Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 3 (2021) 51–58

Geostatistical Analysis of Spatial and Temporal Changes of Pressure Breakers and Water Reservoirs in District 2 of Tehran

Mehrdad Tavakolzadeh[a*]

[a]*M. Sc. in Remote Sensing and GIS, Islamic Azad University, Science and Research Branch, Tehran, Iran*

Received 14 September 2020; Revised 30 May 2021; Accepted 6 September 2021

Abstract

Pressure, as one of the practical and controllable factors in water distribution networks, has an essential role in how water is distributed. On the other hand, pressure control in implemented networks, is possible only by adjusting the control valves. In order to standardize and improve the quality of water supply projects along with minimizing economic problems, the use of relevant rules, criteria, and standards is inevitable and necessary. In the present study, using the spatial information of the study area, including the raster layer of the digital model of region's elevation and the layer point of the location of pressure breakers and water tanks, a data bank was first prepared. Interpolation maps were generated with 95% accuracy, and six-month periods were compared based on these maps. The results showed that the first and fourth periods of the study of water pressure fluctuations were similar. This study established the effect of time on the spatial distribution of water pressure based on the final maps.

***Keywords**:* Water Pressure Fluctuation, Reservoirs, Kriging, Geographic Information System

1. Introduction

Water is one of the most important national assets for which there is no alternative, and it is necessary to save and use it optimally (Mohammadjani and Yazdanian, 2015; Sarmadi et al., 2019). since water is vital for any community, water supply projects are also of great importance and are among the priority projects in each region. Improving the quality level of water supply while minimizing economic problems, specific standards are essential (Hosseini et al., 2019). These standards also need to be reviewed and improved over time and the level of knowledge and life upgrades. In this regard, pressure, including hydraulic parameters, determines the performance and service of urban water distribution networks and is of great importance. High pressure increases leakage, consumption losses and increases the number of network accidents. On the other hand, low pressures in the network will cause insufficient supply or undesirable supply. Also, pressure in terms of performance and condition of structures is adequate on system stability. At high pressures, the probability of accidents, and system failures increases and the stability of the structure as well as the possibility of the system continuing to function and provide good service is compromised. (Apprentice et al., 2005). Therefore, it is desirable for an operator that pressure changes are only within the

[*] Corresponding author Tel: +98-9121577339.
Email address: mehrdad3ps@gmail.com.

acceptable standards in order to achieve the balance of different goals in the network, which are often in conflict with each other in terms of desired pressure changes. In this regard, it is necessary to study and evaluate the spatial and temporal changes in water reservoirs and pressure breakers in each region.

Tabesh et al. (2003) evaluated the hydraulic performance and reliability of water distribution networks from the point of view of hydraulic pressure and its changes in consumption points. Not all incoming water to municipal water distribution networks is consumed, and a significant portion of it is wasted, which is called leakage or unaccounted for water. Leaks in the network are caused by broken and cracked pipes, faulty connections and fittings, or improper performance of piping and fittings operations. Reducing the network pressure reduces the number of leaks and water leakage rate. Using a relation that shows the amount of water storage resulting from the reduction of network leakage as a function of network pressure, it is possible to economically evaluate the benefits of leakage control by applying pressure management. Leakage calculation has been standardized by IWA in recent years using the experiences of different countries (Lambert and McKenzie, 2002). Other researchers such as Araujca (1990), Vaiavamoorthy (1998), Nicolini and Zovatto (2009) have tried to reduce leakage by using flow control valves and determining their optimal setting at their location. To solve their optimization problem, they used the sequential linear programming method. Their objective function was to minimize the amount of leakage in the network. Nicolini and Zovatto (2009) also worked on the location and the optimal number of space-breaking valves using a genetic algorithm. Tabesh and Vaseti (2008) also used a genetic algorithm to optimize the opening rate of flow control valves in the network.

In a study, Abdelbaki et al. (2019) used these tools to evaluate the performance of the drinking water distribution network of an urban cluster in Tlemcen, Algeria. A method was developed by connecting GIS to a hydraulic calculation model. The results showed that the numerical description of the pipes, tanks, and all the accessories that make up the network could be obtained and design irregularities in the urban cluster network were identified.

2. Material and Method

The study area in the present study is district 2, and water and sewerage of Tehran at 51 degrees and 6 minutes to 51 degrees and 38 minutes east longitude and 35 degrees and 34 minutes to 35 degrees and 51 minutes north latitude and its height from the open water level varies between 1800 meters in the north to 1200 meters in the center and 1050 meters in the south. Figure 1 shows the study area based on the zoning of the Tehran Water and Sewerage Organization. The study area is 30 hectares, and the general slope of the area is north-south.

To model the pressure situation in the study area, 3 reservoirs and 17 pressure relief valves in four six-month periods related to the first six months of 1997, the second half of 1997, the first six months of 1998, and the second half of 1998 in GIS environment which were evaluated.

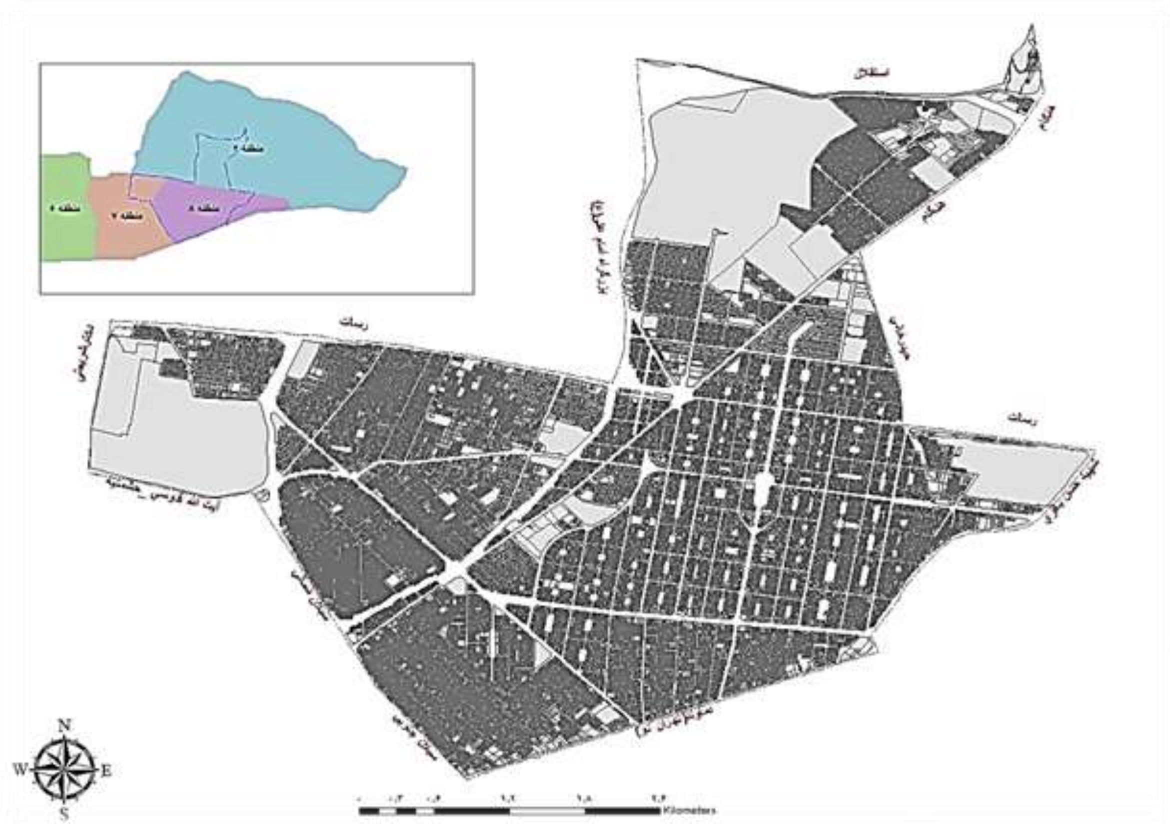

Figure 1. Study area, Tehran, district 2

2.1. Water Pressure

Water pressure in water transmission lines depends on hydraulic factors such as height difference along the route, line pressure drops, dynamic pumping pressure (in non-gravity transmission lines), pressure changes due to sudden flow interruption (ram impact), and nominal pipeline pressure. (Momenzadeh et al., 2019; Paysteh and Keramat, 2021).

2.2. Standard Pressure

Considering that the increase of pressure in transmission lines increases leakage and accidents, the general view in the design of transmission lines should be such that considering the technical and economic aspects, the pressure in different places, observing the minimum required values with respect to hydraulic profiles. The path is the smallest possible value. In any case, the maximum pressure in all parts of transmission lines should not exceed 90% of the nominal pressure of pipes and valves (Heidari Yazdi and Bahramian, 2016). In designing transmission lines, the minimum allowable pressure should be such that due to the hydraulic profile of the route, the hydraulic slope line should never intersect the pipe profile line. However, due to possible errors in executive operations or drawing, the pressure must not be less than 5 meters anywhere on the transmission line. Regarding the minimum pressures caused by ram impact, considering the altitude level of the project site from the sea level and other thermodynamic relations, the minimum pressure value should be such that it does not evaporate the fluid passing through the desired section (Saqi, 2017).

2.3. Reservoirs

The purpose of constructing reservoirs is to provide the required reserves for various purposes such as creating a balance between water inflow and outflow, compensating for fluctuations in consumption, creating reserves for emergencies, accidents, or power outages, and storing for fire and fire water needs. Reservoirs can be constructed by land or air.

It should be noted that in order to prevent the construction of multiple tanks that cause many problems in operation and maintenance for the operator, can be installed by installing pressure relief valves on pipelines that cross the border of two different pressure zones and play a key role in feeding the pressure zone. Below them, the water distribution network connected the two adjacent areas (Abdelbaki et al., 2019).

2.4. Kriging Method

The Kriging method is one of the most suitable and advanced methods for spatial analysis and regional distribution of spatial data. In this technique, a weighted average method is used to distribute the variables so that the closer the variable is to the source, the heavier it is, and the farther away it is, the less weight it will have. Absoluteness in interpolation is one of the main features of the Kriging method, which means that the estimated value of the quantity at the sampling points is equal to the measured values, and the variance of the estimate is zero. This feature causes the kriging estimator to draw the equivalent values in drawing the maximum sampling points and does not want to close and bypass and exceed the boundaries of the study area (Valizadeh Kamran Et al., 2016).

$$Z^{*}(X_0) = \sum_{i=1}^{n} \lambda_i Z(X_i) \quad , \quad \sum_{i=1}^{n} \lambda_i = 1 \tag{1}$$

In the kriging method, the value of the variable at each unsampled point is estimated using a linear moving weight averaging of the values measured in the vicinity of the target point (Isaaks and Srivastava, 1989):

In this equation, Z * (X0) is the estimated value of Z at position X0, iλ is the weight attributed to the variable Z at point Xi, and n is the number of neighborhood points. According to this equation, the sum of the weights assigned to the known values of λi must be equal to one. Weights should also be calculated in such a way as to provide the minimum kriging variance (Shahzad et al., 2020). Seventeen samples were used to model and apply the kriging algorithm in this research. The position of the sample points on the maps can be seen in the results section.

3. Finding and Discussion

In this research, first, the digital model of the height of the area (Figure 2) and its zoning map (Figure 3) were prepared. According to the results, the difference in the height of the region in the north-south direction is approximately 200 meters (minimum height of the study area is 1230 and maximum 1423 meters). According to the zoning map, the slope in the southern parts is gentler than the northern parts of the study area.

Figure 2. Digital model of the height of the study area

Figure 3. Study area, Tehran, district 2

The results of kriging interpolation for the pressure situation in the first period (first six months of 2019) can be seen in Figure 4. According to the results, in all four periods, the central part had the most negligible water pressure fluctuation. In the first half of 2019 and the second half of 2020, water pressure fluctuations were generally scattered throughout the region. In the second half of 2019 and the first half of 2020 the water pressure situation fluctuated less, and the maximum pressure fluctuation was related to the northern parts of the district.

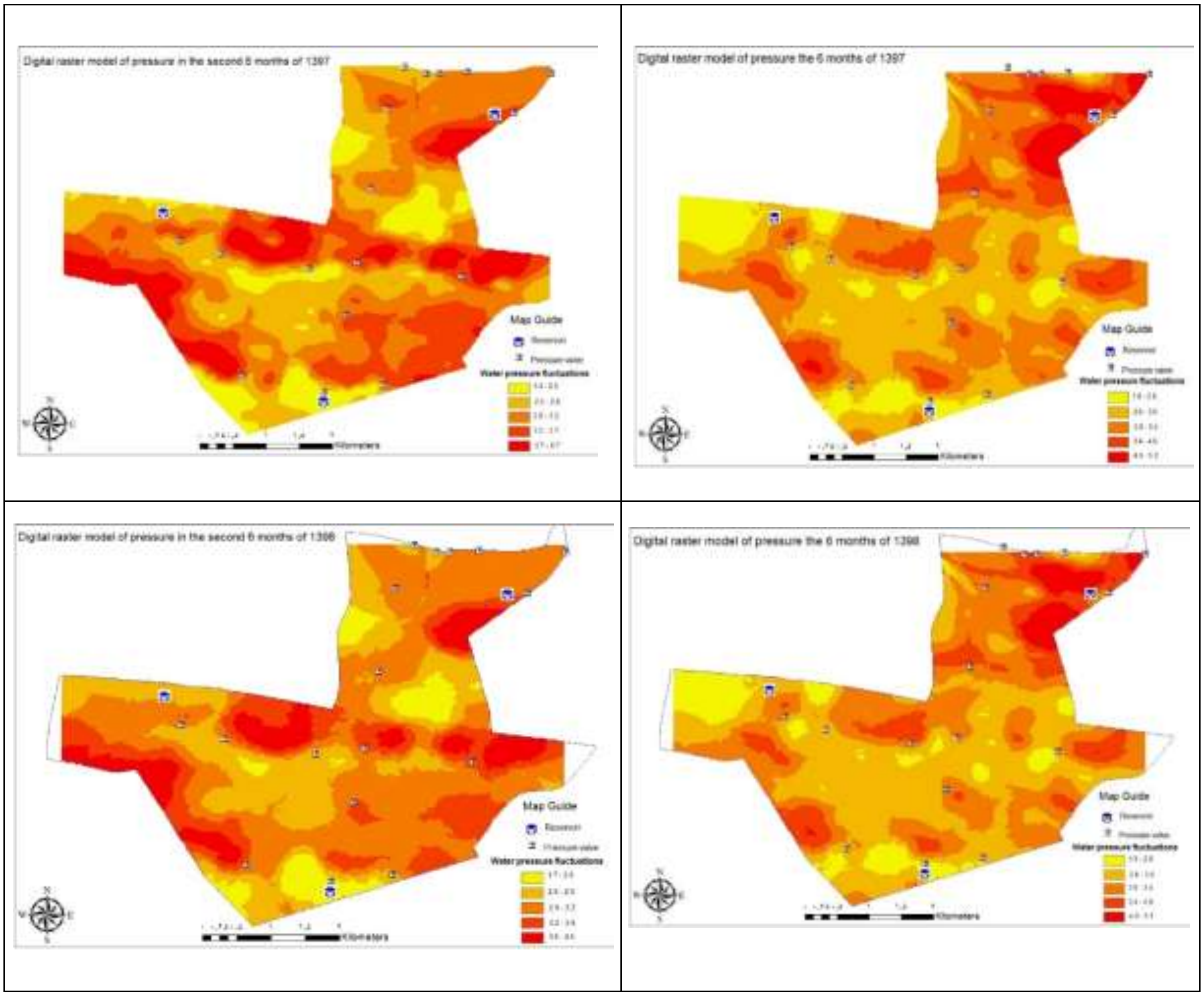

Figure 4. Results of kriging method in zoning water pressure fluctuation for 4 periods of 6 months

Water supply networks as a hydraulic system of water transmission and distribution have always been researchers' focus. In a study conducted by Jahangir et al. (2013), they used water GEMS software for hydraulic analysis. This study showed a 27% efficiency of system management with the help of an intelligent system.

In the research of Jafari Asl et al. (2017), leaks in water distribution networks were investigated. Water leaks cause loss of resources and capital spent on production, transmission, treatment, and distribution of water. The issue of optimal pressure management in water distribution networks is considered to minimizing leakage. For this purpose, the problem of optimal location and optimal settings of pressure relief valves concerning the minimum allowable pressure in the nodes was considered the primary constraint of the problem. In this research, an optimization-simulation model based on one of the types of algorithms was used to solve this problem. The results showed that by providing a spatial-temporal system for optimal location and adjustment of pressure relief valves, the average network leakage rate was reduced by at least 10%, while observing the constraints of the study.

4. Conclusions and Implications

Zoning network is essential for resources in order to perform and properly implement distribution management and pressure management at the distribution network level and reduce actual accidents and losses, as well as ease of control and proper operation during the design period. In order to do zoning, it is necessary to pay attention to the following points: the extent of the network, the volume of existing reservoirs and its development plans, the topography of the city or village, the technical limitations, and the location of the water supply source. For this purpose, different methods such as network zoning with tanks and network zoning by changing the pressure and combining the two are used. In order to provide the minimum pressure and prevent the increase of pressure which leads to the increase of accidents and water losses, and unnecessary use of water, it is necessary to manage the pressure by selecting the appropriate location of the reservoir and pressure zone of the network (Manzavi, 1996).

In existing water distribution networks or in the study of facility development plans and water distribution networks in cities and villages where there is a significant difference in the city or village, it is necessary to perform network pressure zoning. Network-level pressure zoning is any measure that limits the pressure to standard or pressure management. In order to implement the pressure zoning plan, it is necessary to draw the pressure separating lines in a static mode according to the appropriate plans with elevation levels of the urban planning situation and distribution network and volume and height level and maximum reservoir water level and also to observe the technical limit of water pressure. By fully identifying the location of the pipes at the boundaries of these lines, it is necessary to cut off or not connect the pipeline lines between the two adjacent areas. Since the construction of multiple reservoirs at different levels to store and supply pressure in each area poses several problems in land acquisition, water supply to various reservoirs, initial investment, and operation and maintenance for water and wastewater companies, therefore. A primary solution can be used by installing pressure relief valves on the main pipelines that pass through the boundaries of the two pressure zones and play a key role in feeding the distribution network of the lower pressure zone (Abfa, 2012).

References

Abdelbaki, C., Touaibia, B., Ammari, A., Goosen, M.F. (2019). Contribution of GIS and hydraulic modeling to the management of water distribution network. *Advanced Computing and Systems for Securit, 8*, 125-150.

Abfa, (2012). Design criteria for urban and rural water distribution transmission systems. *Water and Sewerage Industry Standard Journal*, 380, 146.

Heidari Yazdi, S. S., & Bahramian, Z. (2016). Risk assessment of pipelines containing crude oil: Case study of Aghajari to Isfahan pipeline. *National Conference on Fire Protection of Buildings and Transportation Systems*, Tehran.

Hosseini, E., Gholami R., & Hajivand F. (2019) Geostatistical modeling and spatial distribution analysis of porosity and permeability in the Shurijeh-B reservoir of Khangiran gas field in Iran. *Journal of Petroleum Exploration and Production Technology, 9*(2),1051–1073.

Jafari Asl, J. F., Sami Kashkouli, B., & Bahrami, M. (ND). Optimal pressure control with the aim of minimizing leakage in water distribution networks. *Water Flow and Sustainable Development, 4* (2), 49-56.

Jahangir, M., Barani, G., & Jahangir, A., (2013). Intelligent pressure management and leakage reduction of water supply networks in Water GEMS environment: Case Study of South Khorasan Two-Fence Water Supply Complex. *Journal of Irrigation and Water Engineering, 4*(13), 45-55.

Lambert, A., & McKenzie, R. (2002). Practical Experience in using the Infrastructure Leakage Index. Lemesos, Greek Cypriot Administration: *IWA Conference Leakage Management: A Practical Approach*. Greece.

Manzavi, M. (1996). *Urban water supply*. University of Tehran Press.

Mohammadjani, A., & Yazdanian, N. (2014). Analysis of the water crisis in the country and its management requirements. *Trend Quarterly, 21*(65-66), 117 – 144.

Momenzadeh, R., Karimi, M., Ebrahimi, M., & Aghamajidi, R. (2019). Investigation and analysis of factors affecting negative local pressure in water transmission lines. *17th Hydraulic Conference of Iran*, Tehran.

Nicolini, M., & Zovatto, L. (2009). Optimal Location and Control of Pressure Reducing Valves in Water Networks. *Journal of Water Resources Planning and Management, 135*(3).

Payesteh, M., & Keramat, A. (2021). Investigation of dependence of hydraulic factors affecting the rate of sudden suction of contamination to transmission lines in transient conditions. *Amirkabir Civil Engineering Journal, 51*(5), 1-16.

Saqi, H. (2018). Presenting a new method for estimating leakage in water supply networks using nodal pressure analysis. *Sharia of water and soil sciences (agricultural science and technology and natural resources), 21*(1), 127-143.

Sarmadi, H., Salehi, A., Zabrdast, L., & Aghababaei, M. (2019). Quantitative evaluation of water component of Tehran metropolis based on DPSIR 2 model. *Journal of Soil and Water Sciences (Agricultural Science and Technology and Natural Resources), 2*(1), 301-315.

Shahzad, H., Umar Farid, H., Mahmood Khan, Z., & Naveed Anjum, M. (2020). An Integrated Use of GIS, Geostatistical and Map Overlay Techniques for Spatio-Temporal Variability Analysis of Groundwater Quality and Level in the Punjab Province of Pakistan. *South Asia, Water, 12*(3555), 1-18.

Valizadeh Kamran, Kh., Roustaei, Sh., Rahimpour, T., & Nakhin Rohi, M. (2016). Determining the most appropriate geostatistical method in preparing a map of groundwater salinity changes: Case study of Shiramin plain, East Azerbaijan Province. *Hydrogeomorphology, 3*(6), 17-32.

Vairavamoorthy, k. (1998). Leakage Reduction in Water Distribution Systems: Optimal Valve Control. *Journal of Hydraulic Engineering, 124*(11).

Tabesh, M., Asadiani Yekta, A. H., & Burrows, R. (2003). An integrated model to evaluate losses in water distribution systems. *Water Resources Management, 23*(3), 477-492.

Tabesh, M., & Vaseti, M. (2008). Leakage education by minimizing exceed Pressure-Iran water resource, 2 (2), 53-66.

Trainee, M., Tabesh, M., & Nazif, S. (2005). Prediction of pressure in water supply networks using artificial neural networks and fuzzy inference .