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Hydraulic Analysis Study and Redesign of The Water Distribution System Simulation Using GIS- EPANET, Case Study: Laylan Sub-District, Kirkuk City, Iraq

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ABSTRACT

This research project focused on examining and (rehabilitation) redesigning water networks in a city using the GIS-EPANET program in hydraulic network analysis. Due to the availability of outline data about the study area from the municipality's water distribution system (WDS), this study dealt with four cases. From a statistical calculation, the last case was best optimized, which resulted in a high pressure and an acceptable velocity as a result of high mean pressure (13.58) m, logical mean velocity (0.43) m/s, and accurate standard deviations of 1.214 and 0.48 for pressure and velocity, respectively. The study found that the network had a shortfall in pressure, estimated at 40%, due to the lack of expansion to accommodate the growing population. However, after conducting the analysis and identifying the problem, it was found that all regions were receiving adequate amounts of water. Nevertheless, the water speed in the pipelines throughout the network was deficient, below the recommended rate, with a minimum velocity of 0.02 m/s in the pipe (p3) but a minimum pressure of 7.02 m at the junction (607), indicating that the network design was ineffective. Comparing the results obtained with the real-world situation, it was discovered that the network has many violations and disruptions, causing water loss and resulting in low pressure reaching the customers. While the study found that the pressure inside the network was within acceptable modeling limits of (7–12) m, there was a reduction in the pressure charge due to the frequent use of water pumps inside the houses, especially as the circulated area was pumped further away. The error between the model and the real problem may be attributed to water leaks and disruptions from trees, gardens, landscaping, and livestock grazing, as well as the absence of a counter to calculate the water discharge volume to consumers.

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1. Introduction

1.1 General:

Water is necessary for all kinds of life on Earth. A person can go for weeks without sustenance but only a few days without water [1]. The global water shortage and conflicts regarding access to water have spurred researchers and scientists to explore alternative sources beyond surface water. Groundwater is one such resource that can be tapped into to meet the growing demands of both the population and industries. Table (1) shows the Iraqi, (WHO), and (European) specifications for potable water. With this in mind, solutions and plans are currently being developed to harness and optimize the utilization of available groundwater efficiently [19]. table (2) shows the specifications and nature of the wells located in the study area. One of the issues with intermittent water supply systems is the highest flow generated at certain times of the day, which is typically much higher than in a constant supply system. The primary effect is decreased pressure and flow at the system's extremities or highest spots. As a result, there is inequity in water delivery and customer grievances. Some system sectors must be given a separate supply plan to minimize peak flow. Consequently, the supply trajectory changes, and the peak flow decreases. This reorganization must be founded on numerous quantitative and qualitative technical factors to achieve an optimum allocation plan [2]. To maintain and nurture our organisms, we need water. Purified water, devoid of contaminants, invigorates and rejuvenates our systems, aiding in recovering from various diseases. Conversely, polluted water poses a health hazard [3]. Bacteria can thrive and lead to sickness if water is left stagnant in pipelines for 20 hours. Any interruption in the water flow can lead to reduced pressure, creating a negative pressure environment that increases the chance of untreated waste being drawn into the water supply. To maintain a clean water system, it is essential to ensure constant positive pressure in the pipelines [4]. It is important to consider the potential consequences of implementing intermittent water sources due to water scarcity, as poor management may lead to unequal distribution to customers and subpar service standards. This should be kept in mind during the planning and operation of such networks [5]. To ensure equal supply and people-driven service levels (PDLS), a set of modified rules serves as the standards' driving force. To achieve this, four design categories include supply length, supply intervals, pressure at the output (or flow rate at the outlet), and other factors such as link type and location (especially for standpipes). The connection between water pressure at a hookup and its outflow is determined through techniques and methods used to calculate all four factors [6]. As the agricultural population shifted towards urban areas, there was a rapid expansion of villages and cities. This is exemplified by the increase in towns with populations exceeding one million, from 78 to 290, between 1950 and 1990. It is anticipated that this number will exceed 600 by 2025. Globally, approximately half of the world's population now resides in cities. Two-thirds of this urban populace lives in developing nations. By 2025, the ratio of urban residents in developing nations is projected to reach four times that of industrialized nations. With the concentration of people in metropolitan areas and the rapid expansion of urban centers, public services in many villages and cities across the emerging world are struggling to keep up, leading to chaotic conditions. From 1990 to 2000, the proportion of urban residents without access to improved water sources rose from 5% to 6%, representing an increase from 113 million to 173 million people, as per WHO/UNICEF survey data. The water distribution system (WDS) is considered one of the city's infrastructures, consisting of physical elements such as pipes, tanks, reservoirs, pumps, valves, etc. The provision of drinking or potable water to end users is essential; hence, the design of a new water distribution network or the expansion of an existing one must prioritize an effective water supply. For individuals involved in designing, constructing, and maintaining public water distribution systems, computing flows and pressures in a complex network have been a significant problem and source of interest. A very complex challenge arises from the analysis and design of pipe networks, especially when the network has a variety of pipes, as is commonly the case in water distribution systems in big metropolitan areas [7]. Many studies have been conducted on WDS hydraulic analysis to evaluate the efficiency of pipes using the Water Cad program, like "Evaluation and Analysis of the Effects of Some Parameters on the Operation Efficiency of the Main Water Pipe in Karbala City" [8]. "Water pressure equalization in pipe network case study: al-Karada areas in Baghdad," where the Globe program balances pressure by minimum cost by choosing a smaller pipe diameter within adequate pressure[9]. Watercad-GIS was also used in another zone of Al-Karada for hydraulic analysis and modeling [21]. Using EPANET2.0 software as a tool to enhance the simulation of the hydraulic behavior of the water supply distribution network, modeling may determine any value of variables by studying the proposed Taq-Taq dams in Erbil city without any improvement to increase pressure or decrease losses [10]. Through the application of state-of-the-art computational tools, this research seeks to provide a deeper understanding of the underlying factors influencing pressure fluctuations and their impact on the performance of the water distribution infrastructure [16]. By addressing the complexities of water flow and pressure management, this study contributes valuable insights that can inform decision-making processes for urban planners, water utility operators, and policymakers. By leveraging computer program simulations [17], pressure analysis plays a critical role in identifying potential issues within the system, including leaks, bursts, and inefficiencies, which can lead to water loss, energy wastage, and compromised water quality [18]. It is known that networks transporting liquefaction water require hydraulic monitoring and water delivery under acceptable pressures from consumers, which requires conducting a hydraulic analysis and indicating the results. The importance of this study is twofold. First, it can be carried out in auditing the hydraulic performance of the liquefaction network in the region, and the region relies on the correctness of its questions, which are pumped directly to the network in addition to GIS maps to show pressures in parts of the network. Second, the hydraulic analysis identifies areas (nodes) of weak pressure and proposes appropriate solutions to address them according to four scenarios.

1.2 Objective

The distribution system aims to provide water to every home, business, and public space. Water must be given to each home adequately and at the desired pressure. As a result, water needs to be transported to the city's streets and roadways before being delivered to individual homes. A carefully thought-out distribution system carries the water from the treatment facility to the separate homes to fulfill this duty. As a result, a distribution system comprises pipelines of various diameters that transport water to the streets, valves that control the flow, service connections to each residence, and distribution reservoirs that store the water that will be supplied into the distribution pipes. The water is pushed directly into the distribution pipes or kept in a water tank before being delivered into the distribution pipes. The primary goal of distribution systems is to create enough water pressure at various places, such as the consumer's tap and the distribution's elevation, to determine where the water treatment facilities are located. This project aimed to combine Mapinfo GIS-ArcMap (10.8) software with a hydraulic model (EPANET 2.0/2.2) to create a more effective management system for a water distribution network in a semi-arid environment. There is an absence of specialized studies dealing with the future adequacy of potable water projects in the city of Kirkuk Governorate in general and in the Lyalan sub-district. However, the increasing population consequently increases the demand for clean water.

1.3 Study area (case study)

The water distribution system was designed for the Nowroz zone in Laylan sub-district/Daquq town, which is 25 km east of Kirkuk city and located at the latitudes of 35°18'46.86"N and 44°30'29.98"E. The system consists of 66 nodes and 71 pipes. The Newroz water station is found in the northwest of Laylan. The water treatment plant (WTP) consists of one underground concrete water tank with a capacity of 200 cubic meters, one groundwater concrete tank with a capacity of 400 cubic meters for collection, and a concrete elevated tank with a capacity of 300 cubic meters, located at an elevation of 12 meters from ground level. The water sources are from four healthy boreholes specifications in Table 2, which are uplifted by a submersible pump with a design capacity of 100 cubic meters per hour but pumping 60 cubic meters per hour to rise to the ground water tank above. Afterward, the pumps with a rated flow of 160 m3/h and a head of 50 meters rise to the elevated tank above for mixing with chlorine to serve the neighborhoods of Newroz by gravity, as shown in Fig. 2 (b). The station has undergone expansion and change since its design, although more than 35 years have passed since it began working.

Nowadays, most of its pipes are made of polyvinyl chloride (PVC) and galvanized steel, with diameters of 6 inches and 4 inches, respectively. The network contains 71 pipes, with lengths of 2744 m and 3548m and diameters of 4 inches and 6 inches, respectively. The junctions are by (66) nodes. The increasing population growth and urbanization led to the extension of new pipes to serve urban areas. To address this, the Laylan water distribution directorate decided to add wells with small chlorination stations directly to locations with

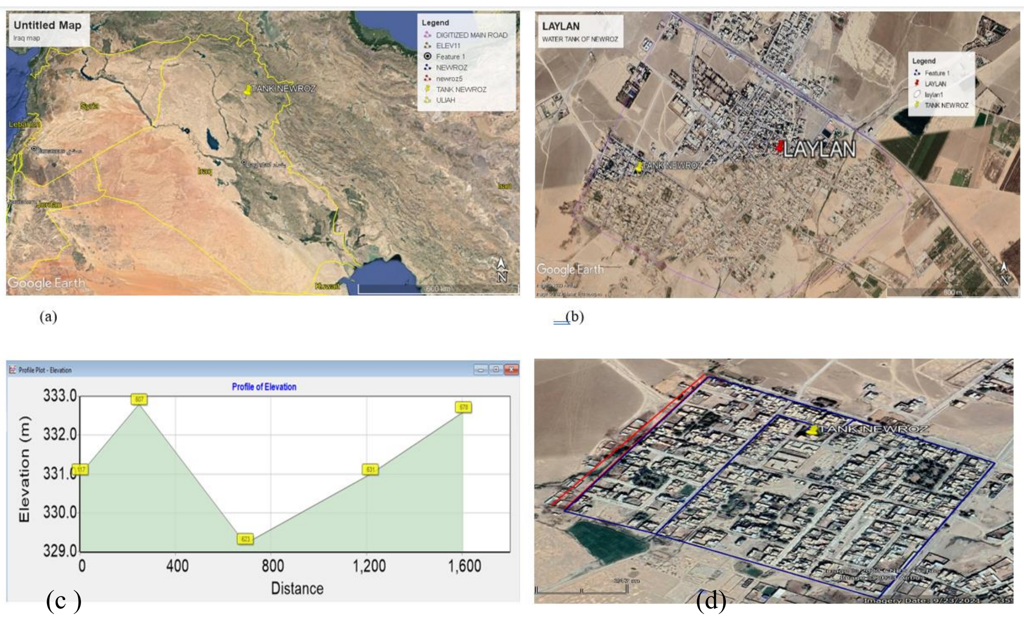


Figure1. (a) Iraq map, (b) Laylan, (c) Elevations of sample of nodes, (d) Newroz zone

Table 2. Samples from the field by the Health directorate, Water directorate, and Authors for water quality in wells from (2022/01/01 to 2023/01/01)

Limiting	**Iraqi Ministry of Health/Laylan directorate field take it**		**Iraqi Ministry of Construction, housing, municipalities and Public Works/Water Directorate field take it.**		**Field takes it by authors.**	
mg/L	Mini. Value	Max. value	Mini. value	Max. value	Min. value.	Max. value.
Cl chloride	25	48	30	46	27	50
Mg Magnesium	27	33	20	30	17	40
NO3	Not applicable				-	-
Na Sodium	12	30	11	31	15	30
SO4 Sulfate	34	70	23	75	32	60
T.D.S	320	400	400	410	380	390
T.H	196	300	225	400	190	290
Ca caliciume	48	58	45	52	42	54

Table (3). Classification of Total Hardness in Water [22].

Total hardness(mg/l)	**Water type**
Less than 50	Soft
50-150	Medium hard
150-300	Hard
More than 300	Very hard

2 Methodology

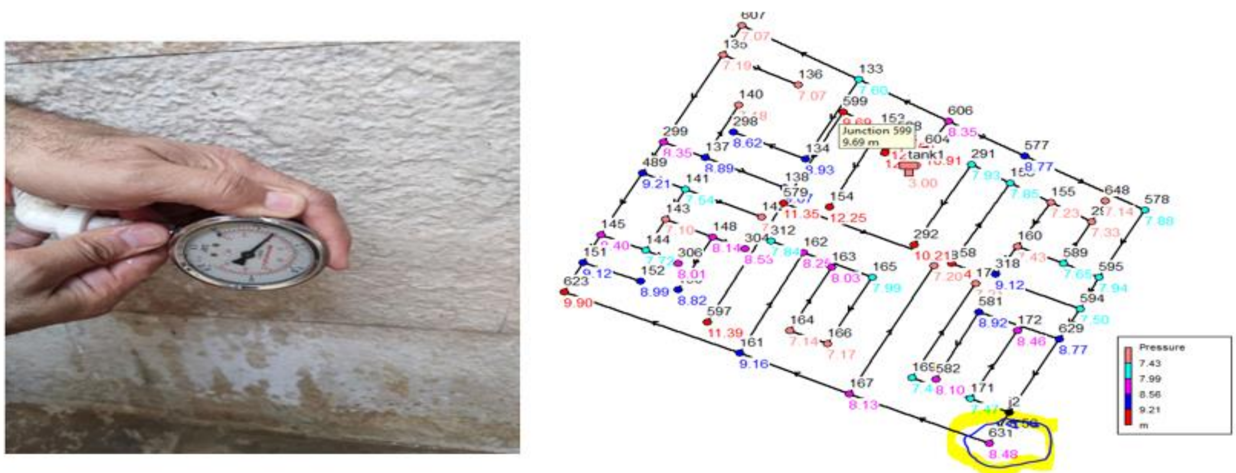
2.1 Materials and tools

The methodology consists of two parts. The first is physical, and the other is not physical, as below: First, physically, the materials are in the field, reading pressures by using a total of two pressure gauges (Fig. 2(a)) below at the same time and place to calibrate one to another to determine the pressure at points of consumption and then comparing the reading with the model. Furthermore, the water is lifted to the hoses of houses to see their height.

Second, the non-physical tools in Newroz are input elevations of nodes using Google Earth Pro software and locations incited by GPS applications like selected nodes, as shown in Fig. 1 (a, b, d). The elevations shown in Fig. 1 (c) were obtained using Google Earth software. Also, use the geographic information system (GIS) shape file in EPANET (sh2epa). A new tool has been developed by "Armando Barreto,." The tool is free to use and can extract geometric data from ESRI-shape files and convert them into EPANET INP files. After running, it gives pressures for junctions, as in Fig. 2(b). The application has been designed with a user-friendly interface similar to that of dxf2epa, providing a familiar experience for the user [11].

Table (4). pressure reading by gauge of field and Epanet model currently for 5 nodes.

Node ID	Elevation	Demand	Head	Pressure(m) (EPANET)	Pressure (Actual)m	Note(error)%
117	331	0	343.25	12.25	12.2	0.41
607	332.8	.71	339.87	7.07	7.0	1.0
623	329.2	.71	339.1	9.9	8.25	17
631	331.1	.71	339.48	8.48	7	18
578	332.6	.71	340.48	7.88	4.9	37



a b

Figure2. (a) reading gage pressure field (8.48) m , (b) with model (EPANET). Read incite (Node 631) is 0.67 bar which approx. equal to 7m.

2.2 Base Demand and Water Distribution Design

Two methods can be used to calculate this demand:

First demand per person with population and base demand values (250 and 200 liters per day per person for urban and rural areas, respectively), which is greater than the value of table (8) and table (9), were adopted and considered acceptable values based on water consumption by the Iraqi Ministry of Construction, Housing, and Municipalities No. 103169 on November 17, 2020, for the city center and its environs [12]. Water demand (DC) for the Newroz zone in the Laylan sub-district is estimated at 200 liters per person per day based on the above guidelines. EPANET 2.2 software for hydraulic problems was employed in the simulation. [6]. The number of consumer buildings was 450, with an average number of members per building of 5 people, which comprised the area zone's total population (p). Equation (1) calculated the required water demand at a specific node [13]. However, this study assumed all nodes had equal demand.

$$Dt = Dc * P \qquad (1)$$

Dt; the Total demand in L/day,
Dc; Demand per capita L/day, Dc= 200 L/day/ capita [12],
P: number of Population, P =450 houses
Db = Dt/Nj ,No. of person per house = 5 capita (person)
Db; Base Demand L/s,
Nj; Number of Junctions
Dt =200 ∗ 5 ∗ 450 = 450,000 L/d
Nj=66 nodes
Time of operation = 4 hours/day

Dt= 450000/4=112 500 L/h (2)
=112,500/3600=31.25 L/S
Db=31.25/66=0.47\ l/s

The distribution system's peak flow was calculated by multiplying the daily highest demand by a factor of 1.5 table (7). EPANET 2.2 program is built on the hydraulic theory of water distribution in pipes. The "Hazen-Williams" equation, with C as the pipe roughness coefficient, is the mathematical model utilized in this design, with C as 130.

Db=0.47*1.5=0.710\ l/s. (3)

Second by Unit area demand, the amount of water the town needs daily in relation to its entire area is known as the unit area demand. The total daily demand is 600,000 liters. Total area = 485*564= 273540m^2.
Unit area demand for Newroz=600000/273540 = 2.193 lit/ m2/day. Areas were estimated for this analysis using Google Earth, which makes them inaccurate.

2.3 Method of System Distribution

There are three methods for the systems: 1) a gravity system, 2) a pumping system, and 3) a system that combines gravity and pumping.[13]

2.4 Distribution Networks' Layout

The four main layout techniques for distribution systems are as follows:
The options include dead-end or tree systems, gridiron systems (loop systems), circular or ring systems, and radial systems.

2.5 The hydraulic head loss caused by pipe friction in which water moves.

The Hazen-Williams, Darcy-Weisbach, and Chezy-Manning formulas can all be used to calculate by Equation (2). The Hazen-Williams formula is the most frequently used to calculate head loss in the US. It was designed exclusively for turbulent flow in water and cannot be used for other liquids. The formula developed by Darcy and Weisbach is the soundest in theory. It applies to all liquids and all flow regimes. For open channel flow, the Chezy-Manning formula is more frequently employed.
The following equation is applied to each formula to determine the head loss distance between the start and the end: the pipe's node.

$$h_l = A * q^B \qquad (4)$$

h_l = head loss (m or ft),
q = flow rate (m3/s, or gpm),
B is the flow exponent, and A is the resistance coefficient. For each of the formulations, the resistance coefficient and flow exponent values are listed in Table (4). Different pipe roughness coefficients that must be obtained empirically are used in each formula. The general ranges of these coefficients for several types of new pipe materials are listed in Table (5). Be aware that a pipe's age can significantly impact its roughness coefficient. Using the Darcy-Weisbach equation, EPANET computes the Friction factor (f) using various techniques depending on the flow regime.

- For laminar flow (Re < 2,000).
- For fully turbulent flow (Re > 4,000).
- For transitional flow (2,000 < Re < 4,000)

Pipes were open or closed based on conditions like tank levels or nodal pressures. These conditions trigger preset times for the pipes to open or close. Essentially, the pipes respond to the changing needs of the system automatically.

Table 5. shows the Hazen-Williams formula, Darcy-Weisbach formula, and Chezy-Manning formula, with definition of all parameters and common factor between equations.

Formulas definition	Hazen-Williams	Darcy-Weisbach	Chezy-Manning
Head loss h_f	hf = 10.67 * C * L * Q^1.85 / d^4.87	hf = f * L * v^2 / 2 * g * d	hf = K * L * v^2 / 2 * g * R
Coefficients	Hazen-Williams coefficient, (C) dimensionless	Darcy-Weisbach friction factor (f), dimensionless	Chezy coefficient, (K)dimensionless
L	Pipe length in meters	Pipe length in meters	Pipe length in meters
Q	Volumetric flow rate in cubic meters per second	Average fluid velocity in meters per second	Average fluid velocity in meters per second
Diameters, or radius	Inside pipe diameter (d) in meters	Inside pipe diameter(d) in meters	Hydraulic radius(R), which is the ratio of the pipe cross-sectional area to the wetted perimeter
G	Acceleration due to gravity (9.81 m/s^2)	Acceleration due to gravity (9.81 m/s^2)	Acceleration due to gravity (9.81 m/s^2)

Table 6. Pipes' new and old roughness coefficients are used with Rynolds number to find friction factor (f) of the Darcy-Weisbach formula, coefficient for Hazen William, and Chezy-Manning formulas.

Material	**Darcy-Weisbach coefficient**		**Hazen-Williams coefficient**	**Chezy coefficient**
	New pipe (mm)	Old pipe t (mm)		
Commercial steel	0.002	0.003	100	0.01
Ductile iron	0.0015	0.0025	120	0.01
Concrete	0.0025	0.005	100	0.013
PVC	0.001	0.002	150	0.012
HDPE	0.0008	0.0015	150	0.011

2.6 Minor Losses

Minor head losses happen when bends and fittings in a pipe network cause additional turbulence. Whether or not considering these losses is essential depends on the network layout and desired level of accuracy. To account for it by Equation (3), a minor loss coefficient can be assigned to the pipe, and the minor head loss is then calculated by multiplying this coefficient with the velocity head of the pipe.

$$h_L = K\left(\frac{V^2}{2g}\right) \quad (5)$$

K is the minor loss coefficient, v is the velocity (Length/Time), and g is the gravitational acceleration (Length/Time2). Minor loss coefficients (K) for various types of fittings are shown in Table 3.

Table 7. Minor loss coefficient [7].

Fitting	Minor loss coefficient (K)
Globe valve	0.5 to 2
Gate valve	0.2 to 0.6
Tee	0.1 to 0.3
Elbow	0.2 to 0.5
Expansion joint	0.05 to 0.1

2.7 Computation of pressures in the pipelines

The pressure present at the node affects the flow rate through the emitter:

$$q = C\, p^{\gamma} \quad (6)$$

Q stands for flow rate (m^3/s), P for pressure(m), C for discharge coefficient(dimensionless), and *gamma* exponent of pressure (dimensionless). 0.5

is for sprinkler heads and nozzles, and the maker typically. [14]

2.7.1 The network is down

When using EPANET, a network is deemed disconnected if there is no way to provide water to all nodes who need it. This may occur if there are no open links between a tank, reservoir, or junction with negative demand and a junction with demand. If a closed link is to blame, EPANET will still try to calculate a hydraulic solution, sometimes with very high negative pressures, and will attempt to pinpoint the issue link in its status report. If no connecting links are present, EPANET will be unable to solve the hydraulic equations for flows and pressures, resulting in an error 110 message during analysis. During extended simulation, nodes can become disconnected as links change over time.

2.7.2 Negative Pressures Exist

EPANET will alert you with a warning message if it detects negative pressures in junctions with positive demands. This could mean an issue with the network design or operation. The presence of closed links in some parts of the network can cause negative pressures to occur, and in such cases, you may also receive a message warning you that the network is disconnected.

2.7.3 Fitting and Accessory

The following is a list of the different accessories that can be attached to the distribution systems:
(1) Sluice valves, also known as gate valves, (2) Air valves, (3) Reflux valves, (4) Relief valves, (6) Altitude valves, and (7) Scour valves.

2.7.4 Parameter Validation

The velocity parameter was validated using continuity Equation (5).

$$V = Q * A \tag{7}$$

$$A = \frac{\pi}{4} D^2 \tag{8}$$

Where;
V; velocity of flow through pipe (m/s)
Q; discharge through the pipe (m3/s)
A: section Area of the pipe (m^2)
D: diameter of the pipe (m)

2.8 Design Standards

Table 8. design standard for simulation contains the design standards for EPANET 2.0 and 2.2 that were applied for this design.

S/N	Description	Standard
1	Base Demand/Average Daily Demand	Based on a daily use per person of 200 liters for the entire residential population.
2	Factor of Maximum Daily Demand	1.25-1.5
3	Factor of Peak hour demand (PHD)	1.5-3.0
4	Head Loss	
5	Head loss for pipe diameter of 100 – 300mm	1.0 – 3.0 m/km
6	Head loss for pipe diameter greater than 300mm	2.0 – 5.0 m/km
7	Velocity	
8	Velocity of flow for pipe diameter of 100 – 150 mm	
9		0.3 – 1.0 m/s (optimum 0.4 m/s)
10	Velocity of flow for pipe diameter of 200 – 300 mm	0.4 – 1.5 m/s (optimum 0.5 m/s)
11	Velocity of flow for pipe diameter greater than 300mm	1.6-3.0 m/s (optimum 0.5 m/s)

2.9 Demand of water:

Table 9. Requirements for water for domestic use [7]

S.NO.	statement	Water Consumption in Liters Per Person
1	Bathing	55
2	Washing of clothes	20
3	Flushing	30
4	Washing the house	10
5	Washing the utensils	10
6	Cooking	5
7	Drinking	5
	TOTAL=135	135

Table 10. water consumption for domestic animals and livestock [7].

Animals	Consumption of Water (Lt)
Cow & Buffalo	40 to 60
Horse	40 to 50
Dog	8 to 12
Sheep & goat	5 to 10

2.10 Model Input Parameters and Results

The following input data files are required to use EPANET, whether physical or non-physical, see Fig. 3 flowchart, and so the following result and report are obtained [15]:

Junction Report:

A junction report defines junctions as locations where links fuse and water enters or exits a network. Fundamental input data such as height above sea level, water demand rate, and initial water quality are necessary to gauge junctions effectively. The results are then computed for a single-period simulation or a time pattern period of a simulation, which includes results of head, pressure, demand, and water quality.

Link or Pipe Report:

The pipe report discusses how pipes function as links in a network that transports water from one area to another. EPANET, the software system referred to, assumes that pipes are always full. Additionally, the flow of water in the pipes moves From the area with higher internal energy per weight of water (hydraulic head) to the area with a lower head. To determine the pipe functionality, EPANET uses various hydraulic parameters such as start and end nodes, diameter, length, roughness coefficient, and status (open, closed, or containing a check valve). The pipe report also outlines different results from the piping analysis, such as flow rate, velocity color coded (Fig. 6) indicated for all cases, average response time along the entire pipe length, average water quality, and Head loss (expressed about them in table 4).

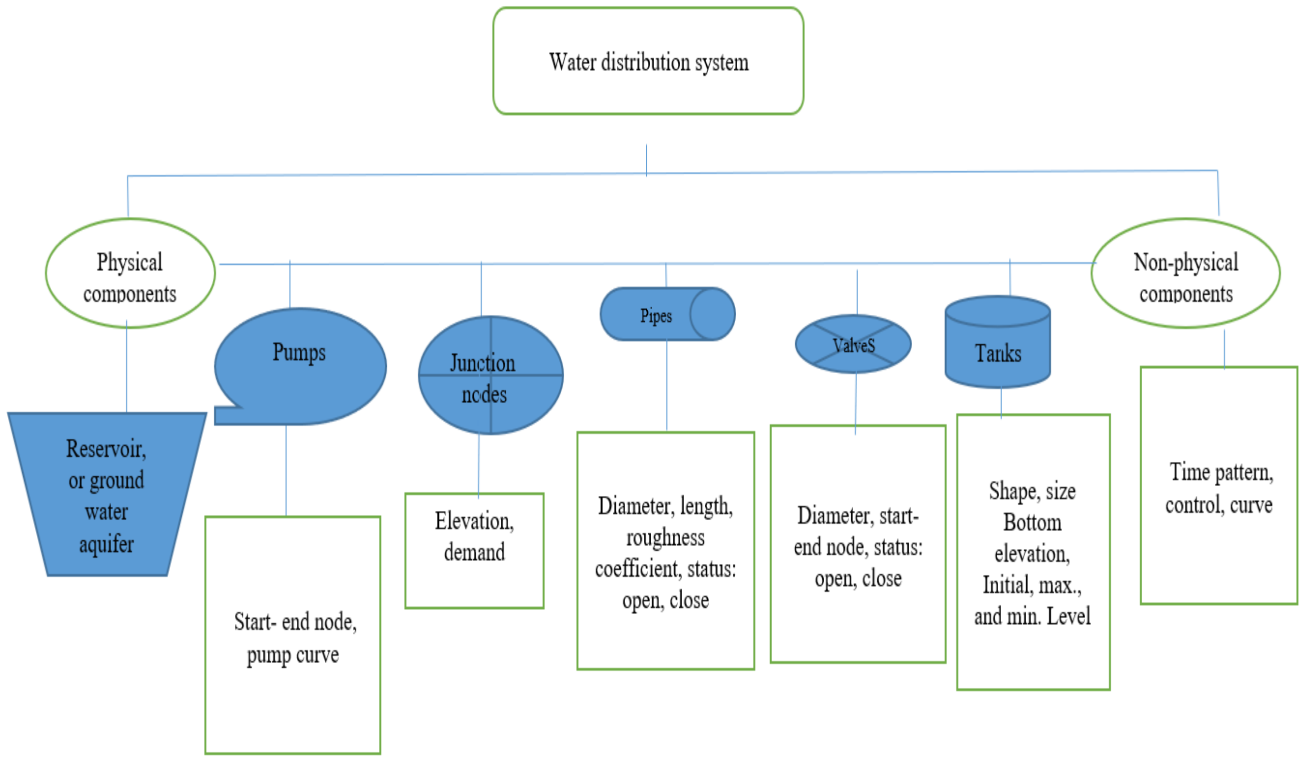


Figure 3. flowchart of model input for water distribution

3. Results and Discussion

The Laylan sub-district has buildings; the greatest are only one story high. Some buildings and the State Department have two stories. After collecting data on the distribution networks of the Newroz area and collecting maps from the Geographic Information System (GIS) shape file to EPANET (sh2epa), hydraulic analysis computes the pressures of nodes, flows, and velocities of pipes. Table 12 illustrates the results of the system.

By utilizing the technique outlined, outputs from EPANET are obtained. The results have been analyzed and compared between the computed results and the actual results of the junctions and the pipe report distribution networks for velocity. According to the EPANET2.2 model, the percentages of junctions with pressure below "7 m," above "10 m," and between "7.1 and 9.9 m" are 1.5%, 15.2%, and 83.3%, respectively. Figure 3 shows the profiles of pressures for all cases at the same selected nodes. Therefore, no significant problems have been identified in the model. However, in reality, there are many problems. We have noticed fluctuations in the residual consumers' pressures before the household pump, tabulated to show the difference between EPANET as in Table (10). Detailing the standards shows that 55% of velocities are below 0.3 m/s, 8% are above 1.0 m/s, and 37% are between 0.3 and 1.0 m/s. Figure 4 indicates the color code for all cases in all pipes. It collected the data and then entered it into the program to extract the tables and curves. The

results were compared to the actual measurements of pressures at the job site, and then we suggested three other models, all of which are the same as the data of the current model, except for a slight change. The contour plan of pressure and head at nodes is given in Figures 4 and 5, respectively. The analysis indicated that the pressure and head were at all the nodes of the system, which are summarized as follows:

- The Model 1 (currently), in which site data was entered, notes that the project is designed on a dead-end or tree system; as shown in Table (11), mean pressure (Ŭp) and standard deviation (σ_p) are 8.606 m and 1.407, respectively. On the other hand, the mean velocity (V̆) and standard deviation ($\boldsymbol{\sigma_v}$) are 0.45 m/s and 0.586, respectively, which are the minimum mean pressure with significant fluctuation.

- Model 2 connected each final point to either another final point or a point close in proximity and ensured that the connected pipes had the same properties. This effectively changed the system from a dead end to a loop. Observed a slight difference in the results compared to Model 1; mean pressure (Ŭp) increased by 15% of Model 1, where the result is 9.92m, and the standard deviation (sigma sub p) is more accurate, where the indications 1.102. Furthermore, the mean velocity (V̆) decreases by 30% in model 1, and the standard deviation ($\boldsymbol{\sigma_v}$) decreases by 10%, which is precise when model 2 shows mean velocity and standard deviation of 0.346 m/s and 0.529, respectively.
- In model (3), the water tank was added with the same capacity as the original tank in place of insufficient pressures, and the dead-end system was kept, resulting in a noticeable improvement compared to Model (2). (Ŭp) increased 6% rationally to model 1, where 9.134 m were obtained, and (Ŭp), and (σ_p) is 1.29; however, this is a decrease from model 2, but a more convergent rate to model 1.
- Model 4 integrates models 1, 2, and 3, simultaneously incorporating a connection to the loop system and an elevated water tank. Because we predicted the best mean pressure (Ŭp) and a standard deviation (σ_p) of 13.584 m and 1.214 m, respectively, besides (V̆), and ($\boldsymbol{\sigma_v}$) are 0.43 m/s, and 0.479 m/s, respectively. We observed a significant improvement compared to the second and third models. It is worth noting that model 4 is more expensive than the previous two. Model 4 is suggested and preferred by decision-makers in managing the project implementation. The area is subject to an increase in the proposed place for the construction of the water elevated tank, large areas belonging to the municipality. The tank is allocated for the construction of residential buildings according to the master plan of the city,

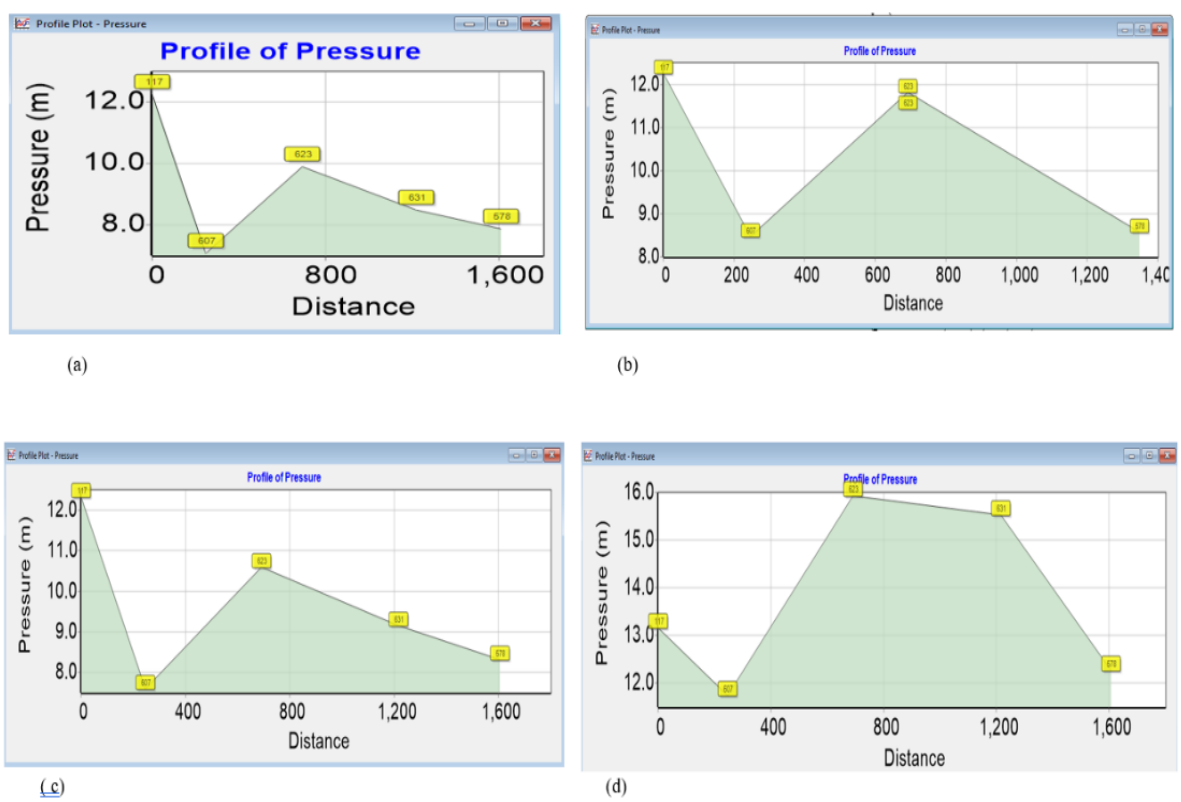


Figure 4. Profile of pressures of some nodes for all cases; (a) currently system without any modifications 1st case, (b) making loop only 2nd case, (c) add tank only 3rd case, (d) connecting loop, and add tank simultaneously

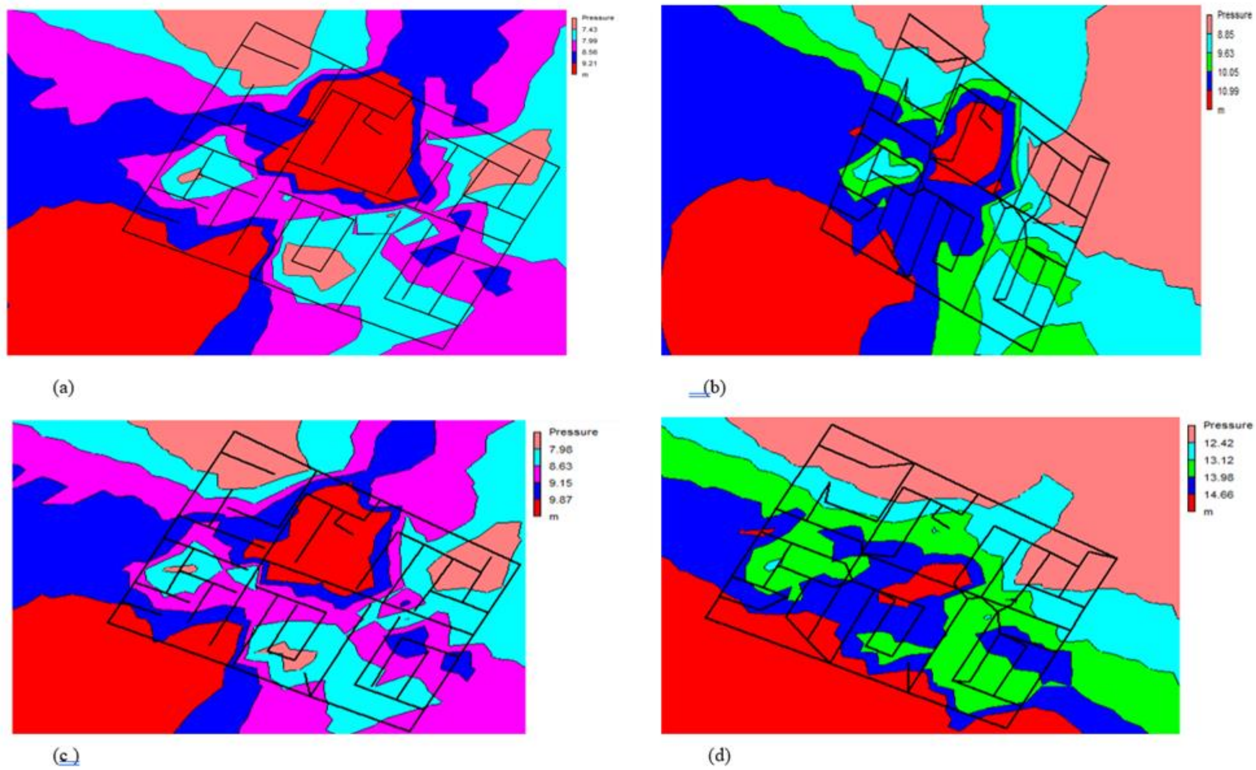


Figure 5. contour maps of Heads for all cases; (a) current system without any modifications 1st case, (b) making loop only 2nd case, (c) Adding Tank with current system 3rd case, and (d) making integration of loop, and adding tank simultaneously

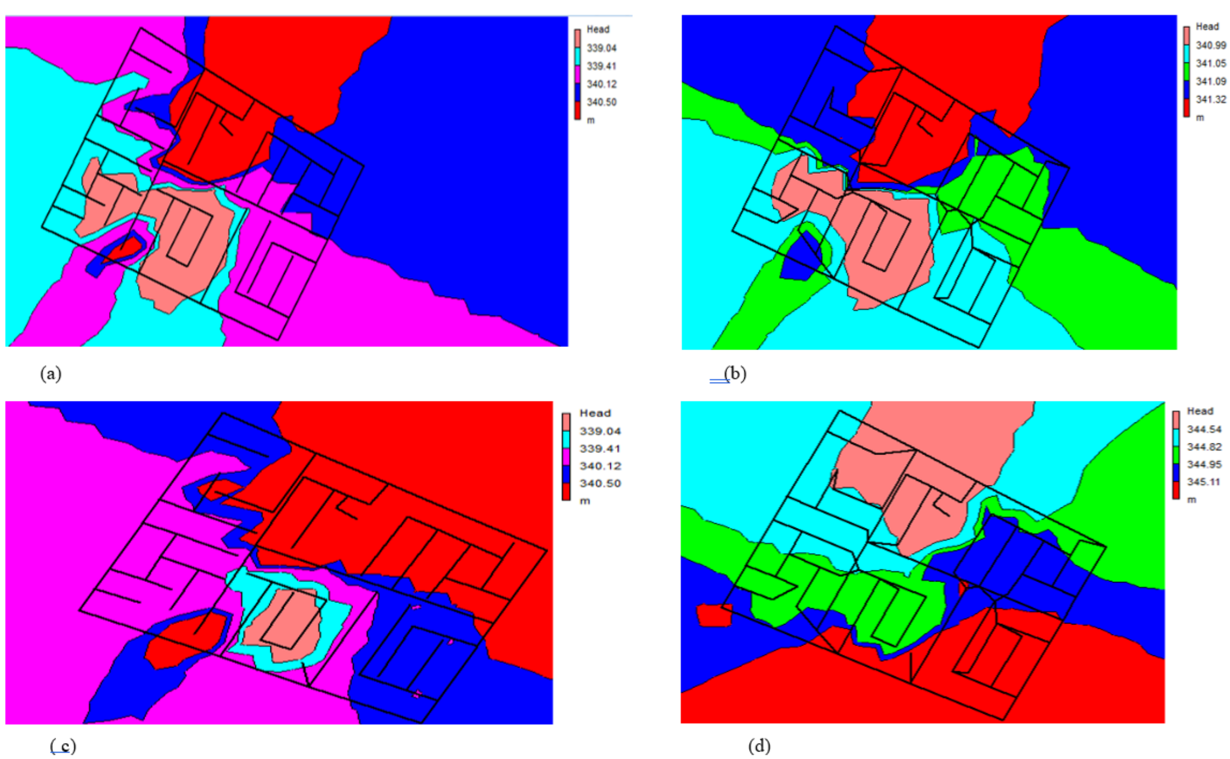


Figure 6. Contour maps of pressures for (a) current system without any modifications 1st case, (b) making loop only 2nd case .(c) adding another Tank to the system 3rd case., and (d) Integration of making a loop and adding a tank simultaneously

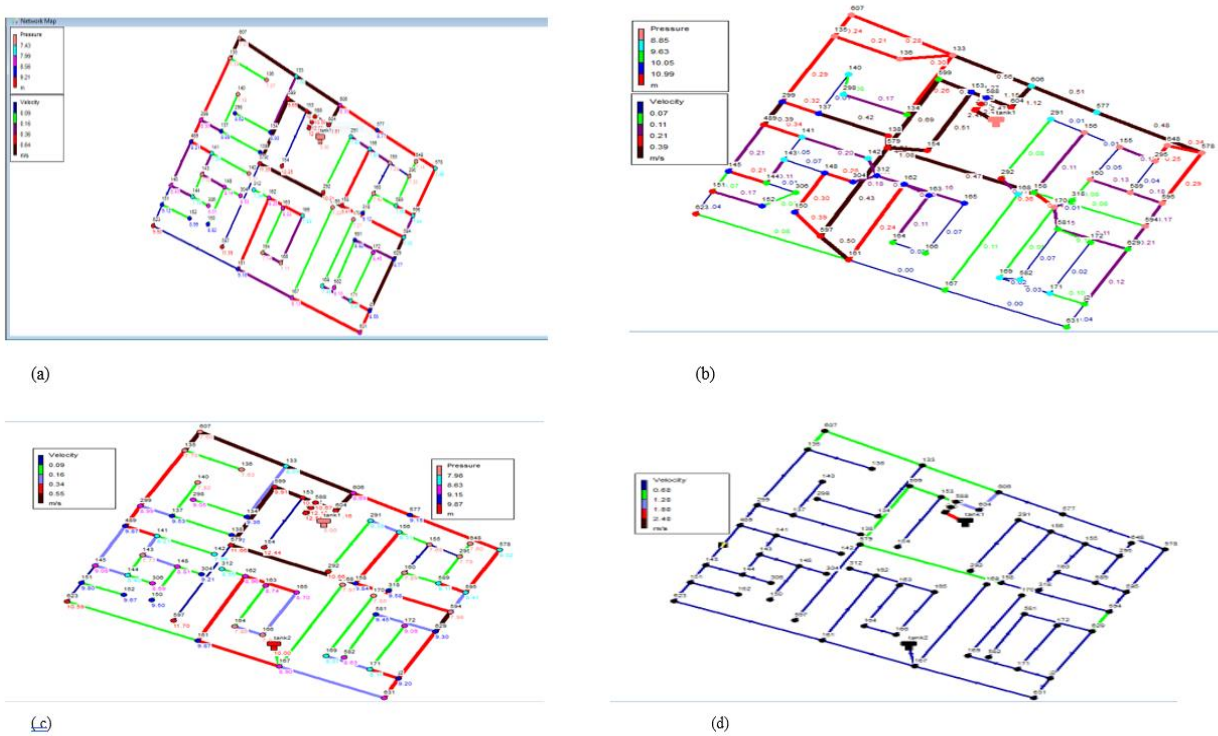


Figure 7. Color code for the velocity of pipes for all cases: (a) currently system without any modifications 1st case, (b) making loop only 2nd case, (c) Adding Tank to the system 3rd case, and (d) making integration of making a loop, and adding tank simultaneous

Table (11). illustrate the results of four cases, changes that occurred in the four models

case	Pressure		Velocity	
	Mean (m) ($\check{U}_p$)	Standard deviation ($\boldsymbol{\sigma_p}$)	mean (m/s) ($\ddot{V}$)	Standard deviation ($\boldsymbol{\sigma_v}$)
case1 actually	8.606	1.407	0.45	0.586094
case2	9.92	1.102	0.34573	0.529455
case3	9.134	1.29	0.419306	0.541616
case4	13.584	1.214	0.428889	0.478618

Table (12). Explanation of figures symbols.

Case	**Elevation Fig. 2**	Pressure **Curve Fig.3**	**Head contour map Fig.4**	**Pressure map Fig.5**	**Network velocity Fig.6**
case1 (actually)	a,b,c,d	a	a	a	A
case2	a,b,c,d	b	b	b	B
case3	a,b,c,d	c	c	c	C
case4	a,b,c,d	d	d	d	D

4. Conclusion

Most of the houses in the Laylan subdistrict are one story; however, some dwellings and the state department are two stories. After collecting data and utilizing EPANET and the methodology outlined, the distribution networks of Newroz area pressure, flow, and velocity have been estimated. Distribution networks' pressure and pipe reporting connections have undergone analysis and real-world comparison. The primary goal of this study is to examine the water distribution network and find any flaws in its evaluation, implementation, and use of the following: Methods of distribution are the gravity system was only used in modeling; however, its field used compound gravity and a pump for one bore well in place, which was the minimum pressure.

- After the investigation of the program, it was discovered that all of the junction pressures and all pipe flows aside from velocity were sufficient to supply water to the study region.

The mean pressure (Ǔp) is 13.584, where the value more significant than the residual pressure to be maintained is 7 m for a sufficient flow in the houses [21][23]. A significant difference with a field is shown in Table (11),

- EPANET-GIS software was used to analyse the WDS.
- Due to the intermittent supply's (4 hours per day) operation, a single period (steady state simulation) is utilized.
- It was discovered that the pipes used as distribution pipes have a diameter smaller than those connected to tanks. That is sufficient to enhance speed eventually. Discharge should also match the basic needs. However, it saves pipes from water hammers.
- This study will help water supply engineers save time because the technique is quick and easy.
- These results are compared and show that the simulated model appears to have more fluctuations in pressure and velocity than the actual network.
- Not having a water conductance meter for any consumers incites inequitable use.
- The novelty of this study is that it(rehabilitation) redesigns the WDS in three scenarios: loop to branch, loop with added tank, and loop with added tank simultaneously without using any valves.

The gap in the research lies in not taking the economic factor into account.
Single-period simulation is used without extended-period simulation to see pattern time.

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I declare that the manuscript was done depending on the personal effort of the author, and there is no funding effort from any side or organization, as well as no conflict of interest with anyone related to the subject of the manuscript or any competing interest.

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7. Conflicts of Interest

The authors state no conflict of interest

8. Recommendation

We recommended the following for decision-makers to enhance the water supply for populations:

- Strong separation of the connection from the Newroz area or the fully closed valves to another area.
- Imposing the installation of a water conductance meter or expensive residential tax to save it.
- Prohibiting any pump used by consumers.
- Adding another water elevated tank and connecting all end junctions to change from branch to loop system.

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