

PROBLEMS OF WATER SUPPLY IN THE
LIVINGSTONE DISTRICT COUNCIL

by

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This Research Project was submitted in partial fulfilment of the Physical Geography, Single subject major requirements leading to the award of a Bachelor of Arts with Education, Degree at the University of Zambia, Geography Department, Lusaka.

(i)

DEDICATION

To my dear parents, brothers and sisters who
with pride have seen me go through thin and thick

(ii)

DECLARATION

I, Excellent Hachileka, declare that this Research Project has been composed by me and that the work recorded therein is my own. All maps and diagrams were drawn and designed by me; and all quotations have been distinguished by quotation marks or otherwise. The sources of all materials have been specifically acknowledged and the Project has not been previously submitted for an academic award.

Signed: _____



Date: _____

31st May, 1989.

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ABSTRACT

An adequate water supply is literally a matter of life or death, not only for human beings but also for every form of animal and plant life. Nevertheless, until recently water has been taken for granted with little thought given to its conservation and use as a natural resource. As populations grow and urban areas expand in size, a proportional increase in water supply is necessary to satisfy increasing demand. However, there are usually problems encountered by water supply authorities in the provision of a regular supply of water.

This study is a detailed assessment of the water supply system of the Livingstone District Council. The major water users were identified into four categories as domestic, commercial, institutional and industrial. Their positions, distance from the reservoirs as well as type of residential areas for domestic users were determined. In turn, the share of the total water for each water use category was determined. The study also assessed the adequacy of water quantities abstracted from the source and problems encountered in the process. This was done by a close examination of the capacities of the pumping equipment, rising mains, treatment plant reservoirs, the distribution system and an evaluation of the waterworks management.

It was established that users were not satisfied with the amounts of water supplied. Tentative water supply problems were identified and in turn investigated closely to determine their effects individually and severally as interrelated factors.

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CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 BACKGROUND TO PROJECT AND UTILITY

One of the major problems faced by the Zambian society is availability of clean water. This is quite evident in that more often than not, the Newspapers carry headlines about water blues. Headlines such as, "water blues haunt U.T.H.", "water crisis hit Ndola" and many more have become a common thing by the day. The water and for that matter safe water supply has reached crisis levels never experienced before in Zambia as a whole. Virtually all District Councils in the country are facing acute water problems and as rightly put by the Decentralization Minister of State in Parliament on the 24th of November, 1988, "no Council at the moment in Zambia can boast of providing water 24 hours to its residents in a day for one year." To underline the seriousness of the matter, the Head of State at one time demanded comprehensive reports and master plans on how District Councils intended to ensure clean water supplies to their communities (Times of Zambia, 22 September 1988). A reliable and regular water supply is very crucial in the development and well being of the community as a whole. However, while it is true that the whole is more than the sum of its parts, it is important that individual water supply systems are studied closely to identify the major causes of the water crisis. By so doing, the water supply problems of the country may be solved individually and severally. Livingstone District Council is a good case study on this subject. This is because of its strategic status and location as a tourist centre while at the same time it is subject to extremes of weather.

1.2 AIMS AND OBJECTIVES

- (i) To investigate water supply satisfaction for varied water users.
- (ii) To assess the adequacy of the water supply capacities of the water works.

- (iii) To investigate problems encountered in the provision of a regular water supply to users.
- (iv) To assess problems encountered in water distribution from reservoirs.

1.3 HYPOTHESES

- (i) All water user categories are not satisfied with the amounts of water supplied to them.
- (ii) The water supply system capacities are not adequate.
- (iii) Distance from reservoirs has no significant effects on the distribution of water to users.
- (iv) The topography of the study area has no significant effects on the distribution of water to users.

1.4 THE SCOPE OF THE STUDY

This study tries to give an insight on the sharing of a common property resource - water in an urban setting. Zambia's water policy on the sharing of water among various users is highlighted. This is given in the first part of the study where emphasis is on the importance and need for a regular water supply to communities. Then an urban setting - Livingstone is isolated and studied as one entity among many, drawing on the common source of water - the Zambezi river. The share of water the town gets, how the amount it gets is determined and finally the pattern of distribution within the urban setting are examined.

1.5 ZAMBIA : AN OVERVIEW

Acute water shortages often beset various sectors of the Zambian society inclusive of both rural and urban areas so much that living in the city is no guarantee that you will find water flowing from a tap. Presently, only 46 per cent of the Zambian population has access to clean drinking water and another 37 per cent of the national population has acceptable sanitation. Available data indicates that 70 per cent of the total urban population of 1.9 million of 33.5 per cent of the total population as per 1980 census has access to clean water. On the other hand, 31.5 per cent of the rural population has access to clean drinking water (Zambia Daily Mail, 22 September, 1988). The United Nations General Assembly formally launched the International Drinking water and sanitation decade in November 1980, ostensibly to focus world attention and action on the needs of more than two million people in the developing countries for safe accessible drinking water and adequate sanitation. Zambia accepted the decade objectives and launched the programme in 1981. However, despite having endorsed the UN water and sanitation decade which is due to end in less than two years from now, the water supply problem in Zambia is even more desperate than in 1981 when it was launched.

The water supply problem in the country is so critical that even life monitoring institutions which cannot and should not afford water shortages have had their services crippled. For instance, Kitwe youths at one time resorted to selling water with a 2.5 litre can fetching K1.60 while a 5 litre tin was selling at K3 when city taps went dry paralysing domestic and commercial activities (Zambia Daily Mail, 22 September 1988). Zambia's perennial shortages of the life sustaining substance, water has not been solved over the years and continues to affect both domestic and industrial activity.

1.6 WATER - A HUMAN NEED

Water is a very basic need of human existence which even the informed reader perhaps may not think of as forming the largest amount of his body weight and volume. Of all the substances that are necessary to life as we know it on earth, water is by far the most important, the most familiar and the most wonderful. History is replete with the sagas of armies that fought over water, of monarchs and priests who worshiped it and health workers who have blessed it, of civilizations that dwindled after losing or mismanaging it and of people who died because of it (Leopold, et.al 1968:9). For sure it is virtually impossible for man to survive for more than a few days without water. Infact, man himself is said to be a porous sack of water with only one third of his body by weight composing other compounds. A human being needs more than a thousand metric tons of liquid per year and only five of solids (Donoso, 1975: 1). Human body composition aside, water forms integral parts of nearly everything on earth. As Prusha (1961: 9) put it, "to make one ton of paper admittedly a dry product, not less than 900 cubic metres of water are needed, to produce a ton of iron an even drier product from the natural ores under conventional methods, not less than 300 cubic metres are needed." Industrial growth, agricultural development, recreation, health care not to mention domestic uses all depend on ever increasing extents on the amounts of water available for use in required quantities and qualities. The waters of life is more than a poetic phrase as Leopold, et.al (1968:103) put it. Life actually arose in water to start the long line of evolution and the Bible on the other hand has numerous chapters in the Old Testament demonstrating the critical roles that water supplies were believed to play not only in the creation of the earth and life but also to maintain it. Today just as ever before, we all need water quite often for one purpose or another.

We need water for our industries in all forms - primary, secondary or tertiary. Health and socio-economic statistics from many countries confirm the tragedy caused by inadequate water; loss of personal and national productivity and incomes (Times of Zambia, November 24, 1988). All in all, water availability in required forms and amounts is certainly a question of life and death. It is indeed a fountain of life, indispensable fluid and all purpose substance of subsistence.

1.7 WATER SUPPLY AND DEVELOPMENT

Development in the context of socio-economic well being and growth of society is largely dependent on water available for use. Water plays a very vital role in industrial development as an input in the production processes, in the agricultural industry for the survival of both plants and animal husbandry as well as sanitation from the social welfare point of view. As Leopold, et.al. (1968:144) put it, "water is the life blood of industry, its most essential material. No other substance except air flows in such volumes through the factories of the industrialised world." One popular view as indicated by Field (1974:59) is that water availability explains growth. Accordingly, localities with access to major bodies of water or streams grow to become great cities while communities stranded on dry land languish.

Without an adequate supply of water, learning institutions close down, industries stop producing and even hospitals stop or suspend normal life saving operations. For example, in Livingstone a predominantly textile industry town, most of the factories have had to cut down their production while institutions like the hospitals and boarding schools have been operating rather haphazardly. As White, et.al (1972:5) stated, it is generally believed that in any country an improved water supply brings economic development and that there is a direct effect between economic development and the provision of safe and ample water supply.

1.8 WATER SUPPLY AND PUBLIC HEALTH

Just as water is basic to human existence, it is equally essential for the maintenance of life. Whenever water is erratic epidemics are most likely. This was re-emphasized in the IDWSSD plan of action in 1984. The close association of human health and water supply dates back to the old days even before Christ. "Hippocrates, usually considered as the father of medicine observed that water contributes much to health. He further identified the role of water and its qualities in the propagation of diseases. This was already in the 4th Century before Christ." (GRZ, 1984).

Even today, community policy is usually guided by the principle that provision of safe water is basic to all material and child health work as is the case with primary health care. A provision of clean water for domestic use can greatly improve health and diminish risks of water-borne diseases. Many a time in Zambia, a number of water-borne related diseases have resulted from erratic water supplies. A number of institutions in Zambia have been closed for fear of epidemics due to water shortages. Of late, the Livingstone Trade Training Institute was reported to be on the blink of closing after a serious water shortage had hit the institution for sometime (Zambia Daily Mail, 3 October, 1988). A few cases of water-borne diseases have occurred as related to water crises in different parts of the country. Recently a typhoid outbreak at Nchelenge Secondary School in Nchelenge District was caused by a water shortage problem at the school (Zambia Daily Mail, April 14, 1989).

It is therefore a general feeling that an increased availability of pure water in ample quantities in domestic premises can make it possible for a new conception of personal and environmental hygiene especially as regards sanitation (William, 1976:3).

1.9 SOURCES OF WATER

Supplies of water may be obtained by drawing directly upon rivers, lakes or springs, by impounding upland surface water in artificially constructed reservoirs or by sinking wells(Thresh,1958:4). As Archer (1971:96) stated, "water supply may be delivered from either surface or underground sources. Portable water exists in the ground in some form and quantity at some depth nearly everywhere on earth. Zambia uses both surface and underground water sources.

1.9.1 SURFACE WATER

Surface water in Zambia has been the major source for most of the urban settlements ever since they were established. According to Archer (1971:96) several other settlements which originally depended on sub-surface sources have reached the limit of ground water exploitation and must now supplement or replace these by surface supplies.

Of the five major rivers of Zambia, the Kafue river system is the most extensively used in that its course happens to pass in town areas of the Copperbelt, Central and Lusaka Provinces. Most of the towns draw water from this river. Kitwe's domestic water supply the largest in the country with a total installation capacity of 104.5 million litres of treated water a day, is taken entirely from the Kafue river. The rest of the Copperbelt towns also obtain their water supply input from the Kafue river and its tributaries. Along its course, it also supplies Namwala, Kafue town and Lusaka over a distance of about 59 kilometres (Archer, 1971:96). Similarly the Zambezi river supplies water to Livingstone and several other small towns in Western Province. The Luangwa, Luapula^{and} Chambeshi^{River}, Lake Kariba and other lakes supply the surrounding town areas. Surface water also supplies water to many areas of the rural settlements.

1.9.2 GROUND WATER

The extent and availability of ground water depends on two main factors; the bedrock geology and the depth of weathering. The best single geological system for groundwater in Zambia is the Katanga - a late pre-cambrian system the age of which is from 590-630 million years. This system contains the best aquifers of the territory, notably the dolomites and limestones of lower Katanga age (GRZ, 1961:1). The greatest water potential in the country is tuitously located along the line of rail and has been exploited by several urban centres. Actually the greatest development in Zambia now lies along the line of railway in a stretch from Livingstone in the South to Chililabombwe on the Copperbelt. By and large the greatest part of this development of towns has been possible only by the exploitation of groundwater. For instance, until 1970 the entire water supply of Lusaka was derived from a number of boreholes in a brecciated zone in dolomite south west of the city with a maximum extraction rate of 54.5 million litres per day (Archer, 1971:96).

On most of the Copperbelt towns the water supply from surface sources is usually augmented by ground water pumped from the mines. In the areas off the line of rail, a number of townships and government out stations derive their water supply from boreholes as the case is in Kasama, Mpika, Katete, Chipata and many more rural areas (Archer, 1971:96). However, the basalt of the Livingstone area are poor aquifers except in vesicular zones at the top and base of the lava flows, and Luapula porphyry similarly has very low groundwater potential (GRZ, 1961:1).

1.10 WATER LAW AND LEGISLATION

In Zambia as in most countries, water supply and sanitation matters are dealt with by a number of statutes. The laws which have bearing on the subject include: the Public Health Act (Chapt. 535), the Local Administration Act of 1980 and the Water Act (Chapt. 312) (GRZ,1984). A Water Board was set up whose main purpose is to enforce the Water Act which govern and regulate the utilization of water for various purposes in the country (Mvunga, 1975:129). In the Water Act, water includes both public and private water.

-----Public water is defined as, "all water flowing or found in or above the bed of a public stream, whether visible or not, including lakes, swamps, or marshes forming the source of such a stream and water therein in the country is public except for rivers forming international frontiers." But this is enhanced by the definition of private water.-----"Water is said to be private if in a swamp or spring, situated and the boundary of which are wholly within land owned by any one landowner and includes water brought to the surface of such aforesaid land." However, inspite of this notion of private water, water is only private in a very restricted sense in that ownership of all water in the Republic is vested in the President, hence the Statutory Regulation (Mvunga, 1975:131).

In the Water Act, three uses to which water can be put are categorized as primary, secondary and tertiary. Primary use means, "the use of water for domestic purposes and the support of animal life." Secondary use means, "the use of water for irrigation of land and pisciculture". Whereas tertiary use implies, "the use of water for mechanical and industrial purposes or for the generation of power." (Mvunga,1975:131).

As regards the use of water for secondary and tertiary uses, any person may submit an application to the Water Board for acquisition of special rights in the use of water. The Water Board may grant in its discretion such water rights in respect of any undertaking of public importance or general utility, the carrying out of which would in its opinion result in public advantage out-weighing the disadvantages (Mvunga, 1975:132). But as regards primary use of water, any person shall have the right to use water which is found in its natural channel at such places to which access may be lawfully had. As for urban use of water, it is worth merely indicating that the special provisions are intended for local authorities which require appropriation of water to meet the needs of the urban population under their respective jurisdictions (Mvunga, 1975:133).

As might be realized from the Water Act, the Act was restricted to surface water only, yet even ground water should be subject to control in the interest of proper use of water. Therefore, in 1981 a new draft of the Water Act was submitted to the Cabinet which included among others, ground water and pollution, and affluent control which were missing in the original Water Act (GRZ, 1984).

However, according to the Local Administration Act of 1980, the District Councils are responsible for water supply and sanitation. Notwithstanding the existence of enforcement provisions in the Water Act, the Water Board believes that as the situation stands at the moment, compliance with provisions of the Act is extremely at the discretion of water users. The Water

Board has no officials to go around Zambia and see to it that those who need to obtain water rights have done so and that the conditions attached to these rights are observed (MMunga 1975:136). All in all, as stated in the Plan of Action for water supply and sanitation of 1984, the present legislation in the field of water supply is grossly inadequate and the power of enforcement of existing Acts is also too weak.

In as far as the solving of the country's water problems, plans for a Water Corporation have been underway but rather overdue. The formation of a Water Corporation was given as a Presidential directive to ZIMCO in 1984. Surprisingly, nearly five years after, the Corporation is not yet born (Times of Zambia, September 23, 1988). It was believed such a Company would avert the situation which had reached a crisis point. However, Lusaka Urban District Council has such a water company already in operation.

1.11 WATER QUALITY PARAMETERS

The term water quality embraces the combined physical chemical and biological characteristics of water. Just as sources of supply vary, the waters obtained may differ depending on the sources upon which they are drawn from. As Thresh (1958:4) explains, what determines the water quality are the substances from the environment and the history of the source area. Pure water does not exist in nature. Rain water collects impurities while passing through the air. Streams and rivers collect impurities from the earth and through the discharge of sewage and industrial effluents and these are carried to ponds, lakes and reservoirs. Infact all surface water must be regarded as potentially polluted at all times from any of the possible sources of supply.

The qualities of water in streams and rivers do vary from time to time in the year due to changes in flow levels. For instance, the volume of flow in the Zambezi varies considerably depending on the time of the year, and so do the raw water qualities. The raw water has corresponding seasonal variations from relatively high turbidity in January to a much clearer water from August to November (A.S.C.O., 1987). This difference in turbidity is brought about by the changes in rates of flow. In January when floods are common, the rate of flow is high leading to an increase in suspended solids and silt particles in the water. In August to November the rates of flow are relatively low and so are the suspended solids.

Different water uses may require slightly different water quality specifications. However, the requirements for domestic water use suits most of the other uses. Below are the water quality parameters as specified by the World Health Organization for water supply authorities.

Unit of measure is milligrams/litre except where specified.

ELEMENT	SPECIFICATION	ELEMENT	SPECIFICATION
1. Arsenic	0.05	13. Colour	15 Degree Harsen
2. Chromium	0.05	14. Copper	1.0
3. Cadmium	0.05	15. Hardness (CaCO ₃)	500
4. Cyanide	0.10	16. Iron	0.3
5. Lead	0.05	17. Manganese	0.1
6. Fluoride	1.50	18. pH	6.5-8.5
7. Nitrate	10.00	19. Sodium	200
8. Nitrate	Be Absent	20. Solids (Total)	1 000
9. Mercury	0.001	21. Sulphate	400
10. Selenium	0.01	22. Chlorine	250
11. Aldrin/ Dieldrin	0.03	23. Turbidity	5.0(NTU)
12. Aluminium	0.20	24. Zinc	5.0

From ASCO (1985)

The concentration of iron and manganese require special consideration to be given in the treatment plant. The U.S. Public Health Service drinking water standards set the limits for iron in drinking water at 0.3 mg/l and the manganese limit at 0.0 mg/l. Both of these metals when present in drinking water can cause staining of clothes and plumbing and through deposition decrease the carrying capacity of water mains (Thresh, 1958:544).

Although the provision of safe water is not the direct responsibility of the Ministry of Health, the examination of water supplies throughout Zambia is carried out by Health Inspectors and Health Assistants. It is also their responsibility to report any unsatisfactory water supplies and ensure that these are corrected (TNDP, 1979:364). In Zambia most of the consumer products are standardized. Unfortunately the water qualities have not been standardized as yet. As a result, most of the water works use the WHO standards. For instance, there has been a publication in the U.S.A. since 1905 dealing with both chemical and bacteriological examination of drinking waters, industrial waters, swimming - bath water and sewerage (Thresh, 1958:547).

CHAPTER TWOTHE STUDY AREA2.1 HISTORICAL BACKGROUND

This study was carried out in the Livingstone District Council area. The first settlement of Livingstone was at the old drift. It was later established at its present site in 1905 upon the completion of the Victoria Falls Bridge and the railway line across the Zambezi river. Livingstone became the capital of North Western Rhodesia and later Northern Rhodesia in 1911 until 1935 when the capital was transferred to Lusaka. The town became the first Municipality in 1928 but the Municipal status was changed to the present Livingstone District Council in 1981 following the Decentralization Act of 1980.

2.2 LOCATION AND RELIEF

Livingstone is situated in the Southern Province of Zambia, some ten kilometres from the Victoria Falls. It is as indicated in Fig. 1 located at Latitude 17° 49'S and longitude 25° 49'E. The town is at an elevation of about 978m A.S.L. though the relief varies up to 883.9m within the town area. At this altitude, it is relatively lower than most of the major towns of Zambia.

2.3 CLIMATE

The climate of Livingstone like most of the country is strongly seasonal. It basically comprises three seasons: the cool dry, hot dry and wet season. The wet season is from November to March, the hot dry season is from about August to October and the cool dry season is from mid April to August. Rainfall and temperature seasonal variations are shown in Fig. 2.

The annual rainfall in Livingstone averages about 727mm of which 93 per cent falls in the period November to March. About 70 per cent of this rainfall occurs in the three wettest months of December, January and February as shown in Fig. 2.

FIG 1: RELATIVE LOCATION OF LIVINGSTONE

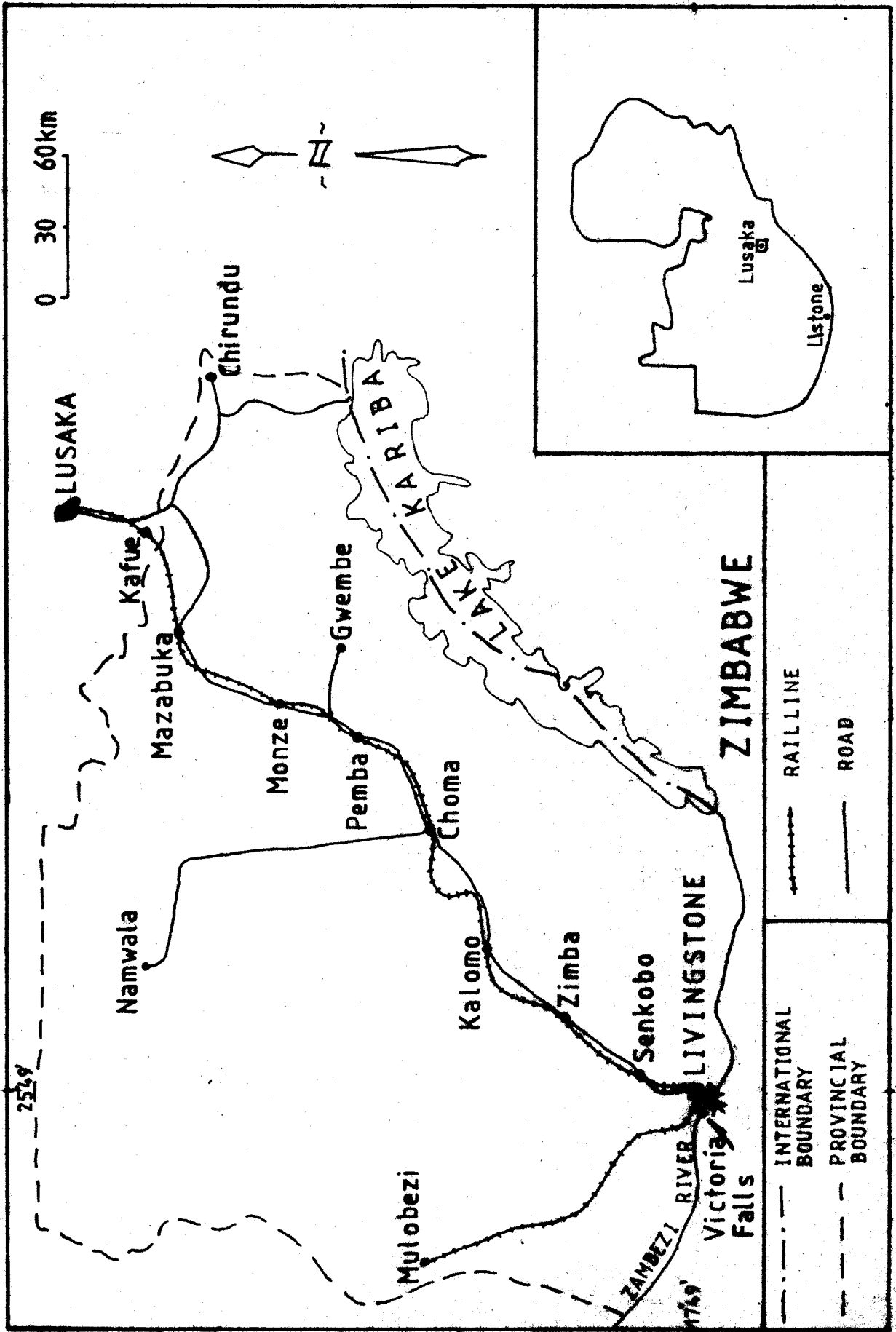
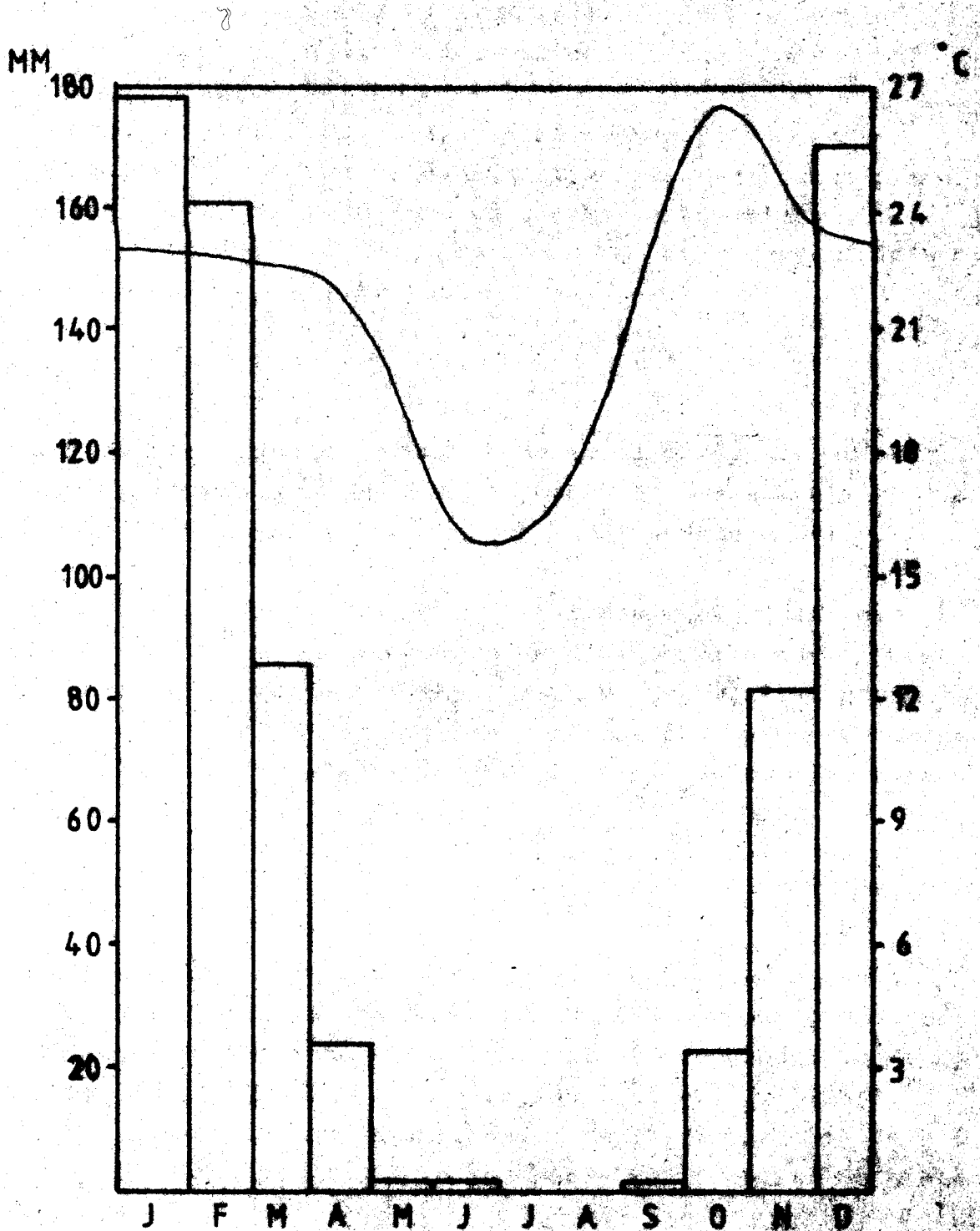


FIG2: TEMPERATURE AND RAINFALL OF LIVINGSTONE



Data From Climatological Summaries For Zambia
(June, 1971).

The mean monthly temperatures range from between 15.9°C in June and 26.6°C in October. However, temperatures in the period December to April are quite steady. The mean maximum is 34.5°C in October while the absolute maximum is 39.4°C in November. On the other hand, the mean minimum is 6.5°C in July while the absolute minimum of 1.6°C is recorded in the same month.

As compared to annual rainfall, annual evaporation is more than threefold at 2295mm. The highest evaporation takes place in the hot dry months of August to October; 205-305mm while the lowest recorded is during the months of December and January ranging from 162mm to 130mm respectively.

2.4 DRAINAGE

Livingstone town lies on ground which is slightly higher with the rivers, Maramba and Nansanzu on one side and a small stream which runs at the foot of the airport hill on the other.

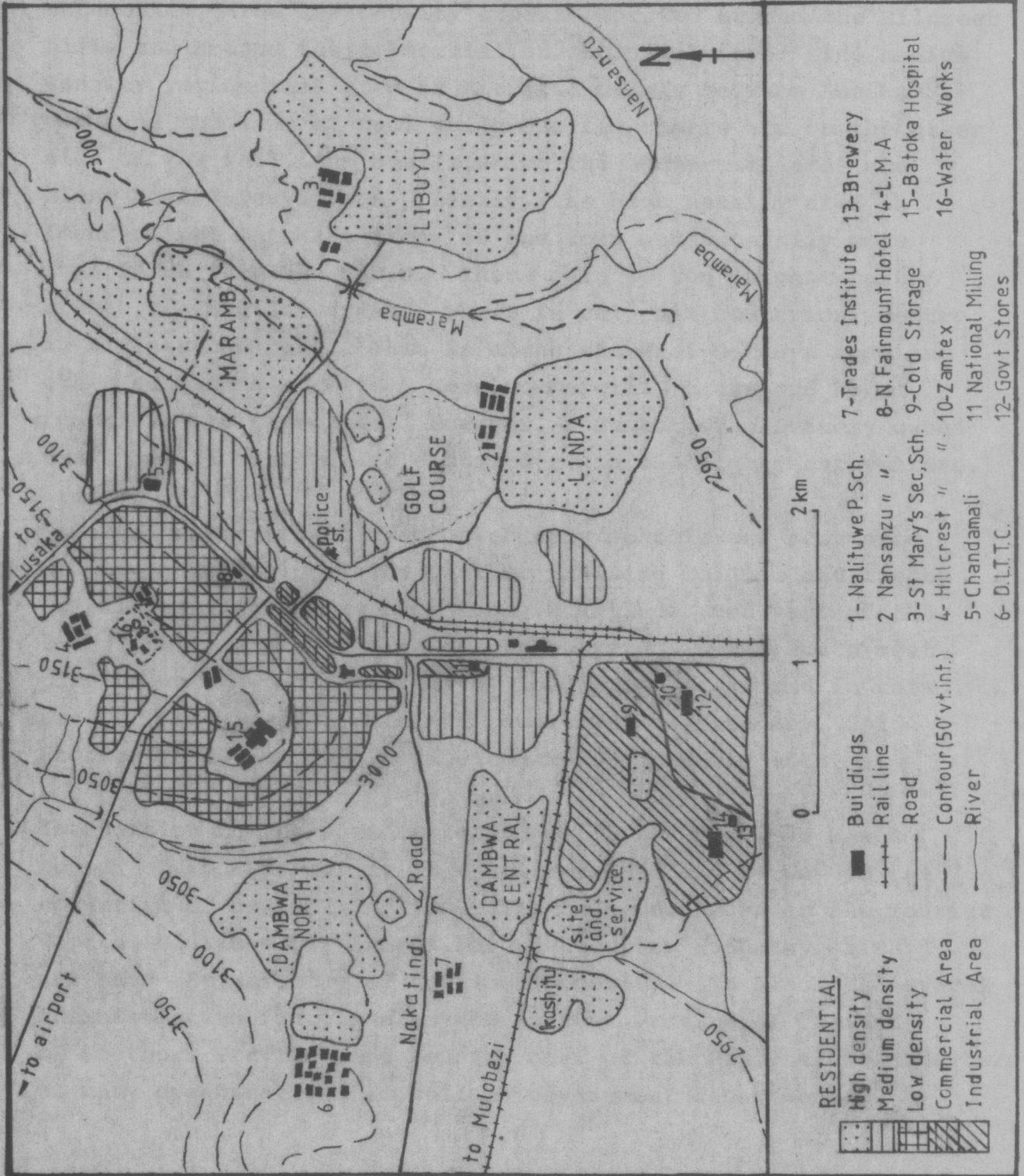
The Maramba runs at the bottom of a terraced gravel valley on the East of the town and before discharging its water into the Zambezi, it is joined by the Nansanzu river. The stream to the west of the town is seasonal and has only a short course while to the south of the town several small streams and canals drain into the Zambezi. (See Fig. 3).

2.5 POPULATION

The population of Livingstone for 1989 as estimated in this study was 98 990. This was based on the 1980 census projected to 1989 at an annual rate of 3.5% by use of the geometric method. This is given as $P_{t+1} = P(1+r)$ (Spiegelman, 1955:238). The population of the town increased from 37 802 in 1963 to 49 063 in 1969 and to 71 987 in the year 1980 (Central Statistical Office, 1981).

In addition to this, the town receives thousands of tourists every year from different parts of the world and locally.

FIG 3: LANDUSE IN LIVINGSTONE AND THE STUDY SAMPLE UNITS



2.6 LAND USE IN LIVINGSTONE

The town of Livingstone can be divided into three major land use areas. These are: the industrial area, commercial area and residential area as shown in Fig. 3.

As indicated in the methodology, residential areas are in three categories. The low density area is located around the Hilcrest hills and around the commercial and hospital area. The medium density residential area is situated mainly between Lusaka road and the line of rail while the few others are on the other side of the rail line over looking the commercial area and along Musi-O-Tunya road. Lastly, the high density area is found on the outskirt areas of the town and generally more than 21 km from the C.B.D. These make up the largest part of the residential areas. There is only one commercial centre in Livingstone town. This is along the Musi-O-Tunya road and other adjoining streets. Here commercial, trade and hotel functions are performed. However, a number of privately owned small retail outlets are distributed in all high density areas.

Several primary schools and secondary schools are scattered around in townships. The Teacher Training College and Trades Training Institute are both along Nakatindi road west of the town. The industrial area is concentrated in the south most part of the town. A variety of industries are found in this area. These include: the numerous textiles, brewery, Cold Storage Board, and the Livingstone Motor Assembly (LMA).

In addition to the various land uses of the town, it has a number of functions. It is a railway head and gateway to the countries of Southern Africa. The town now known as the Tourist Capital of Zambia is famous for the tourism industry which was once the mainstay of the local economy. It also has several administrative functions as the current Provincial Capital of Southern Province and housing most of the Regional Headquarters of many organizations as well as government departments.

CHAPTER THREEMETHODOLOGY3.1 SAMPLING TECHNIQUES AND SAMPLE SIZE

This study looked at four water user categories namely; commercial, industrial, institutional and domestic uses. For each of the four categories, the most appropriate sampling technique was used.

Domestic water use was studied according to residential areas. These were grouped into low density, medium density and high density areas. This categorization was based on the cost and size of houses found in the different residential areas as specified by Knauder (1982:8). A high density area was one which had low cost houses with plot sizes of around 12 x 27m on average. A medium density area was taken to be one of medium cost houses on plot sizes of about 22 x 22m while a low density area was any residential area with high cost houses which referred to any house above the price range and size of the medium and low cost houses defined above. To account for the three variables of residential category, distance from reservoirs and relief, the three residential categories were further sub-divided with respect to distance and relief. All residential areas above 914m A.S.L. were considered to be highlying while those below or equal to 914m A.S.L. were considered to be lowlying. In terms of distance, all residential areas within 2Km radius from the water works were considered to be nearby. Those more than 2Km away from the water works were considered to be far off areas. This resulted into nine mutually exclusive residential strata from which households were picked by use of systematic random sampling. A list of house numbers was obtained from the council housing offices. This was divided into nine parts according to the strata made. That is, each strata had its own sampling list. From each strata households were picked by systematic sampling after the first household was picked using a table of random numbers. A total of 40 households were picked as follows:

Low density areas	-	12
Medium density areas	-	12
High density areas	-	16

The selection of industries was not categorised by either distance or relief because these are located in one area. The selection of industries for the study was purely purposive - judgement sampling. This was done because the industries differ in nature and water use capacities. To start with, four categories were identified as manufacturing, assembling, processing and textiles. From each of these one firm was picked for the study. These were the Brewery, Livingstone Motor Assembly (LMA), National Milling Company and Zamtex. These are shown on Fig. 3.

Commercial enterprises too were selected purposively vis-a-vis water capacity use potential. These included Government Stores, New Fairmount Hotel, the Fire Station, Council tarvens and Maramba local market. However, the market and tarvens were selected by use of systematic random sampling having had obtained lists of each category from the housing authorities.

Stratified random sampling was employed in the selection of institutions. Lists of all primary schools, all secondary schools and colleges were obtained. These then were categorised in terms of distance and relief as for residential areas.

However, only two strata were made here - low-lying distant areas and highlying nearby areas. As for the two hospitals, Batoka was selected by tossing a coin. The following institutions were finally selected in each category and are shown on Fig.3.

(a) Primary Schools

Nalituwe
Nansanzu

(b) Secondary Schools

St. Mary's Girls
Hilcrest

(c) Colleges

David Livingstone
Teachers' Training College
(DLTTC)

(d) Hospitals

Batoka

Chandamali Hostels

All in all, a total of 40 households, 7 institutions 4 industries, 5 commercial enterprises, 2 colleges, 2 secondary schools, 2 primary schools and 2 hospitals were selected for the study sample.

3.2 SOURCES OF DATA

A number of data sources and data collection instruments were used. The data sources included a Topographical map sheet and street plan while data collection instruments were interviews, questionnaire and field surveys. What these entailed are explained below.

3.2.1 MAP SOURCES

A topographical map of Livingstone sheet number 1725D4 was used to provide data on the physical features such as drainage of the study area. Relative distances and relief of the study area were also obtained from the topographical map. This information was used in the spatial stratification of the residential areas in the sampling procedure. The other map source used was the Livingstone street plan. The street plan was used for guidance in the field surveys and location of households; industries, institutions and commercial enterprises.

3.2.2 INTERVIEWS SCHEDULES

Interviews were conducted with various officials in the District Council, Government Ministries, Commercial enterprises and in industries. Council officials included the Council Town Planner, the Council Health Inspector and Council Water Engineer. Others from institutions included school heads, principals and the Hospital Superintendent. In industries interviews were held with the Production Managers while senior management personnel in commercial enterprises were interviewed. The specific interview schedules used in the study are given in the appendix at the end of this report.

3.2.3 QUESTIONNAIRE SCHEDULE FOR HOUSEHOLD HEADS

The questionnaire was the second principle data collection instrument. It was designed for domestic water users in residential areas. As indicated in the actual questions in the appendix of this report, the questionnaire was aimed at collecting data about the residents' water needs and uses, water quantities used, trends in water supply, the family size and general domestic water users' opinion on the water supply service of the Council.

3.2.4 FIELD SURVEYS

These were used on a number of occasions:-

- (i) A survey was carried out for a physical cross-checking of map data as regards relative distances, relief variations and selected physical features.
- (ii) A visit to the intake pumping station was taken for an on the spot orientation of the raw water abstraction process.
- (iii) Several visits were made to the water works which included the treatment plants and reservoirs. This was for the acquaintance of the water chemical treatment processing stages. This was very important in that no plan diagram of the water works was made available by the Council authorities.
- (iv) Lastly a survey for monitoring water leakage loss from faulty taps in public open spaces was carried out. In addition to this, a survey of people's consciousness on water loss was carried out by observing the number of people passing by a tap with running water.

3.2.5 COUNCIL COMPUTER PRINT-OUTS

It was realised that most of the respondents were not aware of the amount of water they used. As a result, to get the actual amounts of water consumed, computer print-outs for water bills were consulted. The water quantities obtained from the computer print-outs were used in the analysis of water supply in the study.

3.2.6 METHODS OF DATA ANALYSIS AND PRESENTATION

The data collected was used to test the four hypotheses of the study by use of statistical tests. This was done mainly by use of the chi-square test and contingency tables. The results were illustrated and represented by use of Bar graphs, group bar graphs, line graphs and pie charts.

CHAPTER FOURTHE LIVINGSTONE WATER SUPPLY SITUATION1. THE WATER SOURCE

The source of water supply for Livingstone town is the Zambezi river which runs from the west of the town southwards towards the Victoria Falls. The water is pumped from the east bank of the river about five and half kilometres south of the town. The length of the river from its source to Livingstone is some 1 280 km and at Victoria Falls the river is almost 2km wide. The river is usually flooded in the rainy season while in the dry season the water level is very low but always enough to cater for the city requirements. Recorded mean rates of flow are 721 million litres per minute in 1958 and a minimum in November of about 14 million litres per minute in 1973 (ASCO, 1987). However, no recent estimates have been made of the potential of the Zambezi river as source of supply. The water qualities too vary with variations in qualities flowing and the rate of flow. The water is fairly clear in the dry season and quite turbid in the rainy season.

The Council has so far not used ground water for the supply of the town but a few establishments in the industrial and institutional water use sectors have own boreholes for supplementing the council supply. The best examples are Zamtex and David Livingstone Teachers' Training College (DLTTC).

2. THE INTAKE AND RISING MAINS

There are two points of intake adjacent to each other. The first of these two intake points was completed and started functioning in 1963. It has three pumpsets of 19.87, 20.96 and 8.73 million litres per day (ML/day) of pump design capacity. The second intake point was brought into operation in 1985. It has three pumps with a total of 46.5 ML/day. When all the six pumps are working at full design capacity, the total

abstraction capacity is 96.06 ML/day. The usable and effective capacity of abstraction far much less. There are only two pumps operating at the second intake point with an optimum amount of 31.2 ML/day pumped to the existing rising mains.

From the abstraction point, two 450mm diameter steel mains deliver water to the water treatment plants over a distance of about 5.7 kilometres. The design capacity of the rising mains is 31.2 ML/day equivalent to the capacity of the two operating pumps. This is as expected because the capacity of the rising mains and pumps are interdependent. The reduction in the design capacity of the rising mains is due to increased roughness of the interior surfaces of the pipes. The capacity reduce with age of the rising mains by increases in silt and air through the renewal of valves in the pipes.

4.3 THE TREATMENT PLANT AND LABORATORY FACILITIES

The present treatment works has two plants intergrated into one to some extent as shown in Fig.4. The old treatment plant was built in three stages of sedimentation and flocculation in 1948, clariflocculation and filteration in 1952, and the accelerator and filters in 1961. This plant was designed to have pre-treatment, flocculation, filteration and chlorination of water. The treatment process is as follows:-

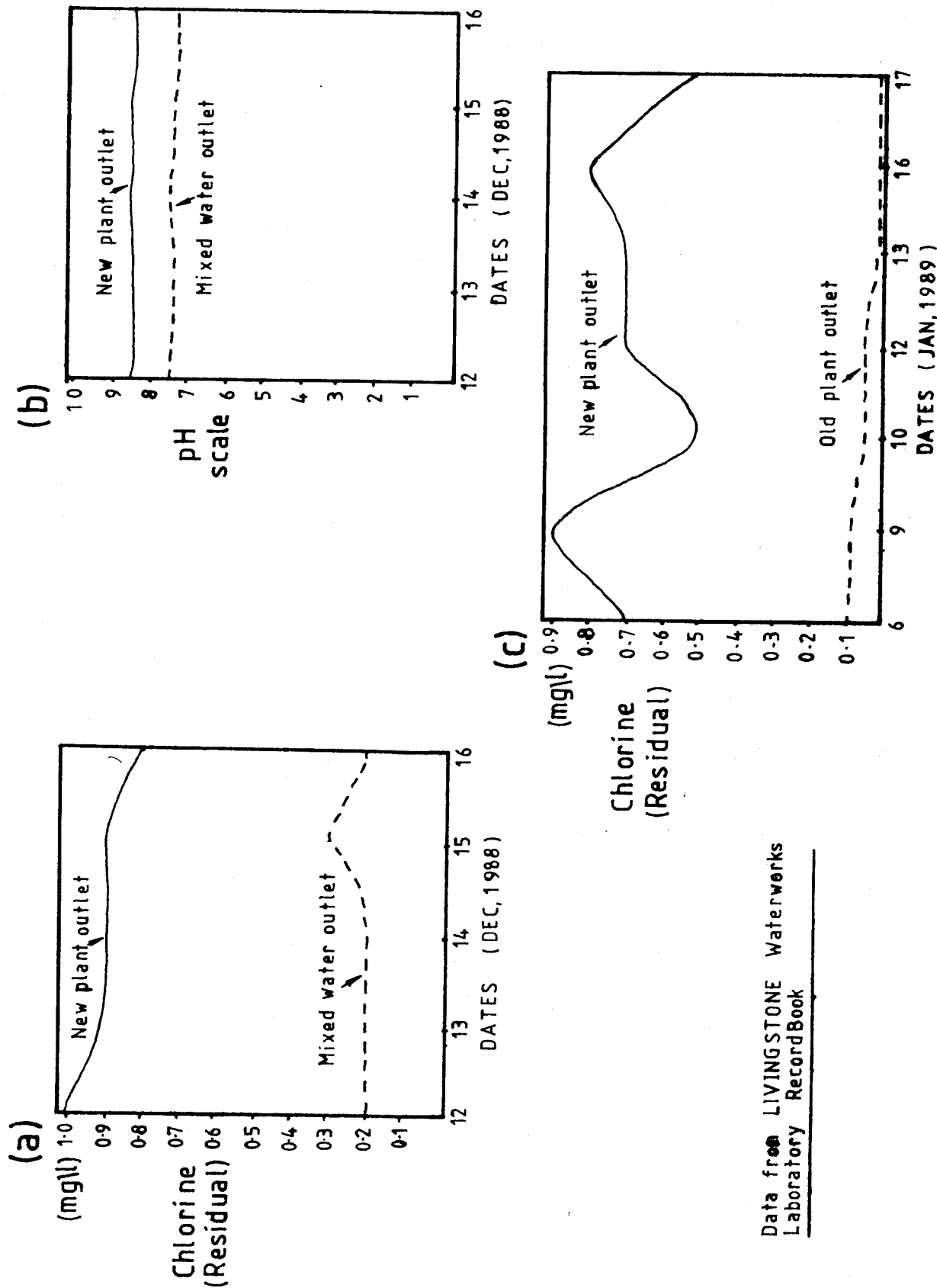
- (a) The raw water from the Zambezi is pre-treated by a dosage of aluminium sulphate. This was designed to be done by an automatic weigh tray with pre-mixing in a flash mixer. This is no longer in use and so the dosage is done manually. Lime is added to soften the water.
- (b) The water is then passed to either a 20m diameter accelerator or a 22.9m diameter flocculator working in parallel as shown in Fig. 4. The total design capacity of the two was 18.18 ML/day.

- (c) From the accelerator and flocculator, the water is passed into gravity sand filters. There are three stages of the filter house with a total design capacity of 98.18 ML/day. However, out of the three stages, only stages II and III are in use with an operational capacity of 13.6 ML/day.
- (d) After filtration, the water is chlorinated and passed into storage within the treatment works. However, it is worth noting that the water in this plant is not treated everyday for no apparent reasons.

An extension to the old plant was completed in June 1988 and started operating in December the same year. This is a modern treatment plant completely automated for all dosage processes. This plant has a treatment capacity of 36.4 ML/day but it is already operating below capacity with one of the 4 filters not working. The treatment process in the new plant is similar to that of the old one except that dosage in this one is automated. Treatment in the new plant is done on a daily basis by two chemists.

The laboratory facilities are installed within the new plant where chemical analysis are carried out to determine the chemical dosage required depending on the raw water quality and to see if the treated water qualities conform with the WHO standards. Unfortunately, the laboratory is lacking most of the required equipment to carry out all the necessary quality tests. For instance, no bacteriological analysis is done while only six chemical tests are made. These are turbidity, PH, colour, ordour, chlorine both residual and free. These are carried out for both the new plant and the old one. There are three categories of water chemically tested. These are, treated water from the new plant, the treated water from the new plant mixed with water from Stage III filter of the old plant and lastly the water from the old plant only. Due to the non-routine treatment of water in the old plant, the three categories of water give different chemical qualities as indicated in Fig.5. (Diagrams a, b and c). This in a way defeats the whole purpose of treatment since the water from the two plants finally mix in the reservoirs. Although the quality of water from the

FIG 5: SELECTED WATER PARAMETER TEST RESULTS



Data from LIVINGSTONE Waterworks
Laboratory Record Book

new treatment plant is good, it deteriorates upon mixing with the water from the old treatment plant where there is no proper treatment at all.

4.4 STORAGE AND DISTRIBUTION

There are seven separate reservoirs within the water works. These are in two categories of three small ones with a total storage of 2.4 ML/day and four big ones with a total of 30 ML/day. In all, the available storage capacity is 32.4 ML/day at a level of approximately 975m A.S.L. Some of the water is pumped to a 1.05 M L high level storage at an elevation of 1 005m A.S.L. (north of the town).

The water distribution system of the town is divided into two distinct areas. These are the high and low level zones. The low level areas are supplied directly from the treatment works reservoirs while the high level areas are supplied from the elevated water tower. The high zone areas include Dambwa North, Hilcrest area and the area around the hospitals. The entire distribution network system was not planned and designed at once for the whole town. This has led to numerous linear pipe networks connected for separate developments in the town. This is expensive in terms of maintenance and cost of installation. Furthermore, the distribution system is difficult to run in that there are no records of all the distribution lines of the town while the marker posts indicating the location of fittings are absent. Underground connections in the distribution pipes have been lost and are only found when water leaks to the surface. The range of acceptable water head pressure by the Department of Water Affairs in a city water distribution system is 15 - 60 metres (ASCO 1987).

However, the water pressure in many parts of the supply system is less than 15 metres. In fact the pressure level in the reservoirs at the treatment plant is only about 14 - 18 metres. The low pressure and linear nature of the distribution network brings about water supply shortages in some parts of the town (ASCO, 1987).

4.5 WATER WORKS MANAGEMENT

The management of the water works can be divided into three basic categories namely, administrative, distribution sector and the mechanical sectors. The water works falls under the office of the Development Secretary. The Development Secretary is supposed to be followed by the Water Works Superintendent and his vice who run the day to day operations of the entire water works. On the distribution sector there is supposed to be a water works supervisor with an assistant who should be in charge of the chemists, plumbers and the rest of the general workers. On the Mechanical Section, there is a Mechanical Superintendent who takes care of all the mechanical problems.

The staff status at the time of the survey was that over 50 per cent were not qualified for the water works operations while most of the posts stated above were vacant. For instance the Acting Development Secretary is a Council Architect who is also acting as the Town Planner. He is the same person in charge of all the operations of the water works administratively. The day to day actual operations and supervision is done by the Mechanical Superintendent.

CHAPTER FIVEDATA PRESENTATION AND DISCUSSION OF FINDINGS5.1 MAJOR WATER USES IN LIVINGSTONE

The major water uses in Livingstone include: domestic, institutional, industrial and commercial. The distribution of water to each of these four categories as estimated in this study are as given in Fig. 6.

5.2 DOMESTIC WATER USE

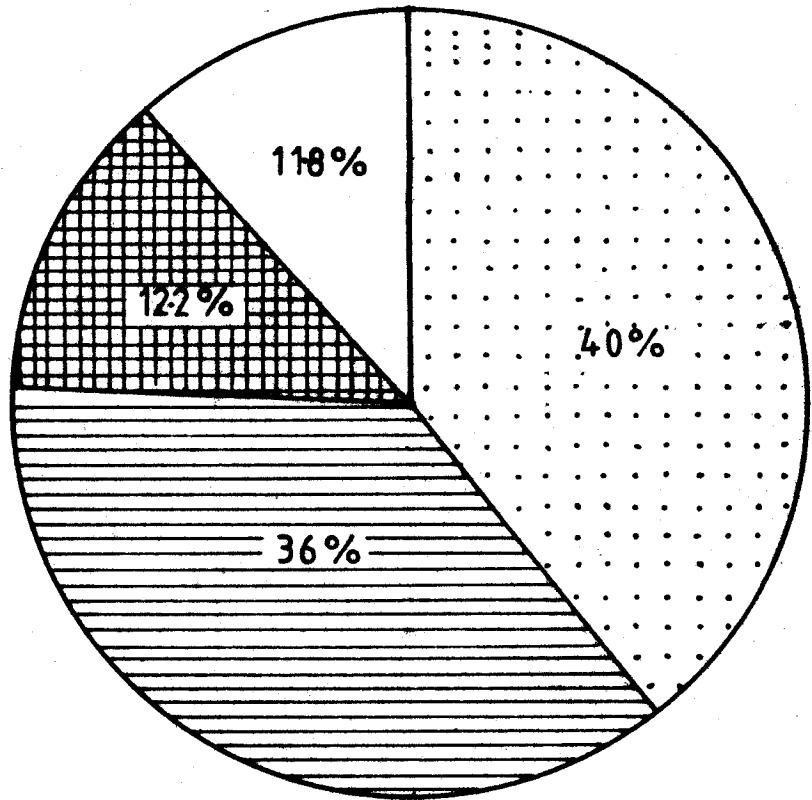
Domestic water consumption in Livingstone as estimated in this study amounts to 8,892,000 litres per day. It was found that in residential areas, population, family size, water distribution and water consumption per head per day vary from one area to another as shown in Table 1 below.

TABLE 1 RESIDENTIAL VARIATIONS

PARAMETER	RESIDENTIAL AREAS		
	High Density	Medium Density	Low Density
Population	40.5%	37.5%	22%
Family Size	8	10	6
Water Distribution	17.4%	34.7%	49.9%
Water Consumption per head/day	118.9 Litres	258 litres	599 litres

The low consumption per head per day in the high density area is a result of the few number of taps available in these areas while the number of people in these areas is the largest. The same factors apply to the medium density in relative sense. In low density areas, there are more

FIG 6: DISTRIBUTION OF WATER AMONG DIFFERENT USER CATEGORIES

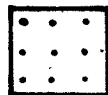


Percentages are based on the total of 23 million litres per day

KEY



Industrial use



Domestic use



Institutional use



Commercial use

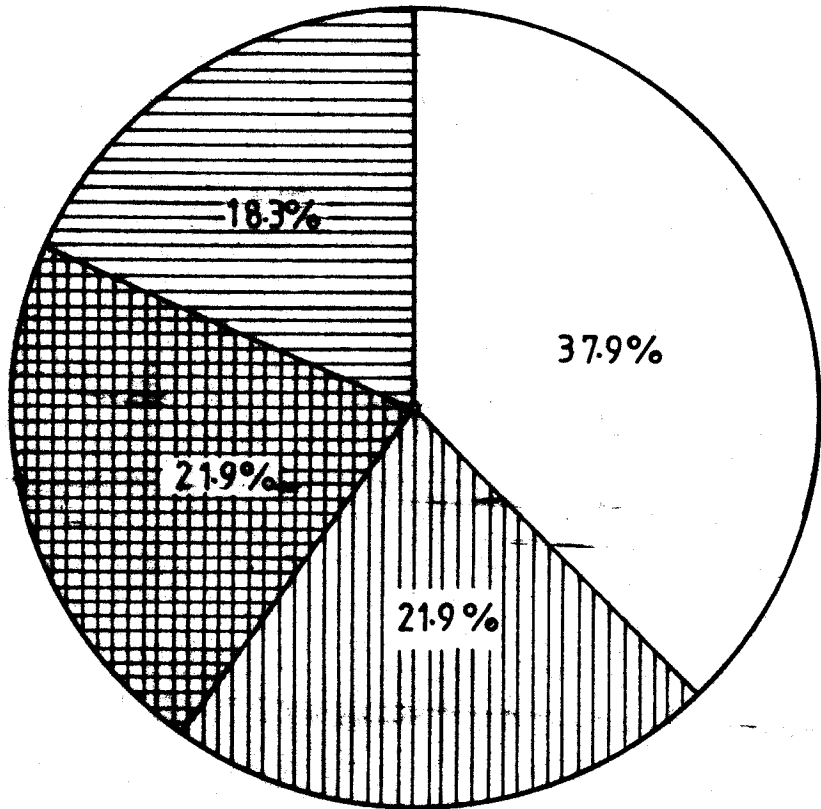
than one tap per household leading to high amount of water supplied. The number of people in these areas too is small, leading to a high water consumption per head per day. In all, one may conclude that there is an immense relationship between residential area density and water amounts supplied. The absolute number of people in households range from 2 to 15 with an average of 7.2 people per household. Averages for each residential area are given in Table 1. It was found that most of the water in residential areas is used in gardening. The other uses include primary domestic uses of cooking, bathing and washing. Domestic animal consumption was the least because most of the people do not keep any domestic animals apart from dogs, cats and chickens whose water consumption is quite minimal.

In general, the water supply to domestic users was irregular so much that only 52.6% of the households interviewed had water supplied throughout the day. In all, about 67% of the households were not getting enough water to meet their needs.

5.1.2

INSTITUTIONAL WATER USE

Institutional water use includes primary schools, secondary schools, colleges and hospitals' water consumption. The proportions of water used by each of the above categories of institutions are illustrated in Fig. 7. In secondary schools and colleges, water is used for day to day primary domestic uses. The bulk of the water in secondary schools and colleges is used in production unit gardening. Except for bathing and washing, the primary domestic uses of sanitation, drinking and general cleaning, are found in primary schools. Gardening is the major water use in institutions as 62.5% of the institutions studied use most of their water for gardening in production units. In hospitals, water is important for use by patients for sanitational purposes, general cleaning, washing, cooking and medicine dispensation.

FIG 7: WATER DISTRIBUTION IN INSTITUTIONS

Percentages are based on the total institutional water use of 828000 litres per day

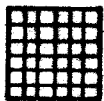
KEY



Secondary schools



Hospitals (2)



Colleges (2)



Primary schools

Water supply to institutions in Livingstone has been very erratic for sometime. This had created a lot of problems in the operations of the institutions. Many a time pupils and students have protested over erratic water supply to their institutions. This is counter productive to the institutions. For example, during one shut-down in 1988, an estimated 18 000 pupils from 19 primary schools were sent home for fear of an epidemic (Times of Zambia, 13 November 1988). As for hospitals, the misery associated with water shortages need not be over emphasized. Livingstone and Batoka hospitals have on several occasions abandoned laboratory tests and cancel some scheduled operations leaving patients at the mercy of various diseases.

Virtually all institutions are affected by sporadic water shortages every year especially in the hot dry season when the demand for water is highest.

5.1.3 INDUSTRIAL WATER USE

The share of industrial water use in Livingstone was estimated to be 27 598 liters/day. Water in industries is used as an input in some industries such as the Brewery. Water in brewing forms the largest per centage of ^{the} final product. Water is also used in processing industries such as the National Milling Company where it is used for moisturing ^{zi} the grain for breakfast meal milling. As for the Textile Industry, water is used for washing up in the numerous processes involved. Without water, the industries have to suspend operations. In addition to the uses of water in industries stated above, water is also used for several primary domestic uses such as general cleaning and sanitation. The supply of water to the industries have been very erratic and operations on several occasions in most industries have been brought to a halt quite often.

To alleviate the sporadic water supply problems, a number of industries have sunk boreholes to supplement the council supply. For example, Zamtex was getting most of the water

it used from own boreholes while Livingstone Motor Assembly (LMA) and the Brewery were in the process of sinking boreholes at their premises to augment the erratic council supply.

5.1.4 COMMERCIAL WATER USES

Commercial water use amounts to 2,806,000 litres per day. In commercial establishments which are mainly service industries, water is needed for the basic primary uses of sanitation, drinking and general cleaning especially in shops. In hotels and other similar establishments, water is used for cooking and other kitchen uses, washing, bathing and in swimming pools, flower beds, lawns and sanitational uses in room service. Without a regular water supply hotel services and related operations are highly handicapped. The Fire Brigade Station one of the service establishment uses a large proportion of water used in the commercial sector of the council.

5.2 THE WATER SUPPLY SITUATION IN GENERAL

For all the water uses identified in this study, the demand levels vary considerably throughout the year. This variation in demand appears to be closely related to the effects of the rainy season with the minimum demand levels being between January and March when it is assumed irrigation of gardens - the major water use in institutions and residential areas is minimal. The water supply problem in Livingstone has been so adverse that development of new industries and operation of existing ones both commercial and industrial has been badly affected. Erratic supply has on several occasions led to complete disruption of industrial and commercial activity.

5.3 METERING OF SUPPLY

Of the four categories of water uses identified, industrial, commercial and institutional uses had metered water supply while in residential areas, high density areas in some parts had no meters. The unmetered residential areas were Maramba

and Libuyu. The water charges used by the council metered users are as follows:-

- (a) High density areas - pay a minimum charge of K10.00 for 12 000 litres with an excess charge of 40n for every 1 000 litres.
- (b) Medium density and low density areas - pay a minimum charge of K17.00 per 18 000 litres with an excess charge of 40n per 1 000 litres.
- (c) For commercial, industrial and institutional users, a minimum charge of K35.00 for 12 000 litres is charged with an excess charge of 60n per 1 000 litres.

Table 2 shows the findings of this study as regards metering of water charges billed from the meter readings.

TABLE 2: METERING AND WATER CHARGES

User Category	Faulty Meters	Constant Charges
Residential	27.5%	17.2%
Non Residential	0%	100%

It was established that of all the households with metered supplies 27.5 per cent had faulty meters and so were paying a fixed minimum charge. On the other hand, all non residential water users's meters were working, an indication that the council attaches more importance to non domestic water users in terms of revenue collection. One other aspect as established from Table 5 was on the recording of water readings. True readings were often disregarded for billing purposes. As revealed from computer print-outs, about 100% of the non-domestic consumers were paying a constant charge for the months of June, July, August and September in 1988. In residential areas, 17.2% of households were paying a constant charge for the same period of time. The users whose water supply

is not metered and those with faulty meters have no financial incentive to use water economically and so do not prevent wastage. All in all, because of the lack of meters in some users' supplies and defective existing meters, water is not charged for on a strictly quantity - used - basis.

4 LEAKAGES IN THE SUPPLY NETWORK

Large amounts of water are wasted through leakages in the water supply system. This is mainly due to the old age of pipes and their small size while there is no systematic method of monitoring leakages. The public are required to report to the water works authorities of any leakages while workers are sometimes deployed to check out for leakages.

In this study, an attempt to ascertain the magnitude of leakage loss on public taps was made. A total of 20 public taps were picked randomly. Of these, 60% were found to be faulty and so could not be closed off completely. Using a 5 litre container water leaking from each tap was filled in and the time to fill the container was noted. This was used to estimate how much water each tap would lose in a day. These were added to find the total leakage loss from the 12 taps. The leakage loss from the 12 taps amounted to 56 926 litres of water in a day with the rate of flow ranging from 1440 to 14400 litres per day. This was enough to supply 26 households of an average family of 8 persons at 277 litres per head/day for one day. In another survey carried out to test people's consciousness of water loss through public tap leakages, 9% of the 132 people who passed by the tap which was wide open closed it. The rest just by-passed the tap with water even splashing to their feet. This was observed for one hour at a centrally placed tap.

5 WATER USER SATISFACTION

The extent to which the water users in the town were satisfied with the amounts of water supplied to them was the first problem that was studied.

To shed more light on this problem, the following hypothesis was tested:-

"All water user categories are not satisfied with the amount of water supplied to them."

Various categories of water users were asked whether they needed extra water or not. Their responses were as presented in Table 3.

TABLE 3: WATER USER CATEGORIES AND EXTRA WATER NEED

USER CATEGORY	NEED FOR EXTRA WATER		
	YES	NO	(TOTAL)
Institutional	(4) 66.7%	(2) 33.3%	(6)
Commercial	(5) 83%	(1) 17%	(6)
Industrial	(1) 17%	(5) 83%	(6)
Domestic	(26) 65%	(14) 35%	(40)
(Total)	(36)	(22)	(58)

N.B. Figures in parentheses are the absolute values on which percentages are based and represent individual subjects interviewed in each category.

$$X^2 = 6.015 \quad \alpha = 0.05 \quad Df = 3$$

As shown in Table 3, all water user categories had most of the subjects in need of more water except for industrial use were only 17% of the industries needed more water than they were getting. Others are 66.7%, 83% and 65% for

institutional, commercial and domestic use respectively. The low percentage for industries is explained by the fact that industries need a specified amount of water especially where it is one of the inputs. This is not the case for the other three categories where water is used in a wide range of areas of application. The hypothesis stated above was tested by use of Chi-square based on the absolute values in Table 3. It was concluded that all user categories are not satisfied with the amount of water supplied to them.

To further determine the significance of the conclusion above, the total amounts of water available in the institutions, commercial enterprizes, industries and households were obtained. This was compared to the amounts of water desired by the users in the sample. The results are illustrated in Fig. 8. It was found that all user categories were getting less water than they desired. However, the deficit between the available and desired water varied from one category to another as shown in Fig. 8.

The ratios of the available water to that desired for each user category were as follows:-

Institutional use	-	1: 1.7
Commercial use	-	1: 1.5
Industrial use	-	1: 1.2
Domestic use	-	1:1.7

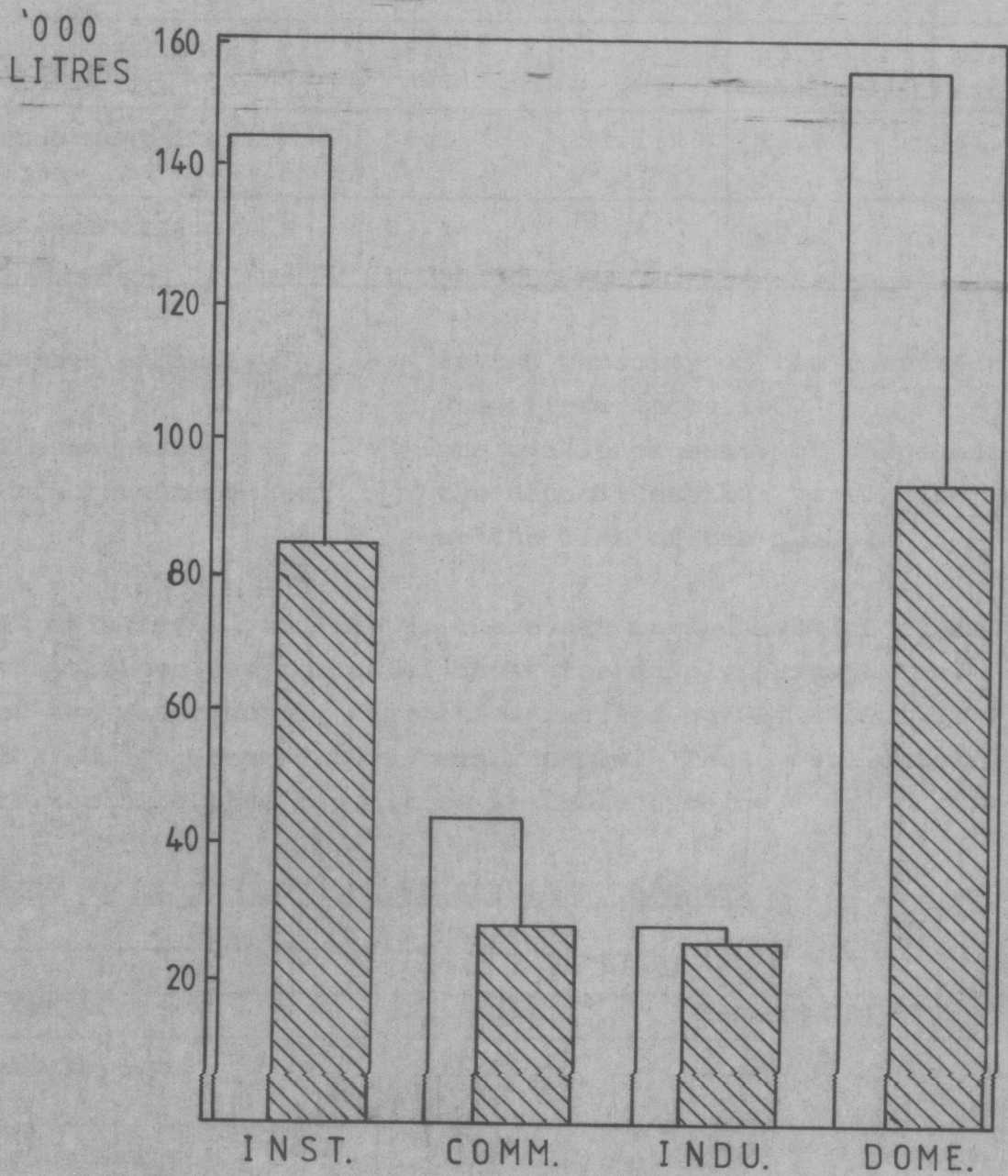
5.6 WATER SUPPLY SYSTEM INADEQUACY

The inadequacy of the water supply system was taken to be the first cause for the dissatisfaction of water users. A second hypothesis which sought to test water adequacy was formulated as below.

"The water supply system capacities are not adequate."

A survey of the water works was carried out to access the capacities of the various components of the water supply system. The supply system components capacities were counter compared in terms of design, present and effective capacities. The findings are presented in Table 4.

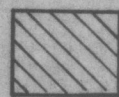
FIG8: A COMPARISON OF AVAILABLE WATER TO THAT DESIRED
BY VARIED USERS PER DAY



KEY



DESIRED



AVAILABLE

TABLE 4: WATER SUPPLY SYSTEM INADEQUACY (1988)

COMPONENT	Capacities in Million litres/day			
	Design	Present	Effective	Shortfall
Intake pumps	96.0	31.2	31.2	64.6
Rising Mains	36.4	31.2	23.4	13.0
Treatment Plant	68.2	50.1	23.4	44.8
Reservoirs	32.4	32.4	30.3	2.1

- Design capacity - is the capacity of the component when first installed.
- Present capacity - the usable capacity of component available.
- Effective capacity - the capacities that were being used at the time of the study.

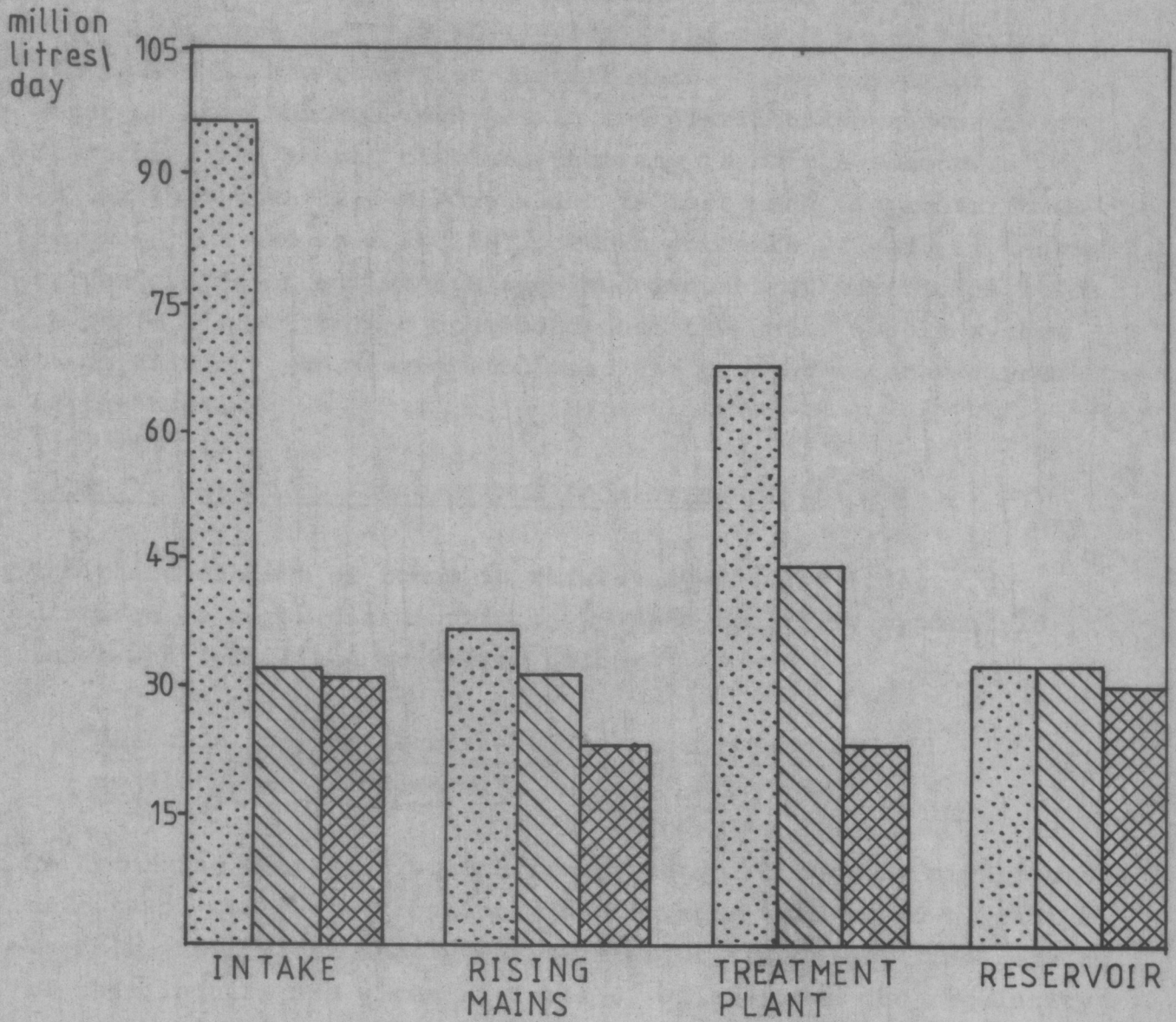
As illustrated in Fig. 9, there are marked imbalances among the various components of the water supply system. An evaluation of the water supply capacities carried out by ASCO (1987) estimated the town's water supply requirements. These were compared to the effective capacities in Table 5 below.

TABLE :5 COMPARISON OF THE REQUIRED CAPACITY TO THE EFFECTIVE CAPACITY

COMPONENT	Capacities in ML/day		
	Effective	Required	Shortfall
Intake pumps	31.2	31.8	0.6
Rising Mains	23.4	32.2	7.8
Treatment Plant	23.4	31.2	7.8
Reservoirs	30.3	32.4	2.1

$$t = -2.424 \quad \alpha = 0.05 \quad df = 3$$

FIG 9: WATER SUPPLY SYSTEM CAPACITY INADEQUACY AND
IMBALANCE



KEY



DESIGN



PRESENT



EFFECTIVE

A total of 31.8 ML/day was needed to supply the town in 1987. It, therefore, follows that the water requirements of the town in 1988 should have been around 31.8 ML/day. From the source 31.2 ML/day of raw water is abstracted and in the process of transmission to the water works, 20% of it (7.8 ML/day) is lost through leakages in the rising mains. That is, only 23.4 ML/day reach the treatment plant. From the 23.4 ML/day treated, 1.2 ML is used as backwash water leaving about 22.2 ML/day ready for distribution. However, a lot of water is lost through leakages in the distribution network. Therefore, the amount of water that may reach the consumers is far less than 22.2 ML/day which is less than the amount that was required for the town in 1987. The hypothesis stated was tested by use of the effective and required amounts of water capacities in Table 5. It was concluded that the water supply system capacities are not adequate to meet the present water requirements of the town.

WATER DISTRIBUTION AND DISTANCE FROM RESERVOIRS

The third subject of focus in this study was the effects of distance on water distribution. To test for this, hypothesis three was formulated as stated below:

"Distance from reservoirs has no significant effect on distribution of water".

To determine whether distance from reservoirs had any significant effects on water distribution, institutions were asked to indicate whether their water supply was regular or irregular. The results of this inquiry are given in Table 6, which shows the regularity of water supply to institutions in far-off areas and nearby areas as measured from the reservoirs.

TABLE 6: REGULARITY OF WATER SUPPLY AND DISTANCE

Distance	WATER SUPPLY				(Total)
	Regular		Irregular		
Far - Off (> 2Km)	(2)	50%	(2)	50%	(4)
Near-by (< 2Km)	(2)	50%	(2)	50%	(4)
(TOTAL)	(4)	100%	(4)	100%	(8)

N.B. Figures in parentheses are absolute values on which the percentages are based and represent the number of institutions in each category.

$$X^2 = 3.841 \quad \alpha = 0.05 \quad Df = 1$$

(The reference point for distances are the waterworks reservoirs).

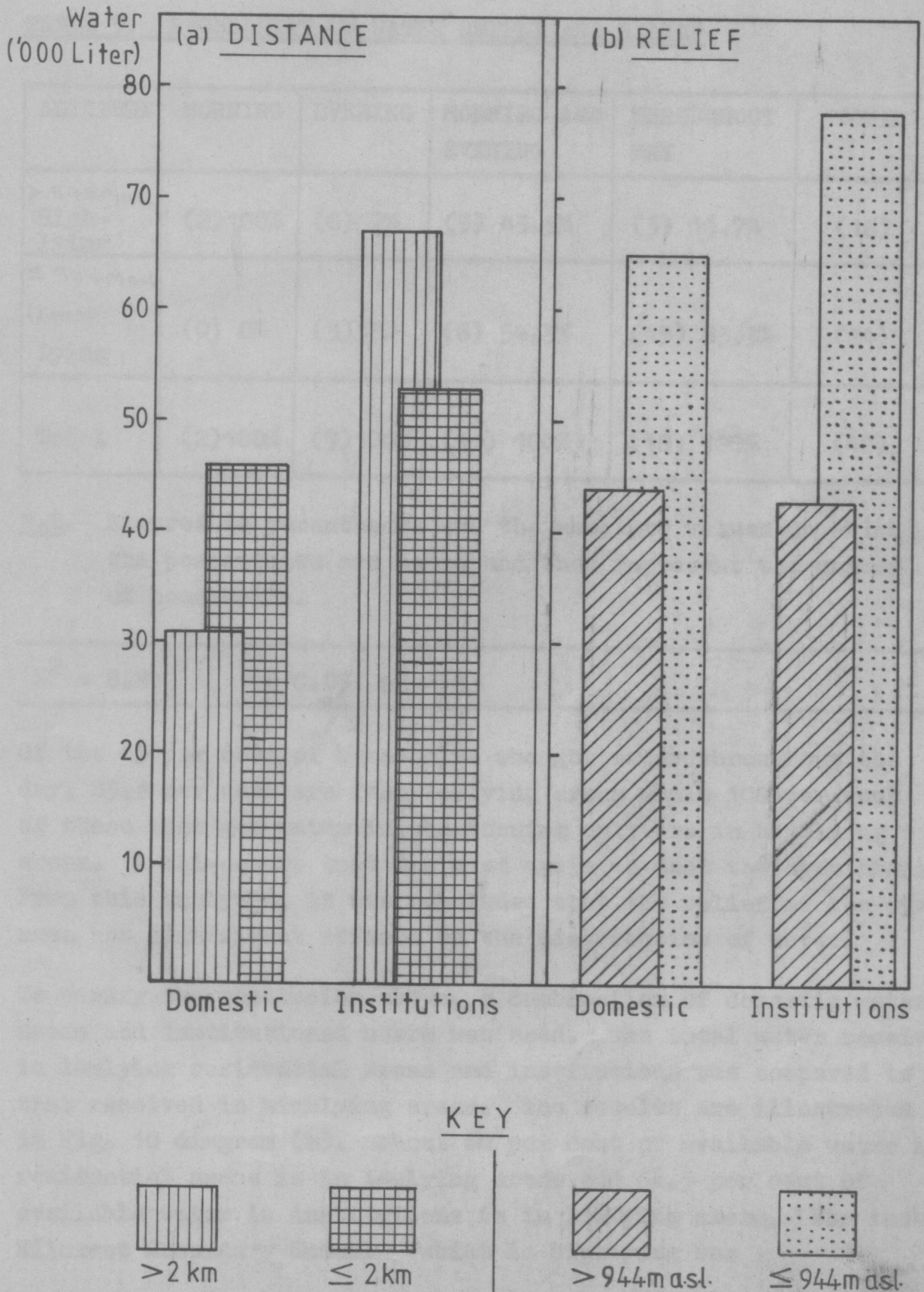
In the distribution of water in institutions, 50% of them in far off places have a regular water supply while 50% of these have an irregular supply. This state of affairs may be taken to verify that distance has little effects on the distribution of water since the same proportion of institutions have a regular and irregular supply in nearby and far-off areas. A chi-square test based on the absolute figures in Table 6 was used to test hypothesis three. It was concluded that distance from reservoirs has no significant effect on water distribution. To verify the significance of the conclusions, the distribution of water received in far off households and institutions was compared to that of those in nearby areas. The results are presented in Fig 10. The residential areas in nearby areas received more water than those in far-off areas. Institutions in far-off-areas in contrast to domestic water users received more water. This means that there are other factors other than distance in water distribution. All in all, distance from reservoirs has no significant effect on the distribution of water.

5.8 WATER DISTRIBUTION AND RELIEF

The relief of Livingstone varies from 899m to 978m A.S.L. The effects of this variation in relief on water distribution was investigated. Thus hypothesis four was formulated.

"The topography of the study area has no significant effects on the distribution of water to users."

FIG 10: THE EFFECTS OF DISTANCE AND RELIEF ON WATER DISTRIBUTION TO SELECTED USERS



To assess the effects of topography on water distribution, the regularity of water supply in highlying and lowlying areas was ascertained. Households were asked to indicate times of the day when water was available on their taps. The findings on this enquiry are in Table 7.

TABLE 7: REGULARITY OF WATER SUPPLY AND RELIEF

ALTITUDE	MORNING	EVENING	MORNING AND EVENING	THROUGHOUT DAY	TOTAL
> 944 Masl (High-lying)	(2) 100%	(6) 67%	(5) 45.5%	(3) 16.7%	(16)
≤ 944 Masl (Low-lying)	(0) 0%	(3) 33%	(6) 54.5%	(15) 83.3%	(24)
Total	(2) 100%	(9) 100%	(11) 100%	(18) 100%	(40)

N.B. Figures in parentheses are the absolute values on which the percentages are based and they represent the number of households.

$$\chi^2 = 8.84 \quad \alpha = 0.05 \quad df = 3$$

Of the 45 per cent of households who get water throughout the day, 83.3 per cent are from lowlying areas while 100 per cent of those that get water in the morning only are in highlying areas. A chi-square test was used again to test the hypothesis. From this analysis, it was concluded that the relief of the study area has significant effects on the distribution of water.

To verify the conclusion above, a combination of domestic water users and institutional users was used. The total water received in lowlying residential areas and institutions was compared to that received in highlying areas. The results are illustrated in Fig. 10 diagram (b). About 60 per cent of available water in residential areas is in lowlying areas and 64.5 per cent of available water in institutions is in lowlying areas. For instance, Hilcrest Secondary School which is highlying was

getting about 600 litres of water/day while St Mary's Secondary School was getting an average of 24 200 litres/day. Hence the conclusion that relief has a significant effect on the distribution of water. This results from the fact that the distribution of water from reservoirs is entirely by gravity which is a function of altitude. Water will flow from high areas to lowlying areas. This leads to water users in highlying areas experience low water flows especially in times of low water pressure.

DISCUSSION OF MAJOR FINDINGSCONCLUSIONS

- (a) It has been established from this study that water users are not satisfied with the amounts of water supplied to them. This can be said to be true for all categories of water users in Livingstone. The council is not able to supply sufficient water to meet the needs of the users in the town. This is because of several problems with the waterworks operations. Since the council is the only authority responsible for the supply of water to the town, the sporadic water shortages are all blamed on it. In other words, the council has failed to provide an efficient water supply service to the town.
- (b) The water supply problems leading to the dissatisfaction of the water users is a result of a number of factors. In this study, it has been established that the water supply system capacities are not adequate to meet the required water demands of the town. The amount of water that can be abstracted, transported to the treatment plant and treated in readiness for distribution in a day is less than the actual amount of water required for a day's town consumption of 31.8 ML/day.
- (c) The relief of the area has a marked effect on the distribution of water available from the reservoirs to the users in different parts of the town. The distribution of water from the reservoirs to users is by gravity which is a function of the gradient between the reservoirs and points of supply. So the lower the area is relative to the reservoir, the higher the slope and the waterhead pressure. Therefore, in lowlying areas water could be readily available. For areas which are highlying, the gradient is low and so is the water head pressure, hence highlying areas receive less water than

lowlying areas. However, under normal operation conditions of the waterworks, all areas high or lowlying can receive water. In case of a water supply problem, leading to less water available in the reservoirs, the water pressure becomes low in highlying areas leading to a shortage of water. This led to the elevation of the high level tower for supplying highlying areas.

- (d) The distance from the reservoirs and point of supply has no significant effect on the distribution of water. As established from this study, distance on its own may not affect the distribution of water. However, distance may affect the distribution of water in one way or another. For example, for a slope to be, there is need to have distance and height. All in all, it can be said that an area many kilometres from the reservoirs but on a lowlying area would get water flowing in taps while a highlying place less than a kilometer from the reservoirs may have no water flowing as was the case for Hilcrest Secondary School.

In a similar study carried out in Chipata by Mbewe (1985), it was established that domestic water use was consuming the largest amount of water supplied to the town (72.7%) followed by institutions (15.5%) and industrial use (11.69%) (Mbewe 1985:52). Emphasis in this study was on residential water use and its characteristics were analysed in detail.

Kalyalye (1986), did a similar study in Ndola Urban. He studied water supply at a township level on a central place theoretical framework. Emphasis was on the times of water availability at different taps, distances covered by residents in fetching water and the rates of flow as determined by distance and relief. Using rates of flow, the study revealed that taps in higher areas had shorter periods of water availability and lower rates of water flow as compared to lowlying areas. It was also established that distance had no effects on the rates of flow of water and that tap leakage was one of the major problems contributing to water loss. (Kalyalye, 1986:20 & 23).

6.2 OBSERVATIONS

The Livingstone District Council has a number of problems in making available water in required amounts and quantities. As observed from this study the major problems encountered are:-

- (a) Persistent breakdowns of pumps both at the intake and treatment plants due to the old age of the pumps. In connection with pump breakdowns at the intake, the two rising mains are not adequate and are too old to accommodate all the water pumped. As such the number of pumps cannot be increased otherwise the leakage in the rising mains can be increased and pumping cost increased in terms of pump fuel.
- (b) Unlike most of the towns in the country, Livingstone Council has not exploited groundwater to augment the surface source whose supply is subject to cut-offs resulting from pump problems at the intake and rising mains. Groundwater reserves certainly exist as demonstrated by Zamtex and David Livingstone Teachers' Training College both of which are using ground water extensively.
- (c) A lot of water is lost through leakages both through underground pipes which are small, corroded and so ^{are} subject to bursts. This has been worsened by vandalism which has resulted into loss of many network pipes and fittings on public taps. Furthermore, the waterworks management has no systematic way of monitoring leakages while it takes longer for them to repair leakages once identified.
- (d) The council has ever since failed to recruit and retain qualified manpower including the indispensable water engineer. This is because the council offers unattractive working conditions and low salaries. As a result, only less qualified or semi-skilled people are employed. The present workers,

therefore, are not able to run the water works efficiently. This results in frequent breakdowns and short operation life of machinery and other equipment.

- (e) The council has not given water supply a first priority in its development programmes. Usually little money is said to be allocated for the water works resulting in the failure of the council to repair or replace equipment and machinery. The lack of funds can also be attributed to the council's inability to implement water bill payments properly. A lot of users have no metered supplies while others have meters which have ever since been broken deliberately or otherwise. This makes it impossible to supply water on a quantity-used-basis for most of the users. Even when people pay water bills, the money is rarely used to improve the water supply system.
- (f) As for reservoirs, the problem is with the high level tower. The pumps used to feed water into the high level tank from the treatment works are small. Breakdowns because of poor management and old age are very frequent and these lead to erratic water supply situations to high level zones. It is in such occasions of pump breakdowns that the effects of relief on water distribution come into play since the reservoirs at the waterworks are at the same elevation as the high level areas.

6.3 DIFFICULTIES ENCOUNTERED AND SUGGESTIONS FOR FURTHER STUDIES

- (a) In studies of this nature, there is need to have a large study sample especially of water users. In this study, time was a limiting factor on the sample size which was rather small for significant generalization^s. Interviews were carried out in afternoons during the week, as such household heads were not available in most cases. Therefore, interviews ended up being carried out with housewives or dependants where both the husband and wife were working.

- (b) The study was carried out during a period of Presidential and Parliamentary general election campaigns. As such people were not very keen to give information especially as regards the causes of water supply problems in the town.
- (c) In areas without meters, it was very difficult to ascertain the amounts of water households use. Some use buckets- big and small, others use plastic containers of different sizes while those with taps within the houses do not fetch water. A study for determining amounts of water used can only be done efficiently if all water users have metered supplies and with meters in perfect working conditions.
- (d) The determination of the exact amount of leakage loss was not possible especially as regards underground water leakages. This can only be done by studying the pipe network system and using residential water meter readings in conjunction with estimates of water supplied to the distribution system. Only if this is done can surface and underground leakage amounts be determined accurately. A perfect estimation of leakage loss in water supply can help in planning and solving problems of water supply. Future studies therefore, should aim at coming up with consolidated water budgets for each water supply system in the country.

6.4 RECOMMENDATIONS

- (a) The existing water supply system must be rehabilitated and expanded uniformly in all components if present and future water demands are to be met. There is need to increase the capacity of the rising mains to match with the capacity of the pumps. The old rising mains must be repaired of all leakages so that no raw water is lost. The old treatment plant must be rehabilitated and all the equipment not working should be repaired or replaced so that it can operate at full capacity with all necessary treatment processes. For the new treatment plant to help solve the water problems of the town, there is need to use both the old and new plant with equal if not more attention on the old one. The council should aim at meeting present and future water demands bearing in mind the ever increasing population of the town.

- (b) The council must devise measures and a systematic method of monitoring and repairing leakages in the whole reticulation. All leakages major and minor must be repaired while all public taps which do not close completely should be repaired so that no water loss can result. The water which is presently lost through leakages can be used to meet part of the water demands of the town even without increasing the capacity of the supply system.
- (c) Groundwater must be exploited wherever the elevation of the water table, aquifer yield, water quality and borehole sites are suitable. Therefore, a study on ground water estimation so that reserves for exploitation are known must be carried out. This can help solve acute water shortages to important institutions like hospitals which cannot do without water or any other shortage for that matter.
- (d) The council must find an efficient way of collecting water bills. All the water users must have metered water supplies while all defective meters should be repaired. If this is done, there can be a reduction in water wastage because it can instil a sense of responsibility to water users. Once all areas are charged on a quantity-used-basis, the whole system can be self supportive. The water charges can provide revenue for the maintenance of the supply system. This can also cut down on the use of water for gardening in the dry season especially in some high density areas where water is supplied free of charge.
- (e) To achieve a good water supply service to the town, the council should give water supply first priority in its development programmes. The frequent breakdowns at the water works are a result of the old equipment and poor management. It is therefore, imperative for the council to employ the necessary qualified manpower to run the water works. There is need

to recruit and retain a qualified water engineer first and foremost. There certainly are qualified water engineers in Zambia. It is up to the council to offer better salaries and benefits to the appropriately qualified manpower. Otherwise, by employing less skilled workers, the council is not saving anything since they seem to incur larger expenses in the repair and replacement of equipment due to poor attention offered by the current unqualified workers. Unless a qualified water engineer and other qualified water supply management personnel are employed, the Livingstone District Council is likely to continue facing sporadic water shortages at the dissatisfaction and frustration of numerous water users.

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APPENDIX 1

INTERVIEW FOR THE COUNCIL TOWN PLANNER

1. When was Livingstone first established? Give a brief history.
2. What is the current area~~s~~ size of the District Council?
3. Other than the Council, who supply water in the District Council?
4. What categories of water users do you have in this District Council?
5. What is the major water use in the District Council from your own point of view?
6. Who determines the water bills the water users pay for the water?
7. What penalties are there for illegal connections?
8. Do you have problems with the water supply?
9. What have been the past trends in water use or requirements of the District Council?
10. Is the water supply available for purposes such as irrigation and market gardening?
11. Are there any more water user establishments that are likely to develop in the next 5 - 10 years?
12. Are there any plans to expand or improve the water supply system in the next 5 - 10 years?
13. Are there any water conservation programs within the District Council?
14. Any special comments on the water supply of your District Council?

THE END

APPENDIX 2

INTERVIEW FOR THE COUNCIL WATER ENGINEER

1. What are the sources of raw water for your water supply works?
2. How far are the sources from the water works plants?
3. How reliable are the water quantities at the sources?
4. Are there any water quantity variations at the source?
5. Are there any negative effects in the raw water you abstract from the treatment point of view?
6. When were the pumping facilities first installed?
7. Have there been any changes to the water works facilities since they were first installed? If yes, when was this done?
8. How much water are you allowed to abstract per year from the main source?
9. Is the amount allocated for you enough to satisfy requirements in the District Council?
10. What is the current capacity of the pumping facilities in use?
11. What is the capacity of the treatment plant?
12. What are the capacities of the reservoirs?
13. Are your water works facilities used to full capacity? If not why?
14. When the water works were last installed, what was the target population for which it was meant and for how long was it expected to sustain the water demands of the District Council?
15. How is the raw water treated to make it suitable for the varied users of the District Council?
16. How many water towers do you have in the District Council and why are they located where they are?
17. Which areas does each one of them serve?
18. Are there any funding or maintenance problems you face in water abstraction?
19. Any administrative problems encountered?
20. What in your opinion are the major problems in the water supply system of your water works?
21. How do you think these problems can be solved and are there any plans in solving them so far?
22. Any special comments on the adequacy of the raw water abstracted for treatment?

ON PROBLEMS OF DISTRIBUTION

1. What categories of water users do you supply water to?
2. How much water do you supply to each of the user category?
3. How much water do you supply for residential areas in cubic metres?
4. Is your water supply metered?
5. Of what advantage has been the metering of your water supply?
6. Why are some users' water supply metered while others are not?
7. Do you have any leakage problems? If yes, what are the main causes of such leakages?
8. How do you monitor the supply networks for such leakages?
9. Approximately how much water do you lose through leakages?
10. Do you have any areas with more regular water supply than other areas? If yes, what do you think brings about the variations in the regularity of water supply?
11. What effects does areal size of the Council have on water distribution?
12. Does the variation in relief of the Council have any effects on the efficiency of the water supply to different areas?
13. What other problems do you face in the distribution of water from reservoirs?
14. Any other special observations on the distribution of water in the District Council?

THE END

APPENDIX 3

INTERVIEW FOR COUNCIL HEALTH INSPECTOR

1. How adequate would you say the water supply service of the council is?
2. What would you say about the quality of the water supplied to users in the District Council?
3. What are the desired thresholds for domestic water use i.e. the quality parameters that must be met?
4. What checks are there to ensure that the desired thresholds are met?
5. Have you had any health problems resulting from erratic water supply in the Council? If yes, when?
6. Is the water supply sufficient for sewerage disposal purposes?
7. Has the water supply situation in the Council anything to do with the distribution of water closet toilets in the residential areas?
8. Which categories of residential areas have been waste hit by the water supply related health problems?
9. Any special observations or comments as regards water supply of the Council and health standards of the Council?

THE END

APPENDIX 4

INTERVIEW SCHEDULE FOR INSTITUTIONS

- a. Name of Institution.....
- b. Location.....
- c. Population of Institution.....

1. When was this Institution set up?
2. For how many people was it meant to cater for when first established?
3. Who supplied water to this Institution?
4. What are the major uses of water in the Institution?
5. Is the water supply metered?
6. How much do you pay for water per month on average?
7. How much water do you use in a day in litres?
8. How regular is the supply of water to the Institution?
9. Where do you get your water when the regular supply is not available?
10. Suppose water supply services were free of charge in this Council, how much water would you need in a day and for what additional uses?
11. Has there been any changes in the population or size of the Institution since it was first established?
12. Has there been any increase in the water quantities supplied to you since the Institution was first established?
13. Is the population and size of the Institution likely to expand in the next 5 - 10 years?
14. Are there any seasonal variations in the water quantities you require? If yes, are these variations taken into consideration by the water suppliers?
15. In your own opinion, what are the major problems in water supply services in this District Council?
16. For how long have these problems been faced here?
17. What do you think the Council should do in order to solve these problems?
18. Any special observations pertaining to the water supply of the District Council?

THE END

APPENDIX 5

INTERVIEW FOR INDUSTRIES/COMMERCIAL ENTERPRISES

- a. Date of interview.....
- b. Name of Industry/Commercial Enterprise.....
- c. Location.....

1. What is the major undertaking of this Industry/Commercial enterprise?
2. Who supplies water for your Industry/Commercial Enterprise?
3. What is the major use of water in the operations of the Industry/Enterprise?
4. How important is water in relation to other inputs that you need in the Industry/Enterprise?
5. Is your water supply metered?
6. How much water do you use in a day for your operations on average?
7. Is the water supplied to you enough? Yes or No?
8. If No in Q7, do you have any alternative water supply to supplement that supplied by the Council?
9. What do you think are the major problems in water use within your Industry/Enterprise?
10. Suppose water was available at no cost and there were no constraints whatsoever in the water supply, how much water would you need in a day?
11. Do you have any water uses in mind which you cannot undertake now due to the inadequacy of water quantities supplied to you?
12. How regular is the water supply to your premises?
13. If the Council somehow failed to supply water to you, would they be responsible for the stoppage of operations and the loses you may encounter?
14. What in your opinion are the major problems in the water supply system in this District Council?
15. What do you think the Council should do to improve the water supply service?
16. Do you have anything else to comment on as regards the water supply in this District Council?

THE END

APPENDIX 6

QUESTIONNAIRE SCHEDULE FOR RESIDENTIAL AREAS

Date of interview.....
Occupation of Head of House.....
Residential area.....
Family size of Household.....

1. Where do you get your regular water supply?

- (a) Communal tap
- (b) Tap outside house
- (c) Within the house
- (d) Tap in the neighbourhood
- (e) Any other.....(Specify)

2. How much water do you use in a day?

.....litres (approximate)

3. Select your water use from the following list in the order of importance to you.

- (a) Gardening
- (b) Cooking
- (c) Bathing
- (d) Washing
- (e) Toilet flushing
- (f) For domestic animals
- (g) Any other.....(Specify)

3.(ii) How many times per day for each category chosen?

3.(iii) How many medium sized buckets for each roughly?

4. Does the amount of water supplied to you meet your uses?

- (a) Yes
- (b) Partly
- (c) No

5. How regular is the water supply at the tap/s you use?
 - (a) In the morning only
 - (b) In the evening only
 - (c) In the morning and evening
 - (d) Throughour the day
 - (e) Any other(Specify)

6. Is your water supply metred? If yes, how much do you pay per month on average?

.....(Kwacha)

7. If you pay a fixed amount, how much is it per month?

.....(Kwacha)

8. Would you rate the charge as being
 - (a) Too much
 - (b) Alright
 - (c) Too cheap

Why?.....

9. From where do you get your water when the regular supply is not available?

10. Suppose water is supplied in your household at no cost and without any constraints in the amount supplied, how much water would you need to meet all your requirements?
 - (a) Same amount as now
 - (b) Twice as much
 - (c) Thrice as much
 - (d) Any other.....(Specify)

11. To what use would you put the water you have stated above?
 - (a) For the garden and lawns
 - (b) For a water closet toilet
 - (c) For more regular baths and washing
 - (d) Any other.....(Specify)

12. What do you think are the major problems of water supply to this area?
- (a) Distance from reservoirs
 - (b) High relief of area
 - (c) Both distance and high relief
 - (d) Inefficiency on the waterworks management
 - (e) Any other.....(Specify)
13. For how long has the water supply system been faced with the problem stated above?
14. What in general do you think are the causes for water supply problems in your neighbourhood?.....
15. Any other special comments or observations as regards the water supply in this area?

THE END