**EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING**
Volume 11, Issue 2, 2026: 137-148 | www.ejmse.ro | ISSN: 2537-4338

DOI: 10.36868/ejmse.2026.11.02.137

# EVOLUTION OF PRESSURE IN A WATER DISTRIBUTION NETWORK OF HDPE CONDUITS DEPENDING ON THE INCREASE IN WATER DEMAND OVER A PERIOD OF 5 YEARS

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**Abstract**

*The increasing global population and urbanization have led to a surge in water demand, posing significant challenges to water distribution networks. This article investigates the evolution of hydraulic pressure in a water supply system of HDPE pipes under varying demand scenarios in future 5 years for a new residential area in Iasi city. A comprehensive analysis of historical consumption patterns and projected demographic changes is undertaken to simulate potential demand increases. The impact of these changes on the hydraulic pressure of the water distribution network is assessed using hydraulic modeling techniques. The results reveal fluctuations in hydraulic pressure, highlighting the need for proactive management strategies to ensure a reliable and efficient water supply. For the period 2026 - 2031, we developed a series of scenarios assuming that water demand will increase by approximately 5% annually and we monitored the evolution of pressure in the system as a result of the mentioned conditions. Interestingly, through hydraulic modeling we simulated the scenarios and also we observed the pressure in the system at each node and the results are encouraging. Thus, the pressures obtained from the simulations based on the hydraulic model in accordance with the expected water requirements are good, and the most unfavorable node has a value of 17.36 meters of water column, but sufficient for the analyzed area. So, this study provides valuable insights for water utility managers and policymakers, enabling them to develop informed decisions and infrastructure plans to meet future water demands while maintaining optimal hydraulic pressure in the network.*

**Keywords:** *pressure, water supply, urbanization, base demands, HDPE pipes*

## Introduction

The water supply infrastructure system is one of the most critical aspects of urban planning and management, as it links the drinking water from the treatment plant to consumer's taps. With the population of large cities continuously growing and expanding, water demand is expected to rise, and it will put additional pressure on the existing infrastructure which can impact its performance [1].

The current water supply systems face several challenges, including aging infrastructure, increasing population, climate change, losses, and varying water demands. A well-designed water supply system must take into consideration future projections to ensure that it meets the growing demands of the population, industrial sectors, and various other consumers [2]. Therefore, understanding and predicting future water pressure patterns is essential for effective decision-making and long-term planning in management of the water resources. This will allow authorities to make informed investments in infrastructure development that align with projected demand, population growth, and environmental changes, ultimately ensuring a resilient and adaptive water supply system that can meet the needs of a growing population.

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The primary objective of a Water Distribution Network (WDN) is supplying consumers with water that meets strict quality standards, satisfies volume demands, and maintains adequate pressure. Achieving long-term operational reliability depends entirely on precise engineering design, quality construction, and proactive network management [3].

EPANET is a widely used software that performs hydraulic calculations within pressurized water networks. EPANET tracks the flow rate of water in each conduit, the pressure at each junction, the water level in each storage tank, and determine the concentration of a chemicals throughout the entire network [4]. For this paper EPANET was used to assess the hydraulic analysis of the water supply distribution network of the study area.

Maximizing hydraulic model accuracy requires a vast array of precise input data. Simulations must integrate exact pipe dimensions, material types, terrain elevation, network connectivity, customer connection points, water source yields, storage tank capacities, and performance curves for both pumps and valves [5].

Recent research confirms that hydraulic modelling is the essential instrument for understanding and improving the behaviour of water distribution systems under evolving demand conditions. Studies published in the last years show a growing emphasis on integrating hydraulic simulation which include spatial data, calibration datasets, leakage analysis, and smart monitoring approaches. For example, recent EPANET-based investigations have demonstrated the value of combining hydraulic modelling with GIS and remote sensing for identifying low-pressure zones, excessive head losses, and network deficiencies that require intervention. Other recent studies have shown that model accuracy improves substantially when demand allocation is based on detailed consumer-level information, such as water meter readings, rather than on simplified aggregated assumptions. At the same time, current research on leakage and pressure-dependent behaviour highlights that pressure is not only a service variable, but also a driver of water losses, energy use, and infrastructure deterioration. These studies collectively confirm that pressure analysis is fundamental for both design and operation, particularly in systems exposed to changing consumption patterns [6],[7],[8].

Although the academic literature has advanced considerably on the hydraullic modelling topic, previous findings also reveal several limitations. A first strength of recent studies is that they provide robust methods to identify hydraulic deficiencies in the system and corrective interventions such as booster pumps, pipe replacement or leakage reduction. They demonstrate that digital models can support practical engineering decisions and improve system performance before investments are implemented directly in the field. However, many of these studies focus either on large urban systems, leakage modelling, or control optimization, and less attention is paid to the evolution of nodal pressure in residential distribution networks subjected to medium-term demand growth scenarios. In addition, while some studies achieve high modelling accuracy through extensive calibration datasets, such approaches are not always feasible for neighbourhood-scale systems, where data availability may be limited and poor. Other studies emphasize system optimization but do not sufficiently examine how future increases in demand may progressively affect pressure adequacy at vulnerable nodes over time [7],[9].

With respect to pipe materials, HDPE pipes are mainly used in water supply systems because of their corrosion resistance and long service life. These properties make them suitable for new developments areas and network extensions. Even so, the material advantages of HDPE do not by themselves guarantee adequate hydraulic behaviour under changing consumption conditions. If future demand increases are not properly accounted for, pressure deficits may still occur at critical nodes, even in systems built with modern materials and appropriate construction practices and technologies.

Against this limitation, a relevant gap remains thus in the recent literature. Although many studies published in last years provide valuable insights into optimization or leakage control, fewer studies examine how nodal pressure evolves over a multi-year horizon in residential distribution systems composed of HDPE pipes and subjected to both decreasing and increasing demand scenarios [6–9]. In addition, the link between pressure-evolution analysis and pump selection during the design phase remains insufficiently explored. This gap is important because designers frequently need to make infrastructure decisions before long-term consumption patterns are fully confirmed.

The present study addresses this need by evaluating the hydraulic performance of an HDPE existing water supply system under conditions of decreasing and increasing consumption, in a residential neighbourhood from the Iasi city over a projected five-year period. The study quantifies water pressure impacts in the water distribution network, pinpoints vulnerabilities among it.

Through hydraulic modeling, we simulated the scenarios and observed the pressure in the system at each node, and the results allowed, right from the design phase, the choice of a pump with suitable characteristics. This is a new approach in the field,as it prioritizes investments and makes the best decision based on the hydraulic model.

If in the initial phase in 2026 there was a problem with the pressure in several nodes, by creating the hydraulic model we managed to choose a pump with good characteristics, so that in 2031 the pressure in the most unfavorable node would have a value of 17.36 meters of water column. The values obtained even for 2031 are good for the respective area. In this way, the research contributes not only to the hydraulic assessment of a local case study, but also to the broader discussion on how demand-sensitive modelling can improve planning decisions in urban water distribution systems.

## Current water supply system overview

A water supply system comprises a network of conduits, pumps, flap valves, storage tank facilities, reservoirs and other special hydraulic construction [10]. This system is designed to meet fluctuating demand patterns and accommodate seasonal variations. However, with the increasing pressure to provide reliable and sustainable water supply, it is imperative that we implement a proactive approach to managing water pressure, incorporating advanced data analytics to optimize system performance, predict potential bottlenecks, and enable real-time monitoring and response.

Romania's current water supply system is a complex network of infrastructure that relies on a combination of surface water, groundwater, and alternative water sources to meet the demands of a growing population [11], [12],[13]. The country has a long history of water management, with many of its water supply systems dating back to the 19th century. Over time, the system has been expanded and upgraded to accommodate urbanization and economic growth.

Despite these efforts, the current water supply system in Romania still faces numerous challenges, including aging infrastructure, inadequate treatment and distribution systems, and inefficient use of water resources. According to the Romanian Ministry of Environment, Water and Forests, approximately 40% of the country's water supply is lost due to leaks and other inefficiencies.

Iasi city is one of the largest cities in Romania. The city is in the northeastern region of Romania and is a prime example of the country's water management challenges. The area presented in this case study is supplied with water from the Prut River. The system includes a distribution water network of reservoirs, storage tanks, conduits and pumps that supply clean drinking water to over 350.000 residents and businesses. However, the city's aging infrastructure and lack of investment in water management systems have resulted in frequent service disruptions, low water pressure, and contamination risks, emphasizing the need for urgent upgrades and modernization.

The city is expected to experience significant population growth in the coming years, putting additional pressure on the city's water supply system. According to the Romanian National Institute of Statistics, the population of Iași is projected to increase by 15% by 2030, resulting in a higher demand for water. This growth, combined with the existing infrastructure challenges, highlights the need for proactive planning and investment in the city's water supply system.

## Materials and Methods

***Study area***

The case study was carried out for a sector of water distribution system that supplies Bucium neighbourhood in the city of Iași, Romania.

Bucium neighbourhood is geographically located in the southern zone of Iași City (Fig. 1). As the neighbourhood experienced rapid growth and urbanization during the 20th century, with the population increasing from approximately 500 residents in 1900 to over 5000 in 1950, the water supply system had to adapt to meet the increasing demand. This led to a series of infrastructure investments, including water tanks and a network of pipelines that aimed to provide a reliable and efficient water supply to the growing population. The water supply system has since undergone significant upgrades and modernization efforts, with the introduction of new technologies and management practices aimed at enhancing the overall efficiency, sustainability, and resilience of the system.

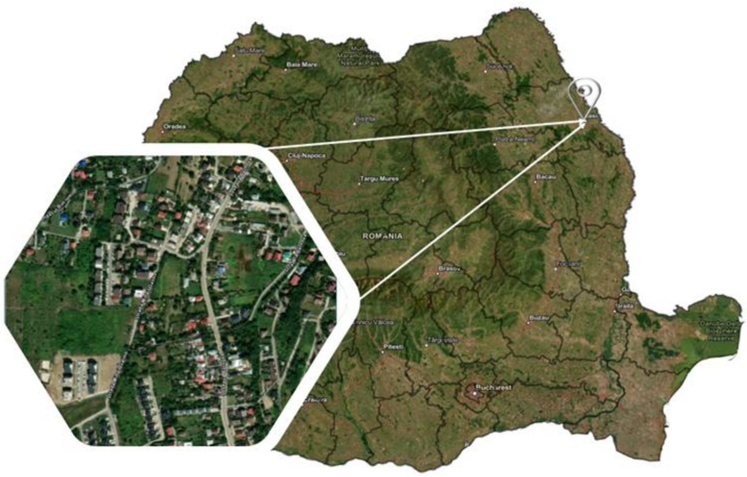



**Fig. 1.** Location of the study area (ArcGIS Online)

Water distribution network in Bucium is characterized by a complex network of pipelines, pumps, and valves that work together to transport and distribute water to households and businesses across the area. This distribution system, comprising approximately 53 kilometres of pipes, is designed to supply water to over 75.000 residents and more than 5.000 commercial establishments, with the majority of its water supply coming from the nearby Prut River. which is treated and processed at the water treatment plant located in the proximity.

The topography of Bucium neighbourhood, varied terrain with lowlands and high hills presents both advantages and challenges for the water supply system. On one hand, the flat terrain facilitates the construction and maintenance of water distribution networks, as it reduces the need for complex pumping systems and allows for more straightforward pipeline installation.

The water supply system in Bucium faces unique challenges, primarily stemming from its geographical location and demographic trends. One of the most pressing challenges faced by the Bucium water supply system is the increasing population density, which, when coupled with the neighbourhood's sprawling residential areas and rising commercial developments, puts immense pressure on the available water resources, necessitating a careful balance between supply and demand to ensure a sustainable and reliable water distribution network that meets the evolving needs of the community, while also considering the topographical constraints of the area.

The growing population in Bucium, coupled with urbanization and increasing water demands from residential, commercial, and industrial sectors, necessitates a comprehensive reassessment of the existing water supply infrastructure to ensure its sustainability and adequate capacity to meet the projected water demands, considering factors such as population growth rates, water consumption patterns and the impact of climate change on water availability. This reassessment should also consider the potential for efficiently managing and conserving water resources, as well as identifying opportunities for upgrading and expanding the existing water

The terrain is varied in the study area (Fig. 2), primarily characterized by residential population, followed by some public consumers. Water distribution is distributed only by pumping.

**Fig. 2.** 3D study area (Google Earth)

The initial water distribution system for this zone was implemented in the early 1970s. It initially consisted of cast iron or steel conduits.

***Data***

The data used for the development of the water supply model includes elements which are directly inter-connected like: conduits, manholes, flap valves, pump or reservoir. The information about water demand and water consumption was assigned to each node. This data is obtained from the water utility company's geographic information system (GIS).

The demand patterns include information about the water consumption patterns of the neighbourhood, such as the average daily demand, peak demand, and seasonal variations. This data is obtained from historical water consumption records or from field measurements. The pressure requirements include information about the minimum and maximum allowable pressures in the system, as well as the desired pressure levels at specific locations. This data can be obtained from the water utility company's design standards or from field measurements.

***Methodology***

For the analysis of this study, EPANET 2.0 was chosen together with GIS software. EPANET was utilized to evaluate the pressure in the water supply system while GIS provided geographic data, model synchronization and results interpretation.

To ensure accurate results, it is important to preprocess the data carefully. This includes verifying inconsistencies in the data, removing missing values, and formatting the data into the required input format for EPANET. Furthermore, correlation analysis and regression techniques can be used to identify relationships between variables, such as conduit diameter, material, roughness, and pressure levels.

After creating the model, it's crucial to calibrate and validate it. The calibration was done by adjusting the roughness coefficient, the demand of consumers and by adjusting the flap valve loss coefficients. The model parameters were repeatedly adjusted until they approximately replicated the behaviour of the actual water supply system.

The steps used to create the model consists of verifying the data and missing information and processing the water system in GIS, building the hydraulic model in EPANET and analysing the results of scenarios, summarized in the flowchart below (Fig. 3).

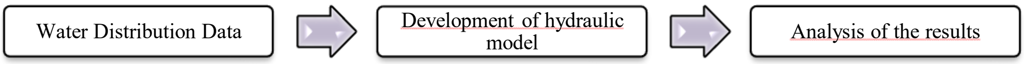



**Fig. 3.** Flowchart Methodology

The GIS shapefiles were transferred to EPANET as an input file (INP), offering precise georeferenced data, including conduit length, ground elevations at the nodes and diameter of conduits.

The units for flow rate used in EPANET model were CMH. The head loss formula utilized for analyses was Darcy-Weisbach (D-W). The properties of nodes and pipes are given in Table 1. The base demands were assigned for each node. The material of the conduits used was HDPE. The benefit of the HDPE pipes is their flexibility which lead to be installed also in coiled form which reduce the number of joints and fittings [8]. Water pressure and its corresponding change in its values were recorded for a one-week period, with time steps of one hour. Seven scenarios were created to analyse how pressure will evolve in the existing situation of water distribution system under different conditions if the demand increases near future.

**Table 1**. Model properties

| Pipe ID | Length [m] | Diameter [mm] | Material |
|---|---|---|---|
| Pipe_163 | 3.41304 | 110 | HDPE |
| Pipe_165 | 82.05765 | 63 | HDPE |
| Pipe_166 | 146.5997 | 63 | HDPE |
| Pipe_168 | 2.890577 | 110 | HDPE |
| Pipe_2911 | 57.60604 | 63 | HDPE |
| Pipe_3027 | 97.32491 | 110 | HDPE |

## Results and Discussions

An analysis of the pressure in the water supply system of a small area of Bucium neighbourhood was conducted to assess the impact of increasing demand on the system's performance. This analysis considered the expanding population of the residential area and the resulting increased demand for water. The results obtained from EPANET model provide valuable information on the hydraulic performance of a water distribution network.

Several scenarios were created in the EPANET model to simulate the performance of water supply system under various conditions:

1. Base Case: Current demand conditions 2026
2. Base Case + New Residential Area 2026: 5% increase in demand
3. Base Case + New Residential Area 2027: 10% increase in demand
4. Base Case + New Residential Area 2028: 15% increase in demand
5. Base Case + New Residential Area 2029: 20% increase in demand
6. Base Case + New Residential Area 2030: 25% increase in demand
7. Base Case + New Residential Area 2031: 30% increase in demand

All simulations were run for a period of 168 hours, with peak demand occurring during morning and evening hours. Results from the hydraulic water models include information about demander pressure for each object in the network (node/conduit). Results quantify the relationship between demand patterns and water pressure propagation in HDPE pipes, validating the hydraulic model's ability to reproduce observed dynamics across the network.

First scenario includes actual situation of water supply system. (fig. 5 – only green pipes). For the second scenario (fig. 5 – all pipes, green and blue) there was developed a newly designed residential area in which we have several new consumers. This area will be supplied through the node – Junction_280, and all the new pipes will be on the left of Junction_280. Following the hydraulic simulation, it is observed according to the basic requirement that the pressure in this area is seriously affected – negative pressure recorded (fig. 5 – b). For this reason, a decision must be made regarding the improvement of the system and providing adequate pressure.

This design stage clearly demonstrates that a pumping station is needed to supply this area with optimal conditions, so that the pressure is ensured within normal parameters. Considering the topology of the land and the water requirement, we chose a pump with the following characteristics: pumping height – 70 m and flow rate – 18.74 m3/hour.

The choice of this pump with these characteristics was also made since the existing network is expected to be expanded, including the water needs for this area. This will be positioned downstream of Junction_280.

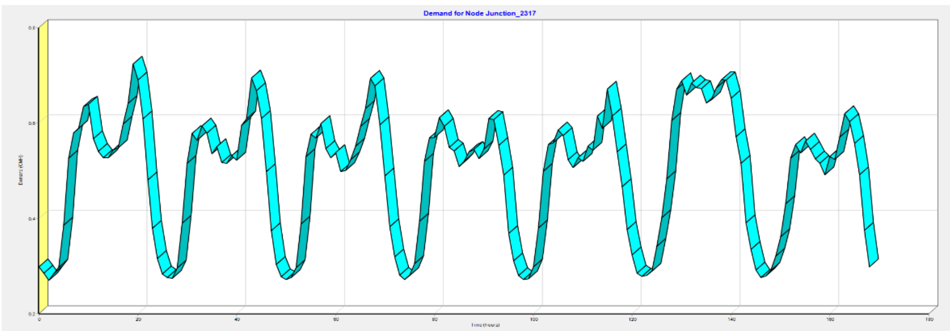
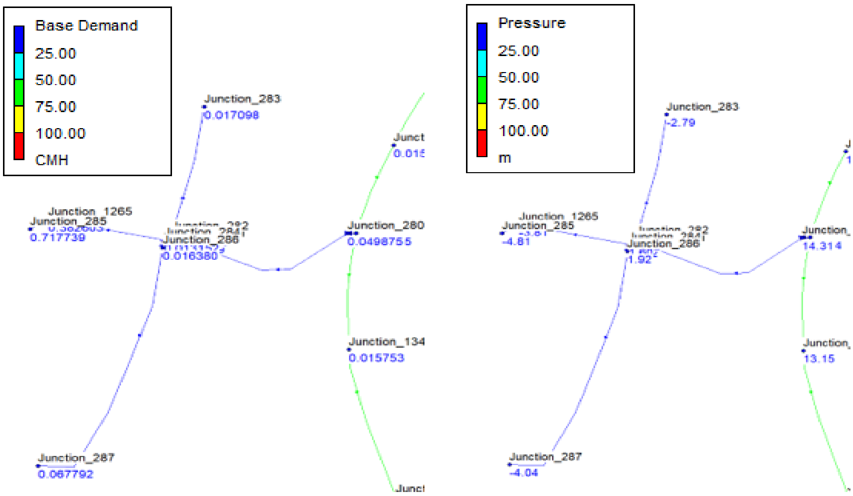



**Fig. 4.** 2026 - Evolution of demand for node Junction_2317 after a simulation of 168 hours – graph view in 3D

In Fig. 4 the graph provides a comprehensive visualization of the fluctuations in water demand at Junction_2317, allowing for a detailed examination of the patterns and trends in water demand over time. The analysis of the graph revealed that the peak demand for water at Junction_2317 occurs during the late afternoon and early evening hours, which corresponds to the typical usage patterns of residential and commercial customers. The 3D graph also shows that the demand for water at Junction_2317 fluctuates significantly throughout the day, with periods of low demand during the late evening and early morning hours.

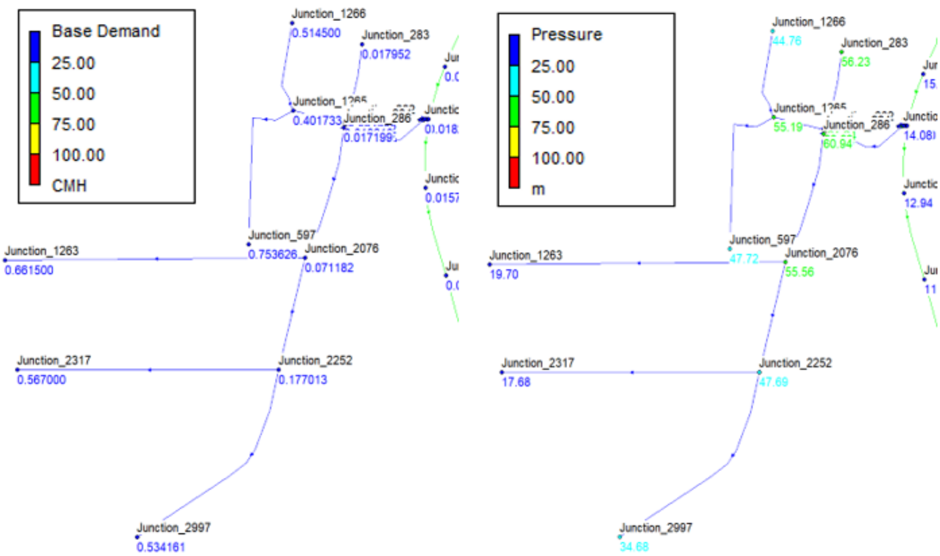
For the third scenario, we have estimated an annual increase in water demand of 5% compared to the reference year 2026. Through these scenarios, we want to observe how the pressure in the system will be influenced depending on the annual increase in water demand. The observed evolution of hydraulic pressure in the HDPE conduits reveals how transient flows, material viscoelasticity, and network demand interact with the shape pressure profiles across the distribution system.

In 2027, the existing network is expected to expand, and implicitly the water demand by 5% compared to 2026. After reconfiguring the new system, we obtained the following results regarding the water demand and the pressure in the nodes – Fig. 5. It is observed that the choice of the pump with the characteristics already mentioned demonstrates that the targeted hydraulic parameters are met – adequate pressure and satisfied water demand for consumers.




a) b)

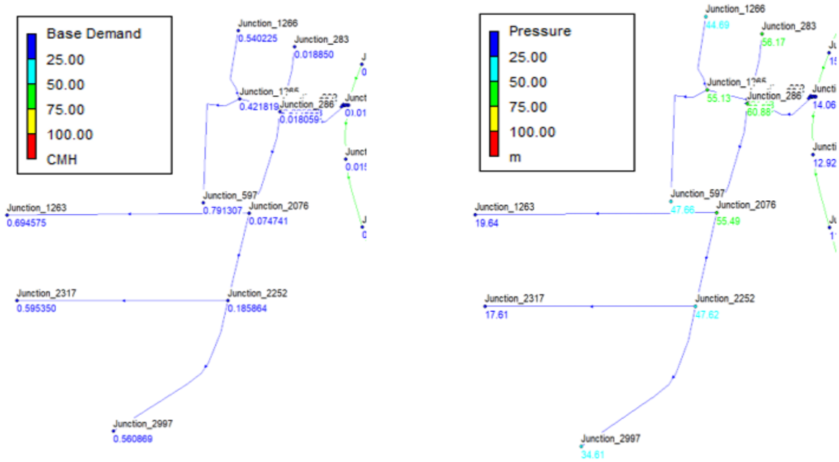
**Fig. 5**. Recorded base demand and pressure values for 2026:
a – base demand recorded for all junctions; b – pressure recorded for all junctions




a) b)

**Fig. 6**. Recorded base demand and pressure values for 2027:
a – base demand recorded for all junctions; b – pressure recorded for all junctions

The most unfavourable node seems to be Junction_2317 with value 17.68 meters of water. But this value is a good one and is within normal parameters for this area – Fig. 6.
For 2028 we have estimated a 5% increase compared to 2027. According to the attached pictures, a slight decrease in pressure is observed in all nodes, including the most unfavourable node. But, even so, the pressure is ensured here too.

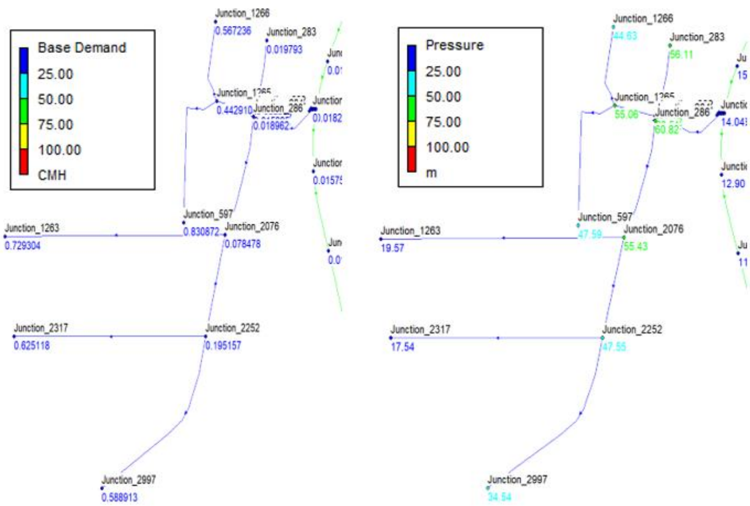



a) b)

**Fig. 7**. Recorded base demand and pressure values for 2028:
a – base demand recorded for all junctions; b – pressure recorded for all junctions

Although the Junction_2317 with a value of 17.61 meters of water appears to be the most critical node, this value remains within acceptable bounds – Fig. 7.

For 2029 we have estimated a 5% increase compared to 2028. According to the attached pictures, a slight decrease in pressure is observed in all nodes, including the most unfavourable node. Nevertheless, the pressure at that location remains adequate.

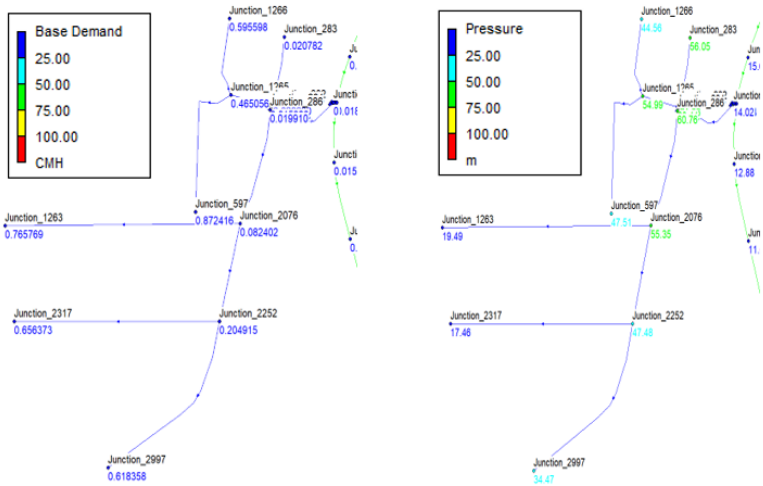



a) b)

**Fig. 8**. Recorded base demand and pressure values for 2029:
a – base demand recorded for all junctions; b – pressure recorded for all junctions

The most critical node seems to be Junction_2317 with value 17.54 meters of water. But this value is a good one – Fig. 8.

For 2030 we have estimated a 5% increase compared to 2029. According to the attached pictures, a slight decrease in pressure is observed in all nodes, including the most unfavourable node. But, even so, the pressure is ensured here as well.

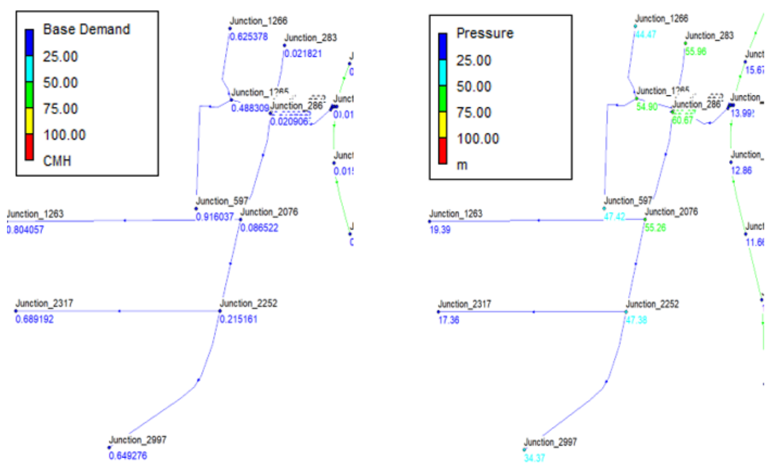



a) b)

**Fig. 9**. Recorded base demand and pressure values for 2030:
a – base demand recorded for all junctions; b – pressure recorded for all junctions

The most unfavourable node seems to be Junction_2317 with value 17.46 meters of water. But this value is a good one – Fig. 9.

For 2031 we have estimated a 5% increase compared to 2030. According to the below Fig. 10, a slight decrease in pressure is observed in all nodes, including the most unfavorable node. But, even so, the pressure is ensured here too.




a) b)

**Fig. 10**. Recorded base demand and pressure values for 2031:
a – base demand recorded for all junctions; b – pressure recorded for all junctions.

The most critical node seems to be Junction_2317 with value 17.36 meters of water. But this value is a good one. Through the scenarios carried out, we have highlighted the evolution of the water distribution system – Fig. 10.

The system decreases slightly over time but remains within acceptable limits. This suggests that the expansion of the water network and the increase in demand of 5% annually can be accommodated by the existing infrastructure, at least in the short to medium term. The pressure in the system from all nodes of this network is successfully ensured, as there are no very large differences between the pressure and water demand, comparing the annual values analysed. The water demand from all nodes is ensured within the parameters. Also, the choice of the pump with the mentioned characteristics demonstrates that in the medium term it is a very good choice.

The 3D graph (Fig. 11) for the year 2030 reveals an increase in water demand at Junction_2317, with a peak value of approximately 0.2 cubic meters per hour, which represents a small increase compared to the previous year.

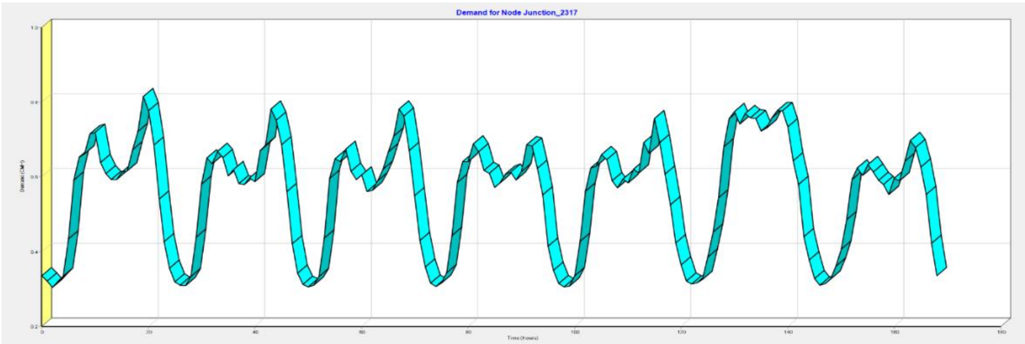



**Fig. 11**. 2030 - Evolution of demand for node Junction_2317 after a simulation of 168 hours – graph view in 3D

This increase in water demand is expected to continue in the coming years, with a projected growth rate of 5% annually.

## Conclusions

The findings of this study demonstrate how important it is to consider the impact of increased demand for the water supply system's pressure levels. The results suggest that the current system can accommodate moderate increases in demand but may struggle to maintain adequate water pressure during periods of high demand, particularly if the population continues to grow at its current rate.

The evolution of water pressure within the HDPE conduits in the water supply networks is a complex phenomenon. It is influenced by hydraulic transients, properties of the material and operational conditions. The viscoelastic behaviour of HDPE material substantially influences the propagation of water pressure wave. This results in an attenuated response of the water pressure response and must be accounted in analysis of the supply system. Transient events and varying demand patterns contribute to dynamic pressure variabilities, which can have an impact on the performance of the conduits and the reliability of the entire system. Long-term fluctuations like as aging or sediment accumulation can further modify hydraulic properties, emphasizing the need for continuous monitoring and advanced modelling approaches. To optimize the performance of water supply network and to minimize the failure risks it is necessary to integrate these factors into the hydraulic design.

The study highlights the significance of conduit pressure in maintaining optimal pressure levels and recommends that water utility operators and managers consider implementing demand management strategies and water conservation measures to mitigate the impact of increased demand on the system.

## CRediT author statement

Anca Zaborila and Catrinel-Raluca Giurma-Handley analysed the data, developed the methodology, conceived and planned the simulation scenarios and performed the hydraulic modelling. Petru Cercel and Ion Giurma monitored the evolution of the water supply system and calibrated the model. All authors discussed the results and contributed to the writing of the manuscript of the current article.

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*Received: March 28, 2026*
*Accepted: June 04, 2026*