QUANTITATIVE MONITORING OF WATER USERS - A KEY IN WATER MANAGEMENT

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***Abstract*:** Rooted in the constant need for data in hydrology and water management, the paper meets this demand by creating a database and by justifying its usefulness through applications.

The software is based on generally accepted methods, being a user-friendly one and ensuring both the precision of the data, interpretations and connections, and their protection.
***Keywords*:** collecting data, operational data, historical data, database.

QUANTITATIVE MONITORING DER WASSENUTZIESSUNG
Schlüssel in Wasserhauswesen

***Zusammefassung*:** Die anwesende Arbeit entsprigt aus dem Bedarf von hydrogischen daten und Wasserhauswesen durch die Bildung einer informatisierten Datenbank und die Begründung ihrer Verwendung durch Anwendungen.

Das Programm gründet auf berühmten Arbeitsmethoden, die sehr leicht verwendet werden können indem sie sowohl die Genauigkeit der Daten, Interpretationen, Verbindungen, aber auch dieser Schützung sicherten.
***Schlüsswörter*:** Die Sammlung der Daten, operationelle Daten, historische Daten, Datenbank.

Introduction

At a time when both hydrology and water management are faced with an ever increasing need of data in terms of quality and quantity, the existence of a database has become extremely important. It is also a given fact that the hydrologists and the water management specialists have at least one computer in their offices, which implies easy access to a computer network that can guide the information to the superior levels of decision in water planning. The novelty of this work lies in the principles this database is founded on:

- stability in time of the methods used for collecting data,
- fast recording and validation of data,
- use of protection criteria on different levels of information for quick data access,
- possibility of linking and converting already existing databases.

The program, written in Visual Basic and operational under Microsoft Access, offers the possibility of introducing, criticising and validating data, as well as processing and using them.

In practical terms, the introduction of several parameters (levels, indexes, hydromechanics equipments' functioning hours) leads to the *hourly, daily, weekly* processing of operational data and further on to setting historical data (*monthly,annually,multi-annually*).

The database itself is created in such a way as to always keep the connection between *hydrology* and *water management* active. Its reports can be either visualised or come into written form, in accordance with the current work methods.

The outcome of this paper lies in using the database in some hydrological studies and in its availability for the quantitative and qualitative monitoring of water.

This method involving computer data storing aims at providing a useful support for different specialists in hydrology and water management, by promoting modern and efficient team work, and last but not least, by conforming to international requirements.

1. Work method presentation

1.1. *Initialisation*

The application views a region proved to be a complex and important one for hydrology and water management (Figure 1). It represents the lower reach of the Olt river drainage basin. The natural hydrological regime of this basin has been strongly modified in time by complex water planning with many users and hydrological structures.

Some characteristics of the studied region are: South of Romania, 143 km in length, surface: 5.500 km^2, 150 important water users (consumptive and non-consumptive, including 9 hydropower plants that fall in cascade), 18 discharges of water into the Olt river and the Danube, ~560000 inhabitants, water exchanges between drainage basins and border region.

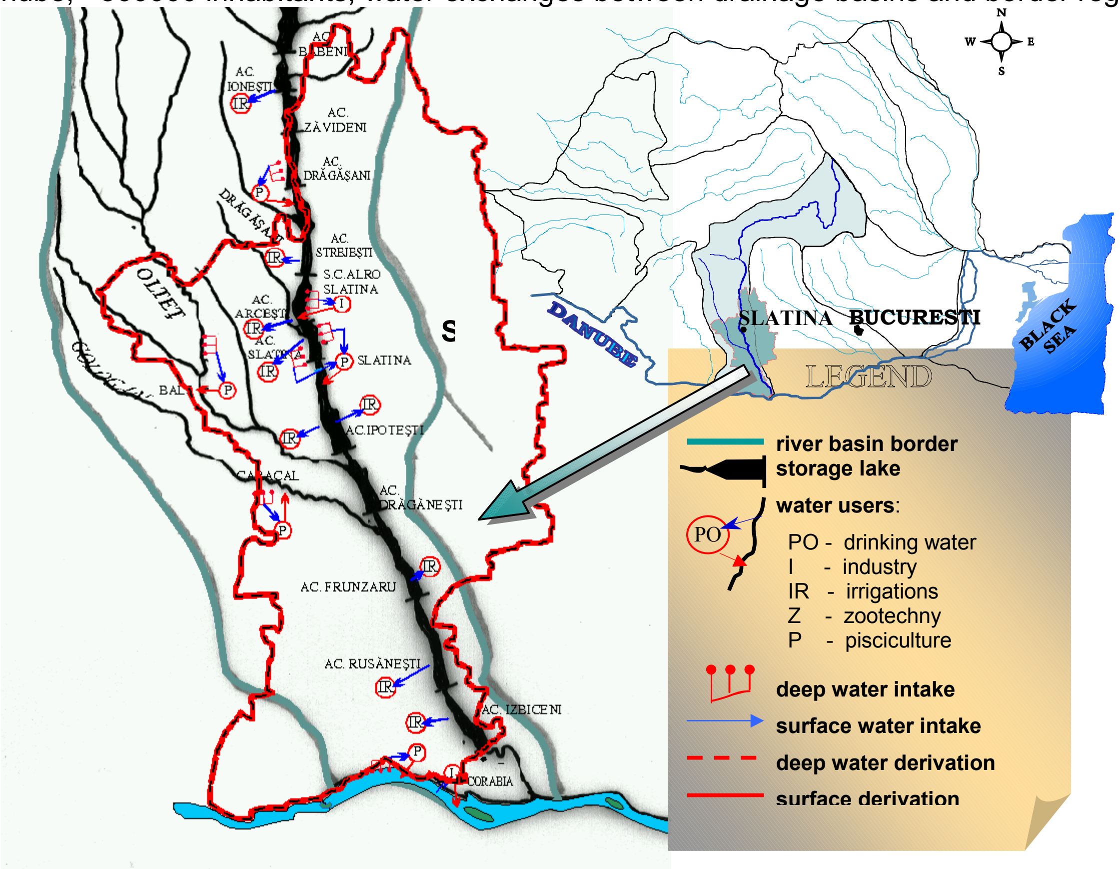
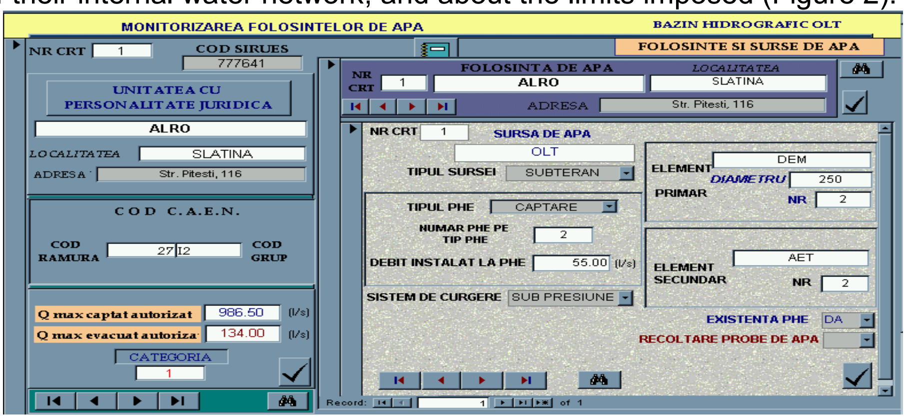


Figure 1. Studied region and its characteristics.

In conformity with water legislation, the water users which can influence the natural hydrological regime are identified, the recording of data being done in the form of a database that can provide general coordinates of the water users and information about the equipment of their internal water network, and about the limits imposed (Figure 2).



These are the first input data of the soft that gradually creates a database structured on two informational levels: <u>historical</u> <u>and operational</u>.

Figure 2. Interface for introduction and the validation of inventory data.

1.2. *Non-consumptive water user. Hydropower plant*

First of all, a few hydraulic, technical and constructive characteristics must be known. This information is necessary to understand the different situations that occur while working in water management and hydrology.

For example, for Rusanesti storage reservoir some of the necessary information is:

<u>Hydraulic characteristics:</u>

- NNR = 57,50 mdM ;
- NME = 59,00 mdM ;
- NmE = 55,50 mdM ;
- NCR = 62,00 mdM ;
- Volume (at NNR) = 78,0 millions m^3,
- Volume (at NME) = 95,40 millions m^3;
- Surface (at NNR) = 1100 ha;
- Length = 15,40 km.

<u>Dam:</u>

- Concrete construction; 5 broad-crested weirs (15m x 13m),
- Flow weir: Q_1(at NNR) = 1101 m^3/ s, Q_1(at NME) = 1394 m^3/ s,
- Total flow weir: Q_{tot}(at NME) = 6970 m^3/ s.

For many years, the capacity curves of reservoirs have been offered by the lakes' administrator, "HIDROELECTRICA" (example: Rusanesti storage, Figure 3).

The values considered, which correspond to a meter-by-meter measurement, are not practical. In Hydrological Services activity, accuracy is necessary. But the needed values are obtained by interpolation, manually. The software application takes over this volume of work, and by mathematic interpolations - accepted by hydrology, offers volume values of stored water against every centimetre of stage (Figure 4).

H (mdM)	VOL(mil.m3)
44.00	0.060
45.00	0.510
46.00	1.820
47.00	3.920
48.00	6.780
49.00	10.870
50.00	15.930
51.00	21.530
52.00	27.960
53.00	35.500
54.00	43.960
55.00	53.050
56.00	62.660
57.00	72.920
58.00	83.930
59.00	95.400

Figure 3. Vol / H by meter

H (mdM)	H "0 staff" (m)	VOL(mil.m3)
44.00	0.50	0.0600
44.01	0.51	0.0645
44.02	0.52	0.0690
44.03	0.53	0.0735
44.04	0.54	0.0780
44.05	0.55	0.0825
44.06	0.56	0.0870
44.07	0.57	0.0915
44.08	0.58	[illegible]
44.09	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	9[illegible].4824
58.93	1[illegible].43	94.5971
58.94	15.44	94.7118
58.95	15.45	94.8265
58.96	15.46	94.9412
58.97	15.47	95.0559
58.98	15.48	95.1706
58.99	15.49	95.2853
59.00	15.50	95.4000

Figure 4. Vol / H by centimeter

Therefore, one spectacular feature of computer-based work system can be used: the graph association with data. Once entering data, the graph display of storage shows the information about the precision of the data (Figure 5).

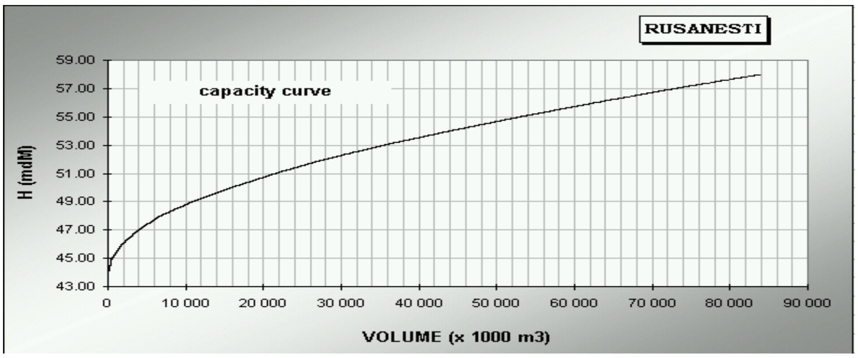


Figure 5. Graph display of the capacity curve

If the capacity curve of a reservoir has to be changed as a result of bathymetric measurements, the former curve is stored while the updated curve automatically enters mathematical calculations.

The input data which are collected monthly, paper records being sent by post mail (Figure 6), could be arriving daily-through Internet from “HIDROELECTRICA” (Figure 7).

C.H.E.................................... Râul....................................

Perioada (luna, anul)..

DATA	NIVEL (mdM)	Hb (m)	G1 ENERGIE (MWh)	G1 durata de funct	G2 ENERGIE (MWh)	G2 durata de funct	G3 ENERGIE (MWh)	G3 durata de funct	G4 ENERGIE (MWh)	G4 durata de funct	Qdeversat (m3/s)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											

Figure 6. Paper recording of data

A. Realizari zilnice ◀ 21.05.2002 ▶ ▶ Listare

CHE	NNR mDM	Nmin ex. mDM	Q afl. mc/s	Q uzin. mc/s	Q fol. mc/s	Q dev. mc/s	Qevac mc/s	HMed. m	DhMax m	P vif MW	Pmax MW.	Energie zi MWh	Energie luna MWh	Zap. cm	Ploa m/mc	Tmp gC
Strejesti	140,00	137,00	160	84	2	0	86	18,33	0,20	14	20	332	7.231		5,0	15
Arcesti	122,00	119,00	84	18	4	0	22	13,34	0,20	0	12	45	4.659		4,0	15
Slatina	108,00	107,00	18	19	0	0	19	10,40	0,10	0	5	53	3.903		4,0	12
Ipotesti	98,00	96,00	19	34	0	0	34	8,76	0,10	0	10	91	2.955		0,0	14
Draganesti	84,50	82,50	35	89	0	0	89	14,49	0,10	17	17	351	5.314		0,0	13
Frunzaru	71,00	69,00	89	60	0	0	60	12,33	0,10	10	10	206	4.541		0,0	13
Rusanesti	57,50	55,50	60	56	0	0	56	14,06	0,10	7	14	204	5.493		0,0	13
Izbiceni	44,00	42,00	56	50	0	0	50	8,83	0,10	5	5	121	3.238		0,0	13
										53	93	1.403	37.334			

Figure 7. Data of interest from the database of “HIDROELECTRICA”

With the help of “Microsoft Access”, a user-friendly interface of introducing and verifying data was imagined. After the introduction and the validation of primary data, it is the software that takes over all the operations necessary to create the database (*Figure 8).*

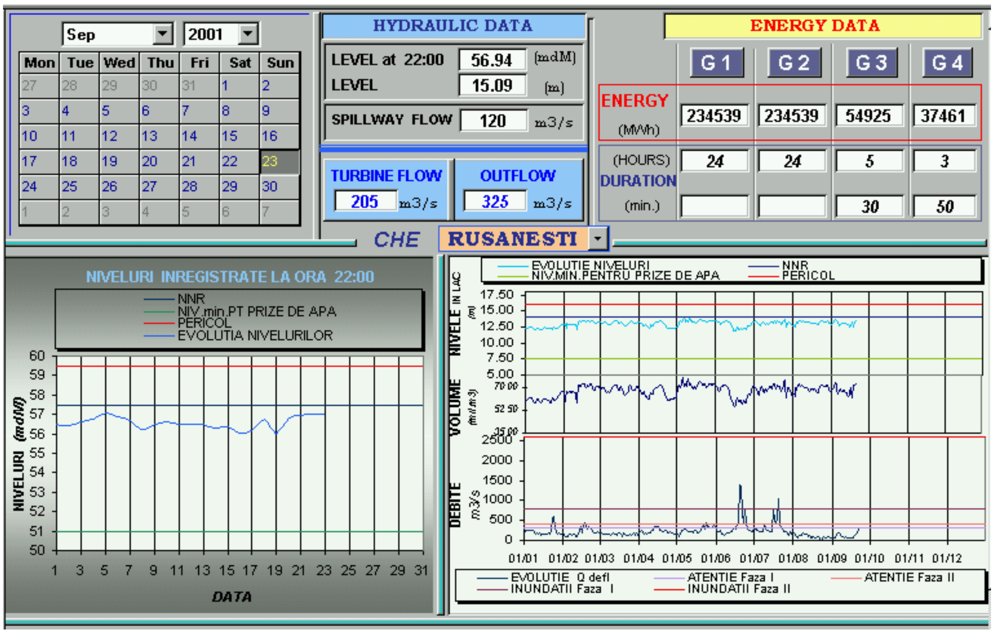


Figure 8. Interface for introduction and the validation of operational data

The soft begins by extracting the storage volume values corresponding to the introduced stages from the capacity curve in the table. Then it automatically calculates, in keeping with the data introduced the daily average usable flow (3) and the daily average outflow (4) in conformity with the method presented in (Diaconu I., Serban P., Pasoi I. *Indrumari metodologice si tehnice pentru reconstituirea scurgerii naturale a râurilor*", I.M.H. Bucuresti, 1980).

The turbine discharge in functioning duration of each turbine is:

$$Q_{TD} = \frac{P_D}{9.81 * \eta_T * H_b} \quad (m^3/s) \tag{1}$$

where:

η_T - the efficiency of the turbine, verified every five years,

H_b *(m)* - average driving head per day,

$P_D = \frac{E}{D}$ *(MW)* – power produced in the functioning duration of one turbine,

E (MWh) – the electric energy produced in the functioning duration of one turbine,

D (hours) – the functioning duration of one turbine per day.

The measure systems in hydropower plants – megawatt meter and the energy totaliser, are very precise; the error of the power value is restricted to the apparatus' error: ± 2%.

The turbine discharge of each turbine per day is:

$$Q_{Td} = \frac{Q_{TD} * D}{24} \quad (m^3/s) \tag{2}$$

The total usable flow is the sum:

$$Q_{Td\,tot} = \sum_n Q_{n\,Td} \quad (m^3/s) \tag{3}$$

and the outflow discharges:

$$Q_{out} = Q_{Td\,tot} + Q_w \quad (m^3/s) \tag{4}$$

This way, a daily graphic evolution of the outflow discharge at the storage lake considered, as well as of the stages and volumes of the same reservoir are given (Figure 6). The operational data are complete.

As the graphics are automatically drawn while the data are fed into the computer (Figure 8), the hydrologist can judge at any time the correctness and the evolution of the data received.

The same diagrams (Figure 8) offer the opportunity of visualising the way this evolution ranges between the minimum levels (corresponding to the water intakes' levels for industry, irrigations, etc.) and maximum levels (corresponding to high floods).

Then the data of interest are automatically transferred to the historical data level of the database which is targeted at annual values for:

- ✓ levels,
- ✓ volumes,
- ✓ turbine discharges,
- ✓ outflow discharges.

From these centralizations (Figure 9) the software extracts the monthly maximum or minimum values recorded, the dates of these events which are simultaneously transferred to the historical level of the database, where they can easily be found due to its user-friendly interface (Figure 10).

The historical data level is available in Romanian, English and French.

One of the most important aspects that should not be overlooked is the fact that the software protects the database at *this historical level* for two reasons: so that the data could not be changed without seeing the *operational data* circumstances, and so that they could not be sold by people who are not entitled to do that.

At this historical level, data display is available in the following form (Figure 9):

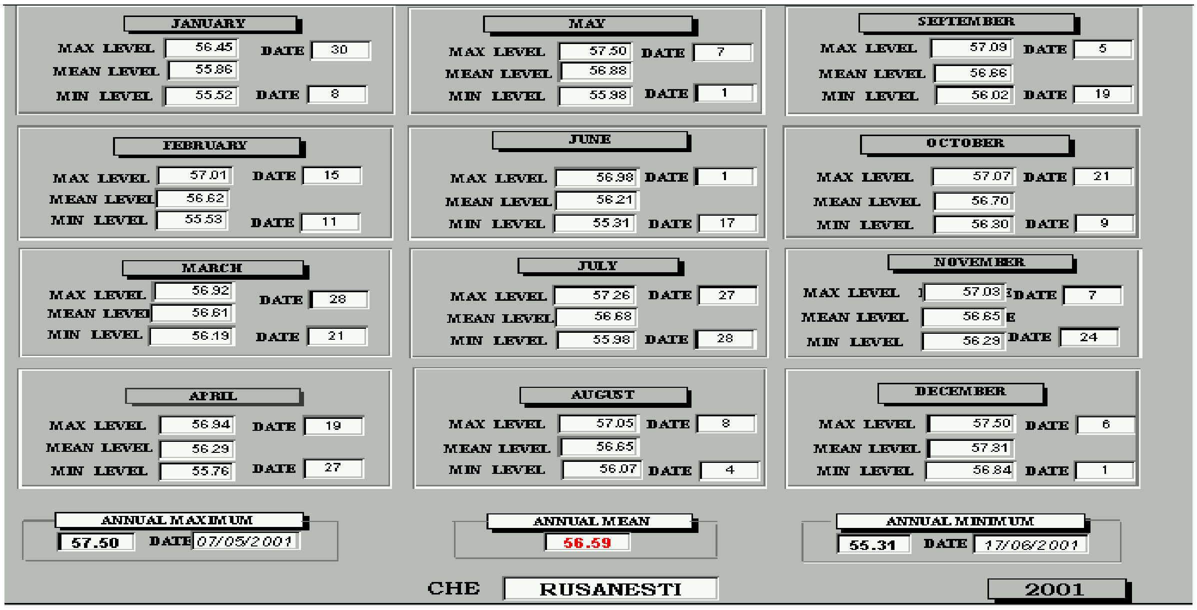


Figure 9. Database display of the historical level. Monthly values

The same screen display architecture (Figure 9) is available for <u>volumes, turbine discharges</u> and <u>outflow discharges</u>. The characteristic values corresponding to the studied year are displayed as follows (Figure 10):

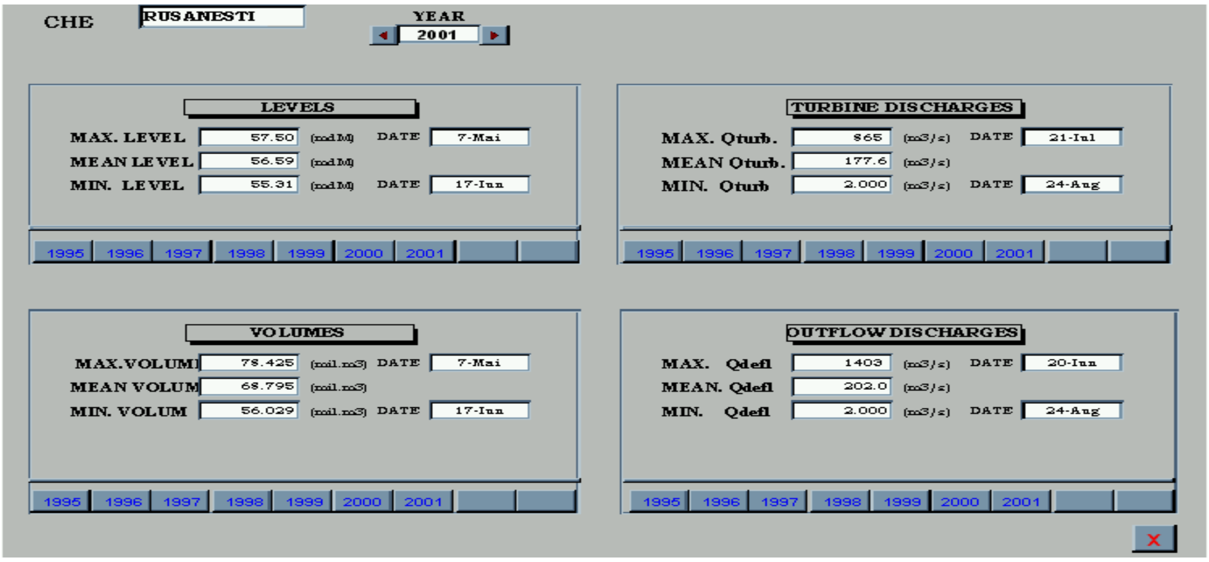


Figure 10. Database display of the historical level. Yearly values

The visualisation of data can be done backwards, by clicking on the button corresponding to the year of interest.

For example, if one wants to choose a hydropower plant, the list containing the names of all the plants in the database is shown. Then, once the year of interest is selected, the database offers the possibility to visualise the data characterising that year from the point of view of stages, volumes and turbine discharges.

The buttons 1995 … 2001 corresponding to each value open access to the evolution throughout the respective year, for each month (Figure 9).

There is yet another way to access the database besides screen display. For any level of information (operational or historical) detailed reports containing all data of interest (as computer files or paper) can be obtained.

1.3. *Consumptive water user. Irrigations*

Even for a few months per year, the rigorous monitoring of water consummation in irrigations is very important for the water management. There are a few reasons:

- Water catching for irrigations has a significant influence on the natural river regime;
- The water quantitative demands of the irrigation systems must be known;
- The financial work system stipulated by contracts must take into account precise values.

In this case, the structuring of the database is based on the <u>operational data</u>. The content of information that arrives from irrigation systems refers to counters of measurement systems or the functioning duration of the pumps for each water intake.

One more time, the soft system includes both the input data and the decision-support. After the data registration, numerical methods (accepted by hydrology and water management) offer the output data structured on different levels of information: daily, monthly and yearly. After that, access to the data is different according to different possible interests. For example, the monitoring of water consumptions inside irrigation systems is of great help for the financial system of water management services. Moreover, a correct monitoring of water volumes extracted from storage lakes is useful for water-balance analyses.

The more frequently – even daily – the input data come in, the more valuable the monitoring of water volumes in storage lakes is.

The database for irrigations may be accessed by simply clicking on the buttons in the following screen capture (Figure 11):

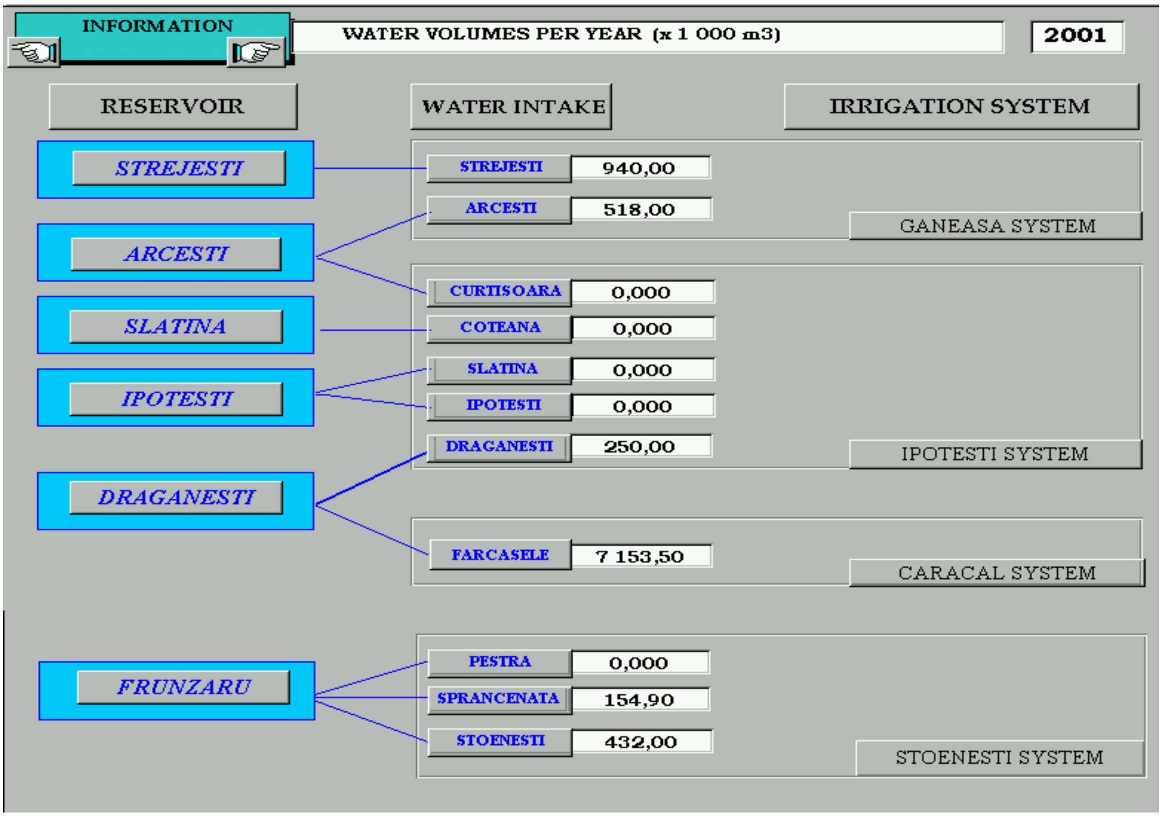


Figure 11. Database navigation interface

The soft prepares <u>maximum</u>, <u>medium</u> and <u>minimum</u> <u>multi-annual data</u> essential for the reconstruction of the natural hydrological regime in conformity with (Diaconu,C. Pasoi,I., *Instructiuni pentru Statiile si Serviciile Hidrologice* - debite de apa si aluviuni, I.N.M.H., Bucuresti, 1997).

Detailed reports that contain all data of interest can also be obtained.

2. Applications

The previous chapters have presented different methods of collecting, processing, and storing data in hydrology and water management. The application was aimed both at the lower watercourse of the Olt river before it flows into the Danube, and a section of the Danube.

The introduction of a computer–based work system essentially contributed to an increase in the processing speed, to a decrease in the number of human errors, to creating connections between former databases and the present one, as well as to protecting data.

In the light of the above-mentioned characteristics, a number of real situations are presented, situations in which the results of the quantitative monitoring of water users constituted or might constitute a key in hydrology or water management.

The data provided by the database will be emphasized being written in italics, underlined.

2.1. *Quantitative monitoring, hydrological forecasting*

2.1.1. Water-balance analysis

The specificity of this river basin is represented by the existence of dams which have modified to a great extent the natural hidric regime of the Olt river. The analysis of the water-balance in storage lakes is very important, therefore, as it is based on the links between *inflow water discharge*, *outflow water discharge* and the *variation of water volume* in reservoirs.

The balance equation applied to all reservoirs which influenced the downstream hydrological regime takes into consideration *the monthly values* of all characteristics.

2.1.2. Surge attenuation in storage lakes

This hydrological study is useful for the water management of the reservoir. The *maximum values and the other values* in high water evolution are accessed from the database. *The graphic evolution of both the inflow and outflow discharges* and of *the volumes* offers information on the exactness of the evaluation of the volumes taken from the reservoir capacity curve.

Case study (Figure 12). Location: Strejesti storage. Analysis: When $Q_{inflow} \cong Q_{outflow}$, the storage variation (ΔW / Δt) is very small. Conclusion: There are no initial reading errors that can modify the final results; the volume values against stages are properly extracted.

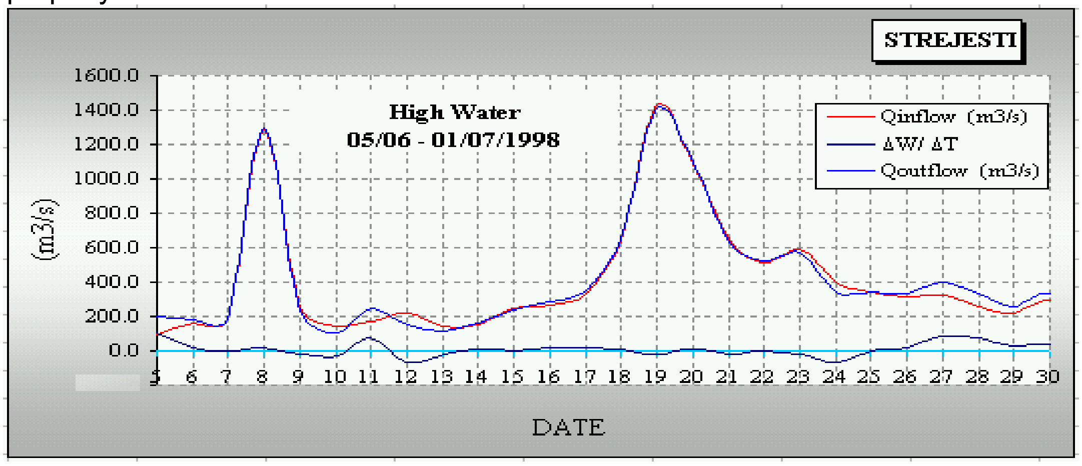


Figure12. Surge attenuation analysis in storage lakes

2.1.3. Dispatcher work system

The display of all the graphic evolutions of *daily levels, volumes, and water discharges corresponding to each storage* lake enables quick and comprehensive interpretations of the water management of an extremely complex system of water works.

2.1.4. Solid discharge-balance analysis

It is very important for reservoir silting evaluation. *Average monthly inflow* *and outflow water discharge* enter the average solid discharge computation (Diaconu,C. Pasoi,I., *Instructiuni pentru Statiile si Serviciile Hidrologice- debite de apa si aluviun*i, I.N.M.H., Bucuresti, 1997). From this point, the software that interrogates the database can and does calculate the quantity of alluvial deposits in reservoirs, at the same time being able to create a corresponding graph (Figure 13).

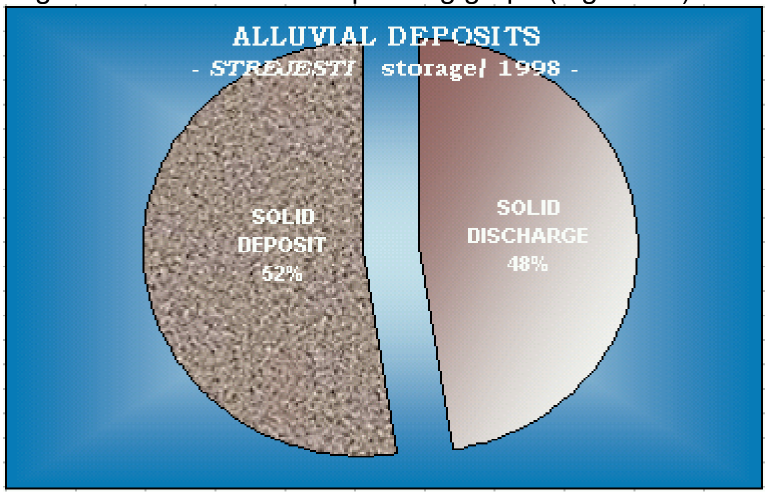


Figure13. Final result of solid discharge-balance analysis / STREJESTI storage in 1998.

2.1.5. A five years' period analysis

The *multi–annual values* gathered over a period of five years are accessed and analysed according to the percentage influence they had on the water balance. (Diaconu,C. Pasoi,I., *Instructiuni pentru Statiile si Serviciile Hidrologice* - debite de apa si aluviuni, I.N.M.H., Bucuresti, 1997).

2.1.6. A five years' period analysis

In order to find out the degree to which water is available for the users, statistic calculations (Drobot,R. *Bazele statistice ale hidrologiei,* serie TEMPUS, E.D.P.-Bucuresti, 1997) can be done using the database created.

2.1.7. Simulations in reservoirs

Different studies of water management in storage lakes (Hubert P., *Eaupuscule. Une introduction à la gestion de l'eau*, série TEMPUS, H.G.A., Bucarest, 1998) can use the database created.

2.1.8. Water discharges forecasting

When applying the theory of probability, the amount of historical data may be insufficient. Data need to be “generated”.

The mathematical method of "generating data" (Simon, Visan, 1974) takes into consideration the multi-annual average values of the data of interest (Drobot,R. *Bazele statistice ale hidrologiei*, serie TEMPUS, E.D.P.-Bucuresti, 1997) (5):

$$Q_i = \overline{Q} + r_1(Q_{i-1} - \overline{Q}) + \sigma t_i \sqrt{1 - r_1^2} \qquad (5)$$

Q_i - average flow "created" by the "i" year,

Q_{i-1} - average flow "created" by the "i-1" year,

$\overline{Q}$ - *multi-annual average values*,

r_1 - auto-correlation coefficient,
t_i - normal stochastic variable.

2.2. *Qualitative monitoring, mathematical model application*

A proper quantitative monitoring applied to the waste water dischargers (e.g. industry) offers a key to qualitative monitoring. Everything depends on the precision of flow evaluation and one's determination to act.

Even if sometimes the flow measurement and waste water monitoring conditions are very difficult, the ability to find the best technical solution depends on the specialist's imagination. The laws themselves are and will always be of great help. The technical support exists, too: basic measurement equipment or standard supplies, the knowledge to create a limnimetric key, or, for the luckiest, the portable flow-meter. More than that, the primary data can be stored in easily accessible database, either by using for example the software "Bareme" (*D.I.R.E.N. Rhône-Alpes*) or the presented database.

Some examples are the following.

2.2.1. The monitoring of the substances discharged

The *instant flows* as well as the *average, hourly and daily flows*, and the water *volumes* of waste water discharged over a given period of time are used for calculating the quantity of substances discharged in sewerage systems or in rivers (6)

$$K = f(C, Q, D) \qquad (6)$$

where:

C – substance concentration ,
Q – flow
D – discharge duration

2.2.2. Pollutants

As a result of accurate flow measurements applied to discharged water (through standard devices, using limnimetric keys or flow measurement systems in open channels), information on its velocity both in common and accidental situations.

For example, in a simple situation in which an area situated upstream of an industrial water discharger or a community, by knowing the wastewater flow and the concentration of the pollutant at the very point of its flowing into the watercourse, one can find out how its concentration reduces to the point of interest. A few details of this method are the following.

It is known that the flow is (7):

$$Q = v \times \Omega \ \ (\mathrm{m^3/s}) \qquad (7)$$

then, the velocity is (8),

$$v = Q / \Omega \ \ (\mathrm{m/s}) \qquad (8)$$

The database already created offers information about channel characteristics (wetted area, levels). That means that the water management services, with supplementary data from Laboratories, can apply a water management forecasting through Streeter-Phelps model (9) (Popa,R., *Modelarea calitatii apei din rauri,* H.G.A., 1998), in a given situation:

$$C(x) = C_0 \times e^{\frac{-k_t}{v} x} \qquad (9)$$

where:

x - distance between the waste water discharge up to the interested point,
v - velocity (m/s),
k_t - reaeration velocity coefficient (10)

$$k = 1{,}8 \frac{v^{0,6}}{h^{0,4}} \qquad (10)$$

h - level (m)

3. Conclusions

The work method presented remains operational as it designed to fit team work. The database created can be useful to many specialists. Moreover, being operational under Microsoft Access, it can be used by GIS systems.

To control, to prove, to act, to progress, these are the imperatives that can forward solutions to the extremely complex problems raised by water management nowadays.

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