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APPLICATION OF THE MODEL METQ FOR HYDROLOGICAL CALCULATIONS

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Abstract
In this study, a conceptual rainfall-runoff METQ model, version METQ2007BDOPT, to simulate daily runoff was applied. The model structure and parameters were fundamentally the same as in the METQ98 model with some additional improvement and semi-automatical calibration performance. The model has proved to be successful for both small (the Vienziemite Brook, 5.92 km^2) and large (the Daugava River, 81 000 km^2) drainage basins. The model METQ2007BDOPT was calibrated to the six different size river basins (the Pērse, the Malta, the Neriņa, the Imula, the Malmuta and the Iecava). These pilot river basins are characterised by one or two prevailing natural conditions such as hilly agricultural lands, agricultural lowlands, sandy lowlands, forested areas, swamps or lakes. The results of calibration showed good coincidence between the measured and simulated daily discharges. The Nash – Sutcliffe model efficiency coefficient *NSE* varies from 0.52 to 0.78 and Pearson correlation coefficient *r* from 0.65 to 0.88 for the six river basins with calibration and validation period from 1956 to 2015. In this study, we found some relationships between the model parameter values and physiographic sub-catchment characteristics.
Key words: hydrological modelling, calibration, conceptual model, river basin.

Introduction

Nowadays, hydrological measurement data has an important role of several hydrological challenges in water management. However, not always all data series of hydrological data can be measured or observed. One of the simplest and easiest ways to obtain hydrological data is application of hydrological models (Bergström, 1991; Seibert, 1999; Uhlenbrook *et al*., 1999; Merz & Blöschl, 2004; Beven, 2012).

During past decades in Latvia some versions of hydrological model METQ have been modified – METQ96 (Ziverts & Jauja, 1996), METQ98 (Ziverts & Jauja, 1999), METQ2005 (Ziverts & Apsite, 2005), METQ 2006 (Ziverts & Bakute, 2007) and METQUL2012 (Grinfelde, 2016). The model METQ is applicable to different dimensions of the river basins and lakes (Krams & Ziverts, 1993; Ziverts & Jauja, 1999; Apsite, Ziverts, & Bakute, 2008) althought the METQ model versions have been used for different hydrological tasks (Jansons *et al*., 2002; Bilaletdin *et al*., 2004; Zivers & Apsite, 2005; Apsite *et al*., 2005).

In this paper, the hydrological METQ2007BDOPT model is described and calibration results analysed.

The aim of this study was to calibrate parameters of the model METQ, version METQ2007BDOPT, of the six different river basins for simulation of daily discharge.

Tasks of the study are:

- to analyse and describe the study areas;
- to apply hydrological model METQ2007 BDOPT for study river basins;
- to analyse and assess calibration results of the METQ2007BDOPT model.

Materials and Methods

Hydrological model METQ2007BDOPT is a conceptual model which can be applied for simulation of daily discharge. Daily meteorological data were used as an input data for running the METQ2007BDOPT model.

Most of the parameters are physically based (Ziverts & Jauja, 1999) and the rest of parameters – A2, DZ, A3, PZ, CMELT, AMELT, DPERC, Beta, RCHR, RCHR2, RCHRZ, and RCHRZ2 were estimated by the semi-automatic calibration.

However, before to start to calibrate the model the climatic files were needed to prepare. Measures of precipitation and air temperature are used to create the climatic files. At least a 13-year period of daily discharge was applied for the calibration of the model parameters. To analyse the results of model calibration, the Nash – Sutcliffe model efficiency coefficient *NSE* (Nash & Sutcliffe, 1970), a Pearson correlation coefficient *r* and average values were used (Ziverts & Jauja, 1999).

In this study, six river basins by one or two predominant HRUs or natural conditions were chosen. The River Pērse basin was characterised by hilly agricultural lands and forests; the River Imula basin – agricultural hilly lands and lowlands; the River Neriņa basin – bog area and agricultural lowlands; the River Malmuta basin – bog area, the River Malta basin – lakes and the River Iecava (upper reaches) basin – sandy lowlands. The water balance and runoff of each HRU were simulated in three storages (Ziverts & Jauja, 1999). Surface runoff (Q_1), subsurface runoff (Q_2) and - base flow (Q_3) are components of total runoff (Fig. 1) from HRUs (Ziverts & Jauja, 1999).

In this study, the conceptual METQ2007BDOPT model was calibrated to such river basins: the upper reaches of the Neriņa (A = 73 km^2), the Imula (A = 232 km^2), the Iecava (A = 566 km^2), the Pērse (A = 249 km^2), the Malta (A = 797 km^2) and the Malmuta (A = 158 km^2).

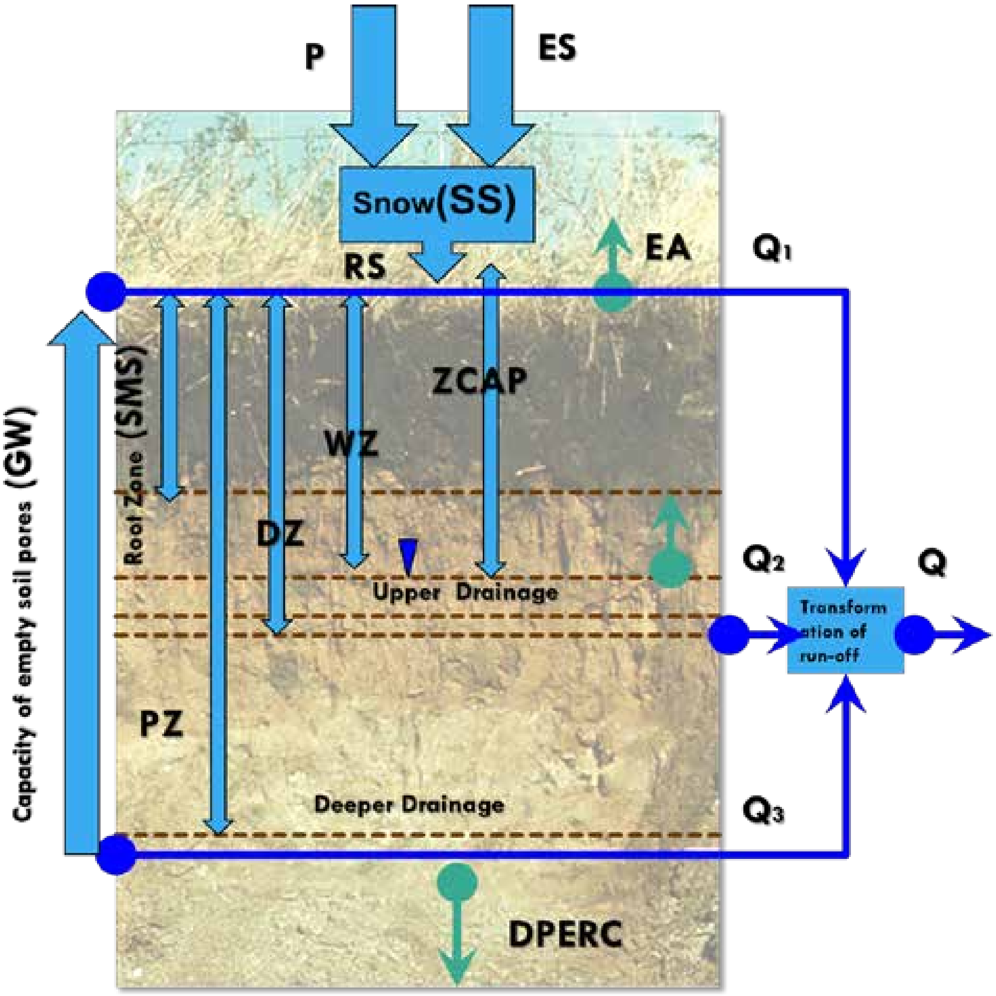

Figure 1. Structure of the hydrological model METQ2007BDOPT.
Source: author's flowchart, 2016.

Study Sites

In this study, the chosen six river basins are located in different places of Latvia and belong to the three largest river basins – the Daugava, the Lielupe and the Venta (Fig. 2). According to Pastor's (1987) regionalisation of Latvian small rivers, the River Pērse basin belongs to the rivers region of the Vidzeme Highland. The total drainage basin is 329 km^2, including upstream hydrological station Ūsiņi – 249 km^2. The average amount of precipitation is 800 mm per year. The area of the River Iecava drainage basin upstream hydrological station is 519 km^2, and it makes 1166 km^2 in total. The average amount of precipitation ranges from 650 to 750 mm per year. The River Iecava belongs to the hilly Upmale Plain and the Taurkalnes Plain. The Neriņa basin area is 118 km^2, and it belongs to the rivers of Piejuras lowland. The River Imula basin belongs to the Austrumkursas Upland, and the total basin area is 263 km^2. The average amount of precipitation varies from 650 to 700 mm per year. Compared to other river basins, the highest amount of precipitation receives the River Pērse because it is located in the Vidzemes Upland. This basin is also characterised by high percentage of forests – 47% cover of the entire basin. Irrespective of the Malta and the Malmuta river basins location in the same hydrological region, they are still different in predominant HRU. The River Malta is substantially affected by the lakes (approximately 35%), while the River Malmuta basin - by swamps area (approximately 40%). The River Iecava basin is quite different from other river basins regarding geomorphologic conditions. Sandy lowlands are dominating upstream of the River Iecava basin as well as forests. The River Neriņa basin is characterised by sandy and agricultural lowlands which occupy 46% of the total drainage basin. However, the River Imula basin is characterised by agricultural hilly lands and lowlands (62%).

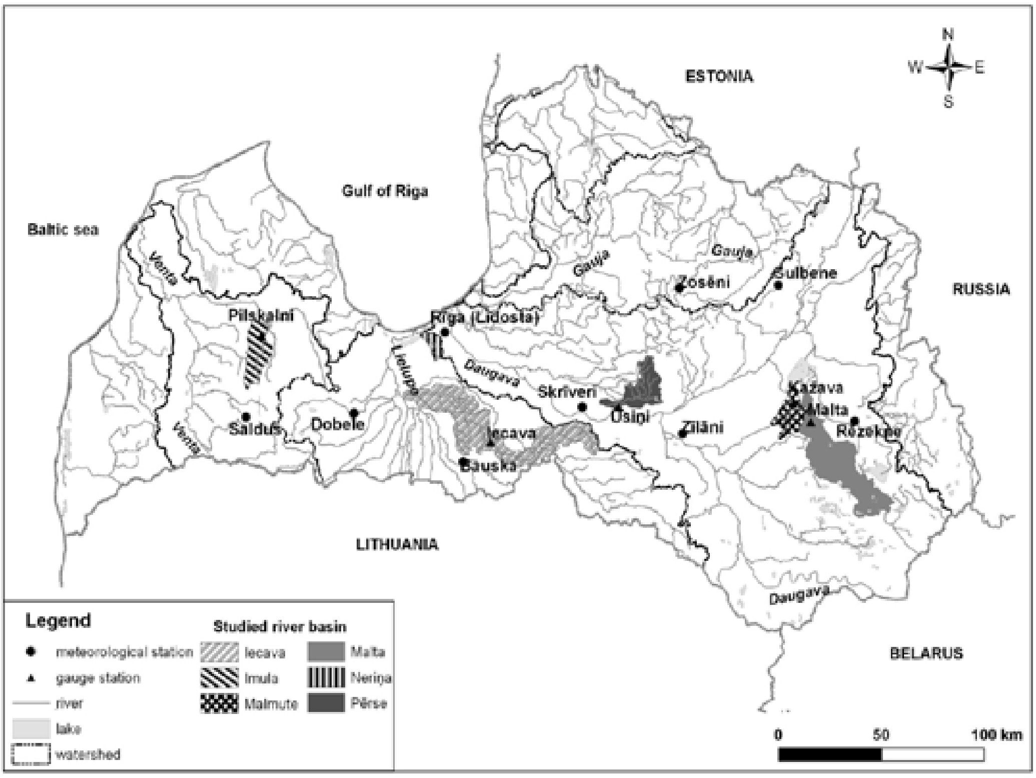

Figure 2. The location of study sites and observation stations (hydrological and meteorological).
Source: author's scheme, 2016.

Results and Discussions

In this research, the data series of at least thirteen years period of six hydrological and nine meteorological stations have been used for the calibration of a hydrological METQ2007BDOPT model for six different size river basins. We can conclude that for such catchment areas, the availability of observation points and the calibration periods is sufficient.

The results of the METQ2007BDOPT model calibration for the study river basins were showed sufficient or good coincidence between the observed and simulated daily discharges from 1956 to 2015: the Nash-Sutcliffe efficiency *NSE* varies from 0.78 to 0.52 and correlation coefficient *r* is from 0.88 to 0.77 (Table 1).

The best performance of the modelling results was obtained for the River Malta basin: *NSE* – 0.78 and *r* – 0.88 (Fig. 3). It is due to precipitation observations in the river basin. There is a meteorological station Viļāni, and its data could be used for the model calibration. The weaker results are obtained for the River Neriņa at Bulduri (Fig. 4).

The main source of difference between the simulated and observed daily discharge is the availability of meteorological stations in the river basins.

Table 1

The results of calibration of the model METQ2007BDOPT

Runoff gauge station	Results of calibration	
	NSE	r
Iecava – Dupši	0.66	0.82
Imula – Pilskalni	0.66	0.77
Malmuta – Kažava	0.52	0.65
Malta – Viļāni	0.78	0.88
Neriņa – Bulduri	0.55	0.78
Pērse – Ūsiņi	0.65	0.85

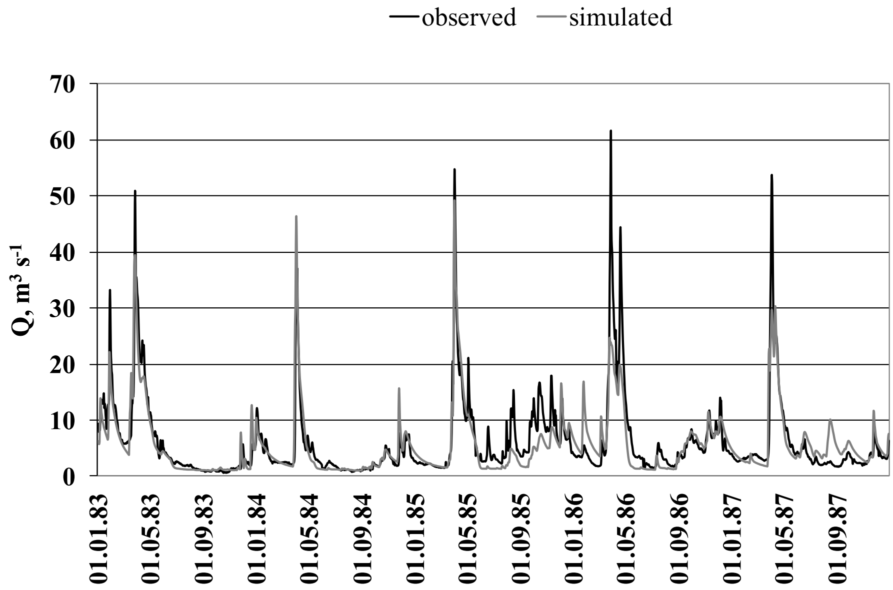

Figure 3. Simulated and observed discharge at Viļāni on the River Malta.

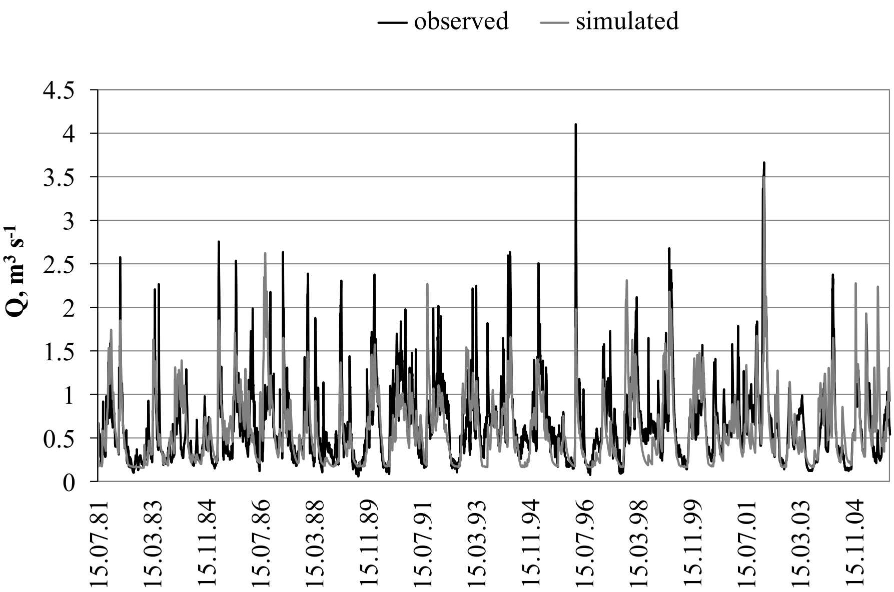

Figure 4. Simulated and observed discharge at Bulduri on the River Neriņa.

For instance, there are no meteorological stations in the River Iecava basin. Therefore, meteorological stations at Bauska, Skrīveri and Riga have been used. The weaker fit was also identified for the River Malmuta basin, and one of the reasons could be not sufficient meteorological observations to perform better model calibration. Since large areas of swamps in River basin play a significant role in the generation of the river runoff, meteorological observations of evaporation from wetlands are important for such basins. Another explanation is connected with a not well-marked riverbed.

The numerical values of model parameters for each basin reflect the physiogeographical conditions, including geomorphological, land use, soil, etc., of the studied drainage areas.

Estimation of a threshold value of water storage in the root zone is based on the previous studies of irrigations regime in Latvia (Ziverts & Jauja, 1999). In the river basins rich in swamps, i.e. the River Malmuta basin, values of WMAX is 20 mm. Soil conditions play a significant role in the runoff generation. According to the results, fillable porosity (ALFA) is one the main parameters which could reflect the geomorphologic conditions of rivers basins. The highest parameter value of ALFA was defined for the River Iecava basin. It can be explained by dominating sandy lowlands. By the hydrophysical properties of the soil structure, the highest value of fillable porosity is for sands. The height of capillary rise (ZCAP) was identified for the heavy soils, i.e. the River Pērse basin, while these values are lower for light soils like sandy ones. Values of coefficient of snow melting (CMELT) in the river basin is higher in more open, not forested areas such as The River Neriņa basin.

Conclusions

1. The results of calibration of the model METQ2007BDOPT for the study, river basins are sufficient (NSE varies from 0.52 to 0.78).
2. The results of model calibration show that METQ2007BDOPT can be used for simulation of daily discharge of river basins with different HRUs – agriculture lands, forests, sandy lowlands, lakes and bog areas.
3. Using semi automatic calibration, model parameter values are found on start values of searching the parameters.
4. In this study, the numerical values of model parameters for each basin show relationship with the physiogeographical conditions, including geomorphological, land use, soil, etc., of the studied drainage areas.

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