HYDRAULIC ANALYSIS OF WATER SUPPLY SYSTEM WITHOUT TANKS

GOCE TASESKI [1], PETKO PELIVANOSKI [2]

[1] *Ss. Cyril and Methodius University Faculty of Civil Engineering – Skopje, taseski@gf.ukim.edu.mk*

[2] *Ss. Cyril and Methodius University Faculty of Civil Engineering – Skopje, pelivanoski@gf.ukim.edu.mk*

1. Abstract

Whether a particular water supply system needs a tank or not depends primarily on the available capacities of the springs used for water supply and their altitude at which they are located in relation to the inhabited place. If the spring capacity is larger than the maximum water consumption per hour, there is no need for tank. Alternatively, the requirement of a tank in order to provide 100% provision for the water supply system is mandatory. In practice, the water supply systems which have not required building of tank for equalizing the consumption with the inflow of water have been very rare. Such example of a larger water supply system in our country is the water supply system of the town of Gostivar and the surrounding inhabited places, which will actually be the subject of analysis in this paper.

According to the previously stated, the aim of this paper is, through the hydraulic analysis of water supply system without tank, to define how big the maximum and minimum pressures are in the water supply network, the losses of water in the system, and by that the possible disadvantages/advantages of the water supply systems without a tank to be considered.

Keywords: Water tank, hydraulic model, water supply, water pressure water fow

2. Introduction

Creating hydraulic-simulation model of an existing water supply system is a complex process for which it is firstly necessary to have entire knowledge of the geometrical characteristics of all the constituent parts of the water supply system, such as: intakes of water, tanks (if any), pipelines, hydro-mechanic equipment, etc. After the geometrical characteristics of the water supply system have been entered into the model, it is necessary to define the initial and the boundary conditions of the model which represent the grounds for the hydraulic analysis of one water supply system. In the hydraulic models of the water supply systems, the tanks are one of the basic elements in which the initial and the boundary conditions for modelling are defined. This paper will analyze the specific system which does not have tank space built, i.e. the water supply is done from a water intake structure where, by means of the gravitation, the water will be transported to all consumers in the system. Thus, the water spring structure will represent a basic element in which the initial and the boundary conditions in modelling will be defined.

According to the previously stated, the aim of this paper is to define the performances of the system through the hydraulic analysis of one water supply system without tank, i.e. to determine the following: the maximum and minimum pressures in the water supply network, the total losses of water in the system, "black points" along the lines in the water supply network, possible requirement of a reservoir, etc.

3. Geometrical characteristics of the system

Subject of analysis in this paper is the water supply system for the town of Gostivar (Figure 1) and the surrounding inhabited places which are supplied with water from the mutual spring "Vrutok", located at an altitude of 684 m above sea level and with the capacity of 400 – 1200 l/s depending on the season [1].

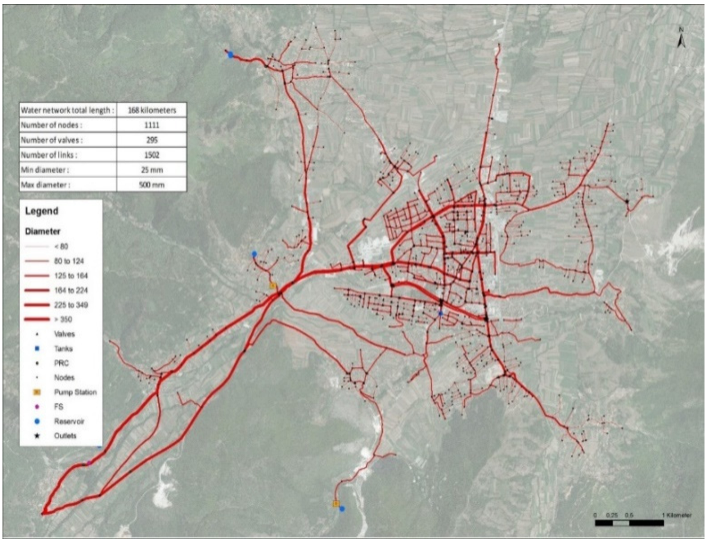

Figure 1. Disposition of the analyzed water supply system

From the spring "Vrutok", the distribution of water to the town of Gostivar (average altitude above sea level of 530 m) and the surrounding settlements is done by two main gravitational supply pipelines, i.e.:

- Right main supply pipeline: made of asbestos cement pipes, with internal diameter of AC DN 250 mm. This pipeline has a break pressure chamber at 644 m above sea level.
- Left main supply pipeline: made on the left side of the river Vardar, where practically two pipelines exist, one of AC DN 350 mm, and the other is PVC DN 380 mm. At 1000 m from the beginning of the left main pipelines, there is a break pressure chamber at 647 m above sea level, in which the two pipelines are connected into one which represents left main pipeline, of AC DN 500 mm.

The two main supply pipelines right at the entrance to the water supply network of the town of Gostivar are connected into one pipeline of AC DN 500 mm.

The characteristics of the water supply network for the town of Gostivar and the surrounding inhabited places are presented in Table 1.

Table 1. Geometrical characteristics of the sewage system

Parameter	Unit measure	Detected in total	Modelled in total
Water supply network:	[km]	168	122
Number of junctions:	N	1111	721
Number of valves:	N	295	259
Number of connections:	N	1502	1073
Min Diameter:	[mm]	25	50
Max Diameter:	[mm]	500	500

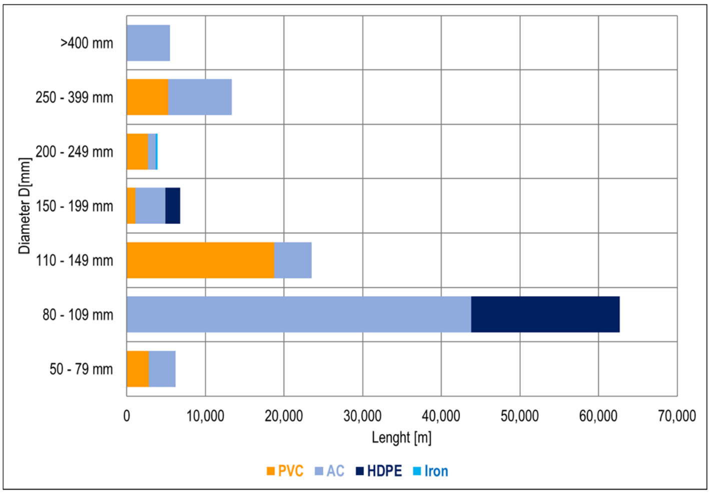

Figure 2. Graphic presentation of the length and diameters of pipelines depending on the material.

In the Figure 2 presents the length of pipes depending on the material and the pipe diameter which are used in the hydraulic model.

Water requirements are analyzed through relevant - reliable data and in this case, it is the General and the Detailed Urban Plan from which the total requirements of water are obtained in the moment of performing the hydraulic analysis. The total net requirements of water which include the requirements of water for the population living in apartment buildings and houses, livestock, commercial and collective buildings are presented in Table 2.

Table 2. Net requirements of water in the moment of the hydraulic analysis of the water supply system

Inhabited place	Consumer type				
	Households [m3/d]		Collective buildings [m3/d]	Industry [m3/d]	Total [m3/d]
	Houses	Buildings			
Town	1,776.0	3,649.0	1,085.0	554.0	11,364.0
Village	3,909.0	0.0	391.0	0.0	

Here we should mention that such calculated requirements of water represent net requirements of water and they do not include the calculations of losses of water whether they are technical or administrative.

4. Hydraulic model

For the hydraulic analysis of the system under pressure such as the water supply systems, the software package WaterGEMS is used, which represents the most sophisticated package for this kind of hydraulic models [2].

The geometry of the network which is imputed from the data base consists of the following elements:

- Pipes (initial and end point, material, length and diameter)
- Junctions (X-Y coordinates, altitude above sea level and water consumption)
- Valves (X-Y coordinates, altitude above sea level, type, material, diameter and connection to the pipes)

For the purpose of obtaining a model that will be close to the real system at creating the model for the water supply system without tanks, the following hypotheses have been used [3, 4, 5]:

- All the pipes of diameter longer than 80mm have been modelled
- Pipes of diameter shorter than 80mm have also been modelled only in the parts where this line is situated between pipes of diameter longer than 80 mm. This has been done for the purpose of observing the concept of that particular part of the network.
- For distribution of the required quantities of water per lines, the automatic function of the software package WaterGEMS has been used – proportional distribution per junctions, separately for the population, livestock, collective buildings and the small-scale industry.
- Large consumers of water are recorded as concentrated consumers in the nearest junction point.

5. Calibration and verification of the results from the hydraulic model

5.1 Calibration of the hydraulic model

For the purpose of performing calibration of the hydraulic model with the actual water supply system, there have been two measurement campaigns performed, where in the first campaign only the flow at 12 points – pipes in total has been measured, while in the second campaign a parallel measurement of the flow and pressure at 13 points in total has been performed, Figure 3.

For the calibration of the hydraulic model, certain hypotheses originating from the results obtained from the measurements have been used, i.e.:

- The water head line does not start from the spring of water but it is at a lower peak elevation from the spring of water, which results in different starting peak elevation in both main supply pipelines.
- The pressure in the measurement points is changeable during the day.
- Four types of variations of the water consumption have been applied depending on the location of measurement.

- There have not been any available relevant data on the coefficient of pipe roughness which, according to the data from the literature, depends on: type of the material, age and the diameter of the pipes.
- Also, there have not been any available relevant data on how big the administrative losses of water are compared to the technical losses of water. Due to that, only the total losses of water in the water supply system have been analyzed in the model, which are modelled in function of the pressure in the water supply network, larger pressure – larger losses and vice versa, with separate coefficient for the town and separately for the villages.

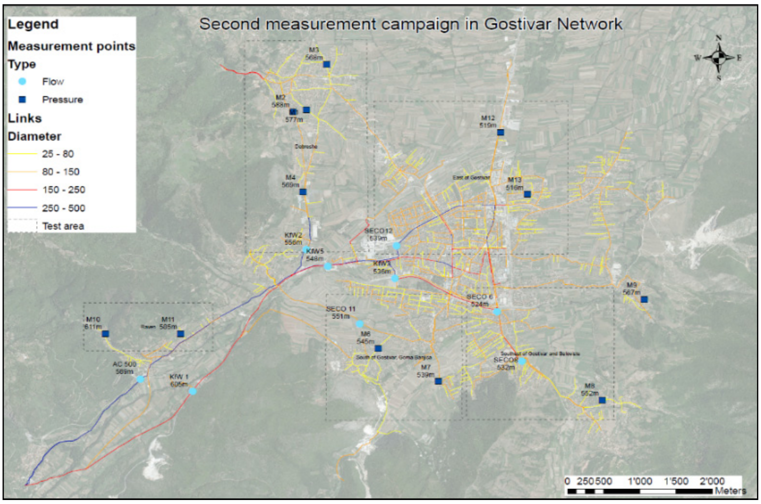

Figure 3. Location of the measurement points from the second campaign

5.2 Verification of the hydraulic model

By applying all the previously mentioned hypotheses in the hydraulic model, verification to the model with the actual water supply system has been performed. Results from the verification on the flow and the pressure of one analyzed point have been presented in Figure 4 and 5.

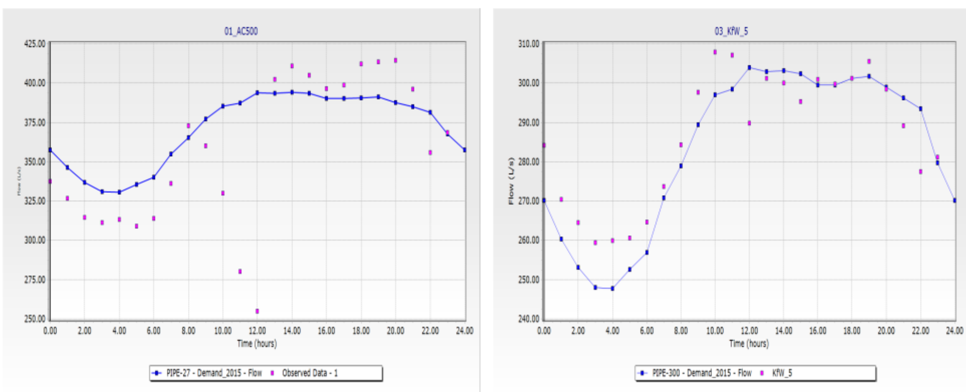

Figure 4. Presentation of the results from the calibration and the verification of the model – pressure

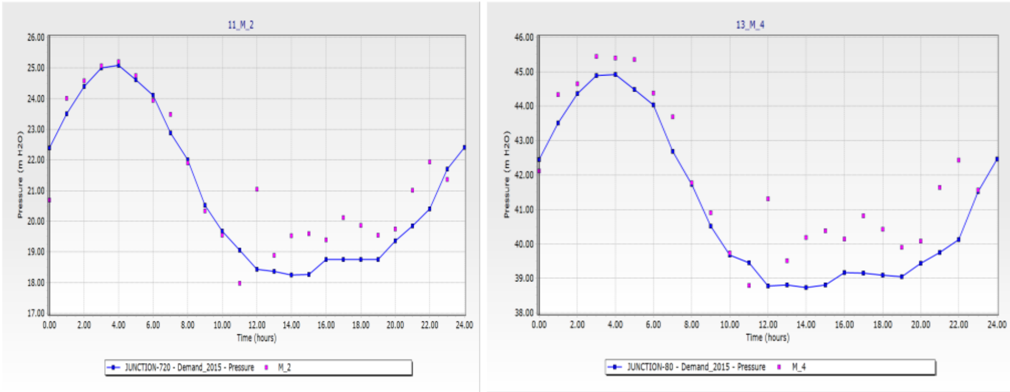

Figure 5. Presentation of the results from the calibration and the verification of the model – flow

6. Analysis of the results obtained from the hydraulic model

From the hydraulic analysis of the water supply system without tanks, the following two significant characteristic states within the system can be realized:

- Certain higher parts of the inhabited places do not have enough pressure for water supply, Figure 6, red color.
- Whereas the pressure in the central town area is larger from the optimal pressure (>6bar) which results in increased losses of water in that part of the system, Figure 6, blue color.

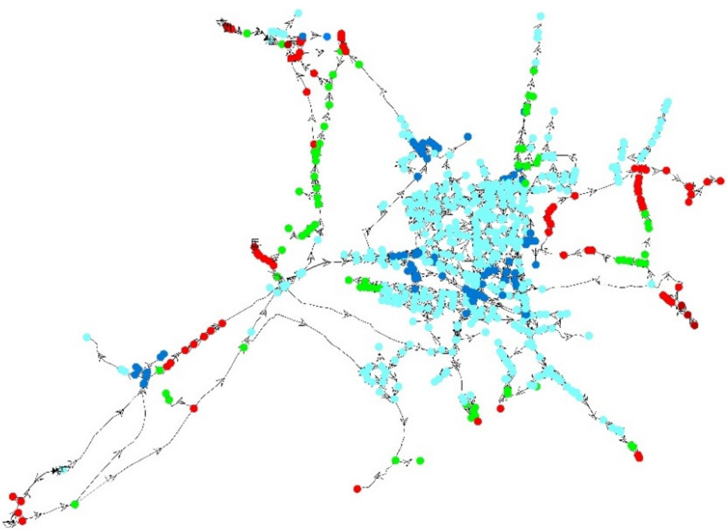

Figure 6. Minimum and maximum pressure

Regarding the fact that the capacity of the spring is much larger than the requirements of water within the system, and not having reservoir space by which the large pressure in the water supply network would be reduced, it has been concluded according to the hydraulic analysis that the total losses of water amount to:

- 71% in the central town area
- 67% in total in all the villages

Also, by means of the hydraulic analysis there have been pipelines - lines detected where the slope of water head is very big, although such states do not have any particular influence to the function of the system as long as the pressure in the town network is high. However, by future reduction to the system it should be taken into consideration that there are “black spots” in the water supply network, and the locations of the pipelines are given in Figure 7 – red color.

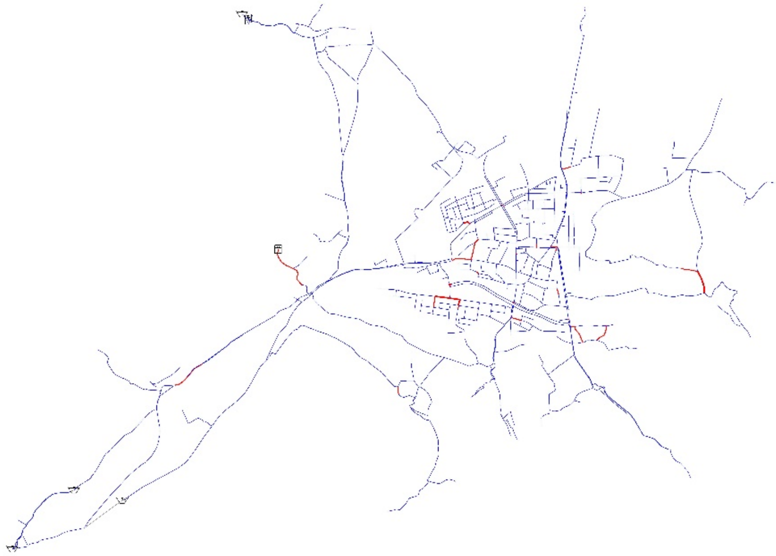

Figure 7. “Black spots” in water supply network

7. Conclusion

From the hydraulic analysis performed for the water supply system without reservoirs, where the capacity of the water spring is bigger than the maximum requirements of water per hour, the following conclusions can be drawn:

- High percentage of total losses of water (71% in the town area, up to 67% in the villages) which owes primarily to the fact that "there is enough water" and there is no need for special attention to be paid to it.
- High pressures in the bigger part of the town water supply network which in certain points are nearly 10 bar.
- In small number of inhabited places, in their higher parts, there is not enough pressure, which owes to the large losses of water in the system and the fact that the entire system is supplied with water as one zone.
- In certain parts – lines there is a short diameter of the pipelines observed – large hydraulic losses per m’

According to the previously stated, as a general conclusion it can be said that even in the case when the capacity of the water spring meets the requirements of water in one water supply system, before making the decision whether to have reservoirs in the system or not, the remaining parameters of the system should be considered, the working pressure within the water supply network above all.

References:

[1] Pelivanoski P., Taseski G., Hydraulic model for water supply Gostivar, 2016.
[2] Bentley WaterGEMS V8i User's Guide, 2017
[3] Fulvio Boanoa, Marco Scibettab, Luca Ridolfia, Orazio Giustolisic: Water Distribution System Modeling and Optimization: A Case Study, 13th Computer Control for Water Industry Conference, CCWI 2015, pp. 719 – 724, 2015
[4] Prabhata K. Swamee & Ashok K. Sharma: „Design Water Supply Pipe Networks“, 2008.
[5] O. Giustolisi, T.M. Walski, A Demand Components in Water Distribution Network Analysis. J. Wat. Resour. Plan. Manage., 138(4) (2012)
[6] O. Giustolisi, D.A. Savic , Z. Kapelan, Pressure-driven demand and leakage simulation for water distribution networks. J. Hydr. Eng., pp/ 626–635, 2008.
[7] Z. Veljanovski ; „Water supply“, 2008.

.