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Investigation of water losses with real time pressure management as a case study in Sakarya

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Urban growth and limited freshwater resources have made water management increasingly critical. As cities expand and water must be transported over longer distances, the cost of supply rises, increasing the importance of minimizing water losses. Leakage in water distribution networks-caused by pipe aging, poor repairs, and manufacturing defects-poses a major challenge. Although complete network renewal is a long-term solution, it is costly and often delayed due to infrastructure constraints. This study investigates a real-time pressure control method as a cost-effective alternative to reduce water losses. A case study was conducted in Sakarya, Türkiye, where the maximum inlet pressure of a distribution network was reduced from 70 m to 45 m using a real-time control system. Over a one-year period, a 19% reduction in water losses was recorded. The network was also modeled using EPANET hydraulic simulation software, showing a 2–4% difference between the measured and simulated pressure values. The findings confirm that real-time pressure management, when combined with accurate hydraulic modeling, offers a practical and efficient tool for reducing water losses and extending the service life of aging water networks especially in urban environments where full-scale infrastructure renewal is not feasible.

Keywords Hydraulic model, Pressure management, District metered area, Pressure reducing valve, Real-time pressure control

Introductıon

Water is one of the most vital and irreplaceable resources for life, development, and sustainability. In recent decades, rapid population growth, unplanned urbanization, industrial expansion, and climate change have led to significant pressure on global freshwater resources[1]. As the world population increases, the per capita availability of water continues to decline. Furthermore, biological and chemical contamination, insufficient protection of water basins, and inefficient water usage practices accelerate the depletion of clean water reserves. The changing climatic conditions observed across the globe, especially prolonged droughts and irregular precipitation patterns, have intensified the urgency of water conservation and effective resource management[2,3]. A substantial portion of water loss in urban areas occurs not due to lack of resources but because of inefficiencies in water distribution systems. These include technical losses due to aging infrastructure, pipeline bursts, undetected leaks, and non-revenue water caused by metering inaccuracies or illegal connections. Such losses not only reduce the efficiency and sustainability of water supply systems but also lead to increased energy consumption, operational costs, and environmental stress. Consequently, water utilities are under increasing pressure to adopt integrated water management strategies that not only ensure reliable water delivery but also minimize losses within the network[4]. In this context, reducing physical water losses in urban water distribution networks (WDNs) has become a primary concern for municipalities and water management authorities. While complete network rehabilitation is an ideal long-term solution, it is rarely feasible due to the high financial, technical, and social costs associated with large-scale pipeline replacements. Therefore, intermediate and more cost-effective solutions, such as pressure control (PC), are increasingly adopted to manage water losses in a timely and economical manner[2,5–8]. PC refers to the process of regulating pressure levels within the distribution system to optimal values that meet consumer needs while minimizing stress on the infrastructure. Excess pressure in pipelines increases leakage volumes and contributes to pipe failures. By reducing pressure to the minimum level required for service, PC

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helps to reduce both the frequency of bursts and background leakage. PC can also prolong the life of aging infrastructure and decrease maintenance costs over time[9].

A widely used technique for implementing PC is the installation of Pressure Reducing Valves (PRVs) at strategic locations within the network. PRVs maintain a constant downstream pressure regardless of fluctuations in upstream pressure or demand. When operated in a real-time control (RTC) mode, these valves can dynamically adjust their settings in response to time-dependent changes in water consumption, such as the distinct differences between day and night demand patterns[10]. Real-time pressure control provides a more responsive and adaptive approach compared to conventional fixed pressure settings. Throughout the day, water demand varies significantly. During nighttime hours, when consumption is minimal, fixed-pressure systems often maintain unnecessarily high pressure, leading to increased leakage rates. RTC systems, in contrast, reduce pressure during these low-demand periods, thereby mitigating unnecessary water losses. At the same time, they ensure sufficient pressure during peak demand to maintain consumer satisfaction[11,12]. To implement RTC effectively, advanced control algorithms and monitoring systems are required. One of the most widely researched and applied methods for regulating PRVs in real-time is the Proportional-Integral-Derivative (PID) controller, which continuously monitors and adjusts valve settings based on feedback signals[12]. Several researchers have proposed calibration methodologies to fine-tune PID controllers in order to prevent instability or oscillations, which may occur due to time delays or unsteady flow conditions. In such dynamic environments, ensuring model stability is crucial for maintaining system performance[13]. Additionally, PRVs are often integrated into more complex control systems that involve hydraulic modeling and decision-support tools. In these setups, optimal valve placement and settings are determined through simulation-based analysis and multi-criteria optimization algorithms[14–16]. While maintaining a constant pressure at a single critical point in the network may appear effective, it does not necessarily ensure optimal pressure distribution across the entire system. Thus, network-wide modeling is essential to identify points of vulnerability and implement more comprehensive pressure management strategies[17,18]. Compared to traditional PC approaches that rely on manual adjustments or time-based settings, RTC offers superior adaptability and performance. Studies have shown that RTC systems not only reduce leakage but also provide more uniform service levels, especially in networks with topographical variability or demand uncertainties[19,20]. Excess pressure remains one of the leading causes of physical water losses in distribution networks. Since most systems are designed to meet peak demands, they often operate under unnecessarily high pressure during off-peak periods[21]. RTC mitigates this by matching supply pressure to actual demand in real time. Moreover, RTC systems have shown their value during exceptional operational conditions such as firefighting or sudden pipe bursts. By rapidly adjusting to these changes, RTC-enabled PRVs prevent further pressure escalation and contribute to system resilience[11].

The effectiveness of RTC in reducing water losses has been demonstrated in several international case studies. For instance, in Oppegård, Norway, an RTC system developed through hydraulic modeling significantly reduced leakage volumes[22]. In South Africa, where water scarcity and aging infrastructure are major challenges, traditional approaches have proven insufficient. As a result, dynamic hydraulic modeling and real-time monitoring tools have been introduced to tackle these issues more effectively[23]. Optimization techniques based on the EPANET platform and genetic algorithms have been used to simulate network behavior and optimize valve operations for maximum efficiency[3,24–26]. Besides hydraulic modeling, Artificial Intelligence (AI) and machine learning techniques have also gained traction. Bohorquez et al. used Artificial Neural Networks (ANNs) to locate pipeline connections and leakage points with minimal error, although locating leaks required significantly more data than identifying pipe connections[27]. Negharchi and Shafaghat developed a real-time control system that reduced pressure fluctuations by 54% in networks with complex elevation profiles, improving operational reliability and consumer satisfaction[28]. Huang et al. proposed a probabilistic framework using Monte Carlo Simulation (MCS) and Global Sensitivity Analysis (GSA) to assess the impact of nodal demand changes in transient conditions, contributing to the predictive capabilities of system models[29]. Marsili et al. further demonstrated that stochastic modeling could replicate the dynamic behavior of water distribution systems influenced by random user demand patterns[30]. In another advancement, Negharchi and Shafaghat introduced a novel ANN-based algorithm with a 99% convergence rate to reduce pressure variability and water loss by developing three-dimensional criteria for real-time pressure control[31]. Other field-based studies reinforce the importance of PRV-based control. For example, in Mutare, Zimbabwe, reducing the pressure from 75 to 80 m to 50 m led to a 25% reduction in leakage, although pressure values below this threshold were found to compromise service quality[32]. In the high-altitude city of Azoges, Ecuador, simulation studies identified that the installation of just two PRVs could reduce leakage by up to 31.62% in the lower-pressure zones of the network[33]. Similarly, Spedaletti et al. used EPANET modeling to identify five key smart meter locations in a DMA, achieving a 12.5% leakage reduction through intelligent flow regulation[34]. Despite these advancements, a significant gap remains in validating hydraulic simulation results with actual field data. Many studies rely solely on theoretical modeling, and the lack of real-world verification limits their practical utility. Specifically, few studies examine how hydraulic models perform under sudden and irregular flow changes, such as those caused by rapid demand shifts or valve operations[35].

This study aims to bridge this gap by conducting a comprehensive comparison between hydraulic modeling results and real-time field measurements in a district metered area (DMA) located in Sakarya, Türkiye. The network is first analyzed under normal operating conditions, and baseline water losses are identified. A hydraulic model is then developed in the EPANET environment to simulate system behavior under pressure-controlled scenarios, both with and without PRVs. Subsequently, a PRV is installed in the field, equipped with real-time control to dynamically respond to changing demand and sudden flow events. Finally, actual performance data from the field is compared with the simulation results to evaluate the accuracy and applicability of the model. The novelty of this work lies in its combined use of real-time operational data and hydraulic simulation to validate the effectiveness of RTC in reducing water losses under realistic conditions. By quantifying the benefits prior to infrastructure investment, this study also provides a cost-effective decision-support framework for water utilities. The integrated methodology and findings may serve as a model for similar applications in medium-sized urban networks where full-scale network renewal is not immediately feasible.

Materıal and method

Real-time control

RTC, as the name suggests, is the dynamic control of a system or a parameter in the system despite the disruptive effects that occur over time. In industrial control systems, it is desired that the controllers produce an output that is continuous in time depending on the value of the error instead of on-off. Effective pressure management in the water distribution network is achieved not by opening or closing the valve entirely but by changing the opening value according to the error given by the system. This real-time intervention can be done with PID, one of the most widely used closed-loop control systems[36]. Although PID control is not as flexible or precise as more complex methods, it is widely preferred due to its simplicity, easy applicability and wide industrial compatibility, providing a fast and sufficiently effective solution in most systems. In this study, RTC was used to instantly increase the PRV outlet pressure in cases where the critical point pressure drops and the fire hydrant is opened (which causes a sudden pressure drop).

Hydraulic model

The pressure will be at its highest if there is no flow in the pipes. However, with the start of the flow in the pipe, the pressure begins to decrease due to the pressure energy that turns into velocity and friction. The height difference due to friction along L in the flow in pipes can be calculated as[37] :

$$h_L = \frac{\Delta P_L}{\rho g} = f \frac{L}{D} \frac{V_{avg}^2}{2g} \tag{1}$$

Here h_L height difference (m), ΔP_L pressure difference along the pipe (N/m^2), ρ density (kg/m^3), g gravitational acceleration (m/s^2), f friction factor, L pipe length (m), D pipe diameter (m), V_{avg} average velocity (m/s) as limits. As can be seen, the losses in a water distribution network vary according to the pipe length, pipe diameter, friction coefficient, and water velocity. Water distribution networks offer the possibility of using water at very different flow rates from many points; the pipe length, diameter, and water velocity vary according to the network. In addition, if there are different types of pipes in the network, the friction coefficient of the pipe also varies.

As it leaves the water transport pipe and moves away from it, the water supply network's diameter is reduced, and it distributes water to the usage areas with branch lines. The energy balance between any two points of the water supply network can be written as follows, provided that there is no diameter change according to the Bernoulli equation, the pipe type is the same, and there is no separation from the pipe[37] :

$$\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_L \tag{2}$$

Here, P pressure, α kinetic energy correction factor, z denotes height. The pressure at the start of the water supply network must be converted into velocity and height difference along the water supply network. Thus, the water you enter can flow from the taps at a certain velocity, providing a comfortable use. However, there will be losses along the pipe if the pressure turns into velocity. In order to meet the minimum pressure at the time of highest usage, the pressure that will turn into velocity and loss must also be available in the network. This situation causes water losses due to leakage to increase during the hours when the usage in the water supply network decreases and the pressure rises. With the developing technology, the PRV's that can be precisely controlled meet the pressure drops depending on the velocity in the water supply network, allowing the network to stay at lower pressures and reducing the water losses due to leakage.

This study chose an area in the water supply network of Erenler district of Sakarya province in Türkiye as the hydraulic model. A flow meter was installed on this water supply network to record water usage for one year. A PRV was added to the network one year later, and the data on water consumption and losses were analyzed. Meanwhile, a hydraulic model of the same network was created with the EPANET software. The algorithm used by EPANET when calculating the water distribution network is the Global Gradient Algorithm (GGA)[38]. The real data in the network and the hydraulic model data were analyzed, and the results were compared.

District metered areas

It is an accepted approach to effectively manage water losses by dividing an extensive water distribution network into smaller isolated areas called DMA[2,39,40]. The main criterion in making this selection is that the pipe length does not fall below the set level of the critical zone pressure within the response time of the PRV. In a DMA, the network is separated from the water transport pipe from a single point, and a completely isolated network from other networks is obtained by delinking other network connections, if any. In this way, water loss rates in each DMA can be easily calculated, and management measures can be implemented effectively[41].

A control room is created at the zone's entrance to control the DMAs. Supplying electrical energy to this room is necessary for the energy needs of the control elements. Two valves, PRV, flow meter, and filters are placed to control the water entering and leaving the room (Fig. 1). The PRV provides PC of the DMA. The flow meter measures the volume of water supplied to the area. The filter prevents solid particles from entering into PRV, flow meter, etc., sensitive devices. In case of any error in the system, the system can be intervened quickly by closing the inlet and outlet valves. The critical point pressure sensor transmits the pressure of the critical point to the

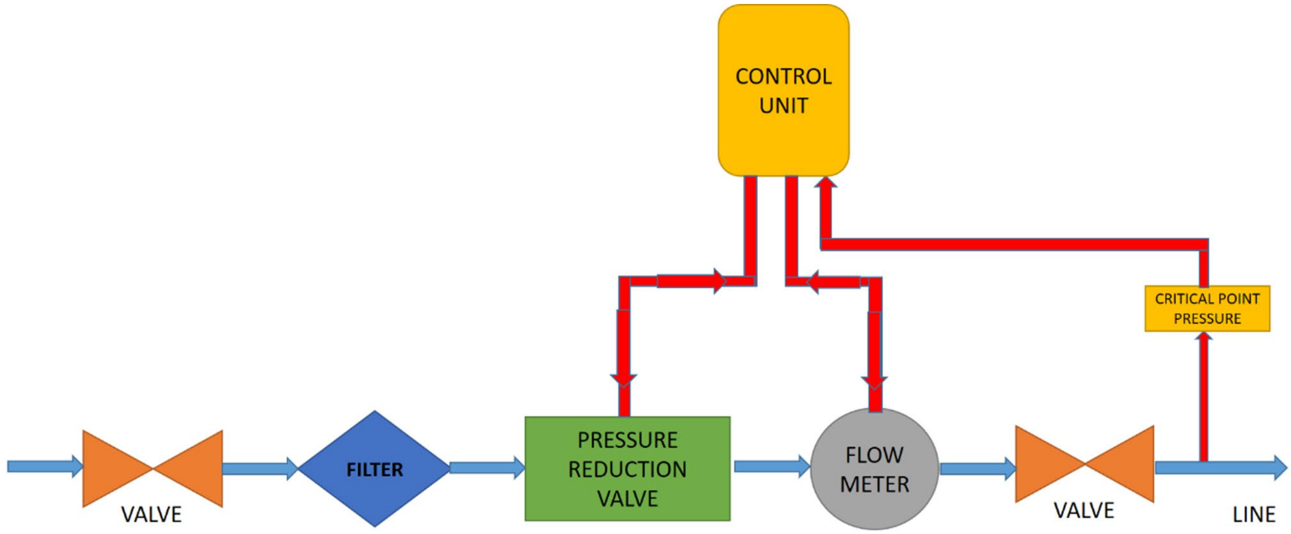

Fig. 1. Schematic view of the DMA.

control unit via the Global Positioning System (GPS) signal. The control unit controls the outlet pressure of the PRV via an actuator. The PRV outlet pressure, which is usually set to 45 m, is increased by the control unit if the pressure of the critical point drops below 20 m. Also, for the control unit fire hydrant, etc., if it detects a sudden withdrawal of water from the places, the outlet pressure of the PRV leaves the control and makes it fully open. Thus, sudden pressure drops in the water distribution network are prevented from disturbing the consumers.

Case study

Field of area

This study was conducted in a DMA in the Yesiltepe Neighborhood of the Erenler District of Sakarya Province in Türkiye. The selected DMA area has a flat topography between 32 and 34 m above sea level. Water supply to the water distribution network in the region is provided from a 15,000 m^3 water reservoir located at an altitude of 104 m above sea level. The water distribution network in the study area serves 991 consumers with a total mainline length of 7762 m (Fig. 2). The tallest building in the region is four floors and 12 m high. It is requested that the minimum pressure on the top floors be 32 m in order to avoid any adverse effects during the water usage of the consumers. The Geographical Information System (GIS) image of the study area is shown in Fig. 3. It has been designed and implemented as an independent zone, where the water supply to the zone will be supplied from a single point from the DMA, and there will be no water inlet or outlet to the system from other neighboring areas.

The diameter and length information of the pipes in the hydraulic model were obtained from the water and sewerage administration in the region where the study was conducted and defined in the system. The flow rate estimates at the nodes were taken into account by taking into account the amount of water passing through the water meters via the consumer management system, the distribution of consumer types (Housing, Factory, Workplace, etc.), and the population data and consumer-based distribution at the node point. The table shows the detailed sections (Supplementary Table S1).

After determining the amount of water (Q_g) supplied to the study area to calculate the loss rate in the region, the water usage indices of the consumers' meter were recorded regularly every month, and the accrual amount (Q_d) was found. The loss rate $(\mathcal{L})$ was determined accordingly (Eq. 3). We can use the following formula to calculate the water loss rate in its simplest form[42,43].

$$\mathcal{L} = \frac{\left[Q_g\left(m^3\right) - Q_d\left(m^3\right)\right]}{Q_g\left(m^3\right)} \times 1003$$

The measurements and analyses during the study were started with the water pipes full and were finished with them full. Therefore, no loss was calculated for filling the pipes or any gain was calculated for emptying them.

Inputs of the hydraulic model

The water distribution network information, currently in the NETCAD program of the selected DMA, has been transferred to the EPANET program. First of all, the equipment used in the drinking water network is designed under the following headings;

- Modelling of water reservoir and pipes (Reservoir volume information, pipe type, PRV, etc.).
- Defining pipe diameter information for the program.
- Defining ground level information (Nodal points, reservoir, etc.).
- Modeling of Consumption Demands (Water consumption information at nodal points).
- Modeling of Consumption Pattern.

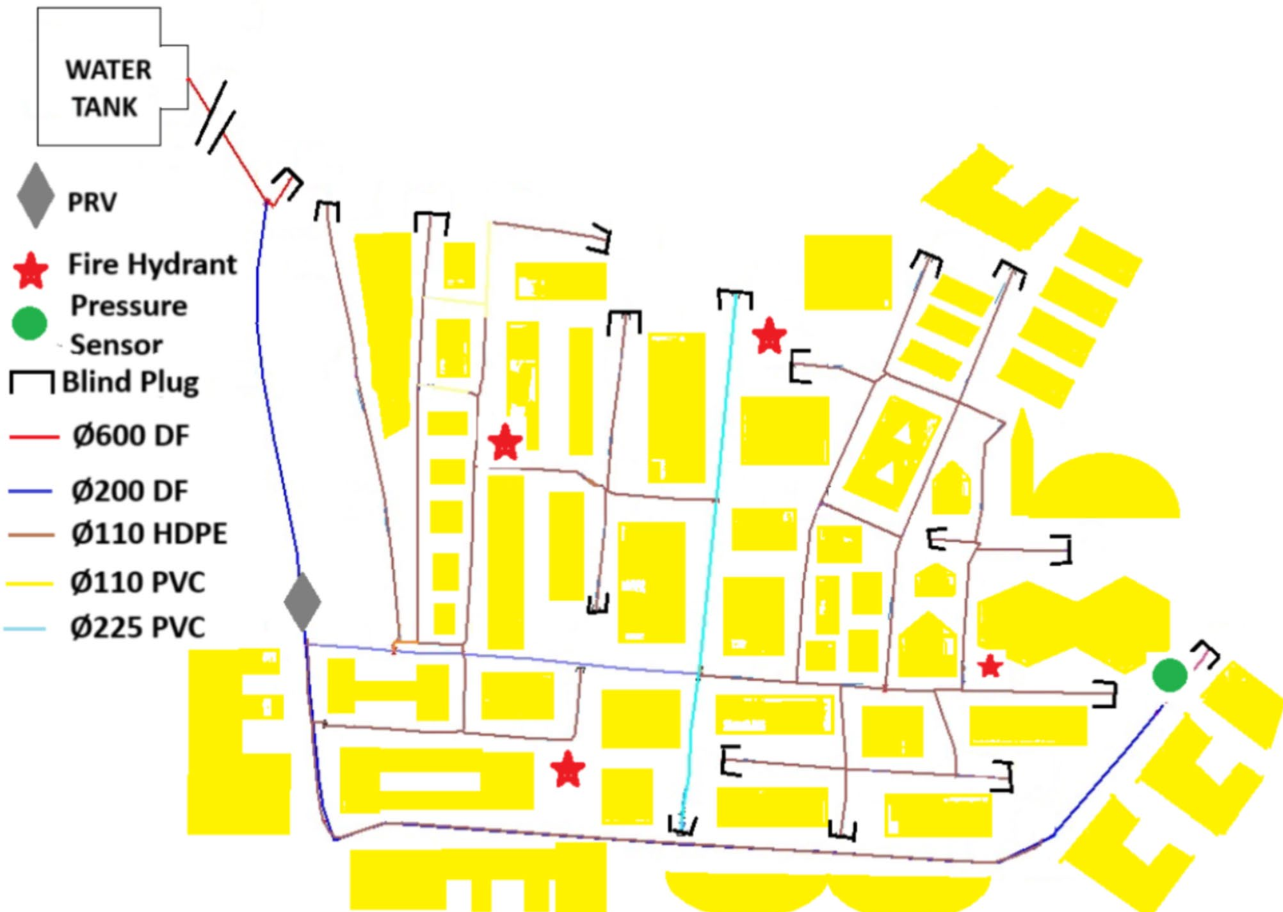

Fig. 2. Network layout.

It was designed in 5 stages. After making all the necessary definitions for the program, 48-hour water consumption in the designed network is simulated in the hydraulic model. For the calibration of the parameters, pressure data was first collected from 3 points in the field with data loggers integrated into the SCADA system. After the hydraulic modeling was established, it was decided to make a 48-hour simulation. The hourly data in the simulation was compared with the data in the field at the same time. Then, the file containing the data in the field was defined in the program from the calibration data section under the projects heading of the EPANET program, and the necessary error rates were taken from the program under the calibration heading in the report section (Table 1).

Water consumption and loss rates before control

The basic approach to calculating water losses was found by considering the standard water balance table prepared by the International Water Association (IWA). Firstly, in order to measure the amount of water supplied to the study area in 2020, Krohne Optiflux 2050 F Remote electromagnetic flowmeter was installed in the DMA, the construction of which was completed before, and data was started to be recorded at one-minute intervals. During this period, the amount of water supplied to the region was monitored via the Supervisory Control and Data Acquisition (SCADA) system without pressure management. This situation is shown in the graph in Fig. 4.

A total of 202 940 m^3 of water was supplied to the region in a year without PC. The lines at the bottom (blue line) of Fig. 4 show the flow information, and the lines above (red line) show the pressure change. The inlet pressure value varies between 70 m and 58 m according to the water usage in the region. Flow rates increase up to 11 L/s during periods of high water demand and decrease to 3.8 L/s when the consumption is low. (Fig. 4). Figure 5 presents the 24-hour variation of inlet pressure and flow rate, providing insight into the system's hydraulic behavior in response to daily water demand fluctuations. The flow rate varies between 3.9 L/s and 11 L/s, indicating higher consumption during the daytime, especially between 08:00 and 14:00, which corresponds to peak demand hours. During this period, the inlet pressure decreases noticeably from approximately 64 m to 58 m, highlighting the inverse relationship between flow rate and pressure. Conversely, during nighttime hours (e.g., 02:00–05:00), the flow rate drops to its minimum levels, and the pressure reaches its maximum value of 68 m. This pattern confirms the expected hydraulic response, where increased consumption results in decreased pressure, and vice versa. The figure thus effectively visualizes the diurnal water usage pattern and supports the analysis presented in the manuscript.

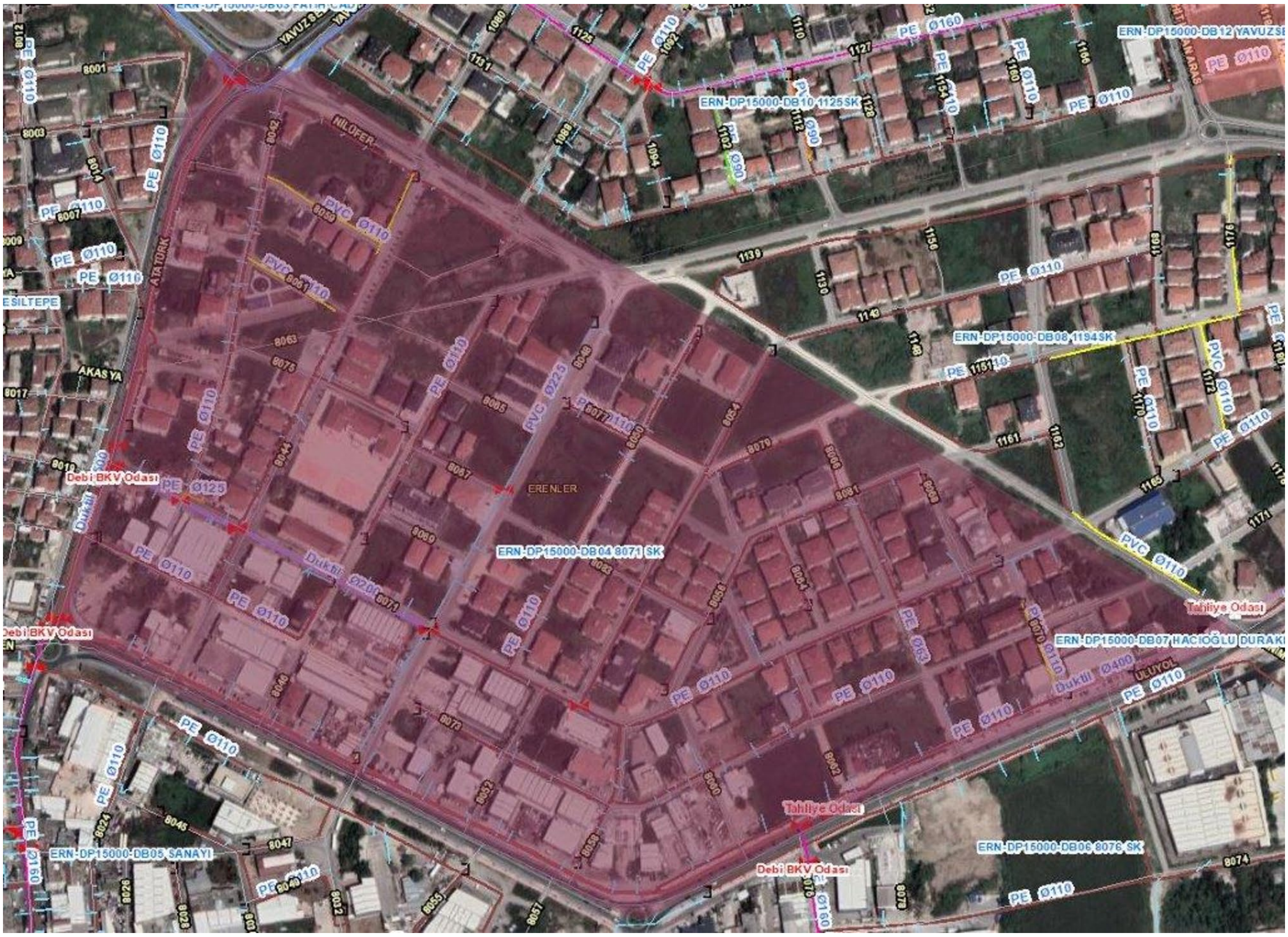

Fig. 3. GIS Image of Workspace, generated in Environmental Systems Research Institute (ESRI) software, version Arcmap 10.3, (www.esri.com/en-us/home).

Location	Num Obs	Observed Mean	Computed Mean	Mean Error	RMS Error
D-15	48	39.6	35.07	4.524	4.974
D-66	48	44.07	42.14	1.926	2.192
D-67	48	68.12	67.14	1.142	1.431
Network	144	50.6	48.12	2.531	3.245
Correlation Between Means: 0.998					

Table 1. Calibration statistics for pressure.

The amount of water supplied to the region in a year and the consumers' usage were recorded monthly. Basis16,992 m^3 of water was supplied to the region in January, and 8,699 m^3 of consumer consumption was realized. In February, the amount of water supplied decreased by about 10% compared to January, and consumer consumption decreased by an average of 2.5% compared to February. In this case, there was a 3.8% decrease in the water loss rate in February compared to the previous month. Similarly, while the increase in the amount of water consumption in August was 5.4% compared to July, there was a 3.2% increase in the loss rate despite a 0.7% decrease in the accrual amount. While the amount of water consumption decreased by 3.6% in September compared to the previous month, it increased by 1.6% compared to July, the amount of accruals decreased by 6.5% and 6.7%, and the loss rates increased by 1.3% and 4.5%. (Fig. 6). According to this evaluation, water losses increase as accrual amounts decrease. According to Bernoulli's equation, the increased pressure when there is no water use also increases the water losses (Eq. 2). This clearly shows that PC systems related to water use will reduce water losses. The annual average water loss rate has been determined to be 49% annually.

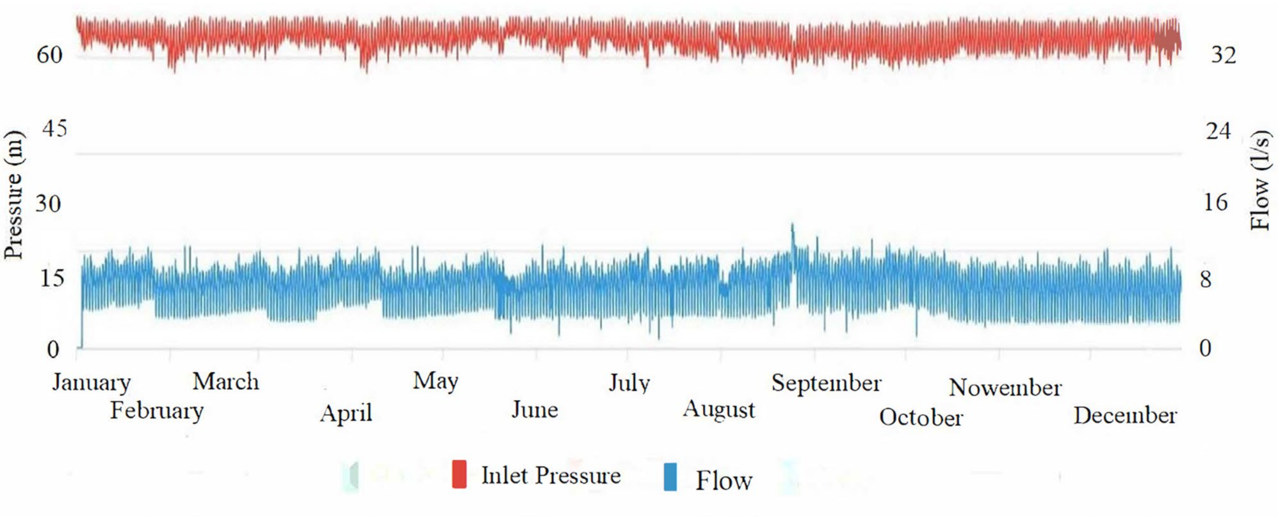

Fig. 4. Graph of inlet pressures with year flow rate before control.

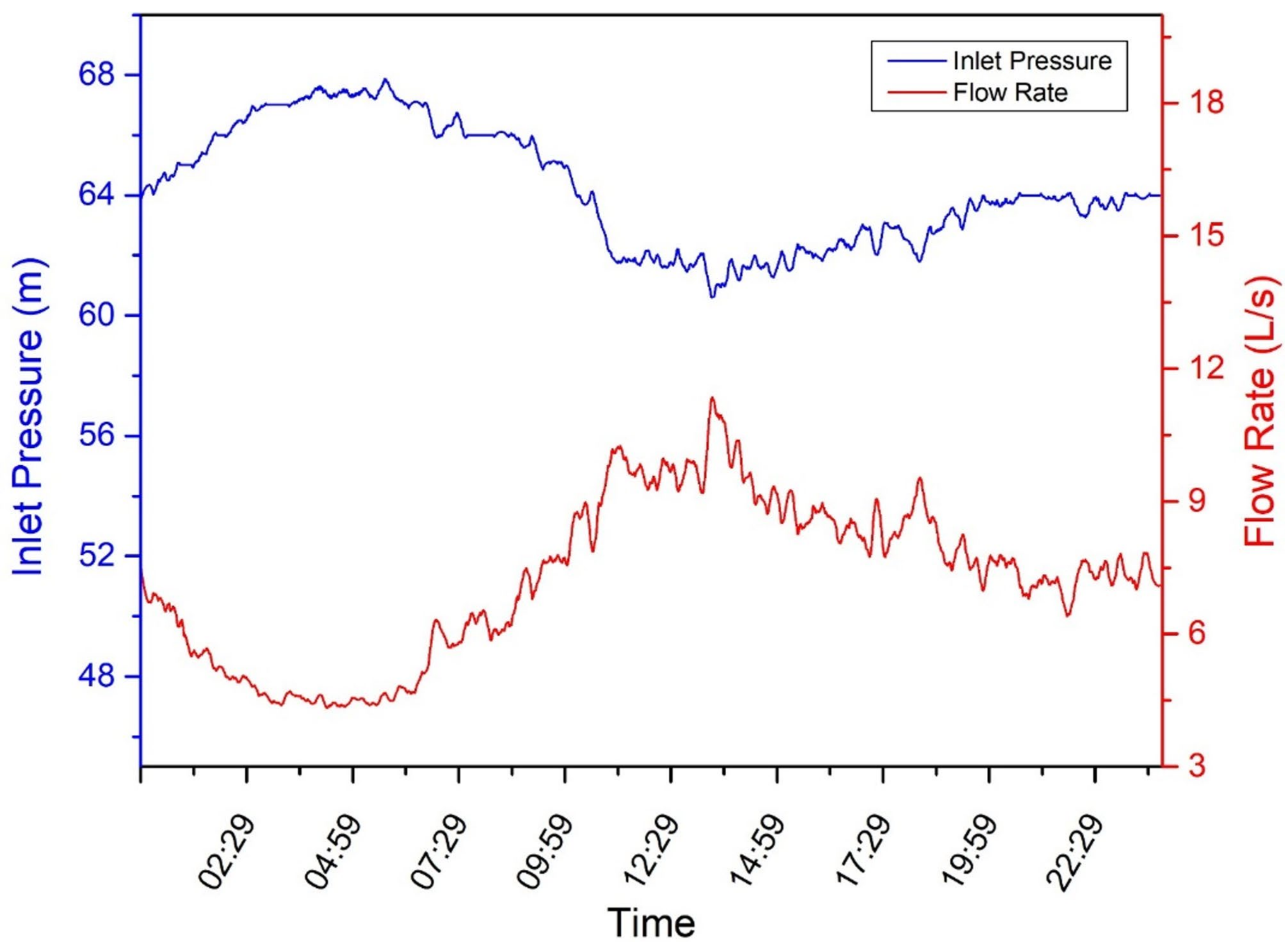

Fig. 5. 24-hour pressure and flow rate before PC for January 1st.

Result and discussion

Water consumption and loss rates after real-time control

In order to analyze the effect of water pressure on water losses in the next year, the piston-type PRV, strainer, suction cup, electronic PRV control, and hydraulic actuator installed in the DMA were commissioned. In order

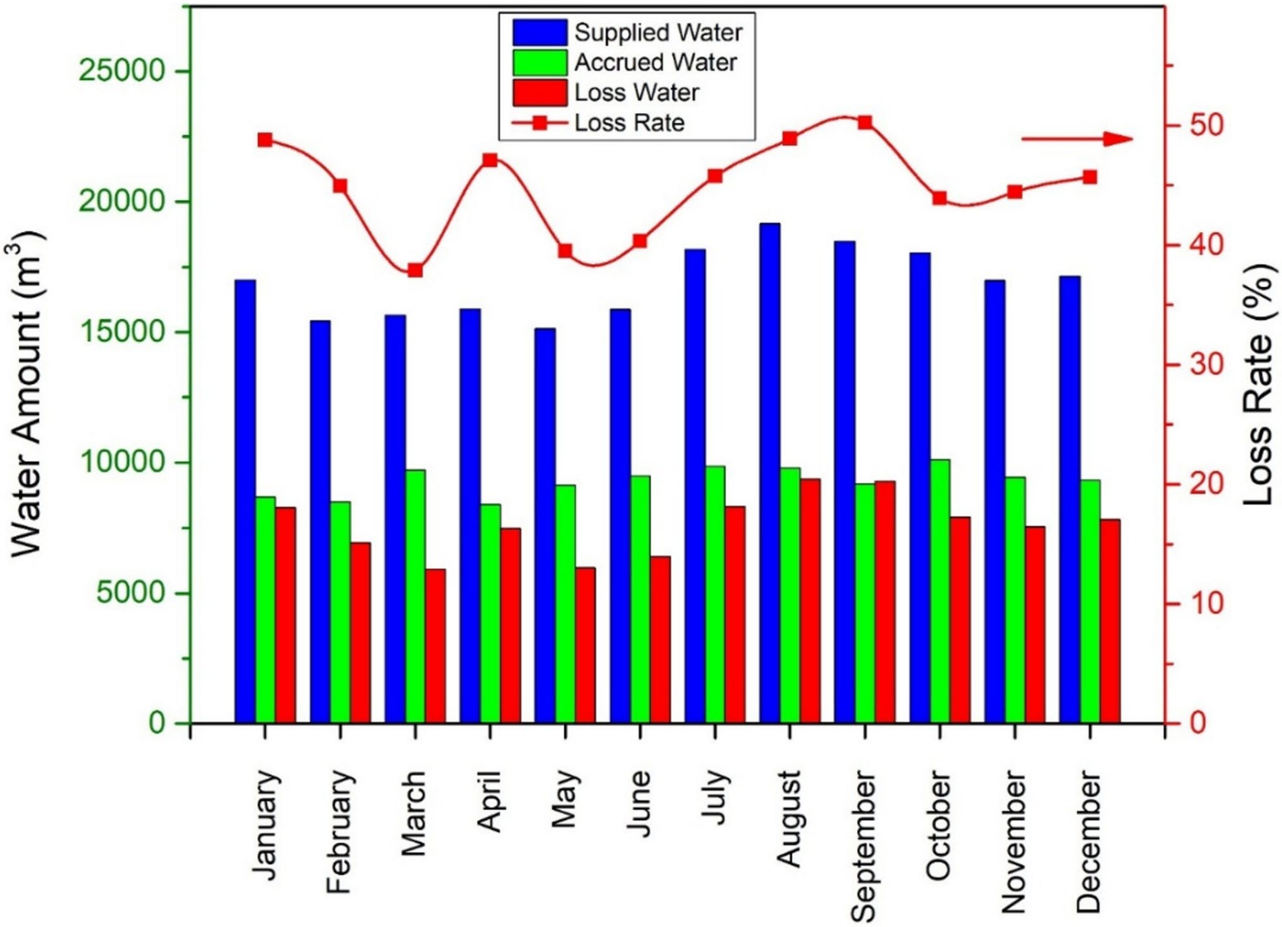

Fig. 6. Monthly supplied water, accrual water, loss water and loss rate before PC.

to analyze the effect of pressure change on water losses caused by leakage, the output pressure of the PRV was adjusted to 45 m, with the minimum pressure at the critical point in the measurement zone being 32 m. During the pressure management implementation, 181,196 m^3 of water was supplied to the region. Thus, 12% less water was supplied compared to the uncontrolled method. In Fig. 7, the flow graph of the water supplied to the area during the operation is shown in blue, the outlet pressure of the PRV in green, and the inlet pressure in red.

During the control, as seen in Figs. 8, 21 and 744 m^3 less water per year was supplied to the DMA, resulting in savings. The amount of accrued water in a year increased by only 1.8% compared to the previous year. This has a positive effect on reducing water losses. Thus, during the pressure management, water losses decreased by 19% on average and reached 30%. This result shows that the network can be operated for a longer time with a lower amount of water without additional investment in water supply. In Fig. 7, it is seen that the outlet pressure of the PRV in March could not be controlled due to the failure. This situation is reflected in Fig. 8 as the increase in the loss rate in the same month. The increase in water supply and losses can be seen in the Fig. 8. Compared to similar studies, higher leakage control rates were obtained in networks with high-pressure drops[32,33]while a slightly smaller leakage control was achieved in our study where the pressure drop was low. It should also be noted that the results of leakage control are directly related to the age of the network, material selection, artistry quality, and working conditions[2].

Analysis of the effect of real-time control on water losses

Water leaks consist of mini cracks and holes in water pipes. There is a direct correlation between the pressure in these cracks and holes and the leakage. The higher the pressure in the water network, the shorter the equipment's economic life, and the frequency and number of failures in the water network are increasing. The pressure method extends both the frequency of failure and the duration of use of the equipment. According to the consumer management system data, the number of malfunctions occurring in the DMA in the uncontrolled year was 39, while it decreased to 23 in the controlled year. The 41% regression in network failures reveals that pressure management plays an active role in reducing water losses and the failures that occur in the network (Table 2).

As seen in the graph in Fig. 9, it is understood that there is a decrease in the amount of water supplied during the pressure management period without affecting the comfort of water usage during the day. Orange colored lines in the graph show the amount of water supplied to the network for 1 week without pressure management.

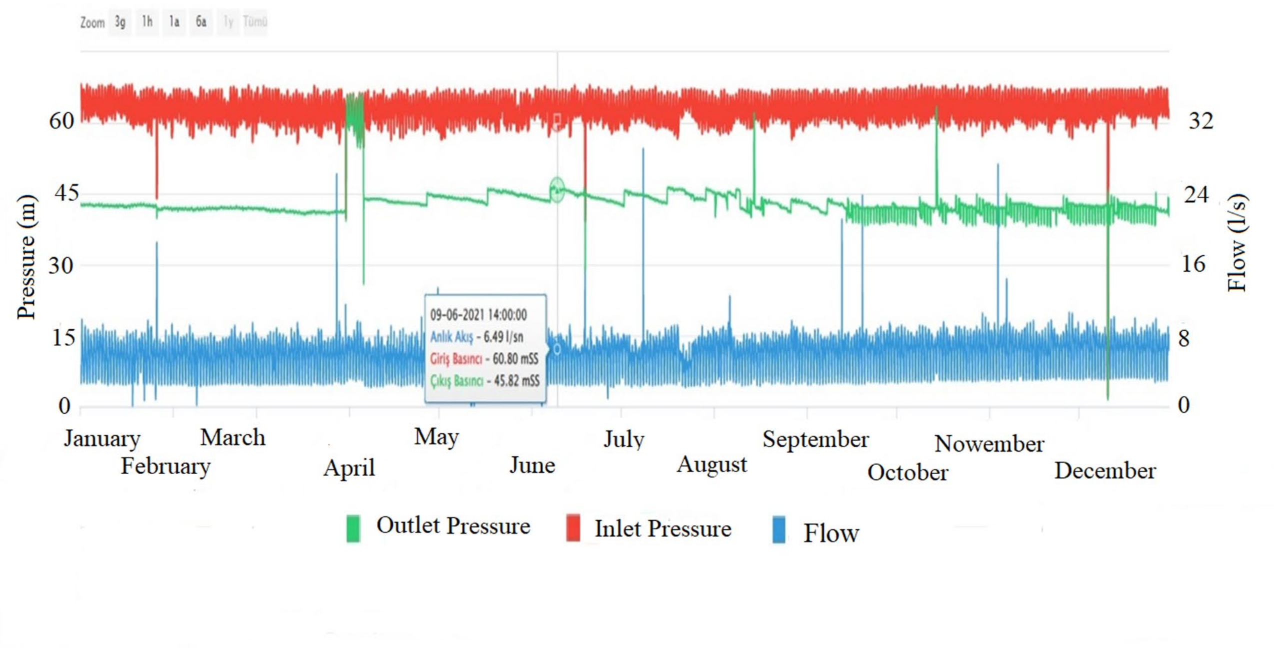

Fig. 7. Graph of PRV's inlet and outlet pressures with flow rate after control.

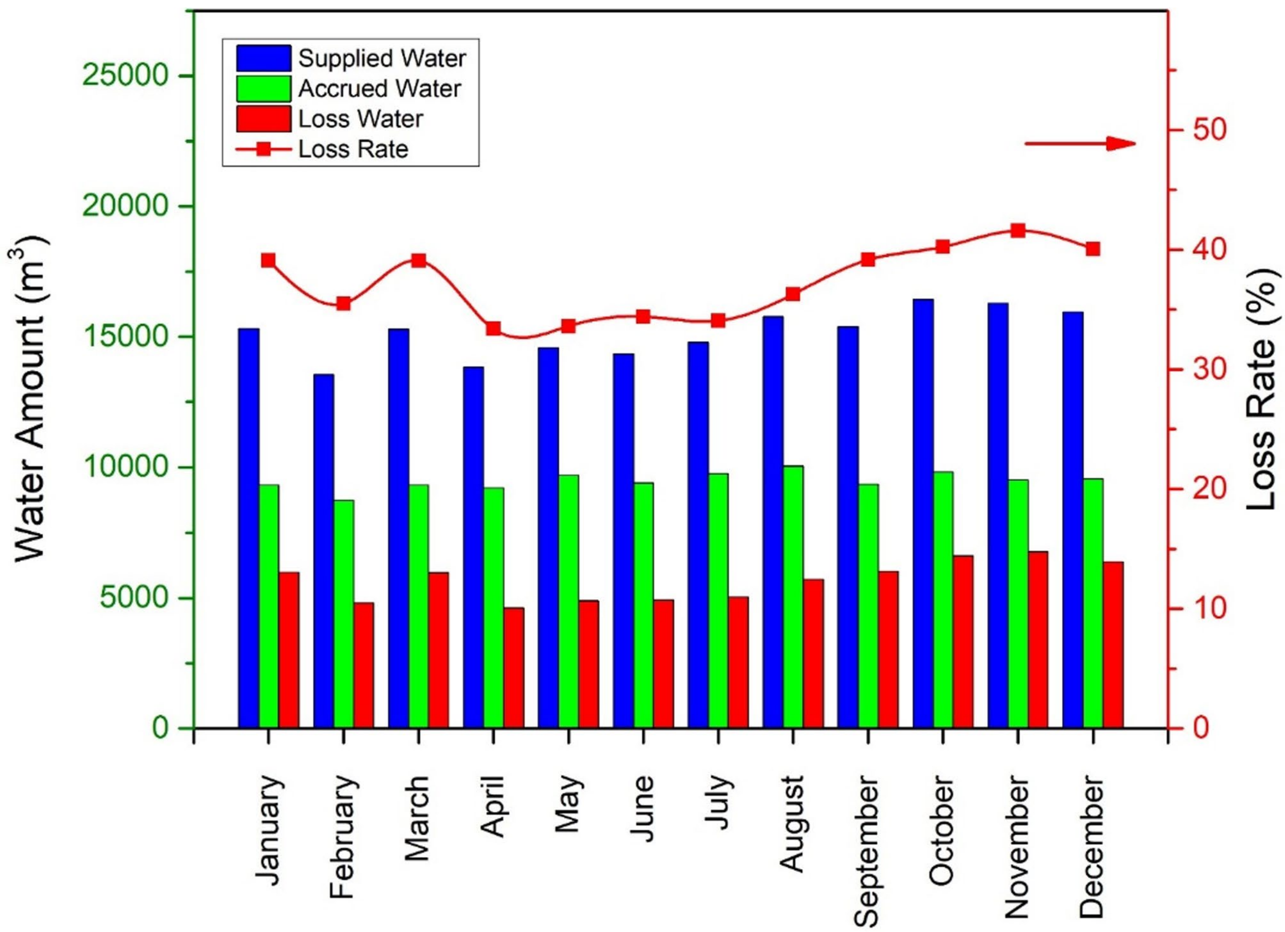

Fig. 8. Monthly supplied water, accrual water, loss water and loss rate after PC.

	Before PRV	After PRV	Amount of reduction	Unit
System Input Volume	202,940	181,196	-21,744	m^3
Number of Burst in the Water Network	39	23	-16	Piece
Average Pressure in the Water Network	66	45	-21	m
Loss Rate	49	30	-19	%
Maximum Flow Rate	11	8.1	-2.9	L/s
Minimum Night Flow Rate	3.9	2.1	-1.8	L/s

Table 2. Comparison table before and after PRV.

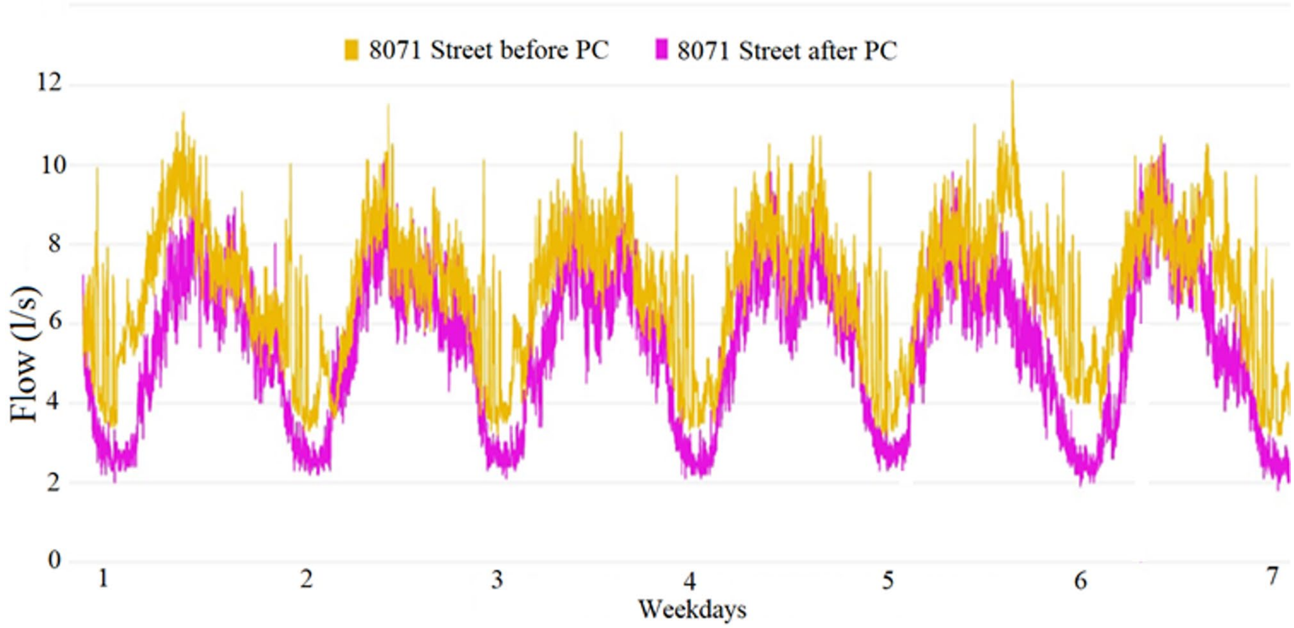

Fig. 9. Pre-control water consumption graph with real-time PC.

During this period, the minimum and maximum flow rates were between 3.9 L/s and 11 L/s. As shown in purple in the same graph, real-time pressure management was performed for 1 week, and it was observed that the water supplied to the network decreased. In this part, the minimum and maximum night flow rates decreased to between 2.1 L/s and 8.1 L/s (Table 2).

Analysis of the hydraulic model

After completing all the stages in the hydraulic model, the PRV in the water distribution network was added to the program. The pressure values were analyzed during the 48-hour simulation period. Before the simulation, the pressure values at the critical point physically determined in the field were also recorded and compared with the outputs in the program.

When the simulation of the hydraulic model started, it was determined that the pressure values changed according to the elevation levels and consumption pattern values, as seen in Fig. 10. During this period, the program was adjusted so that the output of the PRV was 45 m. In the graph in Fig. 10, it is seen that there is a color change at the points in the network depending on the pressure. It has been observed that the average pressure varies between 35 m and 41 m after the PRV in the study area, and the critical point pressure does not fall below 20 m.

During the simulation, the inlet and outlet pressure values of the PRV and the pressure values at the critical point were recorded in the hydraulic model for 48 h. In Fig. 11, the pink upper part shows the PRV's inlet pressure. This graph clearly shows that the pressure changes according to the amount of consumption in the network. The outlet pressure of the PC valve is set to 45 m on average and is shown in green in the middle of the graph. It is seen that there is a partial decrease in outlet pressure compared to consumption. The pressure curve at the critical point is shown in red at the bottom. At the pressure values at the critical point, more pressure loss occurred due to the increased consumption due to the ground elevation level and the amount of water consumption, and it was observed that it went down to 35 m levels. Pressure drop is greater than the PRV output at the critical point during the hours when water use increases. Therefore, the PRV output pressure is always kept slightly above the required level so as not to reduce the comfort of water use on the consumer side (Fig. 11).

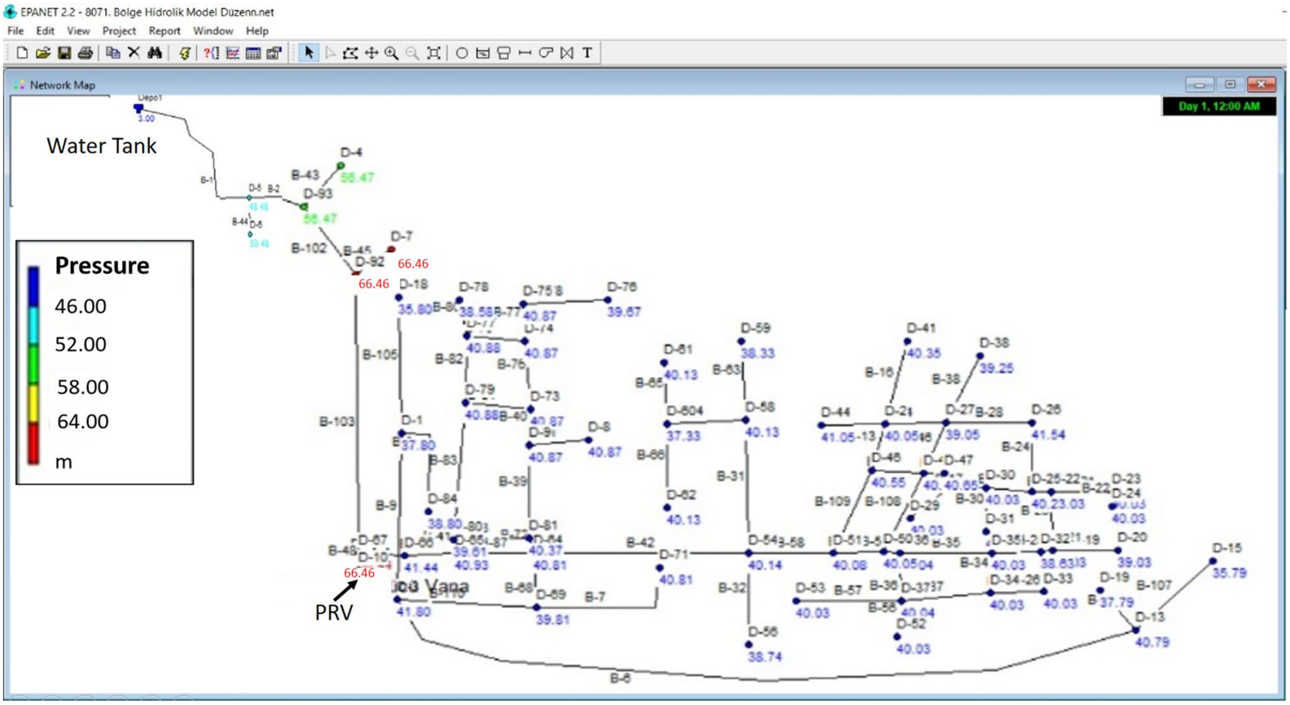

Fig. 10. Pressure values of the hydraulic model.

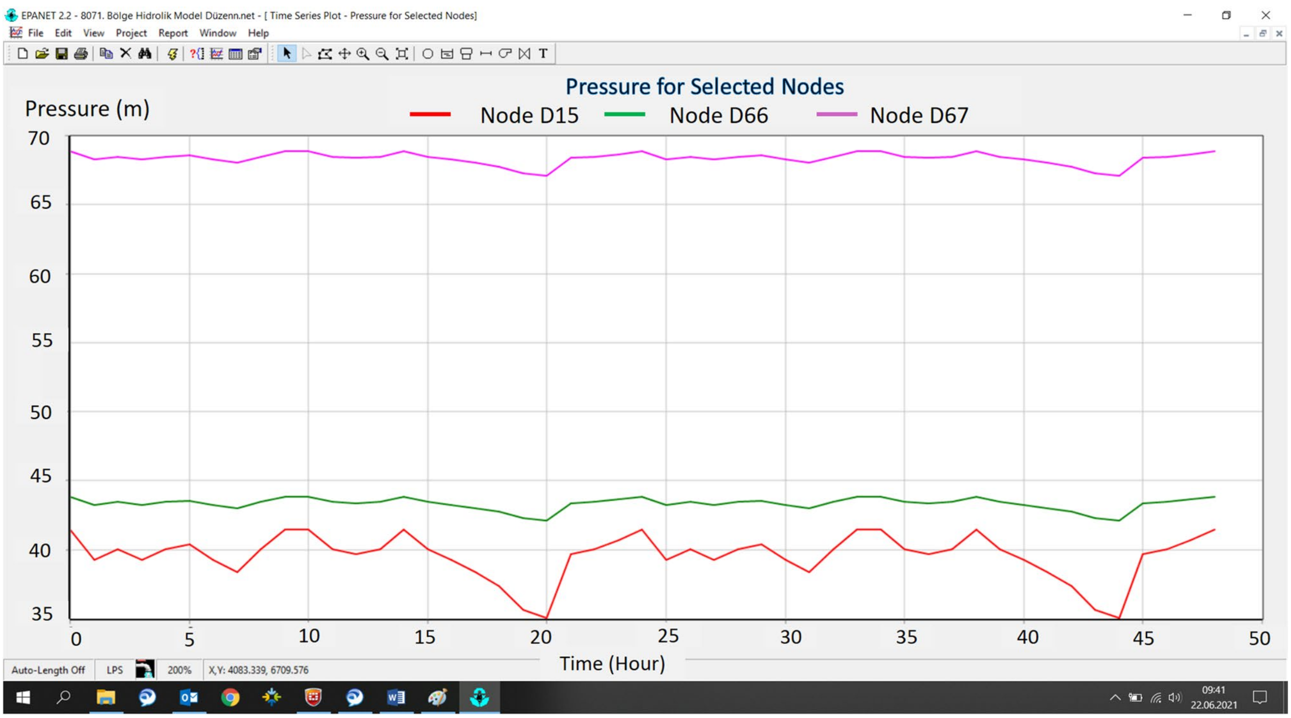

Fig. 11. 48-hour graph of inlet-outlet pressure and critical point pressure of PRV in the hydraulic model.

Comparison of hydraulic model and field data

The stability conditions of the hydraulic model designed within the scope of the study were analyzed by comparing it with the actual data in the field and the real-time PC management applied to the existing water network in the field. Within the scope of the study, the inlet pressure, outlet pressure, and pressure at the critical point of the DMA were compared with the data in the field.

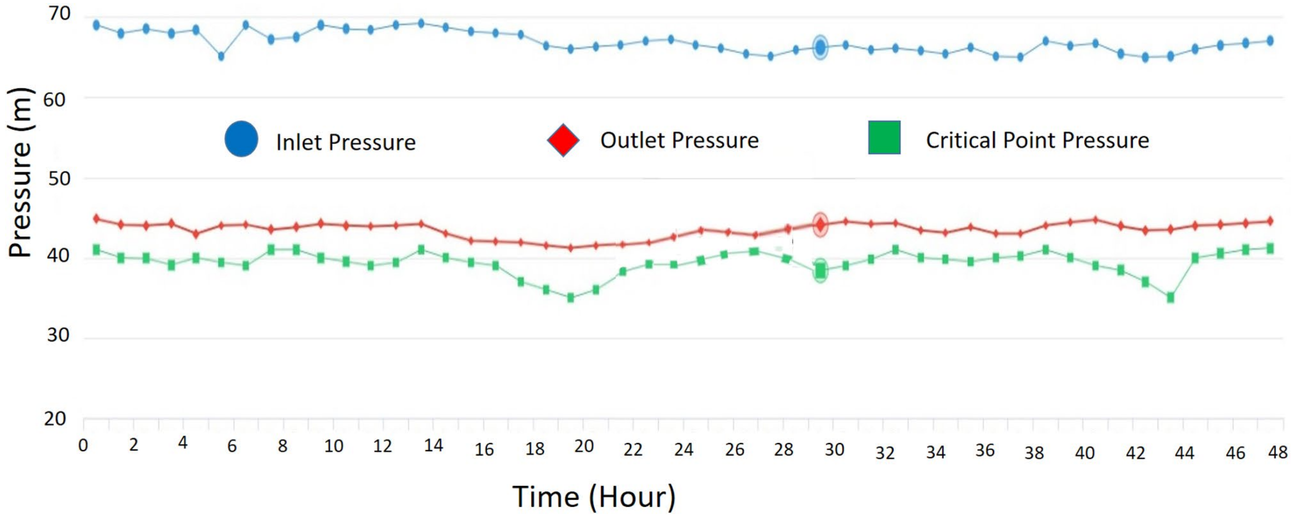

Fig. 12. 48-hour pressure graph recorded in the field.

Pressure values were recorded continuously from three different points for 48 h. The pressure measurements we took in the field for 48 h are shown in Fig. 12. The blue lines in this graph represent the inlet pressure data, the red lines are the output pressure, and the green lines are the critical point pressure. The pressure data in the graph changes according to the water usage pattern. These data are highly similar to the pressure values obtained in the field.

As a result of the study, as can be seen from the pressure graphs, it was observed that there was an error between 2% and 4% between the pressure data measured in the field and the values in the hydraulic model. If the data specific to WDNs in EPANET is entered correctly, the analysis results are obtained successfully. This situation coincides with similar studies conducted under different conditions in the literature[44].

Conclusion and recommendations

This study compared the simulation findings in the EPANET software with the data of a network whose pressure was decreased by real-time pressure management. The data included pressure, flow, water loss, etc. The results collected demonstrate that simulation results that are tailored to align with the network topology can serve as a tool for decision-making prior to investment. Real-time pressure management, one of the methods of combating the loss-leakage problem in water networks, has been applied within this article, and it has been shown that a more effective and economical result can be achieved with water losses. Within the scope of the study, the unnecessary pressure in the water network was reduced, thereby prolonging the economic life of the equipment used and reducing the loss rate. In addition, within the scope of the study, hydraulic modeling of approximately 8 km of water line was done using the EPANET program. When we compare the data in the modeling result with the data we measured from the field, it is seen that the hydraulic model works with an error of 2–4%. The results clearly show that the hydraulic model established in the EPANET program fits with the field data and is reliable. This clearly shows how much water to be saved can be determined with a program before the PC investment is made in the network. The EPANET program is a reliable tool for deciding whether the PC system can continue to be used or needs to be replaced. In addition, these results show that the networks with water supply shortages will provide the opportunity to manage the network for a longer time with the PC method because it is a known fact that the fluctuations that occur due to the compression feature of the air as a result of the water in the network being cut off and the air entering the network cause many malfunctions in the network.

While there was a 12% decrease in the amount of water supplied to the network by PC, there was an increase of 1.8% in the amount of accrued water. This shows that although the consumers continue to use water without changing the comfort conditions, the amount of water supplied to the system has decreased, and thus, the loss rate has decreased from 49 to 30%. The water savings obtained will make up for the cost of the installed system in a short time. It has also been revealed that this method will enable the network to be operated for a more extended period without increasing its share in the water resource and allow investments to be made later.

Data availability

Data can be accessed through the corresponding author.

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Author contributions

MMO1. Literature review2. Creation of the experimental setup3. Data acquisition and analysis4. Creation of the hydraulic model5. Evaluation of the results6. Review of the articleFU1. Data analysis, evaluation of the results2. Validation of the experimental setup3. Development of the hydraulic model4. Literature comparison and validation5. Review of the article.

Declarations

Competing interests

The authors declare no competing interests.

Consent to participate

All authors read and approved the final manuscript.

Consent to publish

All the authors agree to publication of the manuscript in its current form.

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