

## **VUNG TAU – GO CONG DAM MATHEMATICAL MODELLING: ONE SIZE FITS ALL ?**

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### **Abstract**

To resolve the flooding problems of Ho Chi Minh City, the possibilities for a large barrier downstream of the city are under study. In the final design stage a detailed 1-or 2-dimensional mathematical model is necessary to describe water levels and flow in the branches of the estuary system. The authors plea for the use of simple, first-order models, additional to a detailed model. The use of such models is shown as a tool in the preliminary stages of such a project but also as a reflection tool to get a better understanding of the system. The authors strongly argue that such tools are indispensable since the design process is never smooth and is never a linear sequence of theoretically logical steps. Several examples are being given.

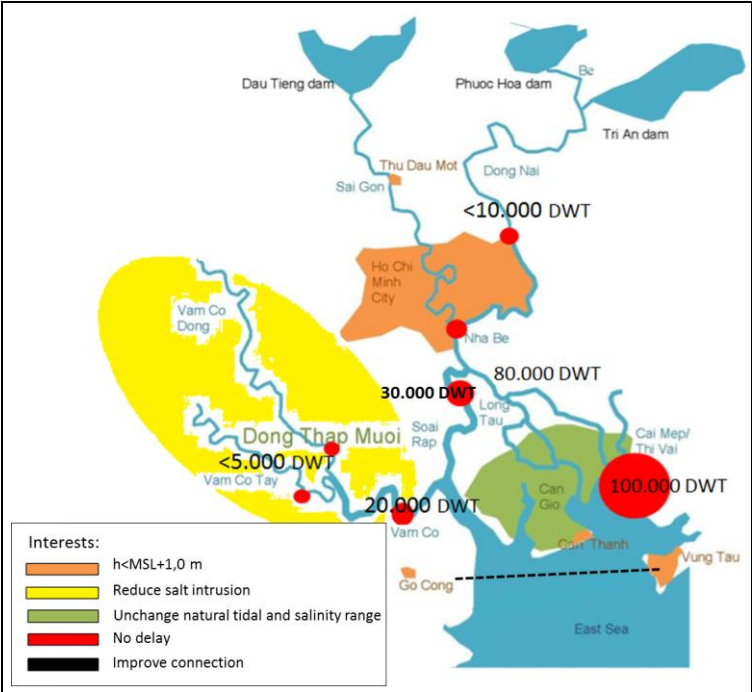
Keywords: flood protection, tides, mathematical modelling, Saint venant equations, system approach

### **1. INTRODUCTION**

Ho Chi Minh City in the South of Vietnam is regularly flooded. Threats come from rainfall, river discharges, (spring)tides and storm surges of which the combination of rain and springtide cause flooding most frequently. An extensive program is being executed to improve the drainage and sewer system of the city to deal with extreme rainfall while for the high water levels in the rivers around the city, a network of levees and barriers was designed and is now under construction. As an alternative to control the waterlevels around the city, a large dam and barrier in the mouth of the estuary is being studied. This alternative avoids the problems with the spatial planning of the levee system in the inner city and could provide some other advantages like the prevention of salt intrusion in the Dong Thap Muoi region which is one of the main rice producing areas of the country. Also the road infrastructure in the southern part of the country can benefit from this plan. Disadvantages could be the impact to the Can Gio mangrove area and to the navigation to Ho Chi Minh City.

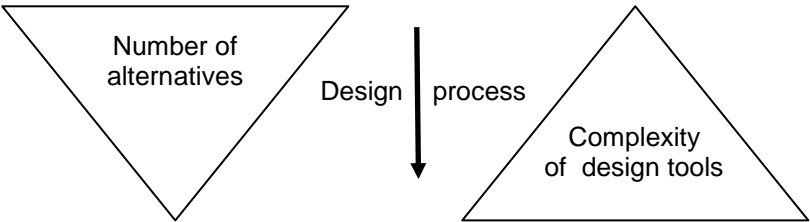
Many studies are being done to come to an optimum for the Vung Tau – Go Cong dam, both of a physical-environmental and of a socio-economic nature. Essential in the judgment of the effect on flooding are the outcomes of hydraulic modelling of the area. Hydraulic models can range from a very simple 1-dimensional to a very detailed 2- (or even 3) dimensional mathematical model. This paper does not deal with the alternatives for this barrier (see e.g. SchierECK et al, 2011) with their advantages

and disadvantages and also not with an extensive treatment of the mathematical modelling of the phenomena but focusses on a systems approach in which simple, first-order models play an important role.



Study area

The next picture shows what many textbooks on design show: at the start of the process, the number of alternatives is large and gets less till the final solution is chosen while the tools being used get more complex. This is basically true but the process is not as linear as theoretically presented. Sometimes during the process it can be useful to go back to a simple tool to reflect on the outcome of a more advanced tool not only to see whether the schematization of the complex is correct but also for the designer to be sure to understand the system.

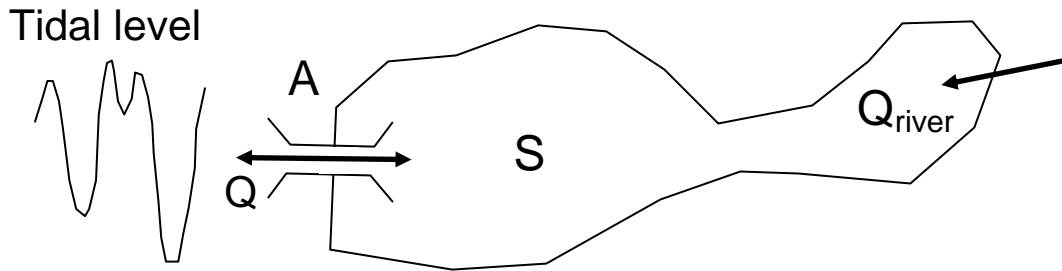


Theoretical course of design process

In this paper examples of both the theoretical and the reflection approach will be given with some simple mathematical models. Basis for the considerations is modelling with the 1-dimensional Saint Venant equations but we will start with what could be named a 0-dimensional approach as the simplest of all tools.

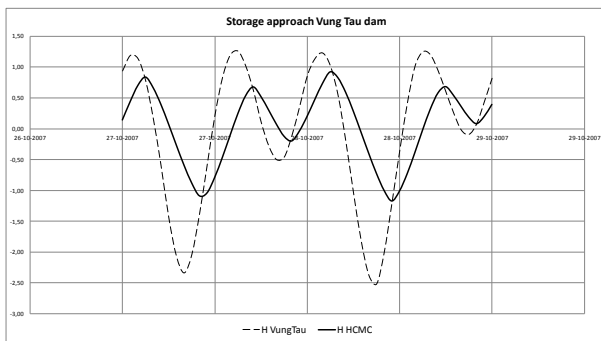
## 2. 0-DIMENSIONAL MODEL (STORAGE BASIN APPROACH)

The hydraulic system of this project can be reduced to a single basin in which a river discharges. The basin is connected with the tide in the sea by means of a hydraulic structure. Input consists of river discharge as a function of time, size of the basin, dimensions of the structure and the tidal fluctuation at sea. In the basin the water level is computed applying the continuity equation (conservation of mass:  $\Sigma Q = S dh/dt$ ) while the flow through the structure is computed with the equation of motion ( $Q = A \sqrt{2g\Delta h}$ ). One could indeed say that these equations form a “degeneration” of the Saint Venant equations into a quasi-static 0-dimensional approach.

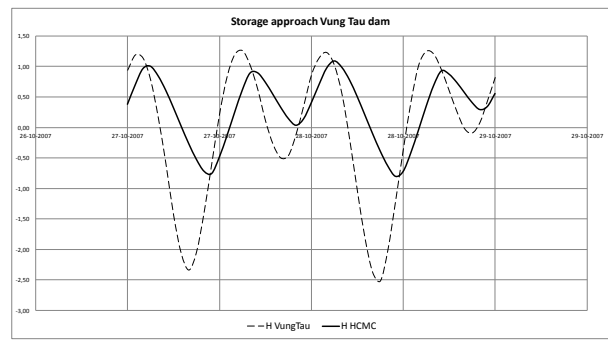


Elements in 0-dimensional storage approach

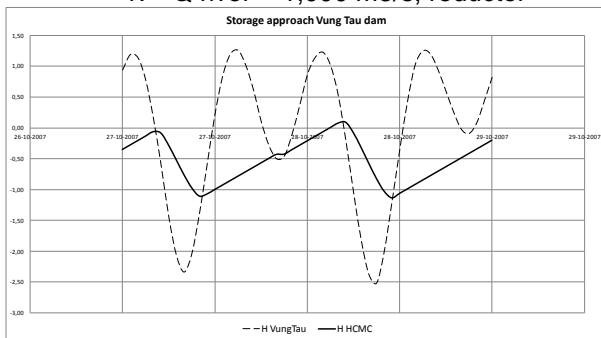
In a preliminary state of the design process the 0-dimensional model (also indicated as a “storage basin approach” from the water being stored in the basin) is a convenient tool to get an idea of how the system works and which parameters to study in more detail. As said in the introduction, the main problem in HCMC is flooding during springtide when the high water levels inundate the inner city. So, first the model is used to see the effect of a barrier on the water levels in HCMC during springtide.



1.  $Q_{\text{river}} = 1,000 \text{ m}^3/\text{s}$ , reductor



2.  $Q_{\text{river}} = 10,000 \text{ m}^3/\text{s}$ , reductor



3.  $Q_{\text{river}} = 10,000 \text{ m}^3/\text{s}$ , discharge sluice

*In all cases the storage area of the basin is 500 km<sup>2</sup>, the structure is 1000 m wide and 10 m deep. The difference is the river discharge (1,000 in 1., 10,000 in 2. and 3.) and the operation mode of the structure (reductor in 1. and 2., discharge sluice in 3.). A reductor is open for both ebb and flood flow and the resistance of the structure reduces the tide inside the basin while a discharge sluice is open during ebb flow and closed for flood.*

Different operation mode of barrier

Indeed, a barrier reduces the high water level in HCMC for average river discharges below the desired level of + 1 m (picture 1). For high river discharges the reduction is not enough (picture 2) but when the same structure is used as a discharge sluice (only permitting outflow, picture 3) the situation is much more favorable. From now on in this paper a discharge sluice will be the standard mode.

Now the model is used to study the variation of some important parameters, the results of which are presented in the tables below. The size of the hydraulic structure ( $A_S$ ) is of course important: the larger the better but also more expensive. The maximum river discharge ( $Q_R$ ) plays a dominant role. There is a possibility to influence this by means of implementing reservoirs upstream but decisions on that will be done by other stakeholders. The size of the basin ( $S$ ) is also an important factor and is determined by the position of the closure dam (e.g. in the mouth of the Soi Rap instead of the Vung Tau – Go Cong line). Here again it is a matter of effectiveness against costs.

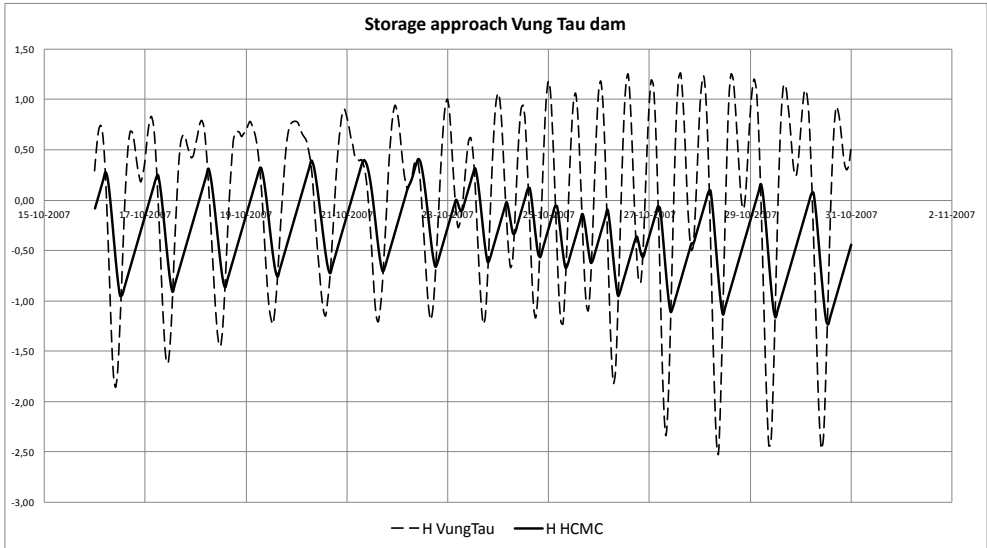
QR						QR					
20000	1,48	1,24	1,15	1,11		20000	1,37	0,83	0,69	0,6	
15000	1,28	0,94	0,86	0,86		15000	1,06	0,51	0,35	0,3	
10000	0,83	0,6	0,56	0,55		10000	0,53	0,1	-0,16	-0,22	
5000	0,1	-0,22	-0,26	-0,29		5000	-0,17	-0,52	-0,74	-0,84	
	5000	10000	15000	20000	AS		5000	10000	15000	20000	AS

Storage 250 km<sup>2</sup>

Storage 500 km<sup>2</sup>

Maximum water level in HCMC for various sizes of storage, discharge sluice and river discharge

From the tables it becomes clear that the river discharge is the most dominant factor, even more than the size of the structure or the dam location. Since the maximum river flood can hardly be influenced, a serious statistical study on the hydrology of the upstream area should be reported and discussed among experts. Also the permissibility of a very rare river flooding in HCMC should be discussed when all the “everyday” floodings by springtide will be solved by the barrier.



Waterlevel HCMC during a 15 day tidal cycle ( $Q_R = 10,000 \text{ m}^3/\text{s}$ ,  $S = 500 \text{ km}^2$ ,  $A_S = 10,000 \text{ m}^2$ )

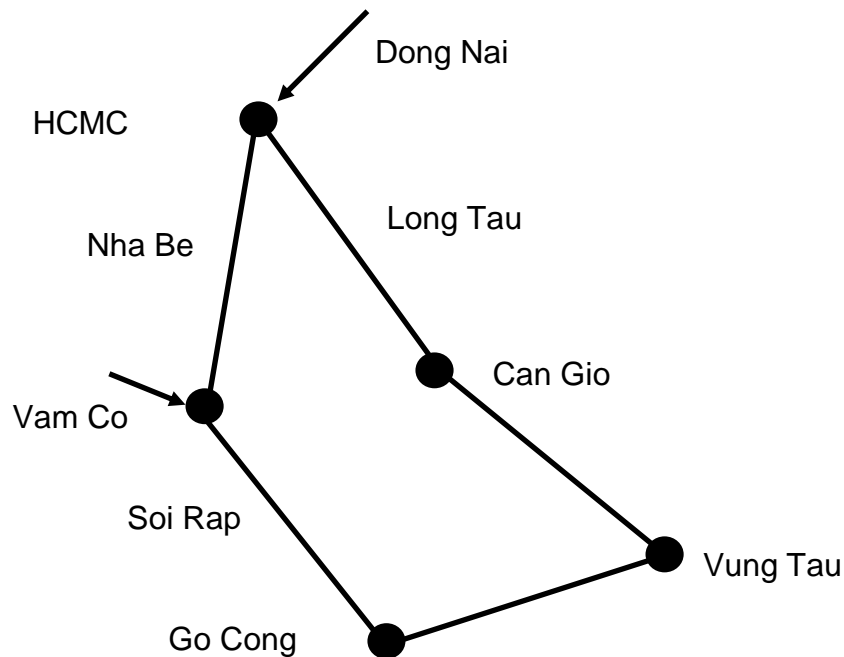
To complicate things further, it appears that the maximum water level in HCMC for a high river discharge with a discharge sluice is not reached during springtide but can also occur during neap tide. This is due to the tidal character in Vung Tau (mixed diurnal and semi-diurnal) where levels remain high during neap, so water can not easily flow to the sea as is the case during springtide.

### 3. 1-DIMENSIONAL MODEL

A 1-dimensional approach, in which the full Saint Venant equations are being solved in a network of nodes and branches, is a standard tool for studies in rivers and estuaries. The hydraulic characteristics with one dominant flow direction in oblong branches makes this an obvious choice. For a detailed study of environmental effects or on the construction planning in the open sea area of the Vung Tau – Go Cong dam, a 2-dimensional model can be useful but for the bulk of the studies, a 1-dimensional approach is the best option.

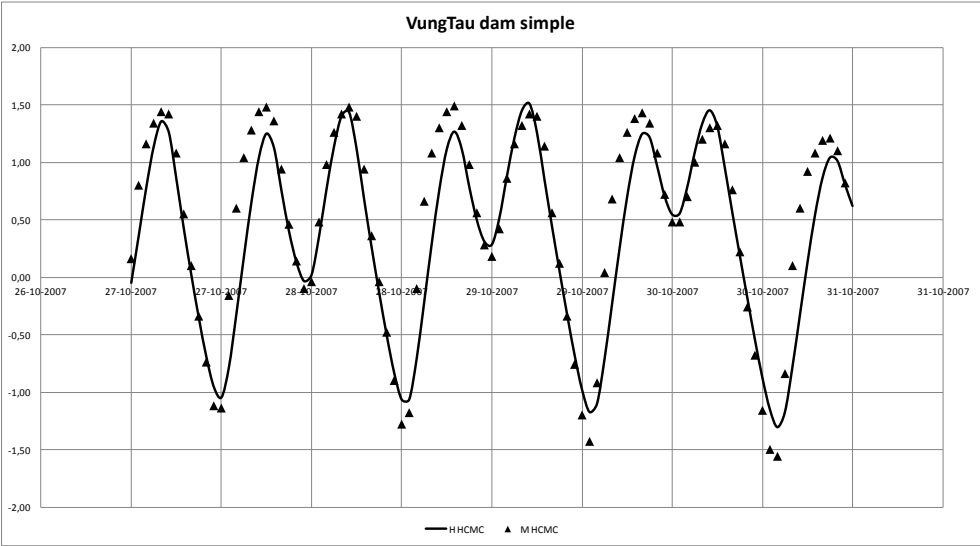
For this option a schematization of the branches in the network has to be made and here the choice is the degree of detail: should only the main characteristics of the network be represented or should every ditch and drainage canal be modelled. It is obvious that the degree of detail depends on the questions to be answered. When only parameters in the main branches are relevant, it is of little use to schematize the total hierarchy of branches. Usually one level lower than the branches at stake (that means only the most important side branches) will be sufficient. However, when small branches are left out, they have to be summarized into the storage of the branches and nodes that are part of the model. Otherwise, the discharges and velocities in the main branches will be underestimated.

In the introduction it was already argued that the growth of the complexity in modelling during the design process is theoretical. The following example shows that it can be useful to go back to a much simpler model in order to understand better the outcome of a detailed model. In the study to come to a conceptual design of the Vung Tau barrier, one of the options was a closed or open Long Tau branch. In order to conserve the mangrove forests in Can Gio, in most plans the Long Tau branch is open to the sea to maintain the tide and the salt water environment. The question is whether a dam upstream, near the bifurcation of the Nha Be and the Long Tau is useful. The results of the detailed model (Sturm, 2011) were not immediately clear. For some combinations of river flood and primary barrier location, a closed Long Tau branch was favourable for lowering the maximum water level in HCMC, for others not. A simple model was made consisting of only 5 branches to see how it worked.



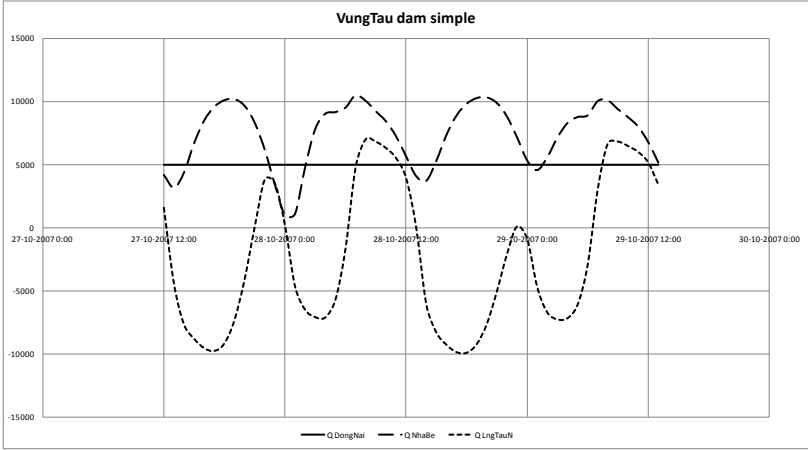
Simple schematization of Dong Nai estuary

This model was run with the measured water levels at Vung Tau and the measured river discharges from the upstream reservoirs and “calibrated” with the measured water level in HCMC. Calibration is an overstatement for such a rough approach but it gives some credibility to the suitability of the model to describe the main characteristics of the system.



Comparison computed and measured water levels in HCMC

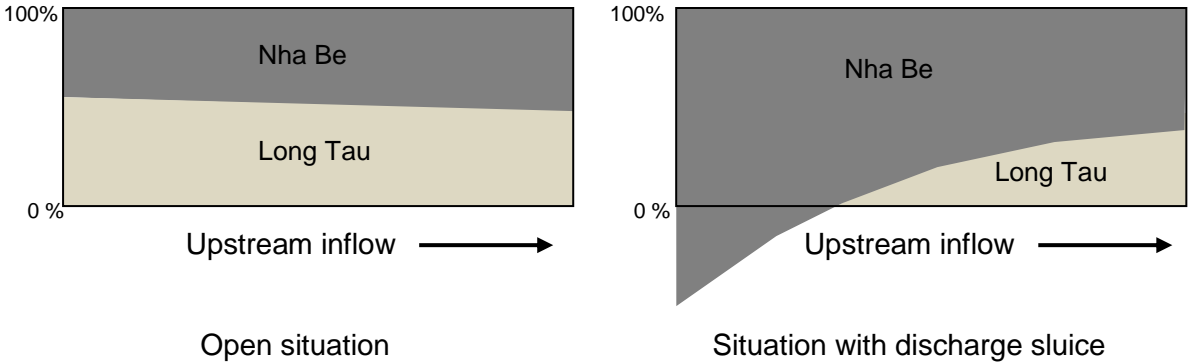
In this model the effect on water levels and discharge distribution was studied for a range of upstream discharges. The picture below shows an example for a constant discharge of 5,000 m<sup>3</sup>/s inflow from the Dong Nai into the system and the distribution along the Nha Be and Long Tau branches. It can be seen that the average flow in the Nha Be is even higher than the total inflow and the flow in the Long Tau is on average negative. In fact water “sneaks” in from the sea through the Long Tau and is discharged again via the Nha Be.



Flow at bifurcation Dong Nai - Nha Be/Long Tau with discharge sluice in mouth of Soi Rap

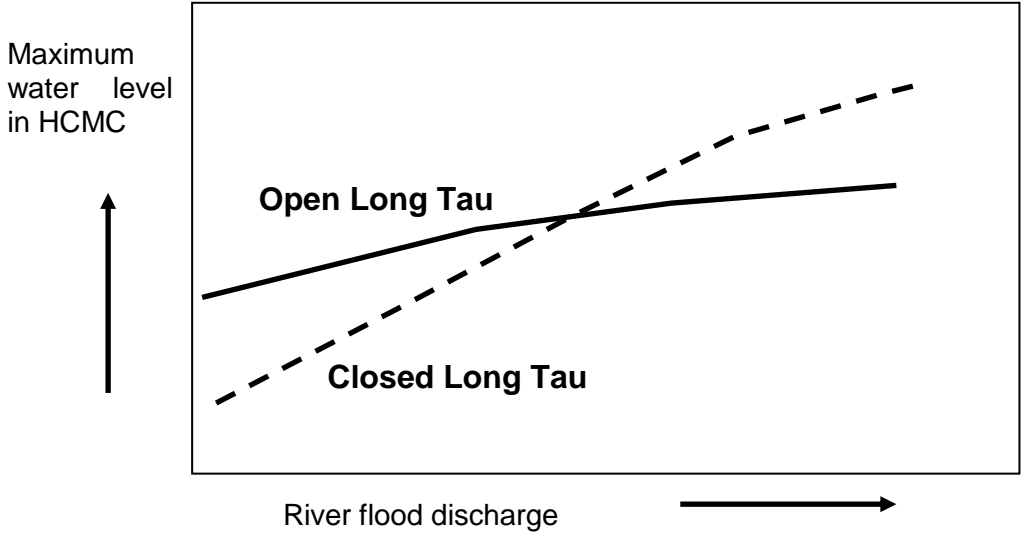
The picture is for a moderately high river flood. For a range of river flows, the next picture shows the results, both for the original, open, situation and for the situation with a discharge sluice in the mouth of the Soi Rap. In the open situation, the flow is more or less distributed 50-50. In the situation with a discharge sluice, working as a valve, the Nha Be forms the easy way out, attracting water from

the Long Tau. With very high river discharges, there is enough pressure to push back the water also in the Long Tau.



Relative distribution of flow over river branches

The effect on the maximum water levels in HCMC is shown in the next picture. For relatively low river floods, a dam in the Long Tau is favorable to reduce the high tidal water levels in HCMC since it prevents water to flow in from the Long Tau into the Nha Be. For extremely high river floods it works the other way around: now an open Long Tau gives an extra drainage capacity for the system. This again stresses the need for a good statistical insight into the river flood discharges and the permissibility of a flood due to river flow. It is also possible to make another discharge sluice in a Long Tau dam to combine best of both worlds.



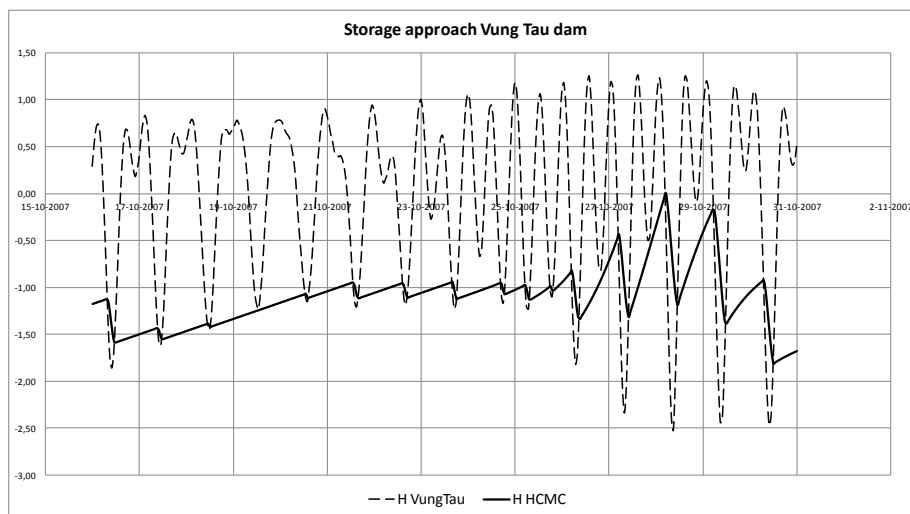
Water levels in HCMC with discharge sluice and open or closed Long Tau branch

Finally, this example shows the important relation between flow and levels in the system. A model therefore should not only be calibrated with measured water levels but also with measured velocities and discharges in the tidal area! Otherwise, one can not be confident enough that the system is being represented correctly in all aspects.

#### 4. DISCUSSION AND CONCLUSION

One could question the added value of additional simple models when a good detailed overall model is already available. E.g. could the analysis given in chapter 3 not also have been performed using the detailed model itself? The answer is yes but it probably would have taken much longer. Moreover, a simple model gives you easily, literally, the larger picture and is of paramount importance in understanding the system. A coherent treatment of schematization, calibration (water levels and flow !), boundary conditions and statistics is more important than the last detail in a mathematical model.

Finally, the authors want to state explicitly that they see this project as a promising solution for the flooding problems in Ho Chi Minh City and the salt intrusion in the area. To illustrate this, the 0-dimensional model is staged once again. Until now most examples were given with constant river discharges for the sake of simplicity. This picture shows the operation of a discharge sluice during a neap-spring tidal cycle with an average river flow followed by an extreme flood wave. It shows that, with the sluice acting as a valve, the water level behind the barrier follows the LW peaks creating space for the flood peak to come. Of course, the water level will not be kept so low for a long time but it shows the versatility of such a barrier. A river flood peak can be predicted many days in advance, giving the water manager time to lower the level in the basin to accommodate the expected peak. It also gives room to either creating a completely freshwater reservoir or to allow salt intrusion to a certain extent. With all these options available, it should be possible to create a sustainable solution for the benefit of most, if not all, stakeholders in the area.



Waterlevel in HCMC with discharge sluice operating in one direction and a river flood peak

#### 5. ACKNOWLEDGEMENTS

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