

Modeling of Urban Water Supply and Water Loss in Distribution System of Adwa Town Using Hydraulic Simulation, Ethiopia

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Abstract

The main objective of this Research is to modeling of urban water supply and water loss in the distribution system of Adwa town under its major water supply source of Midmar Dam. This Research is conducted in Adwa town to model the water supply distribution system, the existing water distribution system of the town is both pump and gravity system. The water from the treatment plant of Adiabun to the storage reservoir by the pump. Then, the stored water is distributed by DCI, PVC, and GI pipe materials to the town by gravity. The research also depends on secondary data from the CSA Census report, and the meter reading reports at the District offices of Adwa town. In this study the data is entered, coded and analyzed using Bentley water GEMS V8i (SELECT series5). The analysis result shows the domestic and non-domestic water supply coverage of the town is 56.13%. The hydraulic Simulation in the existing water system to satisfy the Adwa town has been approved for hydraulic parameters such as head, pressure, and flow rate. The collected data on the number of water losses, causes of water losses, to reduce losses, and the challenges ahead have been collected and analyzed taking international the association best practice of water loss strategies.

Keywords: Water Distribution, Network, Model Calibration, Hydraulic simulation water GEMS modeling, Water loss, Leakage Management, Adwa town, Tigray region, Ethiopia

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1 INTRODUCTION

1.1 background

Water is the need for life on earth. Plants, animals, and humans cannot survive without sufficient water. Our “blue planet” seems to have plenty of this resource. Though, only 2.5 % of worldwide water is new water possibly existing for the drinking of living existences. The remaining 97.5% stays as salty water in the oceans (Ciobanu, 2013).

AWWA (2017) express the water distribution system must provide adequate amounts of water at appropriate pressure with in ad range typically specified by standards used in the water utilities. models are used to predict pressures under specific demands conditions and under a wide variety of scenarios to identify low pressures and to select infrastructure that will improve flow or less pressure deficiency.

The existing water loss breakdown rests on a relatively simple idea: hydraulic simulation software can be used to pretend the behavior of a water distribution network by using different techniques to detect the leakage add into the hydraulic network simulation. The hydraulic simulation software is then able to run all the hydraulic extents related to each specific leakage managing and, pressure and flow values in correspondence of the monitoring points in the real water distribution network (Chandelier, et al., 2013).

Water is unique of the necessities for the existence of living things in general and human beings in particular. For any municipal town, an efficient water supply distribution system is an essential service. Without meeting the water supply-demand of the town, the enhancement of developmental activities and improving the health condition of communities is impossible. Its key role in all spheres of human existence and development has led to a human society facing water scarcity in many regions of the world. The main challenges for the perc pita water demand of the town are the increment of the populations from rural to urban areas and the economic development of the town (Ciobanu, Natalia, 2013).

Water supply Water distributions, system of the town play a significant character in current civilizations being its proper operation straight associated to the people’s welfare and is also a critical part of designing and operating water distribution systems that are capable of serving communities reliably, efficiently, and safely, both now and sometime (Maruf, et al., 2016; Walski et al., 2004).

The existing distribution system of a town is a serious problem that provides safe and drinking water concerned in the Problem hinges on the topographical location of the town in the supply and demand nodes and the physical landscape such as roads, buildings, rivers and so on. The water demand network nodes and distribution pipes with specified measurement, extent, and other physical characteristics. However, the direction of the nodes in the water demand network is due to operational movement and pressure necessities, considerations related to the pumping cost and flow directions that might take place some in distribution such as, loss of acceptable disinfectant residual, low water pressure, intermittent service and aging of infrastructure can result in the declining quality of the water supply(Yazdani & Jeffrey, 2011).

The existing designs made available was prepared by international consultants under the DEVECON Engineers for Adwa town and by the Tigray Water Works Study, Design and Supervision Enterprise (TWWSDSE) on behalf of the Regional Water resource Bureaus. In the current study, the existing designs have been evaluated according to the latest issued design criteria and national urban water supply criteria agreed with the Ministry of Water Resources (MoWR). The existing infrastructure of the town is old and in poor condition. There are frequent interruptions to the scheme due to the breakdown of equipment, shortage of technicians, and inefficient operation and maintenance practices (MOWE, 2006).

Statement of the problem

one of the major challenges of inadequate delivery of water to Adwa town where the topography is a bit higher, the water has no power to reach to the top boundary areas. Due to the elevation structure of the town there is high challenge to reach the enough water to the customers the town has been on the networks of pipes, the head difference due to the elevation of a city varies from one station to other station, selection of water source for less water pressure areas, selection reservoir place, high water consumption in a day. Most of the existing Adwa subsystem network layout is not properly laid, that is obstacles for maintenance, transfer and replacement of old pipes and broken pipe. Most of the water supply network pipeline was installed before the existing road access and residential building is constructed just only using the Adwa GIS master plan. Currently, water distribution lines are found under drainage lines, toilets, ditches, and building and in the residential building compound. There are different old piping systems without network distribution design and near kebele me bale and alula near to pan African university, there is low velocity which is less than the standard range Pressure should be distributed in such a way that on all junctions, appropriate pressure is prepared and the network gains its standard manner. In addition to the pressure, the speed inside the pipes must also be examined. Those problems of water supply and water loss occurred in Adwa for long years, this research work will fill the gap on the problems due to reducing water losses on the components of network into geographical information system dividing large water distribution networks in to districted metered areas, monitoring of flow rates and water pressures, caring out yearly water balance, hydraulic modeling, pressure management, active leakage control, recording water consumption of the users, reducing meter errors and illegal water consumption .

In direction to resolve the above stated problems this research is important to identify the problems of the existing status of water distribution system by modifying of existing drawbacks, evaluating the existing design operation and maintenance facility of the water supply system and non- revenue water losses management system of the town with comparisons the different scenario by using water GEMS V8i and AWWA V5i.

Research questions

The general and specific objectives of the study would be achieved by seeking responses to the following questions:

- ✓ How to model the existing Adwa water distribution network?
- ✓ How much, amount of water being lost every year in the selected sample area?
- ✓ How can be improved the hydraulic characteristics of the water distribution system outcomes?

Objective of the study

General objective

The general objective of the research is to model urban water supply and water loss in the distribution system of Adwa town using hydraulic simulation.

Specific objectives of the study

- ✓ to model the existing Adwa water supply distribution system
- ✓ to model and improve the hydraulic characteristics of the water distribution system outcomes using water GEMS V8i
- ✓ to evaluate and compare the water losses in the selected sample area

RESERCH METHODOLOGY

The research Design

Based on the research objective and questions this chapter discusses in detail the steps taken to construct the hydraulic model the existing water distribution system and water loss of Adwa town. The steps were characteristics of the study area in terms of location, population, climatic conditions preliminary data collection, data analysis, in modelling the urban water supply and depending on the volume of consumption and level of water production after evaluating the distribution of water supply coverage in the town, the water loss from distribution of the utility was analyzed and evaluate the amount of water being lost yearly by identify the causes of water losses, and find out the measures taken by the management to reduce water losses. Using Darwin designer tool water GEMS V8i

and AWWA V5i software. After all the parameters essential to run the simulation are arrive in the model, the Successful simulation run will be providing.

Description of the study area

Adwa town is situated in the central zone of the Tigray region., Adwa is located at Latitude: 11° 38' 00"N Longitude: 37° 56' 00" E. by the 2007 population and housing census of Ethiopia projection, the total population of the Adwa town was estimated to be 60,748 peoples. It Lies 1006 km from the North of Addis Ababa and 224 km away from the capital of Tigray, Mekelle. The maximum elevation of Adwa is 1,975 meters above sea level. The mean maximum temperature of the city is 20°C and the typical yearly rainwater is 668 mm. Adwa town is located at the foot of soloda Mountain, the highest peak in the surrounding. The Landscape is generally a U-shaped valley and the town is mostly in the lowland area. The town has a relatively hot climate throughout the years, however, by Ethiopian temperature zoning, Adwa belongs predominantly to woinadega Zone. Adwa is generally well planned except where some of the old town areas are densely populated.

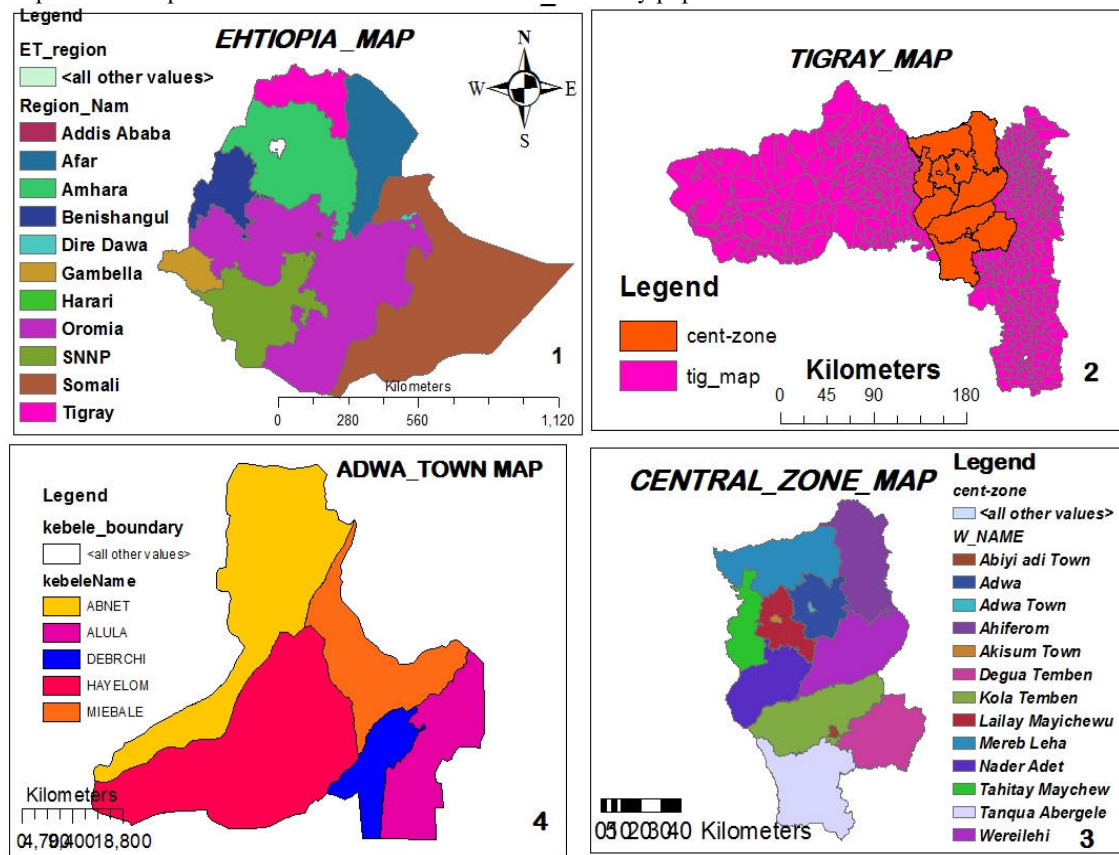


Figure 3-1 location of Adwa town

Creating personal geodatabase using parcels

The cadastral information of Adwa town was taken from planning and GIS experts of Adwa municipality, in AutoCAD file format and to change urban land use manipulating the land-use polygons and assigning the counting the number of houses to enter base water demand to each junction the site offers a choice of some personal geodatabase datasets, the most important being land use land cover maps, ortho- imagery and national elevation datasets to the model nodes. the collected data includes information on buildings, parcels, and blocks for every five kebeles in the town. For this research, the 30-meter dataset was selected. The second important dataset vital was the information regarding houses in each census block. This information must assign base water demands to each node. Then overlap the existing Adwa town parcel boundaries and census block files into GIS and making then census block data.

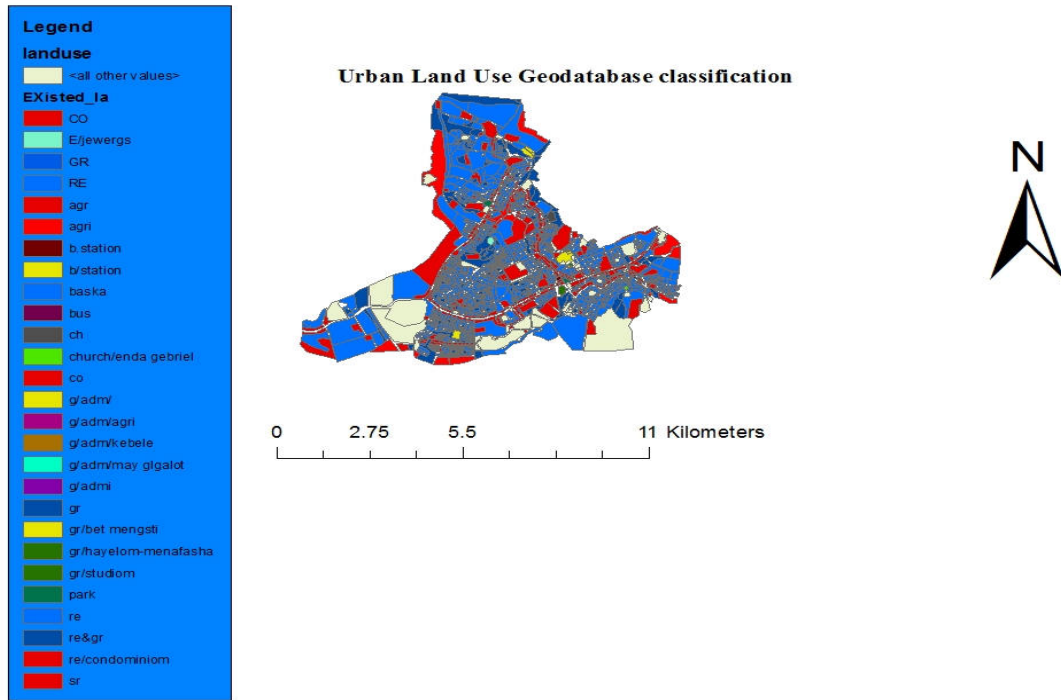
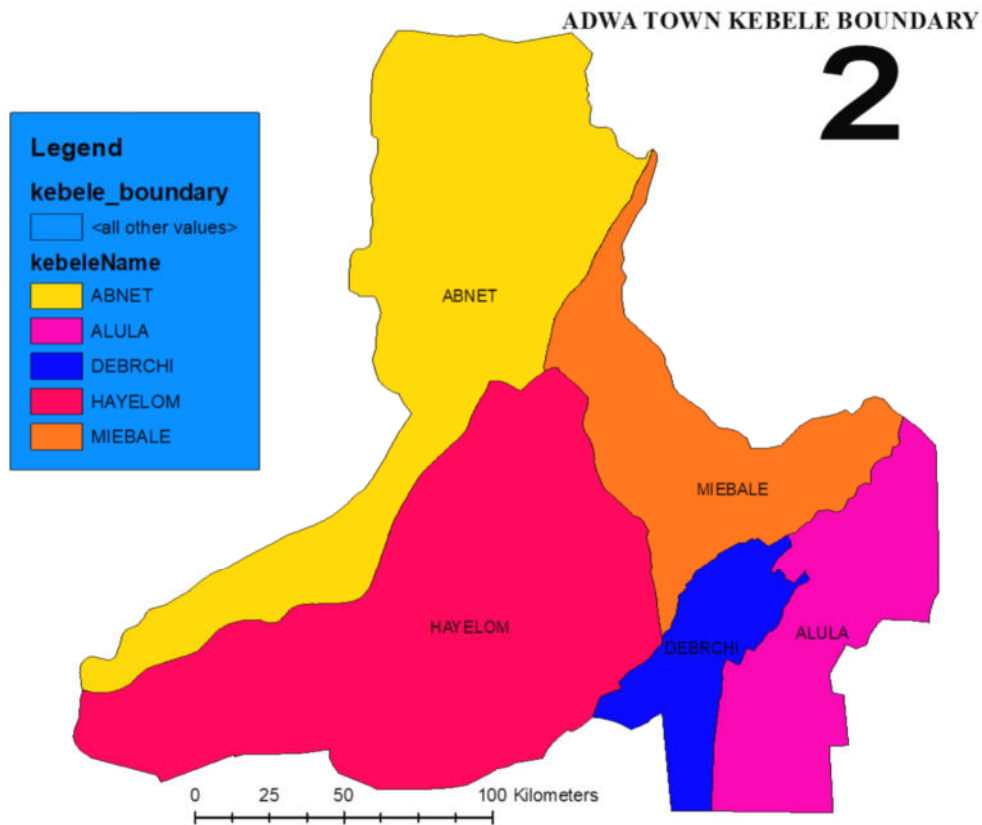


Figure 3-6 urban land use map using geodata base on parcels of Adwa town



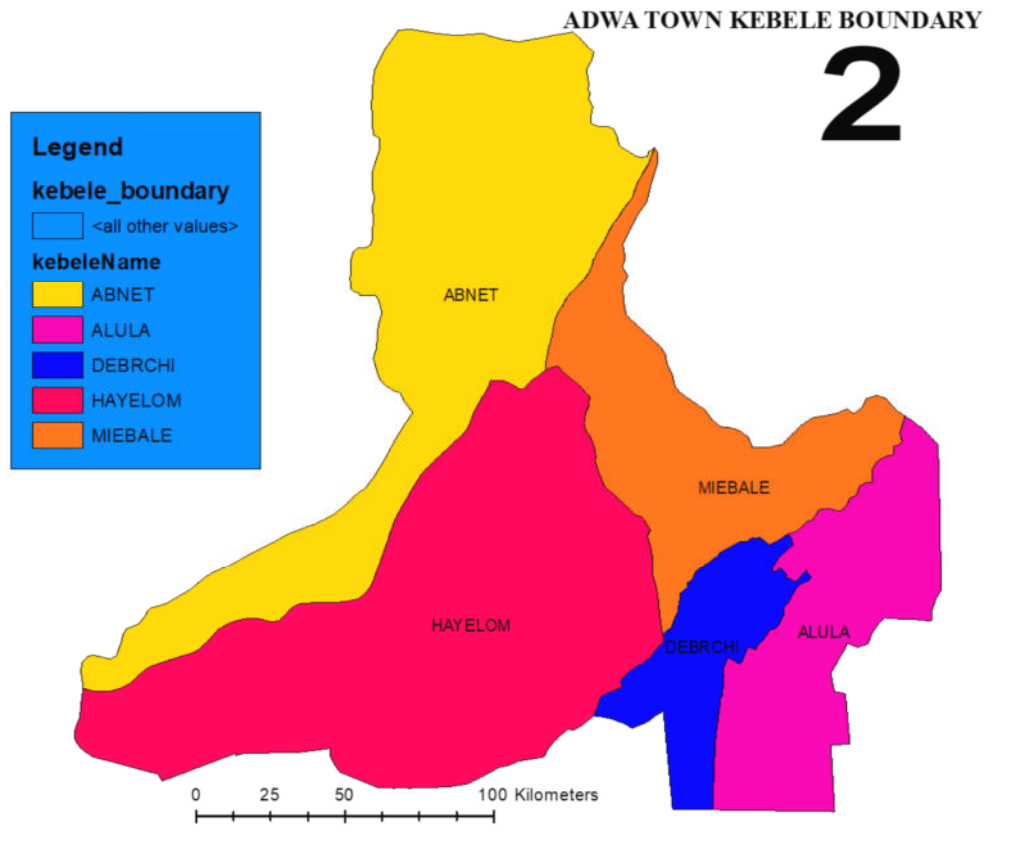


Figure 3-7 Adwa town on kebele boundary

Data Analysis

To analyze the data collected from a different source, both quantitative and qualitative data methods were used. The data were tabulated and analyzed on descriptive statistical methods. Percentages, averages, graphs including histograms have been used to interpret and present the data. The data was used to summarize observed challenges in the WDNs control practices of the selected area. The model of water GEMS and AWWA methods of leakage control has been used to evaluate the existing practice of water losses. During data analysis, the nodal pressure and pipe link velocity has been determined to classify high- or low-pressure zones area of the node/ junction where the pressure is higher or lower than the design criteria of system network. These results of hydraulic network of water supply distribution system of the town bring the idea and approvals that will help to recover the water supply system of the Adwa town.

Per capita water consumption of Adwa town

In Adwa town the growth of socioeconomic activity in both governmental and private sectors there was high water demand in the town. Hence, the per capital water consumption of the town was calculated using the annual water consumption recorded data and projected total population figure during (2019). Therefore, the average water demand of the town was calculated by multiplying the per capital demand with the estimated number of populations as follow.

$$Per\ capital\ consumption\ \left(\frac{l}{c}/d\right) = \frac{Annual\ consumption\ m3 \times 1000 \frac{L}{m^3}}{total\ population \times 365} \quad eq-----$$

a. Assigning base water demand in each supply node

✚ to estimate the existing water demand of each node in the distribution network, it was necessary following the steps below;

Once the average daily water demand of the system was determined, to calculate base water demand for the particular supply node the following equation was used (Zewdu, 2014)

$$Base\ demand\ for\ supply\ node = \frac{population\ served\ by\ the\ node}{Total\ population} * ADD \quad eq\ -----$$

Finally, assigning manually the base water demand into the node. In the same excel sheet, all the node was those

assigned base water demand the above equation the domestic water demand of Adwa town is 44.15 l/sec based on estimated base demand design 2019. **APPENDIX – B** table ones show the sample calculation of domestic demand for assigning base flow water demands to each node. The industrial, commercial, an institutional and public consumption of water was 16.73 l/sec. to assigning the industrial, commercial, institutional and, public demand to each node was calculated using the flowing formula given below.

$$\text{institutional water demand} = \frac{\text{Number of institution served by the node}}{\text{Total number of customers in the institution}} * \text{consumed water demand} \text{ -----eq}$$

Identification of number a of houses around each supply node

The urban geodatabase of the town-based ArcGIS format was obtained from the municipality of Adwa town. In ArcGIS, this, topographic map was displayed and the town distribution network map which was drawn in Water GEMS was exported into the ArcGIS shapefile and overlapped it in the topographic map of the town. Therefore, the number of houses in each census block was physically counted and assigned to the nearest supply node. An excel sheet was created for demand allocation. The first column counted all the 357 demand nodes. The second column showed the number of houses assigned to those nodes. the estimated population in 2019 is 70742 the total number of the residential house was identified in 17254 giving an average count of 4.1 people per house. In detailed calculation in Appendix A

$$\text{average people per house} = \frac{\text{Total current population}}{\text{Total number of the house}} \text{ -----eq 3.2}$$

Determination number of peoples in per single-family residence each supply node

To calculate the population served to each node was the physical counted the number of a house near to the node multiplying the average number of people in each house of the
 $\text{number of people for supply node} = \text{number of houses assigned by that node} \times$
 $\text{average number of people in each house} \text{ -----eq 3.3}$

Creating the Model in water GEMS

This section describes the section involved in building the hydraulic model in Water GEMS V8i. Using this tool one can directly import all the shapefiles at once. To draw physically the network if the drawings and the dimensions are available or the user can import files from AutoCAD and GIS. One very good feature that Water GEMS offers is the Model Builder. In the Model Builder, one can choice the information basis type as shapefiles and then click on the browse button. The user then has to browse to the specific location where the shapefiles and stored and then select all of them. One very important aspect is to consider during modeling is that all the geospatial data files used during modeling should have the same geographic projection. The shapefiles of the water lines, water nodes, reservoirs and, the storage facilities were projected with concerning coordinate system of ortho-images of Adwa town. This coordinate system was addenda UTM-37zone-37. Once the shapefiles are selected then preview the attribute tables of each shapefile. Next to provides and to specify the coordinating unit of the data source.

Results and discussion

a. Water balance system of Adwa town

Essentially ahead of assigning nodal water demand, it is very common to quantify water loss in water supply distribution network the number of water losses in the system from the system input meter to the customers Billed Authorized Consumption is in the quantity of water loss crossways the system is estimated by doing water balance analysis. The difference between the produced and water consumed water is quantified as total water loss. Water loss in the system is frequently due to either leakage in the system or apparent loss which includes; meter inaccuracy, illegal use of water by an authorized person. As shown in the table below 3.14 based on the analysis results the total water loss from the system is 1392181 m³/year and is the Non -revenue water 30.10% of the system views volume.

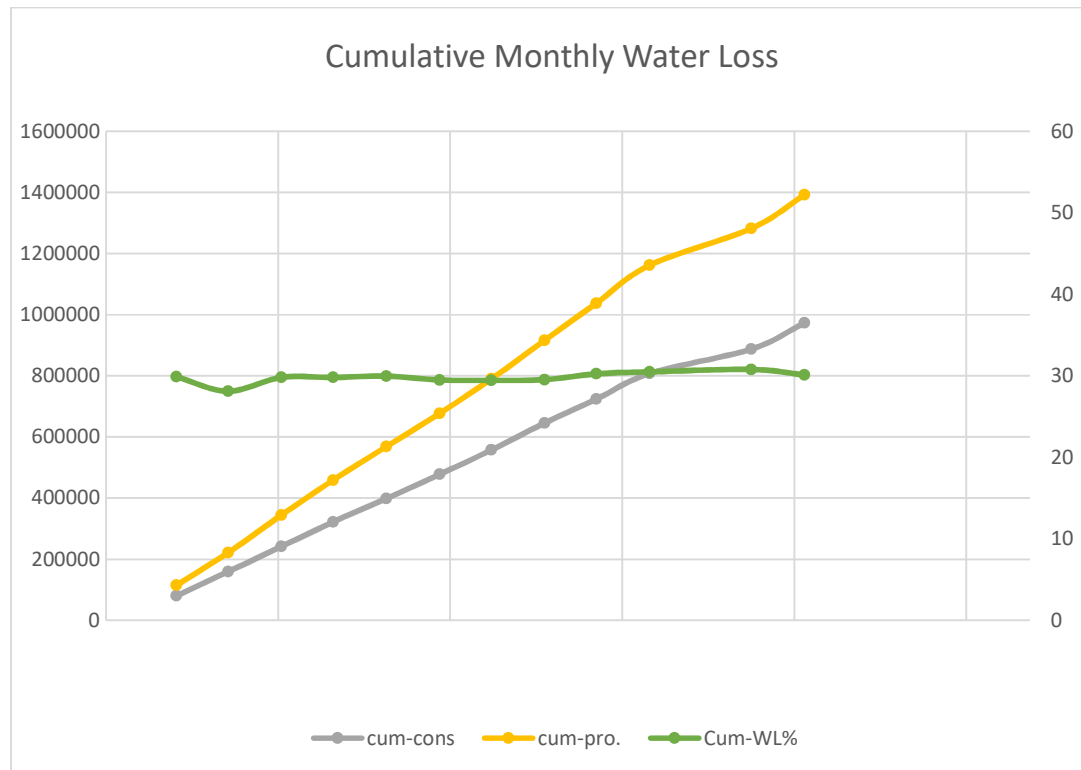


Figure b-1 monthly water loss distribution curve based on cumulative values

It observed from the figure in the above table, the estimated annual volume of NRW in urban water utilities of Adwa town water balance for the year April 2018 to April 2019 is provided accordingly total water supply production to the city is 1392181 m³/year while the corresponding consumption is 973075 m³/year the resulting water loss 419,106 m³/year.

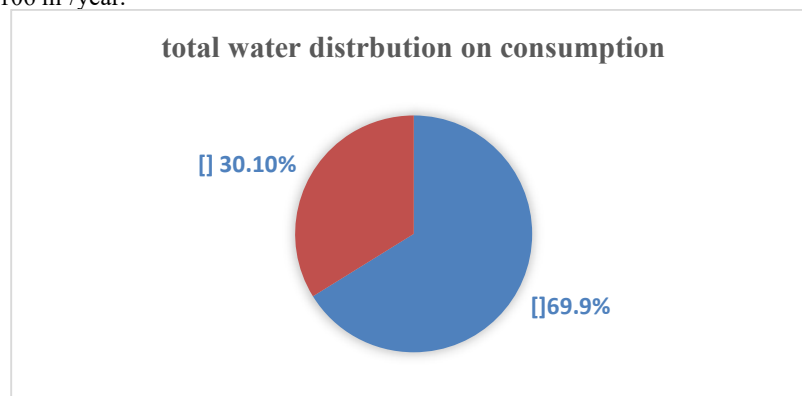


Figure b-2 monthly water loss distribution curve based on the cumulative value

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