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Hydraulic Simulation of Pressure and Loss of Load in Water Supply System Project

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Abstract

Water is necessary for health promotion, as it reduces levels of infectious diseases in the population. In urban centers its demand is increasing. Performing this supply is not a trivial task, especially when it is intended to combine the universalization of this service to sustainable management with actions planned for the conservation and rational use of water. To subsidize the supply, hydraulic simulation software was used, which allows to obtain, among other benefits, short, medium and long term planning. Free domain and didactic interface, the EPANET 2.0 software has been widely used for simulations of water supply, as well as to study the behavior of the parameters of the water distribution network through changes such as increased demand. In this article the objective was to build a water supply system project for a rural area of Alagoinhas-BA, with analysis of hydraulic parameters: pressure and pressure loss, using the EPANET 2.0 software. Based on input information, such as quota and consumption, two simulations were performed: S1, for the year 2023, and S2 with twice the consumption of S1. It was noted that both pressure loss and load loss presented results in disagreement with NBR 12,128/2017. In the next scenarios, therefore, were made using Pressure Reducing Valves and increasing the diameter of the pipes in some stretches.

Keywords: Supply System, Optimization, Hydraulic Modeling, Hydraulic Simulation.

1.Introduction

Water accounts for 70% or more of the mass of most organisms. Its consumption reflects directly on social, economic and sanitary aspects, since it reduces the levels of infectious diseases such as giardiasis, amebiasis and diarrhea, when offered in adequate quality and quantity, as necessary (HELLER & de PADUA, 2006). The uses of water are directed to activities such as food preparation, personal hygiene, hydration and cleaning (TSUTIYA, 2006).

It has become extremely important to design Water Supply Systems (SAA) that meet the needs of populations in the same proportion as it maintains the structure with good hydraulic operation through the fulfillment of parameters such as water quality (AJAZ & AHMAD, 2023). Concomitantly, through proper management it is possible to contribute to the conservation of water resources, reduce the flow required and reduce the actual water losses present in all distribution networks (GOMES, 2019).

The companies responsible for the construction of sizing networks have used hydraulic modeling to reconcile population expansion and maintenance of hydraulic parameters, as it is an available and efficient technique, reliable and less time consuming (AJAZ & AHMAD, 2023). Several softwares allow the simulation of water distribution networks. The models can be presented dynamically or statically. In dynamic models, hydraulic quantities, such as flow in stretches, pressure in nodes, water levels in reservoirs and energy required for pumping, follow the change caused by varied water consumption over time. In static form, values are determined for a specific operating condition, without changing over time (GOMES, 2019).

EPANET 2.0 is a public domain software, in Windows environment, whose Portuguese version was translated by the Laboratory of Energy Efficiency and Hydraulics in Sanitation (LEHNS) of the Federal University of Paraíba (UFPB)to simulate the hydraulic behavior of pressurized water systems over time. The purpose of this work is to build a SAA project for a rural region located in Alagoinhas-BA, with pressure and pressure loss assessment through static and dynamic simulations in EPANET 2.0.

2. Materials and Methods

2.1 Characterization of the Study Area

This study was developed for a rural area located in the city of Alagoinhas/ Bahia. A per capita consumption of 150 liters per inhabitant per day was considered for 100 households, with an average occupancy rate of 5 inhabitants per household. The maximum daily and hourly flow coefficients used were 1.2 and 1.5, respectively (HELLER & PADUA, 2006). The water for supply will be removed from a well, pumped into a reservoir and conducted to the gravity distribution network.

2.2. Input data from the simulations

Initially, the total number of inhabitants was obtained by the following:

$$\boldsymbol{Pop_{year} = tnc\ x\ R_x} \qquad \textbf{(1)}$$

In which, $\boldsymbol{Pop_{year}}$ is the population, in inhabitants (inhab.); $\boldsymbol{tnc}$, the total number of calls per household and $\boldsymbol{R_x}$ is the average occupation rate, in inhabitants per household (inhab./hous.).

After calculating the total number of inhabitants, the flows were calculated: total and nodal, as shown below. The total flow corresponds to all water demand necessary to satisfy the population, while the nodal flow is represented by the nodes inserted in the project. The nodes, in turn, are points that connect the sections and through which water enters and leaves the network towards the residences. In them, individually, the values of quota and consumption were inserted (GOMES, 2019).

$$Q = \frac{Pop_{year}\, q\ k_1\ k_2}{3600\ h} \qquad (2)$$

In which, Q is the maximum daily flow rate, in litres per second (L/s); $\boldsymbol{Pop_{year}}$ is the population, in inhabitants (inhab.); q is the per capita consumption, in litres per inhabitant per day (L/inhab.day); h are the operating hours of the supply system units; k_1 is the coefficient of the day of highest consumption and k_2 coefficient of the hour of highest consumption.

$$q_n = \frac{Q}{n-1} \qquad (3)$$

q_n is the point flow rate, in liters per second (L/s); Q is the maximum daily flow rate, in liters per second (L/s) and n is the total number of nodes in the network.

For the simulation in EPANET 2.0 was adopted the type of distribution network branched with piping in PVC material (roughness coefficient 140). The reservoir was positioned at the highest level in the region to make possible the supply by gravity (GOMES, 2019).

The parameters: pressure and pressure loss were then evaluated in static and dynamic simulations. In the EPANET 2.0 software we opted for one of the formulas widely used to calculate the loss of load in resuscitated systems: that of Hazen Williams (GOMES, 2019).

Initially, the trunk pipe was designed with 75 mm and the others, secondary and tertiary, with 50 mm. Due to the large number of stretches to compose the project, the stretches: 2, 2.1, 2.2 and 3 were chosen to represent this parameter, because their results had greater expressiveness compared to the other Punctual flow, in liters per second (L/s);

The reservoir was positioned at the highest level in the region to make possible the supply by gravity (GOMES, 2019).

2.3 Simulations

The first simulation developed, S1, considered the active population and the number of calls for

2023. In the second simulation, S2, was considered the double of consumption, linked to a probable population growth. In both, the simulation was made for a period of 24 hours of operation of the proposed SAA, with analysis every 3 hours, to contemplate 8 consumption patterns established over these 24 hours, in which the highest consumption occurs between 09 am and 3 pm.

To evaluate the results of the hydraulic quantities was used the NBR12218:2017, which guides projects of water distribution network for public supply. The hydraulic criteria adopted were: minimum dynamic pressure of 100 kPa, maximum static pressure of 500 kPa, minimum diameter of 50 mm for secondary pipes and load loss less than 10 m/km.

4. Results and Discussion

4.1 Project population, distribution and nodal flows

The average occupancy rate ($\boldsymbol{R_x}$) for rural Alagoinhas is 5 inhabitants per household. The number of total calls (*ntc*) to be answered initially corresponds to 100, in the year 2023. These results can be seen in the following table.

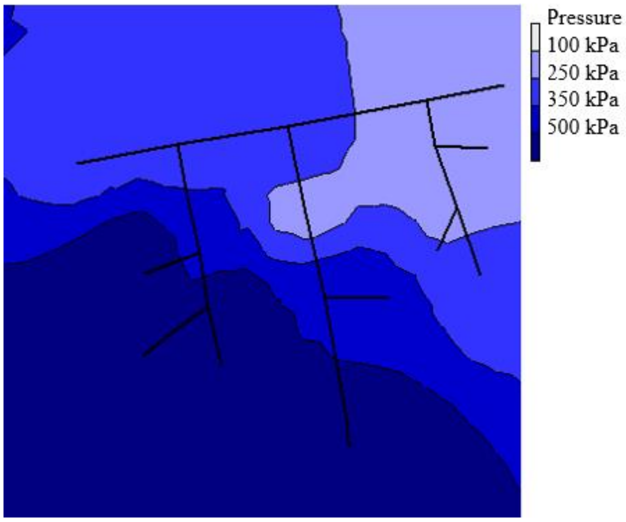
Project population and flow obtained

Number of calls	$\boldsymbol{R_x}$	Pop_{2023} (inhab.)	Q (L/s)	Q_n (L/s)
100	5	500	1,60	0,084

4.2 Simulation 1 (S1)

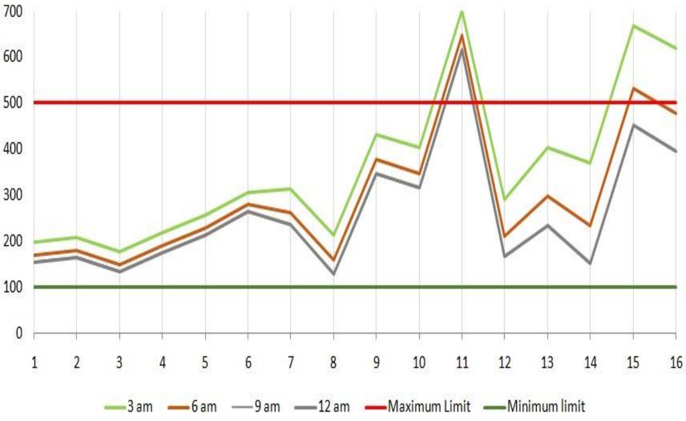
The S1 has demonstrated pressure problems at some of the project nodes. Naturally, the highest pressure values in the nodes correspond to the lowest topographic elevation values of the terrain. In all, 20 nodes were obtained in the simulation, of these 30% presented static pressures greater than 500 kPa. Despite this, there were no pressures lower than 100 kPa, since low pressures cause unpleasantness due to lack of water. The isoline graph in figure 5 below demonstrates the pressure variation in every design in the static simulation.

Figure 1. Graph of isolines with static pressure representation.



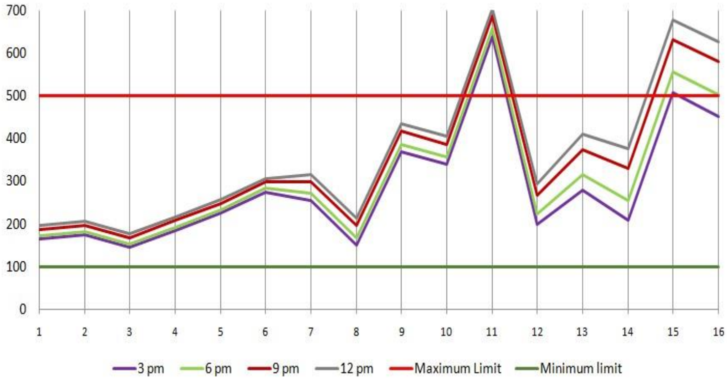
Positively, during the dynamic simulation, in the first 12 hours, there were no pressures lower than 100 kPa. However, pressures above 500 kPa were also noted at different times. The pressure values follow a decreasing pattern, in sync with the increase in consumption, that is, the 3 am pressures were higher than the 12 am. The nodes with the highest pressures were the 11 and 15 nodes.

Figure 2. Pressure chart over the first 12 hours of simulation.



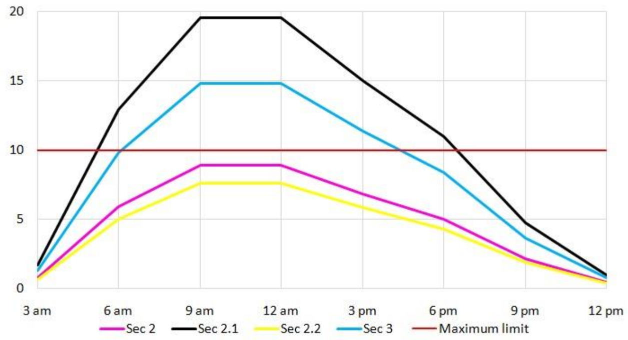
As in the first 12 hours of simulation, the last hours there were no pressures less than 100 kPa and some values exceeded 500 kPa. The 11 and 15 nodes continued to be the highest pressures.

Figure 3. Pressure chart over the last 12 hours of simulation.



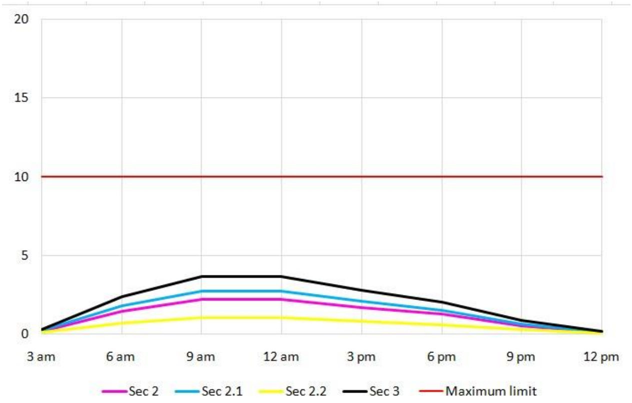
During load loss analysis, it was observed that values greater than 10 m/km occurred, contrary to what was allowed in NBR12218:2017. As can be seen in Figure 8, between 6 am and 6 pm the values of load loss are higher. Especially, in two of the four stretches represented, with higher load loss (the stretches 2.1 and 3), reached values greater than 10 m/ km in this period. After 6 pm, the values reduce. Both sections only fit again in what the Brazilian standard requires after 6 pm. At night all sections have loss of load with appropriate values.

Figure 4. Load loss chart for 75 mm main, secondary and tertiary pipes with 50 mm.



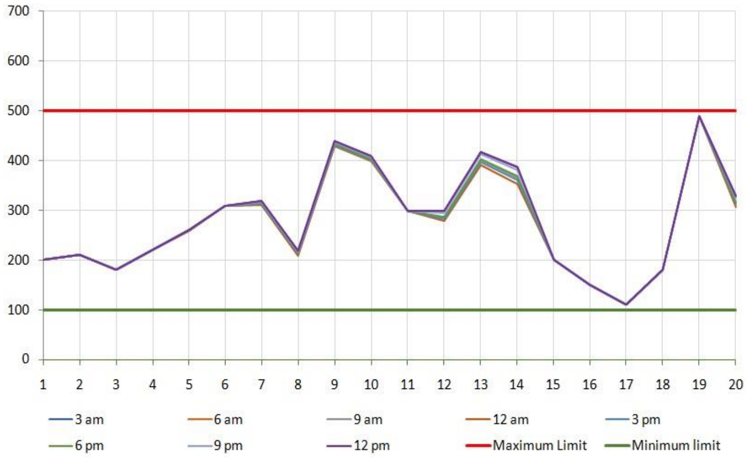
To correct the problem in the values of load loss, the pipe diameters were reevaluated: the trunk pipe was 100 mm, the secondary, 75 mm and the tertiary 50 mm. Thus, all values of load loss in all sections of the project, during the 24 hours of simulation, remained less than 10 m/km. Figure 5 shows this reduction through the stretches that had greater load loss in the previous result, with smaller diameters.

Figure 5. Load loss chart for 100 mm mains piping, 75 mm secondary and 50 mm tertiary.



Pressures directly influence the cost of pumping and the volume of water lost from the system. High pressures are the main cause of real losses, characterized by ruptures in the pipeline, which directly reflect the increase in maintenance and dissatisfaction of the population (TSUTIYA, 2006). The change in diameters brought significant results for reducing load loss, but the pressures did not have significant changes. Therefore, a scenario of correction of this parameter was made through the insertion of VRP in some parts, before continuing to S2. After the changes in diameters and insertion of VRP, new pressure results were obtained in the distribution network, as can be seen in Figure 10. All nodes now have values less than 500 kPa. At no time did nodes occur with pressure less than 100 kPa, which indicates that all points continued with adequate supply. During the dynamic simulation, the pressure values showed little variation.

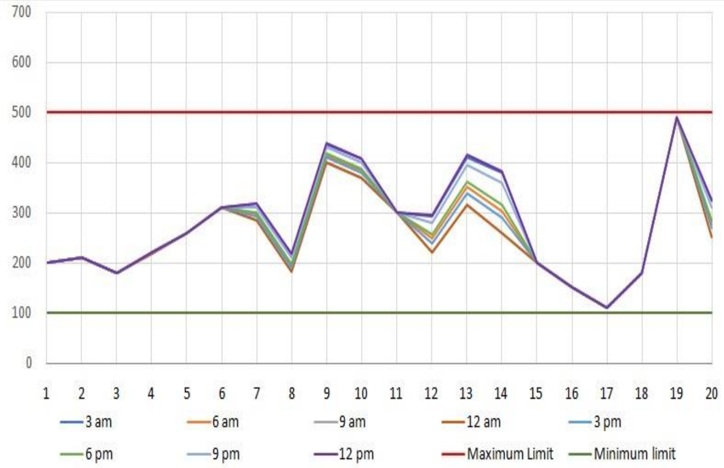
Figure 6. Pressure chart over 24 hours of simulation after corrections.



4.2 Simulation 2 (S2)

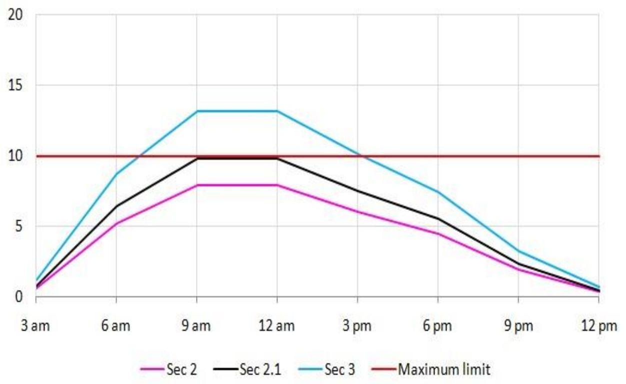
Keeping the corrections made in S2, the pressure showed good results in the face of doubling consumption. Satisfactorily, pressures remained less than 500 kPa and greater than 10 kPa. Figure 7 shows the new results.

Figure 7. Pressure chart over 24 hours of simulation after doubling consumption.



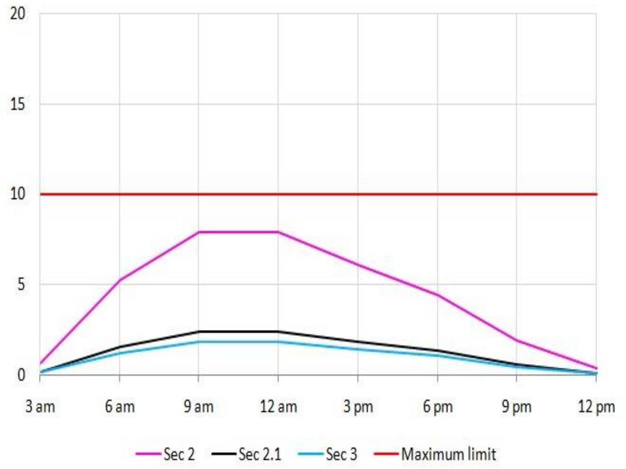
The loss of load in turn, presented complications. Unlike S1, sections 2 and 2.1 maintained acceptable load loss values throughout the simulation, but notably, these values were very close to the maximum allowed, so it was appropriate to adopt some solution to this situation. Stretch 3, in turn, at times from 6 am and 3 pm, presented inadequate values of load loss, as shown in Figure 8.

Figure 8. Load loss chart for S2.



To fix these problems, again, the diameters were re-evaluated. The section 2.1 now has a pipe with 100 mm in diameter and the stretch 3, 150 mm in diameter. After this substitution, the values of load loss were framed as required by the Brazilian standard, as shown in Figure 9.

Figure 9. Load loss chart for S2 after change of meter in sections 2.1 and 3.



5. Conclusions

Building scenarios in EPANET 2.0 software reduces the time to build a project and the chances of error by repetitive calculations. For this specific project, in general, it was noticed that as consumption increases, the pressures in the nodes reduce and the load losses in the stretches increase. Diameter changes were an efficient strategy to reduce the pressure loss, and valves to reduce pressure. In the scenario where consumption doubled, the load loss was influenced, and increased in some stretches, while the pressure values remained the same.

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