Application of the HBV model to the Kasari river for flow modulation of catchments characterised by specific underlying features

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1. INTRODUCTION

This report describes the HBV model application for flow modulation of catchments are characterised by specific underlying features such as karst, swampy and friable sand-gravel deposition on a daily time step by the Kasari river. The model application forms part of the Internal water, Meteorological and Scientific Centres of Estonian Meteorological and Hydrological Institute (EMHI)

2. THE CLIMATE AND HYDROLOGY OF THE KASARI BASIN

The Kasari catchment is located on the west lowest part of Estonia. Its altitude amounts 65 m. The catchment longness and width are more or less equal and these rich 45-55 km. The long-term annual mean of precipitation varies from 700 mm on the west to 765 mm on the east of watershed (from coast to internal area). Temperature (annual mean) varies from 5?C on the west to 4,5?C on the east. A snow pack is observed from December beginning to March ending. The underlying surface features are most important for hydrological regime formation. The hydrological regime of this river is characterised by four classical seasons: the spring flood during March, April and May; summer low flow period with rain floods (June, July, August and September); autumn rain floods during October and November and winter low flow period with slash jam tips (December, January and February) (1).

The hydrological features of water regime are caused by influence of underlying surface agents such as karst, friable sand-gravel depositions and swamps which are widely spreaded at the Kasari basin. Upper portion of watershed (fig.1) is characterised by karst events; there are clay moraine and swamped areas on the middle and lower portions of Kasari catchment. 35 % of catchment area are covered by swamps. The HBV model does not take account this agent as well as another one (karst), and question is: is it possible to use this model as it is for catchments with such agents?

4. THE HBV MODEL APPLICATION TO THE KASARI CATCHMENT

4.1 Basin subdivision

The total catchment area by whole Kasari catchment amounts to 2640 km² and was in the model application divided into the following four subbasins, which are :

I	Valgu,	135 km²
II	Konuvere,	618 km²
III	Teenuse,	634 km²
IV	Kasari	1253 km².

Subbasin I is characterised by the widely spreaded karst events and swamps (24%). Subbasin II has 24% of catchment covered by swamps and karst on upper portion of watershed. Subbasin III is characterised by very high degree of swampy - 35%, and subbasin IV, the lowest portion of total watershed, has 29% of area as swamped ones.

4.2 Analysis of input data

Precipitation is the source of streamflow generation and consequently the most important input parameter to the HBV model. Furthermore, temperature data and long-term estimates of potential evapotranspiration are needed as input. In the model application to Kasari basin 6 precipitation and 1 temperature stations were available for 10 year period (01.01.1981-31.12.1990). There are some gaps in the temperature and precipitation data during this period (01.08-22.09.87 and 01.08-31.08.87). A summary of the station weights on each investigated watershed is given in Table 1.

Table 1. Stations and weights used in the HBV model application.

	WATERSHEDS								
	Valgu (I)		Konuvere (II)		Teenuse (III)		Kasari (IV)		Annual precipitation
Station (Type)	Temp. (%)	Precip. (%)	Temp. (%)	Precip. (%)	Temp. (%)	Precip. (%)	Temp. (%)	Precip. (%)	(mm)
Ellamaa (P)	-		-		0.5		-		800
Kuusiku (PT)	0.1	1	0.7	1	0.28	1	-	1	791
Konuvere (P)	0.1		0.2		0.14		0.2		748
Naari (P)	0.7		0.1		-		0.3		819
Kasari (P)	-		-		0.08		0.2		746
Koodu (P)	0.1		-		-		0.3		711

The double mass technique was used to check the homogeneity of the precipitation and discharge records. This technique takes advantage of the fact that the mean accumulated precipitation for a number of gauges is not very sensitive to changes at individual stations because many of the errors compensate each other, whereas the cumulative curve for a single gauge is immediately affected by a change at the station.

The mean accumulated precipitation for all others station is plotted on the X-axis against that for the gauge being studied, which is plotted on the Y-axis. If the double mass curve has a change in slope at some point in time, it indicates a break in homogeneity. A jag in the double mass curve can be caused by missing values at the observed station or by seasonal differences in the precipitation pattern. The slope of the curve is proportional to the intensity, i.e. if the observed station records exactly as much as the mean of the rest, the curve follows the diagonal. If the station records more, the slope will be steeper and if it records less, the double mass curve will lie below the diagonal.

The double mass curves for stations Konuvere and Teenuse showed signs of inhomogeneity during 1983-86 years. For precipitation stations Naari and Koodu was obtained the following signs of inhomogeneity: since 1983 the Koodu station data have decreased, and since middle of 1984 the Naari station data have increased.

Monthly mean values of potential evapotranspiration were compiled from available evaporimeter pans of the Class A type, situated within the upper parts of the river basin (subbasin II, Kuusiku station). For others subbasins (I, III and IV) no evaporation observations were available. For these subbasins the evaporation data from subbasin II was used the same due to just the same soil, topography and climate conditions. However, the long-term evaporation data from the Bog Station Tooma were used as pattern of rations between these at different microlandscapes. The evapotranspiration values were used for calibration are given in Table 2.

Table 2. Mean evapotranspiration (mm/day) data used in the HBV model application.

(type of surface)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Soil	0.05	0.10	0.32	1.11	2.08	2.37	2.47	1.78	1.30	0.78	0.10	0.09
Swamps	0.07	0.13	0.44	2.00	2.30	2.70	2.70	1.70	1.40	0.80	0.14	0.08

4.3 Calibration

Calibration was carried out by three steps. The first one was done without taking in account those features mentioned above. Furthermore, swampy is the only agent having quantitative expression for catchment area. On the second step the ilake zones were inserted for swamp areas. There is an attempt to put into model the evaporation data for swamps and to use some additional data from stations are not located on Kasary basin on the third step.

Initial data bases of precipitation, runoff and areas for four subbasins were built up. There are no swamps zones into these initial conditions.

Calibration was carried out against the runoff data for the period 01.10.1981 to 31.12.1990 at all four subbasins. In the calibration process the criteria of model performance described in Section 3.3 was used. The modelled and observed hydrographs were plotted and visually inspected and some of them, the bests and worsts ones are presented in Appendix B.

Table 3. The values of the most important model parameters for final calibration.

Parameter	Value	Function
<u>Snow routine</u>		
SFCF	0.95-1.00	Snowfall correction factor
TT	0.5	Threshold temperature for snowmelt
CFMAX	2.5-3.0	Degree-day factor

FOCFMAX	1.5-3.0	Forest factor for CFMAX
<u>Soil routine</u>		
FC	200-300	Maximum soil water capacity
LP	0.3-05	Limit for potential evapotranspiration
b	5-7	Empirical coefficient
<u>Upper response tank</u>		
Ko	0.15-0.30	Flood recession parameter
K1	0.07-0.15	Intermediate flow recession parameter
UZL	30-45	Flood recession threshold
<u>Lower response tank</u>		
PERC	0.2-0.3	Ground water percolation
K4	0.01-0.015	Base flow recession parameter

4.4 Model results

The best results were obtained on the second step. They are given in Table 4.
Accepted way needs some explanations. This one has been chosen during calibration process and after receiving the best results on the first step. The question was: if model has takes in account different kind of lake, is it possible to express through this agent the equal influence of swamp, karst and friable depositions? What are similar to each other?

Table 4. R^2- and accumulated difference values of model fit for the modelled flow to the Kasari basin catchments

Catchment	R^2-value			Accumulated difference		
	step 1	step 2	step 3	step 1	step 2	step 3
Valgu (I)	0.77	0.83	0.79	-121	-32	138
Konuvere (II)	0.77	0.87	0.80	451	181	15
Teenuse (III)	0.71	0.83	0.81	35.1	0.22	-80
Kasari (IV)	0.72	0.89	0.86	124	52	-29

What is marc of lake? Catchment lakes ("ilake" case) redistribute river runoff decreasing tips and increasing low flow discharges. And they enlarge the runoff losts because of evaporation.

Karst redistributes the runoff not only within year like lakes, but between catchments also (2). So the snowfall correction factor for Valgu catchment was 0.95. But it is not obliginal every tip is less than on the surrounding unkarsted rivers. It depends on the fullness of karst cavities. If cavities are empty, part of flood water will discharge ones. And than the tip of flood will be observed: smaller and later. So the

WHC and MAXBAS parameters for Valgu catchment (135 km²) are 0.27 and 2 correspondingly in despite of its size and same slope exposition.

Friable sand-gravel depositions are the factor for runoff regulation also, but more strong one than lakes (3). And evapotranspiration from landscape with such soils is rather less, than from water surface. Friable rock depositions provide the stable low flow for catchments with area more than 50 km² (4)(see table 3, lower responsible tank).

Swamped areas are very similar to lakes due to theirs big evapotranspiration and flood decreasing (5), but they have difference among themselves. Bog does not ever have big catchment area, and it only decreases any runoff (flood and low flow). Fan works like flood plain and only decreases any runoff also (6,7).

Total influence of these agents on the river runoff may be very similar to "ilake" parameter. So at first the amount of swamped area had been taking account as "ilake" zone, and than it has been decreased to some other amount: for Valgu (I) - to 18%; for Konuvere (II) - to 10%; for Teenuse (III) - to 8%; and for Kasari (IV) - to 0%. It is matter that for catchment area more than 1000 km² this artificial step is not needed.

5. DISCUSSION AND CONCLUSIONS

Estonia is a small country and the most significant problem for it is the environment protection against pollution. For this reason a modern computer model for current water resourses estimation is very needed. The quantitative estimation of underlying surface agent's influence on the surface flow and on the catchment water balance, especially in the period of river low flow, gives the possibility for calculation of securitive river flow and water balance of any ungauged Estonian rivers using phisio-geographical parameters.
In this light the following conclusions of the HBV model application on the Kasari catchments have been done for Estonian conditions:

- For catchment area more than 1000 km² this model can provide 89% of the river flow variance in despite of any agents of underlyinf surface.

- For such watersheds the model responded at all flood and low flow events in the available data period, however, not always with the correct magnitude. Consequently, early flood and low flow period warning from the HBV model should be taken seriously.

- For catchment areas 100-1000 km² the HBV model is able to describe 71-79% of the variance of river flow without special triks for taking in account such agents as swamps and karst.

- To get better results (83-87%) it had to insert some artificial "ilake" zone. Consequently,

- the HBV model can be as index for different underlying agents influence estimation on the river runoff.

- To estimate the quantitative the influence of swampy, karst and friable deposition for possibility to use this model for any ungauged river it should be make new investigation for some special river watersheds which are characterised by strong influence of mentioned factors.

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