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Original Article

Optimizing Reservoirs to Provide Water in Times of Crisis, With Emphasis on the Reuse of Treated Wastewater in Different Uses

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Abstract

Background: Natural disasters, such as earthquakes, can disrupt water distribution systems, leading to prolonged water shortages and associated crises. Tehran, with its high seismic risk, necessitates robust emergency water management solutions to ensure adequate potable and non-potable water supply during critical conditions.

Methods: Using GIS and WaterGEMS software, we evaluated the design and placement of emergency water reservoirs in ASP Town, Shahriar. Hydraulic modeling was conducted to optimize the piping, pressure, and flow dynamics for potable water supply under emergency conditions. Additionally, non-potable water reservoirs utilizing treated wastewater were designed for irrigation and fire suppression, incorporating solar-powered pumping systems to ensure energy efficiency.

Results: A 50 m^3 cylindrical steel emergency tank, connected to the urban water network, was proposed to provide 3 L of potable water per person for three days in a crisis. The system includes solar panels, a 250-W pump, and a hydraulic shut-off valve to maintain water quality and availability. For non-potable uses, a wastewater reservoir with a variable-speed pumping station supports irrigation and supplies 12 fire hydrants, meeting pressure and flow requirements during emergencies.

Conclusion: This study highlights the importance of integrated water management strategies, including solar-powered systems and treated wastewater reuse, to improve resilience against natural disasters. The proposed designs ensure sustainable water supply and effective crisis management for drinking and non-potable applications in high-risk urban areas.

Keywords: Emergency water reservoir, Emergency situation, Solar energy, Wastewater treatment plant

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Introduction

Emergencies are unplanned events that pose significant risks to people, facilities, and the environment.[1] Iran, due to its geographical location, frequently suffers financial losses and casualties from natural disasters such as earthquakes, floods, droughts, and storms. A substantial portion of Iran's GDP is spent on disaster recovery, making preparedness essential. Reinforcing infrastructure against earthquakes requires significant investment, and inadequate response can lead to public dissatisfaction. Studies on Tehran's water distribution system reveal that earthquakes cause prolonged water shortages, leading to immediate challenges like fire control, health issues, and potential migration, which can leave people without essential services for extended periods. Delays in water supply restoration can trigger socioeconomic crises.[2] A key approach to crisis management is having a pre-prepared written plan.[3] One recommended solution is installing underground water storage tanks along water transmission lines. In fire emergencies, using non-drinking water to contain flames is advised.[4]

Reservoirs are critical during crises as they must remain operational and maintain water pressure in distribution networks.[5] Since the late 1990s, a collaborative study between Iran and a Japanese university, facilitated by the Japan Cooperation Agency (JICA), has focused on securing Tehran's water supply in the event of an earthquake. The JICA study team has emphasized that installing emergency water storage tanks with automatic shut-off mechanisms is highly effective for crisis management.[6] These tanks are designed to hold enough water to supply 3 L/person for 3 days in the event of an earthquake, with capacities varying from 20 to 100 m^3 depending on the neighborhood's population needs. Strategically, these emergency reservoirs are placed in accessible locations such as parks, schools, and mosques. Multiple tanks with moderate capacities are preferred over a single large tank for redundancy in case of damage. Buried underground and connected in parallel to the main water network, these tanks operate continuously, with water flowing in and out under normal conditions. In emergencies, a sudden pressure change triggers automatic shut-off valves, preserving the stored water.[7] Another benefit of these reservoirs is their secure, isolated structure, which protects against contamination risks that may increase following natural disasters, as seen in Japan's 2011 earthquake, where factors like salinity, radionuclide contamination, and turbidity became major concerns.[2] In emergency situations, several methods can be employed for water supply, including[8]: 1. Utilizing Existing Water Storage Tanks: This method takes advantage of already established reservoirs to meet immediate water needs. 2. Leveraging Wells and Mobile Purification Units: This approach involves accessing groundwater through wells and using portable purification systems to ensure water quality. 3. Extracting Water from Transmission Lines: This method taps into the volume of water present in regional water transmission lines for immediate supply. 4. Deploying Water Storage Tankers: Tankers can be used to transport and distribute water to areas in need. 5. Implementing Emergency Water Tanks: Tanks made of steel or cast iron can be placed strategically within a 1000-m radius to ensure accessibility.

If water shortages persist and existing supply methods are inadequate, bottled water can serve as a supplementary option. However, relying solely on bottled water to meet the needs of approximately 10 million people in Tehran would necessitate about 30 million L of water daily, presenting significant logistical challenges. Regarding the first method, it is important to note that the entire volume of a storage tank cannot be fully utilized as active water supply. To prevent the uncoordinated release of water and ensure the reservoir is not completely depleted during a crisis, at least one-third of the tank's volume should be reserved specifically for emergencies. This can be managed by installing a siphon at the outlet of the main reservoirs. Under normal circumstances, once the water level drops to two-thirds of capacity, a warning should prompt the use of the emergency reserve. If this reserve is accessed, it must be replenished promptly. For the second method, water packaging and purification systems can be set up at wells, with generators supplying the necessary electricity for emergency operations. However, the stability of these systems may be uncertain, given the unpredictable nature of emergencies. Regarding the third method, if water transmission pipelines are damaged, this approach may not be effective in emergencies, as broken pipes would hinder access to the water supply. In the fourth method, while storage tankers can provide additional water, they often present challenges related to water quality and retention. Additionally, the capacity of these tankers may not satisfy the needs of densely populated areas. Thus, the fifth method—utilizing emergency water tanks as part of the distribution network—may be the most effective solution for meeting the needs of people in critical situations. These tanks can provide a reliable water supply when other sources are compromised.

Several factors influence the vulnerability of buried emergency water tanks, including ground vibrations, earthquake intensity, tank diameter, and construction material.[7] Research indicates that cylindrical reservoirs sustain less damage during earthquakes compared to rectangular ones.[9] Moreover, studies have found that steel reservoirs conforming to DIN 2460 standards perform better than ductile iron reservoirs.[10] Given the significant costs associated with these reservoirs, selecting appropriate locations is crucial. They should be situated to provide water to residents within a 1000-meter radius. These boundaries are established to facilitate efficient water supply while avoiding congestion in the centre. Key criteria for site selection include accessibility, proximity to densely populated and critical areas, and the maintenance of hydraulic water distribution networks.[10] Furthermore, open public spaces, areas vulnerable to earthquakes, accessibility, high population density, and proximity to essential public services are all vital considerations for the placement of emergency reservoirs.[10]

This study aimed to design and optimize emergency water reservoirs in ASP Town, Shahriar, to ensure a reliable water supply during natural disasters. For potable water, the focus is on providing 3 L/person per day for three days, using solar-powered pumping and hydraulic modeling to maintain pressure and prevent contamination. For non-potable water, the study explores the reuse of treated wastewater for irrigation and fire suppression, ensuring compliance with environmental standards. The overarching goal was to enhance urban resilience and promote sustainable water management in crisis situations.

Materials and Methods

Geometric Shape, Material and Capacity of Emergency Tank

The area studied is ASP town in Shahriar which is under water and wastewater service company in the west of Tehran. ASP Construction Company has built a town in the west of Tehran province, within the Shahriar County, with a population of approximately 5800. The source of water supplying this town is a deep well and this town does not have a water storage tank. It also has a 4 km distribution network made of polyethylen (PE) and ductile iron (DI). Figure S1 displays an aerial map, and Table S1 provides information on population and emergency reservoir storage.

Based on previous studies and this research, steel cylindrical storage tanks are recommended, with a capacity designed to store 3 L of water per person for the first three days following an earthquake. For ASP Town, the recommended emergency storage capacity is 50 m^3, as specified equation 1.

$$\text{Capacity storage} = \frac{5712*3*3}{1000} = 50\ \text{m}^3 \tag{1}$$

This steel storage tank has a diameter of 3000 mm, a length of 7 m, and is equipped with 14 valves.

A geographic information system (GIS) is a powerful tool for analyzing both spatial and non-spatial data, enabling precise determination of facility locations by incorporating fault layers and infrastructure data. Using GIS, complex land layers, including slope and fault proximity, are mapped for each area.[11] Following a field survey to identify potential sites, a suitable location for reservoir construction is selected, guided by the analytical hierarchy process (AHP) for prioritization. Initially, criteria are weighted using the AHP method, where preferences are ranked verbally and transformed into a scoring matrix. In this matrix, items are scored with a value of one when compared to themselves, while other comparisons are scored according to their relative importance. Each item's score is then normalized by dividing its value by the total column score, and the sum of each row yields the weight of that criterion. Considering the specified criteria and reviewing the active/inactive fault layers and the parcel layer of the target area in ArcGIS software, the empty space at Shamim Mehr School (Figure S2) was recommended for establishing an emergency drinking water reservoir, as it meets all the outlined criteria. Positioning the reservoir in the school's empty space would allow for the use of solar energy to pump water during emergencies and to illuminate the school grounds under normal conditions.

Optimising Reservoir for Drinking Water in Normal and Critical Conditions

Drinking Water in Crisis

These tanks are designed to connect directly to the urban water network, allowing for continuous water flow through the pipes. The inlet and outlet valves feature pressure-sensitive controls that automatically shut off to prevent water wastage and contamination. The Japanese-designed smart emergency shut-off valve, model RE_30 Kurimato, was redesigned by Pishgam Energy Company in Iran. This device, weighing about 1 ton, operates solely on the water pressure within the pipes, eliminating the need for external power sources. In automatic mode, a mechanical pilot detects drops in line pressure and signals the valve operator accordingly. When the line pressure exceeds the pilot setting point and the valve is in its normal state, the emergency shut-off valve can be opened or closed by sending an electrical signal to the solenoid valves within the control circuit. To maintain optimal functionality, the shut-off valve should be inspected and tested at least every six months. The inspection includes ensuring no water has accumulated in the valve chamber, checking for leaks in valves and pipes, and verifying that the valve indicator is in the "Normal" position. The assumption of an incompressible and steady flow, neglecting friction, leads to Bernoulli's law, which states (equation 2):

$$\text{P} + \frac{1}{2}\rho \text{V}^2 + \rho \text{gh} = \text{constant} \tag{2}$$

where, P shows pressure (pa), ρ shows density (kg/m^3), V shows velocity (m/s), g shows gravitational acceleration (m/s^2), and h shows height (m).

Also, flowrate is obtained from equation 3:

$$Q = A*V \tag{3}$$

where, Q is flow rate (L/s), A is area (m^2), and V is velocity (m/s).

A pipe burst results in an increased flow rate and velocity, accompanied by a drop in pressure. According to Bernoulli's equation (equation 4), this pressure drop triggers a signal that causes the valves to close. Figure S3 illustrates the operation of these shut-off valves.

$$\text{P}_{pump} = \frac{\rho * g * Q * h}{\eta_p * 3600} = \frac{1000*9.81*4.2*10.75}{0.5*3600} = 246\,\text{W} \tag{4}$$

where, P_{pump} is pumping power (w), ρ is water density (1000 kg/m^3), g is gravitational acceleration (9.81 m/s^2), Q is flow rate (m^3/h) - for 14 valves 4.2 (m^3/h), and h is head pump (m)- 5 m height, 10 m length, 5% frictional losses.

Then according to equation 5:

$$\text{TDH} = 10 + 0.05(10+5) = 10.75 \tag{5}$$

where, η_p: pump engine efficiency (%)- up to 50%.

Accordingly, the required pumping power is approximately 250 W, depending on energy factors and the volume of water needed at the desired height. The specific pump model should be selected based on these criteria. Pump manufacturers typically provide a chart that allows consumers to determine the maximum power required based on local energy factors and solar irradiance levels, helping to estimate the necessary number of solar panels.[12]

The estimated pumping power needed is around 250 W, influenced by energy factors and the required water volume at the target height. The pump type should be chosen accordingly. Generally, pump manufacturers offer charts that allow consumers to identify the maximum power required based on regional energy factors and solar irradiance, aiding in the estimation of the number of solar panels needed.[12]

To determine the optimal capacity of solar panels needed to start the pump's engine, it is essential first to calculate the pump's average daily energy consumption (equations 6 and 7)

$$E_{c,p}\left(w\,{}^{h}\!/_{day}\right) = \text{P}_{pump} * sunny\ hour = 246*6 = 1476\ w\,{}^{h}\!/_{day} \tag{6}$$

sunny hour: on average in 6 hours a day

$$E_{c,p}\left(w\,{}^{h}\!/_{day}\right) = \text{pumping energy consumption on average} \tag{7}$$

Assuming 10 hours of pumping per day with an average of

6 hours of sunlight, the system would require seven 60 W solar panels and two 100 Ah batteries connected in series to store sufficient energy for continuous operation.

Drinking Water Under Normal Conditions

By installing 200 mm inlet and outlet pipes to connect the tank to the distribution network, and considering optimal water speed and pressure in the hydraulic model, water flows into and fills the tank, then exits to continue its path for regular supply. This setup keeps the tank full and prevents water stagnation. Additionally, perforated plates can be used to encourage water circulation throughout the tank, slowing the flow and further reducing stagnation risk. Figure S4 illustrates the connection between the emergency tank and the water distribution network.

Optimizing the Reservoir for Non-drinking Purposes Under Normal and Critical Conditions

The suggested solution involves installing a storage tank adjacent to the sewage treatment facility, along with a 250 mm ductile iron pipeline extending to the town's entrance. This setup would utilize a pumping station equipped with a variable-speed system, backed by a diesel generator, with fire hydrants positioned at the entrance of each alley for improved accessibility (Figure S5).

Non-drinking Uses Under Normal Conditions of Using Sewage Treatment

The reuse of wastewater from urban treatment facilities is increasingly considered for irrigating green spaces and agricultural lands. This approach addresses the reduction of water from conventional, limited sources, offers a cost-effective and continuous water supply, provides nutrients that enhance soil fertility, and mitigates the environmental impact of wastewater discharge. Since wastewater is produced consistently throughout the year, it can meet irrigation needs in all seasons and weather conditions. According to Table S2, the town under study has about 23 000 m^3 of green space. To irrigate this area, a hydro module of 0.8 L/ha is required, resulting in a total flow rate of approximately 1.8 L/s for the 23 000 m^3 of green spaces. Reuse of wastewater from urban wastewater treatments, especially for irrigation of green spaces and agriculture due to the reduction of water from conventional limited sources of water supply, the availability of cheap and permanent water sources, the possibility of providing nutrients and its effect on soil fertility, reducing cost though purification and reduction of the environmental effects of wastewater discharge into water resources have been taken into consideration.

Qualitative Feasibility of ASP Sewage Treatment for Irrigation

While the reuse of wastewater offers numerous advantages, neglecting environmental standards can lead to plant toxicity, soil structure degradation, and contamination of both surface and groundwater.[13] Therefore, it is crucial that the physical, chemical, and microbial properties of the wastewater meet international standards. Based on the quality parameters of the ASP wastewater treatment plant, and in comparison with the standard parameters in Table S3, this treatment plant is suitable for non-potable uses such as drip irrigation of green spaces between the blocks under normal conditions. Although the use of wastewater is associated with many benefits, but if environmental standards are not considered, it can cause toxicity to plants, destroy the soil structure, and contaminate surface and underground water sources. Therefore, it is necessary that its physical, chemical and microbial characteristics comply with international standards. According to the quality parameters of the ASP wastewater treatment plant and compared with the standard parameters of Table S3, this treatment plant can be used for non-drinking purposes such as drip irrigation of the green space between the blocks under normal conditions.

Results and Discussion

In various parts of Tehran, 100-m^3 emergency drinking water tanks have been installed along water transmission lines based on the population they serve. However, no studies have been conducted on this in the western part of Tehran province. This research focused on the areas covered by water and sewage services in the west of Tehran province. As a pilot project, an area meeting all the necessary criteria was selected for location and hydraulic modeling, leading to the proposal of a 50-m^3 emergency drinking water tank based on the population served. Consequently, we examined and modeled the use of emergency tanks for both drinking and non-drinking purposes, such as fire suppression.

Modelling of Drinking and Non-drinking Consumption in Emergency Situations

Different scenarios for utilizing the emergency tanks and sewage treatment tanks were evaluated. Below, each scenario is detailed, accompanied by the results of hydraulic modeling presented through images and tables.

Scenario 1

Emergency Tank

In the hydraulic model, a pipe with dimensions equivalent to a volume of 50 m^3 is connected to the distribution network in a loop configuration to manage pressure drop. The specifics are as follows:

- Source of water supply: Fed from the water distribution network of ASP town.
- Material and diameter of the inlet and outlet line to the tank: 200 mm polyethylene (PE).
- Equivalent dimensions for the volume of the emergency tank in the hydraulic model: A pipeline with a diameter of 3000 mm and a length of 7 m.

As illustrated in Figure S6, the inlet and outlet pressure of the emergency tank is measured at 31 m of water (mH_2O). Figure 1 shows that within the hydraulic model for the emergency drinking water supply, network pressure ranges from 28 to 31 mH_2O, indicating no pressure drop across the network. Moreover, Table S4 presents the network flow velocity data within the hydraulic model.

Scenario 2

Normal Conditions Using Wastewater to Irrigate Green Spaces

Based on calculations regarding the irrigation needs of green spaces in ASP town, the total flow required is 1.8 L/s, with an operating pressure of 25 mH_2O for the Hunter sprinklers. The pumping head, accounting for localized and longitudinal pressure drops, is estimated to be 30 mH_2O, resulting in a minimum network pressure of 3 bar. Key system details are as follows:

- Water supply source: ASP . wastewater treatment plant
- Material and diameter of dual-purpose transmission line (for green space and fire hydrants): 250 mm DI
- Material and diameter of branch lines for green area irrigation: 63 mm PE
- Selected pump model: High-pressure pump WKL 32-2a

As shown in Figure 2, the network pressure in the hydraulic model for green space irrigation ranges from 37 to 43 mH_2O, ensuring the required pressure. The network speed for emergency drinking water is provided in Table 1. According to Figure 3, the operating diagram of the chosen pump demonstrates an efficiency of 82%, with a head of 49 m and a flow rate of 1.8 L/s, meeting the irrigation requirements.

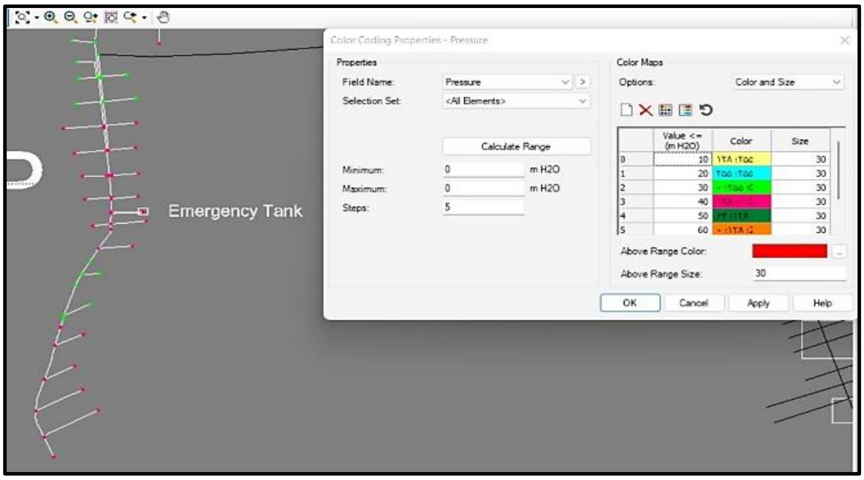
Scenario 3

Use of Sewage to Supply Fire Hydrants

According to the guidelines set forth in publication 117-3 (paragraph 5-5-5-1-2) for ASP town, classified as a

Table 1. Speed Range in Hydraulic Model

Number of Pipe With Speed Statue	Speed (m/s)
2	V≈0
47	0<V≤0.3
46	0.3<V≤1



Color Coding Properties - Pressure

Properties

Field Name: Pressure

Selection Set: <All Elements>

Minimum: 0 m H2O

Maximum: 0 m H2O

Steps: 5

Color Maps

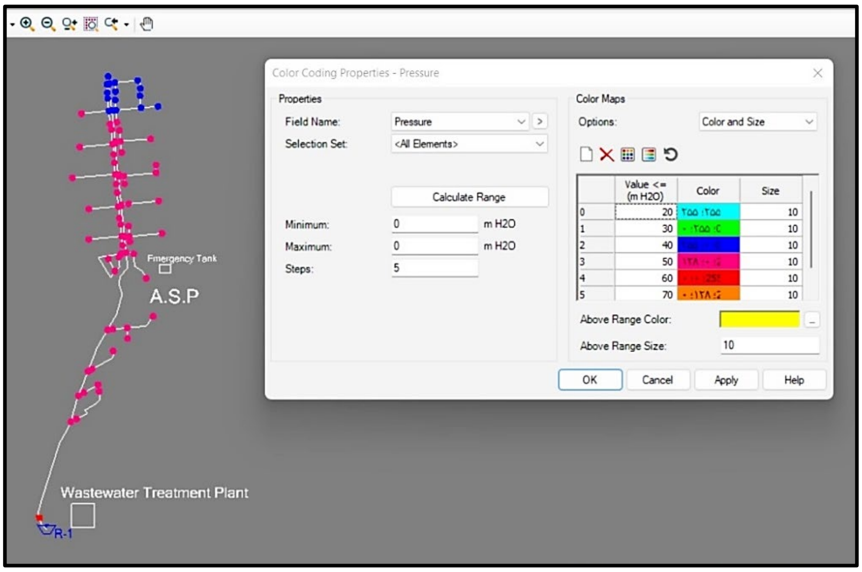
Options: Color and Size

	Value <= (m H2O)	Color	Size
0	10	🟨	30
1	20	🟦	30
2	30	🟩	30
3	40	🟪	30
4	50	🟩	30
5	60	🟧	30

Above Range Color: 🟥

Above Range Size: 30

Figure 1. Network Pressure in Hydraulic Model



Color Coding Properties - Pressure

Properties

Field Name: Pressure

Selection Set: <All Elements>

Minimum: 0 m H2O

Maximum: 0 m H2O

Steps: 5

Color Maps

Options: Color and Size

	Value <= (m H2O)	Color	Size
0	20	🟦	10
1	30	🟩	10
2	40	🟦	10
3	50	🟪	10
4	60	🟥	10
5	70	🟧	10

Above Range Color: 🟨

Above Range Size: 10

Figure 2. Network Pressure in Hydraulic Model

medium-risk area for fire, fire hydrants must be spaced 100 m apart, resulting in the installation of 12 hydrants. Two scenarios have been designed for this setup:

A. Single Fire Incident

To maintain adequate pressure and flow velocity during a fire event, the following specifications are defined:

- Water supply source: ASP . wastewater treatment plant
- Material and diameter of dual-purpose transmission line: 250 mm DI
- Number of fire hydrants: 12
- Required flow rate for fire incident: 20 L/s

B. Multiple Simultaneous Fires

In the case of three simultaneous fires, the following requirements apply:

- A pumping station equipped with a variable flow system is needed, capable of delivering a flow rate of 20 L/s for a single fire or 60 L/s for three simultaneous fires.

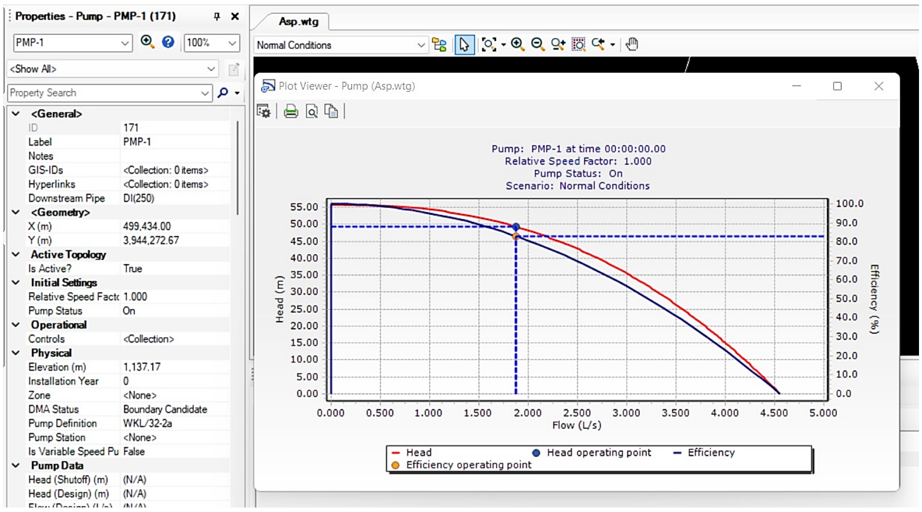
Both scenarios are assessed using a hydraulic model, as the transmission network and water source remain consistent across both cases. The main variable is the flow rate required under different pressure conditions, met by a centrifugal pump (model 200-100), which can deliver 20 L/s for a single fire and up to 60 L/s in the case of three concurrent fires.

In Case A

As shown in Figure 4, the network pressure in the hydraulic model for fire coverage ranges from 35 to 43 mH_2O. Table 2 provides details on the flow velocity within the network lines in the hydraulic model. According to Figure 5, the selected pump operates at 95% efficiency with a head of 47 m and a flow rate of 20.5 L/s, effectively meeting the requirements of the study.

In Case B

Figure 6 illustrates that the network pressure within the hydraulic model varies from 21 to 36 mH_2O, while Table 3 displays the flow velocity across the network. As shown in Figure 7, the chosen pump achieves 74% efficiency with a head of 43 m and a flow rate of 61 L/s, fully meeting the



Properties - Pump - PMP-1 (171)

PMP-1 | 100%

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<General>	
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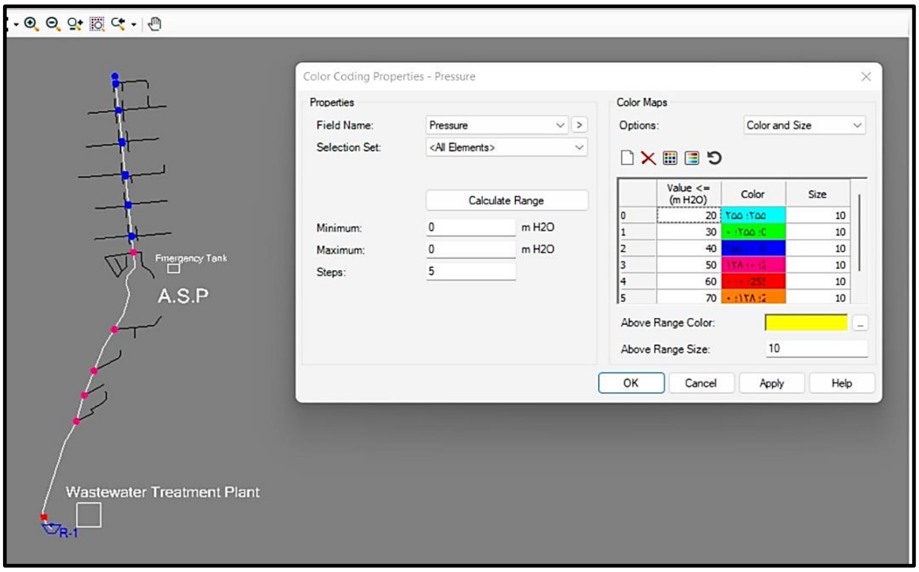
Label	PMP-1
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>
Downstream Pipe	DI(250)
<Geometry>	
X (m)	499,434.00
Y (m)	3,944,272.67
Active Topology	
Is Active?	True
Initial Settings	
Relative Speed Factc	1.000
Pump Status	On
Operational	
Controls	<Collection>
Physical	
Elevation (m)	1,137.17
Installation Year	0
Zone	<None>
DMA Status	Boundary Candidate
Pump Definition	WKL/32-2a
Pump Station	<None>
Is Variable Speed Pu	False
Pump Data	
Head (Shutoff) (m)	(N/A)
Head (Design) (m)	(N/A)

Pump: PMP-1 at time 00:00:00.00
Relative Speed Factor: 1.000
Pump Status: On
Scenario: Normal Conditions

Figure 3. Operating Diagram of the Selected Pump



Color Coding Properties - Pressure

Properties

Field Name: Pressure

Selection Set: <All Elements>

Minimum: 0 m H2O

Maximum: 0 m H2O

Steps: 5

Color Maps

Options: Color and Size

	Value <= (m H2O)	Color	Size
0	20	🟦	10
1	30	🟩	10
2	40	🟦	10
3	50	🟪	10
4	60	🟥	10
5	70	🟧	10

Above Range Color: 🟨

Above Range Size: 10

Figure 4. Network Pressure in the Hydraulic Model

study's requirements.

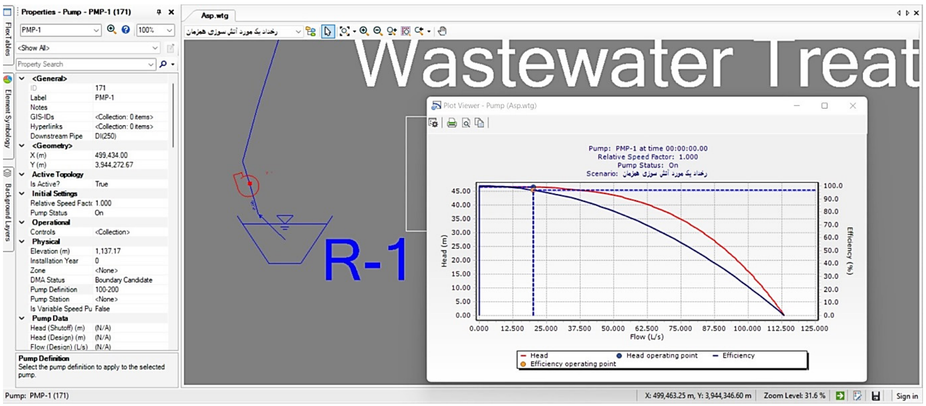
This study incorporated a demographic analysis of ASP town, along with a review of prior research and hydraulic modelling, to design a cylindrical steel emergency tank with a diameter of 3000 mm, length of 7 m, and capacity of 50 m^3, equipped with 14 valves. This tank functions as part of the normal distribution network, and in critical situations,

Table 2. Speed Range in the Hydraulic Model

Number of Pipe With Speed Statue	Speed (m/s)
1	$V \approx 0$
29	$0 < V \leq 0.3$

Table 3. Speed Range in Hydraulic Model

Number of Pipe With Speed Statue	Speed (m/s)
1	$V \approx 0$
0	$0 < V \leq 0.3$
18	$0.3 < V \leq 1$
11	$1 < V \leq 2$


Properties - Pump - PMP-1 (171)

PMP-1 | 100%

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ID	171
Label	PMP-1
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>
Downstream Pipe	DI(250)
<Geometry>	
X (m)	499,434.00
Y (m)	3,944,272.67
Active Topology	
Is Active?	True
Initial Settings	
Relative Speed Factc	1.000
Pump Status	On
Operational	
Controls	<Collection>
Physical	
Elevation (m)	1,137.17
Installation Year	0
Zone	<None>
DMA Status	Boundary Candidate
Pump Definition	100-200
Pump Station	<None>
Is Variable Speed Pu	False
Pump Data	
Head (Shutoff) (m)	(N/A)
Head (Design) (m)	(N/A)
Flow (Design) (L/s)	(N/A)

Pump Definition
Select the pump definition to apply to the selected pump.

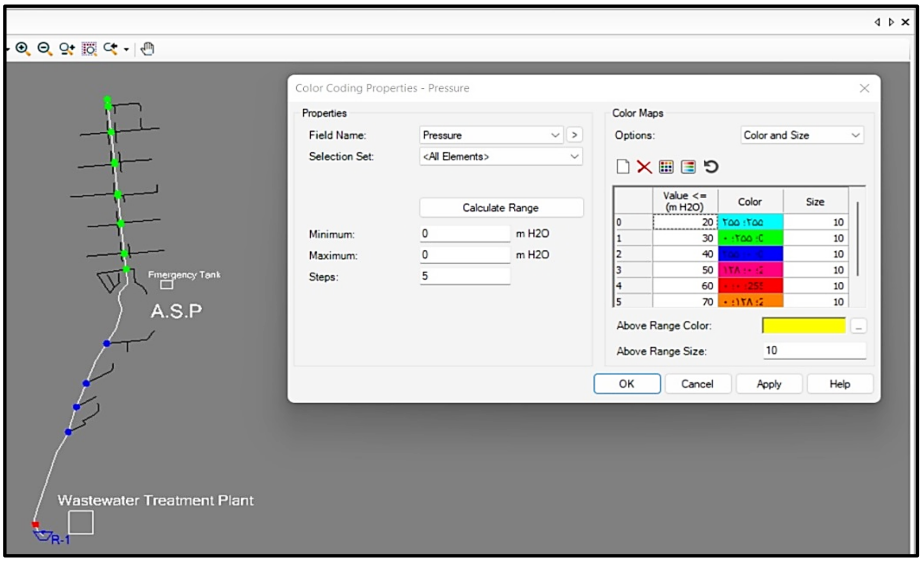
Pump: PMP-1 (171)

Plot Viewer - Pump (Asp.wtg)

Pump: PMP-1 at time 00:00:00.00
Relative Speed Factor: 1.000
Pump Status: On
Scenario: رخداد یک مورد آتش سوزی همزمان

X: 499,463.25 m, Y: 3,944,346.60 m | Zoom Level: 31.6 %

Figure 5. Operating Diagram of the Selected Pump


Color Coding Properties - Pressure

Properties

Field Name: Pressure

Selection Set: <All Elements>

Minimum: 0 m H2O

Maximum: 0 m H2O

Steps: 5

Color Maps

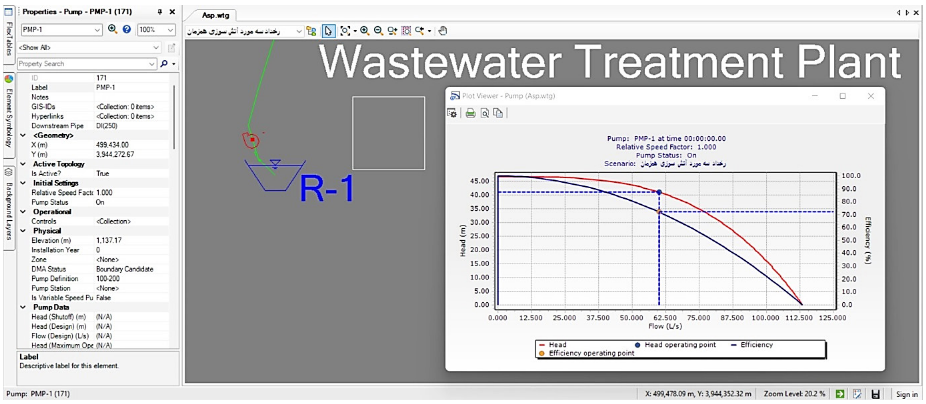
Options: Color and Size

	Value <= (m H2O)	Color	Size
0	20	۲۵۵ :۲۵۵	10
1	30	۰ :۲۵۵ :C	10
2	40		10
3	50	۱۲۸ :۰ :2	10
4	60	۰ :۰ :255	10
5	70	۰ :۱۲۸ :2	10

Above Range Color: 🟨

Above Range Size: 10

Figure 6. Network Pressure in the Hydraulic Model


Properties - Pump - PMP-1 (171)

PMP-1 | 100%

<Show All>

ID	171
Label	PMP-1
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>
Downstream Pipe	DI(250)
<Geometry>	
X (m)	499,434.00
Y (m)	3,944,272.67
Active Topology	
Is Active?	True
Initial Settings	
Relative Speed Factc	1.000
Pump Status	On
Operational	
Controls	<Collection>
Physical	
Elevation (m)	1,137.17
Installation Year	0
Zone	<None>
DMA Status	Boundary Candidate
Pump Definition	100-200
Pump Station	<None>
Is Variable Speed Pu	False
Pump Data	
Head (Shutoff) (m)	(N/A)
Head (Design) (m)	(N/A)
Flow (Design) (L/s)	(N/A)
Head (Maximum Ope	(N/A)

Label
Descriptive label for this element.

Pump: PMP-1 (171)

Plot Viewer - Pump (Asp.wtg)

Pump: PMP-1 at time 00:00:00.00
Relative Speed Factor: 1.000
Pump Status: On
Scenario: رخداد سه مورد آتش سوزی همزمان

X: 499,478.09 m, Y: 3,944,352.32 m | Zoom Level: 20.2 %

Figure 7. Operating Diagram of the Selected Pump

it activates an emergency shut-off valve to prevent water wastage and contamination, ensuring a supply of 3 L per person for 3 days in an initial crisis period. Notably, power outages pose a challenge to emergency power supply. Therefore, based on solar energy data from the global Solargis site, a solar-powered pumping system with an 11 m head, 250 W pump, seven 60 W solar panels, and two 100 A batteries support water distribution through the 14 valves. For post-earthquake firefighting, using potable water is impractical. Thus, this study also proposes a reservoir adjacent to the wastewater treatment plant. With hydraulic modeling, the pressure and velocity required for both critical and normal conditions were assessed, allowing for a variable-speed pumping station using treated effluent. For critical situations, two centrifugal pumps (model 100-200) supply the fire department, while the WKL32 pump irrigates green spaces during normal conditions. The proposed non-potable reservoir connects to a 250 mm DI pipe running upstream, with 63 mm PE branches reaching each green space. Additionally, 12 fire hydrants are positioned along each alley, spaced 100 m apart, per publication 117-3 guidelines.

The Economic Costs of the Plan

A significant portion of Iran's gross national product is allocated to compensate for natural disaster impacts. One of the primary methods to address earthquake risks is through seismic strengthening of key infrastructure across the country, though this approach demands considerable time and financial resources. Tanks, in particular, are crucial for fire control and providing drinking water. Recent earthquakes have caused severe damage to many tanks, leading to not only direct losses but also extended water outages. These outages hinder firefighting efforts, cause health issues, trigger migration, and disrupt lives for days or even months post-disaster. Prolonged water disconnections result in social, economic, and health damages. Thus, emergency buried tanks, though requiring initial investment, can reduce many additional costs over time. Table 4 details the economic costs associated with these emergency drinking water tanks.

In the 1970s, American professor Duke first highlighted the importance of earthquake engineering for essential infrastructure following the San Fernando earthquake.[14] Historically, water supplies were delivered to affected areas via tankers or bottled water.[15] However, in Japan, especially after the 1995 Kobe earthquake, the popularity of emergency water tanks increased significantly. For example, after the 1995 Hanshin earthquake, the city of Kobe (spanning approximately 55,200 hectares and home to around 1.5 million people) installed about 66 large reservoirs.[16] Crisis management has been approached using various criteria, with the AHP employed to determine weighted coefficients for each criterion. This approach has aided in selecting sites for crisis management bases in Tehran. In another study by Faqihi and Mirbagheri, it was concluded that water tanks, especially underground ones, should be camouflaged and fortified to ensure reliable water access during emergencies. Based on these insights, this study suggests prioritizing buried reservoirs in crisis management bases and emergency shelters. Public spaces, such as parks, sports fields, and schools, could also host these tanks in subsequent planning phases.[17]

Table 4. Speed Range in Hydraulic Model

Cost	Price (Rial)
Construction and implementation and transportation of the emergency tank	1,500,000,000
Emergency tank valves and accessories and connections	50,000,000
Purchasing and installing an emergency stop valve	3,800,000,000
Purchasing and installing solar panels and solar pumps	600,000,000
A 6-m^2 shed for storing belongings	150,000,000
Total	6,100,000,000

Numerous vulnerability assessment and seismic improvement projects have been carried out in cities such as Tehran, Bam, Shiraz, Tabriz, Bojnord, and Qazvin. According to Mehrdadi et al, JICA estimates indicate that a 7-magnitude earthquake could cut water access for around four million residents in Tehran for up to 82 days.[2] Emergency water reservoirs could reduce this to one million affected people and cut the water outage duration to 30 days, potentially saving about $400 million in damages. In another study by Haj Malek et al, locations for drinking water distribution stations in Kerman's District 2 were selected based on priority, tank volume, and proximity to residences, resulting in 65 proposed sites with varying priority levels.[13]

The studies reviewed show that pipelines are vulnerable to fault line impacts and landslides, while water distribution networks are susceptible to ground vibrations due to their pipe connections. Emphasis should be placed on buried tanks. Given the current vulnerability levels, efficient earthquake scene management is essential to prevent crises.

This study, following previous research, recommends a 50-cubic-meter cylindrical steel tank for drinking water in emergencies. Unique to this study is the consideration of all critical infrastructure, including the use of solar power for electricity and wastewater from treatment plants, which previous studies did not explore.

Conclusion

This study demonstrates the critical role of emergency water reservoirs in ensuring reliable water supply during natural disasters, with a focus on ASP Town, Shahriar. Through hydraulic modeling and GIS analysis, a 50 m^3 cylindrical steel tank was designed to provide potable water during emergencies, integrating solar-powered pumps and advanced shut-off valves to enhance resilience and sustainability. For non-potable uses, such as irrigation and fire suppression, treated wastewater was effectively utilized, supported by a tailored pumping station and distribution network. The findings highlight the feasibility and importance of integrating renewable energy solutions and wastewater reuse in emergency water management systems. These approaches not only address immediate needs during crises but also contribute to long-term sustainability by reducing reliance on conventional resources. By applying innovative designs and rigorous modeling, this study provides a practical framework for enhancing urban water security and mitigating the impacts of natural disasters. Future work should explore scalability and economic assessments to extend the application of these solutions to other high-risk areas.

Authors' Contribution

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Competing Interests

The authors declare that they have no financial or personal relationships with any individuals or organizations that could inappropriately influence or bias the content of this paper. This includes, but is not limited to, employment, consultancies, honoraria, grants, stock ownership, or any other forms of financial or personal connections.

Ethical Approval

This research was conducted in accordance with ethical guidelines, and no specific ethical considerations were applicable to this study.

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Supplementary Files

Supplementary file 1 contains Tables S1-S4 and Figures S1-S6.

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