THE DANUBE BASIN WATER BALANCE – CASE STUDY: THE NITRA RIVER BASIN

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Abstract: Water balance of the Danube River basin is one of tasks being solved in a frame of the international co-operation in this basin under the umbrella of IHP UNESCO. This task should be finalised as the second enlarged and improved edition of the Hydrological Monograph of the Danube River.

This paper is giving an overview of existing methodology for water balance evaluation on the example of the Nitra River basin. Individual steps of assessment – input data preparation, tuning the model for monthly mean values and tuning the model for a full monthly data set - are described in details.

For input data preparation a digital terrain model and water dividing are used for mean watershed elevation and total basin area estimation. Modified WatBal model is used for water balance assessment for selected example area – the Nitra River basin above the crossection Nové Zámky.

The WatBal model needs as an input data monthly precipitation, air temperature and potential evapotranspiration data. In our case potential evapotranspiration was estimated according to the digitised Budyko method.

This methodology is proposed for application in the common task – Basin-wide Water Balance of the Danube River Basin.
Keywords**:** water balance, potential and actual evapotranspiration, digital elevation model, GIS methods in hydrological modelling, the Danube River Basin.

WASSERBILANZ DES DONAUEINZUGSGEBIETES – EINE FALLSTUDIE: DAS NITRAEINZUGSGEBIET

Zusammenfassung: Die Wasserbilanz des Donaueinzugsgebietes ist eine der Aufgaben, die im Rahmen der internationalen Zusammenarbeit in diesem Einzugsgebiet unter der Schilderung von UNESCO realisiert sind. Diese Aufgabe soll mit zweiter, ergänzter Ausgabe der Hydrologischen Monographie des Donaugebietes zum Abschluß gebracht werden.

Dieser Beitrag bringt einen Überblick der vorgeschlagenen Methodik der Wasserbilanzbestimmung, als Beispiel, im Einzugsgebiet des Flusses Nitra. Einzelne Schritte der Verarbeitung - d.h. die Eingangsdatenbereitung, die Modellabstimmung für die durchschnittlichen Monatswerte und die Modellabstimmung für eine volle Reihe der Monatswerte - sind hier ausführlich beschrieben.

Zur Datenbereitung der Mittelhöhe- und Einzugsgebietsflächenbestimmung werden das digitale Terrainmodell und Wasserscheidelinien benutzt. Das modifizierte WatBal Modell wird bei Wasserbilanzbestimmung des erwählten Gebietes - Einzugsgebietes des Flusses Nitra zum Profil Nové Zámky, appliziert.

Beim WatBal Modell werden als Eingang der Monatsniederschlag, die Lufttemperatur und Monatswerte der potentiellen Verdunstung benutzt. In unserem Fall haben wir die potentielle Verdunstung mit Hilfe der digitalisierten Budyko Methode festgelegt.

Wir schlagen vor die vorgelegte Methodik bei der Lösung der gemeinsamen Aufgabe - “Wasserbilanz des ganzen Donaueinzugsgebietes” zu nutzen.

Schlüsselworte: Wasserbilanz, potentielle und aktuelle Evapotranspiration, digitale Höhenmodell, GIS Methoden im hydrologischen Modellieren, Donaueinzugsgebiet

1. Introduction

The UN Framework Convention on Climate Change (FCCC) declared by the Rio environmental summit in 1992 came into effect in the Slovak Republic on 23 November 1994. Since that time Slovakia joined the scientific programme dealing with mathematical modelling of possible climate change impact. One of studies was performed in consonance with the Slovak National Climate Change Programme for the Nitra River Basin. Already at that time, due to methodological support of the U.S. EPA, model recommended for application was the WatBal model (Yates, 1994a). This model in its first part deals with the water balance itself and successful tuning of this model on the base of existing data for a representative period is a condition for any further study of the climate change impact.

Research project supported by the Ministry of Agriculture of Slovakia was in principle based on this model (Petrovič, 1998a, 1998b), but the solution showed some difficulties in tuning the balance model. Based on available literature and after a personal communication with colleagues of the main author (Yates – Strzepek, 1994b) the recommended and preliminary chosen model was rewritten into individual steps partially in FORTRAN77 (MS FORTRAN v. 5.1) and partially in a form of EXECELL worksheet programmed at the cell level.

A set of developed steps allows to model water balance for selected (sub) basin as a water balance in a virtual point, where all the data are related to the gravity point of a watershed.

2. Input data

Water balance is performed for a (sub) basin of the Danube River area. For estimation of all input data it is necessary to have a basin area and area/elevation distribution, further meteorological data of precipitation (incl. snowfall period) and air temperature (for evaluation of solid and liquid part of precipitation) and finally data on potential evapotranspiration – natural water consumption demand.

2.1 Basins characteristics.

Water dividing lines for the Nitra River basin to the profile in Nové Zámky were estimated from “water management maps” in a scale 1:50 000. Co-ordinates system was transformed into the projection “Lambert Azimuthal Equal Area” system used by the USGS in a model HYDRO1k, which is available at INTERNET. Parameters of the USGS projection system are in the Table 1.

Table 1. Georeferencing information for the USGS European data set HYDRO1k.

Characteristic	*Value*
Units	Meters
Radius of Sphere of Influence	6 370 997
False Easting	0.0
False Northing	0.0
Pixel Size	1000
Longitude of Origin	20 00 00 E
Latitude of Origin	55 00 00 N

According to the water dividing line a set of pixels of the USGS DTM lying inside the Nitra River basin area was selected. This can help - using the “statistics” function in ArcView – to estimate the selected region mean elevation and areal extend, as can be seen in Fig. 1.

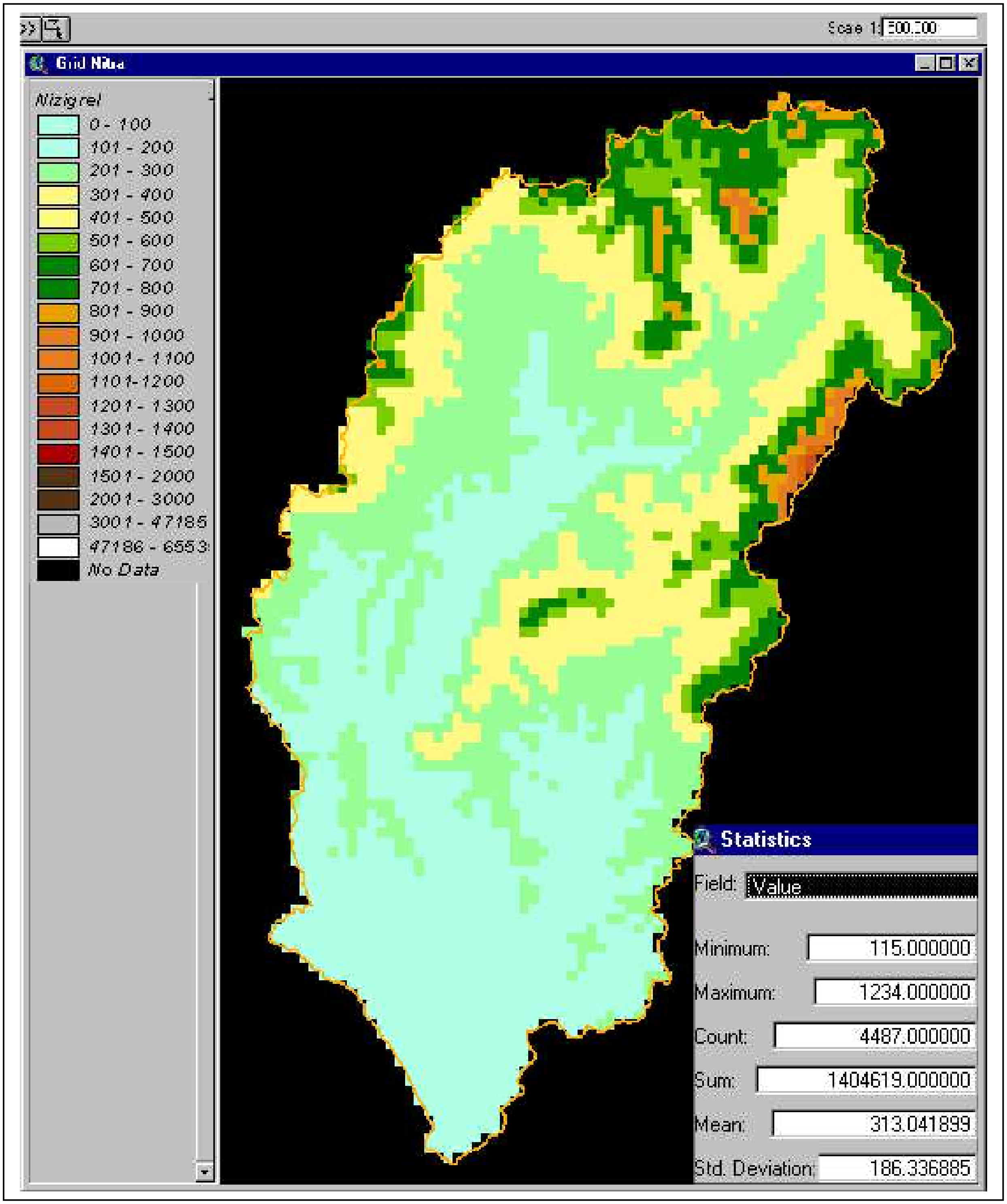

Fig. 1. USGS Digital elevation model – selection for the Nitra River basin.

From the statistical evaluation of obtained grid it can be seen, that pixels are in the elevation range between 115 and 1234 m a.s.l. (in reality between 115 and 1346 m a.s.l.), mean elevation is 313 m a.s.l. and total area (pixels count) is 4487 km^2.

2.2 Meteorological data related to the basin mean elevation.

Available input meteorological stations are shown in Fig. 2.

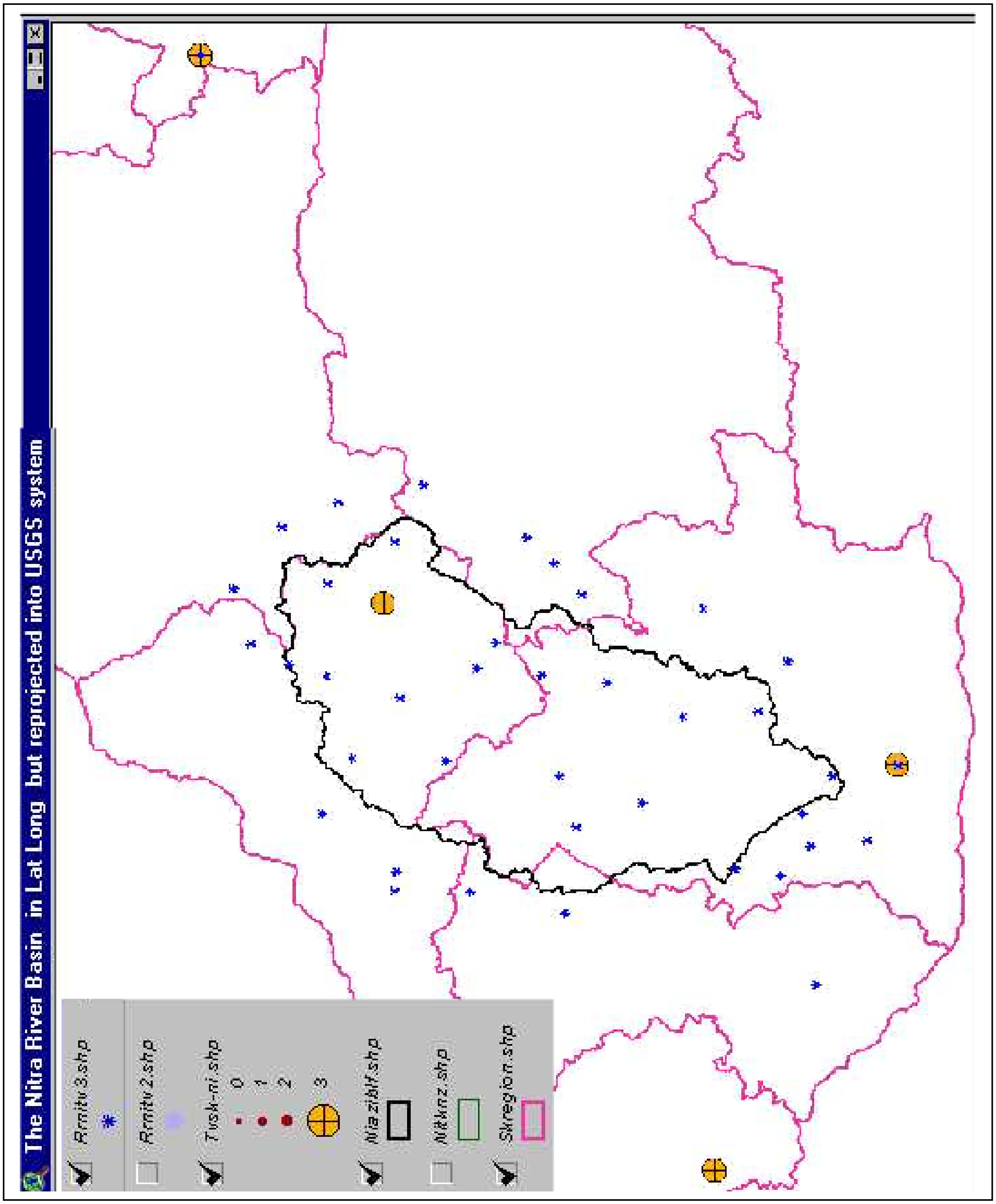

Fig. 2. Meteorological and precipitation stations in the Nitra River basin.

For recalculation of air temperature and air humidity four meteorological stations were used. All of them are lying in a south-west to north-east axis of the selected subbasin and their elevation is in the range from 115 to 1360 m a.s.l., list of stations is in the Table 2.

Table 2. Meteorological stations used for air temperature, air humidity and potential evapotranspiration evaluation.

IND-11	Station	HHH	Deg-N	Deg-E
813	Bratislava, Koliba	286	48,16667	17,11667
858	Hurbanovo	115	47,86667	18,20000
860	Prievidza, Bojnice	280	48,78333	18,60000
933	Štrbské Pleso	1360	49,11667	20,06667

Evaluation of air temperature to the level of mean elevation is based on linear decrease of temperature with increase of elevation. Calculation was performed for each month from 30 years period separately in EXCELL using function TREND in EXCELL keeping parameters in TREND function giving non-zero “b” coefficient of linear regression. For all 360 linear regressions only twice (1964/Jan, 1971/Jan) the correlation coefficient was higher (always negative) than -0.5, when situation could be classified as a large-scale atmospheric temperature inversion.

Estimation of air humidity is more complicated. Based on the equation of vertical distribution of vapour pressure, decrease of vapour pressure ***e*** with elevation growth has to be exponential (linear for ***log e***). Comparison of results obtained by linear regression of relative air humidity with elevation and by linear regression of ***log e*** led practically to the same results. Ratio of the linear estimation of relative air humidity to the relative humidity obtained from exponential regression lies in the range from 0.9706 to 0.9994 with an average equal to the value of 0,9958. Obtained results for the Nitra River basin approve us to use linear regression of relative air humidity directly, the individual error will not exceed 2 %.

Potential evapotranspiration, in principle, is estimated according to Budyko and Zubenokova (Kuz’min, 1976). Set of nomograms was digitised and incorporated into the program in Fortran77. Value of potential evapotranspiration PET is obtained in columns representing given month as an interpolation between lines giving values for computed saturation deficit. In our case the nomogram for a geobotanical region called in Russian literature as forest-step was selected and used. Nodes for this selected set are given in the Table 3.

2.3 Precipitation data.

Areal and temporal variability of precipitation is relatively high. For areal mean monthly precipitation estimation as much as possible precipitation stations with complete data set should be used. In our basin and its close surroundings we selected 37 precipitation stations, which were originally prepared on the base of long-term (1901-1970) precipitation series evaluation by Šamaj and Valovič (1978). These data series were verified and prolonged up to the year 1980 in the co-operation with Mr. Faško from the Slovak Hydrometeorological Institute. Spatial distribution of chosen stations can be seen from Fig. 2.

Areal precipitation monthly totals could be obtained by different methods. The really precise method would be evaluation of areal precipitation from monthly maps of isohyets (drawn and processed e.g. by GIS tools), but this is extremely time-consuming approach. For orographic conditions in Slovakia monthly precipitation data seem to have linear increase of precipitation with elevation (Petrovič Š., 1972).

Similar to the air temperature evaluation an areal precipitation totals for the mean elevation of analysed basin was used, all the processing was done in an EXCELL worksheet by use of the TREND function.

Table 3. Mean monthly potential evapotranspiration in mm per day for forest-step as a function of months and saturated deficit in hPa (milibars).

SatDef	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0,084	0,097	0,161	0,250	0,565	1,330	0,968	0,387	0,233	0,129	0,100	0,084
1	0,403	0,548	0,742	1,170	1,710	2,430	2,130	1,390	0,933	0,645	0,567	0,403
2	0,710	0,919	1,290	1,820	2,360	2,900	2,630	2,070	1,550	1,270	0,950	0,710
3	0,968	1,270	1,730	2,270	2,770	3,270	3,000	2,500	2,020	1,520	1,280	0,968
4	1,100	1,580	2,090	2,650	3,070	3,590	3,230	2,840	2,400	1,840	1,630	1,100
5	1,440	1,860	2,400	3,000	3,370	3,880	3,610	3,140	2,750	2,160	1,920	1,440
6	1,470	2,080	2,680	3,270	3,610	4,130	3,860	3,400	3,060	2,400	2,150	1,470
7	1,480	2,290	2,960	3,570	3,860	4,370	4,100	3,640	3,330	2,680	2,370	1,480
8	1,490	2,500	3,250	3,800	4,080	4,600	4,310	3,870	3,580	2,950	2,570	1,490
9	1,500	2,510	3,260	4,030	4,290	4,820	4,520	4,100	3,820	2,960	2,580	1,500
10	1,510	2,520	3,270	4,230	4,470	5,000	4,710	4,290	4,020	2,970	2,590	1,510
11	1,520	2,530	3,280	4,400	4,660	5,180	4,890	4,450	4,230	2,980	2,600	1,520
12	1,530	2,540	3,290	4,410	4,820	5,350	5,050	4,630	4,440	2,990	2,610	1,530
13	1,540	2,550	3,300	4,420	4,980	5,520	5,230	4,810	4,450	3,000	2,620	1,540
14	1,550	2,560	3,310	4,430	5,150	5,680	5,370	4,950	4,460	3,010	2,630	1,550
15	1,560	2,570	3,320	4,440	5,290	5,830	5,500	5,100	4,470	3,020	2,640	1,560
16	1,570	2,580	3,330	4,450	5,440	5,950	5,630	5,240	4,480	3,030	2,650	1,570
17	1,580	2,590	3,340	4,460	5,580	6,080	5,760	5,390	4,490	3,040	2,660	1,580
18	1,590	2,600	3,350	4,470	5,710	6,200	5,890	5,520	4,500	3,050	2,670	1,590

2.4 Runoff data.

To complete water balance elements a runoff depth data is needed. Measured mean monthly discharge [$m^3.s^{-1}$] in the closing – reference - profile in Nové Zámky is for its use in model recalculated to the runoff depth in mm per month using the basin area estimated from DEM - 4487 km^2 and amount of seconds in particular month.

2.5 Selected period of data processing.

In consonance with the proposal presented at the IHP UNESCO Danube working group meeting in Zagreb the selected (proposed) period is a representative 30-year period and covers monthly data for calendar years 1951 – 1980.

Discussion about effectiveness of such a period usage is theoretically interesting, but practical studies of basic meteorological element trends are showing a growing influence of climate change in our territory after the year 1980. Evaluation of water balance for proposed basic representative period could help to obtain a water balance assessment, which is a base for evaluation of different changes in time series after the year 1980.

On the other hand some countries would like to evaluate water balance for longer period. There is not a significant difference in time needed for water balance evaluation for 30 or 50 year period after having prepared input meteorological and discharge data. It means, that common processing for the basin-wide water balance should be performed in the whole Danube River basin for the same time period. This common data period MUST BE accepted by all the Danube countries, but due to the above mentioned reasons we would like to stress explicitly a need to cover (at least or also) the period of 1951 – 1980.

3. Modified Water Balance Model.

In principle for a water balance evaluation a basic equation is valid, in our case in a form

$$PRE = AET + RUND + DSM + DDWS \quad (1)$$

where PRE is precipitation areal mean total for a given time step
AET is actual evapotranspiration
RUND is runoff depth
DSM is a change (difference) in soil moisture content created in actual time step
DDWS is a change (difference) in "deep water storage" depth
and all members in the equation are in the same units – mm per time step, in our case the time step is a month.

Within model run some supporting parameters are needed:

ATRAIN – is an air temperature threshold; if the air temperature is higher, all precipitation in a basin is in a liquid phase;

ATSNOW – is an air temperature threshold, if the air temperature is lower, all precipitation in a basin is in a solid phase; the condition ATRAIN ≥ ATSNOW must be valid;

PRIESKO – represents a "fast seepage coefficient" and is giving a portion of liquid precipitation, which enter (infiltrate into) the soil layer at the beginning of a time step and play role in the AET evaluation; it must be from the interval <0; 1>;

WACT – is an actual soil moisture value above the wilting point (WP) in a model run in a given time step;

SFFC – is a soil moisture full field capacity, it represents saturated water content (above WP) in a soil layer (implicitly assumed soil layer thickness is 1 m);

WCRIT – a value of soil moisture content (above the WP) threshold, for the actual soil moisture lower than this value the actual evapotranspiration is less than the potential one and can be expressed in a following form

$$AET = PET * WACT / WCRIT \quad (2)$$

These parameters are also used in the model tuning process.

Finally there are some "hidden" internal parameters used representing "starting and ending" values for different variables at the beginning and end of a time step.

3.1 Tuning step 1.

In this part a preliminary tuning of needed parameters has to be performed. Program is working on a base of long-term means of monthly air temperature, air humidity, precipitation and runoff values related to the basin point of gravity located in a mean elevation of a selected watershed.

This step is done with a set of target tasks:

Values of ATSNOW and ATRAIN can be judged by evaluation of a basic elevation extend and considering dynamic meteorology equations. It means that ATRAIN is a temperature in the average basin elevation by which temperature at the highest point of the water dividing line is equal zero. By the temperature higher than ATRAIN, precipitation in the whole watershed is in a form of a rain. Opposite the ATSNOW represents the temperature in the average basin elevation by which temperature at the lowest point of the water dividing line is equal zero. By the temperature lower than ATSNOW, precipitation in the whole watershed is a snowfall. For this first judgement the vertical temperature gradient can be taken as a critical adiabatic gradient – 0.65 °C/100 m.

Snowmelt and mixed precipitation within the different elevation in the catchments for the air temperature between ATSNOW and ATRAIN are considered, too. Snowmelt day – degree - factor “MONTHDEGFAC” is preliminary set equal to 4.0. Practical “tuning” of the model by the method trial and error shown, that probably a higher value has to be used. A detail description is out of the frame for this contribution.

The SFFC and WCRIT should be the same, what represents a basic assumption, that any decrease of WACT below the maximum possible available soil moisture at SFFC causes proportional decrease of actual evapotranspiration according to the equation (2). This can be achieved by optimising the value of PRIESKO, if other values are in a converting range.

All the computation is done in a do loop, where the aim is to achieve the same final actual soil moisture as was the starting one (this is simply done by setting the new starting soil moisture content equal to the old ending soil moisture content).

Practical tuning showed, that model tuning has a convergent solution for quasi real values of SFFC between 70 mm (light sandy soils) and 205 mm (heavy soils).

It is clear, that in assessment of mean monthly water balance the resulting actual evapotranspiration must have the same yearly total. The influence of choosing SFFC and tuning PRIESKO is propagated in the yearly course of monthly evapotranspiration totals, as it is presented in Fig. 3.

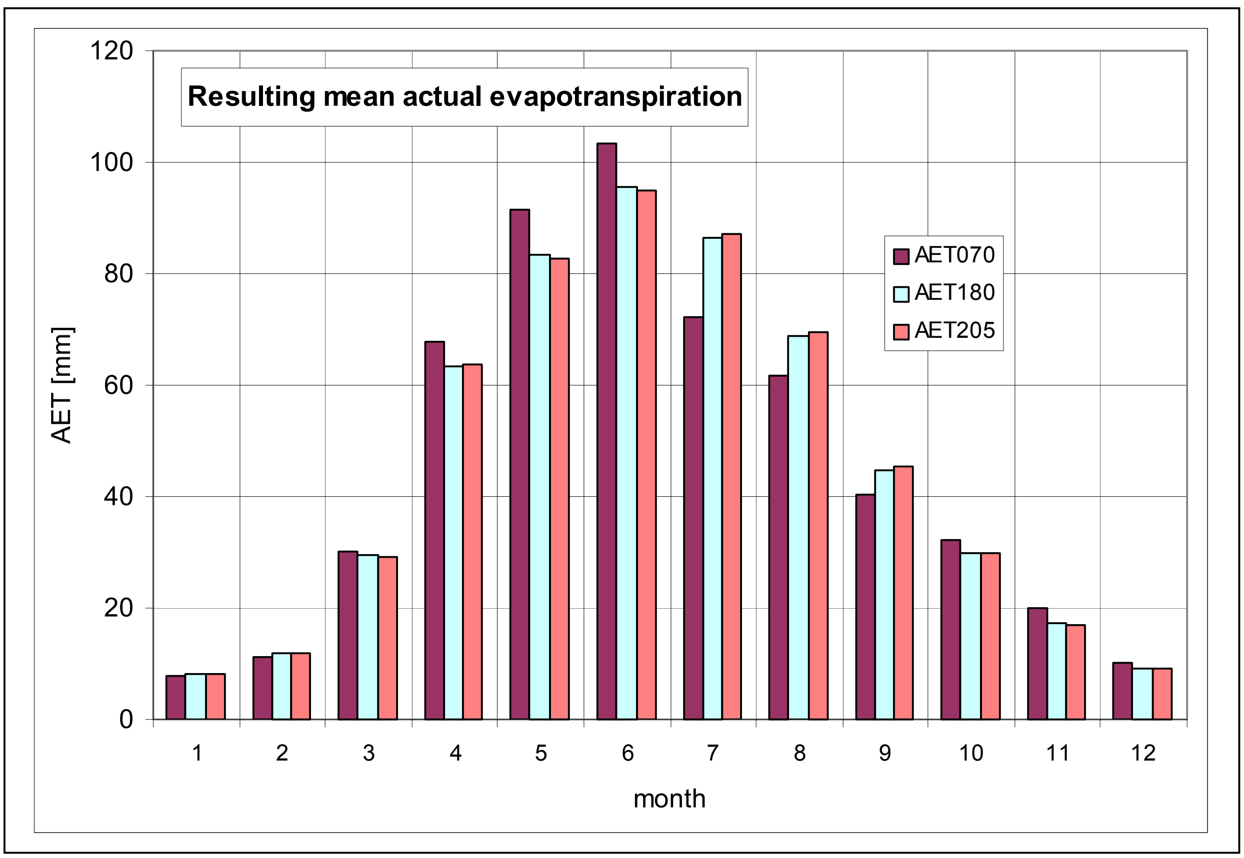

Fig. 3. Resulting monthly mean areal evapotranspiration AETxxx obtained for different values of starting critical soil moisture content WCRIT (xxx in mm) with optimised PRIESKO coefficient.

Results show that evapotranspiration values by sufficient soil moisture for lower WCRIT are higher than in lack of soil moisture, on the other hand a higher WCRIT causes certain delay in soil moisture use for covering evapotranspiration needs.

By tuning the mutual compensation of WCRIT and PRIESKO influence on the error minimising process a relation between these two parameters was found, as can be seen from FIG. 4.

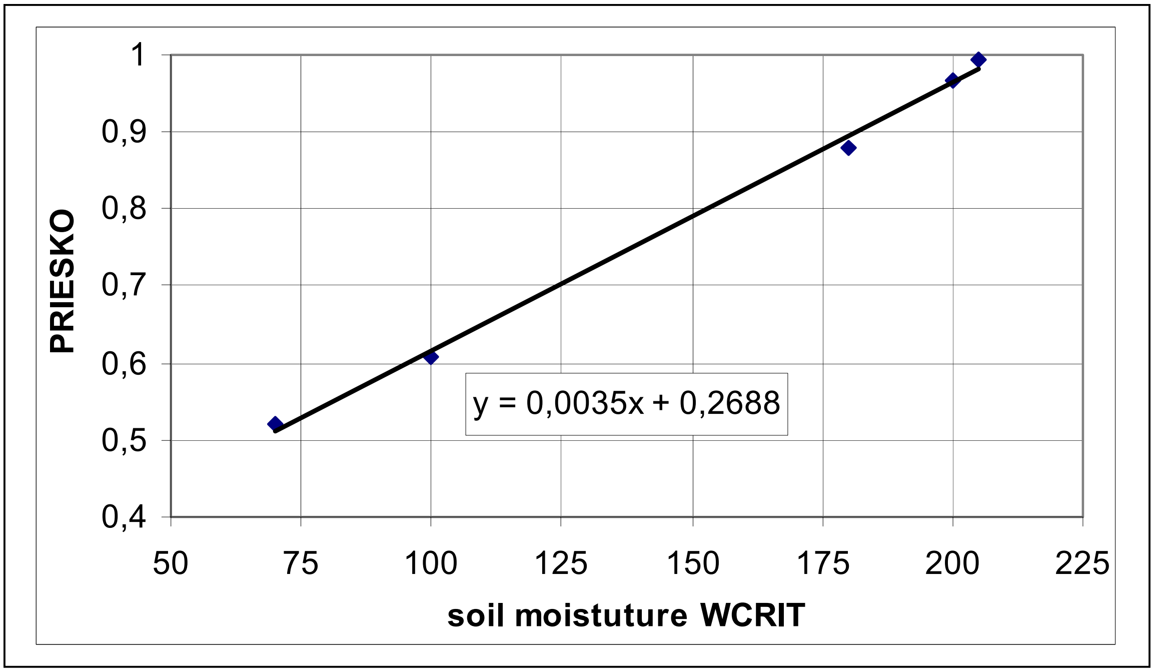

Fig. 4. Optimised values of PRIESKO
for chosen WCRIT values for mean long-term water balance.

3.2 Tuning step 2.

Monthly input data of air temperature and relative air humidity are used for estimation of potential evapotranspiration for all 360 months of 30-year representative period 1951 – 1980. Monthly input runoff data are a base for a runoff depth (in mm) estimation.

Direct processing in MS FORTRAN 77 gives monthly actual evapotranspiration data. In WINDOWS it is necessary to work in an open MS DOS Window due to the direct reading data from a PC console – keyboard. Half automatically tuning of starting soil moisture content values (WSTART), value of water content stored in a solid phase at the soil surface (WSURF1) is performed. For given WCRIT the optimised PRIESKO is also computed. Values of ATSNOW and ATRAIN have the same meaning like it is in a tuning step 1.

Tuning for our parameter combination shows sufficient convergence of PRIESKO for chosen WCRIT and "MONTHDEGFAC" factor. The yearly (mean) actual evapotranspiration total is always the same and within the months (for our set of trials) mean relative amplitude ***relampl*** (3) is less than 15 %, the maximum was in March less than 33 %.

$$relampl = \frac{\max(AETi) - \min(AETi)}{average(AETi)} \qquad (3)$$

Yearly course of evaluated actual evapotranspiration for four combinations of parameters is shown in Fig. 4. In case, that we are dealing only with basic water balance elements such a solution could be sufficient, but further assumed use of the model expect combined tuning of actual evapotranspiration and modelled runoff with minimising any possible error for given data set. Such an approach is described in the paragraph 3.3.

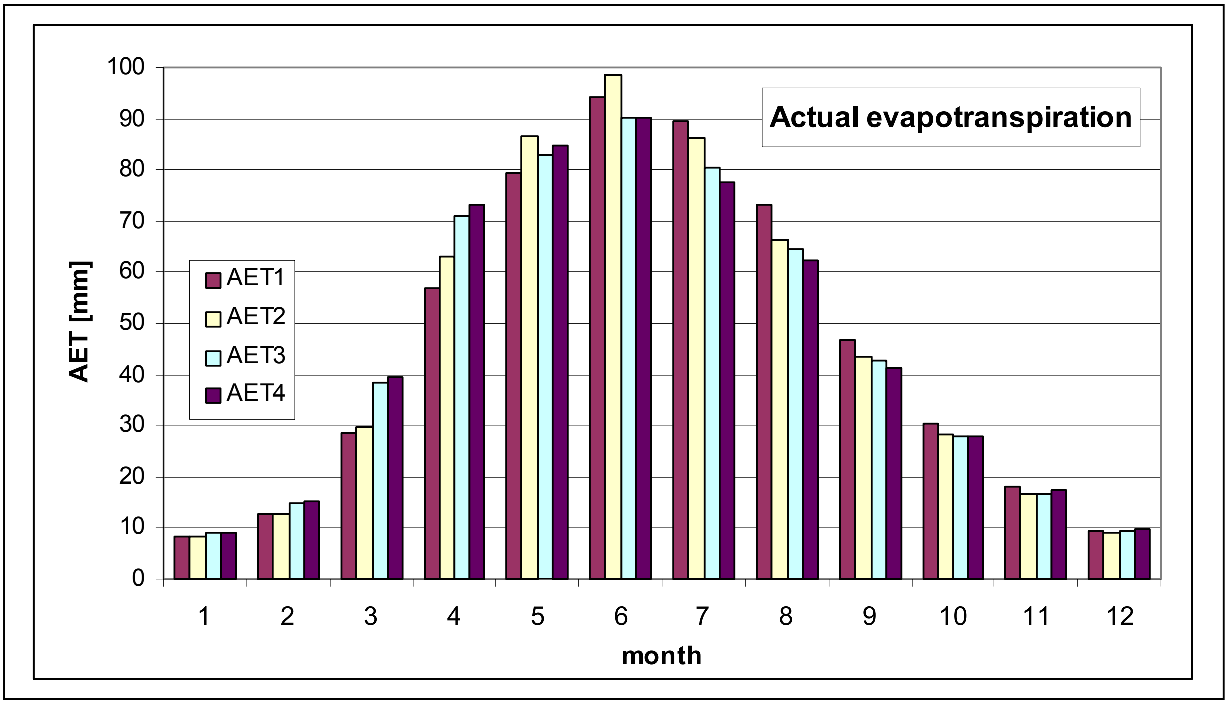

Fig. 4. Resulting means of monthly areal actual evapotranspiration values AETi obtained for different combinations of optimised tuning parameters.

3.3 Tuning step 3.

The main difference between “direct” estimation of actual evapotranspiration and complex tuning of the model in a sense of WatBal model principles is achievement of the best coherence between the modelled runoff depth and the observed one. Tuning is made in an EXCELL worksheet, where input columns represent air temperature TEMP, precipitation PRE, potential evapotranspiration PET (from step 3.2). Observed runoff depth (discharge expressed in mm/month) is used in a two dimensional regression as function of liquid component of precipitation and actual soil moisture content. Different criteria can be chosen for minimising error of results. Obtaining (in do loop) the same soil moisture content and surface (solid phase) water storage at the beginning and by end of time steps is self-evident. In our situation it was not fully possible to gain closed cycle of elements for obtaining all main criteria – the final water balance error equal zero, the mean deep water storage equal zero and final deep water storage having equal to zero. Due to this circumstance tuning in different couples of criteria was performed in EXCELL using internal add/ins function SOLVER. Description of details is out of the frame of this paper. The most effective optimised results are in the Table 4.

This approach allows usage of tuned model for runoff simulation for a period without runoff measurements. It is also possible to assume that tuned parameters are “conservative” in time and optimised model can be used for e.g. climate change impact assessment just by scenario application on input meteorological elements. Comparison of “new” and “old” results gives characterisation of obtained influence.

Within previous tasks in our Institute we have already tried also a different approach to the rainfall – runoff modelling, a model based on antecedent precipitation index (API) and non-linear regression approach. Some results were interesting and giving lower deviations of measured and modelled runoff, but impact scenario application caused significant troubles.

Tab. 4. Results for optimised water balance assessment in the Nitra River basin for the profile Nové Zámky and for the period of 1951 – 1980.
Explanation of symbols: mm – month; yy – yearly sum or average; ATEM – air temperature; PRE - precipitation; PET and AET – potential and actual evapotranspiration; WDELTA – deep soil water content; SOLPRE – solid portion of precipitation; SNMELT – snow melt in given month; WSURF – surface water storage in form of snow and/or ice; PREL – liquid part of precipitation; PRSM – mean soil moisture storage in given month; FLOWMM – runoff depth in mm; FLOW1 – modelled runoff depth; F1/FM – mean of ratios (modelled/measured); (F1-FM)^2 – mean of linear error squares for optimising the FM, modelled runoff depth.

mm	1	2	3	4	5	6	7	8	9	10	11	12	yy
ATEM	-2,2	-0,3	3,6	8,8	13,6	17,2	18,5	17,9	14,1	9,0	4,1	-0,1	8,7
PRE	41,3	41,9	39,5	49,6	60,4	84,3	78,7	69,3	48,1	48,6	60,4	55,7	677,7
PET	11,6	17,6	40,9	75,4	103,2	123,3	122,2	104,2	72,9	44,4	22,4	12,2	750,1
AET	9,0	14,8	38,8	71,5	83,1	90,2	79,9	64,2	42,5	28,0	16,8	9,6	548,4
WDELTA	-1,1	5,5	23,5	35,7	3,2	-11,4	-20,7	-22,1	-21,0	-7,4	10,8	11,2	0,51
SOLPRE	39,3	31,6	16,2	0,2	0,0	0,0	0,0	0,0	0,0	0,5	18,4	42,7	
SNMELT	5,9	25,3	53,6	52,9	1,7	0,0	0,0	0,0	0,0	0,0	0,5	9,1	
WSURF	85,4	91,8	54,4	1,7	0,0	0,0	0,0	0,0	0,0	0,5	18,4	52,0	
PREL	7,8	35,5	76,9	102,3	62,1	84,3	78,7	69,3	48,1	48,1	42,4	22,1	677,7
PRSM	130,5	143,7	166,1	167,9	136,9	124,0	111,8	105,9	100,4	110,0	127,9	133,8	
FLOWMM	11,1	14,1	20,1	18,6	11,5	8,6	8,1	6,5	4,5	6,5	7,3	12,2	129,0
FLOW1	11,1	14,1	20,1	18,6	11,5	8,7	8,1	6,6	4,5	6,5	7,3	12,2	129,3
F(i)/F(i-1)		1,3	1,4	0,9	0,6	0,7	0,9	0,8	0,7	1,4	1,1	1,7	1,19
F1/FM	1,2	1,3	1,3	1,1	1,1	1,2	1,1	1,2	1,1	1,1	1,1	1,2	1,15
(F1-FM)^2	19,8	49,7	98,2	31,3	13,8	33,0	9,4	17,6	2,2	22,6	5,9	56,8	30,03

4. Conclusions

Presented set of models creates a possibility to compute numerical characteristics of water balance for a river basin. Such models can be included into a group of models with lumped parameters. Tuning of all model components and obtaining resulting main water balance elements values creates a base for further study.

It is possible to suppose that (input) areal precipitation could be corrected after a very fine precipitation analysis in GIS technology. On the other hand it is also possible to suppose, that here obtained results are representative enough to be used in GIS modelling of areal runoff depth and areal actual evapotranspiration in GIS environment for tuning. Consecutively evaluation and “drawing” of particular element maps could be developed.

All the used programmes are at disposal for delegated experts participating in solution of the project “Basin – Wide Water Balance in the Danube River Basin”.

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Attachment: List of used precipitation stations for the Nitra River Basin study.

NZV14	ELEVATION	E-DEG	N-DEG	Station
9	211	18,50000	48,58333	BOJNA
23	112	17,61667	48,00000	DUNAJSKA STREDA
28	239	18,78333	48,53333	HLINIK NAD HRONOM
30	266	18,18333	48,83333	Horne Motesice / MOTESICE
36	115	18,20000	47,86667	HURBANOVO
47	510	18,80000	48,96667	KLASTOR POD ZNIEVOM
59	551	18,91667	48,71667	KREMNICA
68	147	17,78333	48,45000	LEOPOLDOV
69	155	18,60000	48,21667	Levice
102	145	18,08333	48,31667	NITRA
103	348	18,65000	48,88333	NITRIANSKE PRAVNO
105	221	18,63333	48,43333	NOVA BANA
106	193	17,83333	48,75000	NOVE MESTO NAD VAHOM
107	119	18,16667	47,98333	NOVE ZAMKY
108	168	18,15000	48,46667	OPONICE
113	113	18,06667	48,03333	PALARIKOVO
117	162	17,83333	48,61667	PIESTANY
118	188	18,46667	48,06667	PLAVE VOZOKANY
910	150	18,33333	48,11667	PODHAJSKA
128	381	18,48333	49,01667	PRUZINA
130	513	18,63333	49,05000	RAJECKA LESNA
133	370	18,76667	48,76667	RAZTOCNO
163	230	18,18333	48,66667	SISOV
144	458	18,41667	48,50000	SKYCOV
165	1330	20,06667	49,11667	STRBSKE PLESO
167	178	18,01667	48,43333	SURIANKY
174	209	18,03333	48,88333	TRENCIN 803 / 809
176	117	17,91667	48,15000	TRNOVEC NAD VAHOM
178	518	18,86667	48,86667	TURCIANSKE TEPLICE
181	250	18,35000	48,75000	UHROVEC
182	482	18,40000	48,88333	VALASKA BELA
185	233	18,43333	48,61667	VELKE UHERCE
188	142	18,31667	48,25000	VRABLE
201	230	18,71667	48,48333	ZARNOVICA
202	111	17,90000	48,06667	ZIHAREC
197	196	18,40000	48,38333	ZLATE MORAVCE
198	603	18,43333	48,95000	ZLIECHOV