SIMULATION OF DAILY RUNOFF AND WATER LEVEL FOR THE LAKE BUTRNIEKS

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ABSTRACT

The Lake Burtnieks with around lying areas is one of the unique objects of the nature in Latvia. In this paper the analysis of mathematic modelling results for the rivers' runoff in the Lake Burtnieks watershed and water level of the lake are presented. First time for the Lake Burtnieks is demonstrated possibility to utilise regular observations of meteorological elements and to use mathematical model, which is adapted to natural conditions for the simulation of daily runoff and water level with a high statistical significance. The efficiency criterion R^2 differs from 0.57 to 0.80 but the correlation coefficient r is from 0.8 to 0.9. Changing meteorological data according to the given scenario of climate changes we can obtain different parameters of the predictable hydrological regime in the future. Results of the study are widely applicable including the calculation of nutrient loading from the catchment area as well.

INTRODUCTION

The Lake Burtnieks is the fourth largest lake in Latvia and locates in North-Easter part of Latvia. The lake is the source of the River Salaca, in which valley one of the largest complex of nature reserves in Latvia is located. The surface area of lake is 40.06 km^2, and total drainage area - 2215 km^2 (which occupies 62% of the River Salaca basin). The Lake Burtnieks is shallow with average depth - 2.2 m. The climate is temperate, cool and humid. The average temperature of a year ranges from +5.0 to +5.5 ^{o}C. The mean temperature is -6.5 ^{o}C in January and +17 ^{o}C in July. The average amount of precipitation ranges from 650 to 760 mm per year.

During last centuries different management actions have been carried out in the Lake Burtnieks watershed. However, not always all information about lakes and hydrological regime of lakes' hydrological networks are possible used for the analysis of ecological situation or necessary conclusions. One of the explanations is that not all parameters of hydrological regime have been observed. Therefore, mathematical model as one of more accepted tools in hydrology could be use (Bergström 1991; Bergström 1992; Brandt and Arheimer 1998; Podstchine et al. 1999; Ziverts and Jauja 1999).

In this paper the analysis of mathematic modelling results for the rivers' daily runoff in the Lake Burtnieks watershed and water level of the lake are presented. Also, first time for the Lake Burtnieks is demonstrated possibility to utilise regular observations of meteorological elements and to use mathematical model, which is adapted to natural conditions. As a catchment example of the relationship between the conceptual model and the hydraulic reservoir routing model is presented as well. The simulated hydrological data are with a high statistical significance and have been applied in the project Water Protection Project of the Lake Burtnieks for the further calculations of nutrient loading and the different scenarios of climate changes (Bilaletdin et al. 2004).

MATERIALS AND METHODS

The watershed model of the Lake Burtnieks has developed for the simulation of daily runoff and water level. This model is based on the specific hydraulic routing model of the Lake Burtnieks and the conceptual models METUL and METQ98 (Krams and Ziverts 1993; Ziverts and Jauja 1999) which are successfully applied to a relatively large river basin in Latvia as the River Daugava.

In present study the Lake Burtnieks watershed (part of the Salaca River basin) is divided in 7 sub-basins and one additional sub-basin between an outlet of the Lake Burtnieks and a gauging station Mazsalaca at the River Salaca (Fig. 1). To consider the runoff heterogeneity in runoff processes the catchment and its river basins and sub-basins are divided in hydrological response units (HRU) characterised by a relative homogeneity with respect to the most important parameters, which include slope, vegetation and soil characteristics. As in the model METQ98 each sub-basin is divided in 5 HRUs: agricultural lowlands, hilly agricultural lands,

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forests, swamps and lakes. The total number of HRUs for the investigated drainage basin is 40.

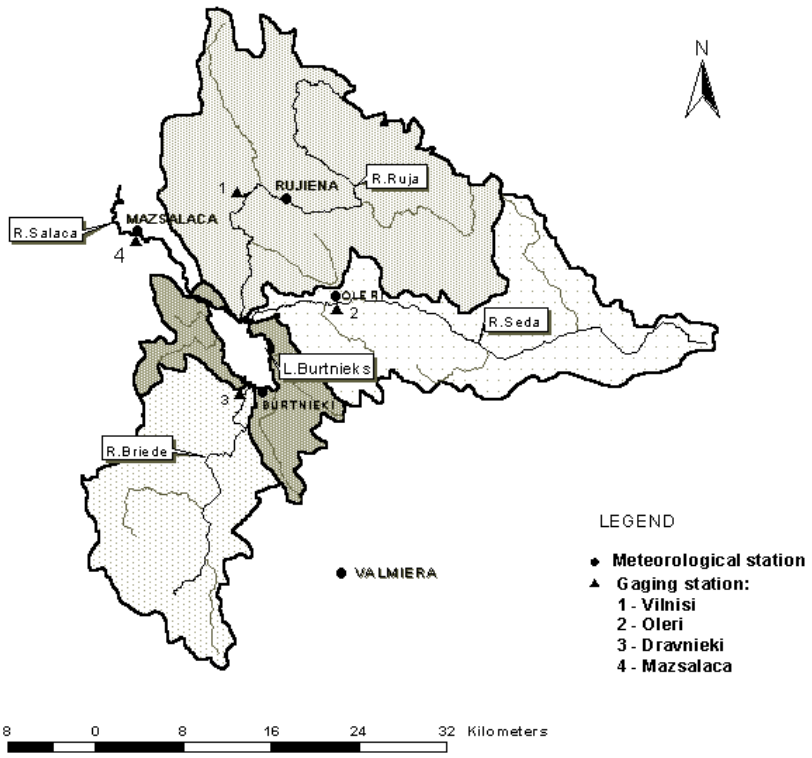

Figure 1: The Sub-basins, the Gaging and Meteorological Stations in the Watershed of the Lake Burtnieks

The model METQ98 applied is a mathematical model for the simulation of the daily runoff and evaporation for the rivers with different catchment areas. Input data for the model are daily mean values of air temperature, precipitation and vapour pressure deficit. The model can be classified as conceptual model and has 22 parameters. However, most of the parameters are physically based and the rest of parameters could be estimated by the calibration. The analysis of the model parameters is based on observed hydrological and meteorological data of the Vienziemite Brook Basin (Ziverts and Jauja 1999).

The water balance and runoff of each HRU has been simulated in three storages: snow (water content in snow cover), soil moisture (water in the root zone) and groundwater.

The total runoff from each of HRU consists of three runoff components: Q_1 - surface runoff, Q_2 - subsurface runoff (runoff from the groundwater upper zone) and Q_3 - base flow (runoff from the groundwater lower zone). The snow accumulation and melting routine in the model is similar to the one used in the HBV model (Bergström 1992). The main difference between the METQ and HBV models is that the degree-day ration in METQ does not have a constant value, but it has a temporal difference depending on the daily potential insolation of each particular day.

In the watershed model of the Lake Burnieks the runoff routing of river channel has been simulated by modified method of the unit hydrograph (a sum of the runoff components $Q=Q_1+Q_2+Q_3$ has been calculated for one day intervals in the each gaging station and then transformed to the downstream at mouth of each sub-basin).

A principally different approach for the hydraulic routing of the Lake Burtnieks was used. The approach is based on common hydraulic methods of open channels. There was a lacking of channel measurements to obtain discharge rating curve Q=f(H) at the outlet of the Lake Burtnieks. However, Q=f(H) on the bases of the typical parameters of Latvian river channels (Golubovskis 1993) has been calculated. More about used parameters, structure and calibration of the watershed model of the Lake Burnieks you could find out in the project report (Bilaletdin et al. 2004).

RESULTS AND DISCUSSION

The observed meteorological data at station Rujiena and the precipitation measurements at stations Burtnieki, Mazsalaca, Oleri and Valmiera for the simulation of the daily runoff in the mathematical modelling of Lake Burtnieks watershed have been used. The time series at least 5-year period of four river discharge (River Briede-Dravnieki, the River Ruja-Vilnisi, the River Salaca-Mazsalaca, the River Seda-Oleri) and one water level of the lake (Burtnieki) stations have sufficiently good data for a successful calibration of the distributed rainfall-runoff model for the watershed of the Lake Burtnieks. Also the used rainfall-runoff model METQ98 simulates total runoff using two approaches: (1) separately for the HRU: hilly agricultural land, agricultural lowlands, forests and swamps, and (2) separately for surface runoff and subsurface runoff in each HRU. However, in this study for the water quality model, the first approach was used (Bilaletdin et al. 2004).

The Figure 2 shows good coincidence between the measured and simulated daily discharges. To analyses the results a statistical criterion R^2 (Nash and Sutcliffe 1970) and a correlation coefficient r are used. The efficiency criterion R^2 varies from 0.57 to 0.80 but the correlation coefficient r is from 0.80 to 0.90 for the tributaries of rivers in the Lake Burtnieks watershed. Also water level calibration of the Lake Burtnieks shows good results: the statistical criterion R^2 is 0.58 and the correlation coefficient r – 0.83 (Fig.3).

The main source of difference between the simulated and observed runoff values is the quality of precipitation input data, as well as the location of the available meteorological stations to characterise the spatial and temporal distribution of precipitation in the drainage basin of Lake Burtnieks. The lowest statistical criterion R^2 0.57 was found for the River Seda. It could be explain by a flat and broad flood plain and a high percentage of the wetlands in the river drainage basin. Thesis reasons determine a specific hydrological regime of the River Seda which differs from others.

As a result of modelling of the investigated drainage area discharge at 8 points for the 10-year period (from 1990 to 1999) were simulated. The results of the model calibration show that the developed mathematical model for the Lake Burtnieks watershed is widely applicable including the calculation of nutrient loading from the catchment areas as well (Bilaletdin et al. 2004).

Also in this watershed modelling the scenario of climate changes for the next 10-, 30- and 60-years were used. Possible hydrological regimes of the Lake Burtnieks and it's basin in the future have been obtained. The results are obvious presented in Figure 4. Having analysed the scenario of climate changes, we could conclude that main tendency in runoff changes are following: decreased in spring flood peaks and as opposite - increased in winter thaw-period.

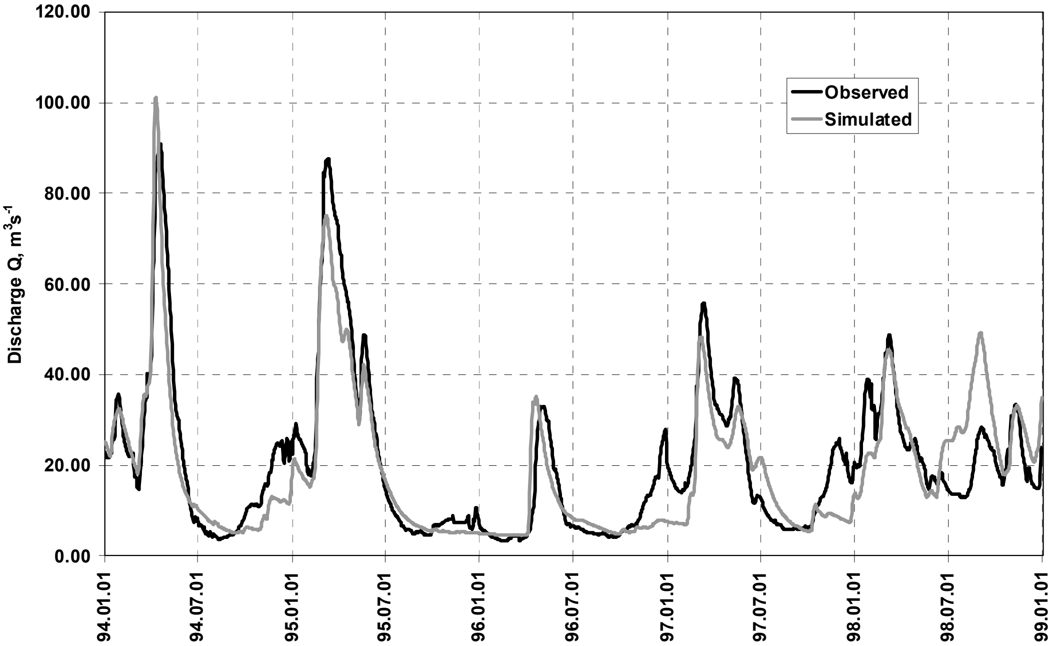

Figure 2: Observed and Simulated Hydrographs at River Salaca – Mazsalaca (R^2=0.8 and r=0.9)

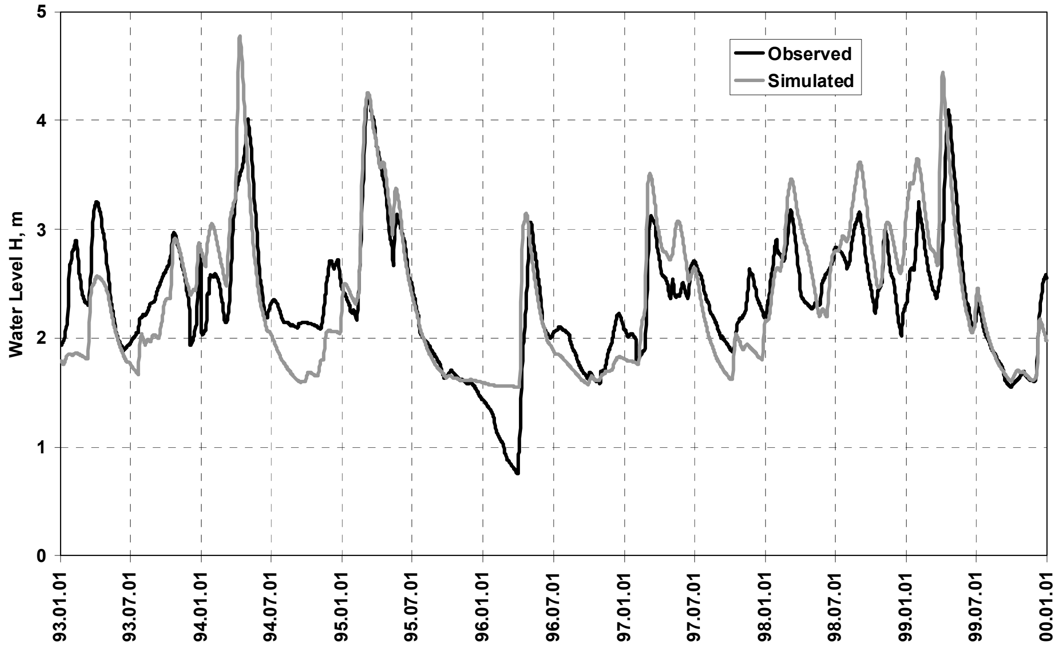

Figure 3: Water Level Calibration of the Lake Burtnieks (R^2=0.58 and r=0.83)

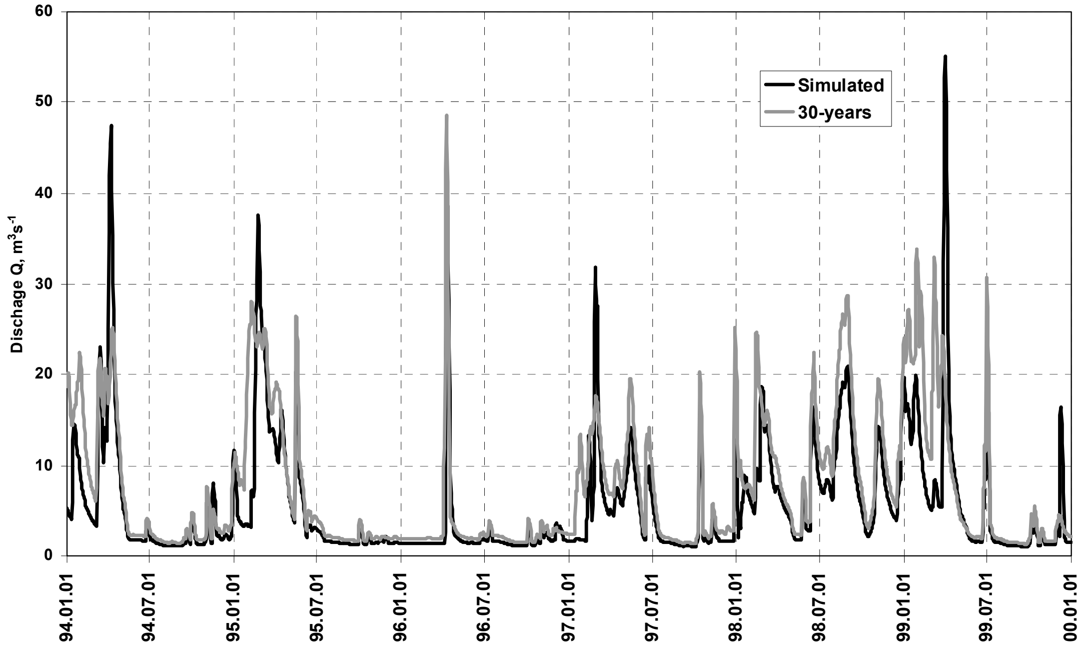

Figure 4: Simulated Hydrographs under the Scenario of Climate Changes at Present and After 30 Years at the River Ruja – Vilnisi

CONCLUSIONS

The obtained results of modelling have revealed that the developed mathematical watershed model of the Lake Burtnieks are widely applicable including the simulation of different hydrological processes in watershed - daily runoff and lake water level fluctuations to the given scenario of climate changes. Also calculation of nutrient loading from the catchment area and to create preconditions for successful forecasting of hydrological and hydrochemical regime in the basin are possible.

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