Analitical surface water forecasting system for Republic of Slovenia

Analitičen sistem napovedovanja pretokov površinskih vod v Republiki Sloveniji

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Abstract: River management is one of the key factors of environmental management. On the territory of the Republic of Slovenia there are four main rivers (Mura, Drava, Sava and Soča) which drain water from the Alpine region in the north of the country and from a typically Karstic part in the south. It is a well known fact that all main Slovenian river flows can take a disastrous proportion in case of strong rain precipitation in their recharge area. For this reason the Environmental Agency of Republic of Slovenia (ARSO) put the hydrological monitoring system and data analysis in a common system known as HIDPRO. HIDPRO is a Slovenian acronym for Hydrological prognostic system. The main aim of Hydrological prognostic system is to analyze the collected data in an oracle database to make flow forecasts and take precaution measures against possible flooding whenever a worst case scenario is predicted.

Izvleček: Upravljanje z vodami je eden od ključnih faktorjev upravljanja okolja. Na območju Republike Slovenije so štiri glavne reke (Mura, Drava, Sava in Soča), ki drenirajo vodo iz alpskega sveta na severu države in kraškega sveta na jugu. Znano je, da v primeru obilnega deževja na zbirnem območju, pretoki rek dosežejo vrednosti, ki lahko povzročijo katastrofalne hidrološke razmere. Zaradi tega je Agencija Republike Slovenije za okolje združila monitoring in obdelavo podatkov v skupni sistem imenovan HIDPRO. HIDPRO je slovenski akronim za Hidrološki prognostični sistem. Glavna naloga hidrološkega prognostičnega sistema je analiza zbranih podatkov v Oraclovi bazi in izdelava prognoze pretokov rek ter v primeru poslabšanja poplavne varnosti opozarjanje prebivalstva.

Key words: river prognostic system, database analysis, client server DSS, data classification, river flow forecasting

Ključne besede: rečni prognostični sistem, klient – server ekspertni sistem, klasifikacija podatkov, napovedovanje pretokov rek

Scientific paper

Introduction

During the 1980s and 1990s a series of programmes for river data collection and analysis were being built in the former Hydrometeorological Institute of Slovenia. During that time data were being collected in an Oracle database. A collection of data measurements has been partly done by the observers on the field and partly by automatic gaugingl stations, which is also the case nowadays. The data collected in database were first stored inside the so-called rough database and after the validation process the data were transferred into a database and opened to the public. As the process of hydrology forecasting has to be done in real time, a series of FORTRAN programmes have been made. The operating system for FORTRAN made software was VAX. A great job was done by programming those FORTRAN programmes. But the main not-yet-solved difficulty was that the programmes were not directly linked to the Oracle database; even more – the data needed for hydrological records coming from weather forecasting super computer had to be put inside the FORTRAN made programmes manually. In addition the reports of final products were sent to the user partly electronically and partly manually. The FORTRAN programmes for hydrological forecasting were used until the end of the previous century. At the end of the last century a decision was made to form a new Hydrological forecasting and decision support system. The main aim was to make a programme system in Windows 2000/XP which would allow hydrologists to use the incoming data in real time and would also help them make a validation process before hydrological forecasting. The Hydrological prognostic system (HIDPRO) was built during a period between years 2000 and 2002. The system was built in the Windows 2000/XP platform and the database Oracle was selected again. The system became operational in the year 2002 and is now the main forecasting and decision support system for hydrology in Slovenia.

Requirements for the HIDPRO system

- For a new system replacement a series of demands were put together.
- Data have to be stored inside Oracle database.
- All data coming from different sources have to be transferred in the system automatically.
- Validation of data has to be done during the process of data transfer from the measurements stations to the Oracle database.
- The hydrologist has to have the possibility to check and change the data during the entire process of forecasting.
- The system has to provide a series of automatic reports for different users (government's offices, newspaper, TV, radio etc.).

On the basis of demands shown above and operating systems used in the government's offices a client server application (Figure 1) was selected for the Hydrological Prognostic System (HIDPRO). This firstly means that data are stored inside the oracle database and secondly that programmes for the data management are made with MS Access XP development programme Visual basic for the Application. The decision to adopt MS Access XP was also made on the basis that people working in hydrology

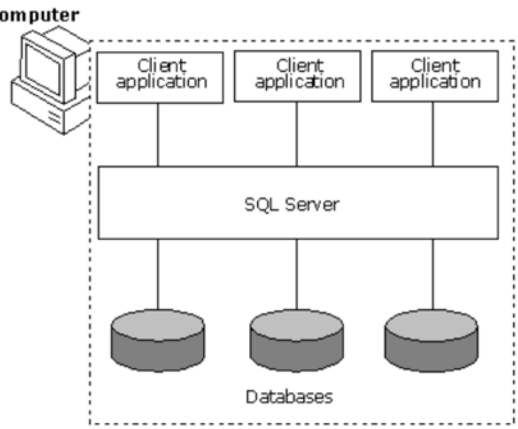


Figure 1. Diagram of HIDPRO client server architecture
Slika 1. Diagram HIDPRO server – klient arhitekture

prognosis are very well acquainted with MS Access and MS Excel.

Data flow and analysis

For a smooth flow of data between different sources and real time validation one has to know a data flow diagram very well. Figure 2 presents a data flow diagram with all check points of automatic validation and phases of hydrology forecasting and decision support system. The detailed look at the data flow diagram (Figure 2) can show there are two very important steps: the first step is the automatic analysis of data coming from automatic gauging station. The analysis in use for this step is only to control the data; if the data are erroneous on a large scale, they are not to be transferred to the rough data of AMP database. The data coming from the gauging stations are the observed river level in centimetres and the river water temperature.

A quick check of data can show if the measurements are inside the logically expected values or not. In case of error detection a numerical value for a type of error is transferred into the database instead of the erroneous value. If the data pass the first check, the river level values are transferred in the rough database of automatic measurements (AMP database). For the hydrology forecasting a data transformation is needed; therefore the water river level data are transformed in the river flow data (Figure 2). The process is done inside the rough AMP database. The data are transformed on the basis of step polynomial functions of high order (Equation 1) which coefficients are obtained by the regression.

$$q = \begin{cases} 96cm \le h \lhd 110cm \Rightarrow 0.103370\text{E}-04 + \text{h}\,0.866970\text{E}-03 + \text{h}^2\,0.225364\text{E}-07 + \text{h}^3\,0.504223\text{E}+01 \\ 110cm \le h \lhd 180cm \Rightarrow 0.140766\text{E}-04 + \text{h}\,0.200405\text{E}-02 - \text{h}^2\,0.148332\text{E}-05 - \text{h}^3\,0.139660\text{E}+02 \\ 180cm \le h \lhd 290cm \Rightarrow 0.639307\text{E}-05 + \text{h}\,0.392923\text{E}-02 + \text{h}^2\,0.518343\text{E}-06 - \text{h}^3\,0.314814\text{E}+02 \\ 290cm < h \lhd 450cm \Rightarrow -0.853863\text{E}-05 + \text{h}\,0.100931\text{E}-01 - \text{h}^2\,0.144057\text{E}-05 - \text{h}^3\,0.186105\text{E}+03 \\ 450cm < h \lhd 540cm \Rightarrow -0.714420\text{E}-05 + \text{h}\,0.879800\text{E}-02 + \text{h}^2\,0.500243\text{E}-06 - \text{h}^3\,0.500243\text{E}-06 \end{cases} \quad (1)$$

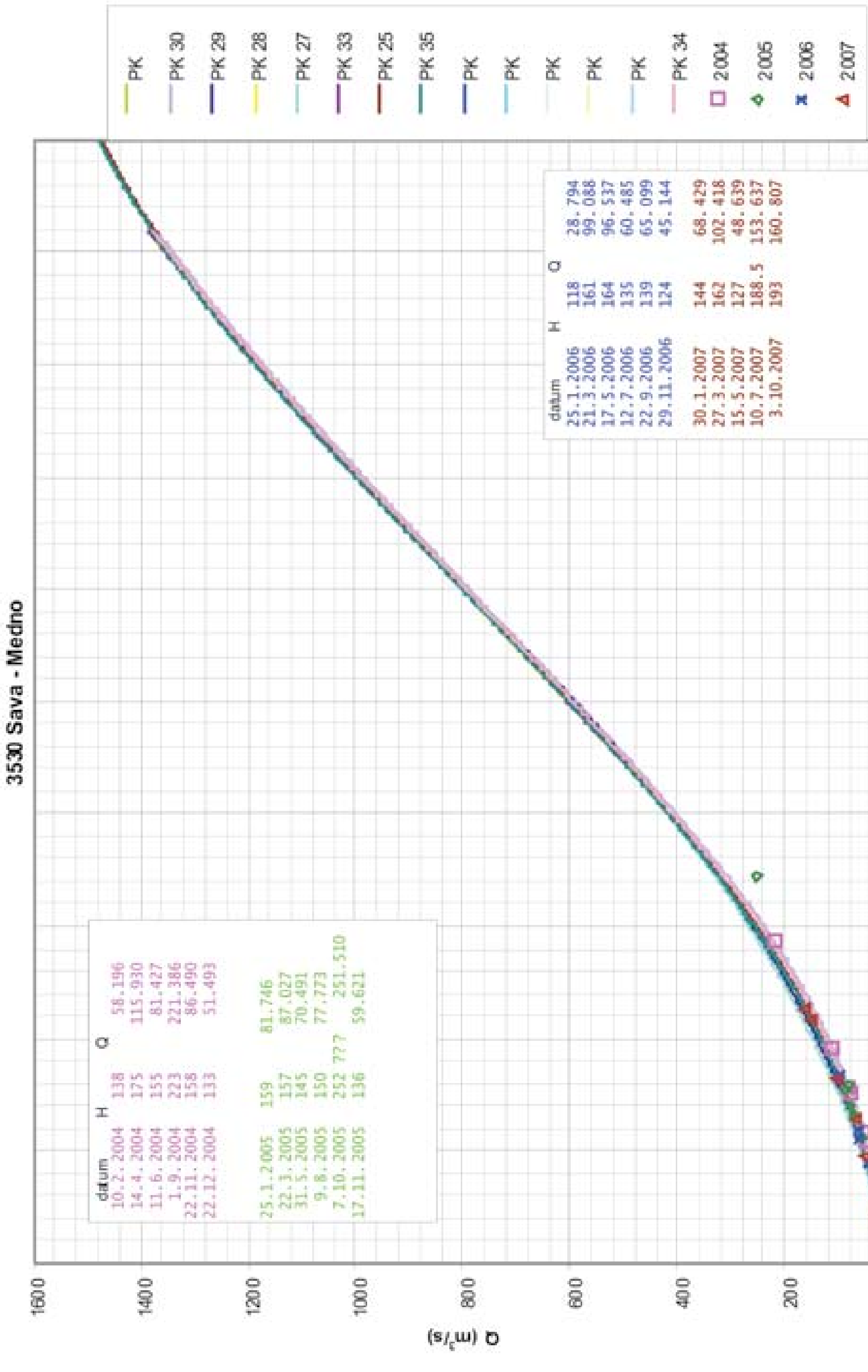


Figure 2. Typical H-Q curve fitted using step polynomial equations
Slika 2. Tipična H-Q krivulja določena z množico polinomskih funkcij

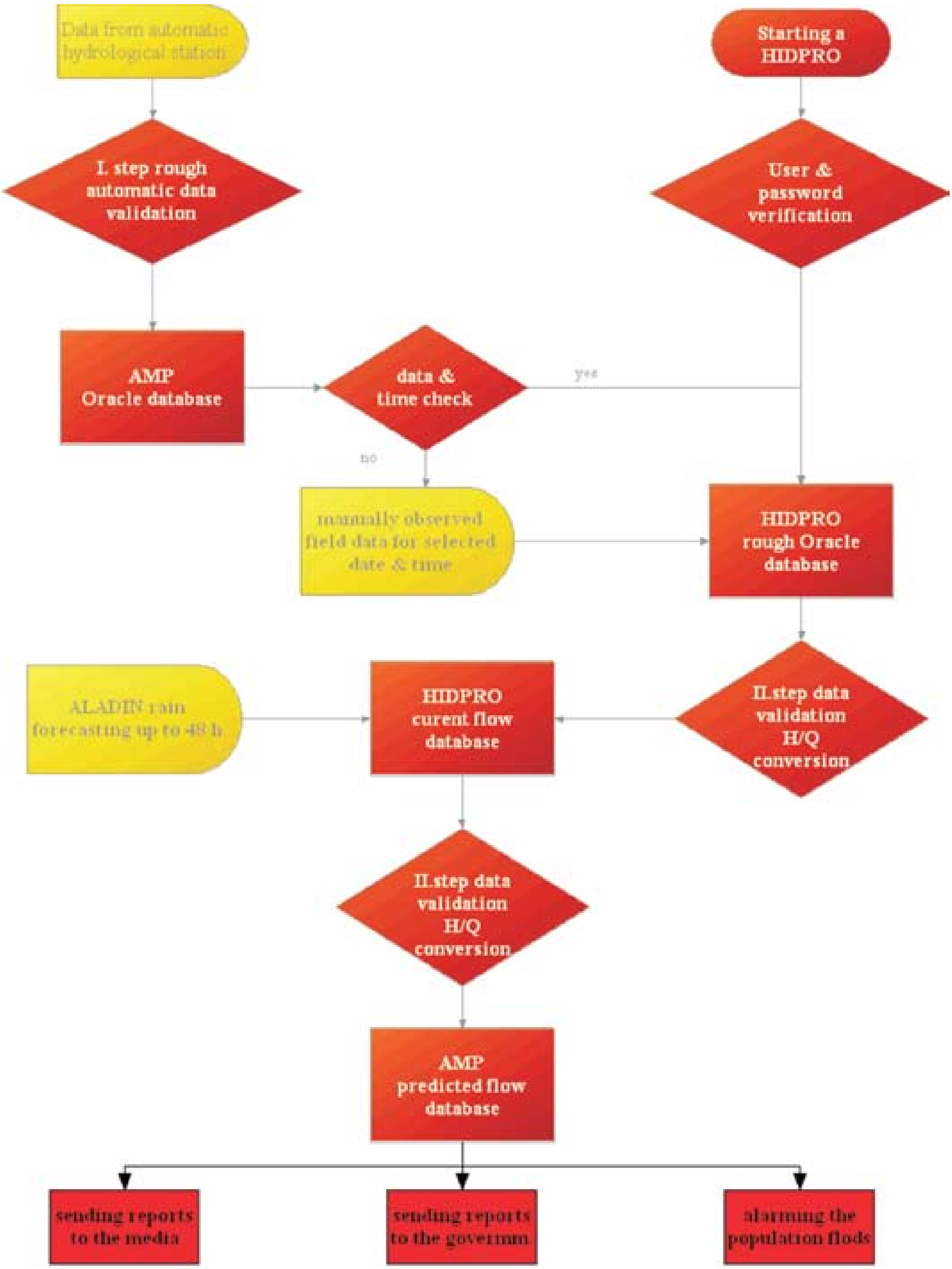


Figure 3. Data flow diagram of HIDPRO
Slika 3. Diagram toka podatkov v HIDPRO-ju

For this, transformation calibration measurements are needed on the river. Due to erosion and sedimentation inside the rivers, this is an ongoing process which means that the calibration can not be done once but has to be repeated in certain time intervals. Thus the time intervals for transformation function are an important key in flow calculations. The function duration is checked during the flow calculation and in case of finding the function out of date, a typical numerical value is shown. This means that the hydrologist himself is able to see the values and on its basis he can inform a technical support team about the problem with the water level – water flow conversion. The out-of-date check process is impeding erroneous calculations of flow from river's water levels, which can be a result of natural changes in river.

As it can be seen on the data flow chart (Figure 3), some measurements are coming from the field observation made manually. There are still series of gauging station which are not equipped with the automatic water level and temperature measurements devices. There are also some controlling measurements on the automatic gauging station which are performed by people under contract. If data sets from the stations are erroneous, data from manual measurements can be used. A special situation occurs when the automatic station is making good measurements but data are not shown for a certain period of time; in such a case a station has to be moved from the automatic station set to a manual station set. The time limit is set up to 2 hours from the time of making a prediction (Figure 4).

There are three important buttons shown on Figure 4:

- Klicane (Calling)
- Zlitja (Conjunction)
- Napoved (Forecast)

The "Klicane" button allows access to the manually measured hydrological station and the automatic gauging stations with 2 hours data missing gap. Button "Zlitje" has to be pressed after entering manual data, thus connecting it with automatic data (Figure 5).

Different coloured cells show unusual condition: if the flow is too low, a green colour is used and if the flow is statistically too high, a red colour is shown. On the basis of colours the hydrologist has the first information of the hydrological situation in the country. A tendency of river flow is also tested: if a river flow tendency is increasing, the sign + is selected; for decreasing, the sign – is selected; and for steady hydrological situation on the gauging station, the sign 0 is shown. The estimation of river flow tendency is possible only in the automatic stations. A statistical approach was selected to classify the two hydrological parameters mentioned before. This means that a statistical table of hydrology seasons characteristics values was made and put in the database for river flow classification. The current calculated flow is compared with the values stored for specific stations in the table mentioned before and if needed, a colour is used to show the actual hydrological situation. The hydrological season's table stores data from statistical analysis of every station and a

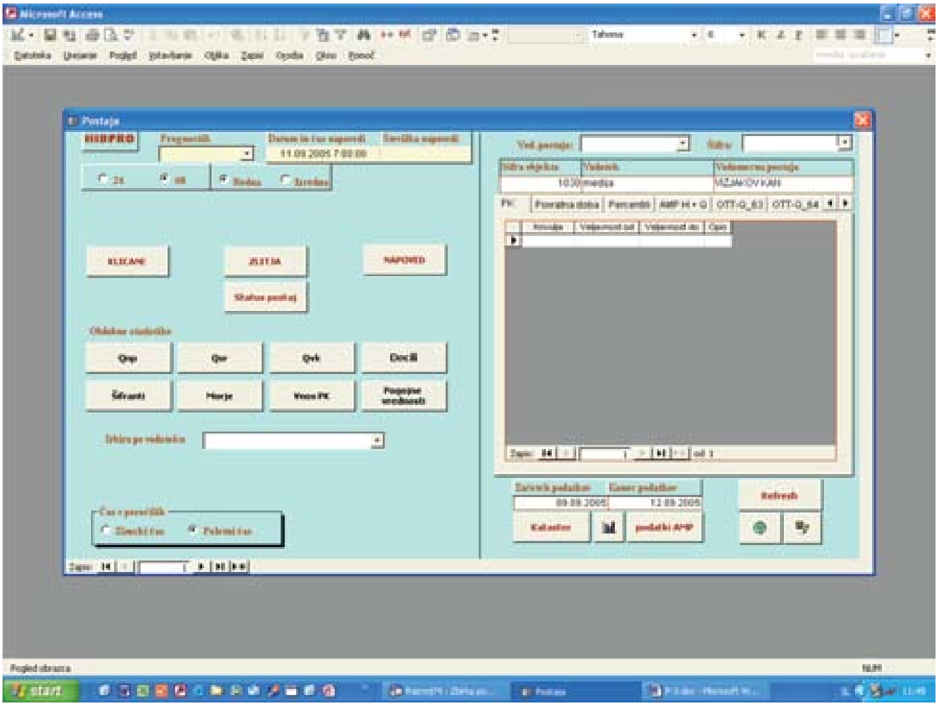
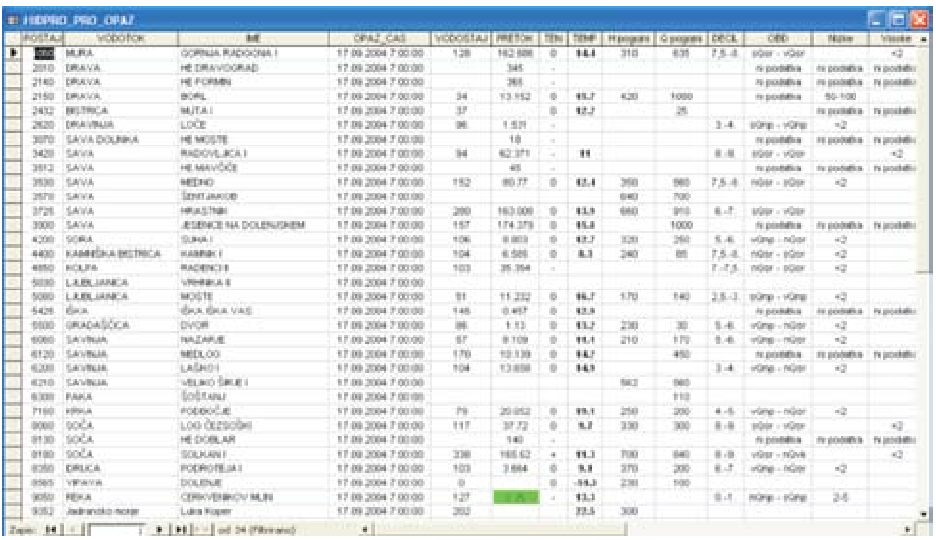


Figure 4. Starting forum made in Access XP of Hydrological prediction system
Slika 4. Začetni obrazec Hidrološkega prognostičnega sistema izdelan v Accessu XP



HIDPRO_PRO_OPAZ

POSTAJ	VODOTOK	IME	OPAZ_CAS	VODOSTAJ	PRETOK	TEN	TEMP	H pogoji	Q pogoji	DECIL	OBD	Nizke	Visoke
[illegible]	MURA	GORNJA RADGONA I	17.09.2004 7:00:00	128	162.808	0	14.4	310	635	7,5 -8	sGor - vGor		<2
2010	DRAVA	HE DRAVOGRAD	17.09.2004 7:00:00		345	-					ni podatka	ni podatka	ni podatk
2140	DRAVA	HE FORMIN	17.09.2004 7:00:00		365	-					ni podatka	ni podatka	ni podatk
2150	DRAVA	BORL	17.09.2004 7:00:00	34	13.152	0	15.7	420	1000		ni podatka	50-100	
2432	BISTRICA	MUTA I	17.09.2004 7:00:00	37		0	12.2		25			ni podatka	ni podatk
2620	DRAVINJA	LOČE	17.09.2004 7:00:00	96	1.531	-				3 -4	sGrnp - vGrnp	<2	
3070	SAVA DOLINKA	HE MOSTE	17.09.2004 7:00:00		18	-					ni podatka	ni podatka	ni podatk
3420	SAVA	RADOVLJICA I	17.09.2004 7:00:00	94	62.371	-	11			8 -8	sGor - vGor		<2
3512	SAVA	HE MAVČIČE	17.09.2004 7:00:00		45	-					ni podatka	ni podatka	ni podatk
3530	SAVA	MEDNO	17.09.2004 7:00:00	152	80.77	0	12.4	350	980	7,5 -8	nGor - sGor	<2	
3570	SAVA	ŠENTJAKOB	17.09.2004 7:00:00					640	700				
3725	SAVA	HRASTNIK	17.09.2004 7:00:00	280	163.008	0	13.9	660	910	6 -7	sGor - vGor		
3900	SAVA	JESENICE NA DOLENJSKEM	17.09.2004 7:00:00	157	174.379	0	15.8		1000		ni podatka	ni podatka	ni podatk
4200	SORA	SUHA I	17.09.2004 7:00:00	106	8.803	0	12.7	320	250	5 -6	vGrnp - nGor	<2	
4400	KAMNIŠKA BISTRICA	KAMNIK I	17.09.2004 7:00:00	104	6.585	0	8.3	240	85	7,5 -8	nGor - sGor	<2	
4850	KOLPA	RADENCI II	17.09.2004 7:00:00	103	35.394	-				7 -7,5	nGor - sGor	<2	
5030	LJUBLJANICA	VRHNIKA II	17.09.2004 7:00:00										
5080	LJUBLJANICA	MOSTE	17.09.2004 7:00:00	81	11.232	0	16.7	170	140	2,5 -3	sGrnp - vGrnp	<2	
5425	IŠKA	IŠKA IŠKA VAS	17.09.2004 7:00:00	145	0.457	0	12.9				ni podatka	ni podatka	ni podatk
5500	GRADAŠČICA	DVOR	17.09.2004 7:00:00	86	1.13	0	13.7	230	30	5 -6	vGrnp - nGor	<2	
6060	SAVINJA	NAZARJE	17.09.2004 7:00:00	87	8.109	0	11.1	210	170	5 -6	vGrnp - nGor	<2	
6120	SAVINJA	MEDLOG	17.09.2004 7:00:00	170	10.139	0	14.7		450		ni podatka	ni podatka	ni podatk
6200	SAVINJA	LAŠKO I	17.09.2004 7:00:00	104	13.658	0	14.9			3 -4	vGrnp - nGor	<2	
6210	SAVINJA	VELIKO ŠIRJE I	17.09.2004 7:00:00					562	980				
6300	PAKA	ŠOŠTANJ	17.09.2004 7:00:00						110				
7160	KRKA	PODBOČJE	17.09.2004 7:00:00	79	20.052	0	19.1	250	200	4 -5	vGrnp - nGor	<2	
8080	SOČA	LOG ČEZSOŠKI	17.09.2004 7:00:00	117	37.72	0	9.2	330	300	8 -8	sGor - vGor		<2
8130	SOČA	HE DOBLAR	17.09.2004 7:00:00		140	-					ni podatka	ni podatka	ni podatk
8180	SOČA	SOLKAN I	17.09.2004 7:00:00	338	165.62	+	11.3	700	840	8 -8	vGor - nGvk		<2
8350	IDRIJCA	PODROTEJA I	17.09.2004 7:00:00	103	3.664	0	9.8	370	200	6 -7	vGrnp - nGor	<2	
8565	VIPAVA	DOLENJE	17.09.2004 7:00:00	0		0	-14.3	230	100				
9050	REKA	CERKVENIKOV MLIN	17.09.2004 7:00:00	127	[illegible]	-	13.1			0 -1	nGrnp - vGrnp	2-5	
9352	Jadransko morje	Luka Koper	17.09.2004 7:00:00	252			22.5	300					

Figure 5. Data form with manually entered data and data coming from automatic stations
Slika 5. Podatkovni obrazec z ročno in avtomatsko vnesenimi podatki iz avtomatskih postaj

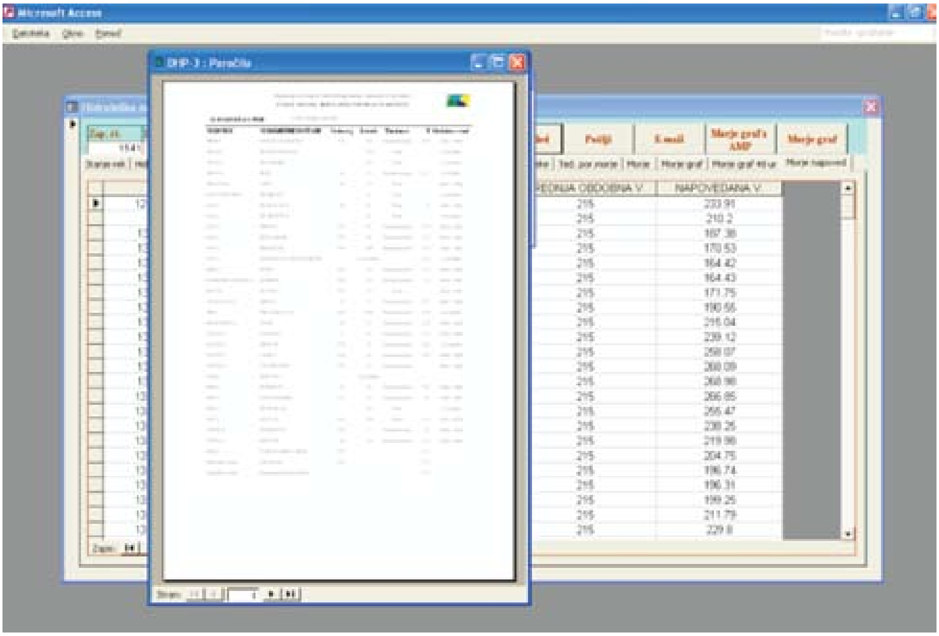


Figure 6. The last forecasting form with all data necessary for hydrological forecasting
Slika 6. Zadnji napovedni obrazec z vsemi potrebnimi podatki za hidrološko napoved

long time data sets are usually used for statistical data calculations. The tendency is to only check if the values in the last half hour have changed; this is made by using a simple mathematical equation where the average value of last half hour is compared with the actual value. If a positive or negative change greater of 10 percent is detected, then a sign of + or – is selected for presentation. If the changes are less than 10 percent a 0 sign is used.

After all hydrological data are available, the last step can take place. By pressing button "Napoved" (see Figure 4), all data are transferred to the forecasting table (Figure 6). During this process data from weather forecasting are put inside the hydrology forecasting table. Two forecast precipitations data are available. They are the 24 and the 48 hour rain precipitations. The data are calculated for the rain fall precipitation's stations, by using the analytical model of hydrological prediction to calculate the flow for the next 24 or 48 hours. The calculated values are compared to the hydrological season's characteristic values; on the basis of this the warnings to the water authority are dispatched.

The river flow prediction is made on the basis of predicted rainfalls for a certain rain measuring station and correlation between the rain and hydrology stations. The correlation or better dependency of river flow on the hydrological station is mainly described with the elementary mathematical functions. In some cases the dependency is described with the mathematical function with predicted precipitations values from the program ALADIN only for the first station in a set of stations on the same river. For all other stations of the same set the prediction is made on the basis of correlation between the river flow on the predicted station and the river flow on the previous station.

Conclusions

The HIDPRO system became fully operational in 2003. Since then, all the hydrological forecasting operations and warnings for high or low river flow have been made on it. The biggest progress is that all data coming from different sources are stored in the same database and logical operations are available for quick data checking; a hydrologist can also check the data after the automatic data checking. The main data flow occurs inside the Oracle database and data from some operational stages are always available to the registered users. A lot of work has been done by transferring the ASCII stored data with Visual Basic procedures to the ARSO net. The main problem was that data structured in ASCII formats was quite difficult to understand, thus there had to be a lot of cooperation between the programmers and developers on one side and the hydrologist and meteorologist on the other side. The problems with data gap, which can occur due to specific meteorological or hydrological conditions, were solved with the procedure of the 2-hour data check. There are also some visual data presentations for hydrologist available and the possibility of human data checking and repairing the erroneous data is always possible. The three step data analysis and checking reports are available to the media and governments offices. In a case of high river flow, the government service responsible for flood alarming is called. Further developments will try to make a connection between numerical river flow prediction modelling and data stored inside the database, thus gradually replacing analytical modelling with the numerical one.

Acknowledgments

The authors are indebted to Mira Kobolt, Mojca Sušnik , Janez Polajnar and Jože Guši Miklavčič for their help in explanations of the hydrological formulas and models.

Povzetek

Analitičen sistem napovedovanja pretokov površinskih vod v Republiki Sloveniji

Na območju Republike Slovenije so štiri glavne reke (Mura, Drava, Sava in Soča), ki drenirajo vodo iz alpskega sveta na severu države in kraškega sveta na jugu. Znano je, da v primeru obilnega deževja na zbirnem območju, pretoki rek dosežejo vrednosti, ki lahko povzročijo katastrofalne hidrološke razmere. Zaradi tega je Agencija Republike Slovenije za okolje združila monitoring in obdelavo podatkov v skupni sistem imenovan HIDPRO. HIDPRO je slovenski akronim za Hidrološki prognostični sistem. Glavna naloga hidrološkega prognostičnega sistema je analiza zbranih podatkov v Oraclovi bazi in izdelava prognoze pretokov rek ter v primeru poslabšanja poplavne varnosti opozarjanje prebivalstva. Med letoma 1980 in 1990 je bila na nekdanjem Hidrometeorološkem zavodu Republike Slovenije izdelana serija programov za zbiranje in obdelavo hidroloških podatkov. V tem času so se zbrani podatki hranili v Oraclovi bazi. Podatke so že takrat zbirali z opazovalci na terenu in z avtomatskimi hidrološkimi merilnimi postajami. Tako zbrani podatki so se hranili v bazi neobdelanih podatkov, po pregledu oz. obdelavi podatkov so bili podatki preneseni v bazo podatkov in s tem dostopni širši javnosti.

Ker je za napovedovanje hidrološkega stanja potrebna obdelava v realnem času, je bila izdelana serija programov v FORTRAN-u. Za osnovni operacijski sitem je bil izbran VAX. Glede na obseg dela, ki ga je tako programiranje zahtevalo, lahko sklepamo, da so takratni programerji opravili zahtevno delo. Kljub temu je glavni problem ostal nerešen, saj podatki med FORTRAN-novimi programi in ORACLOM niso bili povezani in celo vremenske podatke izračunane na super računalniku je bilo potrebno ročno prenašati najprej v ORACL in nato še v FORTRAN-ove programe. Zaradi tega je bil med letoma 2000 in 2003 izdelan nov hidrološki prognostični sistem. Sistem je bil izdelan na Windows2000/XP platformi, hramba podatkov pa je bila spet zaupana ORACLU. Sistem je postal operativen v letu 2003 in ja ta trenutek edini prognostični hidrološki sistem z elementi ekspertnega sistema podpore odločanja na območju Republike Slovenije. Največji napredek je, da so vsi podatki, ki prihajajo iz različnih virov, sedaj hranjeni na istem mestu. V sistemu je vgrajena serija logičnih funkcij, ki omogočajo avtomatsko kontrolo podatkov in so po potrebi lahko tudi še neodvisno kontrolirani s strani ekspertov prognostikov. Glavni pretok in obdelava podatkov se dogaja znotraj ORACLA, ki hkrati omogoča dostop do obdelanih podatkov prijavljenim uporabnikom. Veliko dela je bilo opravljeno za izdelavo procedur v Visual Basicu za prenos podatkov iz ASCI datotek na ARSO omrežje. Glavna težava je bila, da je bila struktura ASCI formatov relativno zapletena, zaradi česar je bila potrebna dobra sodelava med razvijalci sistema in hidrologi prognostiki. Problem izpada podatkov, ki se lahko pripeti med neugodnimi vremenski pogoji, je bil rešen z izdelavo posebnih programskih kontrolnih procedur. Obenem pa so hidrologom na razpolago številna orodja za vizualno prezentacijo in možnosti številnih kontrol in popravljanj obdelanih podatkov.

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