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APPLICATIONS OF THE HYDRAULIC AND WATER QUALITY NETWORK SIMULATIONS

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În lucrare se prezintă principiile de realizarea modelului de simulare hidraulică şi de calitate a apei pentru rețele de alimentare cu apă, precum şi rezultatul studiului efectuat pe rețeaua de alimentare cu apă potabilă a municipiului Băileşti.

In the present paper are shown the principles of making a hydraulic and water quality network simulation model, as well as result of the study made on the water network of the town Bailesti.

Keywords: Water distribution model; Water quality simulations***;*** Hydraulic simulation; Network simulations; Steady-state simulation; Extended-period simulation.

Introduction

The analysis performed in the last few years regarding the situation of the Public Services of Water Supply have shown efficiency and service quality losses. The diagnostic of this services made by the Romanian Water Asociation show that, in most cases, the public water supply services, from Romania, can not satisfy the consumer demands.

Using the informatics tools for planning the management of the water supply and distribution systems has many advantages, among which: the efficient collecting of data, low losses, high operational security and economic upkeep.

1. The applications for the hydraulic and water quality network simulation model

The term *simulation* refers to the process of using a mathematical representation of the real system, called a *model* [1]. Network simulations, which replicate the dynamics of an existing or proposed system, are commonly performed when it is not practical for the real system to be directly subjected to experimentation, or for the purpose of evaluating a system before it is actually built. In addition, for situations in which water quality is an issue, directly testing

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a system may be costly and a potentially hazardous risk to public health.

A simulation can be used to predict system responses to events under a wide range of conditions without disrupting the actual system. Using simulations, problems can be anticipated in proposed or existing systems, and solutions can be evaluated before time, money, and materials are invested in a real-world project.

Municipal water utilities are by far the most common application of these models. Models are especially important for water distribution systems due to their complex topology, frequent growth and change, and sheer size.

Water distribution network simulations are used for a variety of purposes, such as [1, 2]:

- Long-range master planning, including both new development and rehabilitation;
- Fire protection studies;
- Water quality investigations;
- Energy management;
- System design;
- Daily operational uses including operator training, emergency response, and troubleshooting.

2. Implementation principles for a water distribution model

The first step in undertaking any modeling project is to develop a consensus within the water utility regarding the need for the model and the purposes for which the model will be used in both the short- and long-term. After the vision of the model has been accepted by the utility, decisions on such issues as extent of model schematization and accuracy of calibration will naturally follow [1].

Modeling involves a series of abstractions. First, the real pipes and pumps in the system are represented in maps and drawings of those facilities. Then, the maps are converted to a model that represents the facilities as links and nodes. Another layer of abstraction is introduced as the behaviors of the links and nodes are described mathematically. The model equations are then solved, and the solutions are typically displayed on maps of the system or as tabular output. A model's value stems from the usefulness of these abstractions in facilitating efficient design of system improvements or better operation of an existing system.

As with any large task, the way to complete it is to break it down into its components and work through each step. Some tasks can be done in parallel while others must be done in series. The tasks that make up the modeling process are illustrated in Fig. 1[3, 4, 5].

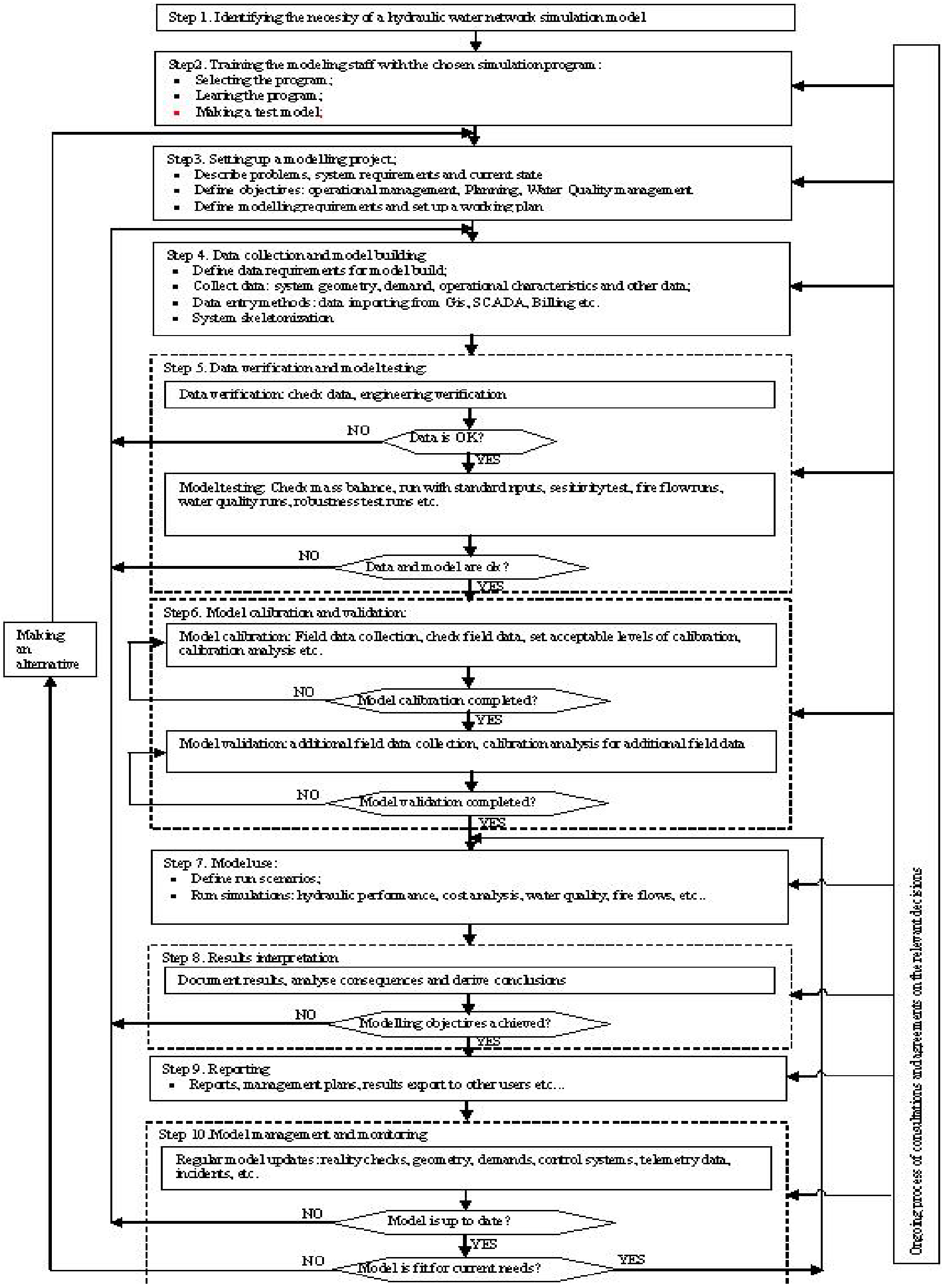


Fig. 1. Modelling process diagram for water distribution systems.

For obtaining informations like: pipe alignment, connectivity, material and diameter; the locations of tanks and valves; pressure zone boundaries; elevations; miscellaneous notes or references for tank characteristics; informations about the locations of roadways, streams and other utilities the following informations sources can be used [1, 2]:

- ➢ Water supply system maps;
- ➢ Topographic maps;
- ➢ Field drawings;
- ➢ Electronic maps and records:
  - Nongraphical data (ex: data base);
  - Computer-Aided Drafting (CAD) ;
  - Geographic Information Systems (GIS).

The concept of a *network* is fundamental to a water distribution model. The network contains all of the various components of the system, and defines how those elements are interconnected. Networks are comprised of *nodes*, which represent features at specific locations within the system, and *links*, which define relationships between nodes.

Water distribution models have many types of nodal elements, including junction nodes where pipes connect, storage tank and reservoir nodes, pump nodes, and control valve nodes. Models use link elements to describe the pipes connecting these nodes. Also, elements such as valves and pumps are sometimes classified as links rather than nodes. Table 1 lists each model element, the type of element used to represent it in the model, and the primary modeling purpose [1, 2].

Table 1

Network modeling elements

Element	Type	Primary Modeling Purpose
Reservoir	Node	Provides water to the system
Tank	Node	Stores excess water within the system and releases that water at times of high usage
Junction	Node	Removes (demand) or adds (inflow) water from/to the system
Pipe	Link	Conveys water from one node to another
Pump	Node or link	Raises the hydraulic grade to overcome elevation differences and friction losses
Control Valve	Node or link	Controls flow or pressure in the system based on specified criteria

After the basic elements and the network topology are defined, further refinement of the model can be done depending on its intended purpose. There are various types of simulations that a model may perform, depending on what the modeler is trying to observe or predict. The two most basic types are [1, 2]:

- ➢ ***Steady-state simulation*:** Computes the state of the system (flows, pressures, pump operating attributes, valve position, and so on) assuming that hydraulic demands and boundary conditions do not change with respect to time;

- ***Extended-period simulation (EPS)*:** Determines the quasi-dynamic behavior of a system over a period of time, computing the state of the system as a series of steady-state simulations in which hydraulic demands and boundary conditions do change with respect to time.

Using the fundamental concepts of steady-state and extended-period simulations, more advanced simulations can be built:

- ***Water quality simulations*** are used to ascertain chemical or biological constituent levels within a system or to determine the age or source of water;
- ***Automated fire flow analyses*** establish the suitability of a system for fire protection needs;
- ***Cost analyses*** are used for looking at the monetary impact of operations and improvements;
- ***Transient analyses*** are used to investigate the short-term fluctuations in flow and pressure due to sudden changes in the status of pumps or valves.

3. Water distribution system modeling for the town Bailesti

General presentation [5]**.**

The town Bailesti is situated in the south part of the county Dolj, in a plain.

To assure the water supply in the town Bailesti there is a working centralized water supply system, composed as following:

- ***Active face*** The active face is assured by a number of 20 water diggings of medium deepness, from what 16 are working;
- ***Adduction pipeline*** Thw water diggings are linked on a single adduction pipeline made from steel with a diameter of 400 mm, posed underground;
- ***The water supply station*** is made from the following: two buried water tanks made from concrete steel at 5000 m^3 each; water tanks with V=750 m^3 and $H_{maxwater}$=45,30 mWaterColumn; clorisation station, pumping station;
- ***The water distribution network*** The network is made from stell, asbestos cement and cast iron with a diameter between 100-350 mm, posed underground. The network configuration is of a annular and ramified type, and is common for the water supply and fire protection (interior and exterior). The total length of the water supply network is of 31975 m.

For modeling the water distribution network of the town Bailesti I chose the program EPANET because:

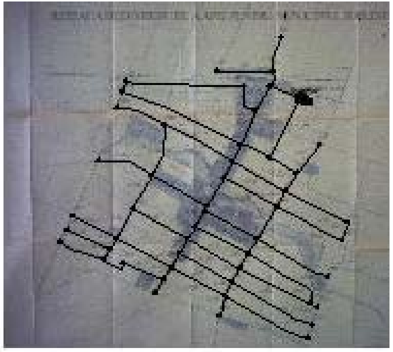
- It is a free program supplied by the Untied States of America Environment

Protection Agency;

- It allow a long term simulation, water quality analysis and it has a graphic interface;
- Because the town Bailesti does not have an electronic map GIS it is not needed for the chosen program to have the integration facilities with the GIS data base.

Model implementation

It has been used as a background, on wich the network elements have been assigned, a paper map wich has been digitized and introducted in the programs window. After assigning the network's elements a network without data was obtained, like in the picture below.



To every element of the network have been attached the characteristic proprieties as in Table 2 [5]:

Table 2

No.	Component	Proprieties
1.	Junctions	Junctions identifier: Junction coordinates; Junction elevation relative to the base of the tank; Base demand – the average demand in 24 hours (m^3/day); Demand model – demand variation in 24 hours
2.	Pipes	Pipes identifier; start junction; end junction; description – I assigned the street on which the pipe is; Label – I noted the material from which the pipe is made; length (m); Diameter (mm); Roughness coefficient Hazen- Williams; Loss Coefficient (dimensionless); Initial status (opened or closed)
3.	Reservoir	Reservoir identifier; coordinates; Total hydraulic pressure.
4.	Tank	Tank identifier: coordinates; Elevation (in the present case the base of the has been considered as a reference level); initial level of the water (m); minimum water level (m); maximum water level(m); minimum volume; volume curve (because the tank has a cone shape); Water mixture model in the tank.
5.	Pumps	Pump identifier; Start junction; End junction; Pump curve (the realiton between the pressure of the pump and the flow through it), initial status (opened or closed); pump efficiency; energy price.
6.	Valves	The valves have not been assigned separately, they have been considered only in the minor losses of pressure which characterize the behaviour of the pipes attached to them.

Hydraulic calibration of the model

The calibration is the comparing process of the model results with the data collected from the field and if it is necessary adjusting the models parameter until the models results are similar with the ones measured in the system.

For measuring the pressure in the pipe network the existing hydrants on the streets Carpați-J7; Locotenent Becherescu-J38; Unirii-J22 and Dreptății-J48 were used. The measurements were made on the 09-15 august week, Friday 13 august and Sunday 15 august, at 06, 10, 14, 18 and 22 hours [5].

According with the specialty papers for a model to approximate the best way a real water network it must assure:

- An average pressure inequality of ±1,54 mWaterColumn with a maximum inequality of ±5,12 mWaterColumn [1];
- An inequality between the measured pressure and the simulated values wich can be of 3,51 mWaterColumn to 7,02 mWaterColumn [2]

Studying the measured values for the pressures and the differences between the simulated values for the four junctions, the following were noticed:

1. For all the junctions the measured value at 6 AM is bigger than the value simulated. This situation can be caused because of a bigger water consum in the model than the one in reality;
2. The further the junctions are from the water tank, the bigger is thedifference between the measured pressure and the one simulated, therefor for junction 44 we have 7 measurements which are different from the simulated model with more than 4 mWaterColumn;
3. At the measurements made at 10, 14, 18 and 22 hours in most cases the measured value is smaller than the simulated value, excepting the measurements made for junction 7 at 18 hours and for junction 38 at 22 hours, which could mean bigger pressure loss in pipes because of not knowing exactly the roughness coeficient C Hazen-Williams;
4. For junction 44 the pressure could not be determined at 10 AM because the measurement instrument did not show any value at ground level;
5. The pressure differences between the measured and simulated value were between 0,88 mWaterColumn the smalest and 4,65 mWaterColumn the highest. This values are among the calibration conditions for the water network.

Simulation run

It was settled the period of simulation of 72 hours, tracing the values of the following parameters: juctions pressure, water quality (the age of the water in pipes and junctions), flow speed through pipes and thw water level in tanks.

It was chosen a longer period than 24 hours because it needs to be watched if the age of the water in pipes stabilizes and if the water level in tanks is the same in different days at the same time of day.

There were simulated two limit situations:

1. When the demand is the highest, between 10 and 11 AM and the pressure in junctions is the lowest and the speed through pipes is high;
2. When the deman is the lowest, between the hours 24 and 01 and the speed through the pipes low and the age of the water big.

By studying the data provided by the EPANET program after the simulation of the water network it can be observed the following:

Junctions pressure. Problemes regarding pressure appear between 9 AM and 13 PM at junctions J27, J40, J41, J42, J43, J44, J45, J46, J47 and J50 when the pressure falls below 10 mWaterColumn;

Water age in pipes. The only situation when this parameter is a higher than 15 hours is in the pipe C29 at 24 hours when the age of the water is 15,6 hours;

Water speed and flow through the pipes. Studying the results of the simulation at 10 AM when the speed of the flow through pipes is the maximum, because of high deman, it can be seen that there are six pipes C11, C15, C20, C29, C43 and C62 in which the speed is below minimum and a pipe C39 where the speed is above the maximum;

Water input from the reservoir and tanks. It has been tracked if there are pressure variations (water level) in the tank at the same hour in the day (10 AM) for the three simulation days. Because the level is the same there is no problem regarding the exhausting of the water in the tank after a larger number of working days.

After studying the existing situation of the water distribution network and the discussions with the management of the town Bailesti the following types of problems were settled which were analised by modeling the water distribution network and by simulating the flow of the water through the network:

- Developing an understanding of how the system operates and training water system operators;
- Assessing the carrying capacity of the existing system;
- Assessing levels of pressures at critical points within the system and assessing the available range of pressure at customer connections;
- Daily operational use;
- Power outage – impact on pump stations;
- Assessing the available range of pressure at customer connections;
- Real time control of the system;
- Identifying the impact of future population growth and major new industrial or commercial developments on the existing system;
- Identifying key bottlenecks in current and future systems;
- Designing the reinforcement to the existing system to meet future demand;
- Optimising the capital works programme;

- Assessing the effects of rehabilitation techniques;
- Assessing the functioning of the system for different ages of the elements;
- Assessing the financial investment for future developments;
- Determinating the age of the water in the system;
- Assessing the flow rate.

Conclusions

There are a lot of direct and indirect benefits by applying the advanced capacities of network modeling. The software can be udes on-line in the operational day by day program. It can also be applied in strategic operations planed to investigate a large range of operational problems.

Simulating the functioning of a water distribution network for planning the management of water supply and distribution systems from a hydraulic and water quality point of view has many advantages which include, efficient data collecting, processing and postprocessing, advanced matemathical model, low losses, high operational security and economical maintainance.

Modeling a control scenario for the water distribution system, may help the network operator to control losses, to reconstruct or plan new networks, to fulfill the demands of new customers etc.

In the present paper it has been presented an original diagram of the modeling process for the water distribution network of the town Bailesti for which it was made a model of hydraulic simulation on which it was tested the functioning in different conditions, having as a study base the worst scenario when the demand of water is the highest.

On the basis of the obtained results it was made a plan of development and rehabilitation of the water distribution system of the town Bailesti for the next years which include: the replacement of the cast iron pipe on street Amza Pelea; the replacement pipe portion on street Victoria starting from street Unirea to the end, because of the underdimensioning or projecting a station of repumping, parallel with the portion of pipe on street Victoria, situated between streed Unirea and street Progresul, for rising the pressure at the normal levels in all the demand points throughout the town; buying two spare pumps at the pumping station from the water supply station and four spare pumps for water diggings, for preventing the failure of one of the actual pumps and restricting water supply throughout the town; making an analysis of population growth and industry development in the town for forecasting the influence they might have over the water consumption and the possibility of solving them.

The model still remains a working instrument for the operators at the water supply station for simulating any network situation that might appear like: pipe breakdowns, water supply problems, pump breakdowns and others like that but for the maintainence personal that can determine very fast where to close the valves to stop the water in any points of the network in cas of issues.

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