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Water Supply Scheme System Design for Peri Urban Areas of Punjab using EPANET

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Abstract:
Water is indispensable for human life and without water, life cannot exist on earth. Every person required 33 to 35-gallon water per day for drinking and demotic purpose. But due to lack of quality, inefficient water supply designs, intermixing of sewage water and unlined sewage water system, quality of water is deteriorated specially in recent decades and affecting a number of people. In present study, it was inevitable to design a water supply system for selected area to provide safe water supply design for a small community. For this purpose, a study area was selected named as chak.no. 253 RB, Samundri Road Faisalabad. The existing water supply system of the village was built 30 years ago with the problems of leaky pipes, mixing of sewerage water with drinking water was causing water-borne diseases like Diarrhea, Cholera, Giardiasis, Typhoid fever, Schistosomiasis. A computer software abbreviated as EPANET (Environment protection agency network) was used to design a water supply system of the area providing input parameters to the software. For this a profiling survey was conducted to determine the length of pipes and the elevation of each junction. The other input parameters such as the diameter of pipes, pipe network map, head losses were provided. Conclusively, EPANET gave a detailed water supply system plan for specific design period. By adopting this design provided by detailed surveys of the area and EPANET will help to control intermixing of sewage water which ultimately improves the quality of water. The new design is based on technology by using modern techniques (Software). It will provide save and continue supply of water to community. It will also reduce the cost of water billing, leakage, decrease the diseases rate and improve the life standard of people's lives in that area.

Keywords: Water Supply System, Water borne diseases, Design, EPANET

1.0. Introduction

Water is a key factor to alive and is indispensable for all living organisms. A person can only live for a matter of a few days without water. So, life cannot exist on earth without it. Considering the quantity of water, about 2.8% of the total amount of water on earth is freshwater of which only 0.6% is groundwater. The rest is available in the oceans and mainly seas, while a negligible amount as soil moisture. Out of the 2.2%, 2.15% is found in the form of glaciers and ice sheets while the remaining 0.05% is available as surface runoff. It is estimated that each person on earth is required 20 to 50 liters of clean safe water each and every day. The quality of water is also a critical factor after quantity and more importantly is the concept of clean water. This clean water is to be used for drinking, cooking, simple hygiene, etc. Providing good and safe drinking-water is world-wide considered to be a fundamental issue for public health protection and must be the primary objective of water supply systems. The best water supply system is a system of engineered hydrologic and hydraulic components which prevents water-related problems and yields a good quality water according to the needs of community [1,2].

The water distribution system is a framework consisting of aspect such as pipes, junctions, tanks, reservoirs, pumps and valves etc. [3, 4]. It is necessary to supply water to the public because Water scarcity is among the major issue faced by many societies worldwide in the 21st century, approximately 1.2 billion people live in areas of physical water scarcity, and 500 million people are approaching this tragic situation [5]. Efficient water supply is of foremost importance in spanning the existing one or in designing a new water supply system [6]. Tube wells are concentrated in the Punjab Province which accounts for 93% of all private tube wells in Pakistan. The ratio of groundwater recharge to discharge is 0.8 and as a result, rapid decline in the water tables has been reported in many parts of the country that's why the water scarcity is the major issue is Pakistan [7, 8]. To fulfil the water demand of the rapidly growing population we need to provide the adequate and uniform quantity of water through the designed network of pipes [9]. Potable water is not well distributed in the world. 1.8 million deaths are attributed to unsafe water supplies every year. Water supply systems must meet requirements for public(domestic), commercial, and industrial activities [9, 10].

Numerous computer tool were developed, out of all the tools available EPANET which is freely available became most popular and convenient for the effective design of complex pipe networks [11]. EPANET is a computer software that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks [9]. EPANET is used to designed to be a research tool for improving or enhancing our understanding of the movement and fate of drinking water constituents within the designed distribution system. By the use of EPANET that is by filling the data into it about several nodes, junctions, pipes, demand and supply (flow), tanks and reservoir, we designed the water distribution system for the study area [12]. EPANET tracks the flow of water in each pipe, the pressure at every node, the height (head) of water in each tank or reservoir, and the concentration of a chemical species like chlorine which is a highly efficient disinfectant and is added to public water supplies to kill disease-causing pathogens such as bacteria, viruses, and protozoans, that commonly grow in water supply reservoirs, on the walls of water mains or pipes and in storage tanks, throughout the network during a simulation period comprised of multiple time steps (Kanth, Manasa, Rupesh) [13]. The EPANET was very useful for the proper designing of the whole water supply system of that village, it also helped to find the present situation of water supply by given the calculated data or values to it which gave the detailed information of running system [5].

Figure 1: Shows the current states of water supply in the examination region.

The water supply pipes are splits and harm. The blending the sewer water in drinking water ordinary. The water conveyance siphons are old, harmed and have low productivity. There is no weight, stream measure is introduced on the siphon outfall pipe. The core objective of present study is to design and develop a plan for equitable distribution of sanitary water for a small community using EPANET software. To achieve this major objective certain secondary objective were required such as i) Profile leveling survey (to get the elevation of each pipe joint from mean sea level and to measure the length of street to get idea of pipes length). ii) Estimation of existing population of the area (to have an idea the total water consumption of the study area).

2.0. Materials and Method

2.1. Study Area

The water supply system was designed for a Village named CHAK. No 253 RB, Samundari road, Faisalabad. Its geographical coordinates were 31° 18' 0" North, 73° 0' 0" East and its original name (with diacritics) is Jahāngīr Kalān. It was at an average elevation of 597ft above sea level Source (PID The bench mark of study area was identified from the canal layout map prepare by Punjab irrigation department, pined in index. The area of the village is 16184.4 square meter and the current population of the area is 7735 (Source: UN-149 & Basic Health Center CHAK NO# 253 RB, Faisalabad, personal comm...). Water supply systems get water from a variety of locations, including groundwater, surface water lakes and rivers or canals [10]. Due to the poor construction of sewerage system, the effect of wastewater on this village groundwater has been increased rapidly.

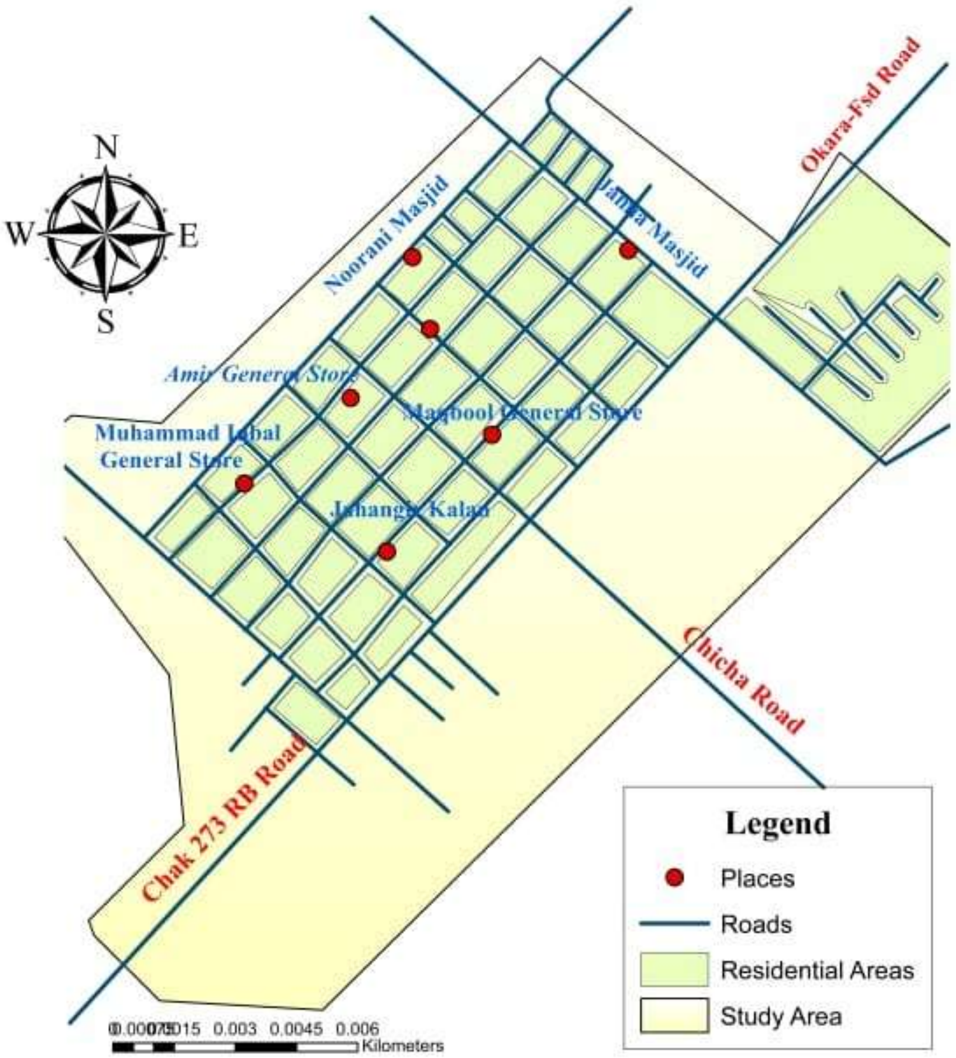


Figure 2: Chak no. 253 RB Faisalabad

The distribution system designed here is Gridiron system. This is also known as interlaced system or reticulation system. The mains, sub-mains and branches are all interconnected with each other. Use of EPANET and filling the data into it about several nodes, junction, demand (flow), elevation, tanks or reservoirs and pipes. In this system, the water is pumped at a constant rate and stored into an elevated distribution tank, from where it is distributed to the consumers by the action of gravity.

2.2. Data requirement

The core objective is design and develop the water supply system for this specific area to minimize the rate of water losses, leakage, its cost and make sure to 100% supply of safe water for all purpose. To complete this task, a questionnaire was prepared to get the information about the people living in the house, number of water tanks, water storage capacity, the number to refill the tank in 24hrs and the problems faced by people due to present damage water distribution system.

It was observed that the water distribution system was built 30 years ago and presently water supply lines are damage. Mixing of sewerage water with drinking water was occurring due to leaky pipes and open sewerage system. It was concluded that the old, inefficient and poor water supply system was causing water-borne diseases as discussed earlier. It was inevitable to design and replace the existing water supply system for that area to avoid all the problems discussed earlier. The materials used for this study include; contour map by doing profile survey, road network map, water demand, population, water supply network and also finally EPANET software.

The total water demand which was obtained after calculate the population for next 30 years for that study area is 468125 gallons, also the study area comes under the rural settlement. By doing a survey in that village the total water demand was used 137.60 L/C/D or 35 US Gallons is calculated. The base demand is calculated at each particular junction is 35 US Gallons. The elevation data of each node is taken by performing the profile leveling. After that, the following steps were carried to analyses the hydraulic modelling of the water distribution network:

2.3. Methodology

2.3.1. Survey of the study area for estimating water demand.

The survey of the area was conducted to get the idea of water consumption per house in 24hrs. To achieve this task a questioner paper was prepared to get the information about people living the house, their water storage tank capacity, and the amount of water used for drinking and domestics purpose. The questioner paper prepared to get all above information from people of that area is pined in index. The remarks also added in this questioner paper by people about that old, leaky and poor water supply system.

2.3.2. Population forecasting

The current population of the village is near about 7735. The previous record shows that there is a constant increase in the village population. The average rate of birth is 188 per year and average death rate is 48 per year. The percentage change in population is 0.79%. After 30 years the population of the study area will be 13375, Growth rate in Figure 2 was calculated by Arithmetic mean method. The birth and death rates of the village population are shown in the table and by graphs.

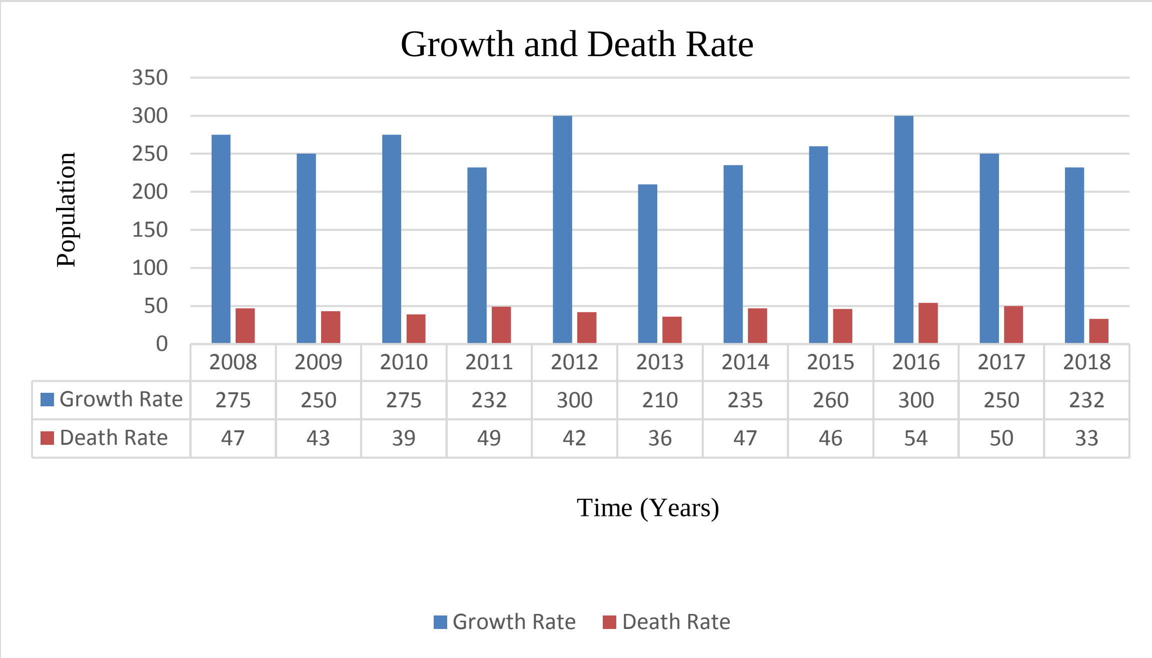


Figure 3: Growth and Death Rate w.r.t Time (Years)

2.3.2.1. Arithmetical Increase Method

This method is use to forecast the population of the old area; which population is grow with slow rate. The change in population every year should be constant almost. The study area is small and average population growth rate is constant [14]:

$$\frac{dP}{dT} = K \qquad Eq(2.1)$$

The rate of change of population with respect to time is constant.

$$Pn = P + nI \qquad Eq\ (2.2)$$

Where
P_n = population of n year
P = Current population
n = Number of year
I = Average change in population

P = 7735; n = 30 year; I = 188;

$P30 = 7735 * (30 * 188) = 13375$

2.3.3. Materials and Measure the lengths of streets

The lengths of streets are measured to get the idea of pipe length required. The pipes used in design are plastic pipes due to feasible in transportation, low prices and do not required heavy machinery for installation and easy to handle. Plastic pipes, if required in modest quantity, are also reasonably feasible to manufacture from imported raw materials. Plastic pipes have distinct advantages over other pipes due to its light weight, availability in long lengths, ease in transporting (to and on the site) and handling and installation. Plastic pipes, due to its longer lengths, have the general advantage that performance is less affected by poor installation. Plastic pipes are very suited for machine installation. Prices for small diameter pipes of all materials are usually comparable. For large diameter pipes, concrete and cast iron are the cheapest choice and plastic most expensive. According to the survey, the length of streets of the study area is,

Table 1: Lengths of pipew.r.t. streets

Points in streets	Horizontal streets	Verticals streets
	For one street (ft.)	*For one street (ft.)*
1st to 2nd	230	160

2nd to 3rd	290	180
3rd to 4rt	280	200
4th to 5th	290	200
5th to 6th	290	180
6th to 7th	260	160
7th to 8th	290	-
8th to 9th	230	-
	Total No. of streets; 8	Total No. of street; 9

2.3.4. Survey report and water required calculation

The survey is done and gets the information from people about

A. No. of people lives in the house

B. No. of the water storage tank

C. The capacity of a water storage tank

D. No. of refilling the water storage tank

The result of survey shows that the average number of people per house are 08, their water storage tank capacity is 116.025 gallon which is fill by one time per day. The average daily water consumption per house is found 272.612 gallon. The water is delivered 5-7 Hrs./day per home. [15-17]. The water consumption by human per capita for bathing, washing clothes, flushing, washing in houses, washing the utensils, cooking and drinking is 14.529, 5.283, 7.925, 2.642, 1.321 and 1.321 respectively [1]. So the total water consumption by Human per capita is 35.663 gallon per day. The total water required for study area is calculated is 468125 gallons. The fire demand and leakage loss are 20% respectively.

Table 2: Water Consumption by Animals [14]

Sr. No	Animals	Water Consumption(Lt)
1	Cow & Buffalo	40 to 60, 15 gallon
2	Horse	40 to 50, 13
3	Dog	8 to 12, 03.
4	Sheep & goat	5 to 10, 02

Total consumption of water = 655408 gallon
No of pump use in design = 02
Flow for one pump = 327704 gallon.

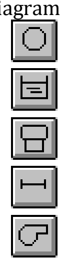
2.3.5. Existing water supply scheme quantification

No. of pumps = 02 Avg. flow of one pump = 0.4 ft^3/sec.
Flow in 7hr/24hr = 0.4*7*60*60 = 10080 ft^3/7hrs
Flow of 2 pumps = 10080*2 = 20160 ft^3/7hrs ≈ 570867.627 L ≈ 125573.323 Gallon(UK)
Avg. water intake by one house = 272.61202 Gallon. Avg. no of houses = 450
Avg. water supply to houses = 272.61202*450 = 122675.409 Gallon.
Losses = 125573.323 – 122675.409 = 2897.914 Gallon

2.4. Modeling and Simulation by using EPANET

2.4.1. Layout map for EPANET

In this research the distribution network of CHAK NO 253, RB Jahangir Kalan Faisalabad was analyzed. This network has 125 links, 66 nodes, 02 pumps and 01 tanks. The diagram with flow direction representation of the network is shown in below:



Junction

Reservoir

Tank

Pipe

Pump

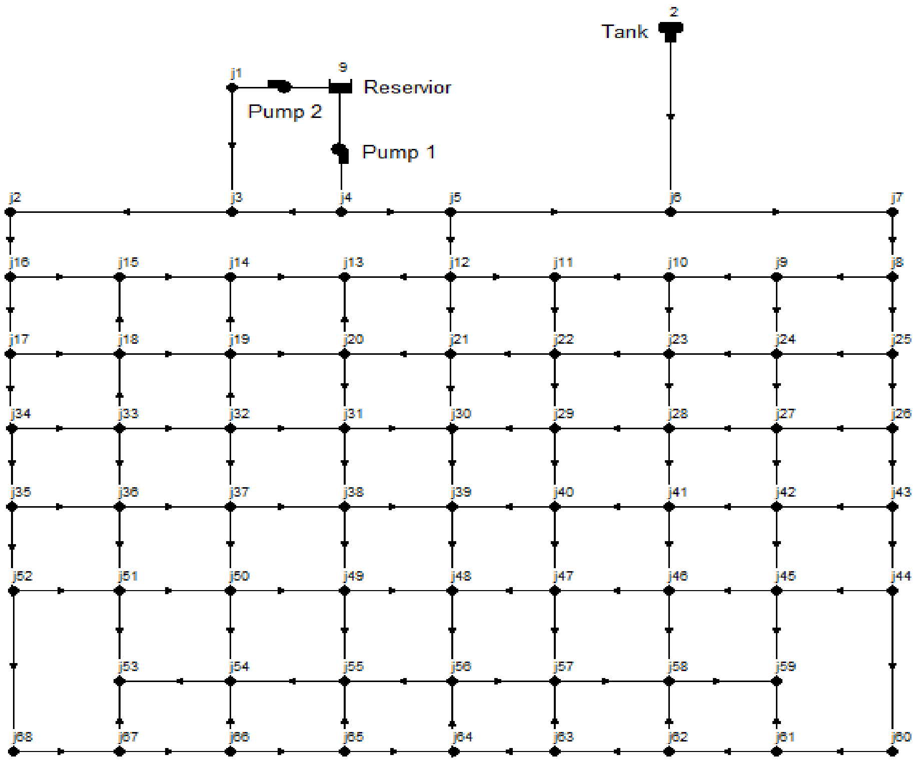


Figure 3: Layout Water Distribution system in CHAK No 253 RB Jahangir Kalan

2.4.2. Calculation the diameter of pipe lines

The scheming of the pipe diameter is chief commission. The precise diameter of pipeline is imperative because the pipe line diameter is unswervingly related with the flow and financial plan. In water supply design the diverse pipes of different diameter are use. The great pipes lines of enormous diameter have the high rate as relate to the unimportant diameter of the pipeline. The choices of pipe for a right diameter is done through the flow, required in pipeline. For large volume of flow, the pipe of the large diameter is required as well for squat flow, the pipe of the small diameter is required in design. There are several scientific equations are used to catch the diameter of the pipe lines by using the flow, slop and roughness of the pipe material. The objective of all these mathematical equations are only find the suitable diameter of the pipe according to the given flow.
As the flow is non-uniform and pipe are plane, so the equation, uses to find the diameter the pipe is [15]:

$$Q = 89d^{2.71}\, I^{0.57} \qquad Eq\ 3$$

Where:

Q = Flow (m^3/sec)
d = Diameter (m)
I = Slop (m / m)

2.4.3. Elevation and base demand values for each Node

The elevation value from mean sea level is assign to each value with suitable slop, measure by the profile leveling. The elevation is in ascending order to give a suit able slope for gravity flow of water in pipe lines. The base demand is average or nominal demand for water by the main category of consumer at the junction, as measured in the current flow units. With the help of elevation data that was collected by profile leveling about the nodes, joints, junctions, discharge, diameters of pipes. The elevations of joints describe the flow direction of high potential to low potential.

2.4.4. Pipe Description

The pipes material is plastic and has the length according to the streets length as describe above in table 1. The roughness of the plastic pipe material is 140-150 [16]. Plastic pipes have unmistakable focal points over different funnels because of its lightweight, accessibility in long lengths, ease in shipping and dealing with and establishment. Plastic creased pipes, because of its more extended lengths, have the general bit of leeway that exhibition is less influenced by the poor establishment. Plastic channels are appropriate for machine establishment. the plastic strip gives an incredible sparing in transportation, taking care of, and establishment

3.0. Results and Discussion

By the use of EPANET various relation are being found between elevation, velocities, flow, pressure, head, demand, etc. these relations can be understood by studying the graphs plotted.

3.1. Pressure vs Flow Distribution

This is the graph between Pressure and Flow. which shows the variation of Flow in different pipes concerning the Elevation provided to the particular pipeline. The color of each pipe is show the value of the Flow in GPM. The scale is according to the color. The Red color show the Flow in pipe is equal or above than 100 GPM and blue color show the rang of flow equal or less than 25 GPM. The pressure at the Nodes is also describe by the color. The Red color show the pressure in node is equal or above than 100 psi and blue color describe the pressure at Node is equal or low than 25psi. With passage of the time, the color of the pipe and Node is change as Flow in pipes and pressure is change in Nodes respectively. The different values of Elevation and velocity are also given in figure 3.

Design of Water Supply System by using EPANET

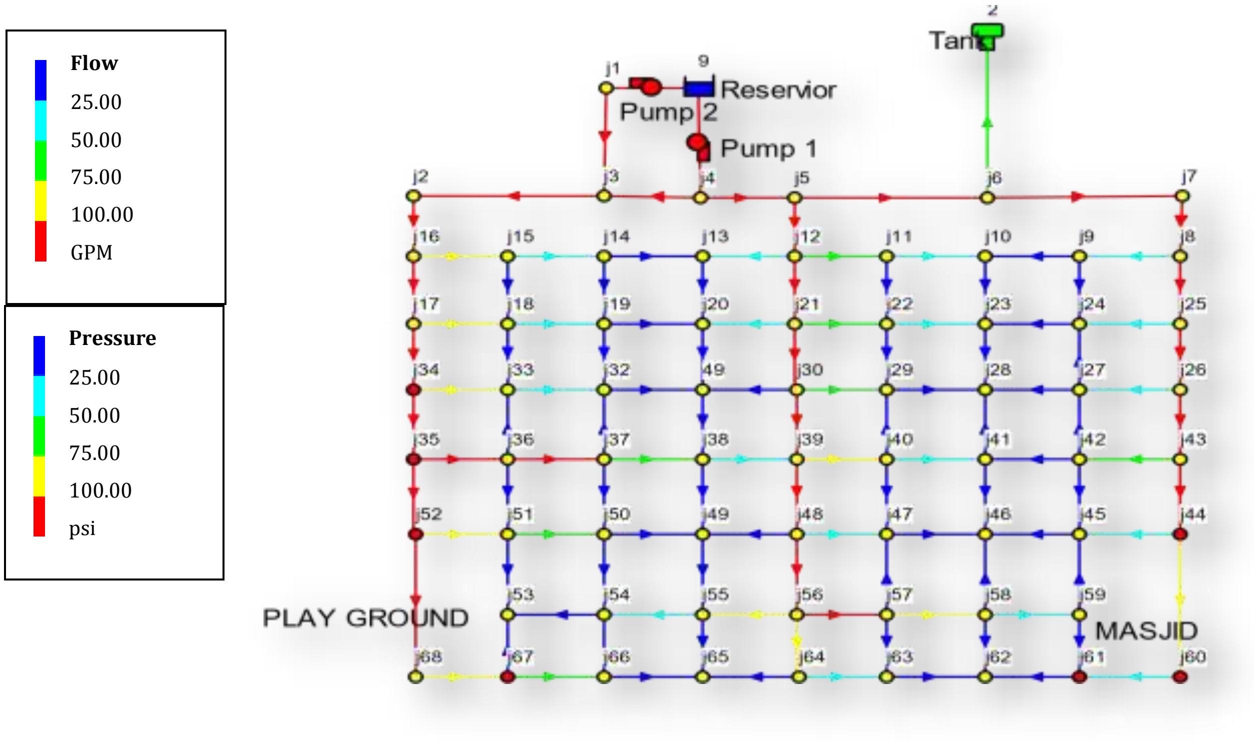


Figure 4: Description of Flow vs Pressure w.r.t Time

3.1.1. Pressure vs Velocity Distribution

This is the graph between Pressure and Velocity, which shows the variation of velocity in different pipes concerning the Elevation provided to the particular pipeline. The color of each pipe is show the value of the Velocity in feet per second. The scale is according to the color. The Red color show the Velocity in pipe is equal or above than 2.00 feet per second and blue color show the rang of Velocity equal or less than 0.01 feet per second. The pressure at the Nodes is also describe by the color. The Red color show the pressure in node is equal or above than 100 psi and blue color describe the pressure at Node is equal or low than 25psi. With passage of the time, the color of the pipe and Node is change as Velocity in pipes and pressure is change in Nodes respectively. The different values of Elevation and velocity are also given in figure 4.

Design of water supply system by using EPANET

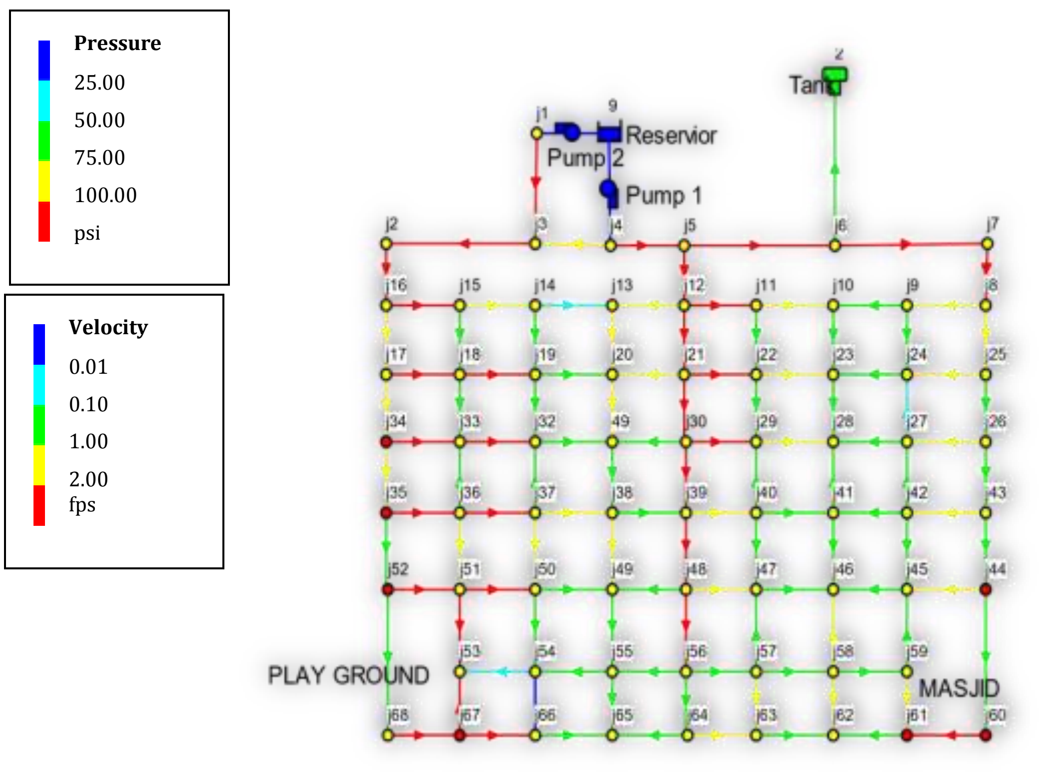


Figure 5: Description of Pressure vs Velocity w.r.t Time

3.1.2. Profile of Pressure at 1:00 Hrs.

This graph shows the pressure at all nodes after running the system after 1hr with respects to the distance between the nodes. The peak pressure is at j67 after one hour is 103.54 psi and minimum pressure at Node j11 is 91.20 psi. The variation in the pressure at all nodes is varies within the sequence.

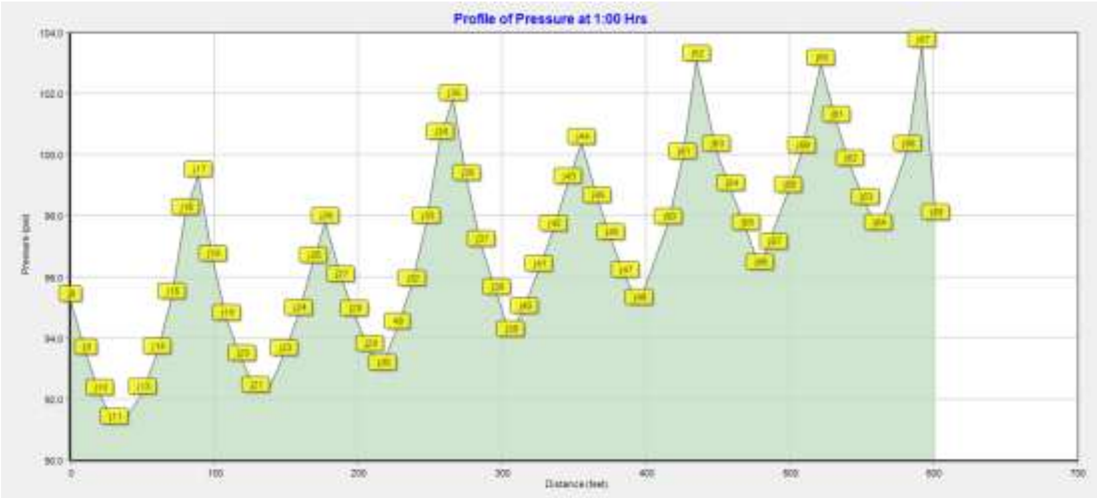


Figure 6: Profile of Pressure at 1:00 Hrs. at System Nodes

3.1.3. Distribution of velocity at Link

This graph shows the variation at the velocity at links. The velocity is continuing increase from starting.

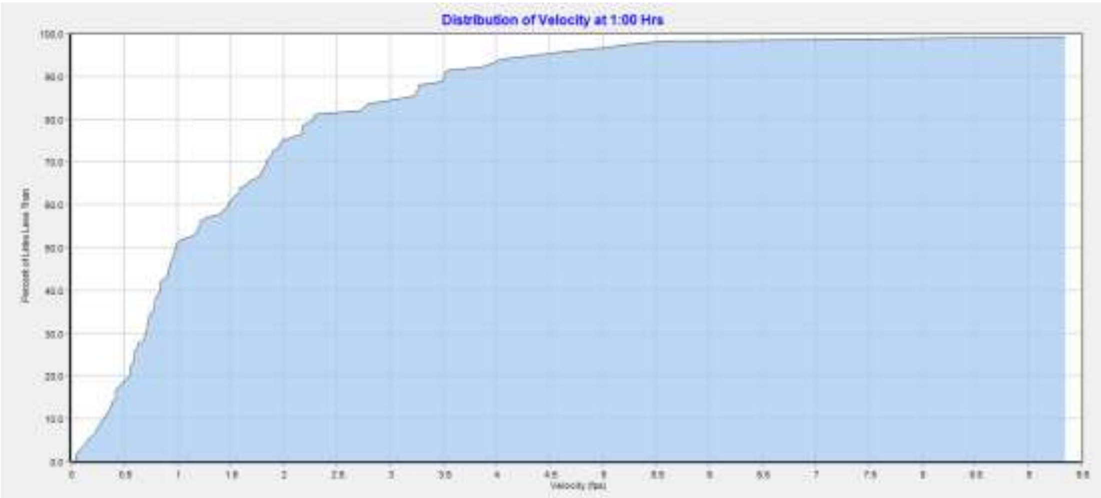


Figure 7: Distribution of Velocity at 1:00 Hrs. in Links

3.1.4. Distribution of the Flow at Link

This graph shows the distribution of the Flow in Links after running the system at one hour. The flow at pipes is continue increase until it is constant.

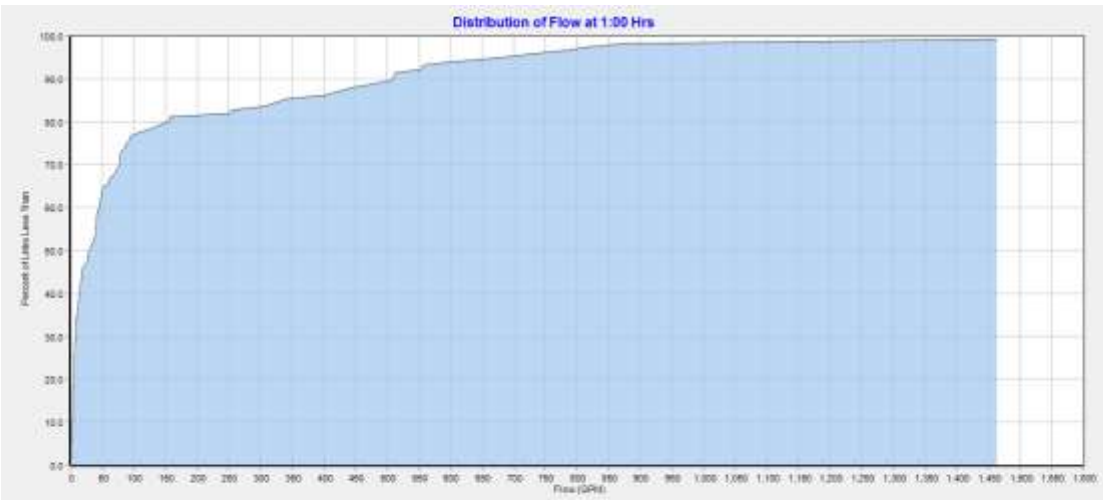


Figure 8: Distribution of Flow in Links at 1:00 Hrs.

3.1.5. Flow in links w.r.t Time

The variation of the flow in links with respect to time is shown in graph. The various links are selected from the system. The peak flow in all links after one and four hours occurs. In peak hour the pressure at system is maximum as well as flow. The flow pattern in selected links is almost common.

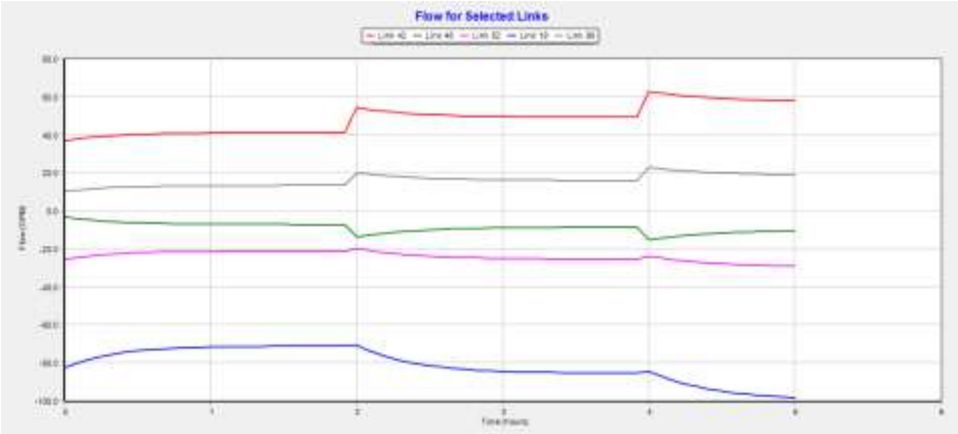


Figure 9: Variations in Flow at Different Selected Links w.r.t Time

3.1.6. System Flow Balance

This system flow balance describes the relation between the consumption and total water demand. As the system run successfully, so the water demand is equal to the water consumption for next upcoming 30 years.

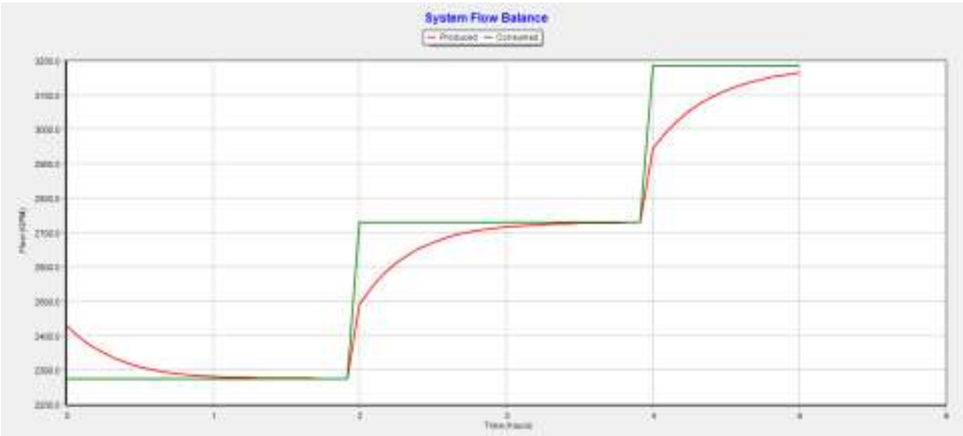


Figure 10: System Flow Balance

3.1.7. Pressure Distribution at selected Nodes

The distribution of the pressure at different node is show by the system in graph. The pressure is sudden drop after running the system 1hr and after 4hrs. the pressure is rise smoothly from 00hrs to 1hrs to for stabilization. Then it decreases continue until at end.

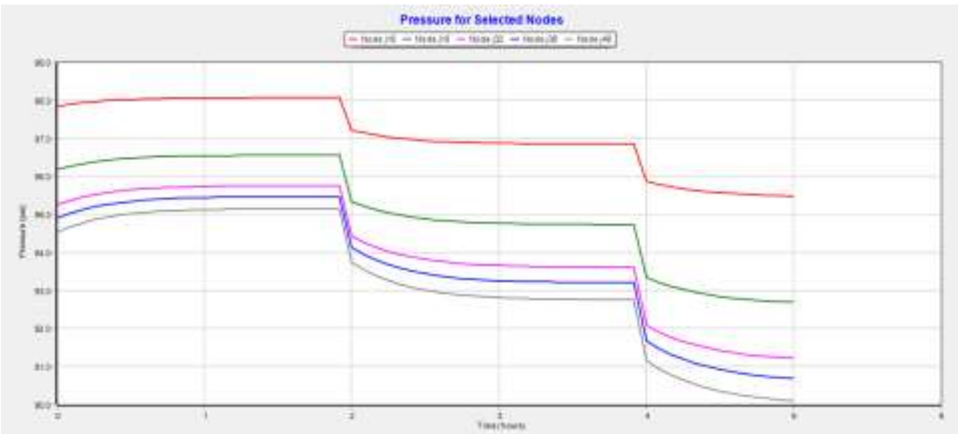


Figure 11: Pressure for Selected Nodes w.r.t Time

3.1.8. Distribution of velocity at selected Links

The graph shows the distribution of the velocity at selected links from the system with respect to time. The rate of velocity in each pipe is depend on its internal diameter. The pipes of different diameter carry the different velocity rate. At link66 the velocity at 00hrs is 3.7-3.8 fps. The variation in velocity of flow is varies with respect to time.

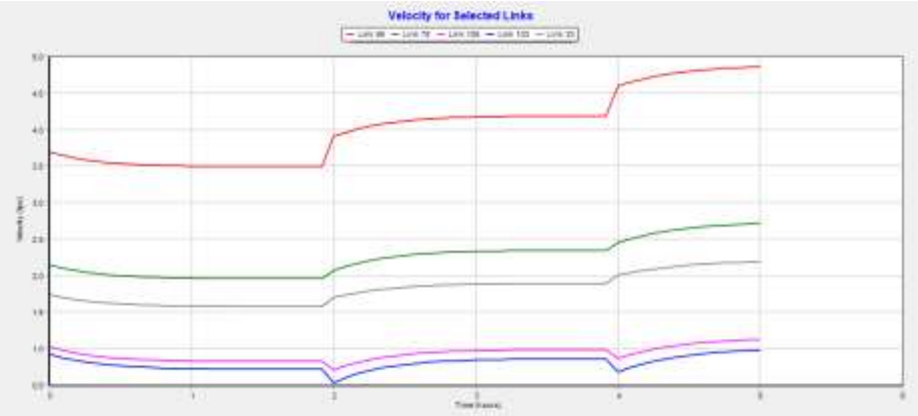


Figure 12: Velocity for Selected Links

4.0. Conclusion

A study area named Chak no. 253 RB Jahangir Kalan Faisalabad was selected. The situation of water quality was deteriorating with time. The whole community was suffering from waterborne diseases due to poor water supply system. In this work, the water distribution system has been designed with the help of EPANET in which a number of nodes, elevation, pipes and demands of the study area. The main view of this research is to analyze the water distribution network and lookout the deficiencies (if any present) in it. First of all, the survey the area and take information about the population and per capita demand of the people by introductive survey and according to that, The design the distribution system for the area. In this system, 2 pumps are used for supply of 125,573 gallons. For storage, only one overhead tank is used at an elevation of 800ft.

Here during the peak hours that is day time hours during morning time the demand for water is more as compared to the other time so the maximum supply is given for 7 to 8 hours a day. And also we concluded from tables and graphs that we obtained from EPANET shows that the demand is more during the peak hours. The different nodes show a different variation of pressures and demand like the pressure is more at nodes 1,2,3,4 as compared to others. The flow (demand) at links 17, 25, 19, 44, 47 are more due to their elevation. The method of distribution here used is combined pumping and gravity system as firstly the water was pumped with the help of pump from underground water source i.e. from aquifers or reservoir and then lifted to the overhead water tank and through there with the help of gravity system is transferred to the main rising pipe or whole area step by steps. The distribution layout used here is Gridiron end system which is according to the same layout of the CHAK NO 253, RB Jahangir Kalan area. At the end of the analysis, it was found that the resulting pressures at all the nodes and the links velocities are satisfying enough to provide water to the whole area.

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