Draft

Mekong River Commission

Basin Development Plan Programme, Phase 2

Assessment of basin-wide development scenarios

Technical Note 2

Hydrological Assessment

(Work in Progress)

February 2010

Note to the reader

This series of technical notes is prepared to serve facilitation and discussion on the assessment of basin-wide development scenarios of the Mekong Basin by stakeholders in the basin countries. The assessment process is continuing and feedback on the initial findings is requested.

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List of Technical Notes

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Note: Technical note on Fisheries Assessment is being prepared. Only power point presentation is available

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Preliminary findings from hydrological assessment

1. Introduction

An assessment has been made of the hydrological implications of the scenarios in relation to the baseline conditions. This has been undertaken using the MRC's agreed suite of hydrological models known as the Decision Support Framework (DSF).

The baseline scenario used for comparison equates to water management infrastructure in the year 2000. Subsequent scenarios examine the impacts of new infrastructure and water demands coming into place. The scenario set-up data include dams, hydropower, irrigation command area expansion, cropping patterns and future domestic and industrial water supply demands at different points in the future. These data are consistent with the agreed scenario descriptions and have been agreed with each concerned country prior to being uploaded into the models. Particular attention has been given to the new dams in the upper Mekong Basin as these have a major influence on mainstream flows. Consultations have been held with expert counterparts in China to review the characteristics and operating rules and, where uncertainties exist, conservative assumptions have been made.

The results of the models have been analysed at 13 locations along the mainstream and Tonle Sap river, corresponding to the key monitoring stations. In addition, the extent of flooding and salinity intrusion has been assessed.

Hydrological analysis locations

CS	Chiang Sean
LP	Luang Prabang
CK	Chiang Khan
VT	Vientiane
NP	Nakhon Phanom
MH	Mukdahan
PS	Pakse
ST	Stung Treng
KT	Kratie
PD	Prek Dam
KPL	Kampong Luong
TC	Tang Chau
CD	Chau Doc

The scenarios consider the implications of progressively larger developments of hydropower in the basin (in the upper basin and in the mainstream and tributaries of the lower basin) and of irrigation development. Compared to the conditions in the year 2000 baseline, the amount of storage in the basin is expected to increase 240% with completion of the dams in the upper basin, and by 379% when dams under implementation in the LMB are completed (the Definite Future situation by approximately 2015). In the 20-year foreseeable future situation, total storage would increase by a further 50-57% compared to the Definite Future Scenario and representing a total increase from the baseline of c.650%.

Active storage

Scenario	Active storage MCM	Increase over BS	Increase over DF
Baseline situation			
1000 BS	9,648		
Definite future situation			
2000 2015-UMD	32,841	240%	
3000 2015-DF	46,257	379%	
Foreseeable future situation			
4000 2030-20Y	72,473	651%	57%
5000 2030-20Y-w/o MD	69,317	618%	50%
6000 2030-20Y-w/o LMD	71,425	640%	54%
6100 2030-20Y-w/o TMD	71,853	645%	55%

The total storage under the Definite Future Scenario will equate to 10% of the basin's mean annual runoff (MAR) of 475 billion cubic metres. The further storage development anticipated in the 20-year Foreseeable Future situation would increase the total storage to 15% of the MAR.

Irrigation, being the major consumptive demand in the LMB, is also expected to increase and under the 20-Year Plan Scenarios an expansion of some 50% in command area in the LMB is investigated with a 68% increase in the amount of water diverted, rising from 12% to 20% of the MAR. It may be noted that nearly all of this growth is in the three countries upstream of Viet Nam.

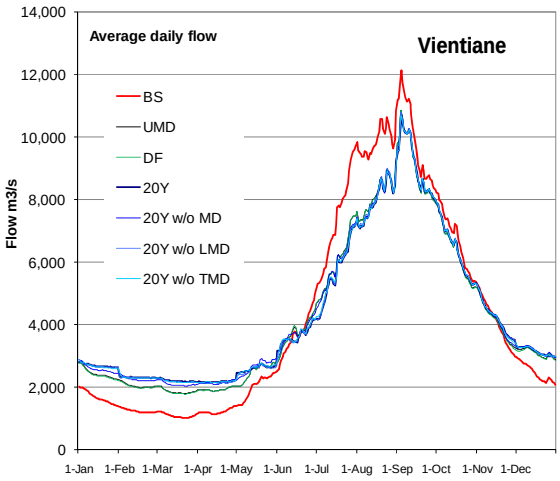
Irrigation development '000ha

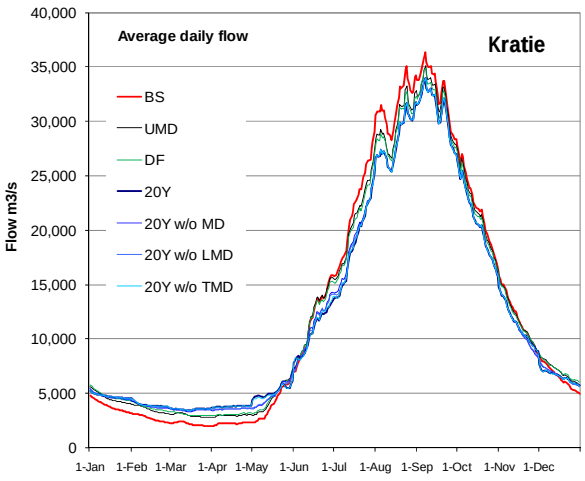
Scenario	Definite Future	20-Year Plan	Increase
Lao PDR	166	451	171%
Thailand	1,412	2,718	93%
Cambodia	504	778	54%
Viet Nam	1,920	2,045	7%
Total	**4,002**	**5,993**	**50%**

Initial assessments have been made on the impact of the scenarios on dry season flow, on water levels, reverse flows into Tonle Sap and on the extent of flooding and saline intrusion. Further more detailed assessments will be presented in the Hydrological Assessment Report in due course.

2. Impacts on flows and water levels

Daily data have been extracted for the flows in each scenario at each of the 13 monitoring sites and compared. As illustrated here at Vientiane and Kratie, the impact of all scenarios is the increased dry season flows and decreased flood peaks in the wet season.





In terms of seasonal flows, it is observed that most of these changes will occur under the Definite Future Scenario due to operation of large two storage hydropower dams in Upper Mekong Basin with active storage about 22,200 MCM (Xiawan and Nuozhadu). Only minor further changes occur from this to those under the 20-year Foreseeable Future situation.

At Vientiane, the dry season flow volume in the Definite Future Scenario is simulated to increase by 41% from the baseline and further more 10% under the 20-Year Plan Scenarios with additional tributaries and mainstream dams in the LMB as well as increased irrigation including intra-diversion of Mekong flow to northeast of Thailand. The water level in April is predicted to increase about 1.2m in near future and raise more 0.4m in the next 20 years.

Vientiane	BS	UMD	DF	20Y	20Y w/o MD	20Y w/o LMD	20Y w/o TMD
	Average season flows (BCM)						
Dry season (Dec-May)	**25.7**	**36.6**	**36.3**	**39.9**	**39.3**	**39.6**	**39.8**
Change from BS %	-	*42%*	*41%*	*55%*	*53%*	*54%*	*55%*
Change from DF %	-	-	-	*10%*	*8%*	*9%*	*9%*
Wet season (Jun-Nov)	**110.4**	**99.3**	**99.2**	**98.3**	**99.0**	**98.7**	**98.4**
Change from BS %	-	*-10%*	*-10%*	*-11%*	*-10%*	*-11%*	*-11%*
Change from DF %	-	-	-	*-1%*	*0%*	*0%*	*-1%*
	Average monthly water levels (m)						
April	**0.65**	**1.85**	**1.85**	**2.21**	**2.16**	**2.16**	**2.20**
Change from BS m	-	*1.2*	*1.2*	*1.6*	*1.5*	*1.5*	*1.5*
Change from DF m	-	-	-	*0.4*	*0.3*	*0.3*	*0.4*
Sept	**8.31**	**7.89**	**7.89**	**7.89**	**7.89**	**7.91**	**7.89**
Change from BS m	-	*-0.4*	*-0.4*	*-0.4*	*-0.4*	*-0.4*	*-0.4*
Change from DF m	-	-	-	*0.0*	*0.0*	*0.0*	*0.0*

Kratie	BS	UMD	DF	20Y	20Y w/o MD	20Y w/o LMD	20Y w/o TMD
	Average season flows (BCM)						
Dry season (Dec-May)	**56.9**	**67.7**	**69.6**	**72.8**	**71.3**	**71.8**	**72.5**
Change from BS %	-	*19%*	*22%*	*28%*	*25%*	*26%*	*27%*
Change from DF %	-	-	-	*5%*	*2%*	*3%*	*4%*
Wet season (Jun-Nov)	**349.4**	**338.5**	**334.6**	**319.6**	**321.2**	**320.7**	**319.9**
Change from BS %	-	*-3%*	*-4%*	*-9%*	*-8%*	*-8%*	*-8%*
Change from DF %	-	-	-	*-4%*	*-4%*	*-4%*	*-4%*
	Average monthly water levels (m)						
April	**6.24**	**7.03**	**7.15**	**7.81**	**7.60**	**7.61**	**7.81**
Change from BS m	-	*0.8*	*0.9*	*1.6*	*1.4*	*1.4*	*1.6*
Change from DF m	-	-	-	*0.7*	*0.5*	*0.5*	*0.7*
Sept	**18.59**	**18.36**	**18.28**	**18.12**	**18.12**	**18.13**	**18.12**
Change from BS m	-	*-0.2*	*-0.3*	*-0.5*	*-0.5*	*-0.5*	*-0.5*
Change from DF m	-	-	-	*-0.2*	*-0.2*	*-0.2*	*-0.2*

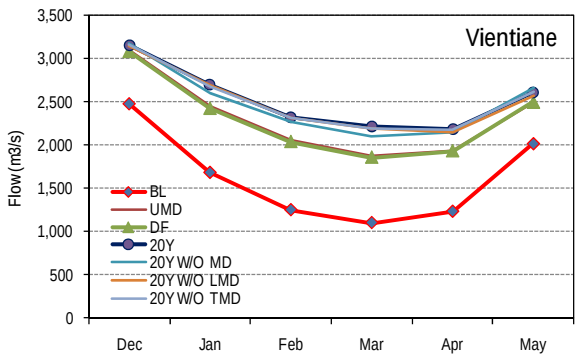
Likewise, average wet season flow volumes and water levels are reduced from the baseline by 10% (or 0.4m) in the Definite Future Scenario, and very small further reduction in any of the Foreseeable Future scenarios.

Changes in flow regime reduce gradually along the Mekong mainstream due to additional flows from tributaries. At Kratie, in next 5 years the dry season flow volume is estimated to increase by 22% and average wet season flow volumes is considered to decrease by 4% from the baseline and only be a further 5% increase in dry season and a further 4% decrease in wet season under the 20-Year Plan Scenario. Similarly, water levels in April will increase by 0.9m from the baseline and water levels in September are reduced by 0.3m in the Definite Future Scenario, and by little more in any of the 20-Year Plan Scenarios.

Small percentage differences are found in both wet and dry season flows and water levels when the results between 20-Year Plan Scenarios with and without mainstream dams in the LMB are compared. The reason of this finding is that all planned LMB mainstream dams are currently designed as run-of-river dams with small storage reservoirs. **Therefore, it may be understood that the development of hydropower mainstream dams in the LMB would not significantly redistribute water from the wets season to the dry season.**

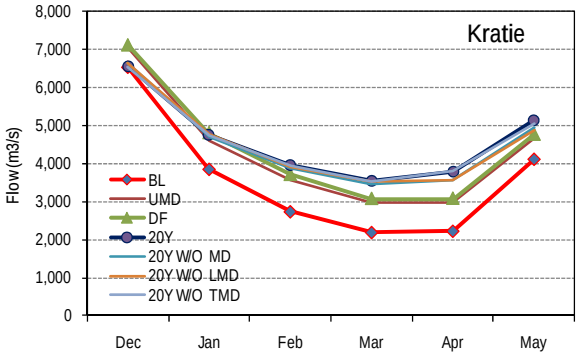
3. Average monthly dry season flows

Data have been extracted for the flows in each scenario at each of the 13 monitoring sites and the average flows for each dry season month (Dec-May) have themselves been averaged over the 15 years (1986-2000) simulated and compared with average monthly flows of the baseline.

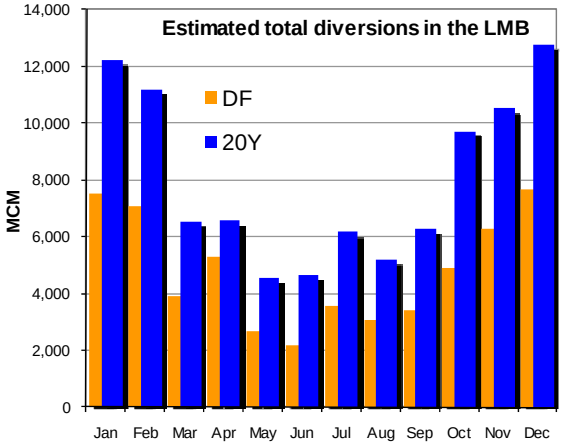


The pictures at Vientiane and Kratie are

consistent with all the remaining 11 stations and show that in all months of the dry season the scenarios demonstrate a significant increase in flows above the baseline, especially in March and April which are the driest months.



It may be noted that evidently much of this increase stems from the increased storage in the Definite Future Scenario and that the change in flow regime from this scenario to those in the Foreseeable Future is less pronounced. This is because, although there is a substantial increase in irrigation demands and diversions in the Foreseeable Future situation, the additional storage included in the LMB tributaries in the 20-Year Plan Scenario more than offsets this. A similar picture emerges when average daily flows are considered.



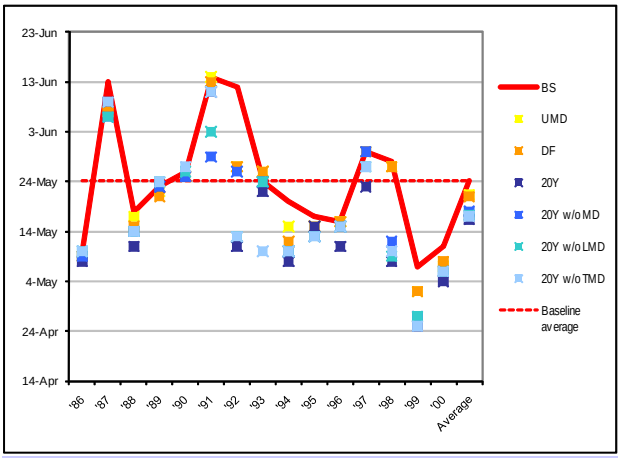
More detailed assessments have been made, focusing on the transitions between the wet and dry season. In early December, daily water levels at Tan Chau station are predicted to be below the baseline by typically 5cm. This situation however occur less than 20% of time considered (< 6 days) in December. At end of the dry season during May, similar circumstances arise right at the end of the month. **With minor adjustments to upstream reservoir operating rules, these small deficits could possibly be removed**.

Nevertheless, the picture that emerges is that with the developments as set out in the scenarios, in all cases the average monthly flows in the dry season will be exceeded.

4. Reverse flow of the Tonle Sap

Flow reversal occurs in the Tonle Sap River when floods rise in the mainstream and levels there exceed those in the Tonle Sap lake, causing the river to reverse its flow into the lake. As the mainstream floods recede and levels fall there comes a point when the levels in the lake exceed those in the mainstream and normal flows resume. Two analyses have been

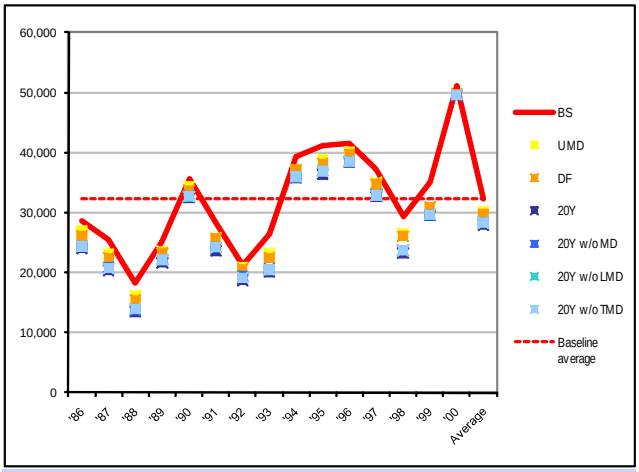
Start date for flow reversal



	BS	UMD	DF	20Y	20Y w/o MD	20Y w/o LMD	20Y w/o TMD
Average start date	24-May	21-May	21-May	16-May	18-May	17-May	17-May
Days earlier	0	3	3	8	6	7	7
Max-min start date	38	43	42	47	40	40	47
Range increase (days)	0	5	4	9	2	2	9

conducted on flow reversal at the Prek Dam monitoring site. The first is to determine the likely impacts on the timing of when flow reversal occurs and the second is to assess changes in flow volume. Both parameters are of relevance to environmental conditions in the lake, particularly with respect to fisheries productivity.

Volume of flow reversal MCM



	BS	UMD	DF	20Y	20Y w/o MD	20Y w/o LMD	20Y w/o TMD
Average volume	32,259	30,145	29,740	27,993	28,358	28,339	28,340
Change from BS	0%	-7%	-8%	-13%	-12%	-12%	-12%
Max-min volume	32,950	33,530	34,286	36,065	35,833	35,633	35,631
Range increase (MCM)	0%	2%	4%	9%	9%	8%	8%

Normally, the reverse flows start in mid May and finish in mid September. The dates of when flow reversal occurs have been abstracted for each year for each scenario and averaged. In comparison to the baseline, reversal occurs slightly earlier in each scenario, but only by typically 3 days under both the Definite Future Scenario (within a natural range of +/-19 days) and by typically 6-8 days under 20-Year Plan Scenarios, both with all mainstream dams and with no or fewer mainstream dams.

In general the scenarios increase the variability of the start date, from +/- 19 days in the baseline up to between +/- 21 and +/- 24 days, for the Definite Future Scenario and 20-Year Plan Scenario with all mainstream dams, respectively. A similar analysis has been conducted on the average volume of flow that occurs each year during the flow reversal period (see overleaf). The results are that under all scenarios there is a predicted decrease in flow reversal volume of 7-8% rising to 12-13% in the 20-Year Plan scenarios.

Kampong Luong	BS	UMD	DF	20Y	20Y w/o MD	20Y w/o LMD	20Y w/o TMD
	Average monthly water levels (m)						
April	**1.55**	**1.63**	**1.63**	**1.68**	**1.66**	**1.67**	**1.67**
Change from BS m	-	*0.08*	*0.08*	*0.13*	*0.10*	*0.12*	*0.12*
Change from DF m	-	-	-	*0.05*	*0.02*	*0.04*	*0.04*
October	**8.31**	**8.15**	**8.08**	**7.91**	**7.93**	**7.93**	**7.93**
Change from BS m	-	*-0.15*	*-0.22*	*-0.39*	*-0.38*	*-0.38*	*-0.38*
Change from DF m	-	-	-	*-0.17*	*-0.16*	*-0.16*	*-0.16*

The simulated water levels at Kampong Luong station show that in April, water levels in the Tonle Sap lake will increase only by 8 cm in Definite Future Scenario due to the incresease of dry season flow along mainstream and further more 2-5 cm in the 20-Year Plan scenarios. In the peak month (Octorber), the average water levels in next 5 and 20 years are estimated to decrease by 22 and 39 cm from the baseline, respectively.

The picture that emerges from these assessments is that higher water levels predicted in the mainstream at the end of the dry season will cause flow reversal to occur slightly earlier with a net reduction in the inflows to the lake.

5. Average daily peak flows

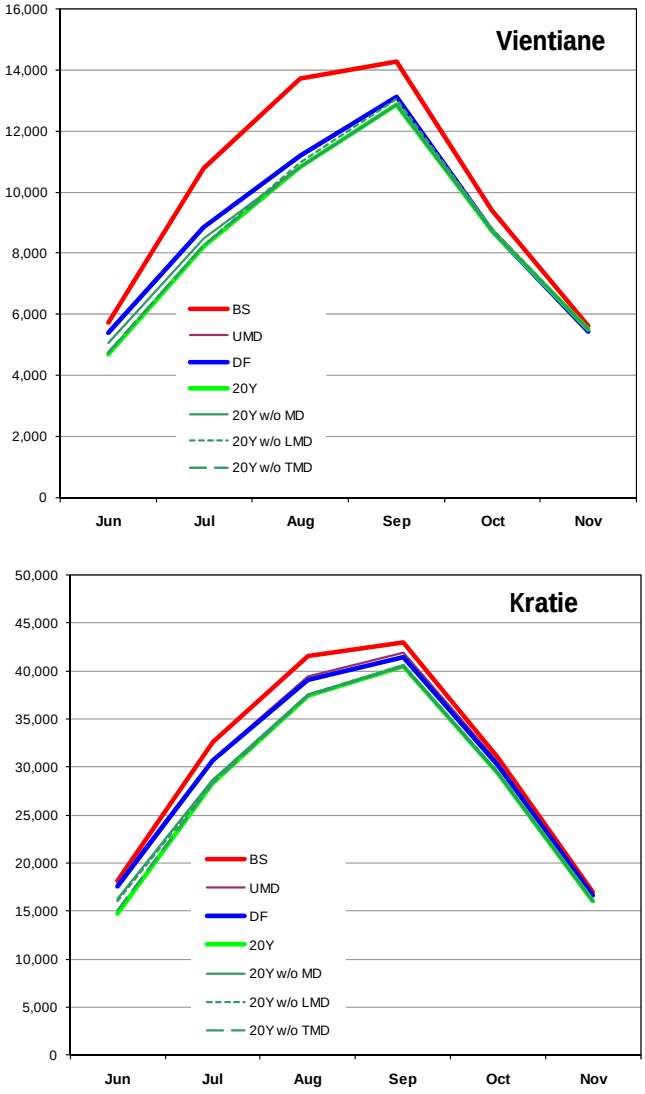
Average daily peak flows have been estimated for all scenarios by abstracting the peak daily flow in each month of the wet season (June-Nov) for the 15 years simulated and calculating the average of these for each scenario.

At Vientiane, the peak flow in September is calculated to reduce by 1,053 m3/s (0.64m) in the Definite Future Scenario and small reduce further more 244 m3/s (0.18m) in the Foreseeable Future scenarios.

Likewise, the picture at Kratie in the peak month of September, peak flows are typically reduced by 1,490 m3/s (0.33m) and 912 m3/s (0.20m). Those pictures are similar to all other mainstream stations wherein there is a predicted reduction in average daily peak flows in each month[1].

In the case of the Tonle Sap river, the impacts on daily peak flows during the wet season are that there will be an increase in the flow reversal period but a decrease in the outflow months.

Average daily peak flows in each wet season month at Vientiane and Kratie for different scenarios



Thus the assessments demonstrate in the mainstream that not only will average monthly flows in the wet season decrease but also so will the average daily peak flows in each month.

[1] There is one very minor exception seen in the results at Luang Prabang where under the 20-Year Plan scenarios the average daily peak flow for September is predicted as less than 1% above that of the baseline, which is well within the accuracies associated the models.

6. Flooded areas

Flooding occurs principally in the delta area, on the Cambodian flood plain and around Tonle Sap Lake. These areas are modelled explicitly in the DSF. This assessment focuses on areas where flooding occurs from the Mekong mainstream, such as Songkram floodplain in Thailand, Vientiane flood plain in Lao PDR, Cambodia and Viet Nam floodplain in Mekong Delta. In other areas such as Chi and Mun rivers in Thailand and Se Kong rivers in Lao PDR, flooding is not a transboundary issue and therefore not considered in this scenario assessment. The reason is that flooding of areas in these river basins is caused by upstream tributaries which are fully located in one country and the impact of the flooding has no transboundary effects,

The assessments include all areas known to flood. Whilst those downstream of Kratie can be modelled with fair confidence, those upstream of Kratie are based on estimates related only to changes in estimated discharges of the concerned river or tributary.

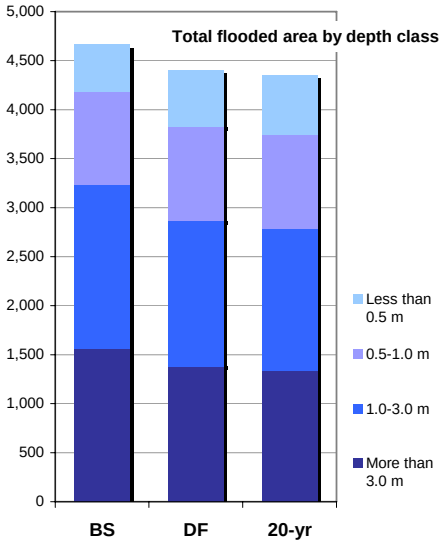
Estimates of the extent of flooding have been prepared for three scenarios as shown below. These demonstrate **an overall 7% reduction in flooded area (309,000 ha)** for the Foreseeable Future Scenario compared with the baseline in average year. The reduction areas are expected to be smaller in wet year and larger in dry year. The greatest area of reduction occurs in Cambodia (142,000ha), whereas the greatest proportions are seen in Lao and Thailand (17% and 19% reduction respectively). Interestingly, most of these reductions occur as a result of developments included in the Definite Future Scenario, with only very small changes (<2%) between this scenario and the Foreseeable Future Scenario.

Flooded area assessments '000 ha

Baseline	Lao	Thailand	Cambodia	Vietnam	Total
Less than 0.5 m	18	17	142	307	484
0.5-1.0 m	25	24	228	668	945
1.0-3.0 m	82	89	708	794	1,673
More than 3.0 m	270	232	1,055	5	1,562
Totals	**395**	**363**	**2,133**	**1,773**	**4,664**

Definite Future Scenario	Lao	Thailand	Cambodia	Vietnam	Total
Less than 0.5 m	16	18	175	374	582
0.5-1.0 m	18	21	205	712	957
1.0-3.0 m	69	79	673	666	1,487
More than 3.0 m	223	176	977	3	1,380
Totals	**326**	**294**	**2,029**	**1,756**	**4,405**
Reductions from baseline	17%	19%	5%	1%	6%

20-year Foreseeable Future	Lao	Thailand	Cambodia	Vietnam	Total
Less than 0.5 m	18	19	177	395	609
0.5-1.0 m	18	21	208	717	963
1.0-3.0 m	69	77	664	634	1,444
More than 3.0 m	223	170	943	3	1,339
Totals	**329**	**287**	**1,991**	**1,748**	**4,355**
Reductions from baseline	17%	21%	7%	1%	7%
Change from Definite Future	**1%**	**-2%**	**-2%**	**0%**	**-1%**



7. Salinity intrusion

Another important issue is the impact on **saline intrusion** in the Mekong delta in Viet Nam. Saline intrusion occurs naturally each year in various branches of the Mekong as a result of combination of sea water and freshwater flows from the upstream reaches. The stronger the freshwater flows, the less salinity intrudes. In the dry season, salinity levels in the river channels are raised up to typically about 80km inland from the coast. The DSF models are able to predict how the extent of saline intrusion will change in these channels under the different scenarios.

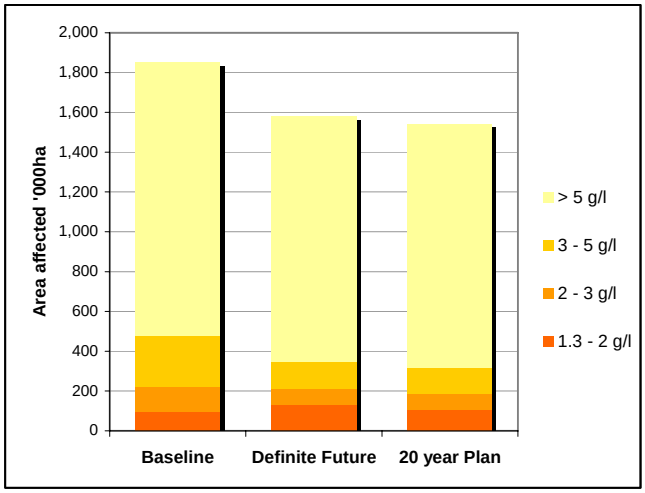
Assessments have been made for the three main scenarios thus far (Baseline, Definite Future and 20-Year Plan). These show that the area potentially affected by salinity levels[2] in excess of 1.3g/l in average year (taken as 1999) are reduced by 15% (272,000 ha) in the Definite Future Scenario and by a further 2% (36,000 ha) under the 20-Year Plan Scenarios.

The simulated results also show that the extension of salinity intrusion will reduce 5-10 km due to increase in dry season flow. However, it is found that in some areas that are far away from the main rivers, daily salinity concentration is possible to small increase above the baseline especially in February and June.

Salinity intrusion concentration in Average year (1999)

'000ha

	Salinity concentrations				Total	Percent
	1.3 - 2 g/l	2 - 3 g/l	3 - 5 g/l	> 5 g/l	area	change
Baseline	94	129	257	1,372	1,851	0%
Definite Future	128	87	131	1,234	1,579	15%
20 year Plan	105	82	131	1,225	1,543	17%



[2] It should be noted that the areas quoted are computed as being within the salinity contours by reference to predicted salinity levels in the river channels. The land areas between the channels are serviced by off-takes at various points along the channels, which allow a degree of control over the salinity levels within the enclosed land. Thus the salinity recorded on the enclosed land may differ from that implied by the map. Hence the areas above are referred to as potentially affected.

8. Conclusions

The conclusions that can be drawn from the above assessments are summarised below.

- **Dry season flows (Dec-May):** All scenarios increase the dry season flows above the baseline, with most of this arising from the Definite Future scenario and further addition from the Foreseeable Future Scenario in next 20 Year. The increasing declines gradually from upstream to river mouth.

- **Wet season flows:** All scenarios reduce average flow and daily peak water levels in the wet season. Again, most of this reduction occur from the Definite Future scenario and little additional decrease from the Foreseeable Future Scenario.

- **Reverse flow in the Tonle Sap river** is also maintained in all scenarios but occurs a few days earlier and in slightly reduced volume and water level in the lake.

- **Flooding and saline intrusion**: All scenarios reduce the extent of wet season flooding and dry season saline intrusion. Most of the change will occur as a result of the Definite Future Scenario.

- **Impacts of Definite Future Scenario**: The impacts of the Definite Future Scenario, when compared to those of other scenarios, demonstrate that the construction of dams currently under implementation especially large two storage hydropower dams in China (Xiawan and Nuozhadu) will have a substantial effect on the natural flow regime of the mainstream by increasing dry season flows and decreasing flood flows and salinity intrusion. By their nature as “firm” projects, these changes will be irreversible.

- **Impacts of Foreseeable Future Scenarios**: The impacts of the foreseeable future scenarios, both with and without mainstream dams, are broadly similar and represent only a small further changes from the Definite Future Scenario. Under the Foreseeable Future Scenarios, the presence of mainstream dams causes only very small further changes to the overall flow patterns at a regional scale.

- **Overall, the assessments demonstrate that the increased storage currently being constructed in the Basin, together with the storages that are planned in the 20-Year Plan scenarios will compensate for the increased abstractions planned over this same period.**

- **In addition, the assessments demonstrate that the impact of the considered mainstream dams in the LMB, at a regional scale, have very minor incremental impact on the mainstream flow regime compared with the inevitable flow changes that will be caused by the Definite Future Scenario (over the next five years). Although, the LMB mainstream dams would not redistribute flow from the wet season to the dry season, their operation may cause significant daily flow fluctuations, which need to addressed beyond this scenario assessment.**