AN EXPERT SYSTEM FOR COMBATING FLOOD CRISIS AND ARIDITY ON EXAMPLE VOJVODINA'S VATER TRANSPORT SYSTEM IN SERBIA

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Summary: This paper presents an outline of a possible solution of an intended expert system for real time operation for flood prevention of rivers and river canals in Vojvodina - Serbia. The system should enable dispatchers to make operating decisions on their own in dialogue with the computer. After a brief presentation of the past floods in Serbia the paper considers possible types of expert systems, and the problem which of the existing ES types should be taken as a base for the water flow management in some crises situations as floods or aridity.

Key words:Expert system, floods, GIS, canal Dunau Tisa Dunau.

1. INTRODUCTION – HYDROLOGY IN SERBIA

Every spring, when snow melts on mountains and rivers grow up, the story about the danger of flooding actualizes. During hot aridity summers, with droughts, stories about the regulation of water flows are top stories again.

Five major rivers: the Danube, Sava, Tisa, Morava and Drina, with many larger and smaller tributaries run through Serbia.

Average annual precipitations on the territory of Serbia are 734 mm, which is about 65 billion m3. The problem is that the precipitations are unevenly distributed through space and time. So, on the territory of Serbia over the range from over 1.500mm in the mountain areas Šara and Mokra Gora, down to only about 550mm, and less, in the wide areas of Bačka and Banat. There is a general unfavorable circumstance: the scarcest precipitations during the vegetation period, when exists the greatest need for water, are in the areas with the highest quality land resources.

On the territory of Serbia the average water flow forms at the level of about 509 m3/s, or about 16 billion m3 per year, with the corresponding average specific water runof of about 5.7 l/s·km2. With the domestic waters of about 1500 m3 per capita and year Serbia is one of the poorest areas of water in Europe. Because there is not enough quality domicile water, it is necessary to use it very rationaly, repeatedly, and multi-use with the implementation of a number of reservoirs for regulation and improvement of water regime.

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The average flow of transit waters of international rivers is about 5163 m3/s, or 162 billion m3/year, which includes waters in unfavorable regimes when the flows are down below 1500 m3/s. Especialy, low water levels of the Serbian main rivers are unfavorable (Drina near Zvornik less than 50 m3/s, Tisa near Bečej ≈ 120 m3/s, etc.)

2. FLOODS AND DROUGHTS

Each river has its own specifics that affect that independently or together with other rivers flood surrounding terrain. In Serbia floods are almost a regular phenomenon due to the nature, but partly due to relative water flow irregularities.

Most recent memories are connected with years 2005 and 2006, when there have been massive floods and when many settlements were destroyed. In the year 2005, due to melting snow in the Carpathians in Romania, 365 houses were flooded in Jaša Tomić village. The village is mostly reconstructed, but still suffered the consequences, and every growth of river Tamiš brings unrest among the locals.

In April 2006, those day's priority problems were large floods. The flooding was caused by heavy snowfall in West Europe, late in the season, and snow melting intensified by heavy spring rains that arrived. Between the 14th and the 16th of April, the water level in rivers reached the highest point in 100 years. After the rivers reached their maximum, the underground waters were a far greater danger. A total of more then 30 municipalities had been affected throughout North and Central/Eastern parts of Serbia[1]. The Serbian government declared a state of emergency in nine municipalities, including Belgrade, for fighting the flooding. The state of emergency and defense measures against floods remained in force even during the May. It was necessary more than six weeks the water level was dropped.

Source: Authors

Fig. 1 - Boulevard near the Belgrade Fair4

Source: Authors

Fig. 2 - Danube – Details from the quay in Zemun April 22nd, 2006

Consequences of those floods are still immeasurable. Some analyses showed that:

- More than 240,000 hectares of land in northern Serbia were flooded, or threatened by underground waters and landslides. Out of the 240,000 hectares, more than 122,000

[4] www.durmitorcg.com , April 9th, 2006

hectares are flooded, more than 112,000 hectares were threatened by underground waters and landslides threatened more than 5,500 hectares of arable land.

- According to the reports, the most threatened areas were the district of southern Bačka with more than 50,000 hectares and central Banat with 42,000 hectares under water.
- The 35 million EUR, allocated from the budget to compensate damage from floods, had been spent urgently in April and the real damage was much more over this sum.

Due to frequent lack of summer rains there are frequent newspaper headlines such as:

- Due to droughts fruit yield even 20% less5
- The yield of corn not near the expected6
- Drought reduced the yield of wheat for 40 million euro7
- Sunflower harvest in the thick of it, yield is less for 20 percent8

Although in the majority of comments, number 20 became a synonym for the reduction of production, it is more than obvious that regulation of water flows is needed.

3. DANUBE-TISA-DANUBE CANAL (DTD)

The curiosity is that Serbia has a canal system in Vojvodina for irrigation and for protection of floods. Before the canal as we know these days, control of surface water has started soon after departure of the Turks from the region. The Austro-Hungarian experts started with the building of the first canal in the period from 1794 to the year 1802.

Source: [2]

Fig. 3 - Watershed in Vojvodina

[5] 03.Okt.2008 god., Izvor: Poslovni magazin
[6] Ekonomist magazin, Broj 432, 01. septembar 2008.
[7] BS Poslovni magazin, May 6th, 2007.
[8] 27.Avg.2008 god., Izvor: Radio Televizija Vojvodine

Danube-Tisa-Danube Canal (DTD)[9] is a unique hydro-engineering system for flood control and hydro technical, amelioration forestry, water supply, waste water evacuation, navigation, tourism, fishing, hunting. It covers the northern part of Serbia - the territory of Vojvodina (Bačka and Banat regions), with the total area of about 12,700 km^2.

The total length of the main canals is 929 km, including new and old canals and streams which were completely or partially reconstructed and thus included in the new system. In the basic canal network there are 51 structures - 24 gates, 16 locks, 5 safety gates, 6 pumping stations, and 180 bridges. There are 14 goods ports on the canals. On the new canals of the water system the Danube-the Tisa-the Danube, reconstructed and new built from the year 1958 to the year 1976, there were built: 84 bridges - 62 carriageway, 19 railway and 3 pedestrian ones. One of the most important structures within this water system is the dam on the river Tisa near Novi Bečej which regulates the water regime in the basic canal network in Banat, for irrigation of about 3,000 km^2.

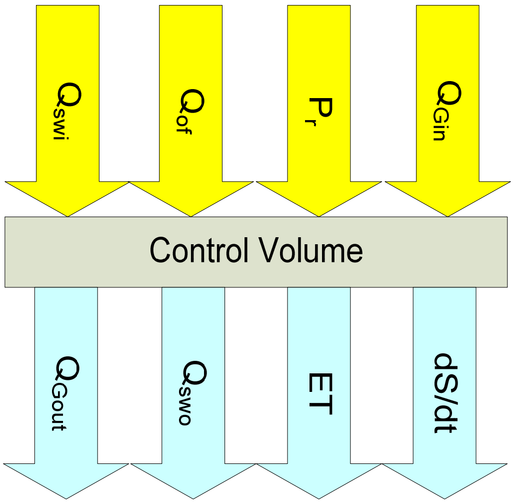
The system gives possibility for drainage of 700,000ha and irrigation of 50,000ha.

4. MODELLING

For creating an expert system for Vojvodina’s hydrology system, bearing in mind different situations in water flow of main rivers and canals, it is necessary to prepare a hydrology model of water flows, geographic terrain model with possible flood fields and finally chose an appropriate design of expert system.

5. HYDROLOGY MODEL

For taking into account external influences and input data for expert system it is necessary to prepare a hydrology model of the whole watershed. There are a lot of components that should be analyzed in different control sections of the basin.



Q_{swi} – Surface water in (stream flow into the control volume)
Q_{of} – Overland flow into a river/canal
P_r – Precipitation into a river/canal
Q_{Gin} – Groundwater flow into a river/canal
Q_{Gout} – Groundwater flow out of a river/canal
Q_{swo} – Surface water out (stream flow out, and overland flow that exits independently of streams, e.g. into flood fields)
ET = Evapotranspiration
dS/dt = Change in the control volume of water (S) per unit time

Source: Authors

Fig. 4 - Sheme of water balance for rivers and canals

[9] http://sr.wikipedia.org/wiki/Канал_Дунав-Тиса-Дунав

In the Figure 4 it is easy to define the equation of water balance for rivers and canals of the basin:

$$\frac{dS}{dt} = Flux_{in} - Flux_{out} = Q_{swi} + Q_{of} + P_r + Q_{Gin} - (Q_{swo} + Q_{Gout} + ET) \qquad (1)$$

On the same way it is possible to form such equation for lakes and flood fields. In praxis, changes in surface water flows and lake’s volumes are dominant so the other components could be ignored. The volume change could be defined approximately as:

$$\Delta V = Q_{swi} - Q_{swo} \qquad (2)$$

6. GEOGRAPHIC INFORMATION SYSTEM

A geographic information system (GIS) captures, stores, analyzes, manages, and presents data that is linked to location. The year 1962 saw the development of the world's first true operational GIS in Ottawa, Ontario, Canada. By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms and users were beginning to export the concept of viewing GIS data over the Internet, requiring data format and transfer standards. More recently, there are a growing number of free, open source GIS packages which run on a range of operating systems and can be customized to perform specific tasks.10

Whether for man-made emergencies such as oil spills, chemical releases, epidemics, riots, acts of war or acts of terrorism, or for natural disasters such as floods, fires, earthquakes, hurricanes or tornados, GIS has proven crucial in preparedness, mitigation, detection, response and recovery.

In China, emergency response systems are being developed to combine GIS and expert systems for real-time monitoring and detection at chemical facilities.

As a direct result of the 1986 Chernobyl nuclear reactor disaster, the United Kingdom has adopted a GIS-based national radiation monitoring and nuclear emergency response system.

Douglas County Emergency Management Agency in Kansas uses digital elevation maps, orthophotos and hydrography data, with information from a disaster/emergency database, a facilities database and a resource database in a GIS-based decision support system for flood impact assessment.

Following the 1997 Spring Creek flood in Ft. Collins, Colorado, the city’s GIS teams saved FEMA assessment surveyors valuable time by combining information from 30 different map layers and printing out hundreds of maps within 24 hours of the disaster.11

[10] http://en.wikipedia.org/wiki/GIS
[11] http://www.edc.uri.edu/nrs/classes/NRS409/509_2002/Donahue.pdf

Source: [7]

Fig. 5 - Map of flood protection of villages and 2016ha of agricultural areas along the river Karaš

USAID program for Planning and Action in Crisis Situations provides assistance to municipalities in Serbia in order to make them more efficient in handling crisis situations, helping them develop a system for planning and responding to crisis situations. In April 2008, seven municipalities in Vojvodina signed a cooperation agreement with this institution. Currently 41 municipalities in Serbia are taking part in this program, and it is planned that by the 2011, 70 municipalities will be involved in the program. For this purpose, bigger investments are planned, and the USAID has given 45 million dollars for support to the efforts of the municipalities to improve the prevention of crisis situations and response to them. [6]

No longer is the question of whether or not GIS can be used in emergency management relevant. GIS is here and its value has been proven. Although great strides have and continue to been taken, the fullest potential of integrating GPS with other technologies has yet to be reached. The GIS becomes the user interface for environmental modeling and GIS data becomes model data. Thus environmental planning can be performed in a highly efficient manner.

7. EXPERT SYSTEM

Today’s information systems could be either of operational or management decision supporting type.

Operational information systems are predominantly data sources for higher classes of information systems used in management.

Higher class information systems for management use could be:

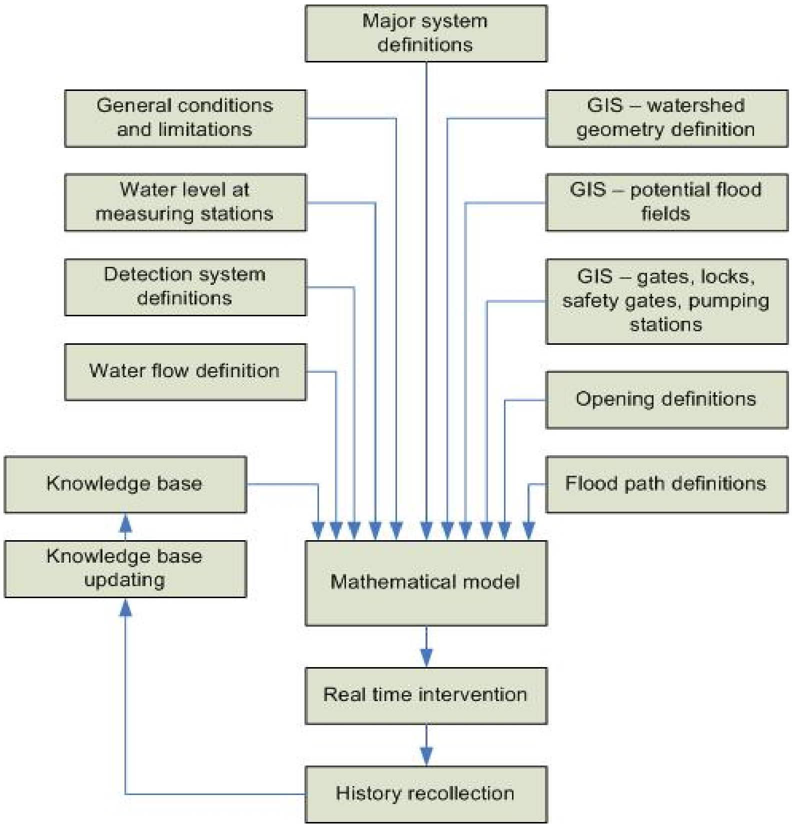
- Management Information Systems (MIS)
- Decision Support System (DSS) or
- Expert Systems (ES).

Managerial information systems serve management by supplying it with useful, partly aggregated and categorized information. Such information is got from inside of the system, rarely from the organization surroundings. So, such information system is not favorable for the purpose of the water flow managing.

Decision support systems are more flexible, and ready for giving support in less structured problem. Decision maker has full control over the process and DSS. That means that decision maker must be a highly qualified person, and that the measures will depend on the decision maker. Because of the much stressed situations during the flood crises and a very high responsibility, that could be a problem.

Compare with DSS, expert systems could provide better potentials for flood crises solving. They are more complex, but they need no full time presents of experts during the crises situation. The expert system knowledge base could be rich enough to solve almost all flood crises situations.

There are a lot of different approaches in choosing of appropriate type of expert system. Without deeper analyze, in this paper, for flood protection it could be suggested use of frame based ES instead of knowledge based or rules based ES. Frames are structures that allow well structured and concise knowledge representing. Frame slots can be used for representing of specific attributes, actions or procedure.



Source: Authors

Fig. 5 - Schema of the expert system structure

Grouping by location is quite normal because there are no many places for influencing on water flow in canals and rivers. Groups of data and actions could be modeled efficiently by zones, separately, and then connected with suitable model interfaces. Some additional benefits could be achieved by using of class-frames.

Figure 5 shows the organizational structure of the expert system created for control of water flows aiming to prevent floods and droughts. The main idea is that GIS and measurement stations give inputs for mathematical model made for calculating water flows in different sections of watershed. General conditions and limitations, as well as opening definitions and water flow definitions in different situations could provide other necessary data for mathematical model for precise control of water flows. During extremely high waters and flood risks, flood path definitions could help to reduce damages by flooding dedicated reservoirs.

Also, during droughts, it is possible to regulate gates openings and collect more water for irrigation system.

During exploitation of the expert system all history could be recorded and analyzed. Conclusions could enrich the knowledge base.

8. CONCLUSIONS

Bearing in mind problems of combating flood and aridity crisis in Vojvodina's hydrology system it could be said that implementation of expert system could take a place. The implementation is connected with some organizational problems, additional equipment and acceptable costs. Frame based expert systems give optimal potentials in nova days, because frames allow well structured and concise knowledge representing, and that frame slots can be used for representing of specific attributes, actions or procedure. The ES schema, given by figure 5, in combination with GIS could be a solid base for anti flood expert system creating.

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