB

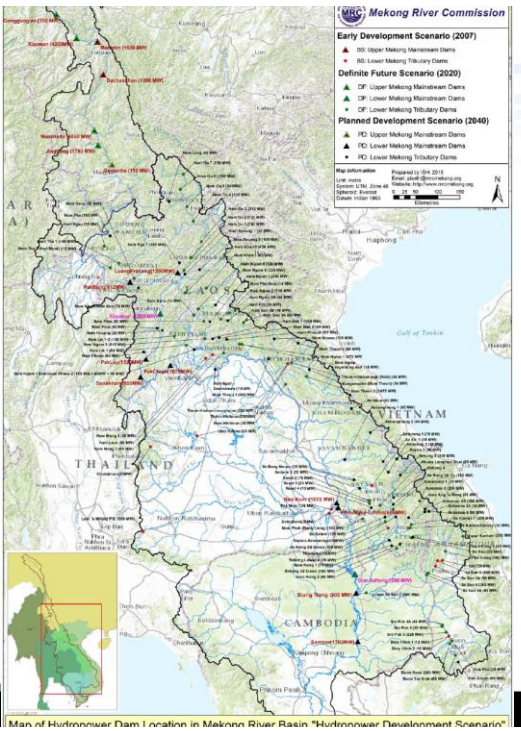
Assumptions and Considerations

- Both MS Dams and Tributary projects included
- Most ambitious plan as all identified projects were included
- Projects have reached different stages(MoU, FS, PDA, CA)

To note that:

- With further studies/optimisation MW / GWh figures may chage;
- Some projects may be delayed after 2040
- Some projects may be cancelled (costs or socio-economy)
- Projects with less than 10 MW not considered





Map of Hydropower Dam Location in Mekong River Basin "Hydropower Development Scenario"

Hydropower development in UMB / Chinese Dams by 2040

Project name	Commissioning Year	Installed Power (MW)	Average annual generation (GWh)
Previous table	Until 2020	21 350	93 761
Ganlanba	2020 - 2040	195	850 1)
Gushui	2020 - 2040	1 900	8 300 1)
Tuoba	2020 - 2040	1 400	6 000 1)
Total		24 845	108 911

1) Data Not Found but calculated assuming plant factor about 50%

Hydropower Development Sub-scenario 1 (HPS1)
Hydropower development in LMB

Assumptions and considerations

- HPS1 corresponds «5 Project Cascade incl. Pak Beng, Luang Prabang, Xayaburi, Pak Lay, Sanakham » and the tributary dams
- No joint operation, i.e. each dam designed and operated for maximized energy production
- «No joint operation»; energy losses because of sediment flushing, fish passages, navigation, water quality are not accounted for

Hydropower Development Sub-scenario 1 (HPS1)
Hydropower development in LMB

Main characteristics for MS Dams

Project name	Full Supply Level	Installed Power (MW)	Average annual generation (GWh)
Pak Beng	340	912	4 775
Luang Prabang	320	1 410	5 600
Xayaburi	275	1 285	7 400
Pak Lay	240	1 320	5 948
Sanakham	215	660	3 696
Pak Chom	192	1 079	5 318
Ban Koum	115	2 000	8 433
Phou Ngoy	97.5	800	2 751
Don Sahong	73	260	2 044
Stung Treng	52	900	5 096
Sambor	40	1 703	7 691

Projects with red ink are not expected to be developed before 2040

Hydropower Development Sub-scenario 1 (HPS1)
Hydropower development in LMB
Reasons for possible delay beyond 2040

Pak Chom; a transboundary project shared by Thailand and Lao, resettlement of a large number of people, project development in early stage with small progress.

Ban Koum; a transboundary project shared by Thailand and Lao, environmental and social conflicts (fishery, resettlement), project development in early stage with small progress.

Phou Ngoy; solely within Lao, about same dam height as for Ban Koum but longer dam (1 300 m versus 800 m), capacity smaller than for Ban Koum because much lower rated head and installed power (800 MW versus 2 000 MW), energy smaller than for Ban Koum (2 751 GWh versus 8 433 GWh), FS has been going on for some years and is still not finalized, environmental and social conflicts.

Stung Treng; solely within Cambodia, requires a long dam for a limited head, inundation of about 212 km^2, the reservoir length about 50 km, environmental and social conflicts (fishery, resettlement), further development reckommended to be delayed by 10 years in 2010 (in report authorised by MRC "Will Baxter: Cambodia most exposed dam threats").

Sambor; solely within Cambodia, requires a long dam for a limited head, capacity 2 600 MW requires 18 km long dam with more than 600 km^2 inundated area, capacity 1 703 MW requires more than 2 km long dam with more than 60 km^2 inundated area, environmental and social conflicts (fishery, resettlement), further development reckommended to be delayed by 10 years in 2010 (in report authorised by MRC "Will Baxter: Cambodia most exposed dam threats").

Hydropower Development Sub-scenario 1 (HPS1)
Hydropower development in LMB
General criteria for examination of tributary projects

The list of hydropower projects in Hydropower Development in the period 2020 – 2040 have been subject to an examination with regards to the following aspects a far as relevant data have been available:

- Transboundary projects
- High costs (above 8 US cent per kWh)
- Plant Factor less than 40%
- Social and environmental red flags
- Identified projects with MOU in Laos in the range of 10 -15 MW whereof estimated 50% will be realized
- The potential of unidentified projects, i.e. projects that will be identified and realized in the period 2016 – 2040
- Hydropower potential in Thailand's provinces in the Northeast (Chiang Rai, Chiang Mai and Phayao) of LMB
- Projects with installation < 10 MW being under the provincial jurisdiction in Lao are not included

Hydropower Development Sub-scenario 1 (HPS1)

Hydropower development in LMB
Summary of assumptions

Criteria	Capacity (MW)	Energy (GWh)
Hydropower Development in the period 2020 - 2040	16 377	74 679
Less MS Dams Pak Chom, Ban Koum, Phou Ngoy, Stung Treng, Sambor	6 482	29 289
Less some projects with plant factor below 40%	269	727
Less 50% of small hydro < 15 MW with MoU	390	1 500
Plus potential of unidentified projects	390	1 500
Plus potential in Thailand's provinces in the Norteast	60	200
Total	**9 686**	**44 863**

Preliminary considerations for HPP Thematic Sub-scenario HPS2

HPS2: Level of Development equal to HPS1 but with Joint Reservoir Operation and good coordination among all MS Dams and by taking into account operation for navigation lock, fish passages, sediment flushing as well as measures to maintain acceptable water quality during and after flushing. HPS2 corresponds to Option 1.3 "5 Project Cascade + Hydro Peaking" in the ISH 0306 Study.

In coordination with the ISH 0306 Study team the following aspects will be discussed in the Hydropower Thematic Assessment Report:

- Outage of energy production during sediment flushing
- Reservoir filling period after sediment flushing
- Periodical water flows for fish passages and associated loss of energy production
- Water abstractions for navigation and loss of energy

Evaluation of the effects of the above aspects will be based on interpretation of results from the model runs, when they are available.

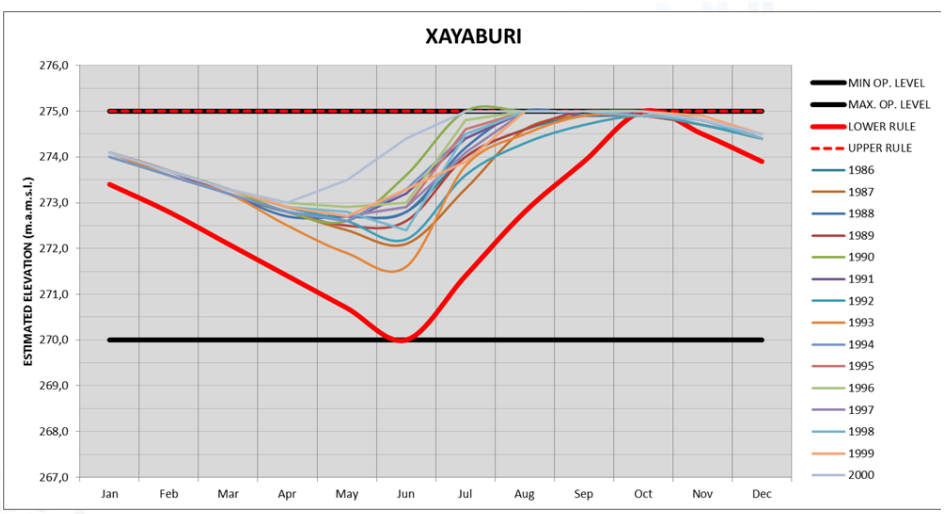
Preliminary considerations for HPP Thematic Sub-scenario HPS3

HPS3: With some basin wide Joint Operation and good coordination among all MS Dams and most tributary dams to strengthen flood management and flood protection measures throughout the LMB as well as to maximize navigation potential.

In coordination with the thematic teams for "Flood protection and floodplain infrastructure" and "Navigation" the following aspects will be discussed in the Hydropower Thematic Assessment Report:

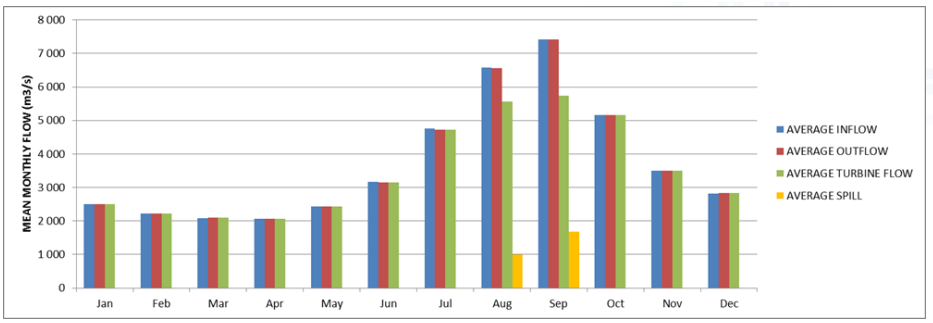
- Loss of energy production during reservoir drawdown because of measure taken by the authorities as a precaution to damp expected flood
- Loss of energy production because of water demands for navigation locks and navigation in reservoirs and river stretches

Observations on modelling of rule curves for operation LMB MS Dams, Case Xayaburi



IQQM model - Xayaburi simulated reservoir levels 1986 - 2000

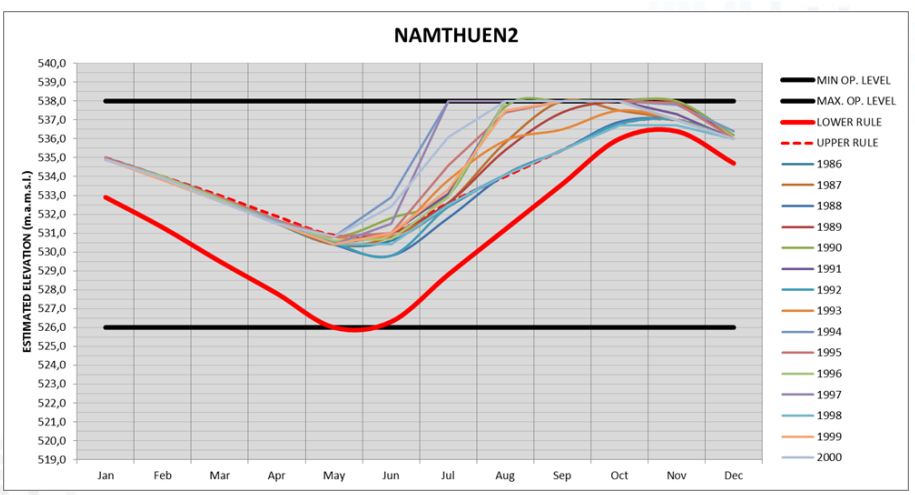
Observations on modelling of rule curves for operation LMB MS Dams, Case Xayaburi



IQQM model – Xayaburi inflow, outflow, turbine flow and spilling 1986 - 2000

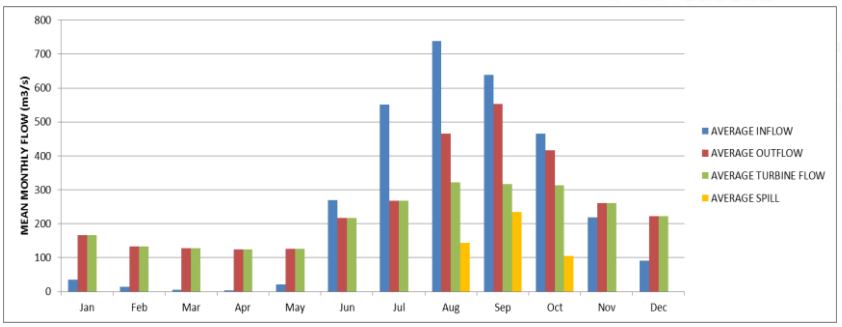
The spilling occurs in the high flow months August and September and it would probably happen in this magnitude even for higher reservoir water levels in the preceeding months. This is because the live storage of Xayaburi is so small that water volumes can only be stored for some few hours and not on a seasonal basis. It seems that the Lower Rule Curve should have been lifted in order to lift the reservoir level in the period January – June. By such model change the head would be increased and consequently the energy production. With such a limited reservoir when compared to the turbine discharge, the reservoir level in the period January – June can be lifted closer to FSL without risking spilling of water.

Observations on modelling of rule curves for operation LMB MS Dams, Case Nam Theun 2



IQQM model – Nam Theun 2 simulated reservoir levels 1986 - 2000

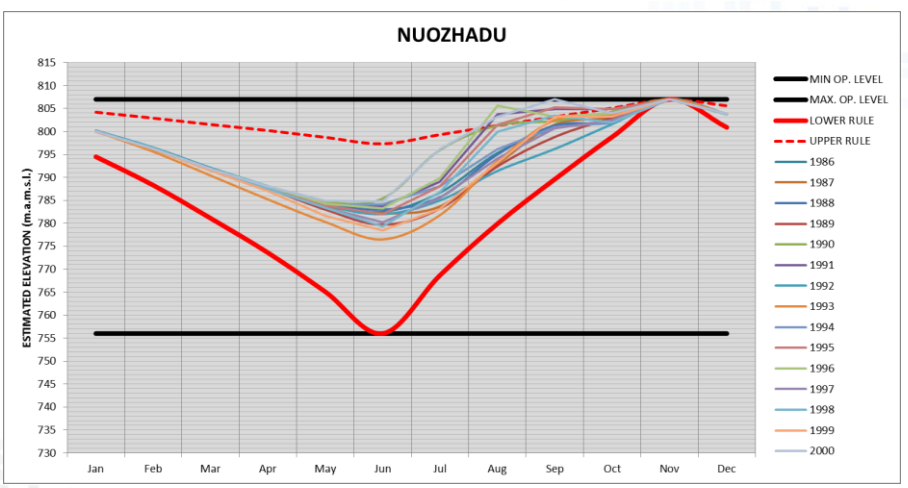
Observations on modelling of rule curves for operation LMB MS Dams, Case Nam Theun 2



IQQM model – Nam Theun 2 inflow, outflow, turbine flow and spilling 1986 - 2000

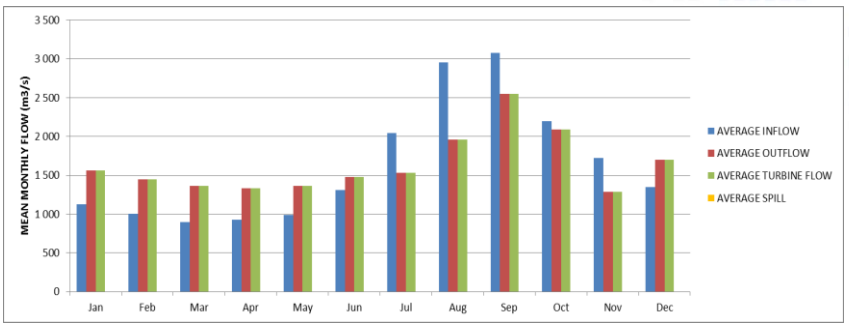
The spilling occurs in the high flow months August, September and October and amounts to close to 16% of the inflow. This is a rather high figure, and it can partly be explained by the simulated reservoir levels which show that the reservoir is not fully utilized. As Nam Theun 2 is a storage plant that can store 42% of the average yearly inflow, one should expect that the reservoir would be fully drained in June – July almost all years. The reduction in pressure head for MOL is only 3.4% of the maximum head, and this fact points towards better utilization of the reservoir to reduce the spilling.

Observations on modelling of rule curves for operation Chinese Dams, Case **NUOZHADU**



IQQM model – Nuozhadu simulated reservoir levels 1986 - 2000

Observations on modelling of rule curves for operation LMB MS Dams, Case **NUOZHADU**



IQQM model – Nuozhadu inflow, outflow, turbine flow and spilling 1986 - 2000

According to this figure there is no spilling. For the period January to July the reservoir water level is drawn down by 12 to 33 m, say in average 22 m, which represents about 10% headloss in relation to the max head of 210 m during the 6 months.
It seems that the Lower Rule Curve should have been lifted in order to lift the reservoir level in the period January – June. By such model change the utilized head would be increased and consequently energy production increased and spilling reduced.

The RTWG is requested to:

- Take note of the progress
- Provide guidance and if possible agree on the proposed mainstream and tributary dams included in development scenarios 2007, 2020, and 2040
- Provide guidance and if possible agree on the proposed mainstream dams included in Sub-scenario 1 (HPS#1) which include dams in the cascade upstream of Vientiane and Don Sahong
- Provide guidance and if possible agree that subs-scenarios HPS#2 and HPS#3 conceptually are based on alternative operations of the dams (i.e., joint operations)

Thank You