Paper from: *Development and Application of Computer Techniques to Environmental Studies*, CA Brebbia and P Zannetti (Editors).
ISBN 1-85312-909-7

Distributed modelling of Lake Tonle Sap catchment

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Abstract

A distributed hydrological model system with a graphical user interface will be applied to Lake Tonle Sap catchment. The main goal of the modelling project is to estimate the quantity and quality of water ending to the lake from nearby catchment areas, and thus provide input to a hydrodynamic lake model. The Lake Ton Le Sap has interesting hydrodynamics, as it is filled during monsoon time by the waters from the Mekong River, and has natural annual surface water level variation of about 7 meters. The final hydrological model system will consist of a distributed hydrological model, a graphical user interface, connections to databases, and GIS functionality. The user interface component provides model experts full access to model properties, but also enables non-expert users to apply the system for standard computations.

1 Introduction

The Lake Tonle Sap, located in Cambodia, is the largest freshwater lake in the South-East Asia. The lake forms a unique hydrodynamic system with the Mekong River in which the lake functions as a retention storage of flood water. During the rainy season from May to October the floodwaters from the Mekong River and lake catchment area flow into the lake raising its surface approximately 7 to 8 meters. In the same time the surface area of the lake grows from the dry season value of about 2500 km2 to more than 13000 km2 at the end of the rainy season. Retention capacity of the lake is estimated to be 80 km3 [1]. During the dry season the lake waters flow back to Mekong, thus decreasing intrusion of saline seawater to the agricultural area in the Mekong delta region [2]. Figure 1 below shows the extent of the flooding in year 2000 wet season time.

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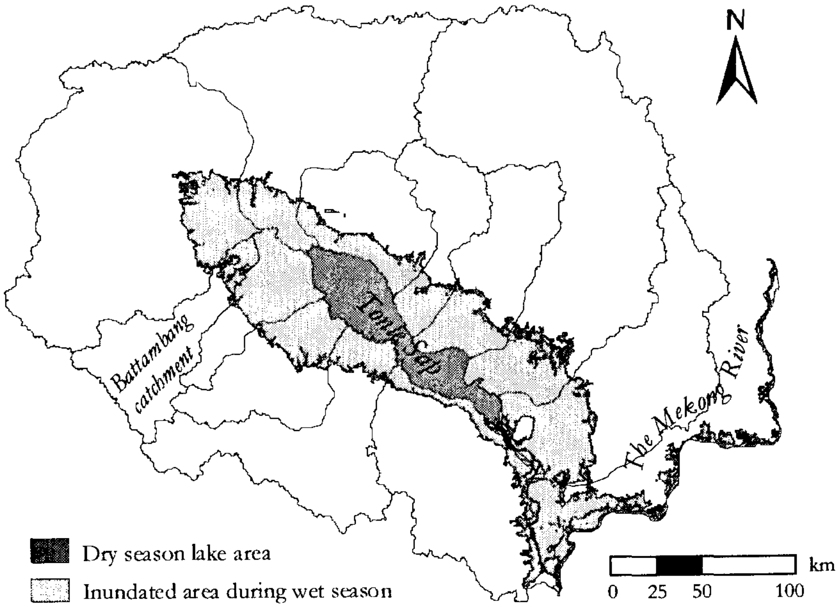

Figure 1: Lake Tonle Sap catchment area with major subcatchments, total area is 94700 km2, of which the inundated area is 17090 km2 or 18.0 %. The midpoint of the lake is located about 12°45' N, 104°10' E.

The Lake Tonle Sap and the Mekong River support special ecological resources of aquatic and wetland flora and fauna. The lake fishery sustains a large population and is important in countywide scale. The annual catch of fresh water fish in Cambodia is at least 300,000-400,000 tons, placing it fourth in the world's top freshwater fish producers. The yearly cycle of inundation is important to the fish reproduction for during the raising flood fish eggs and fry are carried to flooded areas to hatch and grow [3]. However, the specific ecological interactions in the lake are relatively unknown. To understand the interactions better good understanding of the hydrological and hydrodynamic processes in the lake catchment and the lake itself is needed

Long-term developments in the Mekong watershed move towards increasing water use for irrigation and hydropower production. According to a study by S. Nam [3] the recent (post 1980) peak flood levels have decreased when compared to time before 1964, when there were only two dams in the Mekong watershed. Other developments that may have impact to the lake include changes in land use such as cutting of forests. As these developments may affect the lake, it is important to understand the lake hydrodynamics and water quality behaviour. This way it may be possible to estimate the impact of above developments to lake ecology.

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The Mekong River Commission/WUP-FIN Tonle Sap Modelling Project aims to better understanding of lake Tonle Sap hydrology and hydrodynamics by using computational models. As a part of the project a distributed hydrological model VMod will be applied to lake Tonle Sap catchment area to be used to compute input data for a 3d hydrodynamic lake model. This paper will shortly present the main features of the modelling system and show some preliminary results of a model application to one subcatchment.

Not many previous efforts in hydrological modelling of the Tonle Sap catchment can be found. Some older models such as [7] include Tonle Sap as retention storage in an effort to model Mekong delta region. There are some recent efforts using distributed hydrological models, e.g. in [4], but the target area for these have been the complete Mekong river catchment, the size of which is 795500 km2. Conceptual models have been applied to some areas in the catchment by T. Masamoto in [4] and R.W.Al-Soufi in [5]. Also MIKE 11 model was applied to Tonle Sap River and Mekong river junction in [2], the model area also included the Lake Tonle Sap.

2 Hydrological model

VMod, a distributed physically based/conceptual hydrological model, is used to model the Tonle Sap catchment area. The model is based on rectangular grid, where each grid box is individually computed and has an own set of parameters such as ground slope and aspect, vegetation and soil type. In each of the grid boxes following hydrological process are computed: precipitation, snow hydrology, evapotranspiration, seasonal vegetation development, soil water content, ground water height, and flow into streams. Ground water flow and stream flow are computed between the grid boxes.

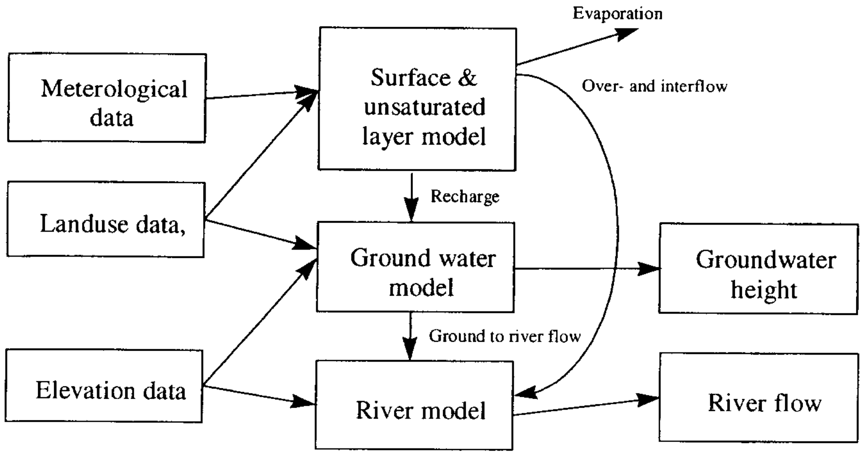

Figure 2: Main components and data flow of the VMod hydrological model

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Each process simulation is based on physical formulation, for example, Penman-Monteith model for evapotranspiration, Darcy's law for ground water flow, and simplified St.Venant equations for river flow. However, often there is not enough data available for using physically based formulas. Simpler semi-empirical computation methods are included into the system if this is the case. The main modules of the model are shown in figure 2.

Typical grid box size for the model is from 0.01 to 1 km2. Time resolution depends on input data resolution, for daily data 3 to 6 hour timesteps have been used. A model application can include any number of grid boxes. Computation time is about 1 min/year for grids containing several thousand grid boxes.

The setup of the model requires digital elevation model and land use data for the target catchment. Other data, such as soil maps can also be used if available. Running and calibration of the model requires meteorological and hydrological timeseries such as precipitation, daily average temperature, radiation data and river flows.

3 Model management system

The data processing and data management functions required to set up the model grid, run the model and see results are gathered together into a model management system (MMS). Main parts of the system are shown in figure 3 below. Typical tasks that the system can be applied to include

- import of raster and vector data from GIS systems,
- creating hydrological model grids based on GIS information,
- import and handling of timeseries data ,
- model parameter setting, model running and parameter optimisation, and
- visualisation of model result timeseries and time-dependent grid data.

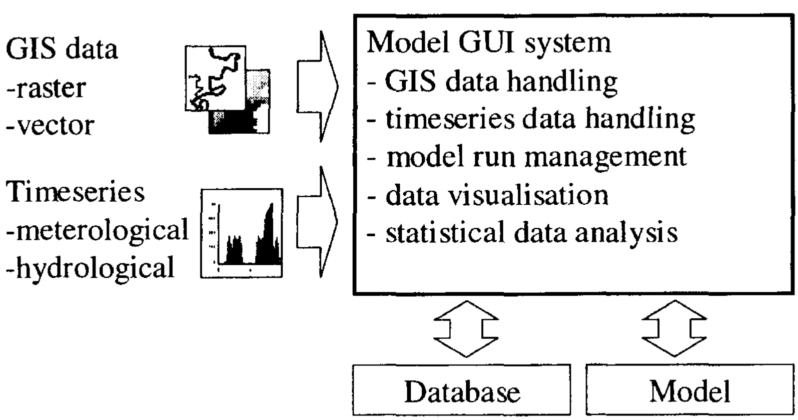

Figure 3: Components of the VMod model management system

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The system is based on a general graphical user interface construction tool, which has previously been used with coastal models [8], [9] and river basins [10]. The GUI construction tool is based on a specific script language for setting up model user interfaces. The task of the GUI tool is to run these scripts and support the construction of user interfaces using the script language. The GUI tool itself is implemented using C++.

4 Application to Battambang catchment

To test the applicability of the VMod model system a rainfall-runoff computation was set up for Battambang catchment, which is a subcatchment of the Tonle Sap watershed. The purpose of the exercise was to find out the required modifications to the data handling and modelling capabilities of the system.

The Battambang catchment is located in the southwest part of the Tonle Sap catchment area. The total area of the catchment is about 3700 km2, the highest areas in the southern part of the catchment reach above 1000 m, while the northern lower part of the catchment is below Lake Tonle Sap high water line at 10m elevations. Lower parts of the catchment contain annually flooded shrub land, rice paddies and garden crop areas. Upper parts of the catchment contain grassland and sparse forest with patches of denser forest. Figure 4 below shows the catchment with computed river network.

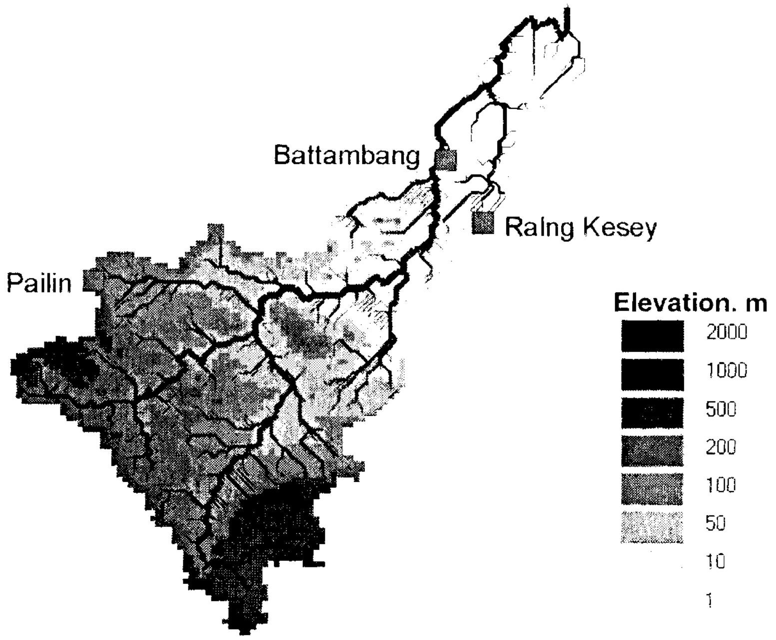

Figure 4: Battambang catchment area, computed river network, elevation grid and weather stations. Grid resolution is 1 km.

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First task of the modelling exercise was to import required GIS and hydrometeorological data into the modelling system. After some expected difficulties the GIS data, that is DEM, land use, catchment border and river network information were obtained and imported to the system. The data quality was evaluated and considered to be sufficient.

One of the main difficulties in the application of catchment models to the Tonle Sap region is the lack of hydrometeorological measurement data from the area. Time series of meteorological data and flow measurements with good coverage of the Tonle Sap catchment exist only for the time 04/1962-04/1963 [6] and for year 2000. Longer time series are available in only few locations. Also, the data quality of the historical time series is not clear. The situation, however, is slowly getting better as new measurement stations are being established.

For Battambang test application flow data from the beginning of the 60's was used. Precipitation measurements were available at three stations shown in figure 4. Pan evaporation from the Battambang station was used to compute potential evaporation values, since no temperature or radiation data was found for the simulation period.

With given data a computed flow time series was obtained. Below in figure 5 computed and measured flow values with monthly averages. For this one-year simulation the first part of the year works quite well. During the rainy season the fit is not that good. This may be due to comparably small number of precipitation points and large variation of precipitation with geographic location. The Lake Tonle Sap surface elevation might also have an effect to the flow.

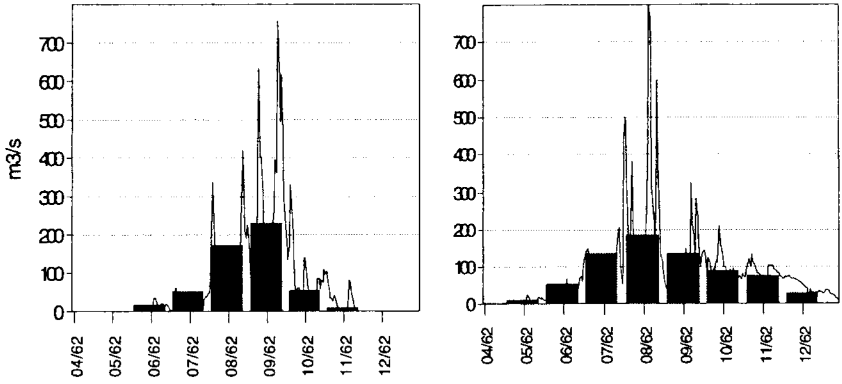

Figure 5: Computed (left) and measured (right) daily and monthly average flow values for Battambang catchment

5 Discussion

The very preliminary computations performed do show some model development requirements. The backwater effect of the Lake Tonle Sap should be taken into account in the model; also during the flooded period part of the flow may go past the gauge and should be accounted for. The sparseness of hydrometeorological data is clearly a problem that is not related to model development. In the future the data situation will improve as more measurement stations are established and the measured data from the new stations becomes available. There also is an ongoing effort to simulate missing hydrometeorological time series using advanced statistical methods.

References

[1] Sopharit, T., *Hydrological Studies of the Tonle Sap/Great Lake area*, prepared for the project CMB\95\003, 'Natural resources based development strategy for the Tonle Sap area'. Ministry of Agriculture, Forestry and Fishery, Directorate of Irrigation, Meteorology and Hydrology, Department of Hydrology, Cambodia. 1997

[2] Chaktomuk Project/DHI, *Chaktomuk Area, Environment, Hydraulics and Morphology, Draft Final Report, prepared for the Mekong River Commission,* 2001

[3] Van Zalinge, N. P., T. Nao, S. Lieng (Eds.), *Management Aspects of Cambodia's Freshwater Capture Fisheries, eleven presentation given in the Annual Meeting of the Department of Fisheries of the Ministry of Agriculture, Forestry and Fisheries.* Mekong River Commission and Department of Fisheries, Phnom Penh, Cambodia, 2000

[4] Al-Soufi, R. (Ed.), *Proceedings of the Workshop on Hydrological and Environmental Modelling in the Mekong Basin*. Mekong River Commission, Technical Support Division, Phnom Penh, Cambodia, 2000

[5] Herath S., Dutta D., (Eds.), *Mekong Basin Studies, Proceedings of the AP FRIEND workshop held in Bangkok January 2000*, International Centre for Disaster-Mitigation Engineering, 2000

[6] Carbonel J.P., Guiscafre J., *Grand Lac du Cambodge: sedimentologie et hydrologie 1962-63*, Ministre des Affaires Etrangeres pour le compte du Comite du Mekong, France, 1963

[7] Van Mierlo M.C.L.M., *Mekong Master Model*, Delft Hydraulics, Delft, The Netherlands, 1991

[8] Lauri H., Alasaarela E., *Integrated Water Quality Management supported by Graphical User Interface, Proceedings of third international conference on Hydroinformatics, held in Copenhagen August 1998*, A.A.Balkema, 1998

[9] Lauri H., Koponen J., Virtanen M.., *Combating nutrient spillage in the Archipelago Sea- a model system for coastal management support,* Environmental Coastal Regions III, edited by Rodrigues G.,Brebbia C.A., Martell E.P, WITpress, 2000

[10] Lauri H., Virtanen M., *A Decision Support System for Management of Boreal River Basin,* Large Rivers journal, to appear