

Water Demand Assessment of Addis Kidam Town, Awi Zone, Amhara Region, Ethiopia

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ABSTRACT
Adequate quantity and quality of water demand is the most important for one town, as well as each individual to develop their economy in different aspects. The main objective of this study is to assess and provide sufficient and safe water demand of Addis Kidam town, Ethiopia. Existing water demand and sources of water supply is not sufficient for all types of demand at current time in study town, it requires more than half of addition water demand. The finding of this study exposed that, existing water supply has more problems, these are the rapid growth rate of population, lack of funding and loss of water leakages. The projected population of town for first and second phase is 37181 and 45640 respectively by using geometric increasing method. Estimated demand of the town is based on types of mode of service and economic status of study area is 13796.84m^3/d and 20423.36m^3/d of maximum daily demand and 20971.2m^3/d and 31043.51m^3/d of peak hourly demand of the town for first and second phase respectively. The existing water source is covers only 33.5% and 22.63% of total current and future maximum daily demands of town communities of first and second phase. At current time needed additional water sources, which is 106.18 l/s and 183 l/s of maximum daily demand and peak hourly demand respectively to meet current water demand of town communities for first and second phase of design period. Capacity of services reservoir for first and second phase is 3000m^3 and 5350m^3 respectively throughout design period. Totally existing water sources and demand is not adequate quantity and quality for town population current and future time.
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1. INTRODUCTION
Adequate quantities and quality of water supply is the most significant through the world for living, developing one town or city and for any actives which required water (Emeike et al., 2017). Adequate amounts and quality of water demand is the most important for one town, as well as for individual persons to develop their economy in different aspects, such as direct or indirect use of water production for their work.

Water is the most fundamental need for all living things like human, animals, and plants, without its existence, will be impossible on land for all living things. Along with air, water is the most necessary source for survival on the earth (Kumar and Desta, 2018).

Most of the developing country like Ethiopia has still very little coverage of potable water supply and sanitation that has resulted the citizens to be suffered with water born and water related diseases (Adegbehin et al., 2016 and Girmay et al., 2017).

Ethiopia is a country, which have adequate amounts of natural water sources that means groundwater sources and surfaces water sources, but it has not adequate quantity and quality of domestic water supply, industrial water demand, commercial and institutional water demand and public water demand throughout the country every year, especial study area (Dagnew et al., 2017).

Study area is Addis Kidam town in Fegita Lekoma worda, Awi zone, Amhara regional state, Ethiopia. Study town have inadequate quantities and quality water supply and sanitation system. Currently Addis Kidam town have one spring with yield of 7.5l/s and one hand dug well water sources constructed during 1972 year. According to rough estimation around 4 litre/sec amount of Water escaped/leaked from spring capping structure. But this source is not sufficient quantity and quality water for current numbers of town population, because the study town is capital town of Fegita Lekoma worda. Due to this reason the numbers of town population increase rapidly year to year or day to day without considering any infrastructure construction like domestic water supply. The population migrate from rural to urban area and also urban to urban area to find better jobs, facilities like electricity, piped water supply, transport, health center, education, etc.

Other major problems of existing water supply are decreasing amounts of existing water sources and failure of electric power to pump water from sources to services reservoir every day (Manoj and Junil, 2015), and also there is not good distribution system and services reservoir capacity is less compared to daily water demand for town communities, which is 75m^3.

Therefore, town communities to get piped water supply maximum 3-4 days for 4-5 hours by dividing into zone, but the quantity of water is not the same throughout the town. The systems of water supply in study town is intermittent system due to lack of adequate quantity of water demand in town, especially new expanded area is not totally gotten piped water supply, in North and South direction of town. Due to this reason 85% of town communities fetch daily domestic water demand from unprotected and unsafe water sources far from their home every day to meet their daily demand for different purposes. They waste more time to collect their domestic water demand every day throughout the year. This causes water borne diseases, like Typhoid fever, Amoeba, Jerrid and etc and damage physical, especially children and women (Adane et al., 2017 and Alua et al., 2019). Because in Ethiopia collecting fetch domestic water supply is the women and children. Therefore, more women and children do not participate on their own economical productivities and education and also children cannot effectively learn their education on time (Akkaraboyina and Adem, 2018).

Objectives of study

General aim of this studying is to forecast feature population of town and analysis required water demand assessments of town communities. Specific objectives of study: -

- To improve existing water supply system
- To fix design period of project
- To select the best method of population forecasting and forecast feature population of town
- To calculate total water demand assessments
- To determine capacity of water sources
- Determine capacity of raising main pipe and collection chamber
- To determine capacity of service reservoir

2. Methodology of study

2.1. Description of the Study Area

The study area is Addis Kidam town, is the capital town of Fagita Lekoma Woreda in Awi zone of Amhara regional state, Ethiopia. It is located at 100 km from the region capital town of Bahir Dar town, 17 km from zone capital town of Injibara.

The woreda has 29 kebeles of which 2 are urban and 27 are rural kebeles with total area of 67,733 ha. There is 24-hour power supply in the study area and telecommunication access.

As per the Ethiopian temperature zoning 75% of the woreda is classified as Dega and 25% is classified under woinadega climatic zone. The temperature record in the woreda ranges from 20°c to 22°c in the woreda and the annual precipitation rages from 1,500mm to 2,500mm with an average record of 2000mm. Location of the study area is shown below Figure 1.

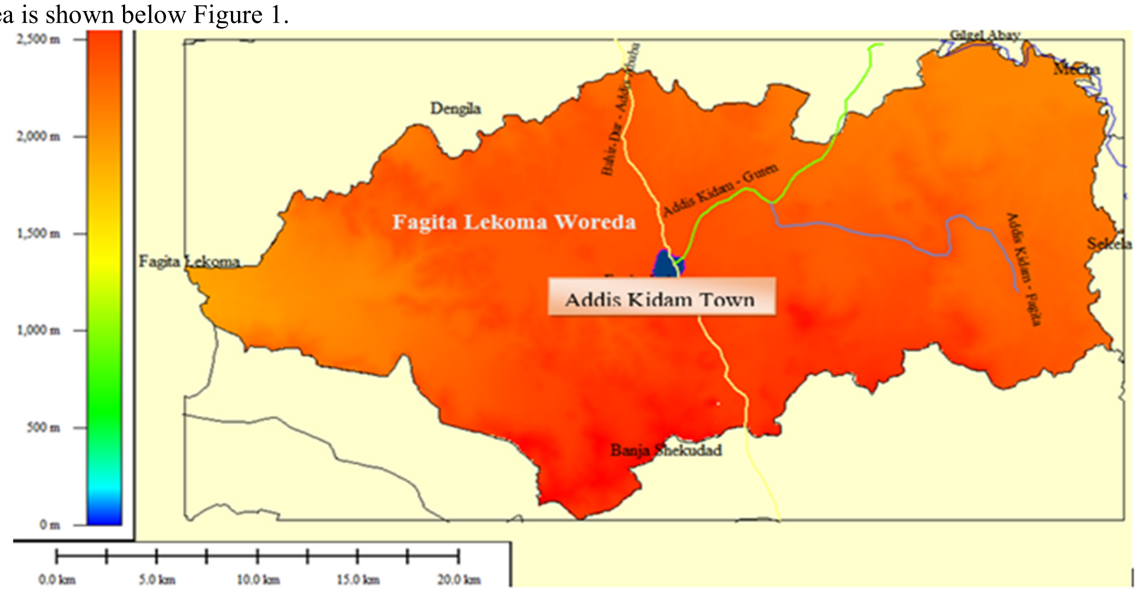

Figure.1: Map of Fagita Lekoma Woreda and Addis Kidam town, Ethiopia (www. amharabofed.gov.et)

2.2. Methodology of the Study

Methodology of this study is to collect necessary data, analysis and interpretation of the study by excel, tables and figures. Methods of data collection is household questionnaire, group discussion, personal observation and interview with stakeholders of study town like, administration office, health center, education center, water, irrigation and energy development offices and households of town about the problems of existing water supply in study area.

2.3. Data Collection and Types of Data

There are two types of data, which are primary and secondary data sources. The primary data is collected from households, field observation starting from existing water sources up to distribution systems, by group discussion and interview some selected stakeholders of town. Many different qualitative and quantitative data are collected from secondary sources, these data are collected from literature reviews of scientific journals and written documents from different offices, like water supply and sanitation office, water, irrigation and energy offices, health center, education center, administration office and other office related to water sources.

2.4. Methods of Data Analysis

After completion relevant data to analysis and interoperate by using excel, tables and figures and also forecast future population and calculate maximum and peak hourly demands of town for future time and design the capacity of necessary components of water supply starting from sources of water supply up to capacity of service reservoir of study area.

3. Design Period and Population Forecasting

3.1. Design Period

Design periods of water supply system is neither long nor short depends of different factors, such as funds, duration of construction materials (like treatment pants, pumping house and distribution systems), anticipated expansion the town and the rate of interest on the loan taken. Due to these reasons the design period of this study town is 20 years, starting from 2022 up to 2042 years. This design period is divided into two phases, first phase is 2022 up to 2032 and second phase is 2032 up to 2042 years.

3.2. Population Forecasting

Population forecasting is the most significant for one town or city to implement any infrastructures, like domestic water supply, road access, developments of town by economy, establish school and health center of town, and any others (Farah and Yonis, 2015). Due to these reasons forecasting of future population of study town is the most important to determine the future water demands of the study town depends on existing numbers of population by using different methods, but a country of Ethiopia mostly used four methods by comparing their percentage error. These methods are Arithmetic increasing, Geometric increasing, Incremental Increasing and Exponential growth rate or Central Statistics Authority (CSA) methods. The Central Statistics Authority (CSA) is a recognized body in Ethiopia to determine the official population figures and growth rates, that should be taken for any development activity throughout the country.

According to 2007 Census, the population in 2007 was 8,906. When projected to 2016, it is around 15,684. This show there is high population movement from rural surrounding areas to Addis Kidam town as mentioned by administration offices. During studying time 80% of the data collected from the Woreda administration Planning, Monitoring and Evaluation section after comparing different population data sources and considering existing population settlement and density of the town. Therefore, the target base population of the town in 2018 is 22,100, this shown below table 1.

Table 1. base population

year	population
2007	8906
2014	12120
2016	15684

Sources: - from Census data and administration office of study town

Growth Rate of Town Population: - General there are three major factors, which affect the growth rate of population, which are Births, it increases the numbers of population, Death, it decreases the numbers of population and Migration, it increases or decrease the numbers of one town population. According to the central statistics Authority country level population growth rates, the growth rates used to forecast population in the project area are listed below Table.

Table 2: CSA country level population growth rates

Year	2015-2020	2020-2025	2025-2030	2030-2035	2035-2042
Growth rate	4.1%	4%	3.8%	3.6%	3.5%

Source: The 2006 Population & Housing Census of Ethiopia Results for Amhara Region, Volume II Analytical Report.

Based above data to calculate percentage error of each method depends on base population of study town to select the best method of population forecasting of future numbers of study area. The actual numbers of population in study area in 2018 is 22100.

Table 3. calculate the constant K_1, G and K_2

Year	Population	AIM	GIM	IIM
2007	8906	-	-	-
2014	12120	459.15	0.052	-
2016	15684	1782	0.147	1323
total		2241.15	0.199	1323
average		1121	0.0995	1323

Sample calculation k =1121 G = 0.0995 K2 = 1323

Arithmetic increasing method (AIM) = $\frac{P2014-P2007}{2014-2007} = \frac{12120-8906}{7}$ = 459.14

Geometric increasing method (GIM) = $\frac{\text{Arithmetic increasing}}{P2007} = \frac{459.14}{8906}$ = 0.052

Incremental increasing method (IIM) = (1st arithmetic–2nd arithmetic) increasing
= 1782 – 459.14 = 1322.86 =1323

Calculate the numbers of population at 2018 by using arithmetic increasing method, geometric increasing method, incremental increasing method and exponential growth rate methods.

- Arithmetic increasing method of 2018 = p_{2016} + nk, where p_{2016} = 15684
  n= 2018 – 2016 = 2
  k = 1121
  P_{2081} = 15684 + 2*1121 = 17926
- Geometric increasing method of 2018 = $P_{2016} *(1+G)^n$, where G = 0.0995, n =2
  $P_{2018} = 15684 *(1+0.0995)^2$ = 18961
- Incremental increasing method of 2018 = P2016 + n (k1 +k2), where k1 = 1121 and k2=1323
  P_{2018} = 15684 + 2(1121 +1323) = 18454
- Exponential growth rate method of 2018 =$P_{2016}*e^{nr}$ where n=2 and r=4.5%=0.045
  P2018 = $15684*e^{2*0.045}$ = 17161

Table 4: percentage error calculation by using four methods of forecasting

Year	AIM	GIM	IIM	Exponential method
2018(actual)	22100	22100	22100	22100
2018(calculated)	17926	18961	18454	17161
% Error	0.189	0.142	0.165	0.224

Percentage Error = $\frac{\text{Actual population of 2018}-\text{calculated population of 2018}}{\text{Actual population of 2018}}$

Percentage error of AIM = $\frac{22100-17926}{22100}$ = 0.189

Percentage error of GIM =$\frac{22100-18961}{22100}$ = 0.142

Percentage error of IIM = $\frac{22100-18454}{22100}$ = 0.165

Percentage error of Exponential method =$\frac{22100-17161}{22100}$ = 0.224

Therefore, the best methods of future population forecasting of study area for next 20 years is Geometric increasing method, because the value of percentage error is minimum than other three methods which is 0.142.
Forecast the future population of study town by using Geometric increasing methods for 20 years of design periods (2022 -2042).

$P_n = P_o *(1+G)^{nr}$ where Pn =numbers of future population
Po = present population of town=22100
n= numbers of year =20
r = population growth rate

Table 5: Summary of projected population of study town

Year	2022	2027	2032	2037	2042
Growth rate	4%	3.80%	3.60%	3.50%	3.35%
Projected Population	25854	31154	37181	44160	45640

Sample calculation

P2022 = P2018 $*(1+G)^n$, where P2018 = 22100
G = 4% = 0.04
N = 4

P2022 = $22100*(1+0.04)^4$ = 25853.87=25854

The total projected population of the town starting design period (2022) and end of design period (2042) are 25854 and 45640 respectively. The numbers of the study town are increase rapidly without any gap through the year. This indicates to needed more amounts of daily water consumption to meet different domestic activities every day throughout the year (William et al., 2015). Because the existing water supply does not much with numbers of current population of the study area, addition to this more people inter into study town from different sub-urban and rural area to find better jobs, better living standard, education, health services, and different infrastructures because this town is capital town of Fegita Lekoma Worda in Awi zone.

4.Water Demand Assessment

Water demand assessment is assessing all types of water required for the given town (Schleich and Hillenbrand, 2009). The major types of water demand or consumption for study town is domestic demand, non-domestic demand, fire demand and unaccounted water losses (Haziq and Panezai, 2017). These demands are calculated depends on standards of MoWR design guide lines and regional guidelines of the study area.

4.1. Domestic Water Demand

Domestic water demand is amounts of water required for different house activities, such as drinking, cooking, bathing, shower, toilet, etc (Arturo et al., 2017). These demands depend on different factors, examples climatic condition, economic levels of communities and social life (Admasie and Debebe, 2016). Totally domestic water demand can be categories into three mode of services. These are: - House connected, Yard connected, Public fountain and None connected (Misgana, 2015). Projecting domestic water demands of Addis Kidam town must be follow the following procedures. Population percentage distribution by mode of service, Establishment of per capital demand by purpose for each mode of service, Projection of consumption by mode of service, Adjustment due to climate and socio-economic condition and Projection of domestic water.

4.1.1. Per capital domestic water demand

Per capital water demand is various from town to town due to different factors (Hussien et al., 2016). These are size of town, numbers of population, types of water supply, quantity and quality of water sources, system of sanitation, climatic condition of area, socioeconomic condition and water pressure in distribution system of town (Feleke et al., 2018). Composition of per capital demand is given below table.

Table 6: Composition of per capital domestic water demand in year 2016 (l/c/d)

Activity	HC(l/c/d)	YC(l/c/d)	PF(l/c/d)
Drinking	2.5	2.5	2.5
Cooking	7.5	5.5	4.5
Ablution	17	12	7
Washing Dish	5	4	4
Laundry	15	8	7
House Cleaning	7	3	2
Bath and Shower	20	4	2
Toilet	6	1	1
Total	80	40	30

Source: - ministry of water resources

To estimate the future water demands of each types of dome of services is by using population growth rates of study area and per capital demands of each activity. According to water Works Design and Supervision Enterprise (WWDSE) had adopted the following growth rates.

Growth rate 2020-2025 up to 2025-2030 is HC=2%, YC=2%, PF=1%

Growth 2030-2035 up to 2035-2042 is HC= 2.5%, YC=1.8%, PF=.9%

Table 7: the domestic water demands of each mode service

Year	2022			2027			2032			2037			2042		
Activity	HC	YC	PF	HC	YC	PF	HC	YC	PF	HC	YC	PF	HC	YC	PF
Drinking	2.815	2.8	2.7	3.3	3.04	2.8	3.7	3.33	2.9	4.2	3.64	3.02	4.75	3.98	3.16
Cooking	8.45	6.2	4.8	9.8	6.69	5	11	7.32	5.2	13	8	5.43	14.3	8.75	5.68
Ablution	19.14	14	7.4	22	14.6	7.7	25	16	8.1	29	17.5	8.45	32.3	19.1	8.84
Washing Dishes	5.63	4.5	4.3	6.6	4.87	4.4	7.4	5.32	4.6	8.4	5.82	4.83	9.5	6.36	5.05
Laundry	16.89	9	7.4	20	9.73	7.7	22	10.6	8.1	25	11.6	8.45	28.5	12.7	8.84
House Cleaning	7.88	3.4	2.1	9.2	3.65	2.2	10	3.99	2.3	12	4.36	2.41	13.3	4.77	2.52
Shower	22.52	4.5	2.1	26	4.87	2.2	30	5.32	2.3	34	5.82	2.41	38	6.36	2.52
Toilet	6.67	1.1	1.1	7.9	1.22	1.1	8.9	1.33	1.2	10	1.45	1.21	11.4	1.59	1.26
Total	90.09	45	32	105	48.7	33	119	53.2	35	134	58.2	36.2	152	63.9	37.9

Sample calculation for year 2022

Activity type: drinking in HC, $HC_{2022} = HC_{2016}*(1+G)^n = 2.5*(1+0.02)^6 = 2.815$

Activity type: cooking in YC, $YC_{2022} = YC_{2016}*(1+G)^n = 5.5*(1+0.02)^6 = 6.19$

Activity type: cooking in PF, $PF_{2022} = PF_{2016}*(1+G)^n = 4.5*(1+0.01)^6 = 4.78$

Table 8: the percentage of population by mode of service level as follow

mode of service	Year				
	2010	2015	2020	2025	2030
HC	3.30%	3.80%	4.30%	4.80%	5.50%
YC	22.20%	25.10%	28.40%	32.20%	36.50%
PF	50.30%	57%	61.30%	59%	56%
NC	24.20%	14.10%	6%	4%	2%

Source: - Ministry of water sources

Table 9: the percentage of population projection by mode of service in study area

Year	Mode of service			
	HC	YC	PF	NC
2022	4.30%	32.20%	59%	4%
2027	4.80%	36.50%	56%	2%
2032	6.20%	40.80%	53%	0
2037	6.90%	45.10%	48%	0
2042	7.60%	49.40%	43%	0

Source: - Ministry of water resources of mode of services

4.1.2. Population projected by each mode of service

Population projected by each mode of service is depends on the total projection of town population and per-capital water demands of each mode of services of the study town, that means

Projected population = percentage of population by mode of service* total number of populations

Table 10: projected population by mode of service

Year	Mode of Service	Total Population	Percentage of Population	Projected Population
2022	HC	25854	4.30%	1112
	YC	25854	32.20%	8354
	PF	25854	59%	15254
	NC	25854	4%	1034
2027	HC	31154	4.80%	1495
	YC	31154	36.50%	11589
	PF	31154	56%	17446
	NC	31154	2%	623
2032	HC	37181	6.20%	2305
	YC	37181	40.80%	15170
	PF	37181	53%	19706
2037	HC	44160	6.90%	3047
	YC	44160	45.10%	19916
	PF	44160	48%	21197
2042	HC	45640	7.60%	3469
	YC	45640	49.40%	22546
	PF	45640	4.00%	1826

Sample calculation of above table for year 2022

Total population = 25854

Population distribution by mode of service, HC=4.3%, YC=32.2%, PF=59% and 4%.

Projected population = percentage distribution of each mode of service * total population

HC= 4.3%*25854=1112 YC = 32.2%*25854=8354

PF=59*25854=15254 NC=4%*25854=1034

4.1.3. Projected daily average domestic demand

Projected average daily domestic demand (ADDD) is production of projected population of each mode service and projected per-capital water demand by mode service of study town (Kassa, 2017).

Projected ADDD (l/d) =projected population*projected per capital water demand

Table 11: projected daily average domestic demand

Year	mode of service	projected population	projected per capital water demand	projected domestic demand
2022	HC	25854	90.09	2329187
	YC	25854	45	1163430
	PF	25854	32	827328
	Total per capital domestic demand			4319945
2027	HC	31154	105	3271170
	YC	31154	48.7	1517200
	PF	31154	33	1028082
	Total per capital domestic demand			5816452
2032	HC	37181	119	4424539
	YC	37181	53.2	1978029
	PF	37181	35	1301335
	Total per capital domestic demand			7703903
2037	HC	44160	134	5917440
	YC	44160	58.2	2570112
	PF	44160	36.2	1598592
	Total per capital domestic demand			10086144
2042	HC	45640	152	6937280
	YC	45640	63.9	2916396
	PF	45640	37.9	1729756
	Total per capital domestic demand			11583432
Total domestic demand (l/d)				39509876
Total domestic demand m3/d)				39509.88

4.1.4. Factors affecting the rate domestic water demand

There are various factor affecting rate of water demand (Asgedom, 2014). These are climatic condition, cost of water, economic status of consumers, pressure in distribution system, quality and quantity of water, water supply and sanitation system and numbers of commercial area.

Climatic condition: -climate of this area is vary from season to season, due to this reason most of time very hot. During this time more amounts of water is required for all persons.

Cost of water: -cost of water is very cost during construction and after construction due to this reason most of communities cannot use piped water because more people are very poor.

Economic status of consumers: -most of living population are very poor, because this town are developing town and also country is developing country, due to this reason most people are not use house connected and yard connected mode of service but to most of town community public fountain system.

Quality and quantity of water: -there is not good quality and quantity water sources, such as surface and ground water total, this affects both economy and health status of communities.

Generally, the study town is affected by different factor natural and artificial activities throughout the year. Due to this reason most children and women lost time to find daily domestic water fare from their home every day, these affects their education, job and production of the individual person and total town as well as the country (Gelame, 2014).

4.2. Adjusted Domestic Water Demand

Projected daily average domestic water demand is adjusted by climatic condition and socio-economic conditions of the study town (Singh and Turkiya, 2013).

4.2.1. Adjusted due to socio-economic factor

Socio economic factor is the major factor for one town to design water supply systems, then this factor given below table.

Table 12: socio economic factor

Group	Description	Adjustment factor
A	Town with high living and very high potential development	1.1
B	Town with high potential and lower living standard	1.05
C	Town under normal Ethiopian condition	1
D	Advanced rural town	1.09

Source: -National water supply and sanitary master plan

The socio-economic factor of study town is selected to be group C, with factor 1 as the town has under normal

Ethiopia condition.

4.2.2. Adjusted due to climatic effect

The Climate of project area has an impact on quantities of water consumptions. To account for changes of average per capital domestic demand, the water demand is multiplied by climatic factors recommended for target area.

Table 13: climatic factor

Group	Mean Annual Precipitation	Factor
A	600 or less	1.1
B	601 – 900	1.0
C	901 or more	0.9

Source: Cost Effective Design Guide line

As per Fagita Lekoma Woreda Agricultural office data, the project area has precipitation ranging from 1,500mm to 2,500mm with mean annual rainfall of 2,000 mm. Therefore, it is categorized in group C, then value is 0.9.

Therefore, adjusted daily average domestic demand is,

Adjusted daily average DD = daily average DD *Socio-economic factor*climatic factor

Table 14: adjusted domestic water demands of study town

Year	Total per capital domestic demand (PDD)(L/D)	Socio factor	Climatic factor	Adjusted domestic demand(l/d)	Adjusted domestic demand (m3/d)
2022	4319945	1	0.9	3887950.5	3887.95
2027	5816452	1	0.9	5234806.8	5234.81
2032	7703903	1	0.9	6933512.7	6933.51
2037	10086144	1	0.9	9077529.6	9077.53
2042	11583432	1	0.9	10425088.8	10425.1

Total domestic water demands of first phase is 6933.51m3/d and second phase are 10425.1m3/d. This indicates amounts of water required for domestic purpose is rapidly increasing time to time. The numbers of population in study area increase gradually throughout the year without any gap.

4.3. Non-Domestic Water Demand

Non-domestic water demand is amounts of water demand required out of domestic water demand, which means industrial demand, commercial and institutional demand, public demand, fire demand, and unaccounted water loss demand (Rathnayaka et al., 2016).

Industrial demand: -is used for different types of industry, especially for small industries like, mining industry, small scale farming, soft drinking factory, food processing factory, metal factory, paper factory and etc. But large industry is not used water demand from town water supply system, because they are required high amounts of water demands, then it use its own sources of water separately. In this town there is not large industry due to this reason assumed 5% of total domestic demand is enough for all industries, which existing at current time.

Commercial and institutional demand: - is used to for different commercial and institutional area in study town, these areas are like hotel, restaurant and bars, shop centre, super markets, metal work, wood work, all consumer profit-based establishments required large volumes of water demand for their business need continuous supply and also governmental and non-governmental offices which live in study area. For this study amounts of water demand of commercial and institutional is assumed to be about 10% of the total domestic daily water demand.

Public demand: - is types of water demand, which use different public area of study town, like school, hospitals, health centres, churches, mosques, meeting hall, bus station, public offices, and public baths. These types of customers are non-profit institutions, which are basic for all community, due to this reason amounts of water required for public demand is assumed to be amount 15% of total daily domestic water demands of study town.

Fire demand: - is types of water demand which is used to fighting fire in study area. But at presents time Addis Kidam town has not any types firefighting and municipal services for firefighting as consumption standard or trends. Normally, firefighting demand is the most important for developing and developed towns and city to fight sudden fire in town or city, Due to this reason to calculate future fire demands of study area by using American insurance association formulas because the numbers of population is not big numbers, because developing town.

$$Q = 4637\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

Where Q=amount of water required, P=population in thousands, the values of P is two depends on phase of project design period, that means for first phase P=37.181 and second phase P=45.64.

The first phase fire demand starting from 2022 up to 2032, if P=37.181

$Q=4637*\sqrt{37.181}(1- 0.01\sqrt{37.181})$ =26550.6L/hr = 637.21m3/d

The second phase fire demand is starting from 2032 up to 2042, if P=45.64

$Q=4637*\sqrt{45.64}(1- 0.01\sqrt{45.64})$ =29210.03L/hr =701.04m3/d

Unaccounted water losses and wastage: - this types water demand is required for extravagance water demand by water losses and wastage by different unwanted activities in one town or city throughout design periods of project in study area. These water demand does not reach directly or indirectly to consumer, due to the following reasons, such as water losses due to defective pipes and valves joints, cracked and broken pipes, faulty valves and fittings. Water losses due to, consumers keep open their taps of public taps even when they are not using the water and allow the continuous wastage of water and losses due to unauthorized and illegal connections (Jeandron et al., 2015). Generally unaccounted water losses and wastage demand is assumed to be 20%-30% of total quantity of water demand, but for Addis Kidam town is 20% of total quantity of water is made to compensate for losses, thefts and wastage of water.

4.4. Average Daily Water Demand

Average daily water demand (ADD) is summation of domestic water demand, non-domestic water demand, fire demand and unaccounted water losses and wastages of water per day throughout design periods of this projects (Rumalongo et al., 2017).

$$ADD = DD + NDD + FD + UND$$

4.5. Maximum Daily Demand

The maximum daily water demand is the highest water demand of any one of 24hr period over any specific year in study area throughout design periods. Maximum daily demand is used to design different water supply components, such as to determine quantities of water sources (surface or groundwater), determine capacity of collection chamber and booster station, raising main pipes starting from sources of water up to service reservoir, capacity of all treatment plants if sources water is surface, capacity of pump and intake structure and capacity of service reservoir of study town (Romano et al., 2016). Due to this reason maximum daily demand have its own factors to calculate maximum day demand of the study town depends on numbers of town population. Therefore, general formulas of MDD is as follows,

MDD =ADD*MDF, where MDD=Maximum Daily Demand
ADD=Average Daily Demand
MDF=Maximum Daily Factor

4.6. Peak Hourly Demand

Peak hourly water demand is highest demand any one of one hour in specific 24hours. The PHD is represents variation in the water demand resulting from the behavioral pattern of the population. Generally, there are two ways. One in morning and second in after noon. PHD have its own factor depends on density of population presents, which is Peak Hourly Factors (PHF). Peak hourly demand is used to design distribution system of water supply schemes of study town.

PHD = ADD * PHF, where PHD=Peak Hourly Demand
ADD=Average Daily Demand
PHF=Peak Hourly Factor

Table 15: the factors of maximum daily demand and peak hourly demand

Population	MDF	PHF
0 to 20,000	1.3	2
20,001 to 50,000	1.25	1.9
50001 and above	1.2	1.7

If numbers of study town population at end of design period is 45640, then this number is ranges of 20001 to 50000, therefore the factors of maximum daily demand and peak hourly demand is 1.25 and 1.9 respectively. As total calculation of water demand assessments of study town is shown below table 16.

Table 16: summarized water demand assessments of study area

Year	Unit	2022	2027	2032	2037	2042
Population	No	25854	31154	37181	44160	45640
Domestic demand (DD)	m^3/d	3887.81	5234.81	6933.51	9077.53	10425.1
Industrial Demand factor	%	5%	5%	5%	5%	5%
Industrial Demand (ID)	m^3/d	194.3905	261.7405	346.6755	453.8765	521.255
commercial & institutional Demand factor	%	10%	10%	10%	10%	10%
commercial & institutional Demand (CID)	m^3/d	388.781	523.481	693.351	907.753	1042.51
Public Demand Factor	%	15%	15%	15%	15%	15%
Public Demand (PD)	m^3/d	583.1715	785.2215	1040.0265	1361.6295	1563.765
Fire Demand (FD)	m^3/d	637.21	637.21	637.21	701.04	701.04
Unaccounted water factor	%	20%	20%	20%	20%	20%
Unaccounted water demand	m^3/d	777.562	1046.962	1386.702	1815.506	2085.02
Average Daily Demand (ADD)	m^3/d	6468.925	8489.425	**11037.475**	14317.335	**16338.69**
	l/d	6468925	8489425	11037475	14317335	16338690
Maximum Daily factor		1.25	1.25	1.25	1.25	1.25
Maximum Daily Demand (MDD)	m^3/d	8086.15625	10611.7813	**13796.8438**	17896.6688	**20423.36**
	l/d	8086156.25	10611781.3	13796843.8	17896668.8	20423363
Peak Hourly factor		1.9	1.9	1.9	1.9	1.9
Peak Hourly Demand (PHD)	m^3/d	12290.9575	16129.9075	**20971.2025**	27202.9365	**31043.51**
	l/d	12290957.5	16129907.5	20971202.5	27202936.5	31043511

Sample calculation of above table is,

ADD =DD + ID + CID + PD +FD + UND

ADD =3887.81+ 194.3905 + 388.781 + 583.1715 + 637.21 + 777.562 = 6468.925m^3/d

MDD =ADD*MDF = 6468.925 * 1.25 = 8086.15625m^3/d

PHD = ADD *PHF = 6468.925 * 1.9 = 12290.9575m^3/d

From above table the first phase of maximum daily demand and peak hourly demand is 13796.8438m^3/d and 20971.2025m^3/d respectively and the second phase of maximum daily demand and peak hourly demand is 20423.36m^3/d and 31043.51m^3/d respectively. As generally water demands of existing system is very less compare to with the current water demands of study town, this cause major problem on town communities' day to day activities in said house and outside their house.

5.Water Source

Adequate amounts of water sources are requirement for study town population to fitful their daily needs up to end design periods of this study (Aynalem, 2015). Due to this reason finding adequate quantity and quality of water sources depends on basic criteria's of select sources of water, such as location, quantity, quality and cost of water during construction and after construction for operation and maintenance cost are the basic need for this town (Iraj and Rao, 2016). Because without adequate amounts of water there is not adequate amounts average daily demand, maximum daily and peak hourly demands of water for town. Due to these reasons the Water Supply Committee of the town, Water Supply service offices and other concerned bodies recommends the water source options for further investigations and the consultant team observed the sites accordingly. Therefore, Water sources for long term sustainable water supply system for study town is described below.

1. **Bilti spring:** Located near to Manguda Michael at around **13 km** from the town down stream of Zimbri Mesk
2. **Amesha Spring:** refer below
3. **Enchetab Spring:** Located in Gafera kebele at around 4.5 km from the town

Considering these spring depends on quality, quantity, easy of spring capping structure, location of collection chamber, distance of the spring source and supplied area or town of study area (Marson, 2015), the Amesha and Enchetab spring is proposed for the first phase and for the second phase of water supply system. The proposed source of water supply "Amesha Spring" is located at Amesha shinkuri kebele with UTM location of N-1221380.35, Easting, E-264469.78 and Elevation of 2476.72m amsl.

The estimated yield of the Amesha spring and Enchetab spring is 17 l/s and 25 l/s respectively. Therefore, a spring collection and Capping structure are constructed at downstream of the recharge area to tap and collect the water potential at selected site is recommended.

The existing spring yield is 7.5 l/s and the escaped amount of water from existing spring capping structure is 4.0l/s, after additional capping structure work, are to be used in the new water supply system. Therefore, the total water source is 53.5 lit/sec.

The required maximum daily demand of study town is 159.68l/s and 236.38 l/s in the first phase 2032 and second phase of 2042 respectively. The existing water source is covers only 33.5% and 22.63% of total current and future maximum daily water demands of town communities of first and second phase respectively. This water source satisfies only one small population of study town. Hence, additional Water Source is required to meet these current and future demand of town and also find additional water source to meet first and second phase of maximum daily demands and peak hourly demand of the study town, which is 106.18 l/s and 183 l/s respectively throughout design period.

5.1. Capacity of Raising Main

Gravity raising main is designed to convey economically yield from spring capping structure to the collection chamber. The total length of the Gravity main line is 3,110m. The size of the economical gravity main line is calculated by using the empirical formula.

D= 0.97√Q to 1.22 √Q, Where Q = Yield of the spring [17 l/s]
D= Economical diameter in meters

Therefore, OD 160mm [ID 127.6 mm] PN16 HDPE pipe is recommended and the flow velocity is recommended 0.6 m/s to 2m/s, then 1.5m/s⇨ Safe for this project.

The spring is susceptible to flooding in the upstream direction. Therefore, retaining wall of length 30m, bottom width 0.9m and top width 0.4m is recommended.

5.2. Capacity of Collection Chamber

The collection chambers are proposed to: Collect water from spring capping structure, serve as night storage of the yield of the spring and Store Water for pumping to service reservoir. Considering the above facts, 75 minutes detention time is adopted calculate capacity of the collection chamber of the yield of the spring. The collection chamber is located at UTM location of N-1,222,971.43, E-266,483.69 and Elevation of 2,393.93m above mean sea level.

Capacity of collection chamber = Q *Detention time, where Q = Yield of the spring [17 l/s]

5.3. Pressure Main Raising Line

The pressure main raising line, from collection chamber to the service reservoir, is designed to convey economically the yield of the spring. The total length of spring up to service reservoir is 4,510m. The economical size or diameter of the pressure main raising line is calculated by using the empirical formula

D= 0.97√Q to 1.22 √Q, Where Q=Yield of the spring [17L/S), D= Economical diameter in meters

Therefore, OD180mm (ID 135.4) HDPE PN20 pipe is recommended. The velocity is 1.2m/s, because to balance the pressure unsaid the pipe of flow and resist the pipe duration.

5.4. Capacity of Service Reservoir

The number and size of service reservoirs are often determined based on number and sizes of the defined pressure zones, topographic suitability, size of the area selected for reservoirs construction, availability of standard reservoir sizes and the volume of water which has to be stored for demand fluctuation purpose (Abdisa and Reddy, 2014). The size of service reservoir is often determined using different methods. The most appropriate and economical approach is to carry out a 24-hour supply and demand simulation and then produce the corresponding design mass curve. To produce such types of curves and generate design curves, it requires reliable historical data on hourly water demand variations of the town. Due to this reason to determine the capacity of service reservoir is by using analytical method and mass curve method depends on given data recorded in study town below table.

Table 17: the 24-hourly peak factors of the Addis Kidam town

Time	1	2	3	4	5	6	7	8	9	10	11	12
Hourly factor	0.3	0.3	0.3	0.3	0.5	0.8	1	1.3	2	1.7	1.6	2
Time	13	14	15	16	17	18	19	20	21	22	23	24
Hourly factor	1.4	1.3	1.3	1.4	1.4	1.4	1	1.2	1	0.8	0.5	0.24

Sources: feasibility study of the study town

Determination of capacity of service reservoir for first phase (2022-2032) year

Total maximum daily demand = 13796.844m3/d or 13796844 l/d

Hourly demand of town = $\frac{13796844\ l/d}{24}$ =574868.5 l/d

Assume pumping hours = 18hr

Pumping rate =$\frac{24hr}{pumping\ hour(18hr)}$ *hourly demand (574868.5 l/d) =766491.333 l/d

Table 18: analytical calculation methods of capacity of service reservoir for first phase(liter)

Time(hr) 1	Hourly factor 2	Hourly supply 3(liter)	Hourly demand 4=2*574869.5 (liter)	Comm. hourly demand 5(liter)	Comm. hourly supply 6(liter)	Excess demand 7=5-6(liter)	Excess supply 8=6-5(liter)
1	0.25	0	143717	143717	0	143717	
2	0.3	0	172461	316178	0	316178	
3	0.3	0	172461	488638	0	488638	
4	0.3	766491.3	172461	661099	766491		105393
5	0.5	766491.3	287434	948533	1532983		584450
6	0.8	766491.3	459895	1408428	2299474		891046
7	1	766491.3	574869	1983296	3065965		1082669
8	1.3	766491.3	747329	2730625	3832457		1101831
9	2	766491.3	1149737	3880362	4598948		718586
10	1.7	766491.3	977276	4857639	5365439		507800
11	1.6	766491.3	919790	5777428	6131931		354502
12	2	766491.3	1149737	6927165	6898422	28743	
13	1.3	0	747329	7674494	6898422	776073	
14	1.3	0	747329	8421824	6898422	1523402	
15	1.3	766491.3	747329	9169153	7664913	1504239	
16	1.4	766491.3	804816	9973968	8431405	1542564	
17	1.4	766491.3	804816	10778784	9197896	1580888	
18	1.4	766491.3	804816	11583600	9964387	1619213	
19	1	766491.3	574869	12158469	10730879	1427590	
20	1.2	766491.3	689842	12848311	11497370	1350941	
21	1	766491.3	574869	13423179	12263861	1159318	
22	0.8	766491.3	459895	13883074	13030353	852722	
23	0.5	766491.3	287434	14170509	13796844	373665	
24	0.24	0	137968	14308477	13796844	511633	0

Therefore, the maximum cumulative of excess demand =1619213 liter=1619.213m^3

The maximum cumulative of excess supply = 1101831 liter=1101.831m^3

Then, Equalizing volume of service reservoir=Max. Cumulative excess (demand + supply)

Equalizing volume of service reservoir = (1619.213 + 1101.831) m^3 = 2721.044m^3

But the total volume of service reservoir = (Equalizing +Breakdown + Fire) volume

Let as assumed breakdown storage of service reservoir as 2-3hr pumping rate, then take 3hr

Break down storage of service reservoir = 3hr * pumping rate

=3hr*31.937m^3/hr =95.811m^3

Les as assumed fire storages of service reservoir as 2 -5l/c/d, then take 5l/c/d

Fire storages of service reservoir = 5l/c/d *No of population

= 5l/c/d *37181 =185.905m^3

Therefore, total volumes of service reservoir (SR) for first phase is,

Total volume of SR = 2721.044m^3 + 95.811m^3 +185.905m^3 = 3002.76m^3

Then provide 3000 m^3 is safe for this phase.

For second phase (2032 – 2042) year

Total maximum daily demand = 20243.51m3/d

Hourly demand of town = $\frac{20243.51m3/d}{24}$ = 843.48m3/d

Assume pumping hours = 20hr

Pumping rate =$\frac{24hr}{pumping\ hour(20hr)}$ *hourly demand (843.48m3/d) = 1012.176m3/d

Table 19: analytical calculation methods of capacity of service reservoir for second phase(m^3)

Time(hr) 1	Hourly factor 2	Hourly supply 3 (m3)	Hourly demand 4=2*843.48m3	Comm. hourly demand 5 (m3)	Comm. hourly supply 6 (m3)	Excess demand 7=5-6 (m3)	Excess supply 8=6-5 (m3)
1	0.25	0	211	211	0	211	
2	0.3	0	253	464	0	464	
3	0.3	1012	253	717	1012		
4	0.3	1012	253	970	2024		1054
5	0.5	1012	422	1392	3037		1645
6	0.8	1012	675	2067	4049		1982
7	1	1012	843	2910	5061		2151
8	1.3	1012	1097	4007	6073		2067
9	2	1012	1687	5693	7085		1392
10	1.7	1012	1434	7127	8097		970
11	1.6	1012	1350	8477	9110		633
12	2	1012	1687	10164	10122	42	
13	1.3	0	1097	11260	10122	1139	
14	1.3	0	1097	12357	10122	2235	
15	1.3	1012	1097	13454	11134	2320	
16	1.4	1012	1181	14634	12146	2488	
17	1.4	1012	1181	15815	13158	2657	
18	1.4	1012	1181	16996	14170	2826	
19	1	1012	843	17840	15183	2657	
20	1.2	1012	1012	18852	16195	2657	
21	1	1012	843	19695	17207	2488	
22	0.8	1012	675	20370	18219	2151	
23	0.5	1012	422	20792	19231	1560	
24	0.24	1012	202	20994	20244	751	

Therefore, the maximum cumulative of excess demand =2826m^3
The maximum cumulative of excess supply = 2151m^3
Then, Equalizing volume of service reservoir=Max. Cumulative excess (demand + supply)
Equalizing volume of service reservoir = (2826 + 2151) m^3 = 4977m^3
But the total volume of service reservoir = (Equalizing +Breakdown + Fire) volume
Let as assumed breakdown storage of service reservoir as 2-3hr pumping rate, then take 3hr
Break down storage of service reservoir = 3hr * pumping rate
=3hr*42.174m^3/hr =126.522m^3
Les as assumed fire storages of service reservoir as 2 -5l/c/d, then take 5l/c/d
Fire storages of service reservoir = 5l/c/d *No of population
= 5l/c/d *45640 =228.2m^3
Therefore, total volumes of service reservoir (SR) for second phase is,
Total volume of SR = 4977m^3 + 126.522m^3 +228.2m^3 = 5332m^3 = 5350 m^3
Then provide 5350m^3 is safe for this phase.
Totally to provide capacity of service reservoir for first and second phase is 300m^3 and 5350m^3 respectively up to end of design periods of study area to balance reservoir problems of current and future time in town.

Conclusion

Existing water sources and demand of study is not adequate quantity and safe quality for current numbers of town population, because the numbers of town population increasing rapidly without any gap throughout the year, but amounts of water demand is decreasing time to time throughout its design period starting period up to now.

The total projection of the town population in first and second phase is 37181 and 45640 respectively for 20 years design period by using geometric increasing methods. Projected water demand of town for first and second phase is 13796.84m3 and 20423.36m3 of maximum daily demand respectively and 20971m3 and 31043.51m3/d of peak hourly demand respectively for current and future time up to end of design periods this town.

Existing water sources of the study town is 53.5 l/s, which is not meet the current water demands of the town, the required maximum daily demand of study town is 159.68l/s and 236.38 l/s in the first phase 2032 and second phase of 2042 respectively. The existing water source is covers only 33.5% and 22.63% of total current and future maximum daily water demands of town communities of first and second phase respectively. To provide additional water source to meet first and second phase of maximum daily demands and peak hourly demand of the study town, which is 106.18 l/s and 183 l/s respectively throughout design period. The capacity of service reservoir of first and second phase of study town is 3000m3 and 5350m3 respectively up to end design period.

Generally, to provide adequate amounts and safe water demand and water sources is the most important for study town to develop by social and economic aspects of the communities throughout their life.

Ethical Statement

Ethical statement of this paper is all participant authors have no any types of compliance to published this paper from Journal of Applied Water Science. All authors are happy to publish this article paper from applied water science journal because its publishing is open access and do not have to pay the article processing charge or free for publication charges. The funding of this article paper is funding information is not applicable or not funding is received before or after publication of this paper for all participant authors. Our interest will be to publish more research papers at current and for future time from this journal.

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