International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Assessing Causes and Challenges of Urban Water Supply: The Case of Mekelle City

Desalegn Berhane Asgedom

Lecturer, Department Head, Adigrat, Ethiopia, East Africa

Abstract: ***Urban water supply is a common problem in Ethiopia as well as in Tigray region. For this reason, the objective of this study was to assess causes and challenges of water supply facing Mekelle city. A survey of 203 households and five official interviewees were sources of primary data. Systematic random sampling was used to select households while purposive for interviewees. The analysis was conducted using statistical package for social scientists software (SPSS). The result indicated that mean daily per capita water consumption during water supply interruption and time of piped water service available is 11.9 liters and 20.46 liters, respectively. Moreover, the production-demand gap and the unsatisfied demand of the city inhabitants were widening from year to year. The study has revealed that shortage of water at the sources, operators lack of technical skill, rapid population growth and quick urbanization are among the major causes that resulted in water supply shortage. The study also indicates that water distribution in the city is not equal; the timing of water service in most areas is at night and non-scheduled. Therefore, capacitating employees of the office through experience sharing from other cities and countries, skill and knowledge upgrading, and good map of water distribution system are compulsory***

Keywords: Households, Socio-economic, Groundwater, Causes and Challenges of urban water supply

1. Introduction

Water is the lifeblood of the world and is considered as a national resource of utmost importance. According to Doe (2007:1) next to oxygen, water is the most important element for human survival. It is the most vital of all public services. Water scarcity affects the entire community, so anything that disturbs the provision and supply of water tends to disturb the very survival of humanity. Water supply is indispensable in both rural and urban areas. Therefore, the accessibility to adequate clean water, to produce food for both rural and urban population, is just one aspect of the role played by water in meeting basic needs and contributing to development (UNESCO, 2006).

In Mekelle city, water is supplied to residents through public taps and pipelines, pumped in from reservoirs, and collected from any available sources. According to Giorgi *et.al*, (2009: 29-30) it is estimated that between 51-60 percent of families have access to tap; other families obtain water through any sources available. In the same reference it is revealed that because of inadequate sanitation and access to sources of potable water each year, residents of the city were suffering from different diseases such as diarrhea.

According to Castro *et.al*, (2009) key water supply problems in Mekelle city include water loss and non-revenue water. In 2008, water losses in the distribution system amounted to 4,456 m3/day. In Mekelle city, water supply coverage often vibrates between 41% up to 51% (WSSO annual report of, 2008, 2009 and 2010). The main supply of water for Mekelle city is primarily from piping connection coming from groundwater at Aynalem well field. This source is augmented by other sources like untreated water from wells, by buying from water vendors and kiosks, and shallow boreholes. According to, Mr. Nega, head of Tigray Water Resource Bureau speech on the second quarter regional parliament forum (2010), the daily water demand by the city community is estimated to be 42,000 m3, which is 1,260,000 m3 per month. As per the annual report of Mekelle Water Supply Service office (2009/10), there are 17 boreholes of water supply sources for the city (for not less than 54,073 households, different government and non-government organizations, industry and service companies...) with a total average yield of 329,330 m3 per month, which is 3,951,954m3/year. This shows there is a significant gap in production gap of 900,670 m3 per month. Even though most water related investigations undertaken in the city show the existence of serious potable water shortages and frequent water service interruption, no investigation is carried out so far in the causes and challenges of water supply in the city. Therefore, there is a need to assess the challenges of water supply in the study area.

1.1 General Objective

The overall objective of this study was to explore the causes and challenges of water supply facing Mekelle city so as to provide information that would help to grasp a clear understanding on the challenges

1.2 Specific Objectives

1) To determine the average water consumption of households per capita per day.
2) To examine the gap in trend of water production and demand of households as of 2008-2010/11.
3) To identify the major causes and challenges of the frequent water shortages in the city

2. Research Questions

The purpose of this study was to assess the challenges of water supply in Mekelle city. Based on these objectives, the following major questions were answered in this research;

- How many liters of water do households collect from different sources each day?

- What is the demand of households in light of the total produced water as of 2008-2010/11?
- What are the possible causes of the water shortage in supply of water in the city?
- What are the challenges of supply of water in the city?

2.1 Scope and Limitation of the Study

This investigation was conducted in Mekelle city. The researcher has got an opportunity (regional report regarding the issue) to evaluate the urban water supply in the region. Due to industrialization and other reasons, water supply problem in the city is worse than in other urban centers of the region. The reason why the scope is delimited to this city is that water supply problem is more serious in Mekelle city than other urban centers. Certainly, water affects every aspect of human beings life, it may deserve research in its all aspect, but this study was confined to assess the causes and challenges of water supply in the city. Besides the study dealt only at household level, so impact of water shortage on industries and commercial establishment, Governmental and non-governmental Organizations, and other institutions were not the concern of the study.

2.2 Significance of the Study

This study is expected to increase the knowledge and up to date information on the city water supply size and its undesirable impacts on the urban community due to shortage of water supply. It will also serve as a working document to policy makers in the water sector and the non-governmental Organizations. Moreover, the finding will further serve as reference data and it opens avenue for any further investigation in the area, and as a useful material for academic purposes.

3. Literature Review

The researcher reviewed the published documents available over a decade related to potable water and attempts to find out the research gap. Vairavamoorthy *et.al*, (2008:330) indicated that water demand is increasing throughout the world for different activities such as for agricultural, recreational and domestic consumptions. Hughes *et.al*, (2009:179) pointed out that water uses for basic domestic activities, such as sanitation, drinking, bathing, and food preparation needs of residents. Bartram and Howard (2003:221) underlined that the role of potable water supply has a vital contribution upon development activities and health of the society, for that reason availability of drinkable water is important components in poverty mitigation. Adequate and reliable water supply is critical for coping with every day urban life. Poor access to potable water has negative impact on development. According to Jouravlev (2004:18) the majority proportion of drinking water supply are consumed almost exclusively by household users. Mohammed *et.al*, (2008) revealed water shortage affects women as female members are traditionally responsible for water fetching.

As demand for water is increasing at higher rate than supply, water resource developments and management is given a great attention. Hughes *et.al*, (2009:176) stated that both new dams construction, harvesting rain water, desalination plants or water recycling are the most common methods of water supply management techniques. O.Schwab and D.Fangmeier (2004) stated that soil and water conservation engineering is the solution of soil and water management problem. International City Managers Association (1957) in Bihon (2009) states that water conservation steps include coating reservoirs to protect leakage, covering reservoirs to reduce evaporation, industrial and agricultural reuse of water.

Elango (2008:5) set out that the main components of water infrastructure are water collection and storage facilities at source sites, water transport via aqueducts from source sites to water treatment facilities and storage and distribution systems. Pipe supplied drinking water is one of the most important sources of urban water. Efforts to assess challenges of urban water supply are important. Kayaga and Franceys (2007:270) disclosed that urban poor often rely on water vendors from their private connection. Water restrictions involve complex rules which control the outdoor consumption of water by urban communities. The challenges in urban water management are ample. Sharma (2008) mentioned that lack of skilled manpower, under pricing of water and lack of a holistic approach and frame work are the major challenges for urban water management. The study aims to explore the challenges of water supply facing in Mekelle city.

4. Methodology

Mekelle was founded in the 13th century. However, its heyday comes soon after Emperor Yohannes IV was crowned as king of kings of Ethiopia (1871-1889). The Emperor chose Mekelle as the seat of his government (Mekelle city administration, 2009). Mekelle city is the sixth largest city in Ethiopia, the largest in Tigray. It is the administrative capital of Tigray National Regional State of Ethiopia. It is located at the northern part of the country at a distance of 870 km from the capital, Addis Ababa. Mekelle is a mid-sized city with total population of 233,012 of which 113,247 are male and 119,765 female (CSA, 2009:22). It is found in 39 28‟ East and 13 28 ‟ North at an average altitude of about 2084 meters above sea level, with an average mean temperature of 19°c and the annual rain fall varying between 50 to 250 mm.

Mekelle city was established at the foot of a steep cliff, Endayesus escarpment on the east side. Like all other large Ethiopian cities, Mekelle is experiencing rapid growth. The city has stretched greatly by engulfing many surrounding villages and towns. In 2006, both Quiha and Aynalem were included within the City limits. Besides villages recently incorporated include Lachi, Adi-kenfero, Feleg Daero, Endamariam Dehan, Adi-Daero, Adi-Kolomey, Serawat, Adi-Wolel, Adi-Ha, and May Alem (Castro, 2009:9).

According to Mekelle city Administration annual report (2008), the administrative territory of the city is divided into seven lowest administrative units: Adi-Haki, Ayder, Hadnet, Hawelti, Kedamay Weyane, Quiha, and Semien. Mekelle Water Supply Service Office (2008) in Kinfe and Tewodros

(2011) suggested that, the city is one of the top fast growing cities in the country with a total area of 150km^2.

The water supply service office in Mekelle has four branch offices located in four administrative units of the city namely in Semein, Hewelti, Ayder, and Adi-haki. This is in order to serve the community nearby to the branches without difficulty, and to save time of service seekers. Besides to domestic use, a large amount of drinking water is used daily for commerce and industries. Initially water is pumped from the sources (usually from groundwater in Mekelle case) to a treatment facility where it is treated to make it suitable for human consumption.

5. Data Type and Sources

To achieve the stated objectives of this study both primary and secondary data were used. These were done through the use of semi structured questionnaires and interviews; this questionnaire was translated to the local language and responded by the household heads in the selected "Ketenas" (small administrative unit) and interviews were conducted with officials of the water supply service office in addition to field observation related to activities during water collecting.

Secondary information were also collected from, published and unpublished documents, Central Statistics Authority (CSA,2009), Mekelle Water Supply Service Office reports, Mekelle City Health Office, Traffic police of Mekelle, Tigray Region Bureau of Water, Minerals and Energy Resources, Mekelle City Administration, Ministry of Water Resource, Internet, and Journals.

6. Research Strategy and Design

This descriptive study was conducted in Mekelle city. The city has a total population of 237,922 and a total household size of 54,073 (Mekelle Health Office, Survey 2011). Mekelle city encompasses seven administrative units (tabia) with different population size and density. These administrative units further sub-divided to 74 "ketenas".

The researcher used the sample size determination formula, which is developed by Yamane (1967:886), to determine the sample size for the study.

$n=N/ (1+N (e)^2)$

$= 54,073/ (1+54,073(0.07)^2$

$= \underline{203}$

Where n is the sample size, N is the population size and it was taken the number of households of the city, as the unit of analysis of the study, and considering the fixed time and budget of the research, the investigator decided the confidence level of the study to be at 93% consequently the level of precision (e) is $\pm$7. Furthermore in the determination of the confidence level the open-ended questions incorporated in the questionnaire, which gave high freedom to respondents were also considered.

As long as there were differences in, population density, landscape that is directly related with pressure needed for water distribution, and number of private meter connection that has an effect on water supply and service among households in different tabias (plural form of tabia), the investigator decided to incorporate all administrative units in the study. As we can see in Table 1.1 below, simple random sampling technique was used to select two "ketena" from each tabia to represent their respective tabias. Moreover, depending on the number of households of the 12 ketenas the probability proportionate sampling technique was followed to determine sample household numbers for each "ketena".

Table 1.1: Selected "ketenas", Number of Households and Number of Sampled HHs in each Ketena

No	Tabia	Number of ketena in each tabia*	Sampled ketene*	Number of HHs*	Number of sampled HHs**	Total Sampled HHs**	Number Questionnaires collected **
1	Adihaki	7	ketena 1	1850	22	46	44
			ketena 7	2025	24		
2	Ayder	14	ketena 6	576	7	16	16
			ketena 7	742	9		
3	Hadnet	9	ketena 9	984	12	26	25
			Endustry	1123	14		
4	Hawelti	10	ketena 9	2001	15	39	39
			ketena 4	1213	20		
5	Kedemay weyane	11	ketena 9	1638	20	40	39
			Maidegene	1650	20		
6	Quiha	7	Awash	293	4	12	12
			Camp	650	8		
7	Semein	16	ketena 1	1179	13	24	24
			ketena 2	900	11		
	Total	74		16,824	203	203	199

A total of 203 households were sampled from these 12 ketenas for the study. Out of these household questionnaires, 98.03% of the questionnaires were responded and collected properly. Moreover, this data from the household survey was supplemented by in-depth interview from Water Supply Service officials.

Table 1.2: Position of Officials who were Interviewees in the study

S.No	*Office*	*Position*
1	MWSSO	Manager
2	MWSSO	Public relation
3	MWSSO	Planning and budget coordinator
4	MWSSO	Case team leader of production and distribution
5	MWSSO	Budget and finance team leader

Source: *Survey result, 2011*

Purposive sampling technique was used to select the sample respondents from the office. The reason was to select cases that were informative and assumed to be familiar with some fundamental issues concerning urban water supply in the city.

In Mekelle Water Supply Service Office, the planning and budget coordinator was purposively selected. This is because he knows the short and long run plan of the office with regard to water supply to the city community. Besides, he is

relatively more accessible to the overall activities of the office and the researcher taught easily to collect relevant secondary data.

7. Data Collection and Instruments

The semi-structured questionnaires incorporate both open and close-ended questions. This enabled the researcher to capture direct answers from the respondents via the close-ended questions, whilst the open-ended questions provide an opportunity the respondents to convey their views as they wish. Consequently, this helped the researcher to collect information that could not be found by close-ended questions. Besides, semi-structured interviews were carried out to collect primary data from the selected five officials of the water supply office. The selection was based on who is in a position to provide the required information for the study.

Four enumerators were selected taking into account their experiences and knowledge of the "ketenes" to handle the questionnaire and they were given training for exactly one day to make them familiar with the aim of the research. The questionnaire was translated in to the local language, Tigrigna. The researcher was supervising the enumerators and implemented field editing at a point. Moreover, the investigator himself gathered relevant data from the officials' via interview. Transit walk was also carried out by the researcher to gain data on the water collecting activities of the children and women during the field visit with the help of observation guide.

Statistical techniques were used to analyze the data obtained from the sampled households and officials. Statistical package for social scientists (SPSS) software version 16 for windows was used in data processing. In the analysis of the results, averages and percentages were mainly used.

8. Results and Discussions

The household per day water consumption is thought to vary with water supply service conditions. To determine the amount of water consumption level per household and per capita per day, three conditions were considered. The first situation is water consumption level during piped water supply interruption, the second condition is water consumption level when there was no piped water supply interruption, and the third condition the amount of water sample households needs to have for domestic activities.

As long as piped water supply interruption has not direct impact on households who did not mainly collect or use from piped water as to those who had pipe connection, they excluded in these three ways of water consumption level assessment. Sample households were also asked of the average daily amount of water consumed for their drinking, bathing, washing and other domestic activities in time of piped water supply interruption. In figure 4.8 it appears 41(22.2%) households utilized from 25-50 liters per day, the majority 66 (35.7%) households said that they consumed 76-100 liters, and only one household respondent used 201-225 liters per day.

According to Mekelle Health Office survey (2011), the average family size of the household of the city is 4.4. However in this study, the average family sizes of the households are appeared to be 5.41 and the calculated average daily water consumption of households per day is 60 liters. On the other hand average water consumption per capita per day is 11.1 liters. Comparing with the national target 20 liter per capita per day (Ministry of Water Resource, 1996), the community's water consumption level is very low relative to the amount of water required to individual for domestic consumption per day.

Based on secondary data from the Water Supply Service Office of the city the current condition related to the water sources, distributions, reservoirs, productions, and pipeline networks in the study city are presented below. The existing water supply system of Mekelle city encompasses pipeline works including transmission mainlines, which are connected to each borehole, collecting water from the sources directly to the artificial storage that is reservoirs. The water supply service office in its 2010 annual report stated that the present major water supply source of Mekele city is groundwater from 17 boreholes. The supplied water is lost due to many reasons.

The water loss during September 2008 to August 2009 is studied and tabled in Table 1.2

As it is observed, in 2008/09 the volume of water effectively supplied is 3,241,647 m3 from the total 4,207,059 m3 produced. Hence, the total water production capacity of the boreholes in 2008/09 was only 133.4 liters per second. This table also shows that, the water loss percent ranged from the minimum recorded in September to the maximum loss (34.23%) in June. Hence, the average water loss of the year is 22.95% of the produced, the highest water loss were registered in the rainy season of the year (June 34.23%, and July 33.73%). The result implies that the water loss registered were one of the predominant sources for water supply shortage in the city. In line with this, Sharma and Vairavamoorthy (2008:210) stated that, leakage from water distribution system and lack of strong meter management are the leading sources for high non revenue water. They specifically suggested in developing countries such as in Asia and Africa, it ranges from 20 to 70%.

Table 1.3: Actual Production of Water to Total Consumption (Sep. 2008 up to Aug.2009)

S. no	*Month*	*Number of wells**	*produced Actual in m^3**	*Consumed amount in m^3 **	*Water loss***	
					In m^3	*In %*
1	September	17	289,417	277,676	11,741	4.06
2	October	18	359,734	280,441	79,293	22.04
3	November	18	370,739	300,322	70,417	18.99
4	December	18	343,329	262,140	81,189	23.65
5	January	19	384,001	288,352	95,649	24.91
6	February	17	376,785	270,381	106,404	28.24
7	March	17	345,019	295,618	49,401	14.32
8	April	16	354,615	286,688	67,927	19.16
9	May	16	343,780	287,591	56,189	16.34
10	June	17	375,343	246,859	128,484	34.23
11	July	17	315,328	208,957	106,371	33.73
12	August	18	348,969	236,622	112,347	32.19
Annual total			**4,207,059**	**3,241,647**	**965,412**	**22.95**

Source: *Water Supply and Service Office Statistical Bulletin 2011

As indicated in the table both the production of water and its demand shown increments, for example total production has increased from 2,963,525 m3/ year in 2007/08 to 3,241,647 m3/ year in 2008/09 and then increased to 3,951,954 m3/ year in 2009/10. Hence there were increments of 278,122 m3 in 2008/09 and 710,307 m3 in 2009/10. The demand of the water by the city dwellers for domestic consumption also shown an increment of 382,155 m3 in 2008/2009, and 5,987,845 in 2009/2010.
Total population of the city further showed an increment. Besides, the unsatisfied household demand reduced to 60.75% in 2008/09 from 63.09 % in 2008/09, and in 2009/10 because of lowering of the production and possibly other reason (s) the unsatisfied demand escalated to 72.21%.

Table 1.4 : Piped Water Supply Interruptions from Private connections

S. no	*Possible causes of water supply interruption*	*Major cause*	*minor cause*	*is not a cause*	*Total in (%)*
1	Shortage of water at the sources	111 or 61.33%	51 or 28.17%	19 or 10.49%	**100**
2	Lack of enough pressure in the system	46 or 25.4%	117 or 64.8%	18 or 9.9%	**100**
3	Operators lack of technical skill to handle equipments such as pumps	138 or 76.2%	22 or 12.2%	21 or 11.6%	**100**
4	Water Supply Service Office fails to undertake fast maintenance	82 or 45.3%	75 or 41.4%	24 or 13.3%	**100**
5	Rapid population growth	113 or 62.4%	54 or 27.1%	14 or 7.7%	**100**
6	Repeated broken down of pipelines	53 or 29.3%	89 or 49.2%	39 or 21.5%	**100**
7	illegitimate connections	25 or 13.8%	63 or 34.8%	93 or 51.4%	**100**
8	Electric power cut	99 or 54.7%	67 or 37.0%	15 or 8.3%	**100**
9	Quick urbanization	155 or 85.6%	21 or 11.6%	5 or 2.8%	**100**
10	Water loss (it excludes unbilled and unauthorized consumption)	62 or 34.3%	72 or 39.8%	47 or 26.0%	**100**

Source: Survey result, 2011

Out of the 181 respondents, 111(61.33%) of them were suggested that the major cause for piped water service interruption in the city was due to water shortage at the source, in which water supply entirely relying on groundwater is not enough. 138 (76.2%) believed that lack of technical expertise of the operators to handle equipments such as pumps was one of the most important causes, in which frequent pump failure was announcing in different mass medias. 82 (45.3%) and 113 (62.4%) have the belief that part of the key causes possibly due to Water Supply Service Office failures to carried out fast repairs in the distribution system and rapid population growth in the city respectively were mentioned. Besides natural growth of the city dwellers, migration of the rural population to city has resulted in additional pressure to the inadequate water. This result go in line with Vairavamoorthy (2007) finding, the author stated that the larger populations will demand larger proportions of water while simultaneously decreasing the ability of ecosystems to provide more regular and cleaner supplies.

The selected officials of Mekelle Water Supply Service Office were interviewed on the causes of drinking water shortage in the city. As per the majority officials four root causes of water supply shortage in the city were mentioned: one shortage of water at the sources in which production capacity of boreholes were declining from time to time and even there were boreholes that totally ceased up production. According to the interviewees this water shortage was the result of poor recharging activities on the water potential sites.

Lack of enough pressure in the water distribution system was also suggested as main cause for water service interruption. Further they exemplified some areas in the city which linked with this kind of problem. Some of these areas were Adi-ha, Kelke debri, Adi-shindhon, Darfure area (Hadnet), Mai-degene, Adi-hawsi and some part in Ayder.

Interviewees of the office said frequent electric power cut was also believed to be one of the chief contributors for the supply interruption. More than ever, in 2009/10 this problem was considered to be worsened. In line with this, in 2009/10 annual report of the office supports the suggestion of the interviewees that due to frequent electric power break all pumps were stopped to function for more than 25,893 hours (which is equivalent to 65 days) in that particular year.

According to the selected officials‟ suggestion rapid urbanization was not left out from the major causes, 99 household respondents thought that the city has shown fast expansion and it was engulfing new villages and towns. Consequently, the water demand by new dwellers increased and it deserves expansion of water supply infrastructure which ultimately leads to water shortages in the city.

Of all the majority respondents, (155 or 85.6%) agreed that the key cause for water shortage at household in the city was because of quick urbanization. 99 (54.7%) suggested that one of the top causes for water service interruption in the city was due to frequent electric failure. Population growth and urbanization are found to be the most leading factors to a dramatic increase in water consumption (Zhoua *et.al*, 2009; Flemming, 2001:1). This population concentration and vast buildings in urban centers in one way or another it creates a pressure on urban water supply systems.

Apart from the root causes, 117 (64.8%) of the sample respondents thought that lack of enough pressure in the system might be one of the minor causes. 89 (49.2%) and 63 or 34.8% of household respondents argued out that frequent broken down of pipelines from the distribution system and illegitimate connection respectively, had slight role to the frequent water supply interruption in the study area. The remaining 72 (39.8%) viewed that water loss was the trivial factor for water shortage in the city.

Generally, the household respondents and the selected officials had common view on some factors which result in service interruption, shortage of water at the sources; rapid

population growth, electric power failure, and rapid urbanization were classified to be main causes of water supply shortage to the city communities. However, frequent broken down of pipelines, lack of enough pressure in the system and illegitimate connections were categorized as minor causes.

9. Conclusions and Suggestions

Generally water supply coverage in developing countries is low. However, water supply coverage in Ethiopia is among the lowest even from most countries in sub-Sahara. As reports indicated, in 2007 national water supply coverage was 52.5% (46.4% rural and 82.0% urban).

Mekelle like most major towns in Ethiopia obtain almost all its domestic water supply from groundwater. The available groundwater sources from where the city is collecting for the domestic and productive consumption is becoming depleted from time to time. This problem is aggravated by the rapid rate of population growth; rapid expansion of the city coupled with other avoidable problems such as electric power failure resulted in the existing water supply to be inadequate. Even though, the Water Supply Service Office is drilling additional boreholes from year to year, there are also wells which are becoming out of use. The water catchment sites are bare and deforested. This hinders groundwater recharging from rainfall percolation. Besides, the produced water do not effectively reached to end users due to water leakage, frequent electric power failure, lack of expertise of employees of the office, inefficiency of management and other related issues. The study showed that the water supply coverage of Mekelle city is often close to 40%. But, because of the aforementioned reasons water supply coverage of the city in 2009/10 was less than 30%. Even though, total water production of the year increased, the unsatisfied water demand of household for domestic activities raised to 72%. This is mainly due to water demand increment. Above all the unequal water distribution in the city made it burning issue. Due to the aforementioned root causes the gap between demand and production is found to increase from year to year. Moreover, Mekelle Water Supply Service Office did not able to catch up with the ever increasing water demand of the society.

Based on the findings the study suggests

1. The existing numbers of boreholes are not enough to supply the ever increasing water demand, therefore, to ensure adequate water supply drilling of additional boreholes/wells or to find new water potential sites for wells are to be considered as a short term solution by Mekelle Water Supply Office.
2. Water source for the city entirely relying only on groundwater is not enough. The groundwater source has to be augmented by surface water. Therefore, as a long-run solution to water supply shortage in the city great attention should be given for surface water development. Moreover, the surface water will have the recharging role to the groundwater sources around its area.
3. Through both physical and biological water conservation techniques around the water potential areas (boreholes sites) groundwater have to be recharged so as to balance the recharging and discharging rates. Therefore, integrated watershed management activities to conserve and enhance the mobile groundwater resource are the best remedy.
4. The study is concluded that the assessment has produced some supportive information, which is expected to help and improve water supply service in the Mekelle city.

10. Acknowledgements

I want to profoundly thank everyone who helped me along this path. I am grateful beyond words on how to thank Dr.Senthilkumar Kalyan and Bihon Kassa (Ass. professor) for their genuine and constructive advice, and reviewing my work sacrificing their golden time from the very beginning. I also want to express my thankfulness to officials of Mekelle Water Supply Office, Mekelle Health Office, Mekelle city Administration Office and Tigray Water Resource Bureau for providing me the necessary materials, information and worth ideas. I am also grateful to respondents in Mekelle city and Water Supply Office for taking the time to listen to me and for the feedback they provided. Most importantly, I want to thank my friends and family for their support and encouragement throughout this process and for believing that I would eventually finish.

References

[1] Andrei Jouravlev (2004), Drinking water supply and sanitation services on the threshold of the XXI century, Santiago, Chile.
[2] Bihon Kassa (2009), household water supply and factors affecting consumption level: the case of Mekelle Town, Tigray, Ethiopia", VDM Publishing House, Germany.
[3] Andrea Castro, Moumié Maoulidi and MCI (2009), A Water and Sanitation needs Assessment for Mekelle city, Ethiopia
[4] Central Statistics Agency (2009), Statistical Abstract, Federal Democratic Republic of Ethiopia.
[5] Jamie Bartram* and Guy Howard (2003), Drinking-Water Standards for the Developing World. *Department of Protection for the Human Environment, World Health Organization.
[6] Kala Vairavamoorthy , Sunil D. Gorantiwar , Assela Pathirana (2008), Managing urban water supplies in developing countries – Climate change and water scarcity scenarios. UNESCO-THE Institute for Water Education, the Netherlands Physics and Chemistry of the Earth 33 330–339.
[7] Khatri, K.B Vairavamoorthy.K (2007), Challenges for Urban Water Supply and Sanitation in the Developing Countries. Delft, The Netherlands.
[8] Matthew S. Flemming (2001), Hydro-crisis in the Middle East: water schemes for a thirstyregion, Master of Arts in national security affairs, naval postgraduate school, Department of ational Security Affairs, United States.
[9] Mekelle City Administration (2009/2010), Mekelle Water Supply and Sewerage Service Office, Volume I, Business Plan Report.
[10] Neal Hughes, Ahmed Hafi and Tim Goesch (2009), Urban water management: optimal price and investment policy under climate Variability†. The Australin ,

Journal of Agricultural and Resource Economics, 53, pp. 175–192.
[11] Sam Kayaga and Richard Franceys (2007), Costs of urban utility water connections: Excessive burden to the poor. Utilities Policy 15 (2007) 270-277
[12] Senthil Seliyan Elango, Urban Water Management. Thesis. Retrieved March 10, 2011, from http://www.aiu.edu/publications/student/english/Urban%20Water%20Management.
[13] Yamane Taro (1967), Statistics, an Introductory Analysis, Harper and Row, New York.
[14] Yi Zhoua,b, K. Vairavamoorthya,b, M.A.M. Mansoor(2009), Integration of urban water services. Department of Urban Water and Sanitation, UNESCO-the Institute for Water Education, the Netherlands.