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SECTORAL WATER DEMAND AND CONSUMPTION IN MAKURDI, BENUE STATE

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PG/M.SC/93/14807
M.Sc THESIS

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UNIVERSITY OF NIGERIA
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A Thesis Submitted to the School of Postgraduate Studies and the Department of Geography, University of Nigeria, Nsukka

In Partial Fulfilment of the Requirements for the Award of Degree of Master Science (M.Sc.).

Department of Geography
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APRIL, 1998.

CERTIFICATION

Mr Ocheri Maxwell Idoko, a postgraduate student in the Department of Geography, with registration number PG/M.Sc/93/14807, has satisfactorialy completed the requirements for course and research work for the degree of Masters of Science (M.Sc) in Hydrology and Water Resources. The work embodied in this thesis/project report is original and has not been submitted in part or full for any other Diploma or Degree of this or any other University.

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ACKNOWLEDGEMENT

Successful execution of a study of this kind undoubtedly cannot be attributed to one man's handiwork. We owe our gratitude to a number of persons who in one way or the other have contributed to this work. Prominent among them is the supervisor Dr R.N.C. Anyadike. His ever ready availability for consultations, meticulous, conscientious and painstaking supervision of every phase of this study have culminated in successful completion of this work.

We wish to acknowledge tne efforts of staff of Benue State waterboard who have assisted us immensely in providing necessary information for use. We are particularly grateful to Mr Askiekaa, A. Director of water supply, Engr. Dzungu, M.; Agba, J.; Ahola, D. and Adoga, P. (Mrs).

Special appreciation also goes to Daudu, V.A., Director of physical planning, University of Agriculture; Engr Dan O. of Benue State University, Major Eneche, E. of Nigeria Army School of Engineering for their various assistance.

We are highly indebted to Council for the Development of Economic and Social Research in Africa (CODESRIA) for funding this research through their small grants thesis award.

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ABSTRACT

This research is concerned with the determination of sectoral patterns of water demand and consumption in Makurdi.

The sector with the highest water demand and consumption is the residential sector. This is followed by commercial and industrial sectors respectively.

The results of a multiple correlation analysis and principal components analysis show that sectoral pattern of water demand is a function of several respective factors. In the residential sector, the factors are:

(i) The family size
(ii) The frequency of water supply
(iii) The level of household sanitation
(iv) The socio-economic status of the head of the Household
(v) The impact of distance covered to fetch water daily; and
(vi) The availability of water infrastructure.

The commercial sector is influenced by the following factors:

(i) The influence of customer size
(ii) The impact of the cost of water supply
(iii) The size of the labour force.

For the industrial sector, the level of production in a day was the important factor.

In view of our findings, the level of water supply should be increased and rationally allocated and managed in order to improve water supply situation in Makurdi.

CHAPTER ONE

INTRODUCTION

1.1 Statement of the Research Problem

Water apart from air is a natural resource that is in great demand. Spatially man's life and activities to a large extent is influenced by this resource. In an urban area water is needed for a variety of purposes: domestic uses include drinking, cooking, washing, bathing, and general sanitation; Industrial water uses is for production, processing, cooling, washing, general sanitation and staff use; Commercial water use includes water use in hotels/ restaurants, hair dressing salons, laundry services, car wash establishments, shops, slaughter houses to mention but a few; and other uses include those of public and institution such as township halls, fire fighting, schools, hospitals, army barracks, offices etc.

Urban areas all over the world are perceived as dynamic centres of human concentration characterised by a wide spectrum of organised socio-economic activities. To this effect, the second world congress on water resources held in 1975 in New Delhi, India, observed that rapid population growth and ever increasing standard of living has resulted in sharp rise in human requirements for water. In the same vein, Dewing (1975), Ayoade and Akintola (1980), Ezenwaji (1990) have also noted that there is a growing demand for food and water due to phenomenal increase in world population and increasing urbanised nature of its inhabitants. Casadei (1987) pessimistic of this trend especially in developing countries of the world opined that with urbanisation resulting into high degree of population densities, it has become increasingly difficult to provide water at its satisfactory level both in quantity and quality.

In Nigeria like most developing countries of the world, urban areas continue to witness uncontrolled influx of rural migrants. With the imbalanced and lopsided development whereby social amenities and socio-economic activities are concentrated in urban areas to the almost total neglect of rural areas, urban areas exert a powerful influence on the rural populace. Rural migrants flock to cities and towns in search of job opportunities, access to social amenities and better standard of living. Consequently a lot of pressure is brought to bear on the quality of urban life and infrastructures crystalising into socio-economic and physical problems of housing, acute water shortages, traffic congestion, environmental pollution and deterioration, inefficient power supply and rising wave of crimes. Since these facilities are not expanded to meet up with the needs of increasing population and socio-economic activities in urban areas, they are overstretched. This results in inefficient services and frequent breakdown of these facilities thereby causing untold hardships.

In our urban areas in Nigeria one of the most felt and difficult problem to cope with that of water scarcity. Life is made both difficult, uncomfortable and unsafe. Socio-economic activities are not also spared. Ayoade and Akintola (1980) have maintained that convenient water supply, electricity, sewerage disposal system, education and recreational facilities are essential social amenities or services necessary for proper functioning of such an urban area. According to them, life would be impossible without a kind of organised water supply. Dietrich and Henderson (1963), Ezewaji (1990) observed that where no pipe water is easily available in adequate amount people turn to sources that are particularly unsafe and thus expose themselves to all sorts of water borne diseases such as cholera, typhoid, diarrhoea and dysentry. In the area of socio-economic activities, Dietrich and Henderson (1963), Mabogunje (1965), Ayoade (1980) have also noted that industry and commerce may be diverted away from areas otherwise suitable for them, production may be reduced or discontinued because of inadequate or unsuitable water supply. Economic losses may result. Ezenwaji (1990) has particularly noted that because of unreliable water supply some industries are sited or relocated near rivers. Car wash and laundry services resort to use of all kinds of untreated water for their services which of course are damaging to those items. The question may arise can people talk of quality of water used when they cannot even get enough?

Makurdi assumed a status of the state capital in 1976 following the creation of Benue State. Consequent upon the changing status Makurdi has continued to witness greater in migration, increased socio-economic activities and spatial development. With the sponteneous growth and development, Makurdi is already suffering problems of social services such as water supply. As a capital town flanked by river Benue, Makurdi ironically experiences acute water shortages relative to demand. With the inefficient and inadequate public water supply people turn to all sorts of untreated water from wells, ponds, river and water vendors which in most cases are not healthy. Some industries and institutions are forced to develop their own water supply.

During dry season the situation is particularly pathetic. Women and children trek long distances to fetch water for household use. A lot of man-hours and energy is spent in the process thus affecting the socio-economic activities. Lateness to school and offices become pronounced among school children and civil servants. And much money is spent daily on water by some households, commercial and industrial establishments. A situation of this kind undoubtably calls for investigation as to the nature of the problem. As a pioneer study findings made will be useful in finding solutions to the problem. Hence, the importance of this study.

1.2 Aims and Objectives of the Study

This study investigates water demand and consumption in the residential sector side by side with those of commercial and industrial sectors. This was done with the view of determining the magnitude and variations of water requirement, among the various sectors. To achieve these objectives the following aims were pursued:

(i) To estimate the quantity of water that is demanded in the various sectors as a basis in determining their sectoral patterns of water demand.

(ii) To determine the quantity of water consumed in the various sectors.

(iii) To identify factors that most significantly influence water demand and consumption in the residential, commercial and industrial sectors as a basis for effective planning.

(iv) To determine the effects of water needs on the socio-economic activities in Makurdi.

1.3 Area of Study

The area covered by this study is Makurdi urban area, the capital of Benue State.

Makurdi lies approximately between Lat 7° 44'N and Long 8° 54'E covering an area of about 28 km^2 (Fig. 1).

The town is traversed by the River Benue which divide it into Makurdi South and Makurdi North. Makurdi South constitutes the bulk of the town. Two bridges (Old and New) are built across river Benue to facilitate communication between Makurdi South and North. On a regional level, these bridges link South Eastern Nigeria to the northern parts of the country. While the Eastern railway line makes use of the old bridge, the new bridge carries traffic on a Federal trunk A road running northward.

Makurdi town has an estimated population of 150,261 in 1996.

1.3.1 Geology, Relief and Drainage

The urban area is underlained by what is otherwise designated as the "Makurdi Formation" (Reyment, 1965). This consists of massive sandstones with beds of arenoceous shales and calcareous sandstones. According to Nwajide (1984), the Makurdi formation is made up mainly of well consolidated sandstones and subordinately bioclastic and biomicritic limestone and igneous rocks. These sandstones according to him, are texturally immature and compositionally sub-mature being of arkosic wacke class. These sandstones are cretecous sediments believed to have been derived from Jos and Cameroun areas deposited by a system of meandering river flow in the coastal plain during regressive phase of the sea in the turanian.

Nwajide described the limestone that occur in Wadatta area of Makurdi formation to consist of bioparite and highly neomorphosed biocrimitic inter bedded with glanomitic carcareous, shally, sub arkosic sand stones and fossiliferous shale.

The areal dimension of Makurdi formation is 800 m thick (Reyment, 1965), 100 sq. km^2 and 400-500m thick (Nwajide, 1984).

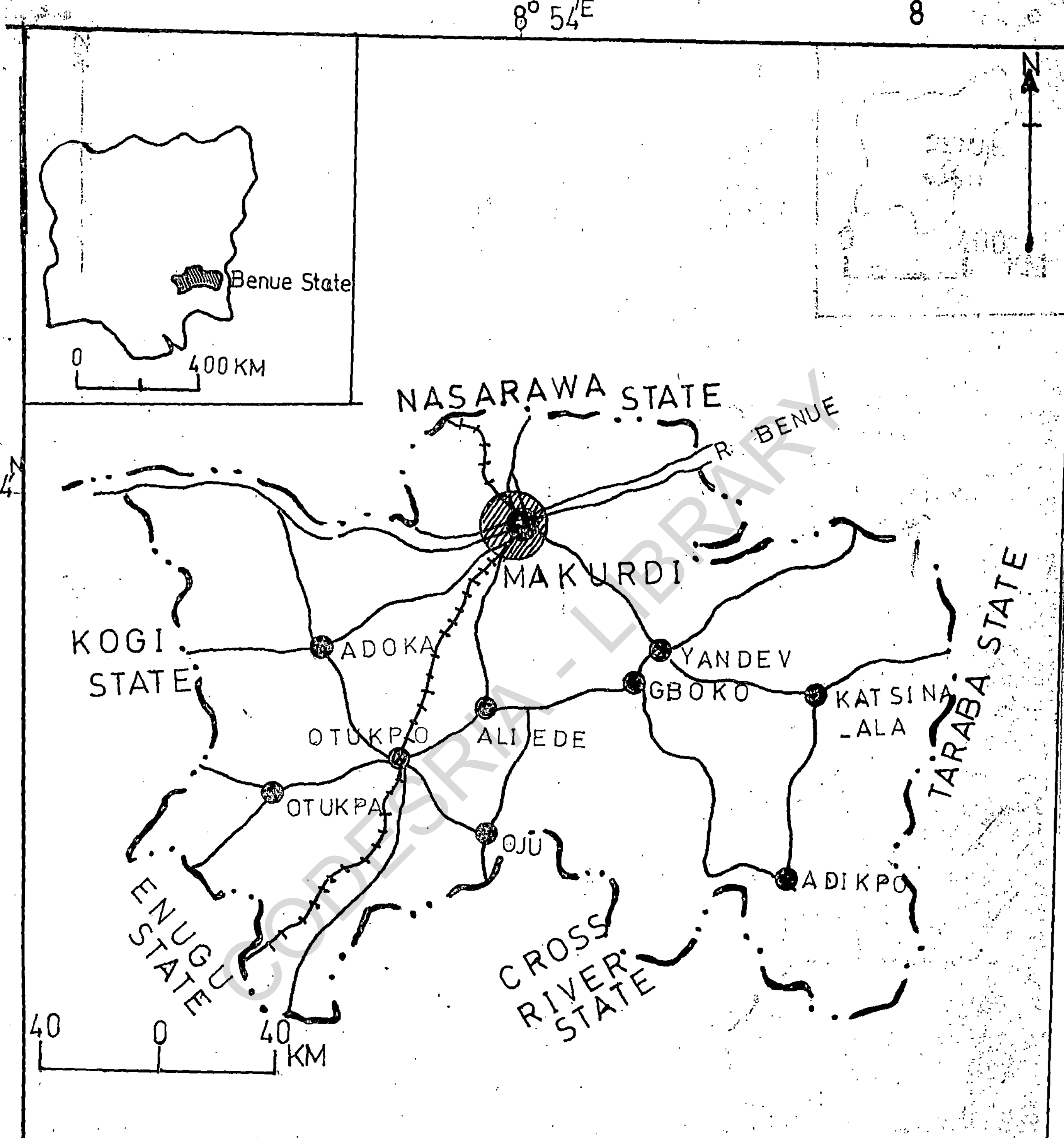

FIG. 1: BENUE STATE SHOWING MAKURDI TOWN

(Source: Ministry Of Land and Survey Makurdi)

The relief of Makurdi is predominantly that of low terrain as it happens to fall within the precinct of lower Benue trough. The physiographic unit is between 50-150m above sea level characterised by moderately sized, low-lying ridges giving it a feature of an undulating plain.

The drainage system of Makurdi is dominated by river Benue. River Benue is at its highest stage between the months of September and October 101.19m above sea level, and about 8.22 higher than the lowest stage between the months of March and April (Bawden and Jones, 1972) when extensive lateral and channel bars of pebby sand emerge. The river has eroded it valley. Consequently the interfluves gave rise to the characteristic undulation seen in the parts of Makurdi South and North (Oibe, 1994).

Due to the general low relief of Makurdi, sizeable portions of the area is waterlogged and flooded during heavy rainstorms. This is conspicuously noticed in parts of Wadatta and Ankpa wards extending to area bounding Government College and Highlevel ward to parts of Wurukum and New G.R.A word. Because of competition for land in Makurdi metropolis, portions of these areas are gradually being reclaimed for developmental purposes, and the rest is committed to swamp rice farming on a small scale.

1.3.2 Climate

Makurdi climatic situation is controlled mainly by two air masses: the South West (tropical maritime) and the north East wind (tropical continental). The former as a rain bearing wind is responsible for dry season in Nigeria. This wind is often accompanied by a cold harmattan wind.

Temperatures in Makurdi are generally high throughout the year due to constancy of insolation with the maximum of 33°C and the mean minimum of 22.5°C with an annual range of 10.5°C. The holest months are February and March (Oibe, 1994)

Humidity in Makurdi is quite high always in excess of 50% and occasionally attending 95% mark (NEDCo, 1959). This is responsible for heavy cloud which remains unbroken for weeks which have effect of lowering the day temperature for the monthsof July and September.

The mean annual rainfall is about 1,290 mm recorded in 210 to 240 days (Ojo, 1977). Rainfall here is mainly convective which starts from April and lasts till October with a peak in July and short break in August described as 'August break' or little doy season. Makurdi thus lies in the Koppin Aw climatic zone.

1.3.3 Population

Central to any effective development planning is the accurate knowledge of a country's population. The population of a country is as much an agent as the beneficiary of any planned economic and social development undertaking. In any development therefore, the population whose advancement is planned for must be given attention and population factor be made an integral part of planning process, not merely an exogenous factor to be taken account of (the Economic Commission for Africa, ECA, 1969).

In Nigeria despite the importance attached to population factor, conducting a successful population census had proved problematic and at the same time an uphill task. This is because censuses in Nigeria are bedevilled with myriad of socio-economic, political and physical problems. Hence figures arrived at, at last are subject of criticisms and debates as they are viewed as being manipulated and therefore, unreliable and unrepresentative of the true population of a place. Notwithstanding, development plan must be drawn based on the population of a place because it is people that must be planned for.

Makurdi became a headquarter of the then Benue Province in 1927 and subsequently a capital of Benue State in 1976.

With the change in the status, Makurdi continues to witness population increases (Table 1).

Table 1

Population Growth of Makurdi

YEAR	POPULATION	REMARK
1952	16,713	1952 Census
1963	53,967	1963 Census
1973	74,468	Projected
1983	102,347	"
1990	128,044	"
1991	132,207	"
1992	136,507	"
1993	140,947	"
1994	145,529	"
1995	150,261	"
1996	155,147	"

SOURCE: 1952, 1963 Census and projections.

1.3.4 Growth and Development

The growth and development of Makurdi may be accounted for in the context of socio-political, economic and cultural changes that took place over time.

Makurdi is traditionally known as Lobi. But with the transfer of the then Benue Province from Abensi in 1927 coupled with the arrival of railway line Makurdi became prominent. Makurdi retained its status as provincial headquarter until the provincial administration was abolished in 1968.

The growth of Makurdi has a lot of setbacks due to political inclination of the majority of the people of the former Benue Province in the defunct Benue Plateau, and the general neglect by past administrations following the abolition of provincial system in 1968 and introduction of Divisional field administration she suffered a great decline. However, with the creation of Makurdi local government in 1976 it revived the growth of Makurdi.

In February 1976, Makurdi became the state capital following the creation of Benue State. Consequent upon the attainment of the new status as the capital, Makurdi has continued to witness increased socio-economic activities, spatial development and greater in migration. This is enhanced by the advantage Makurdi enjoys as is strategically located at the point of convergence of railway and Federal road network from the south to the northern parts of Nigeria. In 1978 a ₦28.6 million bridge was built across river Benue. This has gone a long way to remove the bottleneck often mounted at the old bridge which was used by both the train and vehicles being a single carriage way.

History has it that the Tivs were the original settlers of Makurdi. Other tribes such as the Jukuns, Alogos, Hausa, Idoma and Nupe came to settle with them.

Since the attainment of the status of a state capital remarkable changes have taken place in the area of physical development and socio-economic activities (Fig. 2).

Communication wise, Makurdi has a well built road network connecting different parts of the town. Portion of this network is a double carriage way stretching from Government House at Old G.R.A and Federal Medical Centre terminating at railway by pass in High level ward and 11 km Makurdi-Gboko and Makurdi-Ankpa roads. A Federal trunk A road and railway passes through Makurdi running northward of the country. Most of the Makurdi township roads are tarred. Hence, the poor, narrow, limited dust-laden roads and streets of Makurdi in the past has given way to modernization and development.

Housing condition in Makurdi in the past was quite deplorable as houses were built without proper layout coupled with the poor drainage system. Traditional round huts, bushes and slum were characteristic of Makurdi environment.

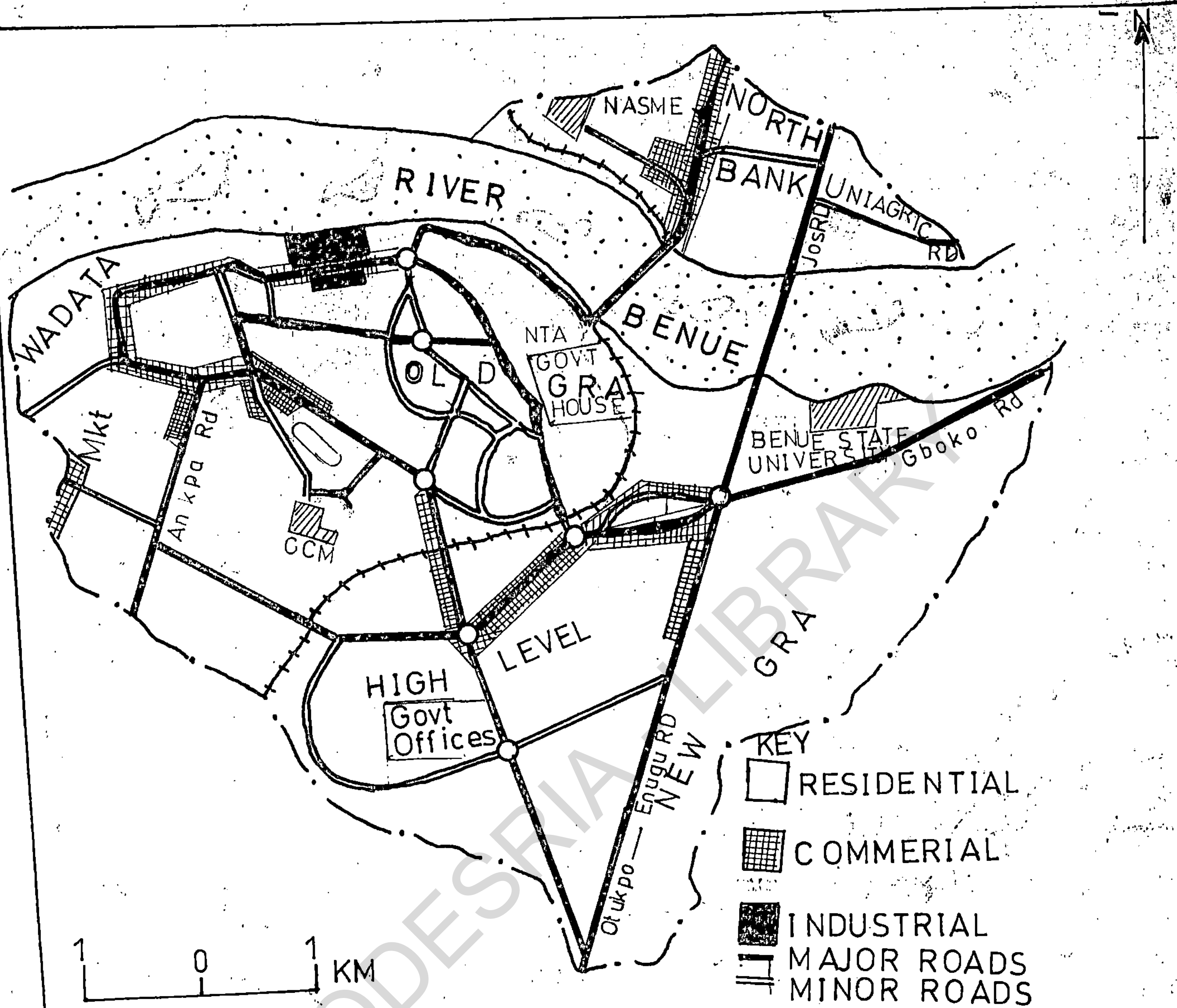

FIG. 2: MAKURDI URBAN LANDUSE (Source: Makurdi Townplanning Authority)

Upon becoming a state capital the problem of accommodation for civil servants was among the first issues that was addressed. The government embarked on housing projects such as Lobi, HUDCo and commissioners' quarters for very senior civil servants, kwarafar and Ankpa quarters for other categories of civil servants.

Other capital projects include the New Secretariat, IBB public square, Aper Aku sports Complex, Tarka Foundation, Benue House of Assembly, Assembly quarters.

To boost the commercial and business life of Makurdi a good number of banks have been attracted to the place. These include First Bank, Union Bank, UBA, IBWA, Allied Bank, ACB, Lobi Bank as the State Bank and Central Bank as Currency depot. To add impetus to the commercial life of Makurdi, an ultra modern market with banking and medical facilities has been built by the state government. Besides, other markets are built in Highlevel, central, Wurukum and North Bank wards.

Industrially, Makurdi is yet to be reckoned with. Benue Brewery Limited (BBL) producers of More beer and Benue Bottling Company producer of Ben soft drinks are the only few industries. Unfortunately these companies have folded because of financial problems. Benue Investment

Company oversees all the activities of state investments.

Before Makurdi became a state capital there was no higher institution. There was only two secondary schools and few primary schools. But today Makurdi has two higher institutions of learning: Benue State University (B.S.U) and University of Agriculture. There are presently eight post primary schools and many primary and nursery schools.

1.3.5 Residential Structure

The perceived residential structure of an urban area in any place is a product of interactions of various factors over time. These include socio-economic, cultural, political and general level of development.

Makurdi residential structure is divided into 8 wards for the purposes of census enumerations. They are: Central, Wadatta, North Bank, Ankpa, Highlevel, Wurukum, Old GRA and New GRA wards (Fig. 3).

1.3.5.1 Central Ward

This ward is one of the oldest centres of Makurdi predominantly inhabited by the Hausas. The area is characterised by Hausa enclosed type of building, two central mosques, and room and parlour kind of apartments. Most of the houses here are old corrugated iron sheets. The ward has a high residential density as there is virtually no land for further development.

The ward occupies an approximate area of 2.5 km^2 sprawling on the height of about 150 m above sea-level and bounded in the north by river Benue.

1.3.5.2 Wadatta Ward

This ward occupies an area approximately 2 km^2 with the height of below 100 m.

Wadatta ward constitutes one of the oldest traditional centres of Makurdi characterised by relices of Tiv traditional round huts. Common house type here are a room and parlour with old corrugated iron sheets. Modern houses are gradually springing up on the major road artery that passes through the ward.

Tiv and Hausa are believed to be traditional settlers of this area.

1.3.5.3 North Bank Ward

This area is referred to as Makurdi North, located at the north bank of river Benue. The evolution of this ward started as a migrant hausa community by the bank of river Benue. This later grew to be one of the full fledged residential area of Makurdi.

The common house type here ranges from the enclosed

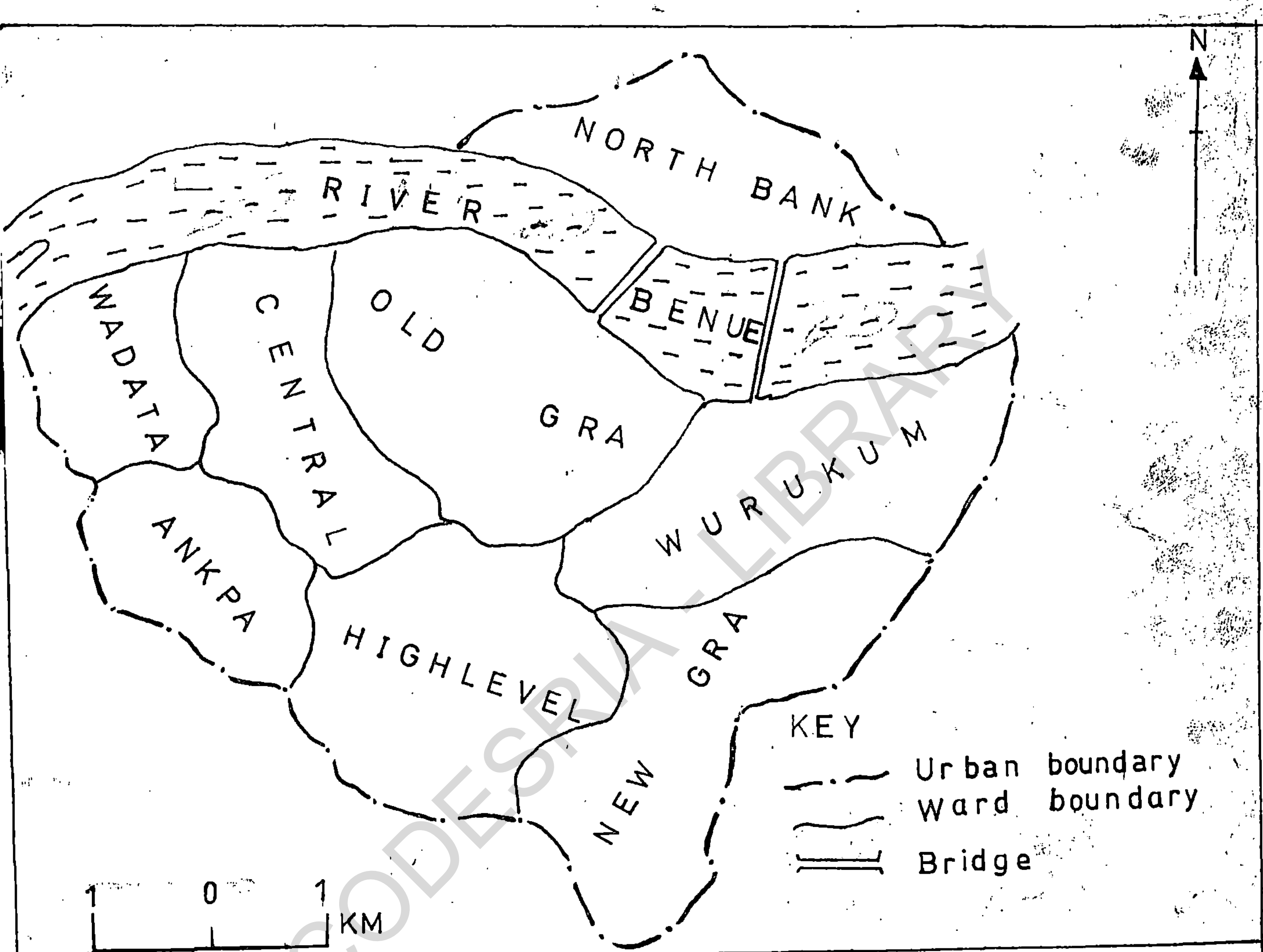

FIG 3 : MAKURDI SHOWING THE WARDS
Source FieldWork (1996)

by local farmers. But today it has assumed a very important status administratively, commercially and otherwise.

Highlevel is regarded as new development area. Residential density here is moderate. Modern apartments such as storey buildings, bungalows, duplexes, room and parlour are common. However, traditional round huts are still seen. HUDCO quarters and Assembly quarter-duplexes of 4 bedroom and 2 bedroom housing estates are located here.

The area covers approximately 3 km^2 with a height of about 140 m.

1.3.5.6 Wurukum Ward

Wurukum formerly known as Walmayo occupies the lowest point of Makurdi of about 50 m, and covering an area of about 1.5 k^2.

The residential density here is moderate. Common house type includes a room and parlour, to few bungalows and storey building that lined the major road artery that passes through the ward.

1.3.5.7 Old GRA Ward

This area owes its origin to colonial times as Government Reserve Area (GRA) presently the area functions as the administrative nerve centre. We have the Government House, Governor's Office, State House of Assembly located here.

Residential density here is low as a G.R.A. Lobi and Kwarafar quarters blocks of 4 and 2 bedrooms for senior and intermediate civil servants are located here. Besides, we have also the presidential lodge, governors lodge and private bungalows and duplexes.

The area occupies an approximate size of about 2.5 km^2 with the height of about 150 m being the highest point of Makurdi relief.

1.3.5.8 New G.R.A

The idea of the development of the new G.R.A. emanate from the fact of wanting to maintain the low status of its residential density.

The residential structure is quite modern and density low. Commissioners quarters - duplex of 8 rooms, alongside with private storey buildings, bungalows, duplexes lined the landscape.

The ward occupies an approximate area of 4 km^2 with the height of about 140 m.

1.3.6 Commercial Sector

Characteristic of most urban areas is a configuration of socio-economic activities crystallised in form of commercial and industrial activities. In Makurdi, commercial activities lined the major road artery and streets (Fig. 2). Concentration of these commercial activities are found lining the major road artery that passes through central ward to Wadatta, and from Highlevel, Wurukum and North Bank area with Makurdi modern market having a concentration of commercial activities. This may be regarded as the Central Business District (CBD). Commercial activities include hotels, restaurants, supermarkets, laundary services, car wash, hair dressing, harbing salons, bookshops to mention but a few.

1.3.7 Industrial Sector

Makurdi industrial base is still at its baby stage as plans for full industrial development has not been realised. However, there are a few industries such as Benue Brewery,, Benue Bottling Company, 7Up and Coca Cola etc. Small scale industrial activities include bakeries, block moulding, boat making.

1.4 Theoretical Framework

Empirically, economists conceive of quantity demanded for any commodity to mean the amount of that good that consumers are willing to purchase given some controlling factors. Some of these factors considered to have significant effect on the quantity demanded of a commodity are: price of that commodity, size of the consumers income, price of other commodities, consumers' taste, size of the household.

To enable us have a realistic appraisal of how some of these factors influence consumers' behaviour as it relates to water consumption, it is necessary to clarify some issues about water as an economic commodity.

Classical economists like Lipsey (1976), Samuelson (1983) and Kontsoyianmis (1989) have categorised commodities into 'luxury goods' and 'goods of necessities'. Luxury goods according to them are those commodities whose income elasticity is greater than unity, that is commodities that can be dispensed of when the price is increased, the consumers stop purchasing them. Goods of necessities on the other hand are those commodities which are essential to life whose demand is completely inelastic, that is even when the price is increased, consumers do not forego their consumption.

Again, commodities are also classified as 'economic goods' and 'non-economic goods'. Economic goods are those goods that are relatively scarce and require a lot of effort to obtain them, whereas, non-economic goods are those that we do not buy even though we make use of them.

Water is an economic commodity when viewed against the backdrop of its socio-economic role. This is true of countries where water is billed as electricity consumption. Water may be regarded as both an economic good and good of necessities. As a good of necessity to life, consumers have no choice to forego its consumption no matter what happens. As a commodity that lacks close substitute, that makes its consumption indispensable. However, it should be understood that water as a substance has no close substitute because no other substance can replace it. But as to its sources of supply in an urban area a consumer is faced with choices to make. In an urban are where we have municipal water supply alongside with other supplementary sources such as river, well, water vendors, private borehole or water works a consumer is faced with alternatives. For instance, in a situation where public water supply is not patronised based on price, unrealiability and inadequate supply, consumers' taste and income, a consumer has a choice to turn to any of the sources. Again, consumers perception of water as a social service in urban areas in Nigeria is demonstrated in the general unwillingness in paying water rates even when the rate is low.

Water demand as used in water management studies is the same as water requirement or needs in a place, and consumption as water supplied or actually consumed in a place. Factors that affect demand for other commodities are identified by researchers as factors also to affect demand for water.

Linaweaver, Geyer and Wolf (1966) in their investigation into factors affecting residential water demand in manicipalities income level were significant factors influencing quantity of water demanded. Income level of the consumer determines many things especially his standard of living. Generally when a consumer income level is increased it is expected that it will go a long way to influence his standard of living. Consistent with these findings, Darr, Feldman and Kamen (1975) in assessing the socio-economic factors affecting domestic water use in Isreal found that income and its surrogates were important predictors of residential water use.

Gardinar and Schick (1964) have found consumer's income to be a significant determinant of urban water demand. They conclude that numerous variables such as per capita value of a house lawn area, number of bathroom per house are explanatory variables which are used in lieu. They observed that houses that have some or all the above variables affected water demand were expected to be high.

Warford (1972), Hirhlifier et al (1972), Mabogunja (1980), Residential Sector

The number of persons in a household

The income level of the head of the household

The educational level of the head of the household

The quantity of water used in washing cloths

The quantity of water used in cooking

The quantity of water used for general cleaning

The cost of water supply to the household

The existence of water tap in a household

The number of hours water runs in tap in a day

The number of water consuming appliances

The supplementary sources of water supply

The distance to the nearest source of water supply.

Commercial Sector

The existence of water system in the establishment

The cost of water supply

The number of persons employed in the establishment

The number of customers to the establishment in a day

The source of water supply to the establishment

The number of workshifts in a day

The day of the week water is mostly needed.

Industrial Sector

The level of production in a day

The number of persons employed in the establishment

The source of water supply in the industry

The number of workshifts in a day

The cost of water supply.

1.5 Literature Review

Researches on urban water demand have been attempted in different parts of the world. While some focussed on water demand in the residential sector, others focussed on industrial and commercial sectors.

Residential Water Demand

Bulk of the studies on urban water demand appear to concentrate on domestic demand. This may not be unconnected with the fact that water is a basic requirement to life as such domestic water use tends to attract more attention before other uses are considered.

Gottlieb (1963) carried out a study on urban domestic water demand in the city of Kansas, identified factors of price and income as important variables determining the quantity of water consumed. In a similar study embarked upon by Linaweaver, Geyer and Wollf (1966) in different municipalities of America, noted that the size of the family was the most influential factor in per capita water consumption. Besides, the place of birth of the head of the household and his educational level influenced his water consumption. The impact of price, dwelling units, surrogates for income and climate were used to also conclude for metered units that consumption was the same as demand and consumption varied markedly between geographical areas. According to them, net income and number of rooms per household do not have significant influence on water consumption.

Turnovsky (1969) investigated a consumer response to commodity uncertain in supply in a town of Massachusetts, based on theoretical model found that domestic demand for water depends significantly on price variance and per capita volume of housing. Price and variance change will affect demand, and a substantial change will be required in either of these variables to bring about some desired changes in consumption.

In an attempt to assess the effects of income of the head of the household on water use using cross-sectional and temporal model to analyse the effects in a city of Chicago, Wong (1972) found that income of the head of the household was a significant factor affecting residential water demand. However, Howe and Linaweaver (1967) in an earlier study determined a cross-sectional demand function for urban water using individual units as samples, they found that consistent with theoretical development, both assessed value of property and number of persons per dwelling unit were significant determinants of the quantity of water demanded. Their study however, revealed economic of scale with respect to household size. Danielson (1979) found that household size consistently explain more variation in household water demand than any other factor.

Darr, Feldman and Kanien (1975) study on the effects of the socio-economic factors on domestic water demand in Isreal, noted that income and its surrogates were very important predictors of residential water demand. Other factors identified in their study include number of persons per household, cultural origin, educational level and age of the head of the household plus number of rooms were valid predictors on residential water demand forcasting model.

Lee (1969) in his study on domestic water use in Bombay, India, found that water demand was closely related to housing condition and more income as to the position of housing connection and range of plumbing facilities. According to him, that demand for water use was a function of accessibility to water supply, housing condition and income level of the head of the household.

In Nigeria, studies on residential water demand have been carried out in different parts of the country.

Akintola and Areola (1980) embarked on a study on domestic water demand in Ibadan city, have found these factors to have significant effect on water use: house type; educational level of the head of the household; income level of the head of household, and water use infrastructure.

Chime (1984) noted in his study on water demand in Abakaliki, that price, educational level of the head of the household were important factors affecting water demand in the residential sector.

Studies carried out by Ugoh (1989), Samson (1991), Amodu (1993) on water demand and consumption in different parts of Kaduna metropolies, noted that cultural habits, standard of living expressed in income level of the head of the household; size of the household, climate, water use, infrastructure in the residence, characteristics of the population were the most factors that influence water demand and consumption.

Ibeziako (1985) in her study on residential water demand in Enugu urban area found these factors to have significant influence on water use: level of household water use infrastructure; frequency of water supply; social status of the head of the household, level of public infrastructure; availability of an alternative water source; and the size of the household.

In a sectoral water demand study by Ezenwaji (1990) in Onitsha urban area, he identified factors of the level of the household sanitation; kitchen water demand, level of water use infrastructure; and general level of water rate in residence to affect water consumption.

Industrial Water Demand

Bower (1966), De-Rooy (1974) studies on industrial water use noted that factors of price and size of industrial output to be very important factors affecting industrial water consumption.

Beckinsale (1969) noted that in most countries the domestic and industrial water consumption increases rapidly with the growth of population, development of industrialization and advances in standard of living and personal hygiene. His study however, indicated that industrial water consumption is on a bulkier scale. Confirming Beckinsale's findings, Leopold (1974) observed that even though water use in house is thought of as a principal reason for existence of municipal water supply system, industries are a major user of water from the system.

Roger and Stevens (1974) in their study on municipal and industrial water use in Seatle, U.S.A. found that the quantity of water usedby a particular industry depends on production and industrial activities undertaken. This has earlier been confirmed by Steward (1971) in which he noted that the commercial and industrial water forcast for a region established that the commercial and industrial plants in Seatle region of U.S.A consume about 34% of the urban water.

Biswas (1979) observed in his comments on environmental assessment in water resource planning that increases in population, per capita income, the need for increased production, shorter working hours and greater leisure are factors that affect water demand for domestic, agriculture, industrial and other uses.

McCuen (1975) study on industrial water use in New York identified assessed value of property and income to be most important factors influencing industrial water consumption. Confirming McCuen findings, Kollar and Brewer (1975) noted that some industries with high value added originally and high gross product originally demanded larger quantities of water.

In Nigeria studies on industrial water consumption have been investigated by some workers.

Mabogunje (1965) major findings were that most industries producing final products for consumption tended to be located in urban centres. The amount of water consumption is determined primarily by the type of industry and size of industrial establishment in terms of output.

Nsa (1981) investigation on industrial water use in Jos metropolitan observed that price and size of industrial activities were important factors affecting water demand.

Ezenwaji (1990) in his study on sectoral water demand in Onitsha urban, Nigeria, found that spatial character of manufacturing industries; level of inadequacy of public standard pipe cost of water consumption, and size of labour force in the industry were important factors influencing industrial water demand.

Samson (1991) noted in his study on water demand and consumption in Kaduna metropolis, that size of labour force, workshifts, nature of industrial activities and general sanitation influence water consumption in industries.

Commercial Water Demand

Past investigations on urban water use tended to be primarily more concerned with the residential and industrial sectors. This is evident in the dearth of data on commercial water requirements. However, with the growing commercial sector attempts have been made in this direction.

Headley (1963) observed that factors affecting water demand in urban residential sector cannot be used to explain that of commercial sector. According to him, commercial sector requires a closer study and better data. Wolff and Wright (1966) in support of Headley's view, noted that factors responsible for industrial and residential water demand and consumption do not apply in commercial sector. To them forcasting with such factors would lead to faulty result.

Whiteford (1972) was of the view based on six models of variation for forcasting residential water demand and use can be extended to commercial sector with modification. These include government regulation, pricing policy, educational campaign, housing trend, supply cost and change in technology. Morgan (1974) noted among the six model outlined by Whiteford, that pricing policy and change in technology would seem to explain most factors determining the commercial water demand in urban area.

McCuen (1975) identified factors of number of rooms contained in the commercial and number of persons per work-shift to be important variables that influence commercial water demand in Massachusetts, U.S.A.

Kim and Mucuen (1979) in their study on factors for predicting commercial water use in Massachusetts, U.S.A, identified factors of labour characteristic-employee water use; customer layout characteristics and water use facilities to be important factors.

Ezenwaji (1990) however, noted that factors of size of commercial work force, cost of water consumption, and availability of water amenities to be significant factors influencing commercial water consumption in Onitsha, Nigeria.

1.6 Research Methodology

1.6.1 Data Collection

In collecting data for this research we relied extensively on the use of questionnaires. Oral interview and field observation. Data collection for this research covered a period of 12 months, that is from April 1995 to April 1996.

Three sets of questionnaires were designed and utilized among the residential, commercial and industrial sectors of Makurdi. In administering these questionnaires, we employed two basic sampling techniques viz: Stratified and random sampling. The rationale for employing stratified technique in this study is that, according to Lee (1969), Danielson (1979) it permits comparison between different wards. Random sampling was also used in the sectors as it allows for equal chances for each household, commercial and industrial establishment of being selected for the study.

For the residential sector, a total of 800 questionnaires were administered among the demarcated 8 wards as adopted by census enumeration which we used as our sample stratum. Out of the total questionnaires recovered, appropriately completed and suitable for use stands at 259. Some of the questionnaires were returned unattended to, that is no response, others were poorly completed thereby unsuitable for use. Again some of the respondents were not found at the time of collection. This poor response may be attributed largely to the problem of illiteracy, misunderstanding of the intention of the research manifested in general unwillingness, hostility and carelessness on the part of the respondents. However, the number of recovered questionnaires is appropriate for any meaningful analysis as there was a fair representation of responses from all the wards.

In responding to the questionnaires, the head of the household was considered elligible. The head of the household as adopted in this study follows the definition by Darr, in this study is that, according to Lee (1969), Danielson (1979) it permits comparison between different wards. Random sampling was also used in the sectors as it allows for equal chances for each household, commercial and industrial establishment of being selected for the study.

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In responding to the questionnaires, the head of the household was considered elligible. The head of the household as adopted in this study follows the definition by Darr, Feldman and Kamen (1976) which is a married person with a family or unmarried person of at least 20 years of age living alone and earning a living.

Data was collected on the educational and income level of the head of the household, number of persons in a household; quantity of water used for cooking; washing cloths and general cleaning; existence of water tap in the household; number of hours water runs in a tap in a day; supplementary sources of water supply; distance to the nearest sources of water supply; number of water consuming appliances and the cost of water supply.

Respondents estimated the quantity of water demanded and consumed by households in units of standard buckets (SON, size 30) being of 12 litres. We then converted the number of buckets demanded into litres. But in households where water is consumed in Jerry cans, drums and tanks already graduated into litres, they were simply to indicate.

For the commercial sector, a total of about 200 questionnaires were administered among the subsectors: Hotels, Hair Dressing salons and Car wash establishments. Out of the total number of questionnaires administered, only 87 were returned. The poor response received here borders on the misconception by the respondents that the data may be used to increase water rate.

Data was collected on the quantity of water demanded and consumed; number of persons employed; number of customers that patronise them averagely in a day; number of workshifts per day; source of water supply; the cost of water supply and day of the week water is mostly needed in the establishment.

Estimation of the quantities of water demanded and consumed was done as in the case of the residential sector.

For the industrial sector a total of 20 questionnaires were administered among the subsectors: Bakeries, block moulding industries and Bottling Companies. Out of the 20 questionnaires, 17 were recovered.

Data was collected on the quantities of water demanded and consumed; volume of production per day; number of persons employed and workshifts, sources of water supply and cost of water supply.

1.6.2 Data Analysis

The major technique of analysis include homogenisation of data after which significant patterns, relationship were deduced through the use of basic statistical parameters such as totals, means, percentages and maps. Hand held calculator Casio Fx was used in computing some of the basic statistics. The outcome is presented and analysed in tables.

Multiple regression and principal components Analytic techniques, more powerful and sophisticated statistical techniques were also used in the analysis. Multiple regression was employed to analyse the relationship between the amount of water demanded by households, commercial and industrial establishments and set of predictor variables and to evaluate the inter-relationship among the variables influencing water demand and consumption. Principal Components Analysis was further employed to collapse the variables into significant factors explaining the underlying dimension of water demand and consumption in households and commercial establishments.

The above multivariate statistical analysis were performed with the aid of University of Nigeria IBM 4361/4 computers. The final results of these statistical analysis were fully used in analysing factors which influence sectoral pattern of water demand in Makurdi.

1.7 Thesis Plan

This study is divided into six chapters. The chapters are carefully organised in an inter-related sequence proceeding from the introduction through the findings to the conclusion and recommendations.

The first chapter is devoted to general introduction segmented into sub-sections. These include statement of the research problem, aims and objectives of the study, area of study, geology, relief and drainage, climate, population, growth and development, residential commercial and industrial, Theoretical framework, literature review, research methodology and thesis plan.

Chapter two dealt with sources of water supply in the various sectors of Makurdi. These include public sources of water supply, supplementary sources of water supply and their relative contributions, and privately developed water supply Agencies.

The sectoral pattern of water demand and consumption in the various sectors is discussed in chapter three. Pattern of water demand and consumption is discussed sector by sector and in subsectors of residential, commercial and industrial sectors. Comparison between the quantities of water demanded and consumed in each sector and total water demanded and consumed among the sectors and their percentage (%) demand is also discussed.

Chapter four is on the analysis of factors that influence pattern of water demand and consumption in the sectors. The factors which affect households, commercial and industrial establishments were identified, parametized and analysed.

Chapter five dwelt on optimal water supply and allocation focussing on plans to increase water supply in Makurdi and management options - Rational water allocation.

Finally, the summary of the major findings of this study, the conclusion and recommendation were the main thrust of chapter six.

CHAPTER TWO

SOURCES OF WATER SUPPLY IN THE VARIOUS SECTORS OF MAKURDI

Water which may be harnessed for municipal uses may come from any of these sources: surface sources such as a stream, river, lake, sea; and underground source as ground water. Where the source is a surface one necessary treatment and purification of raw water is done before it is made available for public consumption. This process is often carried out in a waterworks. But on the other hand where the source is an underground one sinking of a borehole has to be done for the extraction of water. Where ground water is available in sufficient quantities it is generally preferred because of its low cost, good quality, relatively constant temperature and chemical composition, and the fact that it is not so susceptible to pollution as a surface source.

2.1 Public Source of Water Supply in Makurdi

In developing countries, the provision of public water supply as a capital intensive project is regarded as the responsibility of the state. The responsible bodies are therefore, classified as State Water Agencies (SWAs) operating as water boards or corporations or public utilities as in the case of Nigeria (Bassey, 1994).

Originally, the public waterworks in Makurdi was built to supply water to the Government Reserve Area (G.R.A). There were thus no real plans or foresight for expansion in line with future socio-economic and technological development of the country. With Nigerian independence in 1960 and emergence of an increasingly large middle class in the non-G.R.A's of the city, the existing water works could not cope with the rapid urbanisation. Thus the need to build a bigger water works and to explore supplementary sources of water supply became imperative in the residential, commercial and industrial sectors of an urban area.

2.1.1 Makurdi Urban Waterworks

A municipal water system may consist of the following components: an intake structure from a reservoir, a natural river channel or ground well, aqueduct to convey the water from its source to the city, possibly a treatment plant for filtering, disinfecting and softening the water, a city distribution system including reservoirs, pumps, water towers, water main, valves, metering and taps (Kimper, 1965).

The main source of water for the Makurdi water works comes from river Benue which flows through the town dividing it into Makurdi South and Makurdi North. There are two water works, the Old and New waterworks, both of which are located at the Makurdi South river bank.

The Old Makurdi waterworks with a design capacity of 2.25 million litres/day was commissioned in 1963 under the ministry of works, land survey. The water works had only one sedimentation tank, two filter tanks with a holding capacity of 200,000 litres each, two pumps: low and high lift were used at the intake and on transmission lines respectively.

Raw water from River Benue was pumped through a 200 mm conduct to the treatment plant. Treated water is conveyed through a 250 mm pipe to an elevated precast concrete reservoir with a capacity of 900,000 litres built at the Old GRA. From there the water is distributed to consumers by gravity flow.

Under the old scheme, only few areas of Makurdi were connected to the municipal water supply (Fig.4). These areas include the Old Government Reserve Area (GRA) Central, Wadatta and Wurukum wards. Makurdi with a population of 53,967 in 1963 had average daily supply of 758,467 litres, that is a per capita consumption of 14.0 litres per day. The old water works later went out of use due to faulty pumps.

In 1978 a new water works was built by the Benue State Government under the Benue State water board. The development

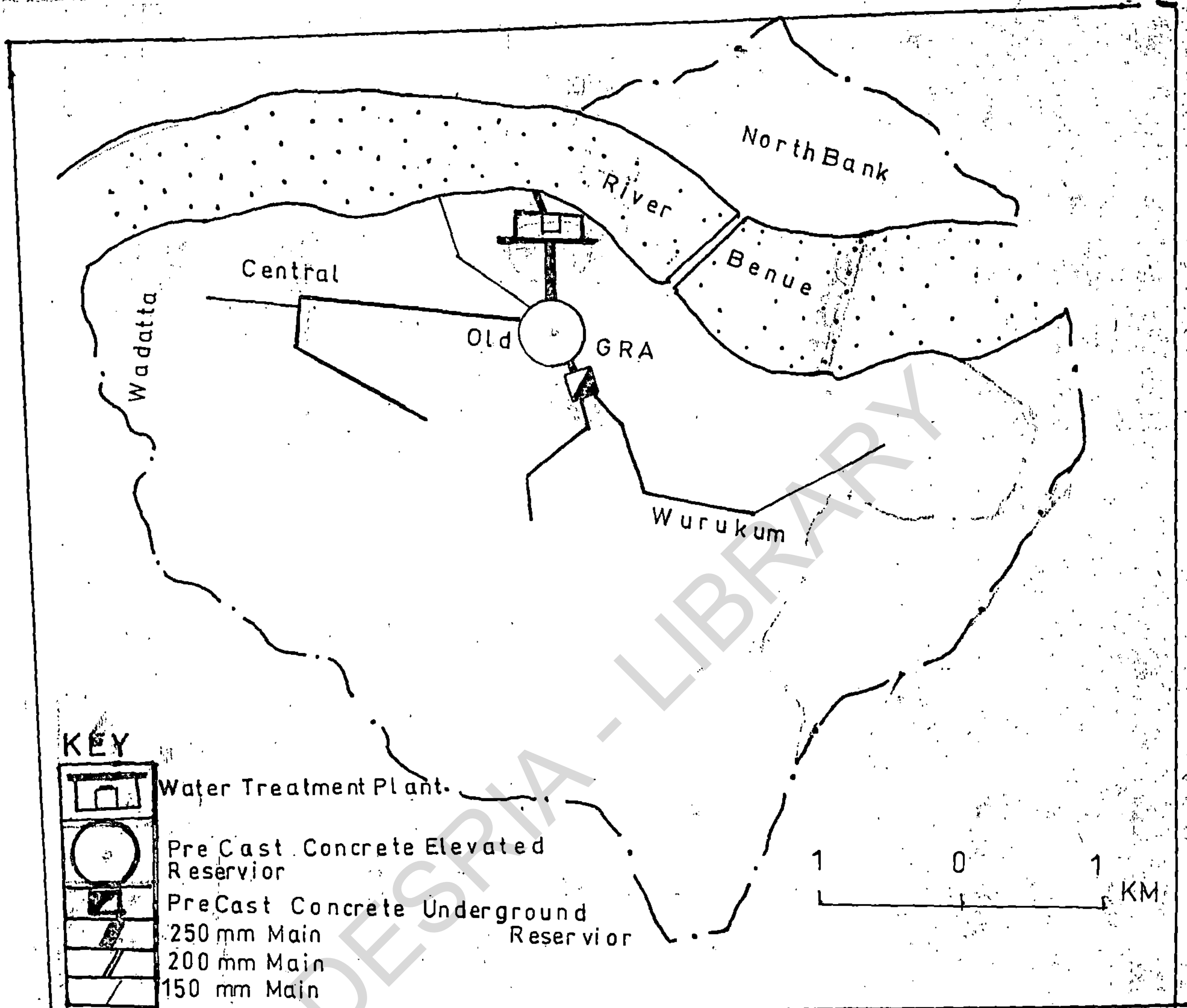


FIG 4 MAKURDI DISTRIBUTION MAIN UNDER OLD SCHEME 1963
(Source: Benue State WaterBoard Makurdi)

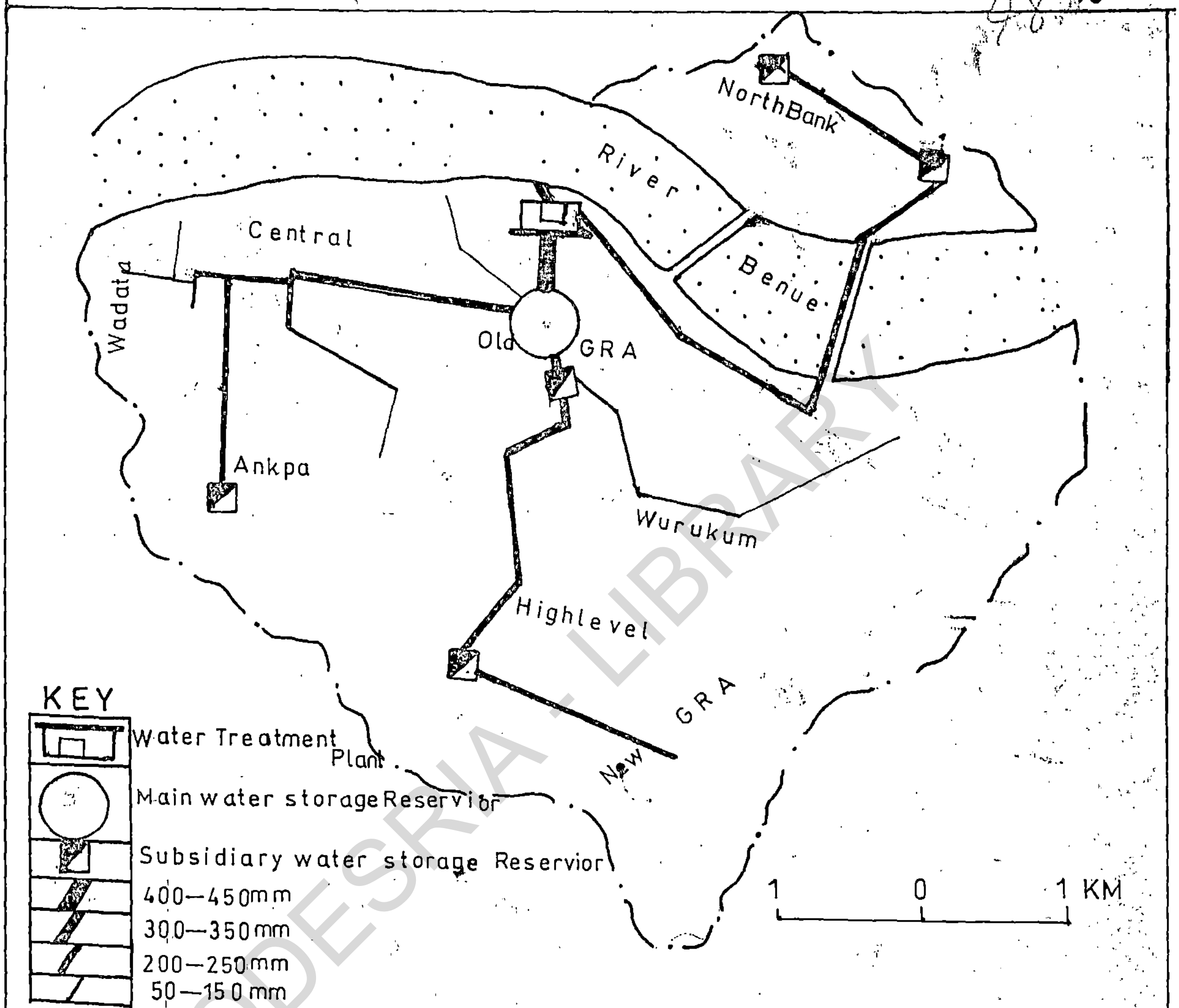


FIG 5 MAKURDI DISTRIBUTION MAIN UNDER NEW SCHEME 1978
(Source: Benue State WaterBoard, Makurdi)

of the New Makurdi waterworks was simply a rehabilitation and expansion of the old water works. The New water works with a plant capacity of 18 million litres/day was formally commissioned in 1978. With the completion of this scheme more areas of the town were connected to the public water supply (Fig. 5 and Table 2).

Table 2

Ward and Year Connected to Public Water Supply

Ward	Population	Year Connected
Old GRA	17,138	1963
Central	21,674	1963
Wadatta	19,711	1963
Wurukum	15,829	1963
High level	20,679	1978
Ankpa	20,933	1978
North Bank	19,034	1979
New GRA	12,938	1981

Source: Field Work

From Table 2, wards like Highlevel, Ankpa, North Bank and New G.R.A were connected to the public water supply under the new scheme.

The New Makurdi water works consist of the following

MAKURDI TREATMENT PLANT LAYOUT

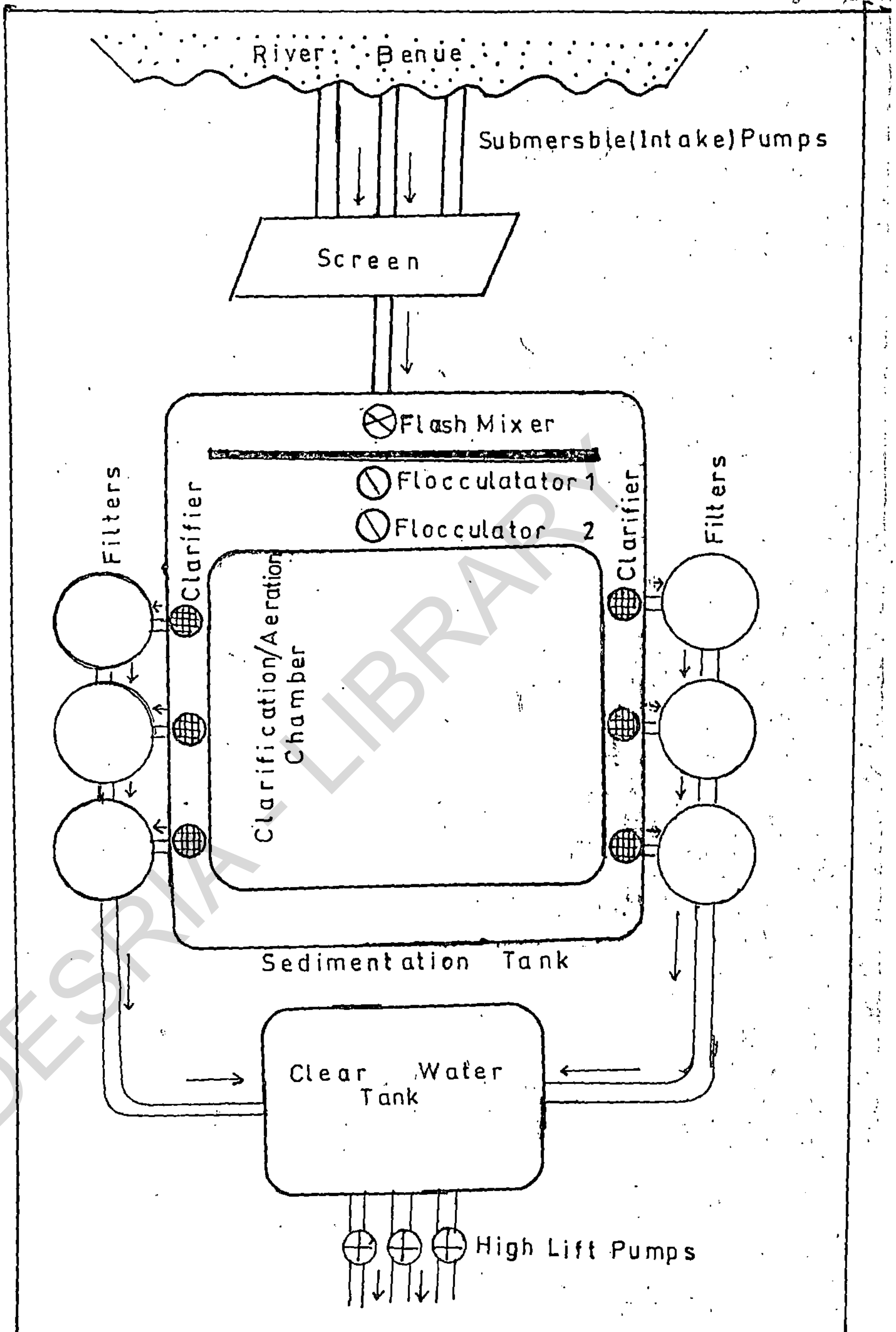


FIG6: SOURCE FIELDWORK 1996

components: three submersible pumps (intake) screens, a sedimentation tank, flash mixer, six filters, six clarifiers, clear water tank, three high lift pumps, four storage reservoirs located at Old GRA, Highlevel and North Bank ward from where distribution is done (Fig. 5) (Plate 1).

The primary objective of water treatment for public supply is to take water from the best available source and to subject it to processing which will ensure that it is potable, that is safe for human consumption, and aesthetically acceptable to consumers. For water to be safe for human consumption, it must be free of pathogenic organisms, and other biological forms which may be harmful to health. Also it should not contain concentration of chemicals which may be physiologically harmful. To provide safe water, the treatment plant must be properly designed and skilfully operated (Culp and Culp, 1974). The product of water treatment may be suitable for general domestic purposes or may be produced for higher pressure stream manufacture of food or beverages, and other specialised industrial purposes.

The Makurdi water works undertake the following water treatment processes: screening, sedimentation, coagulation, filtration, aeration and disinfection (See Fig. 6).

The first stage of the water treatment processes undertaken here is the screening of the raw water. A screen of 10 mm aperture mesh is used at the surface water intakes. Essentially, this is used to prevent entrance of materials such as sand, gravel, wood, leaves, algae, and fishes which may both damage or block the passage of raw water to the treatment plant. The screen is occasionally removed and cleaned manually to prevent it from blocking. For large treatment plant installation, the cleaning of the screen is done mechanically.

Screened water is then pumped into the sedimentation tank for further processing. Sedimentation with coagulation processes takes place in the sedimentation tank. The sedimentation tank is made up of concrete materials, rectangular shaped with a size of 3 by 12 m, a hopper bottom depth of 3m, and horizontal flow rate of 15 $m^3/m^2 d$. The tank is partitioned into three chambers: mixing flocculation, and clarification/aeration chambers.

Screened water enters the sedimentation tank through the mixing chamber. Pre-treatment water process takes place here. Coagulants are directly added to the water here in powdered forms. These chemicals form floc attracting the finely divided particles and colloidal matter in the water into group aggregates that are easily removed by sedimentation.

To ensure that these coagulants mix properly with raw water, they are stirred with considerable violence induced mechanically by flash mixers installed in the mixing chamber. This is done with the aim of removing the fine particles of suspended matter in the water. Coagulants used in Makurdi water works in treatment processes include Aluminium sulfate ($Al_2 (SO_4)_3 \cdot 18H_2O$, Hydrated lime ($Ca (OH)_2$, poly electrolyte as coagulant aid.

Aluminium sulfate which is insolvable and colloidal form floc. Hydrated lime is principally used as coagulants to provide alkalinity in water as it is treated with Aluminium. Poly Electrolyte are used as coagulant aid in form of synthetic, organic water solvable high molecular weight polymers. According to Smethurst (1986), poly electrolyte provides a powerful auxillary bridging and linking action to prevent rapid settlement.

From the mixing chamber, coagulated water passes to the flocculation chamber. Flocculation which is a practice of gently stirring the water which floc has been formed to induce the particles to coalesce and grow is done by means of a mechanical device called the flocculators. The bigger and denser the floc particles, the quicker is the rate of settlement. Two flocculators are installed in this chamber for this purpose. They are kept continuously working. Through flocculation sedimentation takes place. Suspended materials in water separates from water resulting into subsidence or deposition with the removal of suspended materials by sedimentation from the water, water passes to the clarification and aeration chamber.

Clarification of water is done with the use of clarifiers. The clarifiers contain layer of earlier formed sediments in which water passes through to the filter tanks for further clarification. Six clarifiers in a row of threes is built on the either side of the sedimentation tank. To prevent the clarifiers from blocking, sludge dislodgement is continuously done through valves out of the system.

Aeration provides oxygen from the atmosphere to effect beneficial changes in raw water. This is facilitated by the use of aeration nozzles in the clarification chamber. Besides, aeration may liberate undesirable gases such as carbon dioxide and hydrogen sulphide. Sunlight penetrates into the water here.

While screening removes larger suspended solids from water, and sedimentation following chemical coagulation will remove most of the residuals suspended matter. However, there is usually a remain of some floc particles and other suspended materials. To remove them and to further reduce the bacterial content of water to ensure production of clear and attractive water, filters are used. This stage is referred to as filtration stage. Six filters of horizontal steel pressure cylinders containing bed of granular materials of sand are used. These filters are installed in a row of threes on the either side of the sedimentation tank on the ground. Clarified water from the clarifier are delivered into the filter tanks through 10 mm diameter pipe. As the water is passed through the filter tanks remain of floc particles not removed by the clarifier are trapped by the sand materials, clear water is then discharged into the clear water tank. Rapid sand filters are used in the water purification process.

To safeguard against clogging of the filters, leading to head loss backwashing of the filters is done hydraulically and occasionally. Backwashing is the upward flow of water expands, the bed producing a fluidized condition in which accumulated debris is scoured off the particles. Compressed air scouring prior to backwashing improve cleaning and reduces wash water consumption.

Before water is finally discharged for public consumption, it is made to undergo post-treatment. This is to ensure that the water is both safe for drinking and attractive at the same time. Disinfection by post chlorination is a final stage of water treatment processes undertaken in Makurdi water works. Post-chlorination is done because, due to the small size of bacteria it is not possible to ensure complete removal from water by physical and chemical means alone and for potable supplies it is necessary to ensure the death of harmful micro-organism by disinfection (Tebbut, 1977). Hardenberg and Rodie (1961) however, noted that chlorine (Cl) is used in water not only for disinfection, but also for other purposes such as control of algae or other growth in reservoir, prevention of organic in pipe lines especially growth of iron fixing and shime producing bacteria. According to them, since chlorination is a final safeguard of the quality of water, the necessity for a continuous and effective application cannot be over-emphasised. Liquid chlorine contained in horizontal steel pressure cylinders of 864 kg and 1000 kg are used respectively for disinfection. Chlorine is injected into clear water in regulated quantity by dosing meter pump from the chlorination room.

In Makurdi water works, the quantity of water produced, chemical consumed and fuel used in running the generating plants in 1994 and 1995 are given in tables 3 and 4.

Table 3

Monthly Quantities of Water Supplied for 1994 and 1995

Month	Quantities of Water Supplied in 1994 in M^3	Quantity of Water Supplied in 1995 in M^3
January	475,200	313,200
February	411,840	280,800
March	475,200	324,000
April	447,120	330,080
May	427,680	341,600
June	414,720	330,080
July	238,960	341,600
August	247,200	330,080
September	252,000	313,220
October	398,320	324,000
November	376,320	313,200
December	493,420	324,000
Total	4,659,980	3,883,860
Mean	388,337	323,655

Source: Benue State Water Board, Makurdi

From Table 3 apparent decline in the quantities of water supplied in Makurdi is noticed between 1994 and 1995. In 1994 a total quantity of 4,659,980,000 litres/day of water was supplied as against 3,883,860,000 litres/day in 1995 leaving us with a total drop in the quantities of water supplied at 726,120,000 litres/day. Similar trend is also noticed in the mean monthly water supplies. Besides close examination of the quantities of water supplied among the months of the year in 1994 shows that the amount fluctuates. For instance in January the quantity of water supplied was 475,200,000 litres/day, it dropped to 411,840,000 litres/day in February, later rose to 475,200,000 litres/day in March and dropped to 447,120,000 litres/day in April. Similar trend was also observed in the quantities of water supplied in 1995.

In the case of per capita water supply, in 1994 and 1995 as shown in Table 3 stands at 87.7 litres/day and 70.8 litres/day respectively. We obtained the per capita water supply by dividing the mean daily supply by the projected population figures. From the figures of per capita water supply in Makurdi fall below the Federal Government recommended minimum of 115 litres for urban areas. With the low per capita water supply in Makurdi, the implications is that people will be forced to rely heavily on supplementary sources of water supply to meet their water requirements.

The general trend in the declining quantities of water supplied and fluctuating amount of water supplied among the months is however, not without some causes. The main cause identified is when there is a breakdown in any of their pumps both the intake and high lift and they have to make do with either one or two of, instead of all the pumps. Again when they are carrying out a general maintenance and when they are in shortage of diesel for generating plant for adequate pumpages, (Agba, 1996, Personal communication).

As earlier established, before water is made available for public consumption, it must have to pass through all the necessary stages of treatment. The quantities of chemical consumed and fuel used for generating plants in 1994 and 1995 are given in Table 4.

Table 4

Quantity of Chemicals and Fuel Used in 1994 and 1995

Month	CHEMICALS AND FUEL USED IN 1994 (KG/LITRES						CHEMICAL AND FUEL USED IN 1995 (KG/LITRES)					
	Alum	Liquid Chl.	Pow. Chl.	Hyd. Lime	Poly Elec	Fuel '000	Alum	Liq. Chl.	Pow. Chl.	Hyd. Lime	Poly Elec	Fuel '000
Jan.	8600	-	335	-	45	22	5000	370	130	1675	40	20
Feb.	5500	-	225	-	44	20	6050	370	150	600	38	19
March	8350	-	495	-	42	24	5950	430	225	2070	47	21
April	8345	52	-	1650	-	29	7200	380	240	2700	47	22
May	9000	480	-	2400	-	24	7150	460	165	1975	48	23
June	5700	300	-	2900	-	29	6000	530	135	2550	46	20
July	5200	220	-	1735	-	29	6500	400	160	1150	47	21
Aug.	6300	230	-	1570	45	30	6195	460	45	2500	47	24
Sept.	6050	250	-	2300	45	24	6650	400	75	1200	48	23
Oct.	6150	250	45	1300	40	25	5600	370	48	1250	48	22
Nov.	7650	250	135	2100	45	20	4800	370	30	1525	48	22
Dec.	7650	150	120	-	46	41	5950	39	40	1250	48	27
Mean	7041	182	113	1330	29	25	6137	413	121	1704	46	22
Total	84,492	2,182	1,355	15,955	352	297	73,645	4,950	1,450	20,450	552	264

1994	1995
Mean Monthly Cost of Chemicals and Fuel = ₦1,142,880. Annual Cost of Chemicals and Fuel = ₦13,714,560.	Mean Monthly Cost of Chemical and Fuel = ₦1,446,900. Annual Cost of Chemicals and Fuel = ₦17,362,800.

Source: Benue State Water Board (1996).

As can be seen from Table 4, in 1994 a total of ₦13,714,560 was spent in purchase of water treatment chemicals and diesel for the generating plant. This rose to ₦17,362,800 in 1995. The implication of this is that with the rising cost of water production, they may be forced to reduce the quantity of water that is produced and supplied. Alternatively, they may be compelled to supply water that is inadequately treated or even untreated which is dangerous healthwise. In fact the rising cost of water production has been identified as one of the major causes of inadequate water supply in Makurdi (Agba, 1996).

2.1.2 The Distribution Network

The water distribution system according to Demoyer and Hortwitz (1954) and Mcpherson and Prasad (1966) is all water works components from the distribution of finished or portable water by means of gravity storage or pumps through distribution networks to consumers or other users including equalizing storage. The distribution network is therefore a system of conduits and pipes that convey water from the treated point to storage reservoir then to consumers. This is done through distribution mains of various diameter. The Makurdi water works consist of the following components for storage and distribution of water to consumers.

Plate 1

New Makurdi Waterworks Built in 1978.

Plate 2:

Pre-Cast Concrete Elevated Reservoir - Feeder Reservoir
With a Capacity of 900,000 Litres Located at Old GRA.

Table 5

Type of Reservoirs and Area(s) Served

Type of Reservoir	Location	Capacity Litres	Year Installed	Area(s) Served	Present Condition
A) Pre-Cast Concrete elevated.	Old GRA	900,000	1963	Feed other reservoirs	Functioning
B) Pre-Cast Concrete underground	Old GRA	225,000	1963	Old GRA, Central, Wadatta and Wurukum wards	"
C) Elevated Steel tank	Highlevel	900,000	1978	Highlevel, Ankpa and New GRA	Not Functioning
D) Elevated Steel tank	Modern market	400,000	1978	Modern market, part of Ankpa ward	Functioning
E) Pre-cast concrete underground	North Bank	200,000	1979	North Bank	"
F) Elevated Steel tank	North Bank	450,000	1979	North Bank	Not functioning

Total storage capacity 3,075,000 litres

Source: Benue Water Board (1996).

As shown in Table 5, the total reservoir storage capacity of Makurdi water works stands at 3,075,000 litres.

The pre-cast concrete elevated (A) at Old GRA with a capacity of 900,000 litres acts as a feeder reservoir to other reservoirs except the two at North Bank (E) and (F)(Plate 2

Treated water from water works is fed to this storage reservoir which in turn feeds the pre-cast underground (B) located at Old GRA (225,000 litres). This reservoir serves areas like Old GRA, Wadatta and Wurukum wards.

Elevated Steel tank (C) with a capacity of 900,000 litres at Highlevel ward serves areas like Highlevel, New GRA and part of Ankpa ward.

Elevated steel tank (D) with a capacity of 400,000 litres at Makurdi modern market serves the modern market and parts of Ankpa ward.

Treated water from the water works is pumped directly to the pre-cast concrete underground reservoir (E) with a capacity of 200,000 litres which in turn feeds the elevated steel tank (F) which is also located at North Bank. This reservoir has a storage capacity of 450,000 litres.

The elevated steel tanks (C) and (F) at Highlevel and North Bank wards that were installed in 1978 and 1979 went out of use in 1982 and 1985 respectively due to problem of rust resulting into leakages. Areas formerly served by the elevated steel tank (C) at Highlevel are now catered for by the pre-cast concrete underground reservoir (B) at Old GRA, while the pre-cast underground reservoir (F) at North Bank only serves a very limited area of North Bank.

The Makurdi water works distribution mains range from 450 mm to 50 mm diameter. The distribution of water to the various parts of the town is done as follows: (Fig 6)

Raw water from the river Benue by means of intake pumps is transmitted to the treatment plant on a 300 mm diameter steel ductile pipe. A treated water from the water works is pumped to the pre-cast concrete reservoir (A) at Old GRA on a 450 mm diameter trunk transmission main. From this reservoir water is fed to other reservoirs located at Old GRA, Highlevel and Ankpa wards respectively.

Water is delivered to the pre-cast concrete underground reservoir (B) from the pre-cast concrete elevated at Old GRA (A).

Primary mains of 300 mm and 350 mm diameter pipe convey water from the pre-cast underground (B) at Old GRA itself and directly from the pre-cast concrete reservoir (A) to central ward.

Secondary mains of 200 mm and 250 mm diameter transmit water from the primary mains to areas such as Wadatta, Ankpa, Highlevel and New GRA wards. 200 mm diameter pipe conveys water directly from the water works to North Bank ward.

Another secondary main of 150 mm pipe conveys water directly from the pre-cast concrete to Wadatta ward.

Distribution mains of 50 diameter further transmits water from the primary and secondary mains of 350 mm - 150 mm diameter across streets to buildings and consumer service pipe of 31-12.3 mm diameter (Kasimi, 1990).

According to Kasimi (1990) the pattern of distribution network is that of a branching type characterised by dead ends, that is end of water distribution main not connected to the network. According to him, the layout is a single type which necessitates crossing the road by connecting buildings opposite the road.

2.2 Supplementary Sources of Water Supply In Makurdi

The idea of exploring supplementary sources of water supply in urban areas emanates from the inability of the public water supply to adequately meet the water requirements of the growing urban population and the expanding commercial and industrial activities. Supplementary sources of supply therefore tend to fill the deficiency gap created by the public water supply.

Supplementary sources of water supply include all other sources of water supply except that of the public water works. These sources may include any of these: Rain collection, a natural stream or river, pond or spring, well, water vendors, and privately developed borehole or water works to meet their water needs.

2.2.1 Rain Collection

Rain harvestivity is one of the oldest traditional method of water supply. Rainfall intercepted by the roof of houses is collected in containers. To harvest a large quantity of water from rainfall iron roof gutters are installed from which water drains to steel or concrete storage tanks for use.

Although rain harvestivity is a seasonal means of water supply only possible during the rainy season, that is from May to October, it is a supply that is available to the consumers at no price. Besides, it is a better alternative to river water during rainy season when the rivers are highly polluted with impurities washed down by overland flow. Rain collection is a common practice in the residential sector of an urban area.

2.2.2 River

Historically the availability of a surface water source is one of the strong deciding factors in the establishment and development of human settlements. Makurdi has an advantage of being built on the banks of the mighty river

Plate 3

WOMEN AND CHILDREN WASHING AND BATHING AT RIVER BENUE DURING DRY SEASON.

Plate 4

SMALL SCALE WATER VENDORS (MAI RUWA).

Plate 5

LARGE WATER VENDORS.

Benue. Apart from providing a source of water for public water supply, the river also performs the role of supplementary supply for the residential, commercial and industrial uses. For instance, of the sampled households in Central and North Bank wards, 22 out of 34 households and 23 out of 32 households depended heavily on the river Benue for their supplies respectively (Plate 3).

The economic advantage of water supply from a river is that it is used without much cost.

2.2.3 Wells

Where a surface water source is lacking or far distant then ground water provides an alternative source. In Makurdi, all the sampled wells are of shallow type with a mean depth of 3m.

2.2.4 Water Vendors

These are people that hawk water round on commercial basis. We have two types of water vendors in Makurdi. They are:

(a) Those that hawk water on a small scale in 20 litre containers (Plate 4). They sell water directly to consumers at the door step of their houses. This is commonly done by the Hausas popularly known as "Mai Ruwa" in Hausa.

(b) They are those that hawk or sell water on a larger scale using tanker trucks. They sell water majorly to houses or commercial and industrial establishments that have already built water reservoirs. Water bought is delivered directly from the water tankers to these reservoirs (Plate 5). In residential areas, apart from the quantity of water used for household needs, they also retail some quantities in standard bucket (SON, 30) and also in 20, 40 and 50 litre jery cans.

Generally, water hawking is prominent where they are problems of acute water shortages and where public water supply is highly unreliable. For instance in North Bank ward where public water supply is near to nothing water vendors are highly patronised. Of the 32 sampled households 19 depended mainly on water vendors. Here a 220 drum of water sells at ₦35, a 200 litre tank at ₦250 and 4000 litres tank of water at ₦350 respectively.

Hotels and restaurants in North Bank depend entirely on water vendors. Water is sold to them at the following prices: 2000 litre tank at (₦250) and 4000 litre tank at (₦350) and 6,200 litre tank at ₦500.

2.3 Relative Contribution of the Various Sources of Water Supply in the Sectors

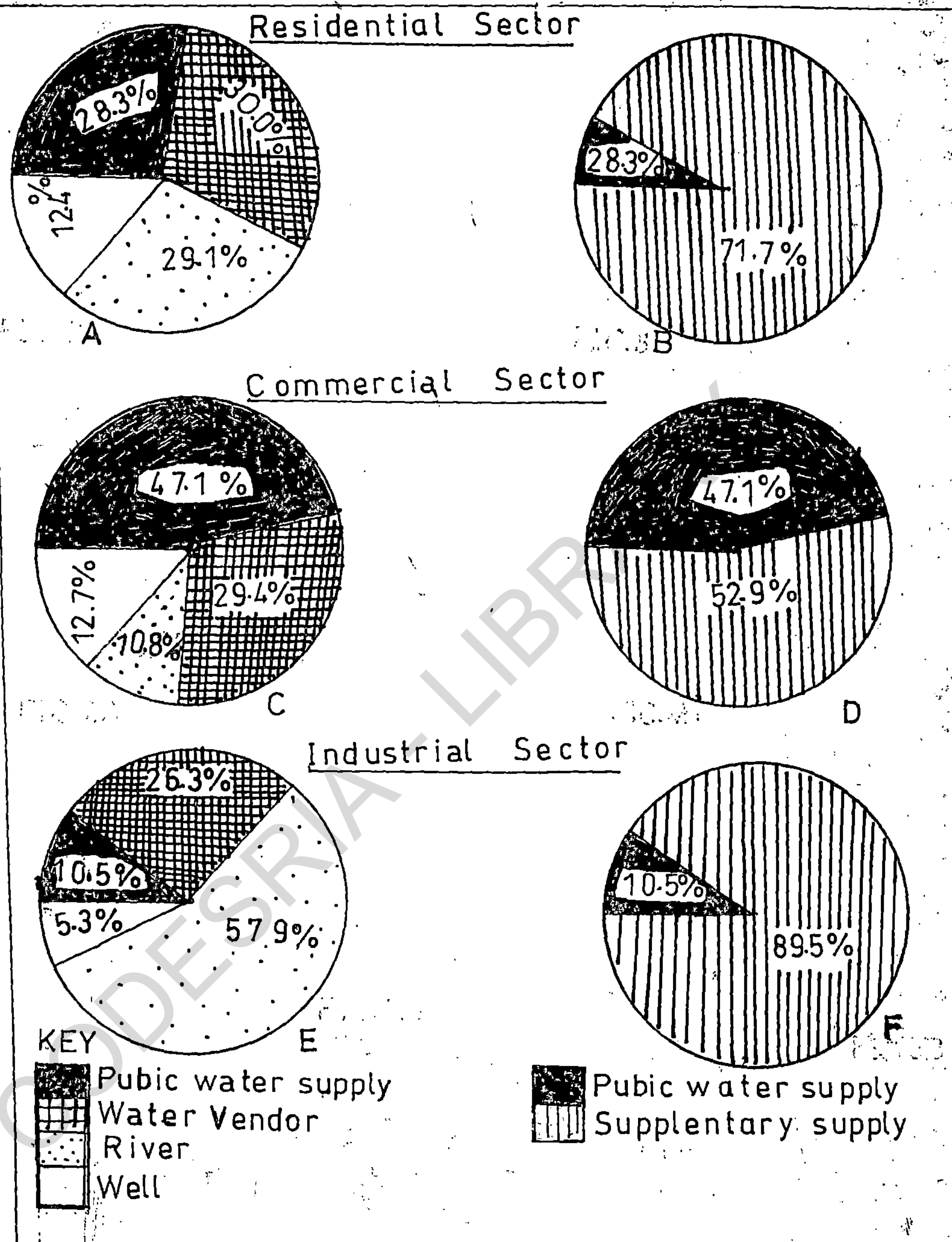
Our investigation has shown that supplementary sources of water plays a very important role in meeting a sizeable proportion of the water requirements of the various sectors in Makurdi.

2.3.1 Residential Sector

In the residential sector based on the sampled households, the % relative contribution of the various sources of water supply in the order of rank are as follows: River (29.3%), public water supply (28.3%), water vendors (30.0%), well (12.4%). This implies that supplementary sources of water supply contributed the highest percentage of (71.7%) of water used in the residential sector while the public water supply contributed only (28.3%). This is depicted in Fig.7 A and B.

2.3.2 Commercial Sector

Commercial sector as used in this study includes Hotels, Hair Dressing Salons and car wash ventures. The (%) relative cumulative contribution of the various sources of water supply in the commercial sub-sectors in their order of rank are as follows: public water supply (47.1%), water vendors (29.4%), wells (12.7%), river (10.8%). Supplementary sources



PERCENTAGE CONTRIBUTION OF THE VARIOUS SOURCES OF WATER SUPPLY IN THE SECTORS (FIG 7) contributed more than 50% water utilized in commercial sector while public water supply contributed (47.1%). This is also shown in Fig.7C and D.

2.3.3 Industrial Sector

Industrial sector as used in this study includes block moulding industries and bakeries. The percentage (%) relative cumulative contribution of the various sources of water supply in the industrial subsectors in their order of rank are as follows: River (57.9%), water vendors (26.3%), public water supply (10.5%), well (5.3%), Supplementary sources of water contributed almost all the water (89.5%) utilized in the industrial sector while public water supply contributed only (10.5%). This is also shown in Fig.7 E and F.

2.4 Privately Developed Water Supply Agencies

These are privately developed water supply sources intended meet the water requirements of industries and institutions in Makurdi. These are: the Benue Bottling Company, the Benue State University, the University of Agriculture and the Nigerian Army School of Engineering (NASME). The need to develop their own water supply schemes emanates from the fact that as very large organisations they need substantial quantities of water on daily basis which public water supply in most cases may not be able to meet. To ensure therefore that this is adequately taken care of the need to develop their own private supply became necessary.

2.4.1 Benue Bottling Company Water Works

The water works was built in 1990 to take care of the industrial water needs of the company. The water works has a plant capacity of 1.8 million litres/day and is fed with raw water from river Benue which is about 1 km away. The raw water is subjected to necessary treatment to the required company quality standard before it is made available for the production of soft drinks. Chemicals used in the water treatment here include Aluminium sulfate, Hydrated lime and chlorine.

The quantities of water consumed in a day in the company is determined by the number of hours of production. In one hour 80,000 litres of water is used in the production process. For a day's production which normally lasts for eight hours, a total of 640,000 litres of water will be consumed in the production process.

2.4.2 Benue State University Water Works

The water works was originally built by the then Benue

Plateau Government in 1974 for the Government Technical College Makurdi. The system broke down in 1977. With the establishment of Benue State University in 1993 taking off temporarily at the college, the water works was rehabilitated to meet the water needs of the institution.

The water works consists of two intake pumps, a sedimentation tank, a fresh water tank, a high lift pump, elevated storage reservoir, transmission and distribution network.

The intake pumps convey raw water from river Benue to the concrete sedimentation tank. Water treatment chemicals such as Aluminium sulfate, Hydrated lime and Chlorine are manually mixed and added directly to the water in the sedimentation tank. The water is allowed for six hours to settle before it is delivered to the concrete underground reservoir with a capacity of 700,000 litres. A high lift pump transmits the treated water to the concrete elevated reservoir with a capacity of 57,960 litres located at the highest point of the University Campus on 200 mm diameter pipe. From here water is distributed to the various parts of the campus: Academic blocks, student hostels, staff quarters, etc. This service reservoir is filled two times in a day, in the morning and afternoon. This means that a total of 2 x 57,960 litres (115,920 litres) is supplied daily.

At this time of this study the University population was 2,600. This means the University has a per capita water consumption of 44.6 litres.

2.4.3 University of Agriculture Water Works

The University of Agriculture was established by the Federal Government in 1988. The University is located in North Bank ward.

The University water works which formed part of the capital project was built in 1990 and formerly commissioned in 1991.

The water works consists of three submersible intake pumps, raw water station, sedimentation tank, two clarifiers, two filters. Clear water tank and storage reservoir. The water work has a plant capacity of 1.8 million.

Raw water from river Benue is pumped into raw water station located at the bank of river Benue. The raw water in turn is transmitted through a 250 mm diameter pipe to the water works for necessary treatment. Chemical used in the treatment of water here includes Aluminium sulfate, Hydrated lime and chlorine. These chemicals are injected into the raw water in the sedimentation tank through a dosing metered pump from the chemical room. Coagulated water is then passed through the clarifiers and filters to the clear water tank from here water is pumped out for distribution to the various parts of the University Campus.

Table 6

Storage Reservoirs At the University of Agriculture

Type of Reservoir	Location	Capacity (Litres)	Area(s) Served
A concrete surface Reservoir (A)	Waterworks	1,800,000	Feed other reservoir
Surface steel tank (B)	Student Hostels A & B	1,200,000	Student Hostels A and B
Elevated steel tank (C)	Student A & B	30,000	Student Hostel A and B
Elevated steel tank (D)	Academic Block A	2,500	Academic Block A
Elevated steel tank (E)	Academic Block B	2,500	Academic Block B
Elevated steel tank	Staff quarters	40,000	Staff quarters
Elevated steel tank (F)	Admin. block	10,000	Administrative block
	Total	3,414,000	

Source: Field work, 1996.

From Table 6, a total storage reservoir capacity of

3,414,000 litres was installed to meet the water requirements of the Campus.

The concrete surface reservoir (A) with a capacity of 1,800,000 litres feed other reservoirs. Water is pumped from this reservoir on a transmission main of 200 mm diameter pipe to the storage reservoirs located at the various parts of the campus. The surface steel tank (B) and (C) with capacities of 1,200,000 and 30,000 litres is filled 5 times in a day for student hostel use. This means student hostels in a day consume 1,200,000 + 30,000 x 5 litres (6,150,000 litres/day). While the reservoir (D) and (E) with capacities of 2,500 litres are filled 2 times in a day, reservoir (F) at the staff quarters with capacity of 40,000 litres and that of the Administrative block with a capacity of 10,000 litres are filled once in a day. On the whole, the University consumes a total of 6,150,000 + 5,000 + 40,000 + 10,000 litres (8,200,000 litres)/day. Out of this quantity of water supplied villagers within the University environ consume an estimated 38% proportion of the water produced in a day (Daudu, 1997).

2.4.4 <u>Nigerian Army School of Engineering Water Works</u>

The water works was built in 1997 to cater for the water needs of the residents in the barracks of the school.

The water work is located at the North Bank of river Benue.

The water works has plant capacity of 1,800,000 litres. The water works is fed with raw water from river Benue. The system consists of a sedimentation tank, clarifier, filter, clear water tank and storage reservoir.

Chemicals used in water treatment here include Aluminium sulfate, Hydrated lime and chlorine. These are added directly to the raw water in the sedimentation tank. Treated water is pumped on a 250 mm diameter pipe to the two elevated steel tanks of 40,000 litres each located at the highest point of the barracks. From these tanks water is distributed to the blocks by gravity flows. As at the time of this study, the population of the barracks was 3,000.

CHAPTER THREE

WATER DEMAND AND CONSUMPTION IN THE VARIOUS SECTORS IN MAKURDI

In water management studies, water demand and consumption have often been used interchangeably (Frankel and Shouvanarikul, 1973; Rees, 1973; Akintola and Areola, 1980; Hanke and Demare, 1982). According to Chima (1994), this is attributed to the fact that consumption of water in a geographical area determines water demand and in most cases factors that affect water demand are also factors that affect the consumption pattern. He however, observed that major differences exist between water demand and consumption. Water consumption is usually less than that of water demand. Because of this difference, Frankel and Shouvanarikul (1973), Rees (1973), Hanke and Demare (1982) and Chima (1994) have used present water consumption patterns to predict water demand for domestic and non-domestic uses.

In this study water demand is used to mean the expected or anticipated amount of water required for domestic and non-domestic uses. While water consumption is used to mean the actual amount of water fetched or consumed by the people. This is often regarded as supply.

3.1 Water Demand in the Residential Sector

In assessing water demand in the residential sector, estimation of the quantities of water demanded were obtained based on the recovered questionnaires. A questionnaire survey of 800 households was conducted out of which 259 questionnaires were recovered. Using the recovered questionnaires the results of analysis of water demanded and consumed are discussed below. The respondents in our survey estimated their household water demand in number of buckets, a standard bucket being of 12 litres (Standard Organisation of Nigeria (SON), size 30). We then converted the number of buckets demanded into litres. The estimates of the quantities of water demanded per household in the wards are presented in Table 7.

Table 7

The Household Water Demand in the Residential Sector

Ward	No. of Sampled Household	Mean Household Size	Mean Water Demand Per Household (Litres)	Total Mean Water Demand in the Residential Sector (Litres)
Central	34	13	1,010	34,340
NorthBank	30	11	908	27,240
Ankpa	37	7	1,608	59,496
Highlevel	39	6	960	37,440
Wadatta	28	5	554	15,512
Wurukum	33	5	560	18,480
Old GRA	33	7	1,212	39,996
New GRA	25	6	1,116	27,900
	Mean	7	991	32,551
			Total	260,404

The mean household size in Makurdi was found to be 7 persons with a mean household water demand of 991 litres per day (lhd) as shown in Table 7. This amounts to a total mean water demand of 260,404 litres (lpd) in the residential sector.

As can be seen from Table 7, Ankpa ward has the highest relative mean water demand of 1,608 litres (lpd). Conversely Wadatta ward has the lowest mean domestic water demand of 554 litres (lpd). This gives us a range of 1,054 litres (1,608 - 554 litres) per household per day. This rather very high range may be explained in the context of various factors that affect water demand in different wards of the city of Makurdi. These may be physical and socio-economic factors.

3.2 Water Demand in the Commercial Sector

Interest among investigators on water demand in urban areas seems to focus more on water demand in the residential and industrial sectors to the almost total neglect of that of the commercial sector. This is demonstrated in the paucity of data on commercial water demand in the urban areas. The implication is they have simply undermined the growing water needs in the commercial sector. According to Kim and McCuen (1979), several factors have generated a need for research in water demand in the commercial establishments. Prominent among these is that economic growth in the commercial sector of the economy has far exceeded that of the residential and industrial sectors. Employment in the service sector of the economy account for nearly 60% of the total employment in the nation. In many cities of the world commercial water demand represents 25% of the total demand.

In this study commercial water demand is used to mean water use in Hotels/Restaurants, Hair Dressing Salons and Car wash establishments. In a study of this kind, it is not possible to examine water demand in all the commercial establishments in Makurdi. What we have simply done is to select some of them as sample for study. The selection of these commercial establishments was informed by the fact that they are among the commercial establishments that need mostly for their daily services. A questionnaire survey of 200 commercial establishments was conducted, out of which 87 were recovered. Our analysis of water demand in this sector is thus based on the recovered questionnaires. They estimated quantities of water demanded in their establishments in number of standard bucket unit (SON, size 30) which has a capacity of 12 litres which were converted into litres, and those that make use of water in drums, Jerry cans, storage tanks already graduated into litres they were simply to indicate.

A hotel is defined for the purpose of this study as an inn or establishment which has provision for eating, drinking and lodging on a commercial basis.

Table 8

Water Demand in the Hotel Establishments

Ward	No. of Sampled Hotels	Mean Water Demand for Hotel (Litres)	Total Mean Water Demand in Hotels (Litres)
Central	4	1,340	5,360
NorthBank	11	1,544	16,984
Ankpa	3	1,140	3,420
Highlevel	15	1,555	23,325
Wadatta	6	1,400	8,400
Wurukum	5	1,490	7,450
Old GRA	6	5,000	30,000
New GRA	3	1,678	5,034
	Mean	1,893	12,497
		Total	99,973

The mean water demand in hotels in Makurdi was found to be 1,893 litres (lpd) with a total mean water demand of 99,973 litres (lpd) in the hotel establishment (Table 8).

As can be seen from Table 8, hotel establishments in Old GRA have the highest relative water demand of 5,000 litres (lpd) while hotels in Ankpa ward were noted to have the lowest mean water demand of 1,140 litres (lpd). This gives a range of 3,860 litres (5,000 - 1,140 litres). This rather very high range in the mean water demand among the hotel establishments in Makurdi may be attributed to a number of factors. These include social factors such as the size of labour force, number of customers that patronise the hotel on daily basis, type of services rendered such as lodging and accommodation and physical factors such as the level of water use infrastructure in the establishment. For instance, our study revealed that Benue Hotels Limited alone at Old GRA ward have a staff population of 121, runs three shifts in a day, has an average number of 10 persons patronising them daily, renders lodging and accommodation services needed about 10,000 litres (lpd). Whereas Top Rank Hotel in Wurukum has staff population of 15 persons, runs two shifts, has an average customer of 5 persons per day, needed 1,200 litres (lpd).

The mean water demand in hotel establishments in their order rank are as follows: Old GRA 5,000 litres (lpd), New GRA 1,678 litres (lpd), Highlevel 1,555 litres (lpd), North Bank 1,544 litres (lpd), Wurukum 1,490 litres (lpd), Wadatta 1,400 litres (lpd), Central 1,340 litres (lpd), Ankpa 1,140 litres (lpd).

Table 9

Water Demand in the Hair Dressing Salons

Ward	No. of Sampled Hair Dress Salons	Mean Water Demand for H/Dress Salon (Litres)	Total Mean Water Demand in Hair Dress Salon (Litres)
Central	4	575	2,300
North Bank	2	260	520
Ankpa	-	-	-
Highlevel	6	675	4,050
Wadatta	6	316	1,896
Wurukum	2	400	800
Old GRA	-	-	-
New GRA	-	-	-
	Mean	445	1,913
		Total	9,566

As can be seen from Table 9, the mean water demand in Hair Dressing Salons in Makurdi was found to be 445 litres (lpd) per Hair Dressing Salon, and with a total mean water demand of 9,566 litres (lpd) in Hair Dressing Salons in Makurdi.

Hair Dressing Salons in Highlevel have the highest relative mean water demand of 675 litres (lpd) while lowest mean water demand of 260 litres (lpd) was recorded in Hair Dressing Salons in North Bank ward. This leaves us with a range of 415 litres (lpd) (675 - 260 litres). The high range in mean water demand noticed among the hair dressing salons in Makurdi may be accounted for in the number of heads averagely dressed in a day. For instance, Hair Dressing Salons in Highlevel ward dressed averagely 10 heads in a day whereas those of Wadatta dressed 5 heads in a day demanded less quantities of water. This suggests that the more number of heads that are dressed in a day, the more will be the quantities of water that may be needed in a day.

Table 10

Water Demand in the Car Wash Establishments

Ward	No. of Sampled Car Wash	Mean Water Demand Per Car Wash (Litres)	Total Mean Water Demand in Car Wash (Litres)
Central	3	1,207	3,621
North Bank	2	625	1,250
Ankpa	-	-	-
Highlevel	2	1,404	2,808
Wadatta	-	-	-
Wurukum	4	1,540	6,160
Old GRA	4	1,150	4,600
New GRA	-	-	-
	Mean	1,185	3,688
		Total	18,439

From Table 10, the mean water demand in car wash ventures in Makurdi was found to be 1,185 litres (lpd) per car wash establishment. This amounted to a total mean of 18,439 litres (lpd) in car wash establishments in Makurdi.

Car wash establishments in Wurukum ward were noted to have the highest relative mean water demand of 1,540 litres (lpd) while the lowest mean water demand of 625 litres (lpd) was recorded among the car wash establishments in North Bank ward. This gives us a range of 915 litres (lpd) (1,540 - 625 litres). This rather very high range suggests that water demand among car wash establishments vary appreciably. This variation may be accounted for in the number of cars averagely washed per day in a car wash establishment. For instance, car wash establishment in Wurukum and Highlevel wards washed an average of 13 cars in a day and have a mean water demand of 1,540 litres (lpd) and 1,404 litres (lpd) respectively. Whereas car wash establishments in North Bank ward washed an average of 6 cars in a day having a mean water demand of 625 litres (lpd). This apparently suggests that the more the number of cars that are washed per day, the more may be quantities of water that may be needed.

3.3 Water Demand in the Industrial Sector

Water demand in the industrial sector as used in this study include water use in Bakeries, Block moulding industries and Bottling Companies. Estimation of the quantities of water demanded in this sector was done as in the case of residential and commercial sectors in sections 3.1 and 3.2.

Plate 6

CAR WASH SCENE

Plate 7:

BLOCK MOULDING SCENE

Table 11

Water Demand in the Bakeries

Ward	No. of Selected Bakeries	Mean Production Per Day (Loaves)	Mean Water Demand (Litres)	Total Mean Water Demand in Bakeries (Litres)
Central	1	500	520	520
North Bank	2	3,000	1,200	2,400
Ankpa	2	5,000	1,500	3,000
Highlevel	-	-	-	-
Wadatta	1	2,000	845	845
Wurukum	-	-	-	-
Old GRA	-	-	-	-
New GRA	-	-	-	-
	Mean	2,625	1,016	1,691
			Total	6,765

The mean water demand in bakeries in Makurdi was found to be 1,016 litres (lpd) and a total mean water demand of 6,765 litres (lpd) among the bakeries in Makurdi (Table 11).

Bakeries in Ankpa ward have the highest relative mean water demand of 1,500 litres (lpd) while the lowest mean water demand was recorded in the baekries in Central ward with 520 litres (lpd). This gives a range of 496 litres (lpd)

This variation in the mean water demand in bakeries in Makurdi may not be unconnected with the level of production per day. As can be seen from Table 11, bakeries in Ankpa have the highest mean production of 5,000 loaves per day and the same time was noted to have the highest mean water demand. Whereas a bakery in Central ward have the lowest mean water demand and the same time has the lowest mean production of 500 loaves. This suggests that the greater the production per day, the greater may be the quantities of water that may be needed.

Table 12

Water Demand in the Block Moulding Industries

Ward	No. of B/Mould. Industries	Mean Production Per Day (Blocks)	Mean Water Demand Per B/Mould. (Litres)	Total Mean Water Demand in B/Mould. (Litres)
Central	4	800	2,120	8,480
North Bank	1	600	1,203	1,203
Old GRA	6	660	1,970	11,820
Ankpa	-	-	-	-
Highlevel	-	-	-	-
Wadatta	-	-	-	-
Wurukum	-	-	-	-
New GRA	-	-	-	-
	Mean	687	1,764	7,169
			Total	21,503

From table 12, the mean water demand in Blockmoulding industries in Makurdi was found to be 1,764 litres (lpd). This amounts to a total mean water demand of 21,503 (lpd). Block moulding industries in Central ward have the highest relative mean water demand of 2,120 litres (lpd) followed by those of Old GRA 1,970 litres (lpd) and North Bank 1,202 litres (lpd). The variations in the mean water demand as recorded among the blockmoulding industries in Makurdi may be explained in the context of the level of production per day. Block moulding industries in Central ward have the highest mean production of 800 blocks per day and the same time was noted to have the highest mean water demand. This implies that the more blocks that is being produced per day, the more the quantities of water that may be needed.

3.4 Water Demand in the Bottling Company

Benue Bottling Company and Nigeria Bottling Company were selected for our study. Our study shows that they produce an average of 400,000 bottles of soft drinks per day and require about 100,000 litres of water per day.

3.5 Water Consumption in the Residential Sector

Water consumed in a household per day corresponds with the total amount of water fetched or collected for domestic purposes. In other words, the amount of water consumed in a household denotes the amount of water actually fetched or collected in a household. Estimation of the quantities of water consumed by household per day was done as in the case of water demand (Section 3.1).

Table 13

Water Consumption in the Residential Sector

Ward	No. of Sampled Household	Mean Household Size	Mean Water Consumption Per Household (Litres)	Total Mean Consumption in Residential Sector (Litres)
Central	34	13	475	16,150
North Bank	30	11	212	6,360
Ankpa	37	7	734	27,158
Highlevel	39	6	575	22,425
Wadatta	28	5	260	7,280
Wurukum	33	5	285	9,405
Old GRA	33	7	740	24,420
New GRA	25	6	380	9,500
	Mean	7	458	15,337
			Total	122,698

The mean household water consumption in Makurdi was found to be 458 litres (lpd). This amounts to a total mean water consumption of 122,698 litres (lpd) in the residential sector as shown in Table 13.

Households in Old GRA have the highest mean water consumption of 740 litres (lpd) while those of North Bank were noted to have the lowest mean water consumption of 212 litres (lpd). This gives a range of 528 litres (740 - 212 litres) (lpd). This rather high range in the mean water consumption in households in Makurdi suggests that wide variation exists in their pattern of water consumption. This may be accounted for in the context of physical and socio-economic factors that influence water consumption in a geographical area. For instance, in our study we observed that most households in Old GRA have at least 12 hours of water supply from the public water supply. Whereas most households in North Bank do not have access to public water supply, they therefore depend heavily on supplementary sources of water supply. It is therefore not unlikely that households in Old GRA will consume more water than her counterparts in North Bank ward. The reason is that the more water that is made available to a household the more the quantities of water that may be consumed and at times could be wasted. But generally, in households where they have difficulty in getting water, whatever quantity that is made available they will try as much as possible to manage it and most cases wastage is avoided.

The mean water consumption in households in Makurdi in their order of rank is as follows: Old GRA 740 litres (lpd), Ankpa 734 litres (lpd), Highlevel 575 litres (lpd), Central 475 litres (lpd), New GRA 380 litres (lpd), Wurukum 285 litres (lpd), Wadatta 260 litres (lpd), North Bank 212 litres (lpd).

3.6 Water Consumption in the Commercial Sectors

Water consumption in commercial sector as used in this study refers to water utilized in Hotels, Hair Dressing salons and car wash establishments.

Table 14

Water Consumption in the Hotel Establishments

Ward	No. of Sampled Hotels	Mean Water Consumption Per Hotel (Litres)	Total Mean Water Consumption in Hotels (Litres)
Central	4	668	2,672
North Bank	11	1,086	11,946
Ankpa	3	690	2,070
Highlevel	15	923	13,845
Wadatta	6	850	5,100
Wurukum	5	498	2,490
Old GRA	6	2,845	17,070
New GRA	3	613	1,839
	Mean	1,022	7,129
		Total	57,032

As can be seen from Table 14, the mean water consumption in hotel establishments in Makurdi was found to be 1,022 litres (lpd). This summed up to a total mean water consumption of 57,032 litres (lpd) in hotel establishments in Makurdi.

Hotels in Old GRA ward have the highest mean water consumption of 2,845 lites (lpd) while the lowest mean water consumption of 498 litres (lpd) was recorded in hotels in Wurukum. This gives a range of 3,347 litres (2845 - 498 litres) (lpd). This rather very high range noted in the mean water consumption among the hotel establishments in Makurdi suggests that a wide variation exists in their pattern of water use. This may be attributed to a number of factors as sometimes indicated. These include number of persons employed in the establishment, number of workshifts per day, number of customers that patronise the hotel averagely in a day, type of services rendered such as lodging and accommodation, level of water use infrastructure and frequency of water supply.

The mean water consumption in hotels in their order of rank as can be seen from Table 14 is as follows: Old GRA 2,845 litres (lpd), North Bank 1,086 litres (lpd), Highlevel 923 litres (lpd), Wadatta 850 litres (lpd), Ankpa 690 litres (lpd), Central 668 litres (lpd), New GRA 613 litres (lpd), Wurukum 498 litres (lpd).

Table 15

Water Consumption in the Hair Dressing Salons

Ward	No. of Sampled H/Dressing Salons	Mean Water Consumption Per Salon (Litres)	Total Mean Water Consumption in Hair Salons (Litres)
Central	4	280	1,120
North Bank	2	120	240
Ankpa	-	-	-
Highlevel	6	380	2,280
Wadatta	6	200	1,200
Wurukum	2	180	360
Old GRA	-	-	-
New GRA	-	-	-
	Mean	232	1,040
		Total	5,200

From Table 15, the mean water consumption in Hair Dressing salons in Makurdi was found to be 232 litres (lpd) and a total mean water consumption of 5,200 litres (lpd).

Hair Dressing Salons in Highlevel ward have the highest mean water consumption of 380 litres (lpd) followed by those of Central 280 litres (lpd), Wadatta 200 litres (lpd), Wurukum 180 litres (lpd), North Bank 120 litres (lpd).

The variation observed in mean water consumption in Hair Dressing Salons in Makurdi may be largely attributed to the number of heads dressed per day. For instance, our study showed that Hair Dressing Salons in Highlevel with the highest mean water consumption was also noted to have the highest number of heads dressed per day. This implies that the more number of heads that is dressed the more may be the quantities of water that may be consumed.

Table 16

Water Consumption in the Car Wash Establishments

Ward	No. of Sampled Car Wash	Mean Water Consumption in Car Wash (Litres)	Total Mean Water Consumption in Car Wash (Litres)
Central	3	920	2,760
North Bank	2	404	808
Ankpa	-	-	-
Highlevel	2	997	1,994
Wadatta	-	-	-
Wurukum	4	1,200	4,800
Old GRA	4	955	3,820
New GRA	-	-	-
	Mean	895	2,836
		Total	14,182

The mean water consumption in Car Wash establishments in Makurdi as can be seen from Table 16 was found to be 895 litres (lpd). This amounted to a total mean water consumption of 14,182 litres (lpd) among car wash establishments in Makurdi.

Car wash establishments in Wurukum have the highest mean water consumption of 1,200 litres (lpd). This is followed by those of Highlevel 997 litres (lpd), Old GRA 955 litres (lpd), Central 920 litres (lpd), North Bank 404 litres (lpd). As sometimes observed, the variation in mean water consumption is mainly accounted for in the number of cars averagely washed per day in the establishments.

3.7 Water Consumption in the Industrial Sector

Water consumption in the industrial sector as used in this study refers to water utilized in Bakeries, Block-moulding industries and Bottling companies.

Table 17

Water Consumption in the Bakeries

Ward	No. of Selected Bakeries	Mean Production Per Day (Loaves)	Mean Water Consumption Per Day (Litres)	Total Mean Water Consumption (Litres)
Central	1	500	220	220
North Bank	2	3,000	744	1,488
Ankpa	2	5,000	1,000	2,000
Highlevel	-	-	-	-
Wadatta	1	2,000	480	480
Wurukum	-	-	-	-
Old GRA	-	-	-	-
New GRA	-	-	-	-
	Mean	2,625	611	1,047
			Total	4,188

From Table 17, the mean water consumption in bakeries in Makurdi was found to be 611 litres (lpd). This summed up to a total mean water consumption of 4,188 litres (lpd).

Bakeries in Ankpa ward have the highest relative mean water consumption of 1,000 litres (lpd) followed by North Bank 744 litres (lpd), Wadatta 480 litres (lpd), Central 220 litres (lpd). The variations in the mean water consumption among the bakeries in Makurdi is largely a function of the number of loaves produced per day. The more the number of loaves that is being produced the more will be the quantities of water that may be consumed.

Table 18

Water Consumption in the Block Moulding Industries

Ward	No. of Sampled B/Moulding Industries	Mean Production Per Day (Blocks)	Mean Water Consumption Per Block Moulding (Litres)	Total Mean Water Concumption (Litres)
Central	4	800	1,130	4,520
Old GRA	6	660	1,470	8,820
North Bank	1	600	705	705
Ankpa	-	-	-	-
Highlevel	-	-	-	-
Wadatta	-	-	-	-
Wurukum	-	-	-	-
New GRA	-	-	-	-
	Mean	687	1,102	4,682
			Total	14,045

The mean water consumption in block moulding industries in Makurdi was found to be 1,102 litres (lpd) and a total mean water consumption of 14,045 litres (lpd) (Table 18).

Block moulding industries in Old GRA have the highest mean water consumption of 1,470 litres (lpd) followed by Central 1,130 litres (lpd), North Bank 705 litres (lpd).

3.8 Comparison of Water Demand and Consumption in the Sectors

3.8.1 Residential Sector

Table 19

Water Demand and Consumption in the Residential Sector in Makurdi

Ward	DEMAND				Total Residential Water Demand for Wards (Litres)	Per Capita Water Demand (Litres)	Mean House hold Water Consumption Per Day (Litres)	Consumption		% Demand Satisfied by Supply
	Population	No. of Households	Mean Household Size	Mean Household Water Demand Litre				Total Residential Water Consumption for the Ward (Litres)	Per Capita Water Consumption	
Central	21,672	1,667	13	1,010	1,683,670	78	475	791,825	37	47
North Bank	19,530	1,775	11	908	1,611,700	83	212	376,724	19	23
Ankpa	20,930	2,990	7	1,608	4,807,920	230	734	2,194,660	105	46
Highlevel	20,678	3,446	6	960	3,308,160	159	575	1,981,450	96	60
Wadatta	19,712	3,942	5	554	2,183,868	111	260	1,024,920	62	47
Wurukum	15,827	3,165	5	560	1,772,400	112	285	902,025	57	51
Old GRA	17,136	2,448	2	1,212	2,966,976	173	740	1,811,520	106	61
New GRA	12,936	2,156	6	1,116	2,406,096	186	380	819,280	63	34
Total	161,135	18,739	129	7,928	20,740,790	1,320	3,648	9,902,402	545	
Mean	20,142	2,342	7	991	2,592,599	165	458	1,237,801	68	46

Source: Field Work, 1996

As can be seen from Table 19, water consumption in households in Makurdi all fall short of their demand. This implies that households were not able to meet all their water requirements.

The overall total water demanded and consumed in the residential sector of Makurdi was found to be 20,740,790 litres and 9,902,454 litres (lpd). This represents 46% of its water requirements satisfied by supply. The per capita water demand was also found to be 165 litres (lpd) and per capita consumption of 68 litres (lpd).

The percentage (%) water demand satisfied by consumption (supply) of 46% translate to be a deficiency of 10,838,336 litres (lpd). This suggests the existence of water shortage relative to demand in Makurdi.

3.8.2 Commercial Sector

Commercial sector as used in this study has been sub-divided into 3 sub-sectors viz: Hotels, Hair Dressing Salons, and Car wash establishment. These sub-sectors are used to analyse the amount of water demanded and consumed in this sector since they constitute the major water consuming sector within the broad commercial sector. The summary of the pattern of water demanded and consumed for each sub-sector of the commercial sector is contained in Table 20.

Table 20

Water Demand and Consumption in the Hotel Establishments in Makurdi

Ward	DEMAND			Total Water Demand for the Hotels (Litres)	Mean Water Consum-ption Per Hotel (Litres)	Consumption	% Demand Satisfied by Supply
	No. of Hotels In Wards	Mean Demand Per Hotel (Litres)	No. of Customers to the Hotel In Day			Total Water Consumption in Hotel (Litres)	
Central	48	1,340	16	64,320	668	32,064	50
North Bank	124	1,544	17	191,456	1,086	134,664	70
Ankpa	18	1,140	8	20,520	690	12,420	60
Highlevel	154	1,555	9	239,470	923	142,142	59
Wadatta	15	1,400	16	21,000	850	12,750	61
Wurukum	37	1,490	9	55,130	498	18,426	33
Old GRA	25	5,000	14	12,500	2,845	71,125	77
New GRA	15	1,678	15	25,170	613	9,195	36
Total	436	15,147		742,066	8,155	432,786	
Mean		893	13	92,758	1,019	54,098	56

Source: Fieldwork, 1996.

The overall total water demand and consumption in hotels in Makurdi was found to be 742,066 litres (lpd) and 432,786 litres (lpd). Hotels in wards like Central, North Bank, Ankpa, Highlevel, Wadatta, Old GRA have about 50% of their water requirements met, while those in Wurukum and New GRA could only satisfy about 30% of their water needs (Table 20). But on the whole hotels establishments in Makurdi have 56% of their water demand satisfied by supply.

Table 21

Water Demand and Consumption in the Hair Dressing Salons in Makurdi

Ward	DEMAND			Total Water Demand in Hair Dressing Salon in Wards (Litres)	Mean Water Consumption Per Salon in a Day (Litres)	Consumption	% Demand Satisfied Supply
	No. of Hair Dressing Salons in the Ward	No. of Customers to the Salon In a Day	Mean Water Demand Per Salon in Wards (Litres)			Total Water Consumption in Hair Dressing Salons (Litres)	
Central	10	7	575	5,750	280	2,800	49
North Bank	7	8	260	1,820	120	840	46
Ankpa	-	-	-	-	-	-	-
Highlevel	17	10	675	11,475	380	6,460	56
Wadatta	14	5	316	4,424	200	2,800	63
Wurukum	6	6	400	2,400	180	1,080	45
Old GRA	-	-	-	-	-	-	-
New GRA	-	-	-	-	-	-	-
Total	54	26	2,226	25,869	1,160	13,980	
Mean		5	445	5,174	232	2,796	52

Source: Fieldwork, 1996.

The overall total water demanded and consumed in Hair Dressing Salons in Makurdi is 25,869 litres (lpd) and 13,980 litres (lpd) accounting for 52% of its water requirements met by supply (Table 21).

Table 22

Water Demand and Consumption in the Car Wash Establishments in Makurdi

Ward	Demand: No. of Car Wash Estab.	Demand: No. of Cars Washed Per Day	Mean Water Demand Per Car Wash Est. (Litres)	Total Water Demand in Car Wash Estab. (Litres)	Mean Water Consumption Per Car Wash Estab. (Litres)	Consumption (Supply): Total Water Consumption in Car Wash Establishment (Litres)	% Demand Satisfied by Supply
Central	3	15	1,207	3,621	920	2,700	76
NorthBank	2	6	625	1,250	404	808	65
Ankpa	-	-	-	-	-	-	-
Highlevel	2	5	1,404	2,808	997	1,994	71
Wadatta	-	-	-	-	-	-	-
Wurukum	8	13	1,540	12,320	1,200	9,600	78
Old GRA	6	8	1,150	6,900	955	5,730	83
New GRA	-	-	-	-	-	-	-
Total			5,926	26,899	4,476	20,892	
Mean		9	1,185	5,380	895	4,178	75

Source: Fieldwork, 1996.

As can be seen from Table 22, the overall total water demand and consumption in car wash establishments in Makurdi, was found to be 26,899 litres (lpd) and 20,892 litres (lpd) representing 75% of its water requirements satisfied by supply.

Car wash establishments were able to meet most of their water requirements because they are placed on a special commercial charge of ₦500 per month as water rate as such have a regular supply of about 12 hours of water supply. Besides, they also make use of water from wells, ponds and gutter for their services.

3.8.2.1 Comparison of Water Demand and Consumption in the Commercial Subsectors

Hotel establishments have the highest water demand and consumption of 742,066 litres and 432,786 litres (lpd) followed by car wash establishments with 26,899 litres and 20,892 litres (lpd) and Hair Dressing Salons with 25,869 litres (lpd) and 13,980 litres (lpd). This accounts for the overall total water demand and consumption in commercial sector of 794,834 litres (lpd) and 467,603 litres (lpd).

3.8.3 Industrial Sector

The individual subsector used for our study here are: Bakeries, Block moulding and Bottling companies.

Table 23

Water Demand Consumption in the Bakeries in Makurdi

Ward	DEMAND			Total Water Demand In Bakeries (Litres)	Mean Consumption Per Bakery (Litres)	Consumption	% Demand Satisfied by Supply
	No. of Bakeries In the Ward	Mean Production Per Day (Loaves)	Mean Water Demand for Bakery (Litres)			Total Water Consumption In the Bakeries	
Central	1	500	520	520	220	220	42
North Bank	2	3,000	1,200	2,400	744	1,488	62
Ankpa	3	5,000	1,500	4,500	1,000	3,000	67
Highlevel	-	-	-	-	-	-	-
Wadatta	1	2,000	845	845	480	480	58
Wurukum	-	-	-	-	-	-	-
Old GRA	-	-	-	-	-	-	-
New GRA	-	-	-	-	-	-	-
Total	7	10,500	4,065	8,265	2,444	4,188	229
Mean		2,625	1,016	1,653	611	1,047	57

Source: Fieldwork, 1996.

As can be seen from Table 23, the overall total water demanded and consumed in bakeries in Makurdi was found to be 8,265 litres and 4,188 litres (lpd) meeting 57% of its water requirements.

Table 24

Water Demand and Consumption in the Block Moulding Industries in Makurdi

Ward	DEMAND		Mean Water Demand Per Block Ind. (Litres)	Total Water Demand In Block Industries (Litres)	Mean Water Consumption Per Block Industries (Litres)	Consumption	% Demand Satisfied by Supply
	No. of Block Moulding	Mean Production Per Block Industry (Blocks)				Total Water Consumption in Block Industries (Litres)	
Central	7	800	2,120	14,840	1,130	9,310	63
Old GRA	12	660	1,970	23,640	1,470	17,640	75
North Bank	2	600	1,203	2,406	705	1,410	59
Total		2,060	5,293	40,886	1,102	28,360	
Mean		687	1,764	1,269	1,102	9,453	66

Source: Fieldwork, 1996.

From Table 24, the overall total water demand and consumption in Block moulding industries in Makurdi was found to be 40,886 litres (lpd) and 28,360 litres (lpd) representing 66% of its water requirements satisfied by supply.

WATER DEMAND AND CONSUMPTION IN THE BOTTLING COMPANIES

Bottling companies in Makurdi has a total water demand and consumption of 200,000 litres (lpd) and 128,000 litres (lpd).

3.8.3.1 Comparison of Total Water Demand and Consumption in the Industrial Subsectors

Bottling companies have the highest total water demanded and consumed of 200,000 litres (lpd) and 128,000 litres (lpd), followed by bakeries with 8,265 litres (lpd), and 4,188 litres (lpd) and Block moulding industries 40,886 litres (lpd) and 28,360 litres (lpd). This sum up to overall total water demand and consumption of 249,151 litres (lpd) and 160,548 litres (lpd).

3.8.4 Total Water Demand and Consumption in the Various Sectors

Table 25

Total Water Demand and Consumption in the Residential, Commercial and Industrial Sectors of Makurdi

Sector	Total Water Demand In the Sector (Litres)	Total Water Consumption In the Sector (Litres)	Deficiency	% Demand Satisfied By Supply
Residential	20,740,790	9,902,454	10,838,336	46
Commercial	794,834	467,663	327,171	59
Industrial	249,151	160,548	88,603	64
Total	21,784,775	10,530,665	11,254,110	48

The overall total water demand and consumption of the various sectors of Makurdi as shown in Table 25, is 21,784,775 litres and 10,530,665 litres (lpd) accounting for 48% of its water requirements satisfied by consumption (supply). This translates to be a deficiency of 11,254,110 litres (lpd). This implies the existence of water shortages relative to demand in all the sectors.

As can be seen from the table 25, residential sector has the highest total water demand and consumption of 20,740,790 litres (lpd) and 9,902,454 litres (lpd) followed by commercial sector with 794,834 litres (lpd) and 467,663 litres (lpd) and industrial sector of 249,151 litres (lpd) and 160,548 litres (lpd).

CHAPTER FOUR

FACTORS THAT AFFECT WATER DEMAND AND CONSUMPTION IN MAKURDI

In this chapter our main preoccupation is an attempt to isolate dominant factors that significantly influence sectoral patterns of water demand and consumption in Makurdi. This may be achieved by two statistical techniques: multiple regression model and Principal Component Analysis.

4.1 Residential Sector

4.1.1 Physical Factors

4.1.1.1 Existence of Water Tap in the Household

It is generally believed that in households where functional water tap exists more water is consumed than those without. When water is readily available in the tap and easily accessible, the tendency is to use more water and atimes misuse it. We shall therefore assign a value of 1 (one) where tap exists, and zero (0) where there is none.

4.1.1.2 Number of Hours Tap Runs in a Day

Mere existence of water tap in a household without water running in them is of no value. Again, the number of hours water runs in a tap in a day will determine the quantity that is made available for household use. It therefore follows that the greater the number of hours water runs in a tap, the greater will be the quantity that will be available for household use. The highest number of hours tap can run in a day is 24 hours. The respondents were asked to indicate the number of hours tap runs in a day in the household. Where water does not run at all we assign value of zero (0).

4.1.1.3 Number of Water Consuming Appliances

The level of water use infrastructure in an apartment affect the quantity of water that may be consumed in a day. The greater the number of water consuming appliances the greater will be the quantity of water that might be needed. Respondents were asked to indicate number of toilets, bathe and shower in their apartment. When it is double we assign value of six (6) and three (3) respectively.

4.1.1.4 Supplementary Source of Water Supply

Supplementary source of water supply is any other source of water supply available to a household other than that of public water supply. This includes water from the well, water vendors, and river. We assign (1) to well, 2 to water vendors, and 3 to river. In a household for instance where they depend daily on buying water from water vendors, they are likely to consume less water than those whose supply is from a public source and pay a flat rate of ₦50 at the end of the month.

4.1.1.5 Distance to the Nearest Source of Water Supply

The greater the distance covered, time and energy spent daily to get water affect the quantity of water that is made available for household use. Where little distance is involved several trips can be made to fetch water to the house. Respondents were simply asked to indicate distance covered daily to get water in km.

4.1.1.6 Quantity of Water Used in Cooking

The rationale behind this is that households with large sizes require more water for cooking than those that are small. Estimation of the quantities of water used in cooking was done by respondents in units of standard bucket (SON, size 30) which were later converted into litres.

4.1.1.7 Quantity of Water Used in Washing Clothes

As applied in the case of quantity of water used in cooking so also it is with washing of clothes. The larger the size of the household, the larger will be the quantities of water that may be needed. Estimation of the quantities of water used in washing clothes is done as in the case of cooking (Section 4.1.1.6).

4.1.1.8 Quantity of Water Used for General Cleaning

This is related to the space occupied by the house. In general, cleaning a small house requires less quantities of water than those of bigger apartment. Estimation of the quantities of water that goes into general cleaning was done as in the case of cooking.

4.1.2 Social Factors

4.1.2.1 Educational Level of the Head of the Household

The educational level of an individual to a large extent determines one's socio-economic status, that is income level, type of job and standard of living. The educational level as used here is adopted from Ezenwaji (1990) study on sectoral water demand in Onitsha urban area. It was done based on the number of years spent in school by the head of the household. Educational level attained therefore, is viewed as function of number of years one spent in a level to acquire a certificate.

Table 26

Educational Level

S/No	Educational Level	Years Spent
1.	No formal Education	0
2.	Primary education	6
3.	Secondary education	11
4.	Nigeria Certificate of Education (NCE)/ Ordinary D National Diploma (OND)	14
5.	Higher National Diploma (HND)/University Degree (B.A., B.Sc.)	16
6.	Higher Degree (M.A., M.Sc., Ph.D)	20

4.1.2.2 The Size of the Household

The number of persons in a household to some extent determines the quantities of water that is consumed in a day. This implies that the greater the number of persons in a household, the greater will be the quantity of water that may be needed. The respondents were asked to indicate the number of persons in their household.

4.1.3 Economic Factors

4.1.3.1 Income Level of the Head of the Household

The rationale behind this is that one's income level determines his standard of living generally. Increases in one's income level may result into improvement in his standard of living. Respondents were asked to indicate their income level per month. Where the respondents are not on fixed salaries like the artisans they were to estimate their income per month.

4.1.3.2 Cost of Water Supply

The cost of water supply to the household affects its water use habits. Where much money is spent daily or monthly on water supply water is prudently managed in a household to save cost. On the other hand where the supply is free or little cost is involved much water is utilized and at times wasted. Respondents were asked to indicate how much they spend monthly on water supply.

4.2 Commercial Sector

4.2.1 Physical Factors

4.2.1.1 Existence of Water System (W.C)

Existence of water system (W.C) in a commercial establishment is believed to influence the quantities of water that is consumed. We therefore, assign the value of one (1) where W.C is available and zero (0) where it is not in existence.

4.2.1.2 Source of Supplementary

Supplementary sources of water supply include other sources of water supply available to the commercial other than public water supply. These include water from well, water vendor. We assign the value of one, two and three to these sources of supplementary supply.

4.2.1.3 Day of the Week Water is Needed Mostly in the Establishment

The quantity of water consumed in an establishment is not the same among the days of the week. The quantity consumed may be influenced by the number of visitors that patronise the establishment in a day which in turn will affect the amount of water needed that day. The respondents were asked to indicate the day of the week that water is mostly needed in the establishment. Since we have seven days in a week we assign the value of one - Monday, two - Tuesday, ... seven - Sunday.

4.2.2 Social Factor

4.2.2.1 Number of Persons Employed in the Establishment

The size of labour force in an establishment influences quantities of water demanded in a day in terms of staff use. The larger the size of the labour force in an establishment, the greater will be quantities of water that may be used. Respondents were asked to indicate the number of persons employed in their establishment.

4.2.2.2 Number of Customers to the Establishment

The greater the number of customers that patronise a commercial establishment in a day, the greater may be the quantities of water that may be needed. Respondents were simply to indicate the number of customers they have averagely in a day in their establishment.

4.2.2.3 Number of Workshifts in the Establishment

The size of the commercial establishment determines the size of the labour force and subsequently the number of workshift they run in a day. Commercial establishments that run more than one shift are likely to need more water. Respondents were asked to indicate the number of workshifts they run in a day.

4.2.3 Economic Factor

4.2.3.1 Cost of Water Supply

The cost of water supply to the establishment is believed to influence the quantities of water that is used. Where much money is committed to buying water monthly, the tendency is to try as much as possible to manage the quantity that is made available. They are likely to use less quantities of water compared to those who spend less on water. Respondents indicated the amount of money they spend on water monthly.

4.3 Industrial Sector

4.3.1 Physical Factors

4.3.1.1 Source of Water Supply

Industrial establishments that depend on privately developed sources of water supply are believed to satisfy most of their water unlike those that depend on public water supply which in most cases is highly irregular.

4.3.2 Average Production Per Day

The volume of production per day in industrial establishment is believed to influence the quantities of water that is consumed substantially. This means the greater the volume of production per day, the greater may be the quantities of water that may be needed. Respondents were asked to indicate their average production in day in their establishments.

4.3.2 Social Factors

4.3.2.1 Number of Persons Employed

As applied in the case of commercial sector (Section 4.2.2.1).

4.3.2.2 Number of Workshifts

As applied in the case of commercial sector (Section 4.2.2.2).

4.3.3 Economic Factors

4.3.3.1 Cost of Water Supply

As applied in the case of commercial sector (Section 4.2.3.1).

4.4 Analysis of Causal Relationship

In our analysis of causal relationship among dependent and independent variables we used a multiple Regression technique. This has been successfully used in geographic researches in determining causal relationships.

4.4.1 The Multiple Regression Model

Multiple regression analysis is a general statistical techniques by which one can analyse the relationship between the dependent or criterion variable and set of independent or predictor variables (Nie, Hall, Jenkin, Staubrenar and Bent, 1975). According to Van Der Geer (1971), the basic goal of this method is to produce a linear combination of independent variables which correlate as highly as possible with dependent variable. This linear relationship can be used to "predict" value of independent variable. Furthermore, the technique enables the individual contribution of each independent variable whose prediction is to be assessed. The general expression for this multiple regression is written as (Johnston, 1991):

$$Y = a+b, X_1 + b_2 + b_3 X_3 \ldots b_n Xn + e \quad (1)$$

Y is the dependent variable, X_1 X_2 ... X_n and the independent variables, b_1 b_2 b_3 ... b_n are the partial regression coefficients; a is the base constant; e is the error term or proportion of the variance not explained by the regression.

The multiple regression model is used in this work to reveal relevant factors contributing to the amount of water demanded and consumed in the various sectors of Makurdi urban. The variables included in this analysis are such that each sector has a set of variables distinct from each other. The variables are specified and allocated as follows:

Residential Sector

TAM - Total amount of water demanded

XINC - Income level of the head of the household

WASH - Quantity of water used in washing cloths

COOK - Quantity of water used in cooking

COST - Cost of water supply to the household

SIZE - Number of persons in a household

EDU - Educational level of the head of the household

CLEAN - Quantity of water used for general cleaning

HOUR - Number of hours water runs in a tap in a day

TAP - Existence of water tap in a household

SUPP - Supplementary sources of water supply to a household

DIST - Distance to the nearest sources of water supply

WCAPP - Number of water consuming appliances

NIB Here we have 13 variables, one dependent and 12 independent.

Commercial Sector

TAM - Total amount of water demanded

WC - Existence of water system in the establishment

COST - Cost of water supply

EMP - Number of persons employed by the establishments

CUST - Number of customers to the establishment in a day

SHIFT - Number of workshifts in the establishment in a day

DAY - Day of the week water is mostly needed in the establishment

N/B Here we have 7 variables, one dependent and 6 independent variables.

INDUSTRIAL SECTOR

TAM - Total amount of water demanded in a day

PROD - Average production per day in the industry

EMP - Number of persons employed in the establishment

SHIFT - Number of workshifts in the industry

SOURCE - Sources of water supply in the industry

COST - Cost of water supply in the industry

N/B Here we have 6 variables, one dependent and 5 independent.

4.4.1 Contribution of Variables to the Explained Variation in Water Demand and Consumption in the Sectors

The contribution of the variables to the explained variations was done using SPSS package programme (Nie, Hull, Jenkin, Stenbrenar and Bent, 1975) run in University of Nigeria, IBM computers. Separate programmes were used for the sectors and subsectors (Appendix E,F,G). The variations are explained thus:

4.4.2.1 Residential Sector

In the residential sector, the total amount of water demanded (TAM) is regressed against 12 variables. The combined strength of relationship between the 12 variables and water demanded and consumed is assessed by multiple correlation coefficient (R) and coefficient of multiple determination (R^2). The contribution of the individual variables to the explanation of the variation is given by R^2 change. The level of variation is the total amount of water demanded that can be explained by linear dependence upon 12 variables (predictors) operating together.

The combined influence of the 12 predictors on water demanded and consumed in the residential sector of Makurdi as revealed by computer analysis showed a multiple correlation coefficient (R) of 0.922, with a coefficient of multiple determination of (R^2) of 85.0%. This implies that the 12 predictor variables jointly accounted for 85.0% of the variations in the amount of water demanded and consumed in the residential sector of Makurdi, leaving out 15.0% unexplained. This 15% which multiple regression model is not able to explain suggests that variables other than those utilized for this study also account for water demand and consumption in Makurdi.

The standard error estimate for this regression is

35.7 litres per household. This means that the average over or under estimation of water demanded and consumed in the residential sector using 12 variables is 35.7 litres. This low figure apparently suggests that household water demand in Makurdi may be fairly actually be predicted by the 12 variables.

The contribution of individual variable to the observed variation was also calculated with multiple regression model.

Table 27

Individual Contribution of Predictor Variables to the Variation in the Total Water Demanded

Variables	Contribution of Variable R^2	% Contribution of Variable R^2	F. Ratio
XINC	0.205	20.5*	0.24
WASH	0.496	49.6*	272.06
COOK	0.080	8.0*	57.45
COST	0.000	0.0	2.07
SIZE	0.004	0.4	1.01
EDU	0.020	2.9	4.40
CLEAN	0.024	2.4	2.09
HOUR	0.000	0.0	4.08
TAP	0.007	0.7	3.46
SUPP	0.000	0.0	0.37
DIST	0.000	0.0	0.00
WCAPP	0.014	1.4	23.82
OVER-ALL CONTRIBUTION	0.850	85.0%	

(* Indicate significant at 0.05 level)

From Table 27, three variables contributed significantly to water demand in the residential sector. A total variance of 78.1% is explained by these variables: WASH (quantity of water used for washing clothes 49.6%); XINC (income level of the head of the household, 20.5%); COOK (quantity of water used for cooking, 8.0%). The other variables are not significant at 0.05 level. The fact that other variables are not significant seems to show that they are not important in explaining the household water demand and consumption in the residential sector of Makurdi. It is also important to note independent variables such as COST, SUPP and DIST contributed nothing to the total variation in water demand. We shall therefore conclude that the most important factors affecting the total amount of water demanded in the residential sector of Makurdi significantly are: WASH, XINC and COOK.

To further clarify these results, the signs that are carried by regression coefficient shall be used to determine direction of the relationship between the dependent variables and the 12 independent variables.

Table 28

Direction of Relationship with Signs

Variable	Sign	Reg-Coefficient
XINC	+	0.027
WASH	+	0.571
COOK	+	0.266
COST	−	0.037
SIZE	+	0.036
EDU	+	0.068
CLEAN	+	0.166
HOUR	−	0.081
TAP	+	0.057
SUPP	−	0.025
DIST	+	0.001
WCAPP	+	0.161

As can be seen from Table 28, all the variables have positive relationship except three. They are: COST, HOUR and SUPP. Some of the relationship are understandable as shown in Table 28. For example variable WASH with a positive regression coefficient shows that a unit increase in the number of clothes to be washed in a household cause water use to be increased by 0.57. This trend is consistent with common sense that the more the number of clothes to be washed, the greater will be the quantity of water that may be needed.

The second variable HOUR has a negative coefficient with the amount of water demanded. The reason for this inverse relationship may be that some household fetch water during the time water runs and store them for use when tap runs dry. Demand therefore decreases when all water containers in a household are filled.

The multiple regression was also performed for water demand in the residential sector in all the 8 wards of Makurdi. The contribution of each variable in the wards is presented below.

Table 29

Individual % Contribution of the Predictor Variables to the Variation in the Total Amount of Water Demanded in the Eight Wards of Makurdi

WARD	XINC	WASH	COOK	COST	SIZE	EDU	CLEAN	HOUR	TAP	SUPP	DIST	WCAPP	TOTAL
CENTRAL	19.6	71.1*	1.2	0.1	0.8	1.0	2.7	0.5	0.0	0.5	0.3	0.7	97.9
NORTH	0.8	45.4*	32.4	0.4	0.0	0.1	0.8	0.5	0.3	0.0	0.0	3.2	83.9
OLD G.	22.5	71.2*	2.3	0.2	0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.0	96.5
NEW G.	66.1*	9.1	10.7	0.5	1.7	3.2	0.2	6.0	0.0	0.0	0.0	0.3	97.8
ANKPA	25.7	40.2*	14.1	0.5	0.1	2.5	0.1	0.3	1.5	1.7	1.1	0.0	97.8
HIGH L.	10.7	63.2*	4.0	0.0	1.4	3.9	1.5	0.1	0.8	0.0	0.0	0.7	85.3
WADATTA	23.7	4.8	8.9	3.8	2.0	0.1	24.3*	9.2	0.1	3.8	6.6	0.1	87.5
WURUKUM	0.7	59.0*	3.4	0.1	1.2	0.3	3.0	0.0	2.1	0.7	0.6	7.9	79.0

(* indicate the most variable at 0.05 level).

Table 30

% Contribution of the Most Important Variable in Their Order of Rank

Ward	Highest Contributor	% Contribution Explained By Highest Contributor
Old GRA	WASH	71.2
Central	WASH	71.1
New GRA	XINC	66.1
Highlevel	WASH	63.2
Wurukum	WASH	59.0
North Bank	WASH	45.4
Ankpa	WASH	40.2
Wadatta	Clean	24.3

From Tables 29 and 30 variable WASH (quantity) of water used in washing clothes in a household was the most important variable and the highest contributor to the explained variation in 6 wards. These are Old GRA, Central, Highlevel, Wurukum and NorthBank. While XINC (income level of the head of the household) and CLEAN (quantity of water used for general cleaning) appeared to be most important variables explaining variation in water demand and consumption in new GRA and Wadatta respectively.

The ward with the highest explanation based on the 12 predictor variables is Central (97.9%). This shows that the 12 variables have successfully explained the variation in the amount of water demanded and consumed in the wards. Looking at the percentage (%) contributions of the most variables, they all contributed significantly to the explained variation except in Wadatta and Ankpa wards. From this analysis, we may infer that variation in the percentage (%) contribution of the most important variables influencing water demand among the wards in Makurdi may be accounted for in the differences in water use habits among the 8 wards of Makurdi.

4.4.2.2 Commercial Sector

In this sector water demand and consumption is analysed in its subsectors. They are: Hotels, Hair Dressing Salons and Car wash ventures.

4.4.2.2.1 Hotel Establishment

Here 8 variables were used. One dependent (TAM) and seven independent (W.C, COST, EMP, CUST, SHIFT, SOURCE, DAY).

4.4.2.2.1.1 Influence of the Predictor Variables on Water Demanded and Consumed in Hotels

In hotel establishment, the total amount of water demanded (TAM) is regressed against seven contributing to its water demand. This yielded a multiple correlation coefficient (R) of 0.925 with a coefficient determination of (R^2) of 85.5%. This means that the seven predictor variables jointly accounted for 85.5% leaving 14.5% to other variables not used in our study.

The standard error estimate for this regression 1,193.99 litres using the 7 variables. This figure suggests that water demanded in Makurdi may be fairly predicted by the 7 variables.

Contribution of individual variable to the observed variation was calculated with the aid of multiple regression model.

Table 31
Individual Contribution of 7 Variables to the Variation in Water Demand in Hotels

Variable	Contribution of Variable R^2	% Contribution of Variable R^2	F-Ratio	Sign
WC	0.094	9.4	3.66	-
COST	0.357	35.7	0.33	+
EMP	0.365	36.5	63.80	+
CUST	0.033	3.3	6.74	+
SHIFT	0.005	0.5	1.73	-
SOURCE	0.001	0.1	0.35	-
DAY	0.000	0.0	0.04	-
OVERALL CONTRIBUTION	0.855	85.5		

From Table 31, EMP (number of persons employed in the establishment), WC (existence of water system in the establishment), COST (cost of water supply to the establishment contributed significantly to the explained variation in water demand and consumption in hotel establishments in Makurdi. These variables: EMP (36.5%), COST (35.7%) and WC (9.4%) jointly contributed 81.4% to the explained variation in water demand in hotels. We shall therefore conclude that factors that significantly influence water demand in hotel establishments in Makurdi are: EMP, COST and W.C.

Regression coefficient of 7 variables and their signs are used to determine direction of relationship of seven independent variables. For instance positive relationship are noted in variables COST, EMP and CUST. This suggests that an increase in the cost of water supply, number of persons employed and number of customers to the establishment may lead to increase in the quantity of water demanded by 0.35, 0.36 and 0.03 units as shown in column 2 of Table 31.

4.4.2.2.2 Hair Dressing Salons

In Hair Dressing Salons, the total amount of water demanded (TAM) is regressed against five variables contributing to its water demanded. This yielded a multiple correlation coefficient (R^2) of 0.973 with a coefficient of multiple determination (R^2) of 94.6%. This means that the 5 predictor variables jointly accounted for 94.6% of explained variation leaving only 5.2% to other variables not used in this study.

The standard error of estimate for the regressed is 14.63 litres. This apparent low figure suggests that these 5 variables may be fairly actually be used to predict water demand in hair dressing.

Contribution of individual variables to the observed variation was also calculated with the aid of multiple regression model as shown in the table below.

Table 32

Individual Contribution of 5 Variables to the Variation in Water Demand in Hair Dressing Salons

Variable	Contribution of Variable R^2	% Contribution of Variable R^2	F-Ratio	Sign
COST	0.252	25.2	0.22	+
EMP	0.035	3.5	12.72	-
CUST	0.657	65.7	174.64	+
SHIFT	0.001	0.1	0.48	+
SOURCE	0.001	0.1	0.29	+
OVERALL CONTRIBUTION	0.946	94.6		

From Table 32 variable CUST (number of customers to the hair dressing salon) has the highest contribution of 65.7% of the explained variation in water demand. This is followed by variable COST (cost of water supply to the establishment) of 25.2%. These two variables jointly accounted for 90.9% of the explained variations in water demand, leaving only 5.1% to the variables not used in this study. We shall therefore, conclude that factors that most significantly affect water demand in hair dressing salon in Makurdi are number of customers to the salon in a day and the cost of water supply.

Regression coefficient of 5 variables and their signs are used to determine the direction of the 5 independent variables. The positive relationship noted in the case of number of customers to the hair dressing suggest obviously that an increase in the number of customers to the salon will lead to increase in the quantity of water demand by 0.65 units. Conversely, the negative relationship observed in variable EMP imply that an increase in the number of persons employed may not necessarily influence the quantity of water demanded.

4.4.2.2.3 Car Wash Establishment

In car wash establishments, a total amount of water demanded (TAM) is regressed against 5 variables contributing to its water demand. The computer result yielded a multiple correlation coefficient (R) of 0.998 with a coefficient of multiple determination of (R^2) of 99.5%. This means that the 5 predictor variables jointly accounted for 99.5% leaving only 0.5% to other variables not used in this study.

The standard error of estimate for the regressed is 38.63 litres. This low figure suggests that water demand in car wash establishment may be fairly predicted by the 5 variables.

Contribution of individual variables to the observed variation was also calculated with the aid of multiple regression model as indicated below.

Table 33

Individual Contribution of 5 Variables to the Variation in Water Demand in Car Wash Establishments

VARIABLE	Contribution of Variable R^2	% Contribution of Variable R^2	F-Ratio	Sign
COST	0.017	1.7	1.53	+
EMP	0.787	78.7	1.82	+
CUST	0.171	19.1	409.54	+
SHIFT	0.000	0.0	0.15	+
SOURCE	0.000	0.0	1.10	-
OVERALL CONTRIBUTION	0.995	99.5		

From Table 33, EMP (number of persons employed in Car wash) has the highest contribution of 78.7% of the explained variations in water demanded. This is followed by CUST (number of customers to the car wash establishment) of 19.1%. These variables alone contributed 97.8% of the explained variations in water demand in car wash establishment. We shall therefore, conclude that factors that most significantly affect water demand in car wash establishment are number of persons employed and the number of customers to the establishment.

4.4.2.2.4 Contribution of Predictor Variables in the Variation in Water Demand in Subsectors

Table 34

Contribution of Predictor Variables in Water Demand in Hotel, Hair Dressing and Car Wash Establishments

Sub-Sectors	Most Important Variable	% Contribution By Most Important Variable	% Unexplained by Most Important Variable
Hotels	EMP	36.5	63.5
Hair Dressing	CUST	65.7	34.3
Car Wash	EMP	78.7	21.3

As can be seen from Table 34, EMP (number of persons employed in the establishments) contributed the most important factor affecting water demand in Hotels and car wash establishments while CUST (number of customers to the hair dressing salon) appear to be most important factor affecting water demand in the hair dressing salon.

From the percentage (%) contribution explained by the most important variable, EMP has the least of 36.5%. This leaves a greater percentage (%) of 63.5% unexplained in Hotel establishment.

4.4.3 Interrelationship Among the Predictor Variables

The regression analysis which we performed in section 4.4.1 to 4.4.2 showed some notable defects. We discovered that several variables appeared to have significant contributions to the observed variation in water demanded, while others have very low or no contributions. This suggests the presence of redundant variables. The reason is that some of them are interrelated. This is clearly shown in Table 35.

Table 35

Matrix of Interrelations of Predictor Variables: Residential Sector

VARIABLE	TAM	XINC	WASH	COOK	COST	SIZE	EDU	CLEAN	HOUR	TAP	SUPP	DIST	WCAPP
TAM	1.000												
XINC	0.459	1.000											
WASH	0.823	0.380	1.000										
COOK	0.696	0.250	0.559*	1.000									
COST	0.068	0.072	0.061	0.116	1.000								
SIZE	0.483	0.093	0.546*	0.597*	0.104	1.000							
EDU	0.390	0.379	0.215	0.199	0.144	0.090	1.000						
CLEAN	0.382	0.342	0.138	0.218	0.137	0.059	0.372	1.000					
HOUR	0.392	0.191	0.258	0.133	-0.090	0.019	0.376	-0.059	1.000				
TAP	0.392	0.232	0.271	0.280	0.123	0.110	0.337	0.100	0.436	1.000			
SUPP	-0.228	-0.188	-0.156	0.088	0.144	0.161	-0.446	-0.066	0.696*	-0.481	1.000		
DIST	-0.088	-0.990*	0.031	0.024	-0.021	0.102	-0.243	0.133	0.225	0.231	0.488	1.000	
WCAPP	0.425	0.387	0.238	0.179	0.029	0.067	0.508*	0.238	0.485	0.459	0.458	0.458	1.000

(* Indicates coefficient significant at 0.05 level)

From Table 35, variable WASH is strongly correlated with variables COOK and SIZE. This apparently suggests that the number of persons in a household affects the quantities of water that might be needed for cooking as well as for washing clothes. Variable EDU is strongly correlated with WCAPP. Educational level of the head of the household (EDU) determines his socio-economic status in the sense of standard of living. This is expressed in terms of a kind of apartment he occupies having water consuming appliances. On the other hand variable XINC showed a very high negative interrelationship with DIST. This is in order as one's income level has nothing to do with distance to the nearest sources of water supply.

Even though significant correlation coefficients were returned, there exist many redundancies in the correlation matrix. It is because of this difficulty of explanation resulting from many significant correlation coefficients that we need a technique for removing spurious correlation while concentrating on those that are orthogonal or according to Davis (1971), offer economy of description. To achieve this we transform our data into orthogonal values through principal components analysis.

Table 36

Matrix of Interrelations of Predictor Variables: Hotel

VARIABLE	TAM	COST	EMP	CUST	SHIFT	SOURCE	DAY	WC
TAM	1.000							
COST	0.671	1.000						
EMP	0.890	0.769*	1.000					
CUST	0.108	-0.322	0.047	1.000				
SHIFT	0.257	0.479	0.470	0.246	1.000			
SOURCE	0.147	-0.592	0.164	0.261	0.237	1.000		
DAY	0.051	0.181	0.088	-0.096	0.041	-0.162	1.000	
WC	0.307	0.431	0.490	0.060	0.614*	-0.233	0.145	1.000

(* indicates coefficients significant at 0.05 level).

From Table 36 of matrix of interrelation of predictor variables in Hotel 8 x 8, some variables showed a high correlation while others have weak or negative interrelation. For example variable EMP (number of persons employed in the establishment) is strongly correlated with COST (cost of water supply to the establishment) implying that the size of labour force in hotel establishment does influence the cost of water supply to the establishments. The bigger the size of the labour force, the greater will be the quantities of water that may be needed in terms of staff use. This will invariably lead to committing of more money to setting the cost of water supply. Variable WC is strongly correlated with SHIFT. This means that the number of workshifts to the establishment influence the frequency of water used in terms of flushing of toilets and bathing. Variable COST showed a positive interrelation with SOURCE. This may be due to error in the information supplied by the respondents.

Table 37

Matrix of Interrelation of Predictor Variables: Hair Dressing Salons

Variable	TAM	COST	CUST	EMP	SOURCE	DAY
TAM	1.000					
COST	-0.226	1.000				
CUST	0.932	0.050	1.000			
EMP	0.242	0.166	0.253	1.000		
SOURCE	-0.270	0.666*	-0.114	-0.062	1.000	
DAY	0.502	-0.076	0.464	0.401	-0.114	1.000

(* indicates coefficients significant at 0.05 level).

As can be seen from Table 37 of matrix of interrelation among predictor variables 6 x 6, variable COST is highly correlated with SOURCE. This means that the source of water supply available to the establishment affects what is spent on water. For instance, in an establishment where the source of water supply is that of water vendors less water may be used compared to where the supply is from a well where no money is spent. Apart from variable SOURCE and COST, all other predictor variables showed weak and negative interrelations and therefore, not significant.

Table 38

Matrix of Interrelations of Predictor Variables: Car Wash

Variable	TAM	COST	EMP	CUST	SHIFT	SOURCE
TAM	1.000					
COST	0.132	1.000				
EMP	0.890	0.261	1.000			
CUST	0.998	0.121	0.895*	1.000		
SHIFT	0.816	0.006	0.882	0.821*	1.000	
SOURCE	-0.530	-0.513	-0.467	0.537*	0.366	1.000

(* indicates coefficient significant at 0.05 level)

From Table 38 of matrix of interrelation of predictor variables 6 x 6 in car wash establishment, EMP is highly correlated with variables CUST and SHIFT. This implies that the number of customers to the car wash establishment in a day determines the number of persons employed and subsequently number of workshifts run in a day. Variable CUST is highly correlated with SHIFT and negatively correlated with SOURCE.

4.5 Principal Components Analysis

The analysis of variance of our multiple regression model revealed a number of apparently redundant variables that appeared to make little or no contribution to the observed variation in water demand and consumption in the various sectors of Makurdi. To isolate the redundant variables for better interpretation one of the statistical techniques widely used by researchers is the principal components Analytical model (PCA). The objective of Principal Component Analysis is to construct new variables possible. This is usually done to condense the whole information into a manageable number of variables and consider these variables in detail without losing any vital information about the variation in the original set of variables. PCA is thus an exploratory technique of constructing new artificial variables (Kshirsagar, 1972; Chukwu, 1994).

The basic equation in PCA are given by the expression (Lawley and Maxwell, 1963):

$$X_1 = \sum_{r=1} Wir\ Zr \quad (i,\ r = 1,\ 2 \ldots p) \qquad (2)$$

where X_1 is the ith observed variate

Z_r is the rth component

W_{ir} is the weight of the rth

Components on the ith variate

Equation (2) shows that the total variance of the variates is accounted for when all the P components are found. PCA is most useful when all the variates, X_1 are measured in the same unit. Our data was therefore standardized to remove the effect of different measurement scales inherent in our raw data matrix. The technique of PCA is further strengthened by the application of orthogonal (Varimax) rotation of the original components without changing the position of the original variables. This enables further determination of distinctive loading of the variables so that each variable has the highest load on and only one component. Explanations are given with reference to structure of the variable loadings on the components together with their separate and joint contribution to the variance of loading pattern.

PRINCIPAL COMPONENTS ANALYSIS OF SECTORAL WATER DEMAND AND CONSUMPTION IN MAKURDI

Table 39

Varimax Rotated Components Matrix: Residential Sector

VARIABLES	COMPONENTS					
	I	II	III	IV	V	VI
XINC	0.147	0.097	0.167	0.922*	-0.041	0.089
WASH	0.776*	0.233	0.029	0.352	-0.023	-0.026
COOK	0.833*	0.077	0.247	-0.046	0.057	0.169
COST	0.083	-0.070	0.041	0.020	-0.027	-0.072
SIZE	0.875*	-0.146	-0.145	0.011	0.026	0.055
EDU	0.010	0.363	0.301	0.235	-0.056	0.188
CLEAN	0.060	-0.052	0.923	0.157	-0.091	0.000
HOUR	0.104	0.888*	-0.136	0.044	-0.075	0.096
TAP	0.180	0.274	-0.002	0.083	-0.136	0.882*
SUPP	0.015	0.739	-0.004	-0.011	0.398	-0.176
DIST	0.051	-0.176	-0.087	-0.039	0.954*	-0.094
WCAPP	0.016	0.671*	0.348	0.309	0.029	0.143
EIGEN VALUE	3.609	2.128	1.443	0.943	0.841	0.679
PERCENTAGE VARIANCE	30.1	17.7	12.0	7.9	7.0	5.7
CUM. PERCENTAGE	30.1	47.8	59.8	67.7	74.7	80.4

(Significant loadings, i.e ± 0.60, are stared)

4.5.1 Extraction of the Components

Using the SPSS package programme (Appendix E, F, G), PCA is performed upon our raw data. Significant loadings are considered from the threshold of ± 0.60 which is statistically significant at 95% confidence level. This cut off value is based on the size of the components loading. According to Johnston (1991) this cut off value is an arbitrary decision and represents 36% (that is 0.60 = 3.36). It is thus chosen to ease interpretation.

Each squared component loading indicates the degree to which the new variables replaces the original variables. The sum of these squared loadings known as the eigen value therefore shows the total variance explained by the component. Hence, the eigen value is employed in accounting for the total explained variance in the data matrix.

The solution to the question of the number of components to be extracted in this work is provided by Kings (1969) rule. The rule is that only those components whose eigen value account for over 5% of the total variance should be extracted.

With 12 variates, there are 12 eigen value and the associated eigen vectors but only 6 eigen values which accounted for more than 5% of the explained variance are extracted here. These 6 components together explain 80.4% of the variance thus leaving only 19.6% to minor factors.

4.5.1.1 Interrelation of Derived Components in the Residential Sector

4.5.1.1.1 Component I

From Table 39 component I has an eigen value of 3.60 and accounts for 30.1% of the total variance. This component comprises number of factors that are highly inter correlated variables. These variables are: SIZE (Number of persons in a household) with the strongest positive loading (+ 0.87) followed by COOK (quantity of water used for cooking) of (+ 0.83) and WASH (quantity of water used for washing cloths) of (+ 0.77). Generally this component is described as the impact which the size of the household have on the quantities of water used for cooking and washing clothes. Component I is therefore identified as the family size.

4.5.1.1.2 Component II

Component II has an eigen value of 2.12 and explains 17.7% of the total variance. Two variables HOUR (number of hour water runs in a tap) and WCAPP (number of water consuming appliances have high positive loading of (+ 0.88) and (0.67) respectively. Conversely variable SUPP (supplementary sources of water supply) has high negative loading of -0.67.

Number of hours water runs in a household and water consuming appliances may be used have to describe the frequency of water supply in a household. We shall therefore, designate component II as frequency of water supply in a household.

4.5.1.1.3 Component III

Component III has an eigen value of 1.44 and accounts for 12.0% of the total variance. Only variable CLEAN (quantity of water used in general cleaning) has a high positive loading of 0.92. Other variables show very low positive and negative loadings as can be seen from Table 39. We shall therefore describe this component as general level of the household sanitation.

4.5.1.1.4 Component IV

Component IV has an eigen value of 0.94 and explains 7.9% of the total variance. Only one variable XINC (income level of the head of the household) has a very high loading of (+ 0.92). We shall designate this component as the socio-economic status of head of the household.

4.5.1.1.5 Component V

Component V has an eigen value of 0.84 and accounts for 7.0% of the total variance. Variable DIST (distance to the nearest source of water supply) has a very high positive loading of (0.95). Other variables have very positive and negative loading. This component therefore, may be described as impact of distance covered to fetch water for household use.

4.5.1.1.6 Component VI

Component VI has an eigen value of 0.67 and explains 5.7% of the total variance. Only variable TAP (existence of water tap in the household) has high positive loading of 0.88. This component may be designated as the availability of water infrastructure.

Table 40

Varimax Rotated Components Matrix: Hotel Establishment

VARIABLE	COMPONENTS				
	I	II	III	IV	V
COST	0.764*	-0.445	-0.205	0.090	0.152
EMP	0.955*	-0.016	0.016	0.028	0.205
CUST	-0.055	0.123	0.981	-0.045	0.056
SHIFT	0.252	-0.097	-0.141	-0.003	0.307
SOURCE	-0.124	0.975*	0.123	-0.074	-0.084
DAY	0.050	-0.073	-0.043	0.993*	0.058
WC	0.255	-0.108	0.074	0.075	0.905*
EIGEN VALUE	2.954	1.232	0.965	0.773	0.688
PERCENTAGE VARIANCE	42.2	17.6	13.8	11.1	9.8
CUM.PERCENTAGE	42.2	59.8	73.6	84.7	94.5

(Significant loadings, i.e ± 0.60, are stared).

4.5.2.2 Interrelation of Derived Components in Hotel Establishments

4.5.2.2.1 Component I

From Table 40 component I has an eigen value of 2.95 and accounts for 42.2% of the total variance. Two variables EMP (number of persons employed in the establishment) and COST (cost of water supply to the establishment) have positive loadings of (0.95) and (0.76) respectively. We shall describe this component to mean the influence or impact of water rate in the establishment.

4.5.2.2.2 Component II

Component II has an eigen value of 1.23 and explains 17.6% of the total variance. Only one variable SOURCE (source of water supply) has a high positive loading of 0.97. We shall designate this component as the type of source of water supply.

4.5.2.2.3 Component III

Component III has an eigen value of 0.96 and accounts for 13.8% of the total variance. Variable CUST (number of customers to the establishment averagely in a day) is the only variable with a high positive loading of 0.98. We shall describe this component as influence of customer size on water requirement.

4.5.2.2.4 Component IV

Component IV has an eigen value of 0.77 and explains 11.1% of the total variance. Variable DAY (day of the week water is mostly needed in the establishment) is the only variable with a positive loading of (0.99). This component may be described as variations in the quantities of water needed in the establishment among the days of the week.

4.5.2.2.5 Component V

Component V has an eigen value of 0.68 and accounts for 9.8% of the total variance. Variable WC (existence of water system in the establishment) has a high positive loading of (0.90). This component may be designated as availability of water use infrastructure.

CHAPTER FIVE

OPTIMAL WATER SUPPLY AND ALLOCATION IN MAKURDI

From our investigation on sectoral patterns of water demand and consumption in Makurdi we observed that water requirements of the various sectors could not be satisfied by consumption (supply). The total water requirements of the residential, commercial and industrial sectors of Makurdi was found to be 21,784,775 litres (lpd) as against 10,530,665 litres (lpd) as consumption with deficiency of 11,254,110 litres (lpd) beside the institutional water need of 4,809,920 litres (lpd). Both the public water supply and supplementary sources of water supply could only meet 48% Makurdi water needs. Our study also revealed that the public water supply is on the progressive decline in terms of water production and supply. This has resulted into greater dependency on the supplementary sources of water supply. In 1994 the per capita water supply in Makurdi was 12,767,264 litres (lpd), it dropped to 10,640,712 litres (lpd) in 1995.

Considering the present water supply in relation to water requirements of the residential, commercial and industrial sectors of Makurdi, of 21,784,775 litres (lpd) we can conclude that what is supplied by the public water supply is grossly inadequate. This situation calls for solution by the way of increasing supplies and to rationally allocate water being supplied.

The problem facing urban water supply schemes in Nigeria resulting into poor performance are outlined by Bukar (1997) as follows: Poor organisational structure of the state water supply Agencies (SWAs) legal framework, insufficient funding, inappropriate technology, lack of proper management by objective (MBO), non-involvement of consumers, inadequate tarrif and revenue collection system, political interference and autonomy. These are neatly classified them as institutional, operational, commercial and financial problems. According to him, to improve water supply in our urban areas these problems must be appropriately and adequately addressed for sustainable potable water supply.

5.1 Plan to Increase Water Supply in Makurdi

The present Makurdi water scheme with a plant capacity of 18,200,000 litres (lpd) is grossly inadequate for the growing sectoral water requirements estimated at 60,000,000 litres (lpd) (BSWB, 1994 Report). Other problems associated with this include inadequate distribution network, leakages from the overhead tanks at Highlevel and North Bank wards that needs rehabilitation. As at the time of our study, ₦300,000 was needed monthly for the purchase of diesel for the power generating plant, ₦210,000 for water treatment chemicals, outstanding NEPA bill of ₦1.5 million. Besides, there is problem of poor revenue collection manifested in general unwillingness to pay by the consumers despite the low water rate.

The problem facing Makurdi urban water supply is not a peculiar one rather it is a true reflection of urban water supplies in Nigeria. Since high capital outlay is required in the development and maintenance of water schemes which in most cases is beyond the ability of the state governments, they often turn to Federal Government for financial assistance in form of loans. According to Bukar (1997), going by the current trend over 80% of investment in water supply development is financed by international donor agencies which is one of the highest in the world, it is also impossible to assume that adequate fund will be made available by the government. According to him, as at the moment no SWAs is executing any capital water project without the support of either the World Bank or African Development Bank (ADB). The problem with Makurdi water supply has in a way received a national blessing with the commencement of National Water

Rehabilitation Project (NWRP) and Petroleum Trust Fund (PTF) urban water supply project.

5.1.1 National Water Rehabilitation Project (NWRP)

There has been a general cry of the poor performance of urban water schemes in Nigeria. The general feeling expressed by the public is that water supply sector was approaching a turning point and that unless new and productive approaches to its management and adequate delivery system are developed and adopted, the sector performance will deteriorate further which may lead to the eventual collapse of facilities.

In 1988 a nation-wide study on rehabilitation requirements of urban water schemes in Nigeria was carried out by the Federal Ministry of Water Resources and Rural Development. To rehabilitate at least 1,000 urban water schemes in Nigeria estimated at the total cost of U.S $814 million. The implementation of NWRP started in 1992 after securing a loan of U.S $46.2 million from World Bank through National Water Rehabilitation Project to rehabilitate at least 30% of the existing water schemes infrastructure. The NWRP has two main objectives:

(i) To improve the level of water supply in selected urban and semi-urban areas by meeting the highest priority rehabilitation needs.

(ii) To address most significantly institutional weakness of SWAs in order to improve their capacities to efficiency operate and maintain their water system.

The NWRP plan for Makurdi water scheme include the following:

(i) Carrying out leak detection programme. Substantial amount of water is lost through damages on distribution lines thereby reducing the quantity of water that eventually reaches the consumers. This is estimated at 50% as unaccounted-for-water (UFW). Benue State Water Board staff are to be trained on this.

(ii) Rehabilitate and equipping the existing laboratory and treatment work site to upgrade it into a state laboratory.

(iii) Renovate a building housing mechanical and electrical workshop.

(iv) Repairing mechanical equipment.

NWRP started in earnest in January 1997. As at the time of this report, they have almost completed that programme.

5.1.2 Petroleum Trust Fund (PTF) Urban Water Supply Programme: Makurdi Water Project

The Petroleum Trust Fund (PTF), designated as a special trust fund was inaugurated in 1994 by the Federal Military Government. This trust fund was set up with the aim of managing themonies realised from the increases in price of petroleum products. This fund is to be channelled to specific projects or areas toward rehabilitating social infrastructures in various parts of the country. These include roads, hospitals, schools, provision of potable water schemes and basic social amenities aimed at improving the condition of life of the generality of Nigerians. Before the introduction of PTF system, a lot of money from petroleum proceeds was pumped into 'ministerial melting pot' but nothing substantial was achieved simply because there was no methodology of spending money neither was there any supervision capacity to see that projects are carried out within specification. The PTF is therefore charged with responsibilities of monitoring and supervising projects funded by the PTF to ensure they are appropriately executed within specification and at the same time are accountable for the management of the resources entrusted to them. Since the inception a measure of success has been witnessed in various parts of the country. Prominent among them is the road rehabilitation projects.

The PTF has allocated a portion of its proceeds toward the cost of rehabilitating and upgrading some of the selected urban water supply schemes. One of these is the proposed new Makurdi water supply scheme.

Existing water scheme is currently served by an 18,200,000 litres (lpd) plant production capacity, having an average per capita water production of 11,000,000 litres (lpd). The present water demand estimated at 60,000,000 litres (lpd) cannot be satisfied because demand far exceed the plant production capacity. Hence an entirely new water scheme is proposed for Makurdi which will not only improve the level of water production, but also the distribution and delivery system.

A two treatment plant capacity of 32,000,000 litres (lpd) each has been proposed totalling 64,000,000 litres when completed. The construction will be in two phases which will be completed in 10 years. The first phase is expected to be completed in 1999 and the second phase in 2009.

The new scheme will include these components which were not part of the existing scheme. Raw water main of 4 Nos gallery units each of them consisting of horizontally laid perforated screens laid parallel to stream, and placed at a depth of 4-5m below water level. The gallery will be surrounded by graded package.

There will also be a collection well of 760,000 litres beside high water level flood plain between infiltration gallaries and treatment work.

New storage reservoirs have been proposed for New GRA (500,000 litres capacity), Airforce base (100,000 litres), New Industrial site (200,000 litres), Central reservoir for North Bank ward (200,000 litres).

New service areas have also been proposed.

Under the existing scheme, areas covered sufficiently by piped supply up to 80% are Upper Wadatta, Highlevel ward, Lobi and Kwarafar Quarters (Old GRA ward), Ankpa and low density area of Government House.

The lower Wadatta, Wurukum areas only receive intermittent supplies reaching 20-50% of the area inhabited.

Since 1978 when the last reticulation improvement was done, the town development has far outgrown the extent of reticulation making it economically difficult to extend distribution network from existing water supply. The new water scheme has proposed to extend service areas:

Makurdi South: Along Gboko Road to Airforce Base; an extension to new GRA - Otukpo Road to Kansio, lower Benue

River Development Authority (LBRDA) Agricultural Development Company (ADC); along Naka Road to proposed industrial site from Wadatta ward through community secondary school.

Makurdi North: Yogbo street toward NASME market, New Layout Road junction to Federal Housing Estate (FHA), from FHA to School of Remedial Studies (SRS) and University of Agriculture.

5.2 Management Options: Rational Water Allocation

Rational allocation of water supply according to Rees (1975a) is a method whereby purified water from the water works is distributed to the consumers in such a way and manner that consumers are supplied enough.

To adequately address the problem of water supply shortages in our urban areas, Ezenwaji (1990) has identified three options that are available to water managers viz: (i) to increase supply (ii) suppress demand (iii) to rationally allocate what is available.

Water management options as adopted in some parts of the world include (a) water allocation based on number of establishments in the sector (b) revenue returns (c) peak demand (d) water need allocation (e) management by objective (MBO).

Water allocation based on the total number of establishments was adopted in Brisbane, Australia. Brisbane recognised two sectors, viz: Industrial and residential sectors. Water is supplied to the residential sectors as social amenities with low tarrif, but industrial sector as economic good with high rate because of its commercial orientation (Rees, 1982).

Revenue return water allocation strategy was adopted in Karachi, Bangladesh (Rees, 1975b). Going by this option, the quantity of water is supplied to a sector based on revenue generation. Residential sector got the least supply because of poor revenue returns. Applying this option in our urban water supply will pose as serious as water supply is regarded as a social service without commercial orientation. Besides, this option will only help to aggravate the water supply situations.

Peak demand water allocation option is a strategy whereby water is allocated to residential and industrial sectors based on their individual peak demand, that is when water is needed mostly. This method has been attempted in Dakar, Senegal and Dar-es-Salam with modification, that is a special tarrif is charged. According to Halmot (1986), it is to limit the amount of water demanded at peak periods. The problem with this option is that if several sectors have their peak demand at the same time, it will pose a problem on which sector(s) to satisfy in view of the quantity of water that is available.

Another water allocation strategy as adopted in Teipei, Taiwan is the water needs option. Here commercial sector has been designated as the sector with the greatest water need as such more water is supplied to them.

The management by objectives (MBO) water allocation option was attempted in New Delhi in the supply of water to urban sectors. In this strategy a group of workers are assigned under a leader to take the responsibility of supplying water to the residential, industrial and agricultural sectors. Group leader writes a report concerning the public workers performance in the sector at the end of each day. This report is then submitted to the General Manager who eventually evaluates them. According to Biswas (1971), this method of appraising water supply to sectors ensures that the problem areas are readily detected and rectified.

Considering the various management options in water allocation as adopted in various parts of the world, management by objective (MBO) appears to the best option for Makurdi water supply. The reason is that there have been no close monitoring of the performance of staff of the Benue State Water Board. In most cases the workers appear redundant. It is not surprising to note that water loss through damages and distribution lines and delivery system may continue for days unrectified. With proper training and motivation of water workers their efficiency will be enhanced resulting into better performance of the water Board.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study is concerned with the determination of the quantities of water demanded and consumed in the residential, commercial and industrial sectors of Makurdi. In this way sectoral allocation patterns of water may be determined and compared with the actual demand and consumption.

From our study we observed that the quantity of water demanded and consumed vary substantially among the various sectors of Makurdi. Residential sector was noted to have the highest water demand and consumption. This is followed by commercial and industrial sectors respectively. Variation in the quantity of water demanded and consumed was also noted among the wards of the residential sector, and in the commercial and industrial subsectors. In all the sectors and subsectors of the commercial and industrial sectors, water demand far exceeded their consumption, which is the actual amount of water consumed. This in most cases suggests the existence of water shortage relative to demand.

Our study also revealed a high dependency on supplementary sources of water supply occasioned by the inability of the public water supply to provide enough water for use. In fact progressive decline in the quantity of water produced and supplied was observed between 1994 and 1995.

The underlying factors identified as being largely responsible for variation in water demand and consumption patterns in the residential, commercial and industrial sectors are as follows:

In the residential sector, these include

(i) The family size

(ii) The frequency of water supply

(iii) The level of household general sanitation

(iv) The socio-economic status of the head of the household

(v) The impact of distance covered to fetch water daily, and

(vi) The availability of water infrastructure.

For the commercial sector, these include:

(i) The influence of the size of customers

(ii) The impact of cost of water supply

(iii) The size of labour force.

In the industrial sector, the level of production was identified as the important factor.

Other findings from our study include inadequate distribution network, absence of public pipe stand and water meters, problem of quantifying the amount of water supplied to various sectors and areas, rising cost of water production in form of procurement of water treatment chemicals and diesels for the power generating plant, and NEPA bills.

6.2 Suggestion and Recommendation

The urban water requirements from this study is quite enormous in view of its growing population and expanding commercial and industrial development. Since the capacity of the existing water scheme is grossly inadequate we therefore, recommend an entirely new scheme with increased capacity. If the PTF Makurdi urban water scheme is successfully executed as proposed it will go a long way to improve the public water supply in Makurdi.

The distribution network of the public water supply s should be extended to areas not presently covered by the existing scheme. And to improve the distribution and delivery system, leaking overhead tanks at Highlevel and North Bank should be rehabilitated and construction of new ones at designated areas. As substantial quantities of water produced is lost through damages and leakages on the distribution lines, leak detection programme should be promptly carried out to prevent wastage and reduction in the quantities of water that eventually reaches the consumers.

The biggest problem facing State Water Agencies (SWAs) is inadequate funding by the government and poor revenue generation demonstrated in general unwillingness to pay even the low rate. They conceive provision of water as a social service which should be free. The public should be educated on their role in bid to have a sustainable water supply. A partial commercialisation to make the Board self-supporting should be introduced and proper accounting system be evolved, such that money generated is properly utilized especially in maintenance of the facilities. Government should increase subvention to the water board to boost their financial position.

Since public water supply and NEPA are regarded as part of essential services and public utilities, NEPA should place water board on a low tarrif as to reduce their running cost.

For proper quantification of water supplied and used water meters should be introduced not necessarily to increase rate in houses and in commercial and industrial establishments.

From our study we observed that the public displayed gross ignorance on the water requirements. In fact some households gave very low estimates on the quantity of water demanded and consumed not necessarily for the fear of increasing water rate to them. The public should be enlightened and educated on water need as it is essential to the quality of life and socio-economic development of a place.

6.3 Areas for Further Study

This study is principally concerned with the determination of the patterns of water demand and consumption in the residential, commercial and industrial sectors of Makurdi urban area. These sectors themselves are broad areas that may be investigated independently as to enable one identify other factors that may significantly influence patterns of water demand and consumption in the sectors.

The responsibility of urban public water supply rest solely on the state government. The possibility of involving the private sector in investment in water business should be explored.

Probable water pollution resulting from urbanisation as River Benue divide Makurdi into North and South may be investigated.

From our study, Makurdi relies heavily on surface water from River Benue, ground water sources could also be investigated.

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APPENDIX A

QUESTIONNAIRE FOR RESIDENTIAL SECTORS

Sir/Madam,

I am a postgraduate student of Department of Geography, University of Nigeria, Nsukka, undertaking a research in the field of Hydrology and water Resources on water demand in Makurdi metropolis.

Could you please supply the information below. Whatever information given will be treated as confidential, purely for academic purposes as data is meant for research.

Thanks.

Yours faithfully,

Sgd./
Ocheri I. Maxwell.

1. Which part of the town do you reside?
   (a) Wadatta ( ) (b) Wurukum ( ) (c) Central ward ( )
   (d) Highlevel ( ) (e) Ankpa Ward ( )
   (f) Old GRA ( ) (g) New GRA ( ) (h) North Bank ( )
2. What is your occupation? ....
3. What is your educational level? ....
4. How many of you are in a household? ....
5. Do you have water tap in your residence?
   (a) Yes ( ) (b) No ( )
6. If Yes, how many hours does water run in your house per day?
   .... per week/month.

7. If you have water system in your apartment, indicate number of flush toilets:

.... showers ....baths

8. Do you have water meter in your apartment?

(a) Yes ( ) (b) No ( )

9. How much do you pay monthly as water rate? ....

10. If you rely on water from the river on public pipe stand indicate the distance covered in Km .... and time spent daily to get water: ....

11. If you depend on water vendors how much do you spend on water daily? .... Indicate the cost per measure ....

12. Apart from getting water from the public water supply what are sources of supply do you depend on?

(a) Well ( ) (b) River ( ) (c) Water vendors ( )

13. Estimate the quantity of water that is expected to meet all the household needs in a day in number of standard buckets (SON 30) .... or litres ....

14. Estimate the quantity of water that is actually consumed in a day in your household in number of buckets (SON, 30) .... litres ....

15. Estimate the quantity of water that is used daily in number of buckets (SON, 30) or litres for cooking .... washing clothes .... general cleaning ....

APPENDIX B

QUESTIONNAIRE FOR COMMERCIAL SECTOR

1. Indicate type of commercial establishment
   (a) Hotel/Restaurant ( ) (b) Hair dressing salon ( )
   (c) Car wash ( )

2. Which part of the town is commercial establishment located:..

3. Number of persons employed:...........................

4. Number of workshifts in a day:.........................

5. Sources of water supply to your establishment:
   (a) Public water supply ( ) (b) River ( )
   (c) Well ( ) (d) Water vendor ( )

6. If your answers to No. 5 above is public supply, how much are you called upon to pay monthly? ....

7. If your supply is from water vendor, how much do you spend on water daily? ....

8. Estimate the quantity of water expected to meet all the establishment requirement daily in litres: .... or number of buckets (SON, 30) ....

9. Estimate the quantity actually consumed in a day in litres .... or number of buckets ....

10. Indicate time of the day ...... or day of the week water mostly needed in your establishment and state reason(s) for it ....

11. What is the average number of customers to your establishment in a day ....

12. Does the cost of water supply to the establishment affect it? ....

APPENDIX C

QUESTIONNAIRE FOR INDUSTRIAL SECTOR

1. Indicate type of industrial establishment
   (a) Bakery ( ) (b) Block moulding ( )
   (c) Bottling company ( )

2. Where is the industry located? ....

3. State reason(s) if any for locating your industry in the place ....

4. Number of persons employed ....

5. Number of workshifts in a day ....

6. Sources of water supply utilized by your establishment:
   (a) Public water supply ( ) (b) River ( )
   (c) Well ( ) (d) Water vendor ( )
   (e) privately developed water works ( )

7. How much do you spend on water daily? ....
   monthly ....

8. Do the cost of water supply in any way affect the price of your products?
   (a) Yes ( ) (b) No ( )

9. What is your average production in a day?
   (a) Number of loaves .... (b) No. of blocks ....
   (c) No bottles ....

10. Estimate the quantity of water that is expected to all the industrial need in a day in litres ....

11. Estimate the quantity of water actually consumed in a day in litres:......................................

12. What time of the day .... or week is water mostly needed in your establishment, and give reason(s) why:..........
    ....

APPENDIX D

QUESTIONNAIRE FOR WATER WORKS

1. Name of the water works:......................................

2. Where is it located? ....

3. How many water supply areas do you divide Makurdi into? ....

4. What is the total amount of water which you serve them daily? ....

5. Is there deficit in one, how do you make up for them? ....

6. Do you have any reason(s) to emphasise the supply of water to any area? ....

7. From which source do you get water? ....

8. Is that enough source to sustain your present supplies to the town? ....

9. What treatment processes do you undertake? ....

10. What is the cost of water treatment in a month? ....

11. How many pumps do you have? ....

12. Do the pumps adequately serve all areas of the town? ....

13. How many reservoir do you have? ....

14. Where are they located? ....

15. What are the capacities of the various reservoirs? ....

16. Is there any reason(s) for locating the reservoir in the place? ....

17. Are all the reservoirs presently in use? ....

18. If No, what are the reasons? ....

19. Is there any way topography of the town poses difficulty for the distribution? ....

20. What is the charging system? ....

21. How many functional public pumps stands do you have?
....

22. If none, what is the reason(s)? ....

23. What is the consumption rate for the various wards of the town? ....

APPENDIX E

SPSS COMPUTER PROGRAMME APPLIED FOR PRINCIPAL COMPONENTS ANALYSIS

```
RUN NAME:          OCHERI: MAKURDI WATER SUPPLY

FILE NAME:         OCHERI MAXWELL IDOKO, GEOGRAPHY DEPART-
                   MENT.

VARIABLE LIST:     TAM, XINC, WASH, COOK, COST, SIZE, EDU,
                   CLEAN, HOUR, TAP, SUPP, DIST. WCAPP

INPUT MEDIUM:      CARD

SUBFILE LIST:      CENTRAL (34), NORTH (30), OLDG (33), NEW G
                   (25), ANKPA (37), HI GHL (39), WADATA (28),
                   WURUKUM (33).

INPUT FORMAT:      FIXED (7.1, 9.1, 3 F7.1, 4F6.1, 4F 5.1).

RUN SUBFILE:       EACH

FACTOR:            VARIABLES = TAM TO WCAPP/REGRESSION =
                   TAM WITH XINC TO WC PP(2) 1

STATISTICS:        1

RUN SUB FILES:     ALL

REGRESSION:        VARIABLES = TAM TO WCAPP

STATISTICS:        1

RUN SUBFILES:      EACH

FACTOR:            VARIAB ES = XINC TO WCAPP/
                   TYPE = PA1/
                   N FACTORS = 8/
                   ROTATE   = VARIMAX
STATISTICS:        4, 5, 6
RUN SUBFILES:      ALL
                   N FACTOR = 8/
                   ROTATE - VARIMAX/
STATISTICS:        4, 5, 6
FINISH.
```

APPENDIX F

SPSS COMPUTER PROGRAMME APPLIED FOR PRINCIPAL COMPONENTS ANALYSIS

```
RUN NAME:         OCHERI: MAKURDI WATER SUPPLY

VARIABLE LIST:    TAM, COST, EMP, CUST, SHIFT, SOURCE,
                  DAY, WC.

FILE NAME:        OCHERI MAXWELL IDOKO GEOGRAPHY
                  DEPARTMENT

INPUT MEDIUM:     CARD

NO. OF CASES:     53

INPUT FORMAT:     FIXED (F. 9.1, F 8.1, 2 F 6.1, 4 F 5.1)

REGRESSION:       VARIABLES = TAM TO WC/
                  REGRESSION = TAM WITH COST TO WC (2)/

STATISTICS:       1

FACTOR:           VARIABLES = COST TO WC/

                  TYPE = PA 1/
                  N FACTORS = 8/
                  ROTATE = VARIMAX/

STATISTICS        4, 5, 6

FINISH

RUN NAME:         OCHERI: MAKURDI WATER SUPPLY

VARIABLE LIST:    TAM, COST, CUST, EMP, SOURCE, DAY

FILE NAME:        OCHERI MAXWELL IDOKO, GEOGRAPHY
                  DEPARTMENT

INPUT MEDIUM:     CARD

NO. OF CASES:     20
```

```
INPUT FORMAT:     FIXED (2 F7.1, F6.1, 3F.5.1

REGRESSION:       VARIABLES = TAM TO DAY

                  REGRESSION =  TAM WITH COST TO DAY
                  (2)/

STATISTICS:       1

FACTOR:           VARIABLES = COST TO DAY/

                  TYPE = PA1/
                  N FACTORS = 7/
                  ROTATE = VARIMAX

STATISTICS:       4, 5, 6

FINISH.


RUN NAME:         OCHERI: MAKURDI WATER SUPPLY

VARIABLE LIST:    TAM, COST, EMP, CUST, SHIFT, SOURCE,
                  WC.

FILE NAME:        OCHERI MAXWELL IDOKO, GEOGRAPHY
                  DEPARTMENT

INPUT MEDIUM:     CARD

NO. OF CASES:     15

INPUT FORMAT:     FIXED (2F8.1, 2F.6.1, 2 F5.1)

REGRESSION:       VARIABLES = TAM TO WC/
                  REGRESSION = TAM WITH COST TO WC

STATISTICS:       1

FACTOR:           VARIABLES = COST TO WC

                  TYPE = PA 1/

                  N FACTOR = 7/

                  ROTATE = VARIMAX

STATISTICS:       4, 5,6

F
```

APPENDIX G

SPSS COMPUTER PROGRAMME APPLIED FOR PRINCIPAL COMPONENTS ANALYSIS

```
RUN NAME:       OCHERI MAKURDI WATER SUPPLY

VARIABLE LIST:  TAM, PROD, COST, EMP, SHIFT, SOURCE
FILE NAME:      OCHERI MAXWELL IDOKO GEOGRAPHY
                DEPARTMENT

NO. OF CASES:   6
INPUT FORMAT:   FIXED (F7.1, F8.1, F7.1, F6.1, 2 F5.1)
REGRESSION:     VARIABLE =  TAM TO SURCE/
                REGRESSION = TAM WITH PROD TO SURCE (2)/

STATISTICS:     1

FINISH

RUN NAME:       OCHERI: MAKURDI WATER SUPPLY

VARIABLE LIST:  TAM, PROD, EMP. SOURCE

FUE NAME:       OCHERI MAXWELL IDOKO, GEOGRAPHY
                DEPARTMENT

INPUT MEDIUM:   CARD

NO. OF CASTS:   11

INPUT FORMAT:   FIXED (2 F 8.1, 2F5.1)

REGRESSION:     VARIABLES = TAX TO SOURCE/

                REGRESSION = TAM WITH PROD TO SOURCE (2)/

STATISTICS:    1

FINISH:
```