

Hydrological modelling of the Mekong River basin

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Abstract The many wetlands along the Mekong River, including Cambodia's Tonle Sap (Grand Lac), are major sources of fish for the riparian peoples and an important part of the regional economy. This resource may be affected by the development of dams and diversions in the basin. The Semi-Distributed Land-Use Runoff Process (SLURP) hydrological model has been applied to the basin. First, only data from the Internet and from public-domain databases were used to provide a comprehensive simulation of the daily hydrological cycle for the main river and tributaries. Simulating the complex hydraulics of the river connecting the Tonle Sap and the Mekong required local data to develop routing relationships. The model takes into account river diversions and dams where data are available. Model outputs can be used to investigate water allocations and the effects of land-use change or climate change on water resources, to evaluate the effects of proposed structures on fisheries and environmental interests and on the performance of irrigation schemes.

Key words Mekong River basin; hydrology; SLURP model; fish; dams

INTRODUCTION

The Mekong River flows from Tibet through the Yunnan Province, Burma, Thailand, Laos and Cambodia, reaching the South China Sea in Vietnam. The riparian people, plants and animals depend on the river's annual cycle of flood and drought. Wetlands along the river, including the Tonle Sap and the Mekong Delta, supply 50–80% of total protein intake for basin residents (Mekong Secretariat, 1992).

The Mekong River usually begins rising in May, and peaks in September or October, with the average peak flow at Phnom Penh greater than $45\,000\text{ m}^3\text{ s}^{-1}$. Flows taper off after November and reach their lowest levels of roughly $1500\text{ m}^3\text{ s}^{-1}$ in March and April. The average annual total discharge is roughly 450 billion cubic metres, ranking sixth in the world.

One of the most important areas in the basin is the Tonle Sap in Cambodia. In the dry season, the shallow Tonle Sap has an area of roughly 3000 km^2 , and the lake drains slowly into the Mekong River via the Tonle Sap River. As the flood season progresses, the Mekong River rises above the Tonle Sap level, and the flow in the Tonle Sap River reverses, filling the lake. The lake typically expands to more than $10\,000\text{ km}^2$. The Tonle Sap is one of the most productive freshwater ecosystems in the world (Pantulu, 1981), supporting 60–75% of the inland fishery in Cambodia, with harvests which have historically reached 100 000 tons per year (Rothert, 1995).

The implications of basin developments on interests such as fisheries and the environment can be studied using distributed hydrological models. Such hydrological models generally require large numbers of data which, in many countries, are not always available. However, global datasets are becoming increasingly available and

data from the Internet can often be used to substitute for ground-based data. The Semi-Distributed Land-Use Runoff Process (SLURP) hydrological model (Kite, 2000) has been used to take advantage of such data sources. This paper describes the development of this model to simulate the hydrology of the Mekong basin with particular emphasis on generating data of use to the fisheries interests.

THE HYDROLOGICAL MODEL

SLURP (Kite, 2000) divides a basin into sub-basins using topography from a digital elevation map (DEM). The sub-basins are further divided into areas of different land covers using data from a digital land-cover classification. Each land-cover class has a distinct set of parameters. The hydrological model simulates the vertical water balance, transforming the daily precipitation into evapotranspiration and runoff separately for each land cover within each sub-basin.

APPLICATION

The distributions of distances and changes in elevation for each point in the basin were obtained from the US Geological Survey (USGS) GTOPO30 public-domain DEM (<http://edcwww.cr.usgs.gov/landdaac/gtopo30/gtopo30.html>) and the distribution of land covers within the basin was obtained from the USGS 1-km digital land cover map of the world (<http://edcwww.cr.usgs.gov/landdaac/glcc/glcc.html>). Figure 1 shows the digital elevation model and the derived river network and sub-basins.

Daily climate data (precipitation, temperature, dewpoint and wind) were obtained from the US National Climate Data Center (NCDC) Global Surface Summary of the Day (GSOD) database (<http://www.ncdc.noaa.gov/cgi-bin/res40.pl>). Radiation data were estimated from daily precipitation data (Kite *et al.*, 1998).

Using these data, the SLURP model simulates the full hydrological cycle for each element of the sub-basin/land-cover matrix and routes the runoff to the nearest stream and downstream through the basin. Dams on the Nam Ngum, Chi and Mun rivers were included in the simulation. In the absence of information, operation rules were assumed. Flows in the Tonle Sap River were simulated from computed flows in the Mekong at Kratie and the volume of the Tonle Sap Lake. Relationships were developed between Tonle Sap level and the flooded areas of each type of land cover using 30-min resolution data from Landsat TM.

RESULTS

The SLURP hydrological model was applied at a daily time interval for the period 1 January 1994–31 December 1998, with no calibration of parameters. Verification was made by comparing the simulated streamflow with recorded Mekong flows at Pakse and the simulated lake levels with recorded Tonle Sap levels. The results show a correlation coefficient of 0.92 and a standard error of 4212 for the flows and 0.97 and 0.72 for the lake levels. Figure 2 shows simulated flows in the Mekong River at Kratie

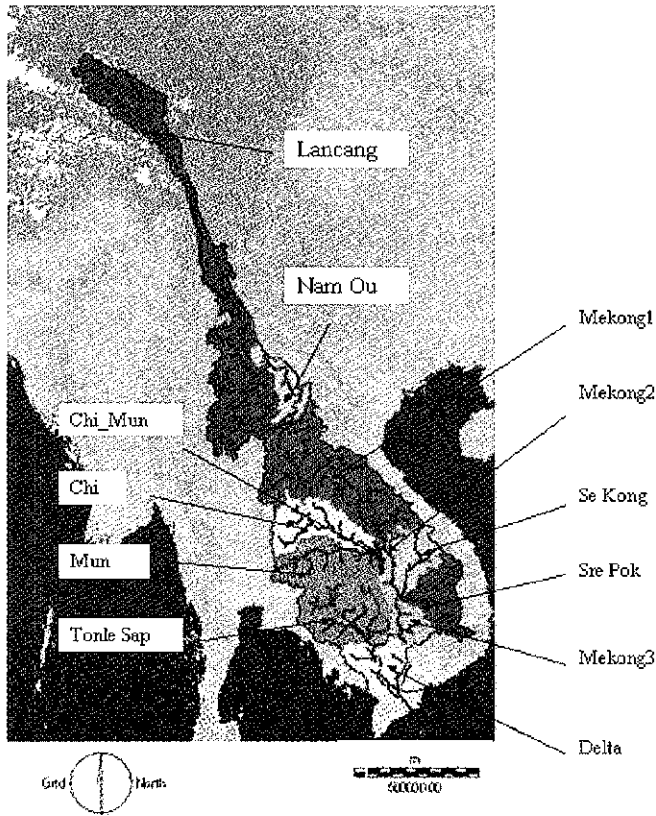


Fig. 1 Digital elevation model of the Mekong basin region showing the derived basin outline, sub-basins and river network.

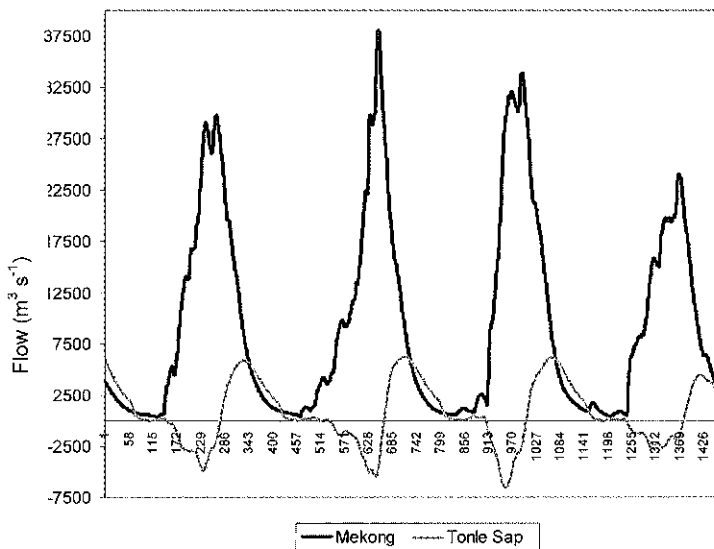


Fig. 2 Daily flows in the Mekong at Kratie and in the Tonle Sap simulated by the SLURP hydrological model for 1 May 1994–31 December 1998.

and in the Tonle Sap River at Phnom Penh. Note the reversing flows in the Tonle Sap River. The simulated levels in the Tonle Sap were then converted to time series of flooded area for the land cover types around the Tonle Sap Lake. These results may be used to evaluate fish productivity and irrigation productivity (Droogers & Kite, 1999) as well as water allocation issues and climate change impacts (Kite, 1993).

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