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Hydraulic and Utility Performance Evaluation of Ataye Town Water Distribution Network, Ethiopia: case for small towns in developing countries.

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ABSTRACT

Evaluating hydraulic and utility performance of water distribution network is a way to check the functionality degree of a system. Water CAD software was used in developing a model and evaluating the hydraulic performance of water distribution system of Ataye Town, Amhara Region, Ethiopia. Both steady state and extended period simulation analysis were carried out to determine hydraulic parameters (pressure and velocity). The model was calibrated using Darwin Calibrator and validity was checked by both correlation coefficient and scatter plot. The utility performance was also evaluated using international water association performance indicators. The simulated result for steady state analysis showed that 68.7% of the nodes operated within optimum adopted pressure (15-60 meter) and 93% of the distribution pipes had a velocity of <0.6 m/s which was a minimum adopted velocity. For extended period simulation 34.3% during maximum demand time and 16.8% during minimum consumption hours had pressure <15meters. 10.8% had negative pressure during maximum demand hours located at Sudan, Selama, and Zigba sefer and 14 nodes (8.4%) during low consumption time had a pressure greater than 60meter, which was a maximum adopted pressure. The areas of high pressure were located at around mosque, Worku Hotel and Hamus Gebaya. The distribution system performs within the adopted pressure at minimum demand time (74.7%) and maximum consumption hours (65.1%). 23.5% of the systems had a velocity of 0.6-2 m/s and the rest had a velocity less than 0.6m/s during high demand time. During low consumption hours, 100% of the system velocity was estimated to be <0.6m/s. Based on the IWA performance indicators, water utility of Ataye Town was evaluated and had low, technical, financial, personnel, and environmental performances. Finally, the distribution system was modified and optimized by providing alternative connections with pressure reducing valves and changing pipe diameter to improve the hydraulic performance and reduce system disruption of the Town.

Keywords: Extended period simulation; Hydraulic performance; IWA Utility performance; Steady state analysis; Water CAD

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1. INTRODUCTION

Availability of potable drinking water and provision of safe sanitation facilities are the basic and minimum requirements for healthy living (Trifunovic N., 2006). Water distribution systems are designed to adequately satisfy the water demand for domestic, commercial, industrial, and firefighting purposes at all times and at satisfactory hydraulic performance (Terlumun U.and Robert E.,2019). Most water utilities fail to deliver water because of poor distribution system and the efficiency of the water utility is very low. In Southern Ethiopia customer satisfaction is below 50 percent (Kassa, k., et al., 2017).

The utilities' performance efficiency has a direct effect on the performance of the distribution systems (Van den Berg and Danilenko A., 2017). The performance efficiency of utilities is responsible for the proper functioning of the systems and the efficiency is seriously very poor in developing countries, like Ethiopia. The reason behind the low services of the utilities is that they are provided in a monopolistic environment mostly by government. In the absence of market forces, it is hard to find motivation for efficiency. For instance, in the case of Ethiopian water utilities that sell water at a subsidized rate to help the poor and therefore utility personnel payments are also low, as a contributing factor. All the stakeholders in the water supply business have realized that, , utilities can be forced to continually improve their performance by assessing the performance of the services in a systematic way, with the consequential benefits for all those involved (Alegre, H. et al, 2009).

The distribution network is responsible for delivering water from the source to consumers at serviceable pressure (Zyoud S., 2003) which is the main contributor for technical aspect of the utilities performance. Because of failure of system components and variation of demand, occasional disruptions may occur over the service life of the system. Some of the factors which affect the performance of a distribution system are incorrect design, population increase, increase service connections than estimated, expansion of service areas, failure of distribution network components, and increase roughness of pipe surface as a result of ageing (Terlumun U. and Robert E.,2019). The rapid growth of population and expansion of service connection in Ataye increase water demand which exerts extra load on existing water supply system. As a result, some consumers are left with little or no water supply.

The aim of this study was to evaluate the Ataye Town water supply system by International water association (IWA) utility performance indicators and by water CAD based hydraulic analysis in order to identify the problems to provide technical suggestions.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out at Ataye Town located in North Showa, Amhara Regional State, Ethiopia. The Town is located at latitude between 10° 19ˈ and 10^{o} 22ˈ North and Longitude between 39° 56ˈand 39° 58ˈEast, 280 km away from Addis Ababa. It belongs to Awash Basin which is located at an average elevation of 1450m. It belongs to semi-desert climatic zone with two main seasons (rainy and dry seasons).

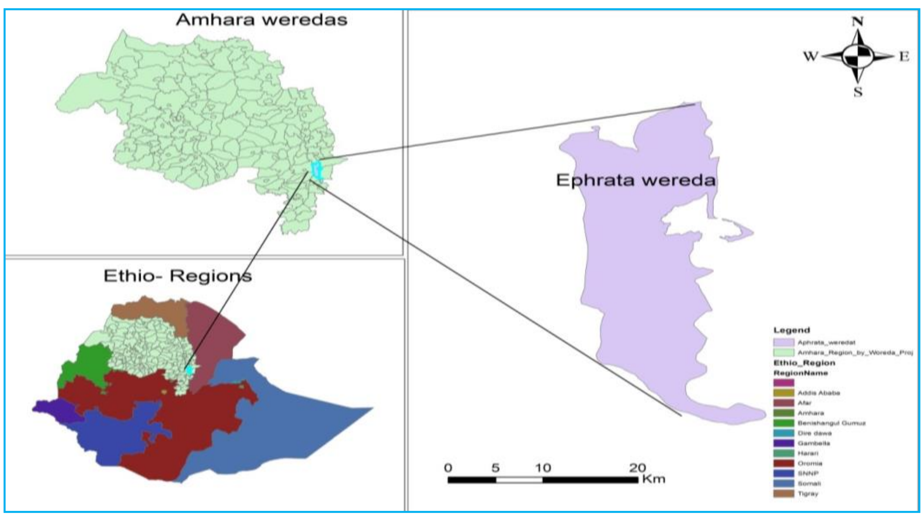

Figure 1 Location of Ataye Town in Ethiopia

Existing water supply system of Ataye town was constructed in 2014/2015 and designed for 30 years. The source of water is from three well fields of deep boreholes. The Town water utility had average daily production capacity of 24.8 l/s (2142.72m^3/d) (ATWSS, 2020).

2.2 Data Collection

To build the model of the distribution network and to evaluate hydraulic & utility performance, the required data of the distribution system parameters were gathered. Pressure, tank water level, location, and elevation of points were collected by field surveying and direct measurement. Daily water production and consumption, pipe, tank and pump, financial and water tariff, staff and customer, and well history were collected through Key Informant Interview annual report and design document, and as built or completion report document review.

2.3 Allocating Demand

For population forecasting the geometric increase method is mostly applicable for growing towns and cities having vast scope of expansion (CSA, 2007). The population projection of Ataye Town was calculated using equation (1):

$$Pn=P_o(1+r)^n \qquad (1)$$

Where, P_o= base population, P_n = population at n decades or year, n = decade or year, r = rate (percent increase).Three modes of services are given in the Town: house connection (35%), yard connection (48%), public fountain (15%) and unprotected water source users 2% (ATWSS, 2020). The per capita demand of the town was projected and allocated to each node by mode of services. The annual growth rate was 2 % for public fountain users and 3% for yard and house connection (Mamush, 2016).

For preliminary calculation of the nodal demands, a simple method was applied using water consumption rate per linear meter of distribution pipe. Once the total demand on each pipe was determined, the pipes were separated between two corresponding nodes. This method was based on the assumption that service connections were evenly distributed. To assign base demand to each nearest supply node, the houses around each supply nodes were identified with direct count. The demand of each node depends on the population around the node (along half of pipe length connecting two nodes) multiplied by base demand. Unit consumption per meter of the pipe length for each loop was estimated by

$$ql = \frac{Ql}{\sum_{j=1}^{m} Lj,l} \quad \text{(2)}$$

Where, Ql. is the average demand within loop l (along a pipe), and Lj is the length of pipe j forming the loop and ql is unit per meter flow.

2.4 Water CAD model preprocessing

Distribution layout survey data from Auto CAD civil-3D was imported into Bentley Water CAD v8i using model builder. The imported distribution layout was edited using property dialog box by entering the following: nodes elevation, base demands, pipe diameter, pipe length, pipe material, friction factors, tank base, minimum and maximum level, tank diameter, reservoir elevation and pumps input data. In order to build and analyze the distribution network 38,950 m pipes with internal diameter of 50-200mm, 3 tanks, 4 boreholes with submersible pump, and 166 junctions were used.

2.5 Model Calibration and Validation

After the first run, the model was calibrated using Darwin calibrator by adjusting sensitive parameters related with flow like pipe roughness coefficient and water demand until it becomes within the acceptable limit. Therefore, for this study the model data quality was analyzed by comparing and calibrating the computed pressure data with the actually measured ones. Pressure readings were taken at specific time using pressure gauge at 10 sample points for calibration and 10 samples for validation.

Finally validation was done with equation (3) using the correlation coefficient equation (R^2) method using Microsoft Excel.

$$R^2 = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\sqrt{\Sigma(X-\bar{X})^2} * \sqrt{\Sigma(Y-\bar{Y})^2}} \quad \text{(3)}$$

Where: R^2 = coefficient of determination, X and Y are the computed and observed pressure values, and $\bar{X}$ and $\bar{Y}$ are mean value of computed and observed pressure, respectively.

For the calibration, the head loss between sample (main nodes and the site) where pressure was measured has been considered which include only the elevation head. Pipe friction loss was ignored since the distance between the points was 10-20 m, assuming friction losses were insignificant.

2.6 Model Simulation and Analysis

The distribution network analysis was conducted using Water CAD software by building distribution system model. Hazen–Williams equation was used to compute pressure and velocity at both steady state and extended period simulation of the water supply system. The hydraulic performance of the distribution network was identified and evaluated by comparing these hydraulic parameters with design criteria of the distribution network and areas of high or low pressure zone. The static pressure in the distribution system is the pressure head in the network is equal to the height to which the column of liquid could be raised (Swamee and Sharma, 2008). The adopted design criteria for the evaluation that is 15- 60 meter of water (mw) and flow velocity 0.6- 2 m/s was according to MoWR (2014).

2.7 Utility Performance Evaluation

To evaluate the utility performance, a set of IWA key performance indicators (KPIs) were used as the basis for the performance evaluation. The KPIs used were selected and adopted based on the availability of data. Under the IWA system, performance indicators (PIs) were classified into 5 groups: personnel, technical, environmental, quality of service and economic and financial Alegre et al. (2017). PIs could be different for developing and developed countries owing to the availability of data (IWA, 2006). The methods of calculation for performance indicators are shown in Table 1. Finally, the analyzed results were discussed by comparing them with benchmark target, which was obtained from IWA standard and MWIE (2014) guideline for GTP II.

Table 1 Key performance indicators and their calculation methods

No.	KPIs	Method of calculation	Unit
1	Average daily per capita water consumption	Total billed water (m^3) during the assessment period x 1000/ (365x total number of served population)	l/c/d
2	Average selling price per m^3 of water	Total billed water sales (Birr)/ Total domestic, institutional, and commercial water sales (m^3)	Birr
3	Operating costs per m^3 of water sold	Operation & Maintenance (O&M) and administrative costs/ Net water sales (m^3)	Birr
4	Working ratio (Efficiency Ratio) for water service	Operation & Maintenance (O&M) and administrative costs / Operating revenues from water	number
5	Collection efficiency	Water fees collection during the year / total annual water billed sales (Birr)×100%	%
6	Non-Revenue Water (NRW)	Total billed quantity (m^3) during the assessment period/ (Total supplied water during assessment period ± difference in stored quantities in utility reservoirs) x 100%)	%
7	Staff productivity index (SPI) per1000 customers	Total number of working staff/ (number of active water subscribers)/ 1000 customers	Numbe r
8	Water losses in (m^3) per km in the distribution per year	Total water losses during the year (m^3)/ Total Network length (km)	m^3
9	Water samples taken from distribution network containing free chlorine residual (RC)	Number of Samples taken from network containing free chlorine residual/ Total number of tested samples for RC x100%	%
10	Water samples (taken at distribution) free from total coliform contamination	Number of tested water samples (taken at distribution) free from total coliform contamination/ Total number of tested samples for this purpose x 100%	%
11	Samples (taken in distribution) free from fecal coliform contamination	Number of tested water samples (taken at distribution) free from fecal coli form contamination/ Total number of tested samples for this purpose x 100%	%
12	Microbiological tests	Number of microbiological tests carried out during the assessment period/ number of microbiological tests required by applicable standards during the assessment periodx100%	%

2.8 Optimization of the distribution network

After analyzing and identifying the distribution network problems, the distribution system was modified by different mechanisms. Nine pressure reducing valves (PRVs) were provided at P-69, P-70, P-72, P-79, P-81, P-83, P-86, P-191, and P-193 to reduce excess pressure in the distribution system. Alternative connection was another way to increase pressure and flow velocity. T-1 was connected with J-98 and T-2 with J-41. The pipe diameters of P-140, P-141, P-142, P-144, P-145, P-147, P-148, P-150, P-151 and P-152 were resized and the pump operation time changed. Thus, the distribution system was improved. Besides, injecting additional water into the system was another way of improving the system.

3. RESULTS AND DISCUSSION

3.1 Population and Demand projection

The population of the town at 2020 was 31,600. According to the Ministry of Water guideline (MoWR, 2014), the percentage of population served by house connection (HC), yard connection (YC), and public fountain (PF) were estimated for 2021, 2025 and 2030. Water consumption varies with mode of services. Customers with house connection use more water than customers with yard or public tap connection. Table 2 shows Ataye Town population and water demand projection up to 2030. The total domestic demand can be worked out by multiplying the per capita per day demand with population served by each mode of service.

Table 2 Population and demand projection by mode of service

Description		**Years**		
Population/Service Levels	2020	2021	2025	2030
Population	31600	32709	37549	44596
Percentage (%) of Population Served by:-				
House connection	35	36	40	44
Yard connection	48	49	53	56
Public Fountain	15	14	7	0

Description	Years			
Per Capita Demand (Lpcd)				
House connection	70	71	75	80
Yard connection	30	31	35	40
Public Fountain	25	26	30	35
Demand by Service Standard (m^3/d)				
House connection	774.2	836.39	1128.72	1575.7
Yard connection	455.04	507..48	699.52	1006.4
Public Fountain	118.5	119.15	79.22	0
Average domestic water demand (m^3/d)	1347.74	1463.03	1907.46	2582.11
Commercial & institutional demand (10 %)	134.77	146.3	190.75	258.21
Unaccounted water demand (25 %)	336.93	365.8	476.86	645.52
Projected average water demand (m^3/d)	**1819.44**	**1975**	**2575.1**	**3485.8**
Maximum day factor	1.2	1.2	1.2	1.2
Maximum daily water demand (m^3/d)	2183.34	2370	3090.09	4183
Peak hour factor	1.7	1.7	1.7	1.7
Peak hour water demand (m^3/d)	3093	3358	4377.63	5925.9

The average water demand of Ataye town in 2025 will be **2575.1** m^3/d. The town water utility has four boreholes with total average daily production capacity of 24.8 l/s (2142.72 m^3/d) (ATWSS, 2020) which cannot meet the water demand after 2022. So, there should be additional source after 2022. Base or average water demand for each node was computed and assigned based on population, types of demand, and mode of service around the node. Public fountain may not be used after 2030. House connection will be more than yard connection after 2021 as the income of the population increases.

3.2 Model Creation, Calibration, and Validation

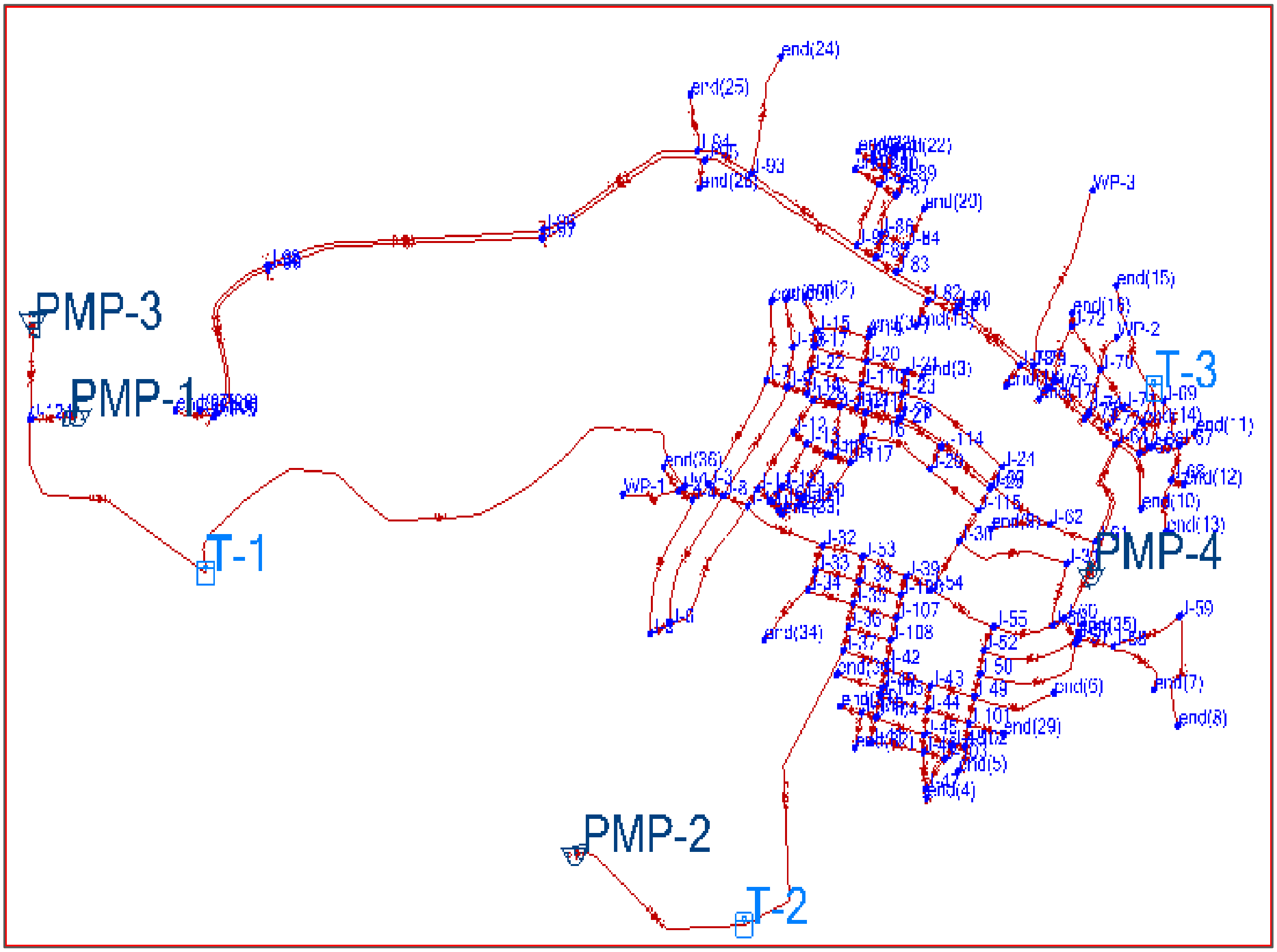

Figure 2 Ataye Town Distribution network layout

Figure 2 shows the water distribution network of Ataye town designed with water CAD. The model has 166 nodes, 222 pipes (links), 3 tanks, 4 reservoirs (boreholes) and 3 pumps. Table 3 shows measured and simulated pressure at different time and sample nodes. Head losses between the two points were added to measured pressure at customer tap to get measured pressure at sample node.

Table 3 Simulated and observed pressure at specific time after the first run

C	Nodes	Measurement time	Simulated model pressure (mw)	Measured pressure at costumer tap (mw)	Head losses b/n nodes and customer tap (mw)	Likely measured pressure at sample Node (mw)	Error(m)
1	J-63	7:00	26	22.07	0.58	22.65	-3.35
2	J-32	17:30	29	25.48	0.7	24.78	-4.22
3	J-10	18:00	24	21.40	0.83	20.57	-3.43
4	wp-1	11:00	0	0.00	0	0.00	0
5	J-8	17:00	20	18.54	0.41	18.13	-2.87
6	J-9	18:30	20	18.34	0.85	17.49	-2.51
7	J-62	8:25	55	49.55	1.05	48.50	-6.50
8	J-6	16:35	10	7.63	0.53	7.10	-3.90
9	J-73	17:50	30	26.70	0.11	26.81	-3.19
10	J-76	15:00	52	49.65	0.03	49.62	-2.38
11	J-78	18:30	28	24.97	1.46	23.51	-4.49
12	J-81	7:30	27	18.33	0.59	17.74	-9.26
13	J-75	19:30	56	52.10	1.02	51.08	-4.92
14	J-71	8:00	30	26.09	0.92	25.17	-4.83
15	WP-3	11:20	2	0	0	0	-2.00
16	end(32)	6:00	4	0	0	0	-4.00
17	J-101	23:00	13	8.67	0.36	9.03	-3.97
18	end(3)	13:00	52	48.76	0	48.76	-4.24
19	J-117	21:00	53	42.94	0.66	42.28	-10.72
20	end(21)	5:00	18	12.75	0	12.75	-5.25

Note: mw= meter of water

The error was the calculated difference between measured and simulated pressure. The negative values for error showed that simulated pressures were greater than the measured pressured. At all junctions except wp-1, the simulated and the measured pressure values had differences in relationship. The model was over estimated at those junctions. So, model calibration using Darwin calibrator was done. In Table 3, nil values for pressure indicated that there was no pressure at the junction during the measurement time and the nil head loss values showed that there was no head difference between sample nodes at customer taps.

The measurements were taken at 20 junctions at different location in the town. Nil pressure was recorded at WP1 in Selama, at WP3 in Zigba Sefer and at the end (32) in Sudan Sefer.

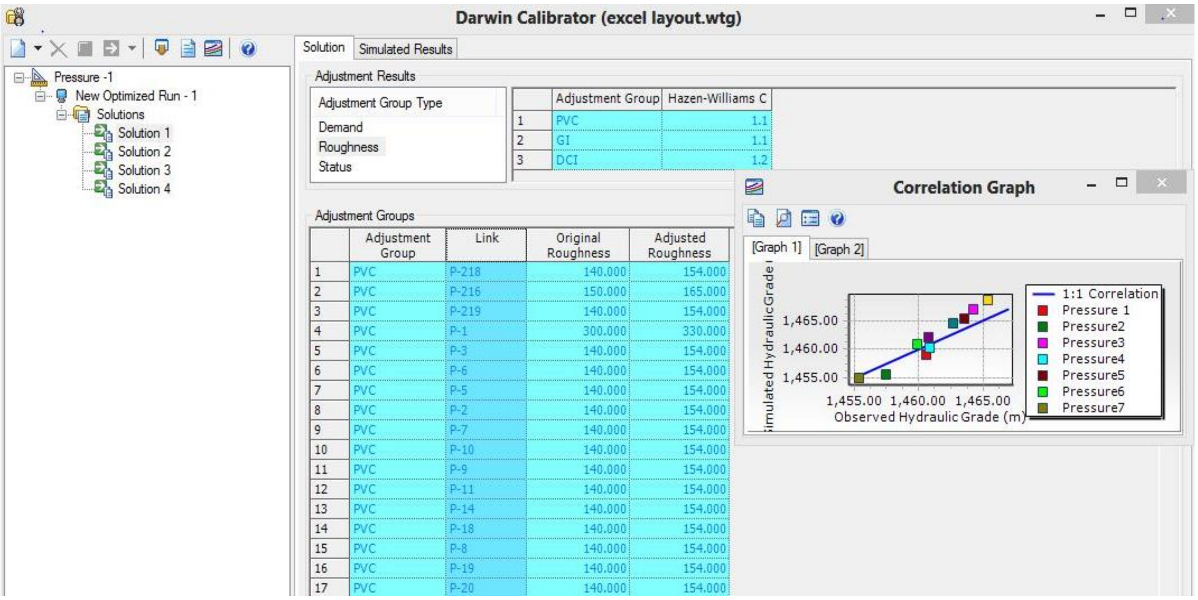

Figure 3 Original and adjusted pipe roughness values and correlation graph after model calibration

Figure 3 shows Darwin's calibration result of original and adjusted pipe roughness and correlation graph. The correlation graph showed the relationship between measured and simulated pressures.

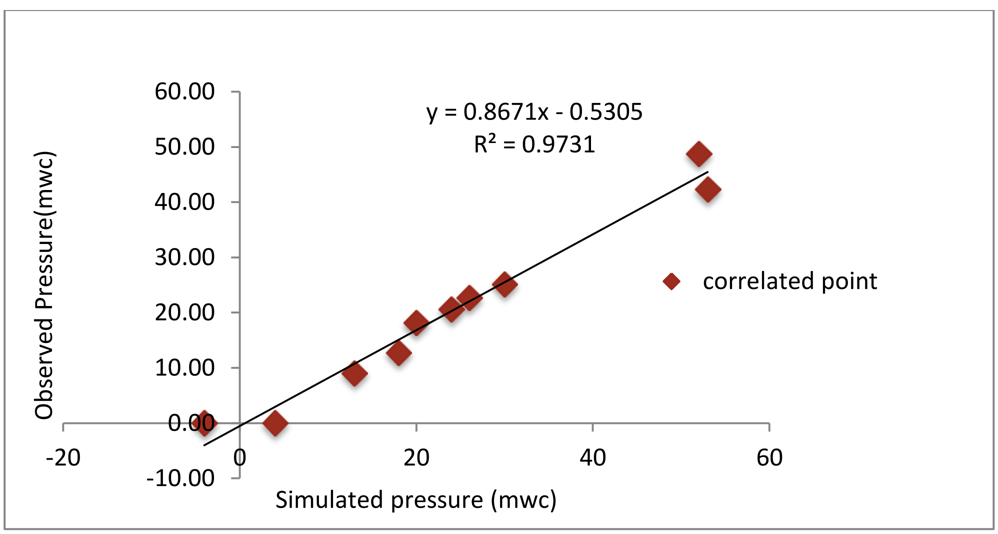

Figure 4 Scatter plot of simulated versus observed pressure for validation

In Figure 4, x-axis refers to simulated pressure while y- axis indicates observed pressure for 10 sample points which were used for model validation. After calibration, the model was validated using correlation coefficient equation (R^2) for scatter plot of observed versus simulated pressure. The more the correlated points approached the line the more the data had linear relationship. For both methods the correlation coefficient (R^2) value was 0.97 (97%) which implied strong linear relationship between observed and simulated pressure. Thus, the simulated was in agreement with the real one.

3.3 Pressure and velocity analysis

3.3.1 Pressure for steady state analysis

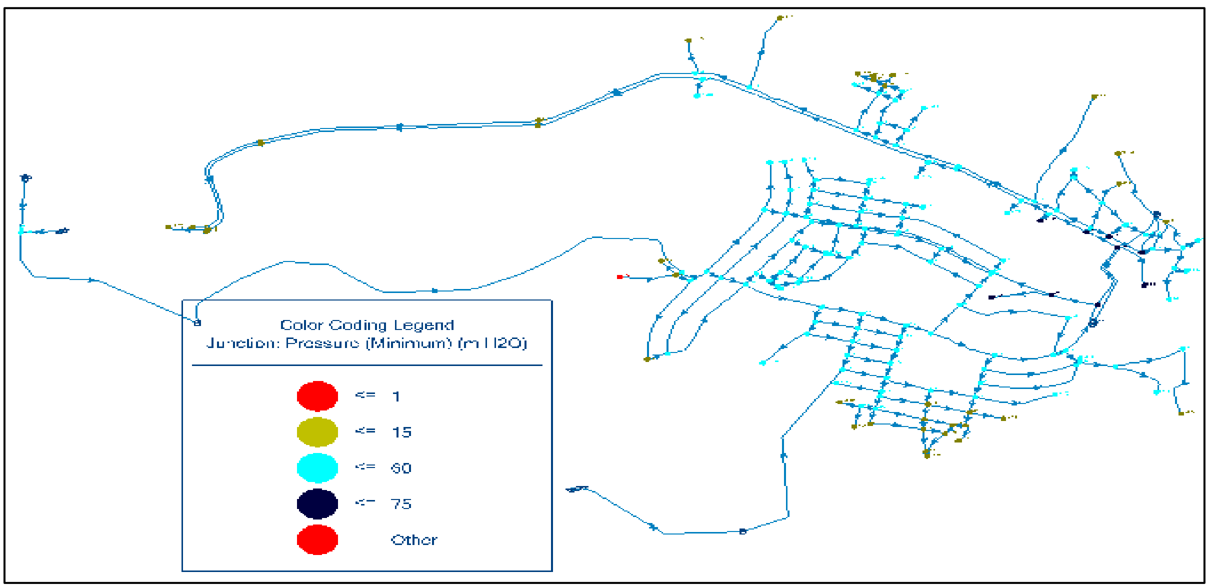

Figure 5 Pressure values for steady state analysis from Water CAD.

Figure 5 shows the model result analyzed at steady state run for the average daily demand, which does not change at every node 24 hours of a day. The nodes with red color represent negative pressure (<=1m), nodes with yellow color show pressure in the range **1- 15 m**, nodes with aqua color represent pressure **15-60 m** and those with blue color show pressure greater than **60 m**. From simulated result for steady state analysis, one junction (**WP-1**) located at Selama Sefer had negative pressure, 37 nodes (**22.29%**) had pressure below minimum adopted pressure (15m), **9** junctions (**end (9**), J-61, J-62, J-64, J-65, J-75, J-77, end (10), and end (17) or (**5.4%)** had pressure greater than maximum adopted pressure (60m). The remaining **119** nodes **(71.68%)** had pressure in the range **15-60 m** which was optimum adopted pressure range (MWIE 2014). For steady state analysis only **15** pipes in Zigba, Slama and Sudan Sefer or **7%** of the distribution system performed with optimum velocity of (0.6m/s to 2 m/s). The rest was operated under optimum velocity.

3.3.2 Extended Period Simulation (EPS) Result

Extended period simulation showed more detailed variation of hydraulic parameters, demand, supply, and tank level fluctuation in 24 hours of a day.

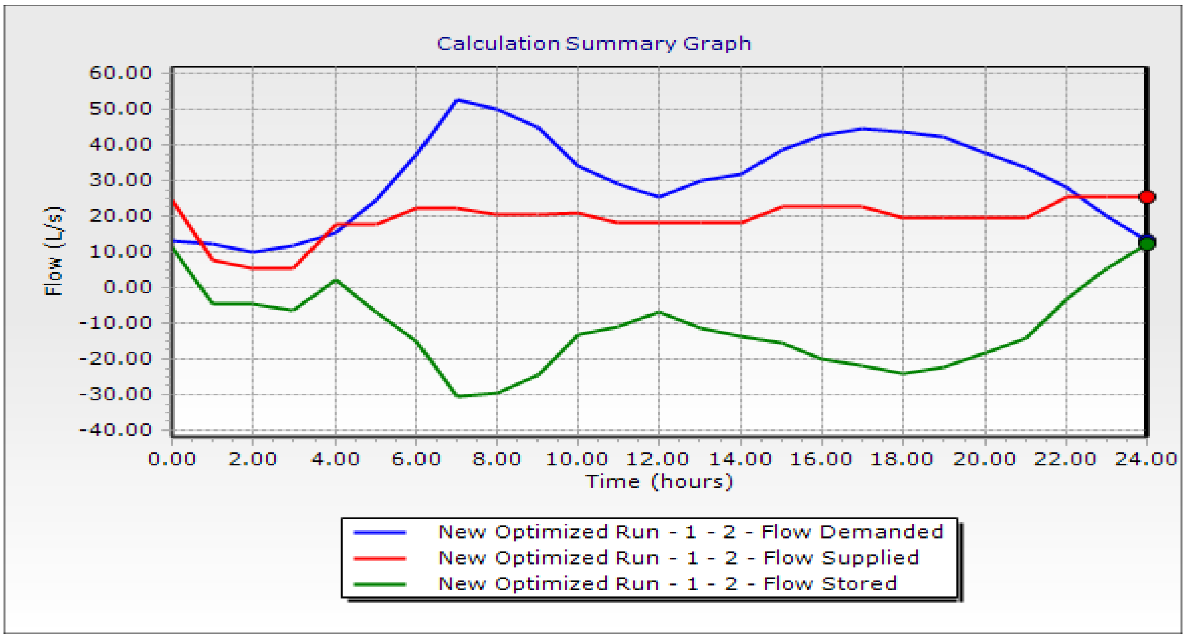

Figure 6 demand, supply and tank storage fluctuation summary graph

Figure 6 shows that base flow demand reached a peak of 7:00 (52 l/s) and flow supply was 22 l/s. So, tank storage was -30 l/s. The negative sign indicated that the tank was at full status. The flow stored from 0:00 to 1:00 and 22:00 to 24:00 was taken as positive, which means the tank was draining/ overflowing.

It was difficult to discuss all 166 nodes in 24 hours. The low and high pressure occurs at low and high demand time, respectively. High daily demand for this study occurred from7:00 to 9:00 and 17:00 to 19:00. Low daily demand happened within 0:00 to 3:00 and 22:00 to 24:00 hours. The maximum pressure was **70** m at end (10) and minimum pressure was -**14**m at wp-1.

In Figure 7, areas or nodes with red color represent less pressure of 1 meter water column (mwc), pink color shows area with pressure **1- 15**m, blue color represents **15-60** m pressure, and aqua color represents areas with **60 to 70**m pressure at peak demand time. **18** Nodes (wp-1, J-47, end(4), J-69, end(15), wp-3, wp-5, end (24), end (25), J-98,J-99, J-100, end(27), end(28), end(5), WP-4, end (22) and end (32)) with red color had negative pressure at maximum demand time. **39** nodes had pressure **1-15 m** at maximum demand time. End (10) had greater than 60m pressure even at maximum demand time. The remaining **108** nodes with green color had pressure **15-60m** (**65.06**%) which adopted optimum design pressure.

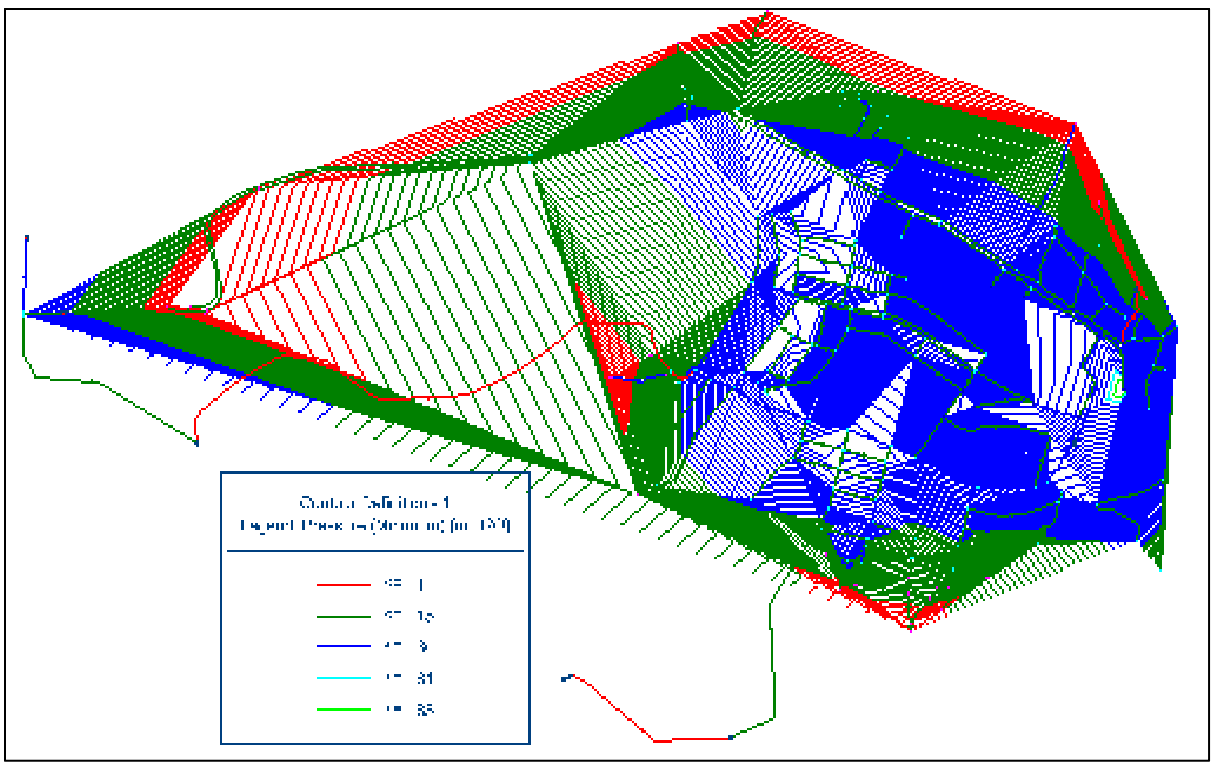

Figure 7 pressure contours map of the model during peak demand time

Figure 8 shows pressure contour map of distribution during minimum demand time. During minimum demand times, **28** nodes or **16.86%** were operating under the minimum adopted pressure (1- 15m). Areas with aqua color and located at 02, Laygnaw Ataye, Sudan Sefer and Zigba showed less pressure of 15mwc. **14**nodes (J-30, J-31, J-61, J-62, J-115, end (9), J-64, J-65, J-74, J-75, J-77, end (10), end (17), and end (18)) or **8.4%** areas shown with red color and located around Worku Hotel, Roman Hotel and Mosque, had pressure greater than **60m** during low demand times. **124** nodes (**74.7%)** were operating within optimum adopted pressure (15-60m). This was represented by blue color. **57** nodes (**34.34%)** during maximum demand times and 28 nodes (**16.86%)** during minimum demand time had pressure less than 15m H_2O in the distribution system, which was not sufficient for effective system performance. **18** nodes had negative pressure during maximum demand time. That means **4500** people around these nodes could not get water during maximum daily water consumption hours. **14** nodes during minimum demand time and **1** node during maximum demand time had pressure greater than 60mwc which was a maximum adopted pressure. These pressures had adverse effect on the performance of the distribution system. Pipes and valves around these nodes burst; thus, causing high water loss in the system. Only **74.71%** during minimum demand time and **65.06%** during maximum demand time of the distribution system were performing within the optimum adopted pressure.

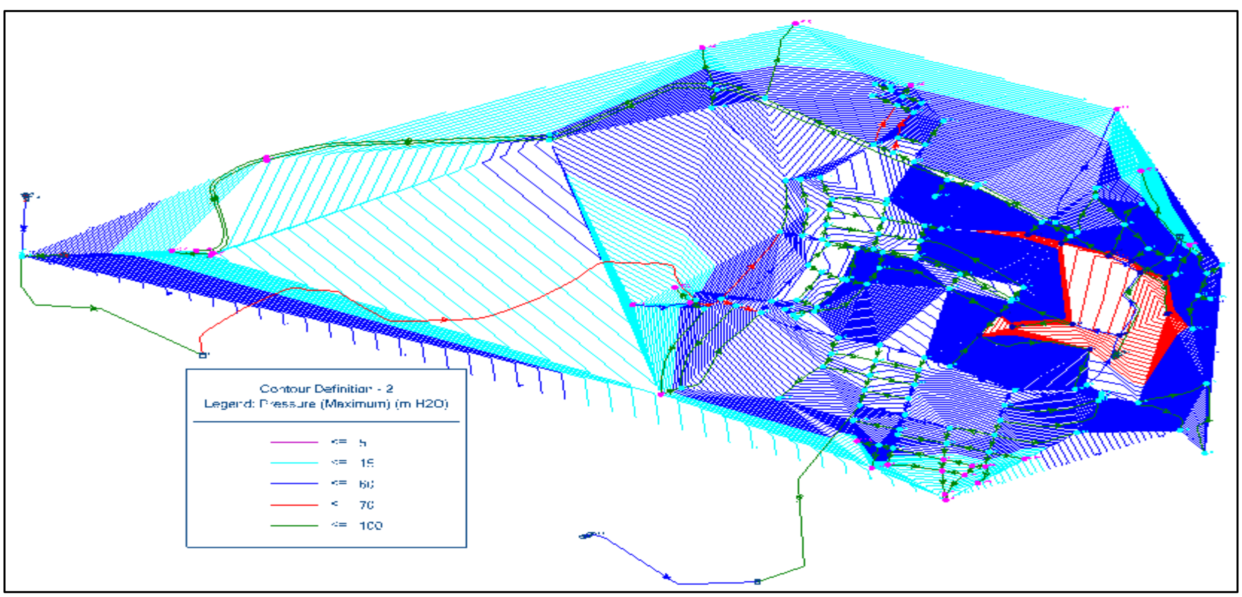

Figure 8 pressure contour map of Ataye Town distribution during minimum demand time

3.3.3 Flow Velocity for extended period simulation

Figure 9 shows the flow velocity for extended period simulation at maximum demand time. The maximum velocity was 1.61 m/s in P-1 at high demand hours and the minimum velocity was 0.0 m/s. **8** pipes (p-1, p-5, p-10, p-11, p-18, p-124, p-124, and p-137) with red color in Figure 9 had velocity of **1.08-2 m/s** at high demand hours**. 42** pipes with blue color represent a velocity of 0.55m/s to 1.08m/sand. The green color shows a less velocity of 0.55m/s at peak demand hours. All pipe flows had a velocity less than 0.60 m/s at low demand hours in the distribution system. At high demand hours, **50** pipes **(23.47%)** had a velocity of 0.6m/s to 2m/s which were believed to be optimum adopted velocity. The remaining had a velocity of less than 0.6m/s. There was not a pipe with a velocity greater than 2m/s in the distribution system.

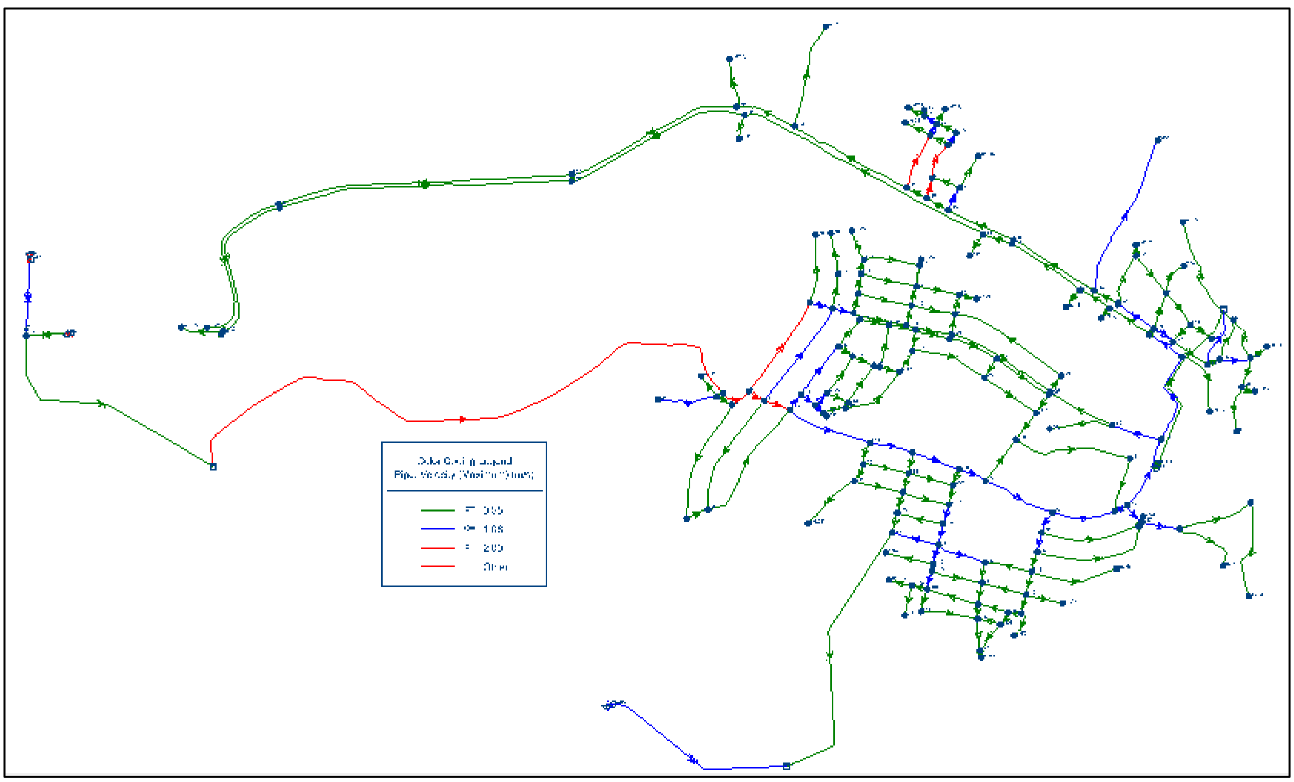

Figure 9 Result flow velocity for extended period simulation at maximum demand time

3.4 Mitigation by modifying the distribution network

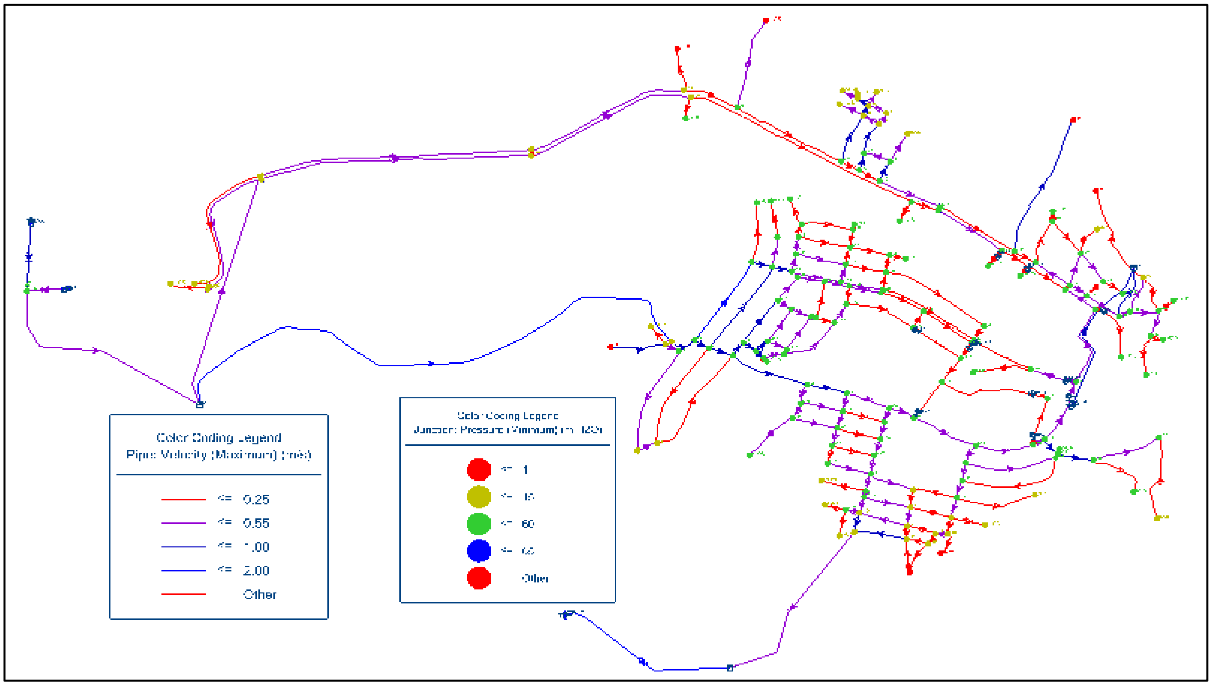

Figure 10 Modified and Optimized Networks by adjusting pipe diameter and connection points

Figure 10 shows the modified pressure in the accepted range of the distribution system by adding, or replacing pipes or elements. Based on the results of the model simulation, the distribution system was modified to reduce observed high pressure and increase low pressure and velocity. Nine pressure reducing valves (PRV) were added at P-69, P-70, P-72, P-79,P-81,P-83,P-86,P-191,P-193 to adjust the pressure. Alternative connection is another way to increase pressure and flow velocity. T-1 was connected with J-98 and T-2 with J-41 as shown in Figure 10. The diameters of P-140, P-141, P-142, P-144, P-145, P-147, P-148, P-150, P-151 and P-152 were resized (increased or reduced). After modifying the model, numbers of nodes with negative pressure were reduced from 18 to 8 and junctions with high pressure were reduced from 14 to 3 nodes. So, by applying the above mechanisms the distribution system was improved. Besides, additional water should be injected into the system by placing a storage tank at appropriate location. The utility may improve the distribution system based on these findings.

3.5 Utility Performance Evaluation

Table 4 shows the utility performance of Ataye town against International Water Association (IWA) performance indicators. For urban water supply, average per capital water consumption was 50 l/c/d for category-4 towns/cities (with a population range of 20,000-50,000) (MWIE), 2015). But average per capital water consumption of Ataye town in 2020 as shown in Table 4 was 23.18 l/c/d which was much lower than 50 l/c/d. Water supply coverage of the town was 83%.

In Table 4, the working ratio or efficiency ratio of the study area was **0.75** which showed that the utility was generating surplus income and could cover its operating, maintenance, and administrative costs. According to GTP-2 national plan, the utilities should 100% recover their operation and maintenance costs. So, the utility had good performance in this condition. Revenue collection efficiency of the utility was **95**%. There was 5% (103, 636.1 ETB) outstanding balance collected from the previous year. This ratio reflected the efficiency of the staff in performing their duties and consumers' willingness to pay. The IWA benchmark target was 100%. Therefore, the utility had less performance in collecting arrears from customers. Non-revenue water of the study area was 18.15%. Based on the national plan for Water Supply and Sanitation Sub-sector (2015/16- 2019/20), urban Non-Revenue Water (NRW) was planned to decrease from 39% to 20% by 2020 for urban water supply utilities. According to the national plan, there would be 59,318.52m^3(18.15%) of annual NRW in the distribution system.

Table 4 Ataye Town utility performance indicators by IWA utility performance indicators

Category	Performance indicators	Computed value	Benchmark target
Technical performance	Water supply coverage (%)	83	100
	water production (liters/person/day)	28.32	variable
	Water consumption (liters/person/day)	23.18	50
	Non-revenue water (NRW) (%)	18.15	<20

Category	Performance indicators	Computed value	Benchmark target
Financial performance	Average water revenue (Birr/m^3) annual water sold	1,958,631.5	
	unit operation cost of water (Birr/m^3 produced)	8.78	
	Operating Ratio (Efficiency Ratio)	0.75	<1
	Revenue collection efficiency (%)	95.00	100
	Average water selling price(Birr/m^3)	7.32	variable
Quality of service	Continuity of service (hours/day) and /week	24	24
		7	7
	No. of complaints/1000 connections	1025	variable
Human resource utilization and management	Staff productivity index (SPI) per1000 customers	7.44	7
	Staff training participation (%)	16.67	30
	Labor cost versus operational cost (%)	4.61	20
water Quality/ Health or environmental	Water samples taken from distribution network containing free chlorine residual (RC) (%)	25	100
	Water samples (taken at distribution) free from total coli form contamination (%)	58.33	100
	Samples (taken in distribution) free from fecal coli form contamination (%)	50	100
	Microbiological tests (%)	16.67	100

Staff productivity index (SPI) per 1000 customers was the other personnel performance indicator that considered the efficiency of managing human resources of the utility. For this study, staff productivity index per 1000 customers was **7.4.** But the benchmark for African water utilities was **5** (Van den Berg and Danilenko, 2017) and IWA benchmark was 7. The staff productivity index was more than the benchmarks and this could incur additional cost on the utility. All the performance indicators related to water quality/ health was under the benchmarks which showed less performance of the utility in water quality control activities.

4. CONCLUSIONS

The study was focused on evaluating Ataye town hydraulic performance by water CAD, and the utility performance by IWA performance indicators. The population and water demand of the town was projected until 2030 and the projected demand exceeded the current water production capacity of the town, which suggested the need for additional water sources. In some areas, there were insufficient pressures to satisfy the required demand at all times. The lowest pressure (<15m) was identified during maximum demand (**34.34%)** and during minimum consumption (**16.86%). 10.84%** of consumption nodes had negative pressure during maximum demand hours meaning; around 4,500 people were not getting water during this time. The distribution system performed within the optimum adopted pressure only **74.71%** during minimum demand time and **65.06%** during maximum demand hours. **14** nodes (8.43%) had pressure >60m which was maximum adopted pressure and this caused water losses in the system. **23.47%** of the system pipes had optimum adopted velocity of (0.6 -2m/s) and the remaining had a velocity less than 0.6 m/s during high demand time. Hence, the distribution system had limitations hydraulically. Based on the results, the network was modified by providing pressure reducing valve, resizing pipes diameter and alternative connection of pipes and junctions to reduce observed problems.

The town water utility performance was also evaluated by IWA performance indicators. The performance indicators showed that the utility had low technical, personnel, and environmental performance. Thus, to the researchers recommend that the distribution network should be modified by providing pressure reducing valve, resizing pipes diameter, alternative connection of pipes, and junctions. Additional water wells should be added into the system besides improving the utility performance.

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