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TASK OF EPANET ANALYSIS OF EXISTING WATER DISTRIBUTION SYSTEM AT DIRE DAWA CITY, ETHIOPIA

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***Abstract*— Many problems in provision of adequate water supply to the rapidly growing and developing cities are increasing dramatically recently. Dire Dawa, the second populist city in Ethiopia is one of such cities where the existing water supply system ceases to supply adequate water needed by the residents. The main problem associated with the present water supply system is due to expiry of the existing design. Based on information available, this was designed earlier 1982 and commenced in 1992. During this time gap residents had faced severe water shortage and various problems. Hence, at this stage, time has come to redesign the existing water supply system at Dire Dawa.**

For the present study and analysis, Sabian region of Dire Dawa city is selected in all aspects like population; existing water supply conditions and type of material used for pipes etc. for study area are considered. This study mainly aims to give approximate required values for next thirty years. Hence population is projected accordingly and the corresponding results are presented in further sections. In order to alleviate the present problem of study area, a computer based tool called EPANET (Environmental Protection Agency NETwork) analysis is selected and processed the network in order to obtain accurate and approximate results with in no time. In this study, various hydraulic parameters like required pressure heads at nodes, head of water, friction factor, velocity in various pipes of network, flow etc. are studied in detailed and found that they are in permissible limits as per standards which are shown in further sections.

Keywords—EPANET, Network analysis, population projection, pressure head, head of water, velocity and friction factor.

I. INTRODUCTION

In general, any water distribution system consisting of consisting of various hydraulic elements like pipes, tanks or reservoirs, pumps and valves etc. It is necessary to provide portable or safe drinking water to the end user for 24 X 7. Therefore, computation of flows and pressures is of great important challenge for a hydrologist in now a days for big and complex network. In earlier days, many methods have been employed to compute those pressure or flows in the networks. Later on, those methods were gradually related to various computer programs in order to make the work more simple and reliable with in a small period of time. Based on the availability over a wide range of computer based programs EPANET (Environmental Protection Agency Network) analysis is one of the tool which has a vast application in dealing simple to complex networks.

One of the earliest theories into finding solution to water flow and pressure in water distribution network includes the popular Hardy Cross method which is a best iterative method for determining the flow in pipe network systems where the inputs and outputs are known, but the flow inside the network is unknown. The Hardy Cross method is an adaptation of the Moment distribution method, which was also developed by Hardy Cross as a way to determine the moments in indeterminate structures. The method was later made obsolete by computer solving algorithms employing Newton-Raphson method or other solution methods that removed the need to solve nonlinear systems of equations by hand.

Further the reliability of water distribution system can be computed by treating the demand, pressure head, and pipe roughness as random variables. It can also be assumed that water demand and pipe roughness coefficient follow a probability distribution, and then used a random number generator to generate the values of random variables for each node and pipe. It leads to hydraulic simulation and computed pressure heads at the demand nodes, provided the demands are satisfied. Finally, nodal and system hydraulic reliabilities can be computed using EPANET

II. OBJECTIVES

The main purpose of this study is to improve in hours of supply to end user and for future generations of this city by providing adequate water supply on modifying the present existing water supply scheme. In addition to this, following are some of the objectives of this present study are:

- Improve the quantity, quality and levels of service of water supply as per the standard demand of the study area to ensure the sustainable health of the population;
- Sustain the provision of water supply services by building the capacities of the utilities and to improve the efficiency of existing scheme.
- Make the water supply service reliable by improving the capacity of the schemes correlated to the progressive demand and the operation and maintenance activities by improving accountability, transparency and participatory levels of the community;
- To reduce the leakage percentage to acceptable level and supply reliable services to the city residents

III. JUSTIFICATION FOR THE USE OF EPANET

The EPANET software developed by the USA Environmental Protection Agency is adopted because it is for general public and educational use and it is available free on-line. It has the capacity to analyze unlimited number ofpipes and tanks. EPANET has become a popular tool in analyzing complex and simple water distribution networks in both the developed and developing countries of the world. EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network. EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. In this paper it was used to carry out the hydraulic analysis of the distribution network of the study area. The results obtained are verified and observed that the pressures at all junctions and the flows with their velocities at all pipes are feasible enough to provide adequate water to the network of the study area. In addition to above, following are some more basic advantages for EPANET tool, for its wide range of applications.

- Flow rates in the network is obtained by using linear method.
- Head losses due to friction are computed using Darcy-Weisbach(D-W), Hazens – Willams (H-W) or Mannings (C-M) formulae.
- It has the capability in considering minor losses from bends, fittings, etc.
- It also can duplicate demands which vary over time.
- It can also handle for different demand patterns for each node.

IV. STUDY AREA

Dire Dawa, lie in the eastern part of Ethiopia country as shown in following Fig. 1 and 2, covers about 133,262 hectares which is second largest populist city. The geographical coordinates of Dire Dawa Administrative Council are between 41^o 38' E and 42^o 19'E longitude and 9^o 27' N 9^o 49'N latitudes with altitude ranging from 1130 to 1335 meters above sea level. Study area is situated in the Awash River Basin, having Hills and steep slopes are found in the South, moderate and gentle slopes span to the north. The distribution system of the town is divided in to three pressure zones namely P-I, P-II, P-III. Of all these regions, study area, Sabiyan region belongs to P-II region ranging from 1195 to 1240 MASL (Above Mean Sea Level). The current sources of the water supply system for this study area are mainly from Sabian boreholes and Legedol Spring : known to have providing uninterrupted service for the last 100 years is expected to provide in the range of 20-30 l/sec, In conjunction to this, Sabian Pumping station are supplementing the gab by in water demand.

Each of the regions in study area is consisting of its own service reservoir and proper distribution network based on population during the past years. The water distribution system for the present study area is of direct pumping to end users with storage during minimum consumption hours; stored in existing reservoirs and distributed by gravity systems during high consumption period of the day.

Fig. – 1: Location map of Ethiopia

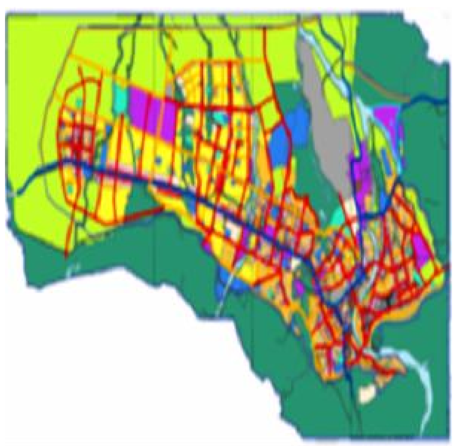

Fig. – 2: Dire Dawa network map

Following methodology is adopted during the network analysis for the study area and mentioned here below.

- The latest imagery of the study area is collected using Google satellite imagery as per the known latitudes, longitudes.
- Base map is generated at this stage by the method of digitizing using Auto CAD tool.
- Different layers are generated to distinguish well-known places such as temples, churches and mosques etc, representation of sources for the distribution of water to study area if any existing, which was shown in Fig. 3.

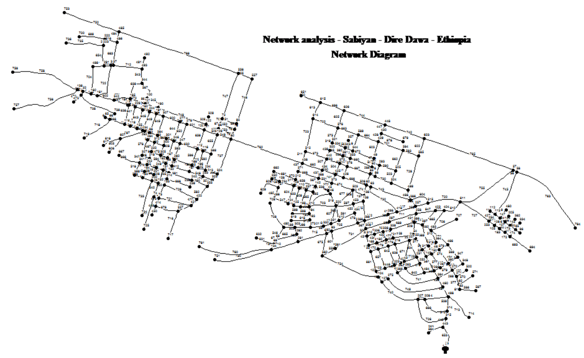

Fig. 3: Network map of Dire Dawa

- Scheme design is prepared as per the required output by using various available input parameters like population of the study area, rate of growth in population and elevation at required point to install service reservoir etc as shown in Table - I.
- In the initial trail, diameter of all pipes in the network, roughness co-efficient and material used in the network are assumed to be constant.
- Following are main assumptions made in this network analysis are:
  - Demands at each node are constant.
  - Pipe material used in the network is same
  - Only a single pipe is connected between two nodes.
- Therefore with all the available input parameters, now the network is run through EPANET tool and the results are thoroughly checked with standards.
- At the final step, the output results that are obtained after successful RUN from EPANET tool, they are cross checked thoroughly with standard required values.
- If any of the corresponding values are not with in permissible limits, then the network is adjusted accordingly to the required input parameters and again the network will be examined in EPANET tool.

- This process is repeated until the parameters like velocity, friction factor, water head, pressure head, diameter, friction factor and elevation values are in the specific range.
- Following are some standard specified values for various hydraulic parameters.
    - Maximum Static water pressure of 70m and minimum of 3 m in the distribution network.
    - Pipes with greater than 300mm shall be used based on the corresponding ISO standards.
    - The minimum and maximum velocity of flow should be fixed to 0.6m/s and 2.0m/s for distribution respectively.

TABLE I. SCHEME DESIGN FOR NETWORK

i)	Population as per 2008 census	=	75000	No's
	Base Year of the Scheme i.e completion of the scheme	=	2017	
	No. of House Holds		30000	
	Growth of Population proposed	=	0.021	2.1%
	By the method of Geometrical incremental method, population for the ultimate year is forecasted as follows: $\mathbf{P_n = P(1+I_g/100)^n}$			
	Base year Population (2017)	=	94264	No's
	Prospective population (2027)	=	116039	No's
	Ultimate Population (2037)	=	142844	No's
	This proposalis designed for a period of 30 years, where the forecasted population for the year 2037, from the base year is estimated to be 204199 No's.			
ii)	Per Capita Supply (including losses)	=	80	lpcd
iii)	Pumping hours	=	15	hrs
iv)	**Storage capacity (GLSR)**	=	33.33	% of Prospective Demand
v)	Demand for year 2017 - (Base year)	=	7541120	lpd
	Base demand in LPM	=	8379.02	lpm
v)	Prospective Demand for the year 2027	=	9283120	lpd
	Prospective LPM	=	10314.58	lpm
vi)	Ultimate Demand for the year 2037	=	11427520	lpd
	Ultimate LPM	=	12697.24	lpm
vii)	**<u>Infrastructure</u>**	**-**		
	Source	**=**	Bore well	
	Storage capacity of OHSR	=	3094373	ltrs
	Assuming Fire and other emergency services, Therefore assume 10 % excess of the total capacity of the total volume of the tank			
	10 % total capacity	=	309437	ltrs
	Therefore total capcity of tank to be provided as	=	3403811	ltrs
	Rounding off to the nearest value, Provide tank capcity as	=	4000000	litres
		=	4	Million litres
	Capacity of existing tank at Bridge café	=	1700000	litres
			1.7	Million litres
	Hence, Finally provide tank capcity as	=	2.30	Million litres

	Therefore, provide a GLSR of capacity 2.7 Million litres for the study area. (As instructed by Government authorities of water supply board)			
	R.L of GL . at GLSR	=	1218.61	M
	Highest GL. in Distribution network	=	1218.61	M
	GL at GLSR	=	1218.61	M
	LWL of GLSR	=	1219.61	M
	MWL of GLSR (LWL+10 M)	=	1229.61	M

The above table shows the scheme design for study area which consists of total capacity of reservoir to be provided with Ground Level (GL) of reservoir, Initial water level and corresponding maximum water level of reservoir. Hence, scheme design reports the final capacity of reservoir along with other additional details.

It can be clearly seen that, a storage capacity of 2.7 Million liters is provided for the study area at an elevation of 1218.610 m which is highest elevation in the study area.

VI. RESULTS AND DISCUSSIONS

The input parameters thus obtained from the above scheme design and from the network data, are thus used to run the network using EPANET tool and following observations are made.

Network consists of

- Number of Junctions / nodes 298
- Number of Reservoirs / tanks 1
- Number of Pipes 439

Following table represents the basic input required for network of present study area to run in EPANET tool such as length of pipe between two nodes, internal diameter of pipes, assumed internal diameter of pipes and roughness of pipes.

TABLE II. INPUT PARAMETERS OF NETWORK REQUIRED IN EPANET TOOL

Pipe No.	Start node	End node	Length (m)	Assumed Diameter (mm)	Base Demand (LPM)	Roughness (C)
29	30	31	9.32	132.40	21.63	130
32	33	34	13.17	132.40	21.63	130
35	36	37	15.53	132.40	21.63	130
41	42	43	24.85	132.40	21.63	130
44	45	46	26.25	132.40	21.63	130
47	48	49	27.98	132.40	21.63	130
50	51	52	29.77	132.40	21.63	130
53	54	55	31.42	132.40	21.63	130
56	58	57	32.67	132.40	21.63	130
59	60	48	33.03	132.40	21.63	130
61	62	63	33.28	132.40	21.63	130
64	65	66	33.82	132.40	21.63	130
67	69	68	36.64	132.40	21.63	130
70	71	72	36.81	132.40	21.63	130

As it was mentioned in the earlier sections,that in the initial trail the internal diameter of pipes and base demand are assumed to be constant which can be seen from table – 2.

Hence by using the above input of network for the present study area, using EPANET tool, following output can be generated which is presented in Table – 3

TABLE III. OUTPUT GENERATED FROM EPANET TOOL FOR PIPES

Link No.	**Start node**	**End node**	**Length**	**Diameter**
29	30	31	9.32	265.20
32	33	34	13.17	237.00
35	36	37	15.53	237.00
41	42	43	24.85	237.00
44	45	46	26.25	213.00
47	48	49	27.98	237.00
50	51	52	29.77	213.00
53	54	55	31.42	298.40
56	58	57	32.67	151.40
59	60	48	33.03	237.00
61	62	63	33.28	298.40
64	65	66	33.82	189.40
67	69	68	36.64	170.20
70	71	72	36.81	237.00

Table – 3 represents the exact value of internal diameter of pipes after the successful run in EPANET tool, which is fixed based on various parameters like base demand, elevation and pressure head required at various nodes. Also, from above table it may be seen that, all the diameters of pipes are according to standards which were specified earlier.

On the other hand, outputs at various nodes for the network like pressure head, water head and base demand are shown in Table – 4.

TABLE IV. OUTPUT GENERATED FROM EPANET TOOL FOR NODES

Node number	Demand (LPM)	Head of water (m)	Pressure head (m)
753	21.63	1215.39	47.59
736	21.63	1215.39	43.83
759	21.63	1215.38	42.49
700	21.63	1215.39	42.26
485	21.63	1215.39	41.45
222	21.63	1215.39	40.12
486	21.63	1215.39	39.57
223	21.63	1215.39	39.06
488	21.63	1215.39	38.31
557	21.63	1215.45	37.74
291	21.63	1215.39	37.41
556	21.63	1215.44	37.34
651	21.63	1216.23	36.05
136	21.63	1215.39	35.79
36	21.63	1215.39	35.78
492	21.63	1215.39	35.51

Table – 4, shows that output generated from EPANET tool for the study area at various nodes. It may be seen that, the values like head of water, pressure head were all in permissible limits as per the specifications which are mentioned earlier.

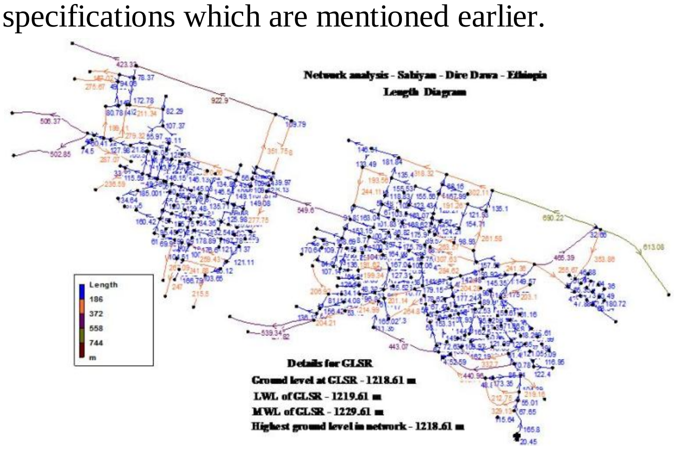

Fig. 4: Length diagram of the network

Finally, output from the EPANET tool generated are represented in the form of pictures in following figures from 4 to 7.

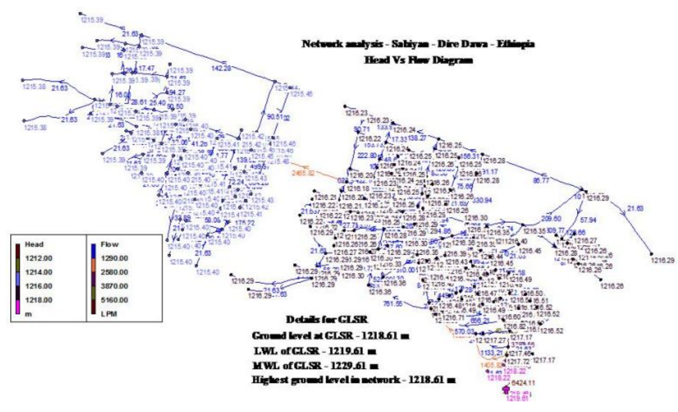

Fig. 5: Flow diagram for the study area

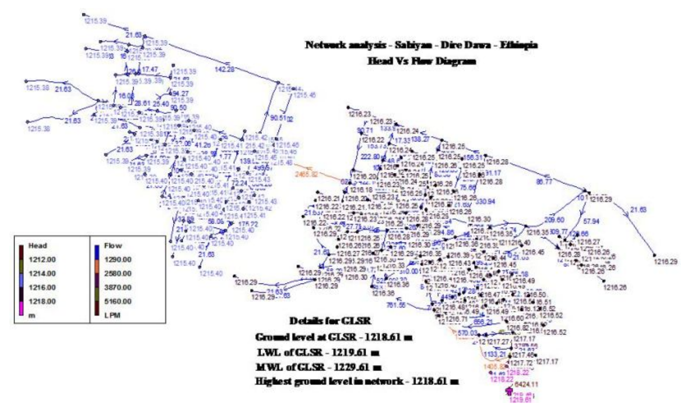

Fig. 6: Head vs flow for the study area

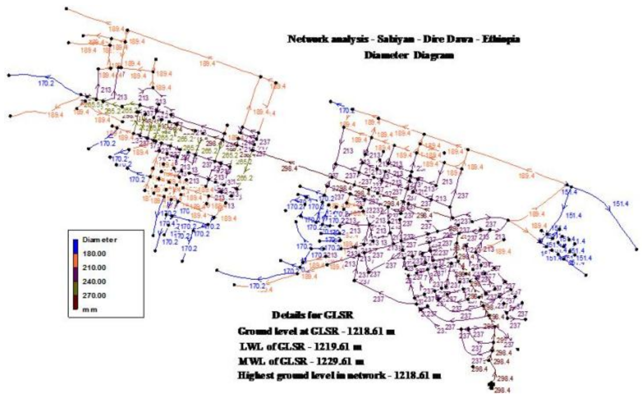

Fig. 7: Diameter diagram of the study area

VII. CONCLUSIONS

Following conclusions are drawn from the above study which are as follows:

- The residual pressure at all nodes is found to be greater than 3 m. Hence, the flow can take place easily to all nodes without any disturbance.
- The assumed internal diameter of 132.40 mm is insufficient for all the links in the network. Hence, based on the elevation at nodes, base demand diameter of pipes can be fixed for the network.
- Various hydrological parameters like base demand, pressure head, head of water and friction factor etc can be easily observed even for a large or complex network.
- By using tools like EPANET, the analysis can be done with in a short period of time even for complex to simple type of networks.
- The designed network can also withstand for 5 % increase in population for future growth instead of 2.2 % as it was consider now in the scheme design.
- It is recommended that valves of different types like sluice valves, air valves and pressure valves are to be installed at various locations of network.

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