4.5 Scenario Simulations

4.5.1 NT2 Impact Simulations

The NT2 impacts on the Tonle Sap system were simulated by substituting the Kratie input hydrograph from baseline to the post-NT2 hydrograph for Kratie. Figure 14 shows the Kratie hydrographs for the baseline situation and for the post-NT2 situation. The latter is the result of simulations with MikeBasin, as accounted for in Section 3.1.2. Only a small time window is shown in order to make the difference more visible, since the difference is very small in proportion to the actual discharge.

Figure 15 shows the simulated post-NT2 water levels in Tonle Sap. For clarity, only a three-year time window is shown. Figure 16 below shows the difference between the post-NT2 water levels and the baseline situation, i.e. the net impact due to NT2. It is seen that in September 1969, when the water level peaks at around 7.5 masl, there is a water level reduction of 8 cm due to NT2. The following two years, the reduction of the maximum water level are smaller, only 5 and 3 respectively. Figure 35 shows the difference for the entire 50 years simulation period. It is seen that there is a very large variation of the impact from year to year.

Figure 17 shows a summary plot of the NT2 impact on the lake level. The figure shows, that in September, the *mean reduction of the lake level will be 3-4 cm*. In 10 % of the years however, the reduction may exceed 6 cm.

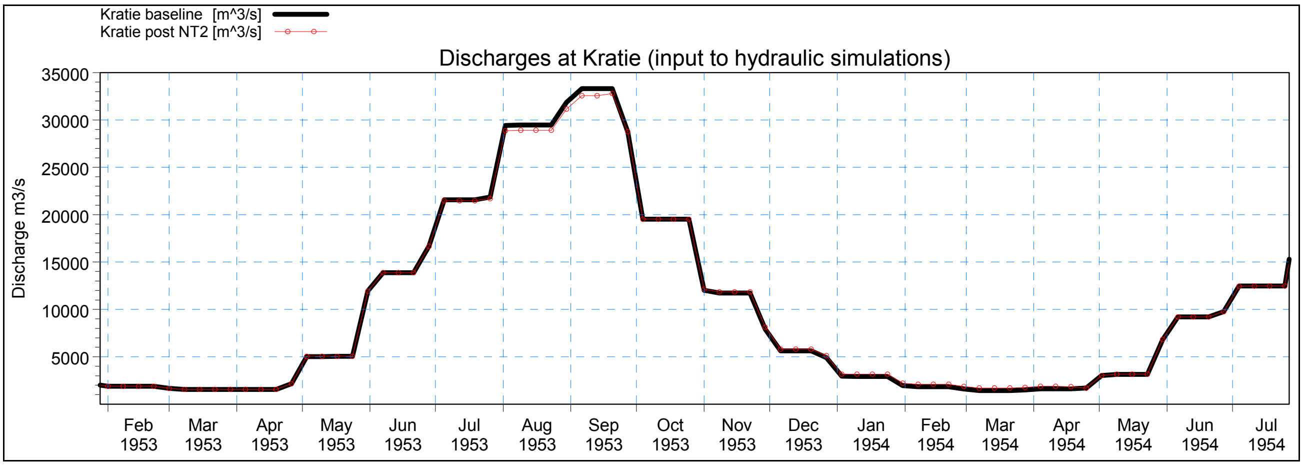

Figure 14 Input to hydraulic simulations, discharge at Kratie. Baseline and post-NT2

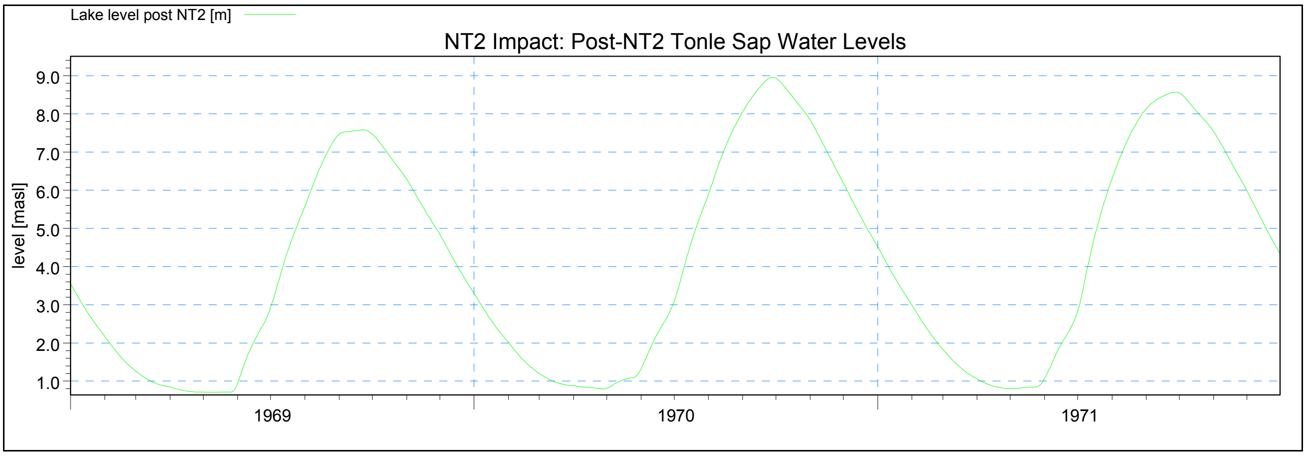

Figure 15 Daily Simulated Tonle Sap water level: Post-NT2.

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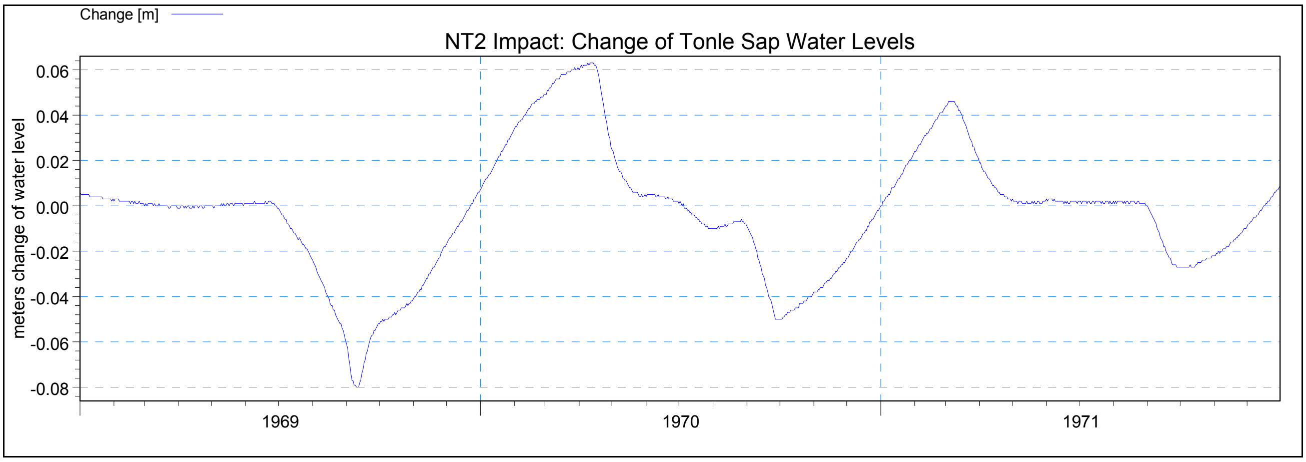

*Figure 16 NT2 impact on Tonle Sap lake levels: Simulated **change** of lake level (post-NT2 minus baseline). Negative figures means reduced level. Should be related to Figure 15.*

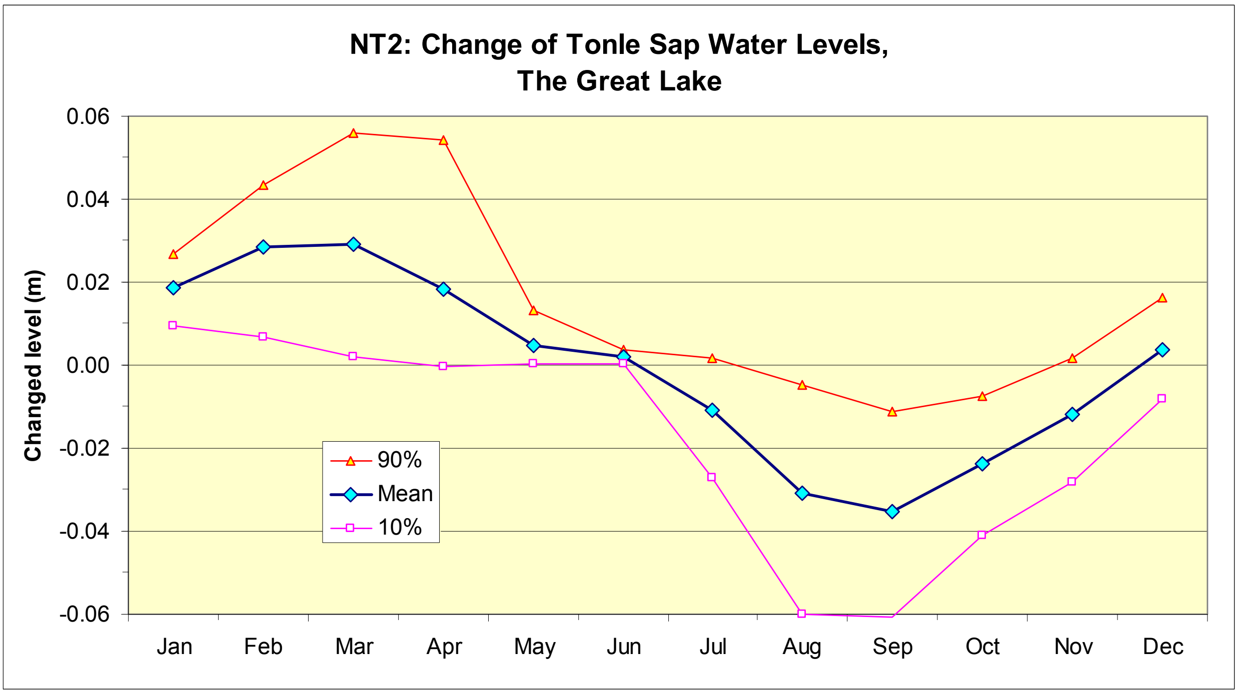

Figure 17 Summary of simulations 1950-2000 of NT2 impacts on Tonle Sap lake levels. Mean, 10% and 90% percentiles of 50 years of simulations.

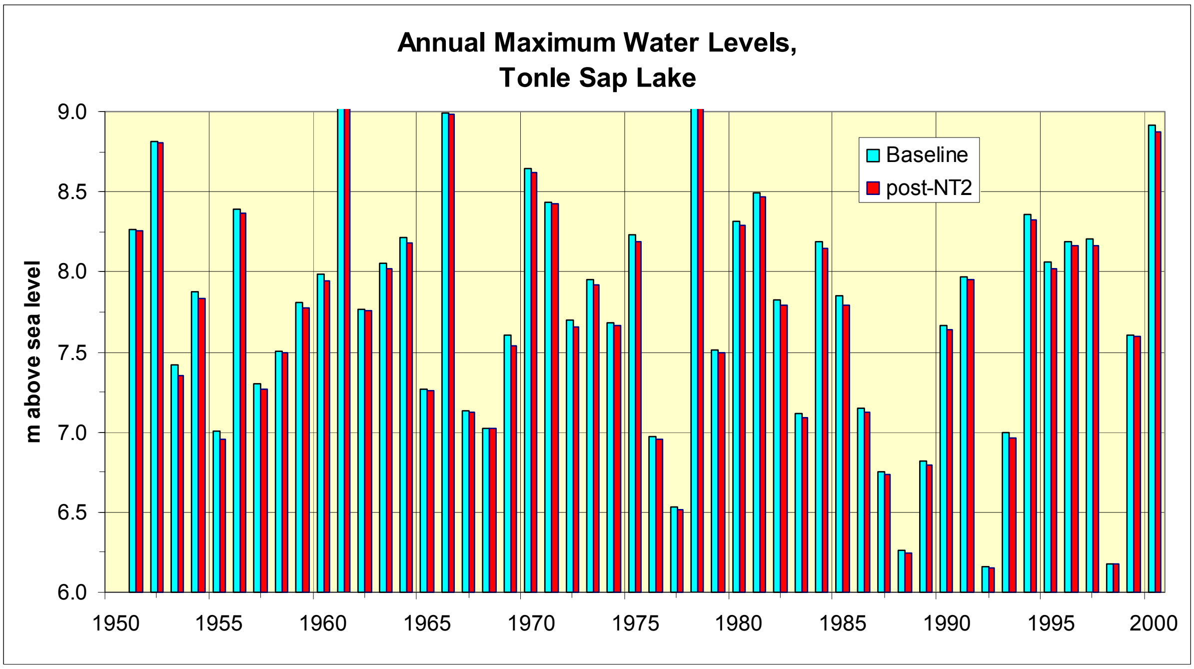

Figure 18 Annual Maximum Water Level, Tonle Sap. Baseline and post-NT2.

4.5.2 Cumulative Impacts 2010 and 2025

Input to the hydraulic simulations were the results from the MikeBasin water balance simulations in terms of the discharge at Kratie, which is shown as Figure 19. The hydraulic model simulated the response of the Tonle Sap/Mekong system due to the changed upstream conditions. The resulting simulated water levels of Tonle Sap are shown as Figure 20 for a three-years time window together with the baseline simulation.

As a summary of the simulation results, Figure 21 shows the impact variation over the average year of the 50 years of simulations. The annual maximum lake level (October-September) is reduced by around 20-25 cm in 2010 and by 55-60 cm in 2025. It should be noted that the impacts are largest in September, but the lake level is highest more often in October than in September.

Table 4 gives a summary of the most essential impacts as results of NT2, Cumulative Impacts 2010 and 2025, respectively.

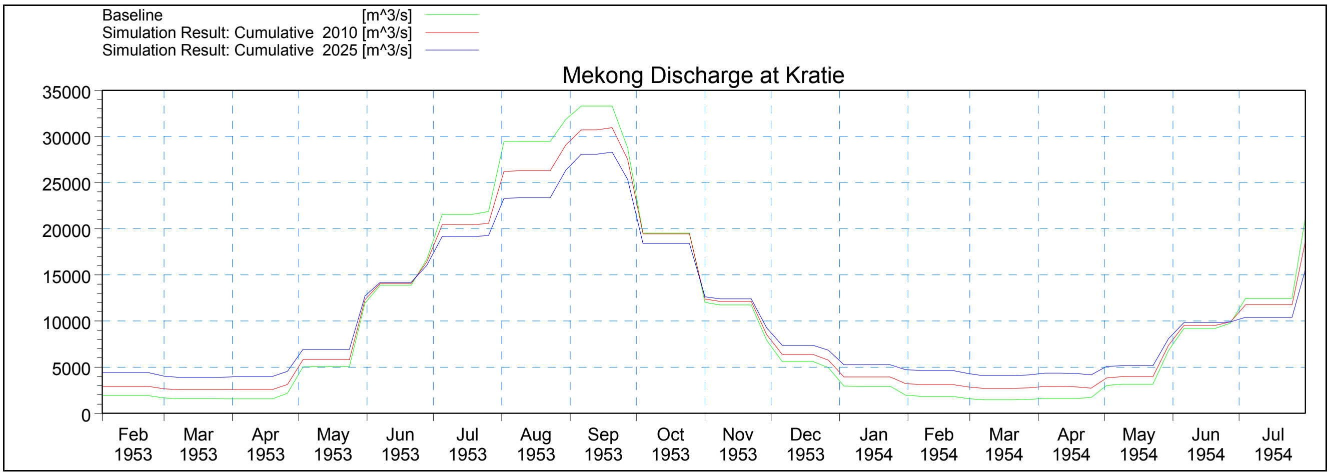

Figure 19 Input to hydraulic simulations: Discharge at Kratie as a result of cumulative impacts 2010 and 2025.

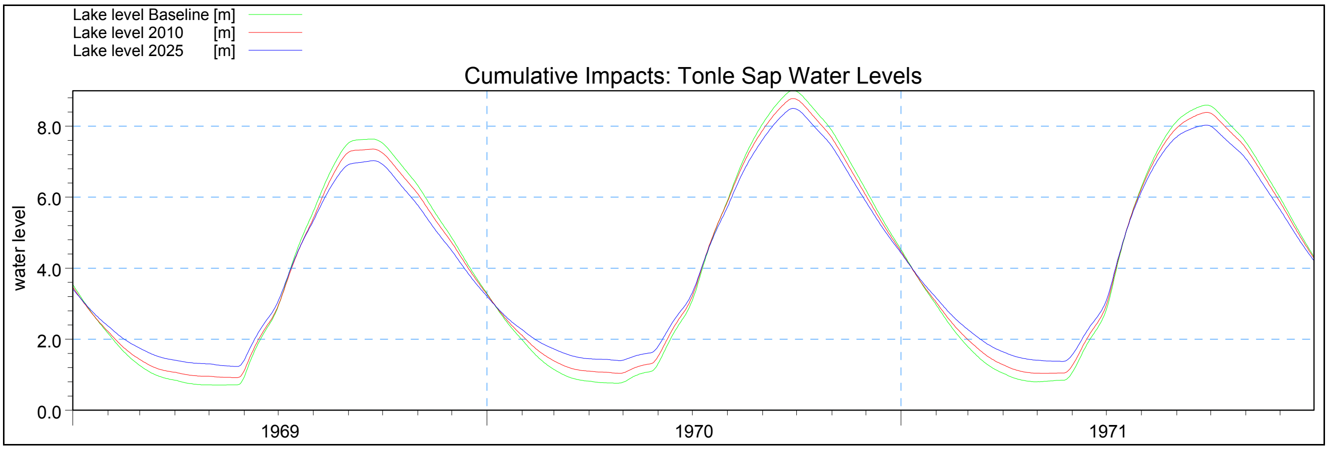

Figure 20 Simulated Tonle Sap water levels: Cumulative Impacts 2010 and 2025.

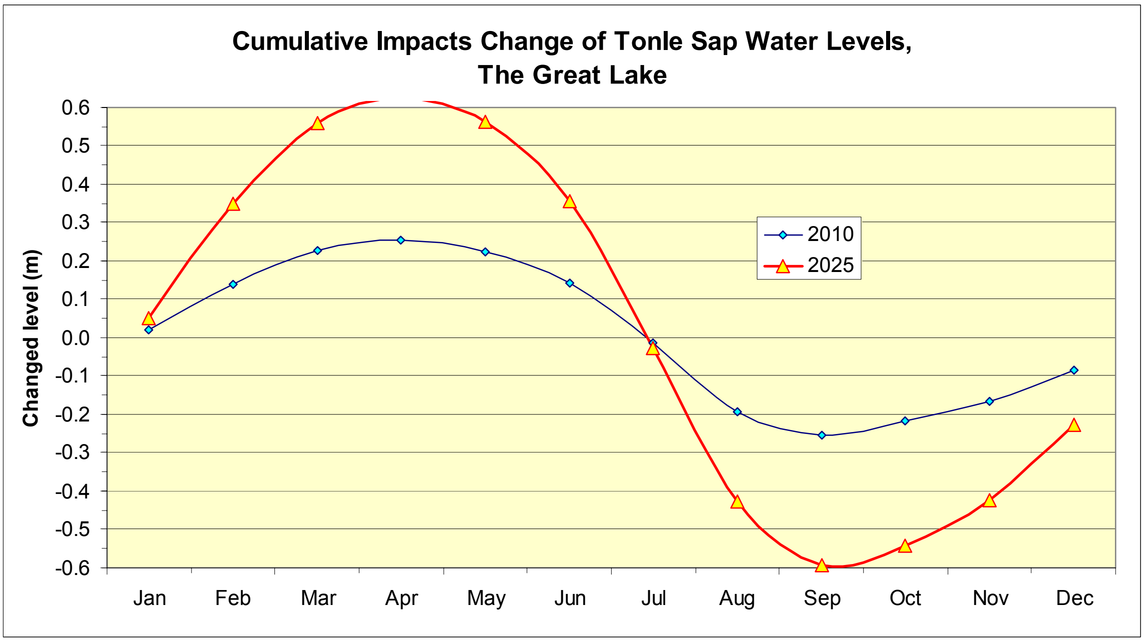

Figure 21 Change of Tonle Sap water level. Average of entire 50 years simulation period, 2010 and 2025 Cumulative Impacts.

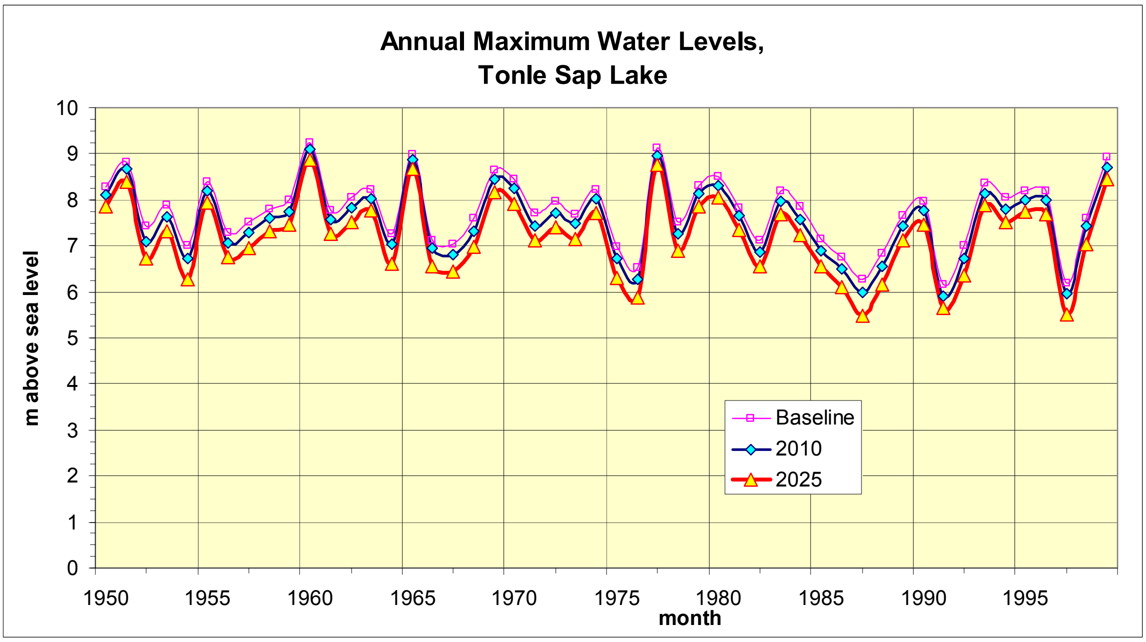

Figure 22 Annual Maximum Water Level in Tonle Sap (September or October). Baseline, 2010 and 2025 Cumulative Impacts.

Table 4 Summary of key simulation results for impacts on Tonle Sap Lake: ***Wet Season***

	Average Annual Maximum Q at Kratie	**Discharge Change**	**Average Annual Maximum Lake Level**	**Level Change**	**Average Annual Maximum Lake Area**	**Area Change**
	[m^3/s]	**[%]**	**[masl]**	**[cm]**	**[km^2]**	**[km^2]**
Baseline	35,250		7.64		9895	
Post-NT2	35,050	-0.6%	7.61	-3 cm	9855	-40 km^2
CIA 2010	33,565	-5%	7.42	-22 cm	9540	-355 km^2
CIA 2025	31,020	-17%	7.10	-54 cm	9030	-865 km^2

Table 5 Summary of key simulation results for impacts on Tonle Sap Lake: ***Dry Season.***

	Average Annual Minimum Q at Kratie	**Discharge Change**	**Average Annual Minimum Lake Level**	**Level Change**	**Average Annual Minimum Lake Area**	**Area Change**
	[m^3/s]	**[%]**	**[masl]**	**[cm]**	**[km^2]**	**[km^2]**
Baseline	2000		0.89		2410	
Post-NT2	2040	+2%	0.91	+2 cm	2420	+10 km^2
CIA 2010	3050	+53%	1.14	+25 cm	2555	+145 km^2
CIA 2025	4470	+124%	1.52	+63 cm	2785	+375 km^2

4.5.3 Impacts in the Delta

In the present baseline situation, saltwater intrusion is an important problem in the Delta. The mechanism that is causing saltwater intrusion is the combination of an extremely low gradient through the Delta, i.e. for around 300 km from the Sea, and the rather high tidal amplitudes, namely around 3m (+/- 1.5m). When discharges are small in the dry season, the high tides cause an inflow of seawater into the rivers. The tidal oscillations are measured as far upstream as Phnom Penh, although the saltwater itself does not propagate so far upstream. Flow reversal, i.e. flow going upstream, occurs as far upstream as Tan Chau and Chau Doc close to the Vietnamese/Cambodian border. Figure 23 below shows observed discharges at Tan Chau and downstream and illustrates the frequent occurrence of negative flows at My Thuan.

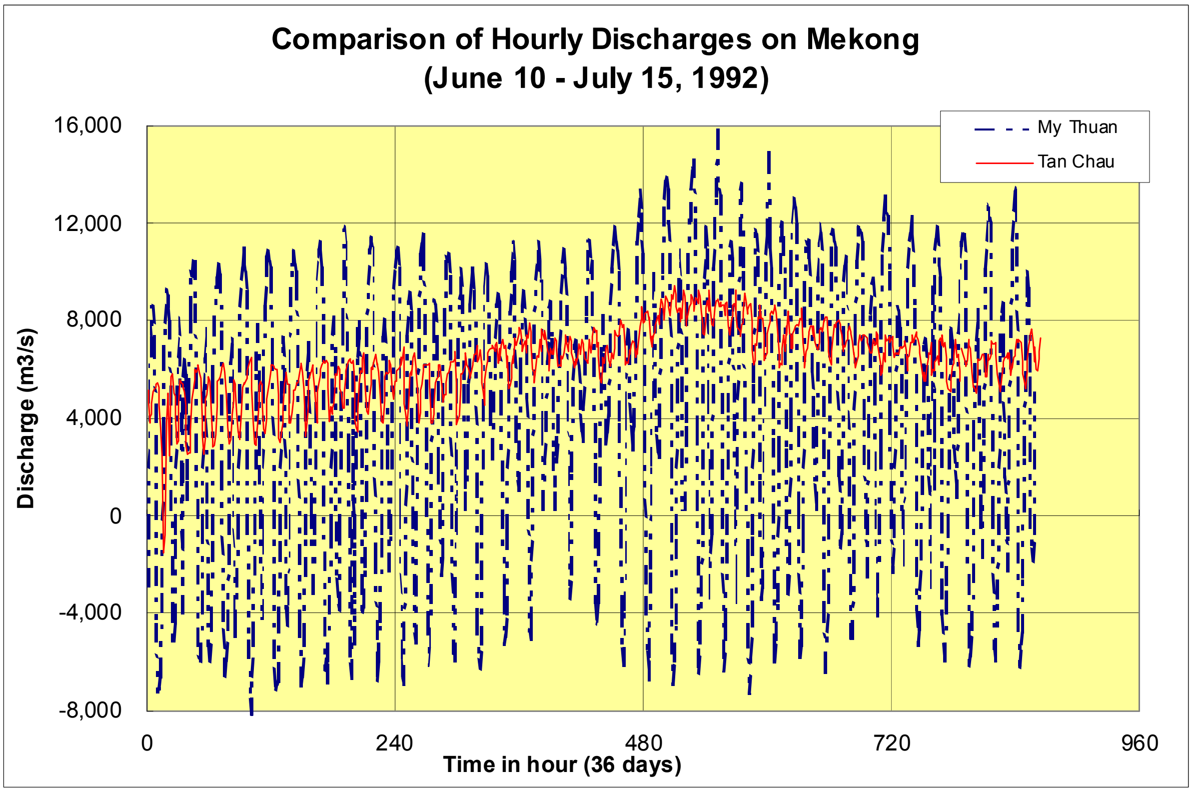

Figure 23 Observed Mekong discharges under tidal influence. Stations Tan Chau at Cambodian/Vietnamse border and my Thuan 90km further downstream. Source:WUP-JICA 2003.

Due to the regulation by hydropower, river discharges through the Delta are increased in the dry season. The increased dry season discharge reduces saltwater intrusion. The results from the hydraulic modelling are used to quantify the reduction of saltwater intrusion. It should be noted that the model is somewhat simplified in the Delta, by reducing the large number of parallel river branches to five model river branches. The results should therefore be considered as indicative. The main focus is however the *difference* between baseline and scenario simulation, and it is believed that the inaccuracy in the difference, i.e. *net* impact, is less significant.

Figure 24 below shows the tidal discharge variations in an example time interval in the dry season, when seawater intrusion is significant (large negative discharges). The location is at the beginning of the Delta. The figure shows simulated river discharges at 6 hour intervals, thus illustrating the in- and outflow of seawater in terms of negative, resp. positive discharges. In the shown example, discharges are above 4500 m^3/s in 3 out 4 timesteps (18 of 24 hours) every day, but in one time step (6 hours interval) the discharges are negative and between 1000 and 2000 m^3/s most of the time.

Concerning the impact of NT2, the figure shows that the generally increased dry-season flow which is a result of the regulation, generally “lifts” the NT2 curve. This implies that the negative discharges become “less negative”. In order words the seawater intrusion is reduced. In the shown example, the inflow is reduced by approximately 300 m^3/s. The change of the negative flows is outlined by the distance between the two envelope curves through the lowest marker points for the two simulations (baseline and post-NT2, resp.).

The above example was presented as an illustration. At other times of the year, the impact may be different. Therefore a more representative way to assess the impact, is by looking at duration curves, i.e. the relation between a discharge value and the proportion of time that flows are smaller than that value. By inspecting the value zero, the duration curve yields the proportion of time with negative flows, i.e. seawater intrusion. The impact on saltwater intrusion by scenarios can be expressed as a *changed duration* of negative flows.

Figure 25 shows the Flow Duration Curve computed for Tan Chau at the beginning of the Delta at the Cambodian/Vietnamese boundary. The input data to each curve are the discharge time series simulated for a 50 years period (1950-2000) with 6 hours time step. The figure however only shows part of the curve for discharges below 6,000 m^3/s, i.e. dry season flows. It is clearly visible that more drastic scenarios have more impact in terms of increasing the discharges (in the dry season) and correspondingly, reducing the duration of time with negative discharges.

For a closer look at the impact on seawater intrusion, Figure 26 provides a zoom to the smallest and negative discharges. The Baseline duration curve (bold) crosses the Q=0 m^3/s horizontal line at 9.5%, i.e. in the baseline situation, the flow direction is upstream in 9.5% of time. The Post-NT2 curve (located closely to the left of the Baseline curve) intersects the zero line at 9.3%. This means that negative discharges occur 2% less time. This is a beneficial impact, although marginal.

For the two Cumulative Scenarios, the impacts are seen more easily. As shown by Figure 26, the duration curve for the 2010 scenario intersects the Q=0 m^3/s at 8.4% and for the 2025 scenario at 6.1%. This corresponds reductions of the time with negative discharges by 12% and 36%, respectively. This means substantial beneficial impacts with respect to saltwater intrusion.

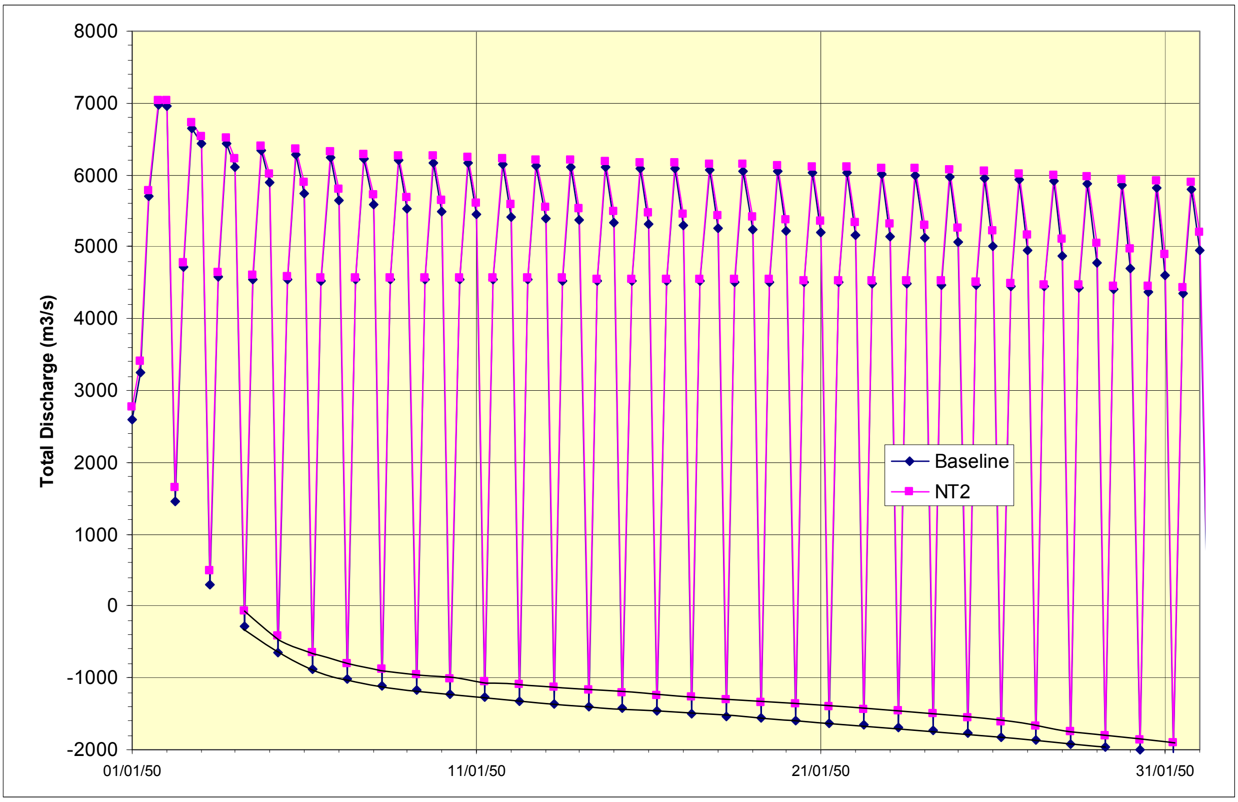

Figure 24 Simulated tidal oscillations of discharge in the Mekong Delta. Two lines outline the "envelope" of negative flows for the two scenarios: pre- and post-NT2.

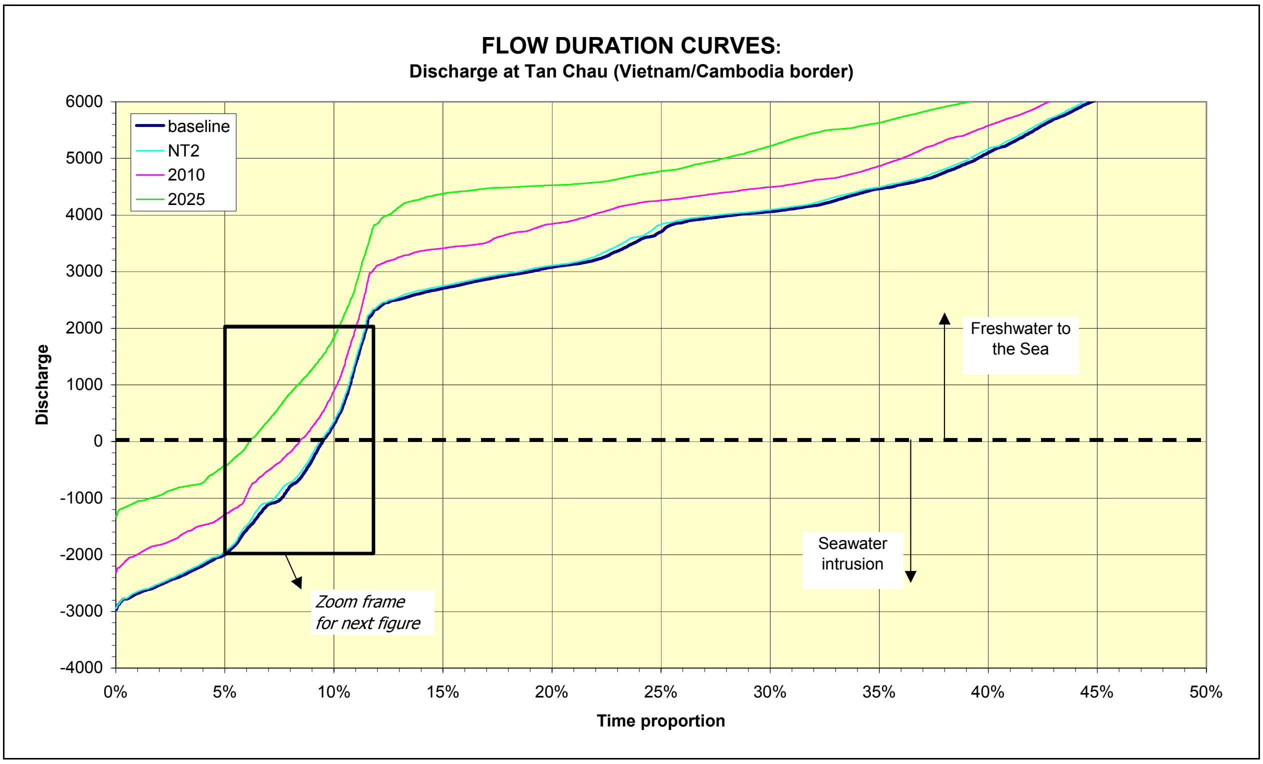

Figure 25 Flow Duration Curve (Discharge interval <6000 m3/s, i.e. dry season). Illustrates scenario impacts on flow duration: Duration of negative discharges is reduced due to regulation. The bold frame indicates the area that is zoomed to on Figure 26.

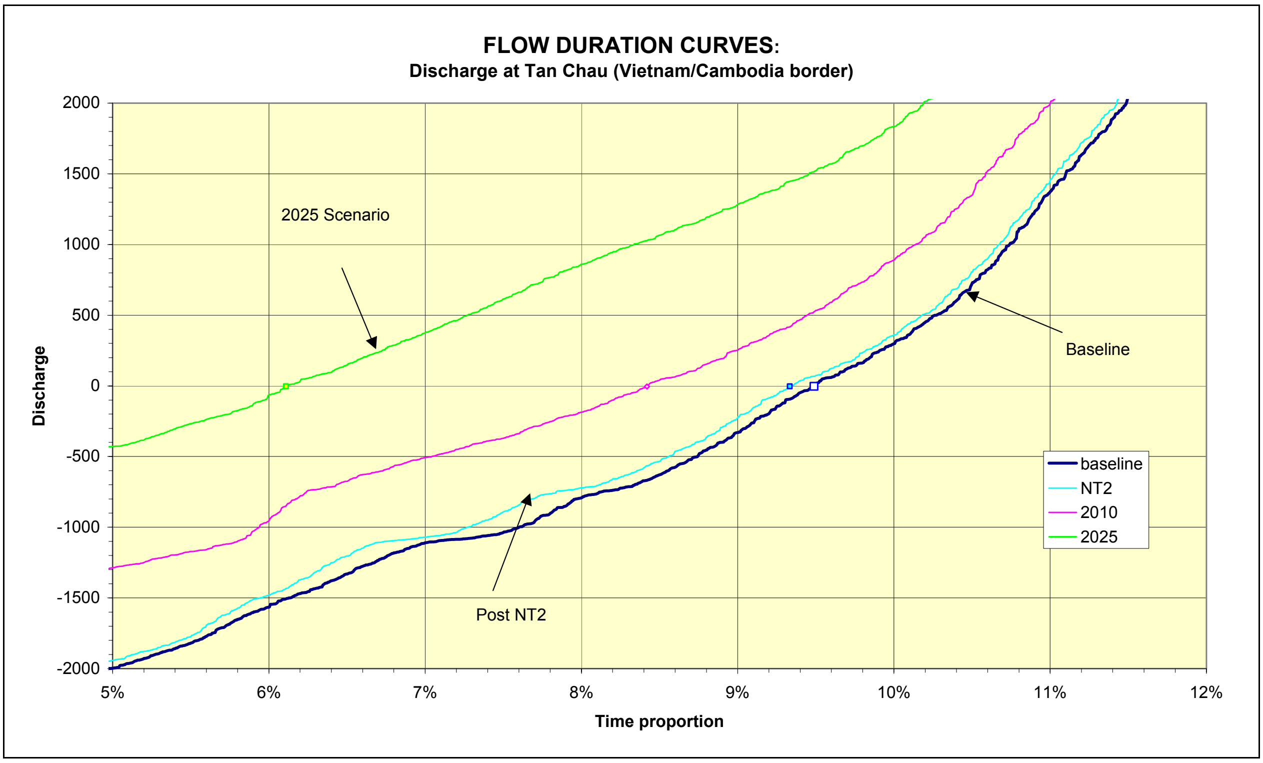

Figure 26 Flow Duration Curve (Discharge interval <2000 m3/s). Illustrates scenario impacts on flow duration: Duration of negative discharges is reduced due to regulation..