*

INVENTORY AND ASSESSMENT OF WATER SUPPLY SCHEMES IN OWERRI TOWN, IMO STATE

BY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN HYDROGEOLOGY

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DECLARATION

I hereby declare that this thesis is a record of my own field research and has not been submitted for the award of a degree at any other University. Information and excerpts from both published and unpublished work of others have been acknowledged in the text.

Oha Maduabuchi Jude

CERTIFICATION

This project thesis entitled Investory and Assessment of Water Supply Scheme in Owerri Town, Imo State by Oha Maduabuchi Jude meets the regulations governing the award of the degree of M.Sc. in Applied Geology (Hydrogeology) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Chairman, Supervisory Committee — Date: 7th November 1987

Member, Supervisory Committee — Date: _____

Head of Department — Date: 30/11/87

Dean, Postgraduate School — Date: 15-2-88

DEDICATION

This work is dedicated to my elder brothers, for their contribution towards the advancement of education in the family, and to Chinedu E. Oha.

ACKNOWLEDGEMENT

The encouragement, assistance and fatherly advice of my supervisor, Dr. K. Schoeneich is gratefully acknowledged. Also, the assistance towards the successful implementation of the programme by Dr. E. C. Ike, the Head of Department and other members of staff of the Department is acknowledged.

However, the production of this work received the blessing and assistance of my parents and elder brothers, especially Mr. E. E. Oha, Mr. I. U. Oha and Mr. C. E. Oha. My special thanks go to the following friends: Messrs. P.C. Onyenekwe, M. Onoh, A. Umaru, T. Askira, N. Obaje, O. Nwogbo, S. Aneke, O. Adonri and V. Puegeren.

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ABSTRACT

An inventory of water supply and distribution for Owerri and environs in the Eastern part of Nigeria has been carried nut. The Owerri cown water supply scheme was commissioned around 1960 as a battery of boreholes, with an average yield of 567.75 m^3/d. In the late 1970s, the number of boreholes increased considerably. Today, this intake has been abandoned and a new impounding reservoir at a nearby stream, is the only source.

The bacteriological quality of the impounding stream is below minimum standard and a treatment plant was constructed to ensure the supply of potable water. Water distribution has been enhanced through the provision of elevated water towers and ground level reservoirs.

However, analysis of the available borehole data show that the yield of the Aquifer is high and that in future, Owerri should be supplied from groundwater scheme as a means of reducing overhead costs.

TABLE OF CONTENTS

Chapter		Page
	Title Page	i
	Declaration	ii
	Certification	iii
	Dedication	iv
	Acknowledgement	v
	Abstract	vi
	Table of Contents	vii
	List of Tables	ix
	List of Figures	x
	List of Plates	xi
	List of Appendices	xii
	Abbreviations	xiii
1	INTRODUCTION	1
1.1	Location	1
1.2	Relief and Drainage	2
1.3	Temperature	4
1.4	Rainfall	7
1.5	Geology	10
1.6	Hydrogeology	16
1.7	Vegetation	18
2.	POPULATION AND WATER DEMAND	20
2.1	Population	20
2.2	Water Demand	24

Chapter		Page
3	WATER SUPPLY SCHEMES	29
3.1	Groundwater Supply Scheme	29
3.1.1	Okigwe road groundwater Scheme	29
3.1.1.1	Quality of water	33
3.1.1.2	Technical description	36
3.1.1.3	Distribution network	37
3.1.2	Rural groundwater scheme	40
3.1.2.1	Technical description	45
3.1.2.2	Distribution network	46
3.2	Surface Water Scheme	46
3.2.1	History and yield	47
3.2.2	Raw water quality	50
3.2.3	Method of abstraction	53
3.2.4	Treatment	55
3.2.5	Distribution network	65
3.3	Number of Connections	67
4	FUTURE DEVELOPMENT	70
4.1	Plans for Future Extension	70
4.2	Recommendations for Future Development	73
5	SUMMARY AND CONCLUSION	77
	REFERENCES	78
	APPENDICES	81

LIST OF TABLES

		Page
Table 1.1	Monthly mean temperature for Owerri station from 1976 to 1985	5
Table 1.2	Monthly rainfall total for Owerri station from 1976 to 1985	8
Table 1.3	Determination of sediment composition of the Coastal Plains Sands in Owerri	13
Table 2.1	Forecast of population in Owerri	21
Table 3.1	Borehole data from the Okigwe road groundwater scheme	31
Table 3.2	Water analysis for the Okigwe road groundwater scheme	34
Table 3.3	Borehole data from the rural groundwater scheme	41
Table 3.4	Quantity of construction materials used for the Otamiri surface water scheme	47
Table 3.5	Chemical analysis of the raw water from the Otamiri River.	52
Table 3.6	Result of Bacteriological analysis of water from the Otamiri pumping station	61
Table 3.7	Chemical analysis of treated water from the Otamiri Head works	63
Table 3.8	Classification of drinking water quality based on Hardness (after Walker)	64

LIST OF FIGURES

		Page
Figure 1.1a	Map of Nigeria showing location of Owerri	3
Figure 1.1b	Map of Owerri and Environs	3
Figure 1.2	Mean, maximum and minimum temperature from 1976 to 1985	6
Figure 1.3	Monthly average rainfall for Owerri from 1976 to 1985	9
Figure 1.4	Geological Map of Owerri and Environs	12
Figure 1.5	Graphic logs comparing the lithologies in three Boreholes across the profile AB in Fig. 3.3a	14
Figure 1.6	Plot of Borehole depth against yield in Owerri	17
Figure 2.1	Projection of population growth for Owerri	23
Figure 2.2	Projection of average daily water demand in Owerri	27
Figure 3.1	Borehole locations at the Okigwe road groundwater scheme	30
Figure 3.2	Distribution network for the Okigwe road groundwater scheme	38
Figure 3.3a	Borehole Locations for the Rural groundwater Scheme	42
Figure 3.3b	Plot of screen length against yield ..	44
Figure 3.4	Sketch (front view) of the Weir and intake units	54
Figure 3.5	Schematic sketch of the intake, treatment and distribution units at the Otamiri river Headworks	56
Figure 3.6	Otamiri surface water distribution network	66

LIST OF PLATES

		Page
Plate I	Front view of a Borehole connected with a flowmeter at the Okigwe road groundwater scheme.	93
Plate II	Side view of the sedimentation tank filled with water, at minimum turbulence and provided with the Scraper bridge at the Otamiri treatment Headworks	93
Plate III	Front view of the 20,000 m^3 North East Ground Level Reservoir (NEGLR) at the Water Board premises, Owerri.	94

APPENDICES

		Page
Appendix A	Mean monthly maximum temperature for Owerri station from 1976 - 1985	81
Appendix B	Mean monthly minimum temperature for Owerri station 1976 - 1985	82
Appendix C	Data on borehole depth and yield.	83
Appendix D	Estimate of daily water demand in Owerri	84
Appendix E	International Drinking Water Standards and Objectives (after Walker 1978)	85
Appendix F	Logs of selected boreholes in Owerri	86
Appendix G	Structural design of Otamiri EWT	89
Appendix H	Structural design of Orji/Junction EWT	90
Appendix I	Structural design of Ubomiri EWT	91
Appendix J	Structural design of Avu EWT	92

AC	Asbestos Cement
AD	Anno Domini (in the year of the Lord)
BH	Borehole
CDT	Chlorine Demand Test
Cm	Centimetre
CWE	Chief Water Engineer
ECSWB	East Central State Water Board
EWT	Elevated Water Tank
GLR	Ground Level Reservoir
G.S	George Stow
GSN	Geological Survey of Nigeria
H	Height
Lpcd	Litre per capita day
L/S	Litre per second
M	Metre
M^3	Cubic metre
M^3/d	Cubic metre per day
mg	Milligram
mg/L	Milligram per litre
m^3/hr	Cubic metre per hour
mm	millimetre
m^3/s	Cubic metre per second
NEGLR	North East Ground Level Reservoir
NWSC	Nigeria Water Supply Company
PPM	Parts per million
PVC	Polyvinylchloride
SSW	South of South West
TDS	Total Dissolved Solids

UNICEF	United Nations International Children's Emergency Fund
WAWWDAS	West African Water Drilling and Allied Services
$\underline{\nabla}$	Water Level
Φ	Diameter
<	Less than
>	Greater than

Chapter 1

INTRODUCTION

The work attempts to present an inventory of water supply and distribution for Owerri and environs, based on data from the archives of Imo State Water Board. During the Nigerian civil war of 1967 to 1970, many vital documents were destroyed. It is indispensable to reconstruct and represent the general picture of the water schemes, with a view to preserving their history for posterity.

The population of Owerri has almost doubled since the creation of states in 1976. The result of this is obvious, the total water requirement is on the increase, and per capita water consumption is also on the increase. The need arises to examine the past and present water supply schemes so as to access their adequacies as well as the future of water supply demand. However, recommendations for future water resources utilization in the town has been considered in order to avert serious water crisis.

1.1 Location

The location of Owerri in the context of this work is delimited by the extent principally serviced through the municipal and rural water supply schemes under the supervision of the Owerri Zonal Water Board. The area falls within latitudes $5^{o}25'10"N$ to $5^{o}34'N$ and longitude $6^{o}56'05"$ to $7^{o}09'E$. The towns covered by the scheme are

indicated on Figure 1.1.

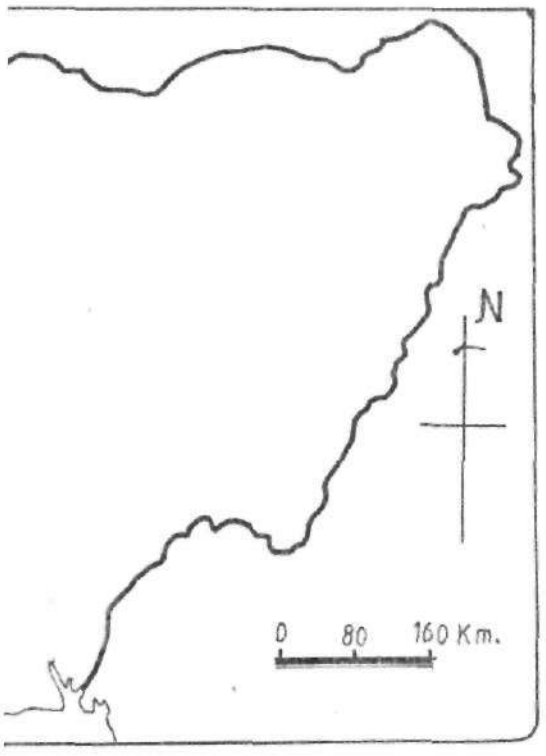
Three - quarters of the towns in the project area are located within the Owerri Local government area (southern part). The rest are located within the Mbaitoli/Ikeduru local government area (northern part). The boundary is shown on the map.

1.2 Relief and Drainage

Owerri is on almost a flat terrain with only a very gentle slope. From the centre of the town to a radius of about 3 km it is flat. There is a very gentle rise from this point to about 100 m above sea level, which is the highest contour limit in the area and the flat nature being retained thereafter. The elevation ranges from below 57 m to over 100 m above sea level. The present land forms are the result of the normal processes of erosion controlled by the lithology and structure of the formation. The rest include the application of watershed management.

The major Rivers draining the area include: Nwaorie, Otamiri, Okitankwo and Mba. The trend and location of these Rivers have been shown in Figure 1.1. Runoff, resulting from high intensity of rainfall, drains into those rivers, especially during the rainy season. In effect, flooding is well controlled in Owerri.

MAP OF OWERRI AND ENVIRONS



showing location of Owerri

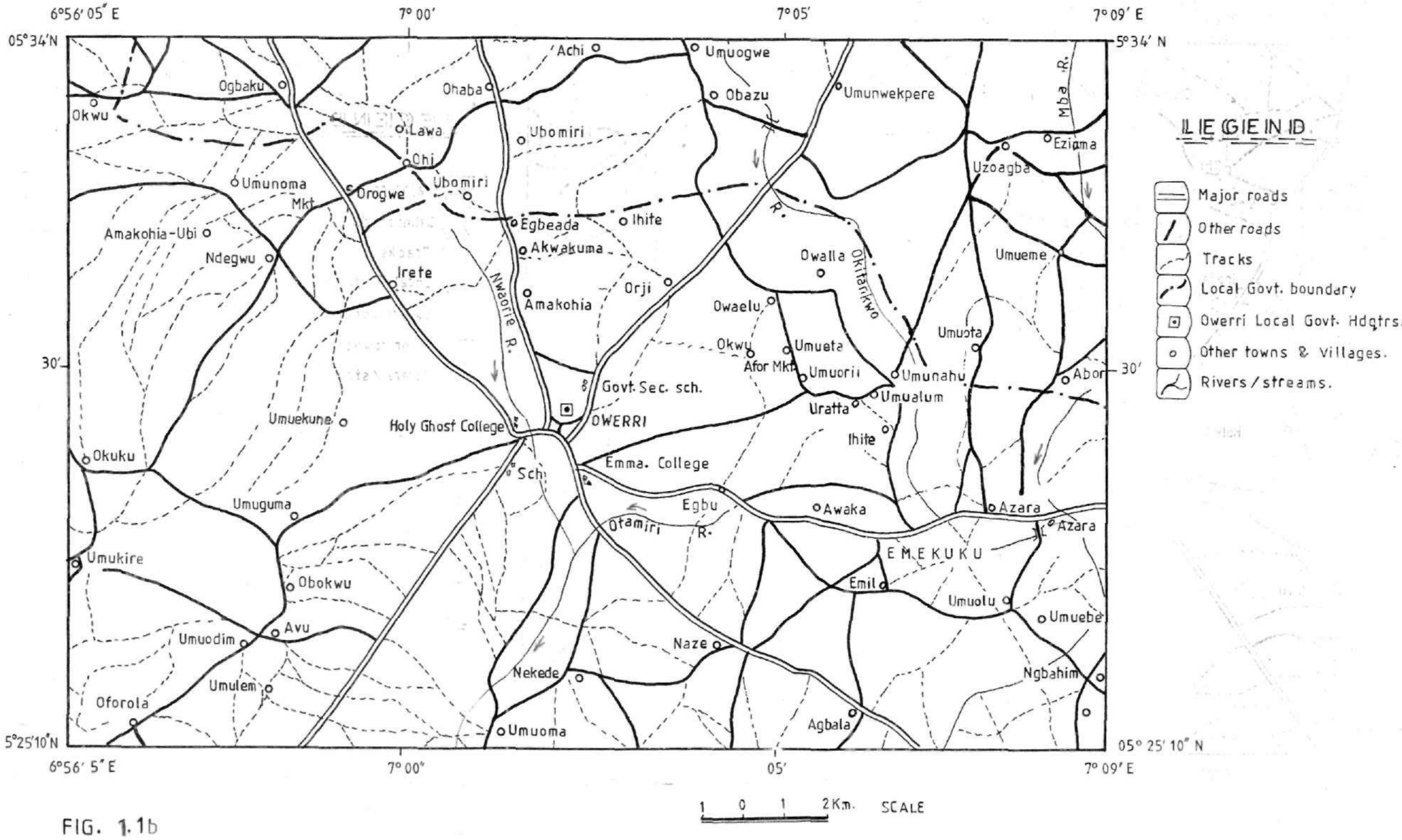


FIG. 1.1b

(adapted from Owerri Provisional Map, 1981)

1.3 Temperature

Owerri is located within the equatorial zone with hot and wet climate. The mean monthly temperature varies between 29.32°C being the mean monthly temperature for February and 25.76°C, the mean monthly temperature for July (see Table 1.1). The proximity to the sea and equator could be contributory factors.

According to Monkhouse (1976), onshore winds in the tropics, blowing from over the cooler ocean, tend to modify temperatures on the coastal margin. On the other hand, onshore winds such as the westerlies may in winter carry mild temperature from over the oceans on to the continent margins. Owerri is located close to the Atlantic Ocean and all these climatic factors impinge on the town.

However, temperatures vary in the two season experienced in this area. The hottest months fall within the dry season which lasts from November to April. Appendix A, illustrates that temperature values within these months are quite high and February forms the peak with 35.79°C.

Temperatures are usually low during the rainy season which lasts from May to October (see Appendix B). The annual range of fluctuation is 3.56°C. According to Monkhouse (1975), the oceans and those land margins affected by oceanic influences tend to have more equable temperature, with low seasonal ranges. This has been illustrated in

Table 1.1 MONTHLY MEAN TEMPERATURE FOR OWERRI STATION FROM 1976 - 1985
(Unit °C, Lat 05°29'N. Long 07°02IE Alt. 90.91m)
NIGERIAN METERORLOGICAL SERVICES OWERRI

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC	YEAR
X	X	X	X	X	X	24.7	24.9	26.1	26.3	26.9	27.6	1976
27.5	28.7	28.9	28.7	28.0	26.1	25.7	25.9	26.5	26.8	28.7	26.9	1977
27.1	29.3	28.3	27.5	27.5	26.8	25.7	26.0	26.2	26.7	27.1	28.4	1978
28.7	28.7	28.5	28.5	27.9	26.7	26.3	25.7	28.3	26.9	27.7	26.6	1979
28.9	29.8	28.7	28.5	27.2	26.5	26.0	25.9	26.3	26.5	27.4	27.3	1980
26.7	29.0	28.7	28.6	27.5	27.1	25.7	26.0	26.1	26.7	27.0	28.3	1981
26.7	28.9	28.5	28.6	27.6	27.1	25.9	25.5	25.9	26.6	27.1	27.9	1982
26.9	30.2	31.3	29.9	28.4	26.8	25.8	25.4	26.4	27.3	28.5	27.8	2983
28.1	29.9	28.9	28.3	27.7	27.3	26.5	26.7	26.3	26.7	27.9	27.3	1984
28.6	29.4	29.7	28.1	27.9	26.8	25.3	26.3	x	26.9	27.8	27.1	1985
249.2	263.9	261.5	256.7	249.7	241.2	257.6	258.3	238.1	267.4	276.1	275.2	TOTAL
27.69	29.32	29.06	28.52	27.74	26.8	25.76	25.83	26.46	26.74	27.61	27.52	AVERAGE

X = Not recorded

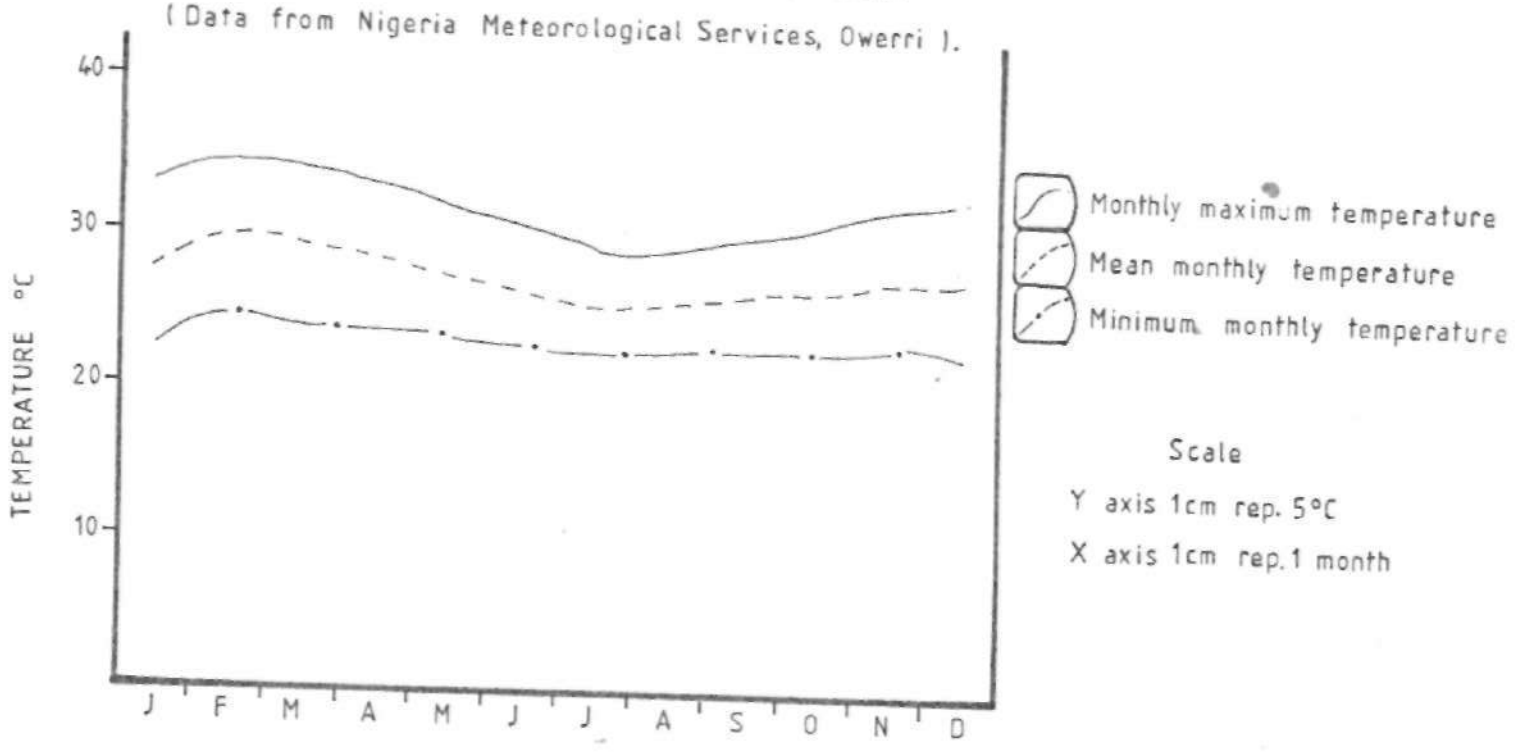


Fig. 1.2 Mean maximum and Minimum Temperatures from 1976 to 1985.

Fig. 1.2 which present the mean, maximum and minimum temperatures. The interval between the mean line and the maximum temperature line as well as the minimum temperature line appear to be virtually constant from January to December.

Control resulting from precipitation and cloud cover may be responsible for the low annual range of temperature. The coldest months occur between July and September (see Fig. 1.2).

1.4 Rainfall

The tropical maritime air mass which is warm and wet, originating from the southern high pressure belt, crosses the equator, picks up moisture from over the Atlantic Ocean and enters Nigeria from the south (Tloeje, 1981).

Another contributory factor to heavy precipitation in Owerri is the high humidity of over 80%. However, the generation of moist air current through excessive heating, which condenses in the cloud and subsequently precipitates, can equally contribute to rainfall in the area.

The amount of rainfall recorded in the area is presented in Table 1.2. The table shows that precipitation takes place in Owerri throughout the year. On the average, much of the rainfall is within March and October (see Fig. 1.3).

The rainfall histogram in Fig. 1.3 indicates that the area has a double maxima rainfall regime. There is a sharp

Table 1.2 MONTHLY RAINFALL TOTAL FOR OWERRI STATION FROM 1976 - 1985
(Unit - - mm, Lat. 05°29'N, Long 07°02'E AL+ 90.91m)
NIGERIAN METEOROLOGICAL SERVICES OWERRI

JAN.	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC	YEAR
TR	158.6	209.0	210.8	133.9	409.5	220.3	265.0	237.4	400.7	53.7	102.6	1976
24.0	19.3	85.5	86.4	165.3	286.5	399.8	284.2	283.4	228.4	0.2	25.4	1977
TR	47.9	177.0	265.8	309.4	200.5	227.5	355.9	432.5	326.4	53.5	TR	1978
26.0	89.7	143.1	167.2	213.3	420.7	297.7	366.3	534.6	319.7	107.6	0.0	1979
TR	9.9	83.8	219.7	161.3	497.1	307.9	463.3	234.3	251.0	167.9	TR	1980
84.9	17.0	104.4	180.5	342.1	345.1	341.2	325.7	522.7	122.2	31.1	0.0	1981
59.2	110.6	137.3	102.5	326.5	303.6	429.9	258.7	268.5	313.3	97.1	0.0	1982
0.0	1.0	50.8	54.6	257.5	293.8	274.8	157.9	573.5	23.3	32.1	38.1	1983
0.0	8.5	109.6	204.8	218.5	372.8	285.6	338.1	297.1	291.5	29.8	5.1	1984
51.0	8.8	259.9	149.5	354.3	279.2	416.2	433.5	250.7	125.2	64.4	3.6	1985
245.1	466.3	1360.4	1641.8	2482.2	3408.8	3200.9	3248.6	3734.7	2401.7	637.4	174.8	TOTAL
49.02	46.63	136.04	164.18	248.22	340.88	340.09	324.86	373.47	240.17	63.74	34.96	AVERAGE

TR = Trace

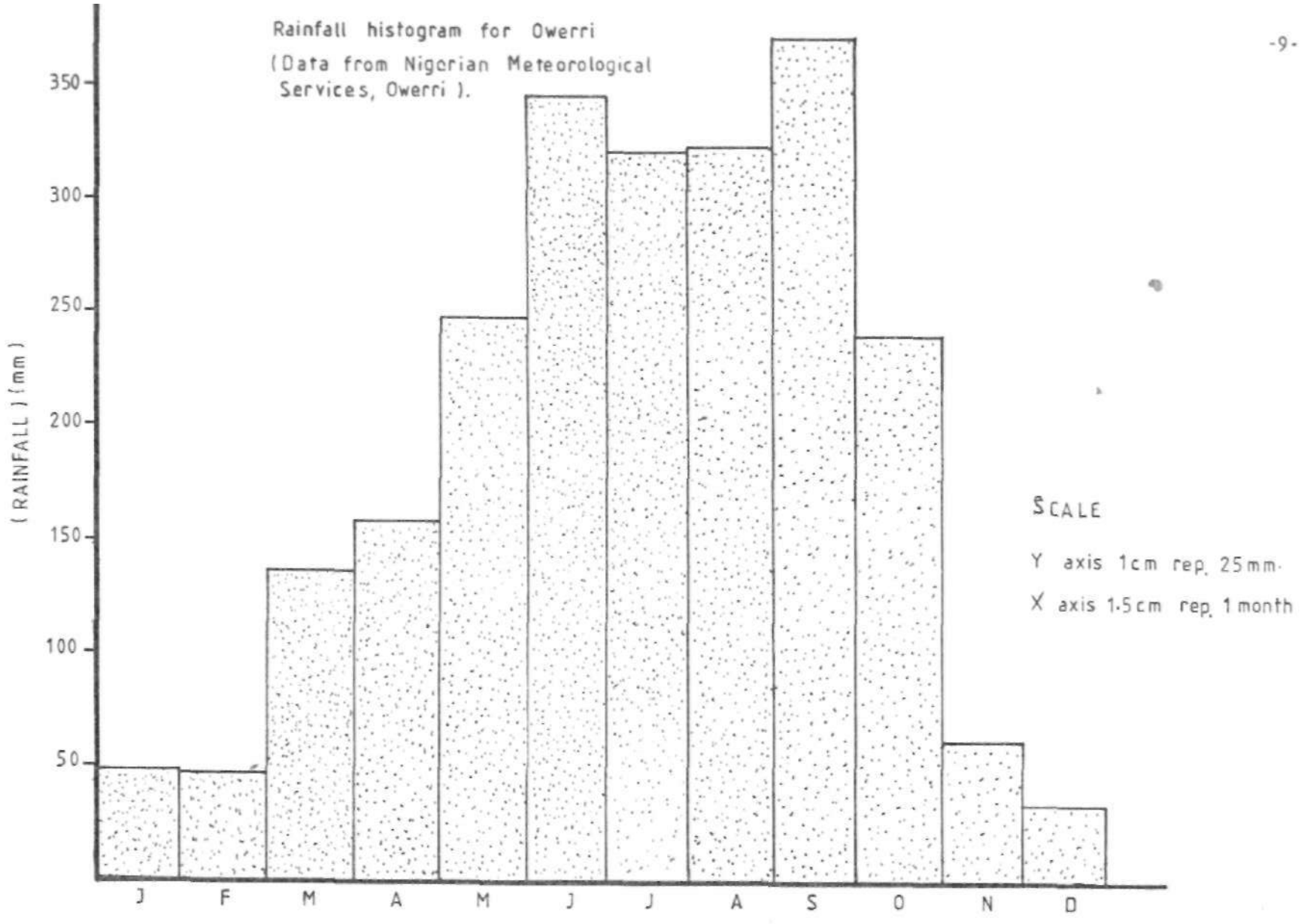


Fig. 1.3 Monthly average rainfall for Owerri from 1976 to 1985.

rise in rainfall in the month of May and June. However, a greater proportion of the rain is recorded in September and forms the secondary peak. The intensity of the rain is always high within this period.

Rainfall decreases in the month of November, when the influence of the hot and dry tropical continental air mass from the Saharan low pressure belt, through northern Nigeria, is felt in the area. The monthly minimum occurs in December.

Daily variations in rainfall may be considerable especially when heavy downpours are recorded. Table 1.2 shows that an average of 2342.26 mm of rainfall is recorded annually in Owerri.

1.5 Geology

Owerri forms part of the Niger Delta basin consisting of the Benin, the Agbada and the Akata formations. The Benin Formation occurs across the whole Niger Delta from the Benin - Onitsha area in the North to beyond the present coastline (Short and Stauble, 1967). It is underlain diachronously by the Agbada Formation with the Akata Formation at the bottom.

According to Short and Stauble (1967), the name, Benin Formation was reinstated by Reyment (1965) for the "Coastal Plains Sands" which crop out in the Old Benin, Onitsha and Owerri Provinces. For the purpose of this work, Coastal

Plains Sands has been chosen to conform with the recent geological publications in Nigeria.

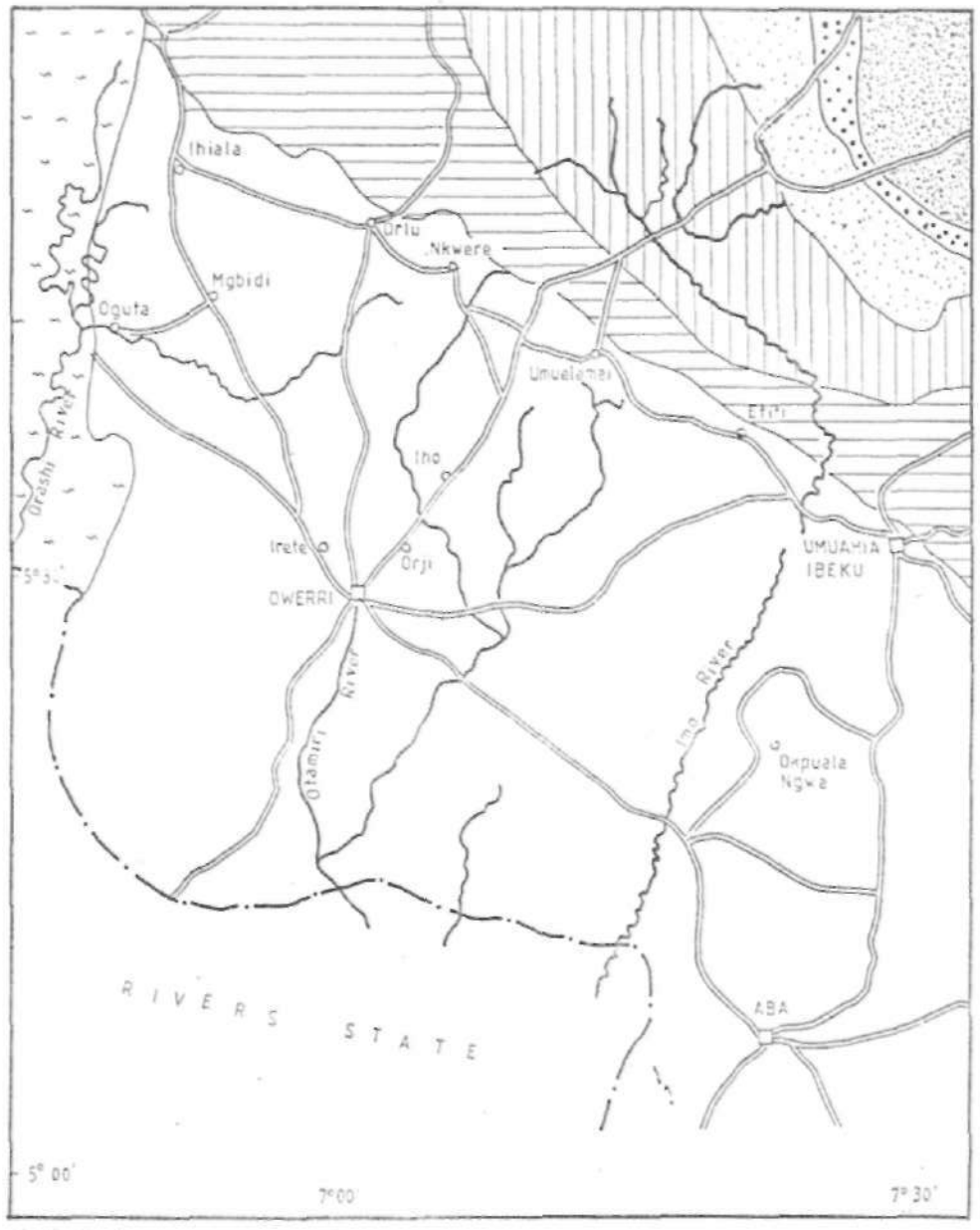
The geological map of Owerri shown in Fig. 1.4 illustrates that the project area is located within the Coastal Plains Sands. It occupies more than three - quarters of the present Imo State (see Fig. 1.4). On the northern part, the Coastal Plains sands gradually grades into the Ameki group. On the western portion, it merges with the alluvial sediments of the Orashi River.

The sediments consist of unconsolidated fine to coarse grained sands of various colours, gravels some silt, clay and grit lenses. Grit is defined as angular fine or medium grained sand. The sedimentary units are represented in Fig. 1.5.

The Coastal Plains Sands is easily recognisable because of the high sand percentage. Five borehole logs were selected in the study area to determine the composition of the various units contained in the Coastal Plains Sands. The analyses are represented in Table 1.3.

It shows that sand and gravel alone form about 85% and above of the entire composition of the formation. Lithologic correlation of three Boreholes (BH) in Fig. 1.5 confirms the composition. The sediments are generally poorly sorted and the grains are subangular to well rounded. The sandstones are white and in some areas yellowish to brown due to limonite coating. The sands are poorly sorted.

GEOLOGICAL MAP OF OWERRI AND ENVIRONS





SCALE
5 0 5 Km.

GEOLOGICAL FORMATIONS
SEDIMENTARY ROCKS
(after Tahal consultants)

- Alluvium (Holocene)
- Coastal Plains Sands (Pleistocene - Oligocene)
- Bende Ameki Group (Upper - middle eocene)
- Imo Shale Group (Lower Eocene - Paleocene)
- Upper Coal Measures (Upper Senonian)
- Falsebedded - Sandstones (Upper Senonian)
- Lower Coal Measures (Upper Senonian)
- State boundary

FIG. 1.4

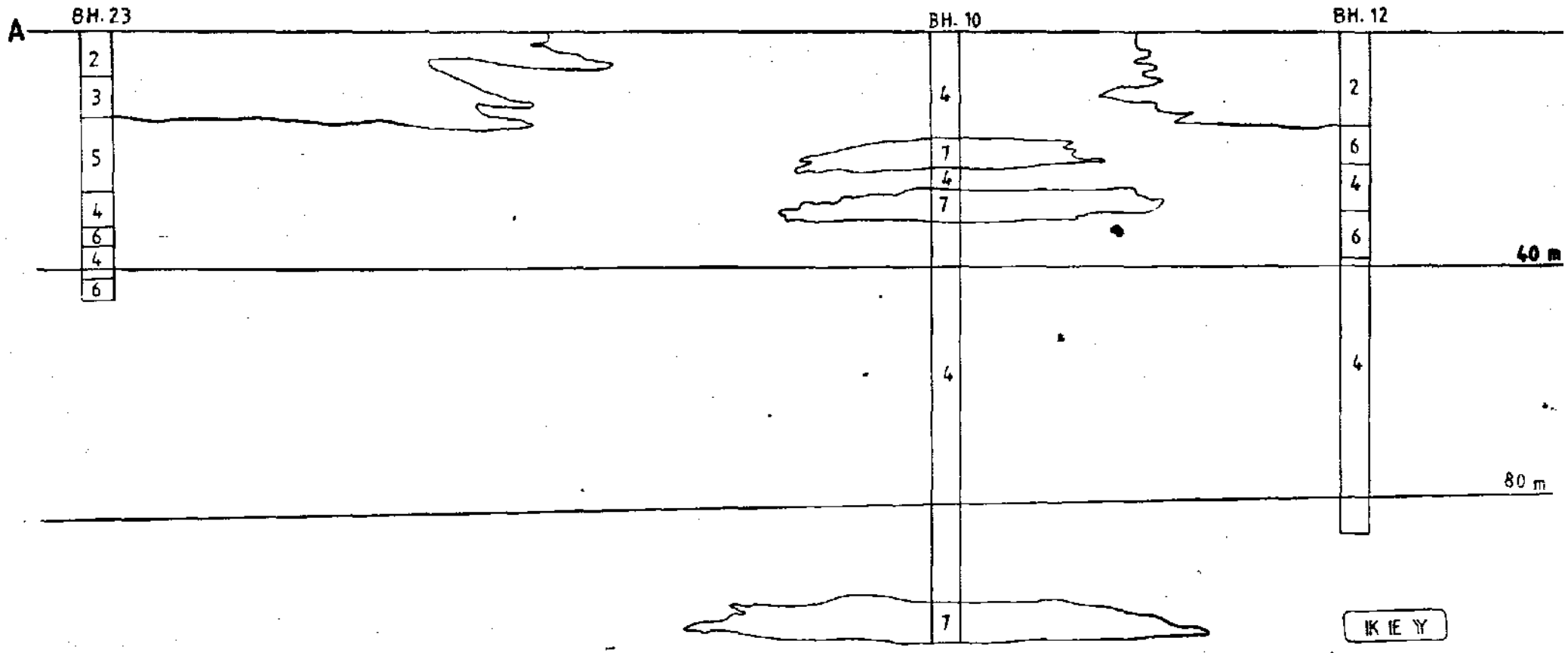
Table 1.3 DETERMINATION OF SEDIMENT COMPOSITION OF THE COASTAL PLAINS SANDS IN OWERRI

BOREHOLE No	CLAY	SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRIT	GRAVEL	TOTAL DEPTH
10	-	-	25.96	35	24.38	19.81	-	105.15m
11	-	2.28	39.1	6.1	18.28	18.5	2.6	80.86m
12	9.5	1.23	-	29.12	33	-	13.4	86.25m
22	16.75	-	62.48	50.3	53.34	-	-	182.87m
23	5	-	2.0	2.0	17.2	-	19.8	46.00m
24	5.5	-	4.0	4.5	23	-	6	43.00m
SEDIMENT THICKNESS	36.75	3.51	133.54	127.02	169.2	38.31	41.8	550.13
SEDIMENT RATIO	0.0668	0.0063	0.2427	0.23089	0.30756	0.0696	0.07598	
% COMPOSITION	6.68	0.63	24.27	23.09	30.76	6.96	7.6	99.99%

* WATER BEARING STRATA
  SAND ... 78.12%
  GRAVEL .. 7.6%
  TOTAL 85.72%

* SEALING STRAIA
  CLAY ... 6.63%
  SILT ... 0.63%
  GRIT ... 6.96%
  TOTAL ..14.27%

* - NIL



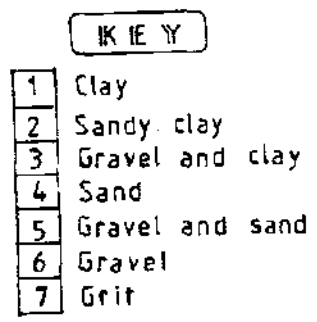


Fig. 1.5 Graphic logs comparing the lithologies in three boreholes across the profile A B (see fig.3.3a). (Data from Imo State Water Board).

According to Hazell (1958), there is normally no lateral continuity of bedding. Graphic logs of three boreholes were selected with a view to comparing the lithologies and probable extent of bedding (see Fig. 1.5). The arrangement on the diagram suggests that Hazell's statement is correct. The structural setting is characterised by low dips which in most cases trend SSW.

The phenomenal monotony of the terrain and the very straight river courses may be accounted for by the absence of any postdepositional tectonic disturbances and by the homogeneity of the rock structure (Udo, 1970). Generally, the basin sands and sandstones are mainly deposits of the continental upper deltaic plain environment (Short and Stauble, 1967). The age of the formation ranges from Oligocene to Pleistocene.

1.6 Hydrogeology

The groundwater resources of Owerri come from the Coastal Plains Aquifer. This is perhaps the most extensive groundwater source in the Niger Delta, with large supplies being taken for both industry and public water supply purposes. It is also the basic source of supply for most of the rivers in the region.

Recharge of the aquifer comes naturally and directly from infiltration due to heavy precipitation on the outcrops of the Coastal Plains Sands (see Fig. 1.5). According to Balek (1977), the recharge from rainfall is significant where the rainfall coincides with increased humidity, otherwise any recharge is reduced by evaporation.

The depth of some operating boreholes in the aquifer range between 91.44 m and 96 m. Appendix C shows that the average borehole depth is 88.78 m. Static water level recorded in the area ranged from 27 to 57 m which is a good result.

Appendix C, reveals that most boreholes recorded yields of 48.01 litres per second (L/S) and above, which is an excellent result. The average yield of all the boreholes in Appendix is 33.96 L/S.

Correlation between borehole depth and yield in Owerri (see Fig. 1.6), based on borehole parameters in Appendix C,

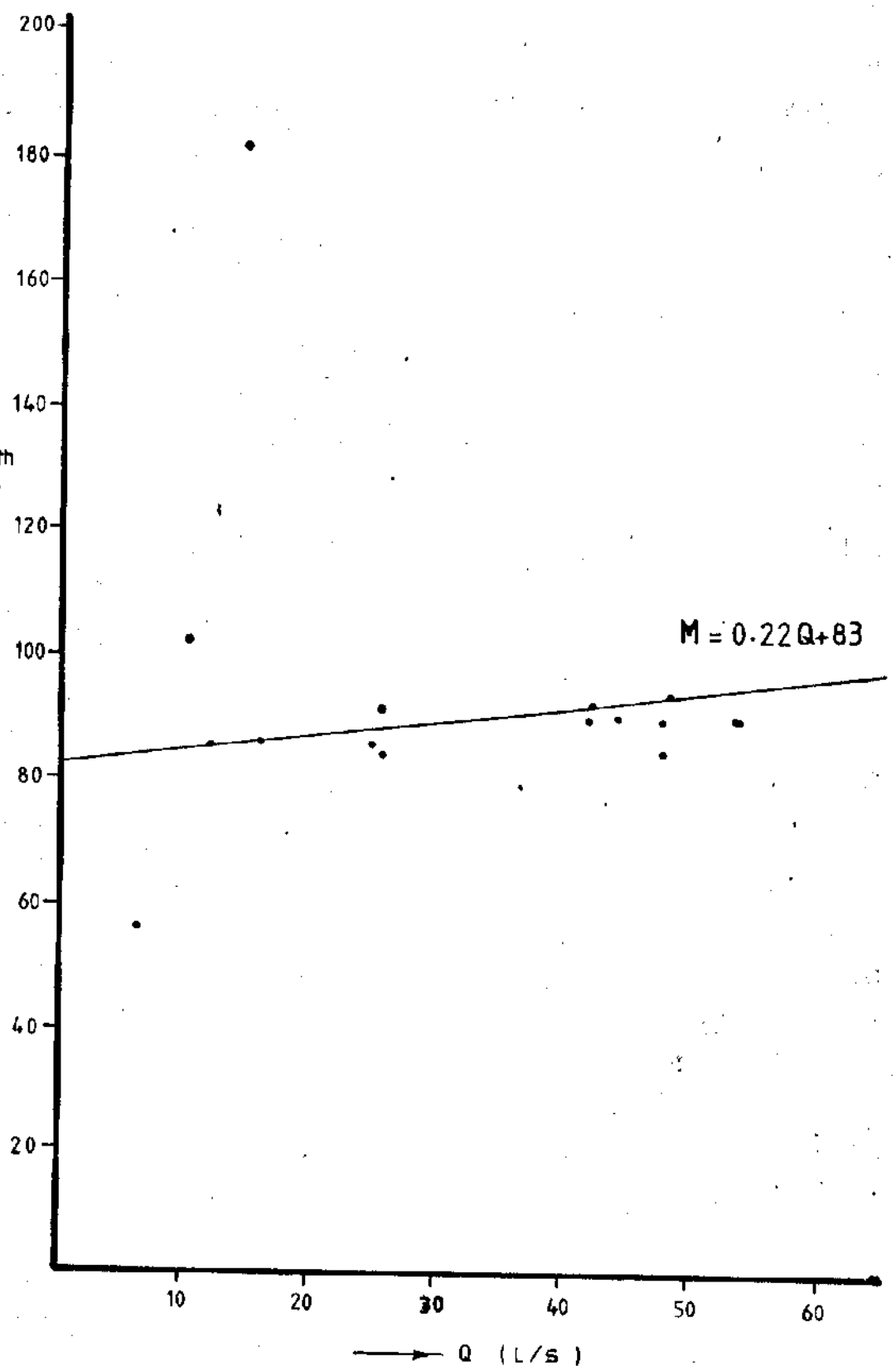


Fig. 1.6 Plot of borehole depth against yield in Owerri.
(Data from Imo State Water Board)

indicates that there is a relationship between borehole depth and yield. Therefore, the yield in the Coastal Plains Aquifer is slightly dependent on borehole depth. Groundwater flow is influenced by the structural trend of the area. The direction of flow is N - S towards the sea. There may be a reversal of this trend at some locations where groundwater is feeding any of the rivers.

However, insufficiency of data has handicapped the preparation of water-table maps, the determination of static and dynamic water resources of Owerri. The actual depth of the aquifer has not been determined. The greatest depth penetrated in the aquifer is 182.9m, recorded at BH 22 in Uratta. The least is BH 24 at Obibi with a depth of 43m (see Table 3.1). This implies that the depth of the aquifer is variable.

1.7 Vegetation

Owerri is located within the high forest vegetation belt of Nigeria. The high annual rainfall (2342.26 mm), the high humidity (generally over 80%) and the long wet season (8 to 10 months) ensure an adequate supply of water and the continuous presence of moisture in the air. These promote perennial tree growth (Iloeje, 1981).

The actual vegetation shows a varied combination of different types of plant groups which can be classified into cultivated and semi-natural vegetation. The cultivated vegetation can be observed in relatively large areas which include houses, factories, farmlands, along the roads and

within the vicinity of the Government house Owerri. They attain a height of between 2m. and 15m. However, shrubs and grasses in this group grow very densely. They are prominent where taller trees have been cleared.

The semi-natural vegetation consists of wild plants which have not been planted deliberately by man. They are dominant in the rural areas especially around Uratta, Naze, Uzoagba Ubomiri etc. The trees are tall with straight stems and heights ranging from 15m to 60m. They include Mahogany, Iroko, Obeche, Oil palm trees and tropical ceder.

Chapter 2

POPULATION AND WATER DEMAND

2.1 Population

Owerri has witnessed an upsurge in population since the creation of states in Nigeria in 1976. A lot of people opted for their home states and this had a tremendous impact on the population (Oha, 1987). A close study of table 2.1 establishes this fact.

However, it has been one of the most densely populated towns in Nigeria. The reasons have been short and long term policies in the social and economic structure of the town. Social changes have been the controlling factors over natural growth trends. Birth and mortality fluctuation as a result of advances in medicine, public health standards and family planning policies, have been a major factor.

Previous economic development plans have immensely contributed to the rapid development of Owerri in respect of its status as a state capital. The development plans have favoured housing projects, provided for an increase in the number of industries, expansion of traditional activities and rapid growth of government services.

In effect, the basis of urban development revolved around transport development and administrative organisation (Orubuloye and Oyeneye, 1983). All these have enabled Owerri to absorb a considerable number of new comers from the rural areas of the state. Improved educational opportunities in the state capital led to influx of youths into

Table 2.1 Forecast of Population in Owerri (Ministry of Economic Development and Planning Owerri)

Communities within the serviced area	1963	1975	1980	1985	1990	1995	2000	2005
Ubomiri	11,316	15,218	17,218	19,482	22.043	24.939	28.215	31.923
Emii, Emekuku	18,379	24,718	27,966	31,641	35,799	40,503	45,826	51,849
Orji, Amakohia, Owelu Akwakuma, Owalla	7,099	9,547	10,802	12,222	13,828	15,645	17,701	20,028
Avu, Umunouma	5,524	7,428	8,405	9,510	10,760	12,175	13,775	15,585
Irete, Ndegwu, Orogwe	8,039	10,811	12,232	13,840	15,660	17,717	20,045	22,680
Ogbaku	13,377	17,978	20,354	23,030	26.067	29,483	33,359	37,743
Obazu, Achi	7,320	9,833	11,139	12,602	14,259	16,134	18,254	20,655
Nekede/Obinze Umuoma	16,463	22,136	25,050	28,342	32,066	36,280	41,048	46,443
Naze, Awaka, Eghu	12,143	16,331	18,477	20,905	23,653	26,761	30,277	34,256
Agbala	1,698	2,284	2,584	2,923	3,308	3,743	4,236	4,795
Owerri Rural Total	101,358	136,284	154,227	174,497	197,433	223,380	252,736	285,957
Owerri Urban	26,017	34,988	42,599	51,828	63,056	76,717	93,338	113,561
TOTAL	127,375	171,272	196,826	226,325	260,489	300,097	346,074	399,518

the town with a view to securing employment commensurate with their qualification.

Records from the Director of Statistics, Ministry of Economic Development and Planning, Owerri, indicated that estimates of the present population were based on the 1963 census. Population forecasts for Owerri Urban and rural were based on growth rates of 4.5% and 2.5% respectively (see Table 2.1). Some State capitals in Nigeria have recorded growth rates greater than 5% necessitated by rapid and viable economic development.

In the 1963 census, the projection in the project area was subdivided into Owerri Urban and Owerri rural for clarity. A look at Table 2.1 show that at that time Owerri urban had a population of 26.017 people while Owerri rural had 80,661 inhabitants.

The present population is estimated at 51,828 for Owerri urban and 174,457 for Owerri rural. Estimates of future population of Owerri were based on past and present figures. According to AL-Layla et al.,(1977), one of the factors affecting the forecast of population is that when the rate of population increases, accuracy decreases.

There may be minimal errors in the sense that the growth rate by the year 2005 AD, could be greater than 4.5%, but the projections are within acceptable limits. Populations of 285, 957 for Owerri rural and 113,561 for Owerri urban for 2005 AD are reasonable. The graphic presentation of the projection in Fig. 2.1 show a steep and rapid growth rate up

Projection of Population Growth for Owerri

(Data from Director of Statistics, Owerri)

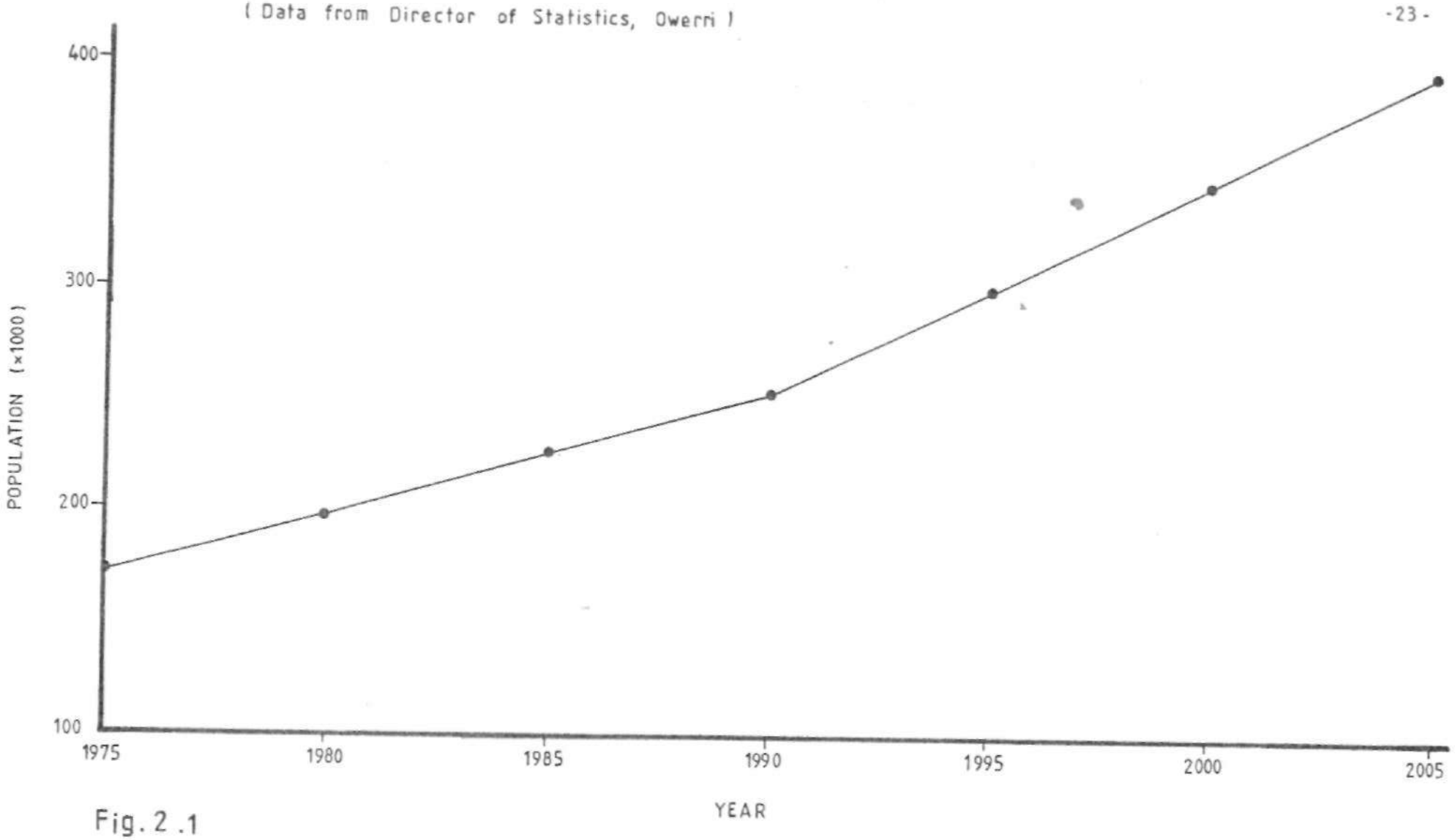


Fig. 2 .1

to the year 2005 AD.

The basis of population forecast for this project is that any water supply scheme must be planned to serve the present as well as the future needs of the town. Therefore, future population must be assessed while designing the water supply. This requires foresight and judgement.

2.2 Water Demand

Water supply to Owerri urban in the past, between 1958 and 1985, came from the Okigwe road groundwater scheme. The system was based on boreholes located within the premises of the State Water Board. In Owerri rural, a series of boreholes were drilled within this period mainly for domestic use.

The Okigwe road groundwater scheme from 1958 to 1964 supplied an average of 567.75 m^3/d to an estimated population of 27,000 inhabitants. Analysis of these figures shows that the litre per capita demand was 21.03 Lpcd. Within the period, the social infrastructure had not improved much. It also supplied from 1976 to 1985, an average of 23,000m^3/d to an estimated population of 43,000 people. The data show that an equivalent of 53.5 Lpcd was recorded. This was grossly inadequate for domestic demand alone and not comparable to most cities in this country. However, commercial, industrial and agricultural sections probably suffered water shortage.

Social infrastructure had improved tremendously within

this period. It is a well known fact that as the Socio-economic status of a society improves, the demand for water also increases. According to Akintola and Areola (1980), the Capita consumption of water in residential areas in Ibadan city in 1976 - 1977 was 551 Lpcd.

The present water supply scheme comes from the Otamiri Surface Water Scheme from which distrilution commenced in November 1985. Between 5 November and 14 December 1985, a total of 1,325,700 m^3 was supplied from the scheme. This amounted to an average daily consumption of 44190 m^3/d. and a total of 195.25 Lpcd was recorded.

In April 1986, allthe towns that constitute Owerri Rural had their system connected to the Otamiri Supply Scheme. Between 5 March and 4 April the same year, a total of 1,221,768 m^3 was supplied resulting to a daily average of 40,725.63 m^3. An estimated population of 226 325 people were served. It implied that an equivalent of 179.94 Lpcd was recorded including industrial, commercial, agricultural and domestic consumption.

It is assumed that domestic consumption accounts for more than half of the total supply due to routine household activities which include drinking, bathing, washing, cooking etc. However, the distribution system is not metered with the result that the relative volumes for different purposes are not recorded. The significance of estimates for water use and prospective demand is that they show the relative volumes of use for different purposes. The uses to which the water is put contribute to the vitality of human settlement or the quality of life, agriculture, industry and the social infrastructure.

In forecasting water requirements for the future, it is essential to analyse the past and present consumption rates as the basis for predicting future trends of consumption. According to Tahal (1977), the future water requirements for Owerri will depend on a number of interrelated parameters that will determine further development; these include population growth, number of houses connected to the supply system, extent of public institutions and commercial enterprises, and the volume and type of industrial plants.

In Nigeria, attention has been directed towards agricultural development, industrialisation and improvement of living standards. These will serve as determinants to the forecast of future water demands.

In Owerri, there are major organised agricultural bodies that use enormous quantities of water for their daily operations. These include the Agricultural Development Corporation (ADC) located at Nekede, Imo state Agricultural Development Accelerated programme '(ISADAP) sited at Owerri and environs, and many private organisations involved with livestock production. The supplies to these bodies are not metered which made it difficult to estimate the exact quantity of water to be used for future operations.

In estimating the future water requirements of Owerri for agricultural operations from 1985 to 2005 AD, the assumption is that the supply and distribution facilities will be improved within this period. Therefore, an estimate of 10,000 - 30,000 m^3/d. may be reasonable by the year 2005 AD.

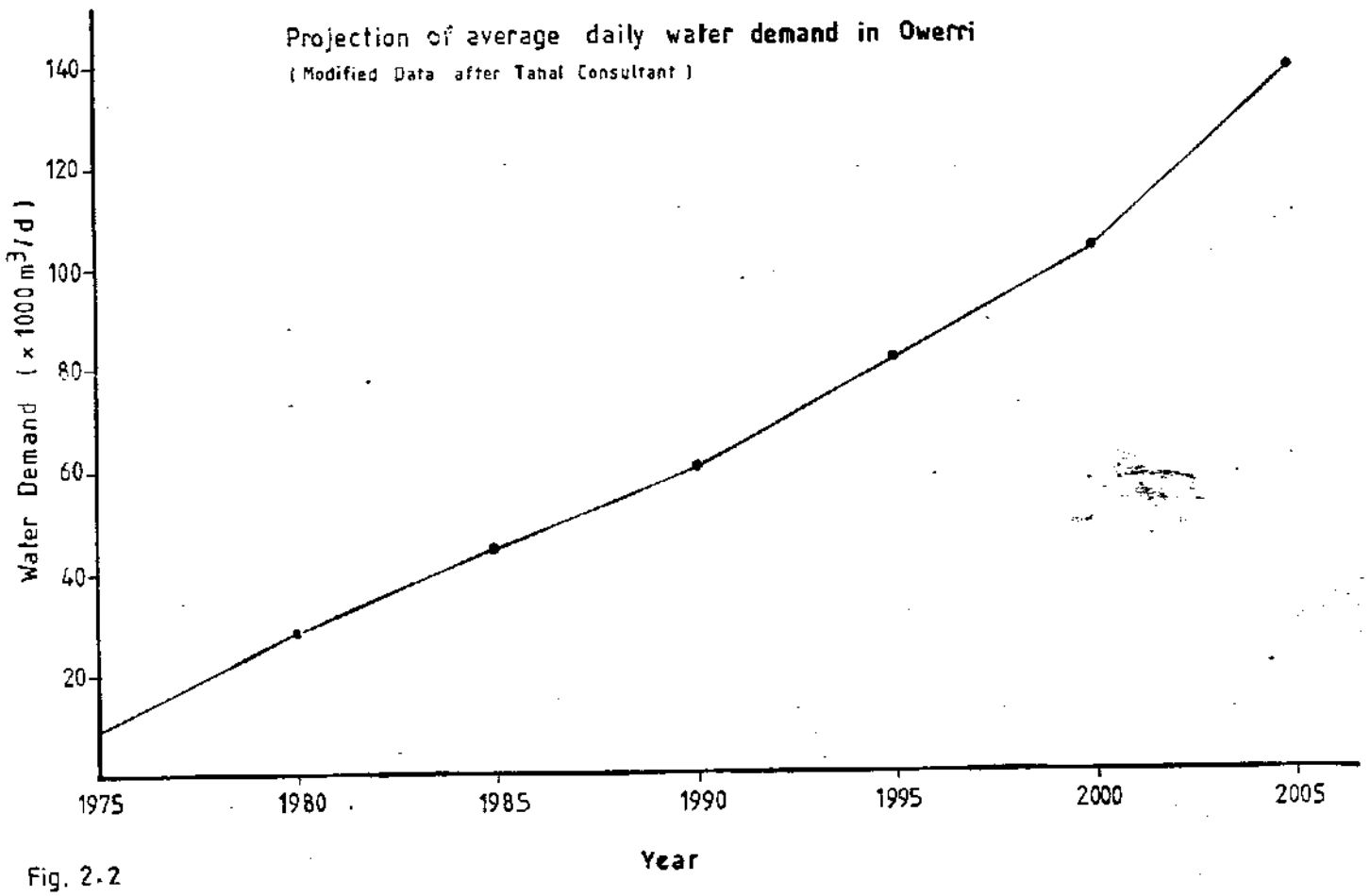

Projection of average daily water demand in Owerri
(Modified Data after Tahal Consultant)
Water Demand (x 1000 m3/d)
140
120
100
80
60
40
20
1975
1980
1985
1990
1995
2000
2005
Year

Fig. 2.2

A masterplan for industries and other enterprises has been drawn up for Owerri by Fingerhuth and Partners Limited, with offices at Owerri and Zurich in March 1978. It is predicted that the industrial, commercial and domestic demand will increase. An estimate of 4,000 - 20,000 m^3/d depending on the type of plants and volume, may be realistic.

The prediction of the future domestic water consumption of Owerri will be entirely dependent on the population growth and standard of living. A look at Fig. 2.1 shows a rapid rise in population and by the year 2005 AD, it would have doubled to almost 400,000 people (see Table 2.1). An estimate of 350 Lpcd may be reasonable.

Estimates and predictions of future water demand for various purposes for Owerri have been made. An overview of the average daily water demand in Owerri up to the year 2005 AD, has been represented in Fig. 2.2. The graphic illustration reveals that there will be a rapid rise in water consumption rate before 2005 AD.

It is most likely that Owerri will experience serious water problems beyond 1990 AD. It is recommended that provisions for meeting with future water requirements be made in good time.

However, some recommendations have been made in chapter 5 of this text, towards tackling future water problems in the project area.

Chapter 3

WATER SUPPLY SCHEMES

3.1 Groundwater Supply Scheme

The operation of this scheme was based on boreholes drilled between 1950 and 1985 in the project area. The groundwater scheme has been subdivided for clarity into Okigwe Road groundwater scheme which served Owerri Urban and Rural groundwater scheme which served the rural areas.

3.1.1 Okigwe Road groundwater scheme

This water supply scheme was based on boreholes located on the north eastern part of the town. The site is along the major road leading to Okigwe from Owerri and forms the present Imo State Water Board premises (see Fig. 3.1).

Drilling for water supply in Owerri started in the late 1950s and by 1959, three boreholes had been drilled at the water works premises (present site of Imo State Water Board). These boreholes recorded an average yield of 567.75 m^3/d.

In 1965, an additional borehole was drilled by Nigeria Water Supply Company (NWSC) for the Water Board (then Water Corporation). The yield was 48.01 litres per second (L/S) and the number of boreholes increased to four (see Table 3.1). This was a boost to the supply scheme. The outbreak of the civil war prevented further drilling activity.

However, the existing boreholes were rehabilitated after the war. Another borehole was drilled in 1975 to augment the

BOREHOLE LOCATIONS AT THE OKIGWE ROAD GROUNDWATER SCHEME

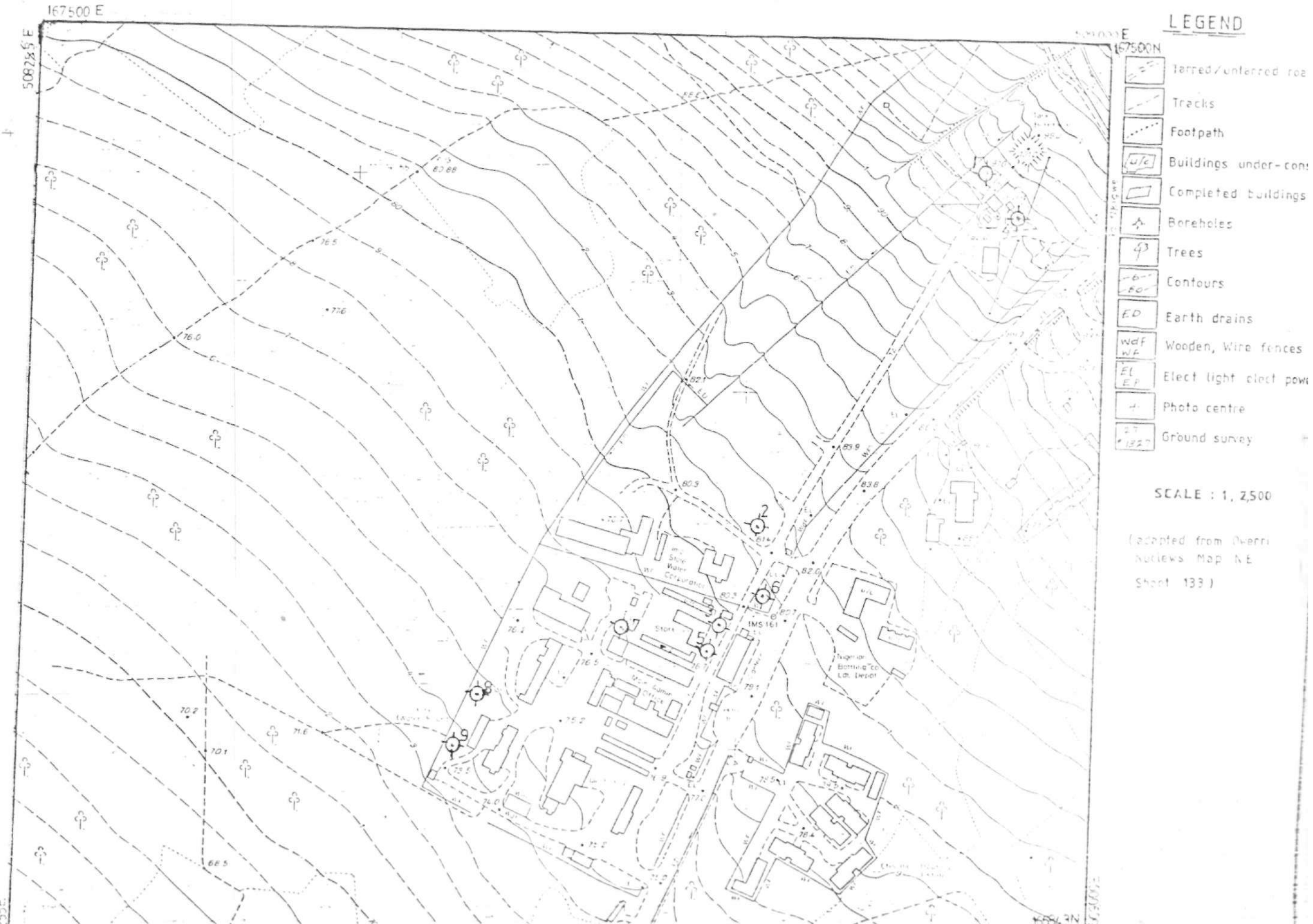


Table 3.1 BOREHOLE DATA FROM THE OKIGWE ROAD GROUNDWATER SCHEME

LOCATION	BOREHOLE No.	DATE DRILLED	DRILLING COMPANY	TOTAL DEPTH (M)	CASING DIAM (INCHES)	CASING LENGTH (M)	SCREEN DIAM (INCHES)	SCREEN LENGTH (M)	STATIC WATER LEVEL (M)	YIELD (L/S)	DRAW-DOWN (M)	SPECIFIC CAPACITY (L/S/M)
OWERRI	1	-	-	-	-	-	-	-	-	-	-	-
"	2	-	-	-	-	-	-	-	-	-	-	-
"	3	-	-	-	-	-	-	-	--	-	--	-
"	4	1965	N.W.S.C	-	-	-	-	-	-	48.01	-	-
"	5	1975	N.W.S.C	94.49	12	67.97	10	16.15	29.26	48.36	3.35	14.44
"	6	1976	G.S	91.44	12	60.96	8	30.48	28.04	44.16	1.92	23
"	7	1976	G.S	91.44	12	60.96	8	18.29	28.35	53.62	1.68	31.92
"	8	1976	G.S	91.44	12	60.96	8	18.29	21.95	53.62	1.92	27.93
"	9	1976	G.S	91.44	12	60.96	8	18.29	-	-	-	-

- Not traced.

quantity supplied. The drilling was carried out by NWSC and the yield was 48.36 L/S. With this, the number of boreholes increased to five. In 1976, four additional boreholes were drilled by George Stow (G.S) Limited. The number of boreholes within the Water Board premises increased to nine. The total yield of all these boreholes was estimated at 1,100 m^3/hr.

A study of Fig. 3.1 shows the location of the nine boreholes within the premises of the State Water Board. Between January and February 1981, the following boreholes developed problems with low yield 1,2,8, and 9. In April the same year, boreholes 1 and 2 were out of use. Subsequently some other boreholes broke down.

Reasons for the malfunctioning of these boreholes were not determined but several possibilities could be adduced for the failure. According to Walton (1970), the groundwater reservoirs in humid regions having adequate replenishment are by no means devoid of groundwater problems. Pumping from closely spaced production wells cause a decline in water tables or artesian pressure. When this happens, the yield will definitely decline and the cost of pumping the water will increase enormously. A look at Fig. 3.1 shows that the boreholes are close to one another and that decline of the yield could be possible for this reason.

According to Walton (1970), if the transmissivity of the aquifer is inadequate, the water levels in production wells will decline whether the aquifer as a whole is adequately

recharge or not. This problem is common in cities that use large quantities of groundwater. It is obvious that large quantities of groundwater was abstracted at the Okigwe road pumping station. Therefore, the possibility of this problem occurring is not ruled out.

Other problems could arise from inefficient pump operation caused by worn, corroded or plugged parts. Deposits of scale, corrosion products, micro-organism growths in the production - well screen and clogging of the production - well screen by mud, sand silt could be responsible for the breakdown.

Finally, administrative lapses probably due to financial constraints could be a contributory factor to the failure. Periodic maintenance of the production wells are essential to prevent the incidence of clogging. If the management lived up to expectations, four boreholes would not have broken down completely at the same time. According to Walton (1970), with the use of modern materials and construction techniques and appropriate maintenance, most production wells could last for 40 years or more.

The scheme was finally put out of use in December 1985 when the new water scheme became operational.

3.1.1.1 Quality of Water

Results of water analysis by the Water Board laboratory on one of the boreholes at the Okigwe road groundwater scheme is tabulated in Table 3.2. The data is not representative of all the boreholes within the site, rather it gives an insight on the raw water quality.

Table 3.2 Water Analysis from the Okigwe Road Groundwater Scheme

Item	Units	Value
Colour	-	--
pH	-	5.1
Temperature	^{o}C	26
Electrical Conductivity	-	-
Total Hardness as $CaCO_3$	ppm	20
Calcium Hardness as $CaCO_3$	"	10
Magnesium Hardness	"	10
Calcium as Ca^{++}	"	4
Chloride as NaCl	"	5
Chloride as Na	"	8.25
Total Iron as Fe	-	0
Silica as SiO_2	ppm	7
Carbon dioxide	"	18
Phenolphthalin acidity	"	5
Alkalinity as $CaCO_3$	"	5
Nitrate as Nitrate Nitrogen	"	1.1
Nitrate as NO_3	"	4.8
Nitrite Nitrogen as N	"	0.005
Nitrite as NO_2	"	0.02
Ammonia NH_3	"	-
Sulphate SO_4	"	-
Total phosphate as PO_4	"	-
Manganese as Mn	"	-
Total solids dried at $103^{o}C$	"	20

Source of Sample - Ministry of Works yard (Imo State Water Board premises)

Submitted by Chemist I: Date of analysis 7 - 3 - 84

* - Trace

The acidity is low with a pH value of 5.1. This could be as a result of free carbon dioxide encountered during precipitation. The water is colourless. According to Walker (1978), the higher the pH, the more intense in the colour; but if the solution is sufficiently acidified, the colour will be appreciably reduced. Chemical parameters, total dissolved solids (TDS), hardness and alkalinity are major water quality indicators and are useful in making regional comparisons (Grigoriev and Whetstone, 1972).

A commonly reported item in water analysis is total dissolved solids (TDS). Total dissolved solids in a water sample includes all solid material in solution, whether ionized or not (Davies and DeWiest, 1966). It does not include suspended sediment, colloids or dissolved gases. Therefore, chemical analysis is designed to determine the quantity of TDS in water with a view to regulating the water for human consumption. High value of TDS in water could change the taste of water as well as causing gastro-intestinal irritation (WHO, 1971).

Appendix E, Canadian Drinking Water Standards and Objectives (1968) adapted from Walker (1978), was used as the basis for comparison of Table 3.2. The water is very good with low chloride content. Table 3.2 shows that the parameters are quite low when compared with Appendix E, which is an indication of good quality water.

However, water intended for consumption must be free from organisms and concentrations of chemical substances that may be a hazard to health. Therefore, supplies of drinking

water should be as pleasant to drink as circumstances permit.

Water treatment consisted of addition of lime into the service reservoir to boost the pH to about 7.1. Chlorination was carried out to eliminate micro-organisms in the water. Chlorination when properly applied produced other benefits such as the removal of colour, the correction of taste, odours and the suppression of unwanted biological growths since there was no special treatment plant (Palin, 1974).

Maintenance of groundwater quality at acceptable levels is one of the major requirements for successful utilization of groundwater reservoirs (Walton, 1970).

3.1.1.2 Technical description

The type of casing and screen materials used for the completion of the wells were not recorded. A close study of Table 3.1 shows that all the boreholes had uniform casing diameter. The screen diameter were fairly uniform.

All the wells had subversible pumps installed. They were electrically powered. Sources of power came from public power supply system and standby generators in case of power failures from the public system.

The top of the boreholes were fitted with steel pipes called rising mains. The rising mains were connected with flowmeters which recorded the discharge (see Plate I). Water from the mains were channelled to the nearby ground level service reservoir, which had a capacity of 680m^3 for treatment and final distribution to the city.

3.1.1.3 Distribution network

The Okigwe road groundwater distribution network is represented in Fig. 3.2. It was the first stage of the Owerri Water supply network which was commissioned on 14 June 1960, by the Ministry of Works C.W.E. Enugu. Water came from three boreholes located on the northern section of the network. The boreholes were connected with two generators installed in the power stations as shown on the map. The average daily withdrawal of water was 567.75m^3.

The boreholes were connected with steel pipes called rising mains (Plate 1) to the major 10 inch steel - distribution pipeline to the city (see Fig. 3.2). The diameter of the pipes was reduced with distance to increase the velocity of the water in the pipes. The subsequent pipes included 8 inch, 6 inch and 3 inch AC pipes to the furthest corners of the city.

The pipes were attached with sluice valves at the pipe joints to check back flow means, thereby allowing the water to flow in one direction only. Walker (1978), expressed back flow means as a condition, induced by a differential in pressure, that causes the reverse flow of water into the distribution system of a portable water supply. About 43 sluice valves were installed during the first stage of the pipe network.

Many hydrants were provided at strategic locations as represented in Fig. 3.2. A hydrant is used on the mains to

DISTRIBUTION NETWORK FOR THE OKIGWE ROAD GROUND WATER SCHEME

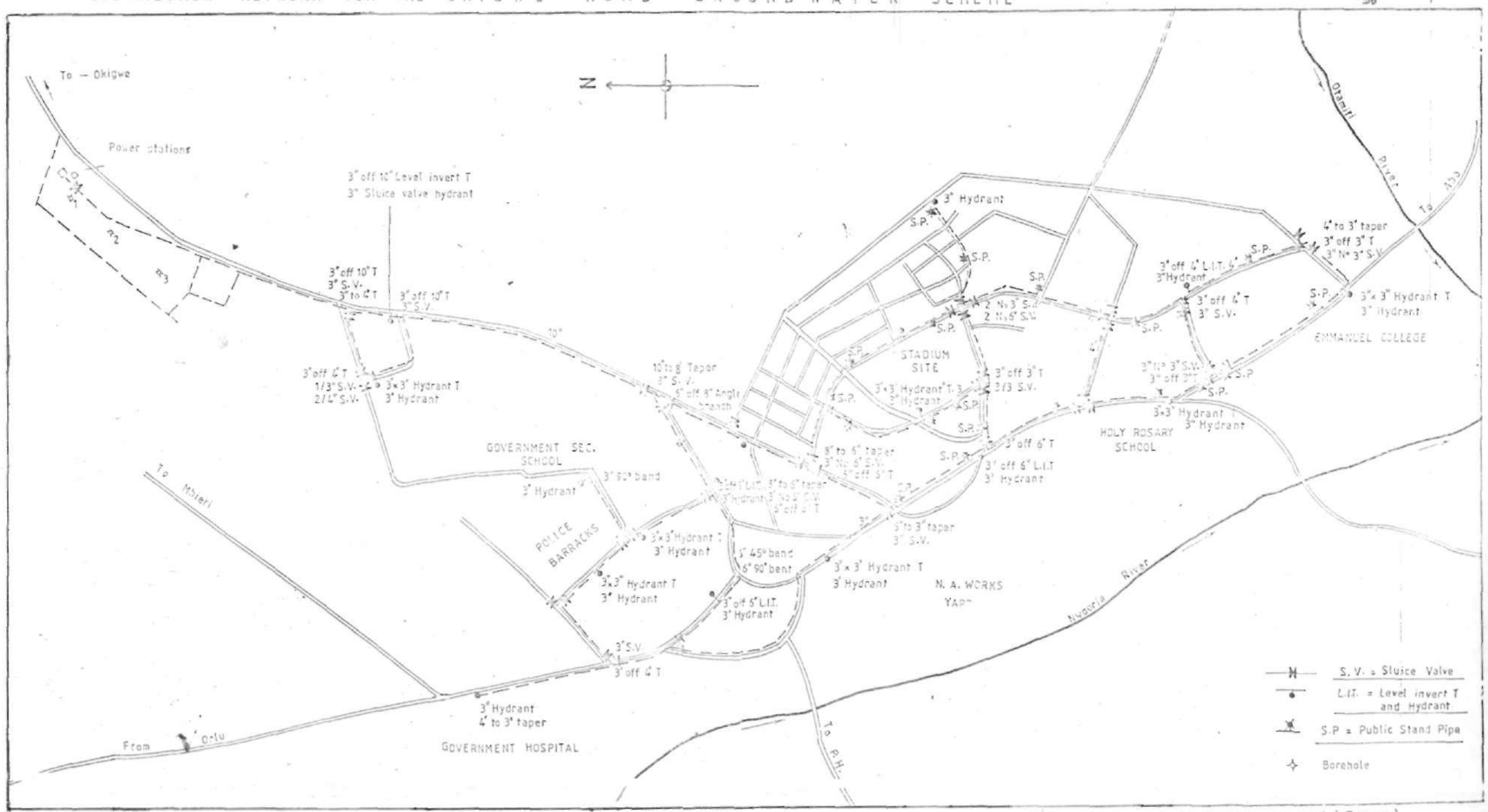


FIG. 3.2

(After Ministry of Works Engr (water Dept.) Enugu)

provide a connection for fire-hoses to fight fire. Hydrants readily available include flush and post types. The flush hydrant is placed inside a cast iron box which is level with the sheet surface (Al-Layla et al. 1977). Post hydrants project at above 1m. above the surface of the street. The flush hydrant has been referred to as LIT in Fig. 3.2.

Public stand pipes were provided in the distribution network for accessibility to the populace within the city. The laying of the pipelines were guided by the Structural Plan of the city prepared in August 1959.

Later, additional boreholes were drilled to improve on the water demand, and by 1976, the number had increased to nine (see Fig. 3.1). A reservoir was constructed for storage, treatment and distribution of water by gravity. More AC pipes were laid for the extension of the service mains with a view to serving more people. This era formed the second stage of the distribution network. An average of daily withdrawal of 26,400m^3/d was distributed at this stage of the network.

The locations of the subsequent boreholes have been shown in Fig. 3.1, and were connected with rising mains to the major distribution pipeline. However, the first stage of the Owerri Water supply pipe network formed the nucleus of water distribution network in Owerri. Plans incorporating the extended pipes in the second stage were not reproduced.

The third stage of the Owerri water supply pipe network was expanded and developed with the commencement of the Otamiri surface water scheme. The original plan was retained and additional service mains were installed which accommodated the

the extension to the ground level reservoirs and elevated water tanks.

3.1.2 Rural groundwater Scheme

Rural groundwater scheme in this context, imply the provision of portable water to the towns adjoining Owerri urban without direct connection to the municipal supply system. The water came from boreholes drilled in these towns, some with overhead tanks and standby generators to pump the water before distribution.

The operations of these boreholes were supervised and co-ordinated by the Owerri Zonal Water Board. The towns affected by these exercise have been represented in Table 3.3. The respective locations are shown in Fig. 3.3a.

Drilling for the rural water scheme started in 1964 at Mbieri. The programme was carried out by the Geological Survey of Nigeria (GSN). Two boreholes were drilled at Mbieri in May and August respectively. The borehole drilled in May was supervised by F. Baltaro, while M.E. Offodile supervised the other in August.

In 1966, four boreholes were drilled, one for Egbu town and three for Emekuku town. The yields were substantial (see Table 3.3). The hostilities of 1967 to 1970 prevented drilling activities. Thereafter, the process of reconstruction and rehabilitation slowed down the operations of the Board.

In 1976, five boreholes were drilled by George Stow Limited. One was drilled at Mbieri, two for Nekede town to

Table 3.3

BOREHOLE DATA FROM THE RURAL GROUNDWATER SCHEME

LOCATION	BOREHOLE No. (BH)	DATE DRILLED	DRILLING COMPANY	TOTAL DEPTH (M)	CASING DIAM. (INCHES)	CASING LENGTH (M)	SCREEN DIAM (INCHES)	SCREEN LENGTH (M)	STATIC WATER LEVEL (M)	YIELD (L/S)	DRAW DOWN (M)	SPECIFIC CAPACITY (L/S/M)
AMAKOHIA	10	1981	H&E	103.63	10⅜	53.83	10	-	48.15	10.72	5.70	1.88
MBIORI	11	1964	GSN	86.87	12½	73.15	10	48.15	51.82	16.82	3.66	4.6
"	12	1964	GSN	86.26	12⅜	70.10	10	13.72	51.82	12.6	1.52	8.29
"	13	1976	GS	93.88	12	42.67	8	48.77	-	42.1	13.72	3.07
EGBU	14	1966	-	57.91	7	49.68	6	8.23	34.44	6.31	5.79	1.09
EMEKUKU	15	1966	-	92.05	10	77.11	8	7.92	47.24	26.18	4.57	5.73
"	16	1966	-	85.04	10	77.11	8	7.92	47.24	26.18	4.57	5.73
"	17	1966	-	86.60	10	74.68	8	7.92	47.55	25.85	5.49	4.71
NEKEDE	18	1976	G.S	90.22	12	60.96	8	27.43	27.43	42.74	1.00	42.74
"	19	1976	G.S	90.22	12	60.96	8	27.43	27.43	48.01	1.52	31.59
UZOAGBA	20	1976	G.S	85.34	12	73.15	8	12.19	54.80	48.01	3.00	16.00
"	21	1976	G S	91.44	12	79.25	8	12.19	56.47	42.74	6.99	6.11
URATTA	22	1982	WAWDAS	182.9	6½	155.4	6	15.2	39.00	15.17	-	-
OFORCLA	23	1985	UNICEF	46.00	4	37.00	4	-	-	-	-	-
OBIBI	24	1984	UNICEF	43.00	4	36.00	4	-	-	-	-	-

- Note traced.

BOREHOLE LOCATIONS FOR THE RURAL GROUNDWATER SCHEME

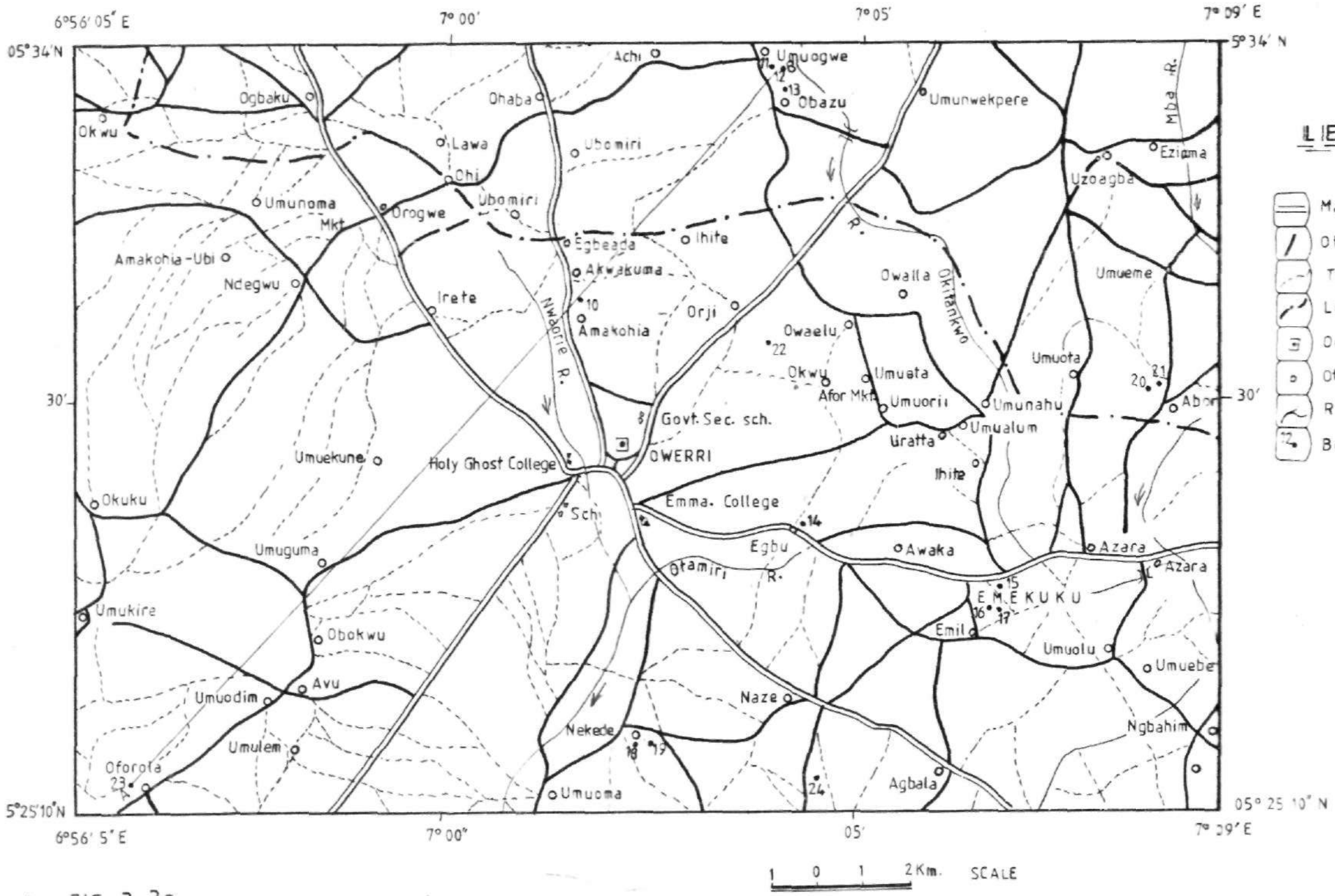


FIG. 3.3a

(adapted from Owerri Provisional Map, 1981)

carter for indigenes and students of the higher institution located in the area. The other two were drilled in Uzoagba. One significant remark about these boreholes is that they had very high yields (see Table 3.3).

In 1981, another a borehole was drilled at Amakohia by Hardel and Enic Company. The following year, another borehole was drilled for Uratta town by the West African Water Drilling and Allied Services (WAWDAS) Limited. It was under the auspices of the Federal Department of Water Resources, Enugu.

Boreholes BH23 and BH24, were drilled in 1984 and 1985 respectively at Oforola and Obibi by UNICEF, under the UNICEF Assisted Rural Drinking Water Project in Owerri. They were provided with hand driven pumps. On 5 March 1986, most of these towns were connected to the distribution network of the Otamiri surface water scheme. Some of the boreholes have been abandoned as a result of the change (see Fig. 3.6).

The lithologic logs of some selected boreholes have been represented in Appendix F, for indepth understanding of the geology of the project area which has been described earlier in sub-chapter 1.5.

An attempt to establish a relationship between the screen length and the yield of the production wells in the area has been represented in Fig. 3.3b. The plot of screen length against yield, vividly illustrates that the yield of the aquifer is not quite dependent of the screen length selected.

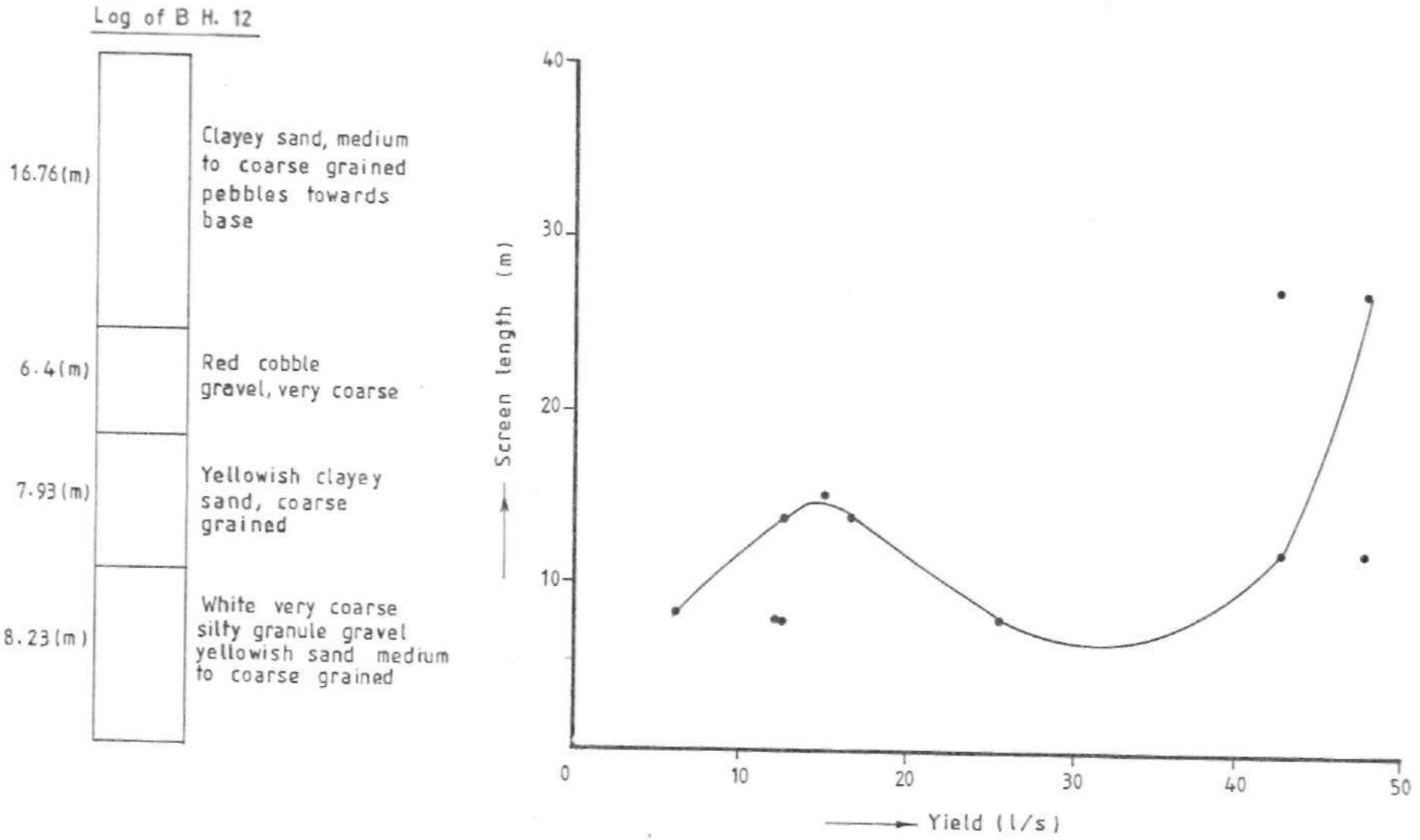


Fig. 3.3b ' Plot of screen length against yield.

According to Walton (1970), as along a screen as possible should be used to reduce entrance velocities and the effects of partial penetration of the aquifer by the production well. The general consensus has been that, about half of the open area of the screen will be blocked by aquifer material with the result that only 50% of the actual open area will be effectively utilized. Otherwise, the productivity of the well may be reduced.

The plot of screen length against yield could reinforce the earlier assertion that the yield in the Coastal Plains Sands is high. It also illustrates the influence of lithological units on yield.

3.1.2.1 Technical description

The borehole parameters represented in Table 3.3, indicate that the screen diameter of the production wells were uniform despite slight variations in some boreholes. The Johnson Everdur screens were used. According to Todd (1980), Everdur bronze screens are very good in acid water and are corrosion resistant in normal groundwater.

The casing lengths were controlled by the depth of the static water levels. The casing diameter probably depended on the casing sizes available as well as drilling method.

However, submersible pumps were attached to BH10 - BH22, operated by generators. The pumped water was channelled through rising mains to the general distribution towers for circulation by gravity. Hand-driven pumps were installed in BH23 and BH24, probably to save costs.

3.1.2.2 Distribution network

The general distribution network map for the rural groundwater scheme was not traced. The system was designed to reach the citizenry, as a result distribution was through public stand pipes.

Generally, asbestos cement pipes were laid close to the commonly used roads in the respective towns to distribute water from the service towers. At strategic positions, service pipes were connected to provide public stand pipes for people within the kindred or clan. The exercise extended to several kilometres of road, depending on the yield of the production wells.

In November 1980, a total of 128 public stand pipes were recorded at Mbieri, Emii/Emekuku 13, Egbu 7 etc. Private connections were a recent event due to economic growth and improvement in living standards of the people. A total of 452 private connections were recorded at Mbieri in July 1984.

3.2 Surface Water Scheme

The Surface Scheme is called the Otamiri Surface Water Scheme or the Owerri Regional Water Scheme. Most people referred to it as the Owerri New Water Scheme.

The scheme is based on the abstraction of surface water from the Otamiri river. The river rises from Egbu town located in the southern part of the project area (see Fig 1.1b). The point of abstraction is about 3km from the source of the river

upstream, designed to achieve maximum abstraction from the catchment.

3.2.1 History and yield

The proposal for the construction of the Otamiri Surface Water Scheme by the dam method was made in February 1976. The contract for the preliminary investigation report was awarded to Tahal Consultants Nigeria Limited by the former East Central State Water Board (ECSWB) under the then East Central State Government.

In 1977, the Imo State Water Board (then Imo State Water Corporation), inherited the planning report. In 1978, the contract for the design of the scheme was awarded to Tahal Consultants. The Civil Engineering works were carried out by Sharbiv Construction Company (S.C.C) Limited from 1981 to 1983. Reference to Table 3.4 below, reveals the quantity of construction materials used for the scheme.

Table 3.4 Quantity of Construction materials and Manpower used for the Otamiri Surface Water Scheme

Item	Quantity
Concrete	17,000 m^3
Steel	4,000 tons
Cement	8,000 tons
Sand	8,000 m^3
Gravel	16,000 m^3
Steel pipes	15 km.
Asbestos Cement Pipes	128 km.
Skilled and Unskilled Manpower	420,000 man hours/day

Contract for the supply and installation of equipments at the site was awarded to Pianimpianti (SPA - Milano - Italy) in 1981. The equipment included pumps, electrical fittings etc. The instrumertation was completed in 1983.

On 22 July 1983, the then Civilian Governor of Imo state, Chief Samuel Mbakwe carried out a commissioning exercise at the Headworks of the scheme. The period coincided with the political campaign programmes of 1983.

However, water supply from the scheme commenced in November 1985, with an average daily supply of 44190m^3/d. Finally, the scheme was commiseioned on 18 May 1986, by the then Military Governor of Imo state, Navy captain Allison Madueke.

The estimated value of the discharge at Otamiri River is 1.3m^3/s and daily withdrawal ranges between 35,000 - 44,000 m^3/d. Determination of the reliable yield of rivers would normally be based on analysis of low flow sequences drawn from extensive records of stream flow data (Tahal, 1977). In the absence of records, estimates were made based on few measurements. According to Nwosuegbe (1987), the construction cost of the Owerri New Water Scheme was ₦34 million.

However, the reasons for the change of scheme was not disclosed. Schemes were changed with a view to providing adequate and safe drinking water for the expanding population. Other reasons included political pressure groups and vested interest groups. The political pressure groups consisted

indigenes of the town who wanted particular projects sited in their town. The vested interest groups were mostly the contracting firms that wanted huge profits out of the contract. It is likely that one of the reasons enumerated above prompted the change.

In water resources management, whenever a choice has to be made between alternative sources, the quality of the raw water as well as the adequacy and reliability of the sources must be considered. Also, potentialities for expansion should be examined. Some other parameters relating to quality and instrumentation should be considered with reference to cost benefit analysis.

The choice of a source requiring a minimum amount of treatment must always be regarded as preferable to the installation of sophisticated purification plant (WHO, 1971). The economic base of the state may not be viable enough to support the installation of such plants which is a basic requirement in surface water development.

According to Balek (1977), surface water is not good for consumption in areas with abundant rainfall because of the presence of various bacteria and parasites and of contamination. Owerri falls within the high rainfall zone in Nigeria. This may be confirmed by a close study of the graphic illustration in fig. 1.3. It is recommended that future surface supply should be discouraged to save cost that may accrue from regular treatment and instrumentation.

Groundwaters are generally free of ammonia but most surface waters contain a small concentration (less than 0.2 mg/l) as a result of contamination by animal excreta (Short, 1974). The concentration may be increased by the discharge to the water course of raw sewage, industrial and agricultural wastes. Also, deliberate dumping of all types of wastes is a major factor responsible for the deterioration of river quality. Treatment of contaminated water is always difficult and expensive when chlorine is applied. Chloramines are formed and they are slow-acting compared with free chlorine.

The economic importance of subsurface water can hardly be emphasized too strongly. It is more desirable than surface water because it is commonly free of pathogenic organisms and needs no purification for domestic and industrial uses (Davies and DeWiest, 1966). It maintains almost a uniform turbidity and colour is generally absent. Groundwater storage is generally greater than surface water storage (Davies and DeWiest, 1966). Most of the rivers in the project area, are fed from the Coastal plain aquifer.

3.2.2 Raw water quality

The chemical quality of raw water from the Otamiri is fair. A summary of Table 3.5, indicates that the water is soft with a pH of 5.3. The turbidity is very high which is an evidence of pollution. It is a common phenomenon in the rainy season due to discharge of flood materials into the river. Turbidity values are minimal in the dry season. Also, high concentration of iron may have contributed to the high value

of turbidity.

The colour of the raw water is relatively high, though within the acceptable limits by the World Health Organization (WHO). According to Walker (1978), colour is a good visual indication of pollution or post treatment contamination. Coloured waters are objectionable to domestic consumers and industrial users due to problems caused in washing clothes, manufacturing food stuffs, etc. Total alkalinity and hardness occurred at very low concentrations.

According to Nwosuerbe (1987), the Otamiri river in Owerri, is polluted as a result of human, domestic and industrial activities. For this water supply to be wholesome and fit for human consumption, it must be treated with adequate type of chemicals in the right dose.

Municipal and industrial waste often contains high concentrations of chemicals and particularly of nitrogen and phosphorous compounds which are often discharged into water sources (Obeng, 1980).

It is obvious that contaminated water serves as a ready source and possible reservoir for agents for communicable diseases e.g. diarrhoea and dysentry. Bacteriological analysis of the raw water represented in table 3.6 indicated 33 coliforms in 100 ml, mostly Escherichia coli (E. coli). E. coli is definitely of faecal origin and its presence should be considered as a sure indication of faecal pollution calling for immediate action (WHO, 1971).

One could justifiably conclude that the biological quality of Otamiri river is below minimum standard.

Table 3.5

Chemical Analysis of the Raw Water from the Otamiri River

Source of sample .. .. .. Otamiri pumping station
Submitted by .. .. .. Scientific Officer
Date submitted .. .. .. 20 - 10 - 86
Date of analysis .. .. .. 10 - 9 - 86
File number IWB/OT/LAB/1

Item	Unit	Value
Colour	Mg Pt/l	15
pH		5.3
Turbidity	NTU	69
Conductivity	Us/cm	14
Total Alkalinity	Mg/l	12
Acidity	"	6
Total Hardness	"	4
Calcium Ca^{++}	"	1
Iron (Total)	"	0.4
Manganese	"	0.25
Aluminium	"	Nil
Chloride	"	"
Sulphate	"	"
Total chlorine	"	"
Free (Residual) chlorine	"	"

3.2.3 Method of abstraction

The sketch of the Weir and intake units in Fig. 3.4, gives an insight into the method of abstraction. The function of the stilling basin is to reduce the discharge of the river, thereby facilitating the flow of a greater quantity of the water into the intake chamber.

The radial gate is designed to channel a greater portion of the water into the chamber. It is always installed when pumping is to be carried out. The trash rack checked the entrance of large suspended particles in the water into the chamber. In effect, it acts as a macro-sieve to the raw water.

Water is being pumped from the intake chamber at the low lift pumping station. Four vertical spindle pumps are located at the station, and each of these pumps has a capacity of 925 m^3/hr. and is electrically powered. As at September 1986, only three pumps were used, with one placed on Standby.

Pumping is carried out through a ϕ900 mm steel pipe up to the aeration unit. The pipe is fitted with a venturi and a flowmeter to record the quantity of water that passed through. A butterfly valve was installed with a ϕ600 mm steel pipe, to by-pass the aeration unit to the flash mixing unit. The essence is to ensure regular water supply to other treatment units in case of a breakdown at the aeration unit.

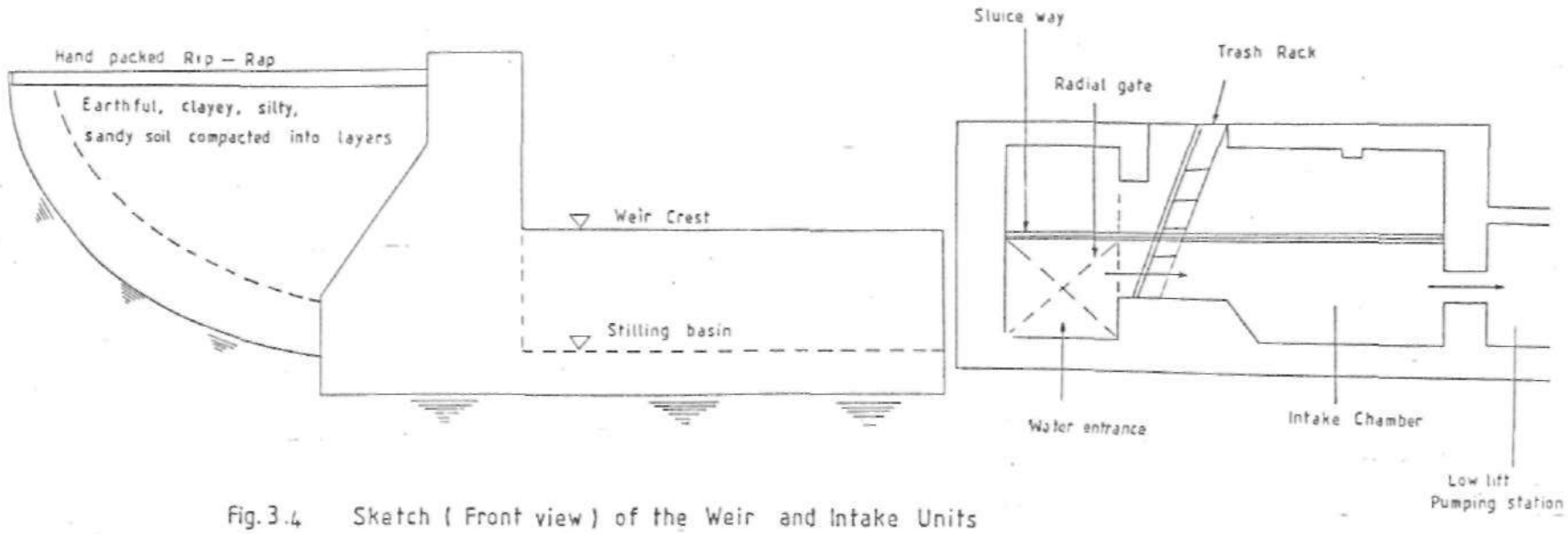


Fig. 3.4 Sketch (Front view) of the Weir and Intake Units
(after Imo State Water Board)

3.2.4 Treatment

Treatment of water is a necessity towards ensuring that supplies of drinking water do not constitute a danger to the health of the consumers. Treatment should, however, be adequate to deal with changes in the quality of the raw water and produce a finished product of consistently high quality, however great the demand on the supply may be (WH , 1971).

Treatment is carried out systematically in the following units: aeration, flocculation, sedimentation filtration and chlorination. Bacteriological analysis is carried out in the laboratory at the Head works prior to chlorination.

Aeration

The raw water is spried in the aeration plant through 75 spray nozzles. The water divided into fine droplets, flow down from the spray nozzles screwed on the branch pipes to the bottom of the aeration basin which is sloping and designed to channel water into the flash mixing unit (see Fig. 3.5).

The essence of this process is to permit the oxidation of iron salts dissolved in the water so that it could be removed by settling and filtration. It also permits the release of sulphur dioxide and carbon dioxide. Oxygen enrichment of the water is also envisaged. According to Walker (1978), spray aerators are effective and provided they can be economically designed, as a decorative fountain they can be attractive.

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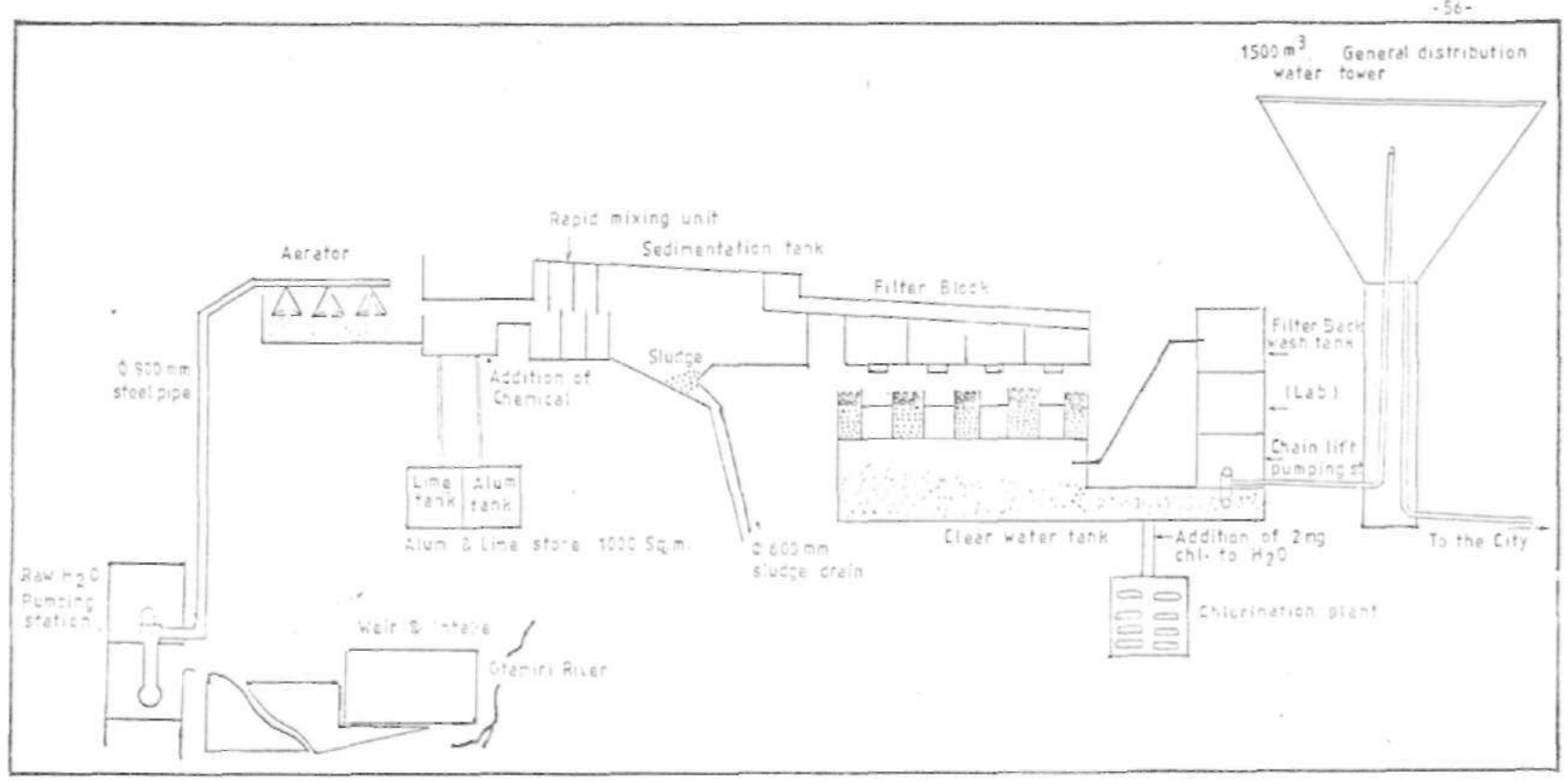


FIG.3.5 Schematic sketch of the intake, treatment and distribution units at the Otamiri River Head works, Owerri, (after Imo State Water Board).

FLOCCULATION

Chemical reagents are added into the aerated water immediately on entering the flash mixing channel (see Fig. 3.5). The chemical added include:

(a) Hydrated lime (Calcium hydroxide) which buffers the pH of the water from 5.3 - 5.5 to 7.2, since the raw water is acidic. The quantity is about 15 mg/L, depending on the raw water quality

(b) Aluminium sulphate (Alum) which is a coagulant and when dissolved in water, form flocs with suspended particles in water. Alum is acidic and the lime boosts the pH. The quantity added is dependent on the season. About 66 mg/L is used in the rainy season and 20 mg/L in the dry season. However, the two chemicals are added simultaneously for effective reaction.

Reaction:

$$Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow \underset{\text{floc}}{\downarrow 2AL(OH)_3} + 3CaSO_4$$

The flocculation unit consists of two chambers with a capacity of 962 m^3. The chambers include:

(1) Rapid mixing section for rapid mixture of lime and Alum for uniformity. Failure to uniformly mix the dosing chemicals into the water flow is a major cause of poor plant performance (Walker, 1978).

The mixing is achieved with concrete and wooden buffles constructed in such a way to permit complete dispersion of the reagents in the raw water.

(2) Slow mixing section for the formation of heavy and big flocks in order to attract some of or all other colloids. The time allowed for both rapid and slow mixing is called detention time or resident time. It is based on the velocity and quantity of water which is read from the flowmeter.

Rapid mixing is allowed for 5 mins., while slow mixing is allowed for 20 mins. If the detention time exceeded the specified limits, settling would start taking place instead of in the sedimentation tank.

Chemicals used are in solid forms and are dissolved proportionately.

For Lime, 6% of solution = 6 grams per 100 ml.
" Alum, 20% of solution = 20 grams per 100 ml.

Sedimentation

The sedimentation Tank is a very big basin and divided into two sections with a total capacity of 4840 m^3 (see Plate II). The aim is to allow for settling of the flocs having achieved good flocculation.

Settling depends on the size of flocs and the detention time, because the process of settling is by gravity. The detention time in this unit ranges from 1.5 to 2 hours. After this time, all flocs that could be pulled down by gravity must have settled. Settlement is carried out with minimum turbulence (no disturbance).

The basin is equiped with a scraper bridge, which has two sludge bottom blades. When complete settlement of the materials or particles is achieved, the bridge is switched on to move forward and back for 30 mins. each (see Plate II). The settled materials are collected by the bottom blades of the scraper bridge during the motion of the bridge and driven into the sludge cones (see Fig. 3.5). From the sludge, the flocs flow into the river at the downstream discharge point.

Filtration

This unit consists of four twin filter beds which work on parallel basis. Water flows from the sedimentation tank to the filtration unit. The aim is to remove particles that could not settle in the sedimentation unit. The method is by rapid sand filtration (see Fig. 3.5).

The sand particles were arranged in three layers and the sizes vary. The topmost layer is filled with 2 mm sized sand particles, middle layer with 1.5mm. and the bottom layer with sand particles of 0.8mm.

Particulate suspended matter in the water penetrate into the pores of the filter bed and adhere to the grains of the filter media. As more particles are trapped in this fashion, the free passage through the filter is diminished. The sand is then backwashed using pressured water.

Filtered water flows into the filter bottom, passing through filter nozzles installed in the concrete platform into the clear water tank (Fig. 3.5). The average filtration rate is 7.56 m^3/sqm/hr and the capacity is 4370 m^3.

Bacteriological treatment

Bacteria are usually small enough to pass through a normal granular filter bed and will do so unless they are attached to a particle of floc. (Walker, 1978). The quality of water supplied is critically important to human health. Biological pollution through faecal contamination may increase the incidence of morbidity due to water borne diseases. Water circulating in the distribution system, whether treated or not, should not contain any organism that may be of faecal origin (WHO, 1971).

Treatment is carried out with a chemical called Membrane Enriched Toepol Broth. The solution is made by dissolving 76.2 grams in a litre of water. It is used in detecting E.coli (coliform) and suppresses other bacteria in the water.

The indicator used is Sodium dodecyl sulphate (lauryl sulphate) and the volume of raw water used for the test is 100 ml. After making a solution of Teepol in the test water, it is sterilized in the autoclave at $12^{o}C$ and 15 Lb pressure for 15 mins. If colonies of coliform or E.coli were detected, a recorded quantity of chlorine would be added with a view to exterminating the coliforms.

Disposable petri-dishes containing filter pads are used in filtering the water. The filtrates are filtered again using membrane filter. The resultant filtrates are stored in the incubators at a temperature of $30^{o}C$ for 4 hrs and $44^{o}C$ for 14 hrs. All other coliforms would have been eliminated at this stage.

The concentration of chlorine used is calculated accordingly and applied in disinfecting the water before distribution. This is called the Chlorine Demand Test (CDT). The analysis represented in Table 3.6, was carried out at the Head works using this procedure. The sample indicated 33 coliforms in 100 ml of the raw water. The coliform content is high when compared with the World Health Organization recommendations.

Table 3.6. Result of Bacteriological Analysis of Water from the Otamiri pumping station

Source of Sample	Otamiri Headworks
Place of Analysis	Otamiri water Laboratory
Submitted by	Lab. Technologist II
Date of Sampling	14 October, 1986
Time of Sampling	9.30 am. to 9.45 am.
Type of Analysis	Faecal coliform
Technique	Membrane Filter Technique
Media used	Membrane Enriched Teepol Broth
Temperature of Incubation	30°C for 4 hrs, 44°C for 14 hrs.
Time of Incubation	18 hrs.

Period of Analysis	Sampling Point	Coliforms/ 100 mL	Remarks
Before treatment	Venturi	33	Unsatisfactory
After treatment	Tap near filtered	-	Satisfactory
After treatment	High lift	-	Satisfactory
After treatment	Consumer Lab.	-	Satisfactory

Comments: All tests in normal range

Recommendations: Water is recommended for drinking according to WHO's recommended standards for drinking water.

Chlorination

Many disinfectants have been developed for the treatment of raw water especially the surface water. These include: Ozone, chlorine dioxide, chloramine and free chlorine. According to Fiessinger et al. (1981) chlorination, particuarly for the removal of ammonia and the maintenance of a disinfectant residual in the distribution system has decisive advantages and will be difficult to replace.

The filtered water from the clear water tank flows into the chlorination chamber, composed of two units. The aim is to eliminate pathogenic organisms. Some coliform bacteria have been identified e.g. Salmonela group, E.coli etc. The quantity of chlorine used depends on the level of pollution CDT carried out during bacteriological test, governs the quantity of chlorine added to eliminate all the organisms. Efficient chlorination yields a water that is virtually free from coliform organisms (WHO, 1971).

The quantity added is 1.5 kg/hr to 2.300 m^3/hr. A small quantity of chlorine of about 0.25 mg/L is left in the water after treatment and is called the residual chlorine. This quantity takes care of possible pollution in the distribution. According to Gordon (1981), the presence of a disinfectant in the water distribution system helps to maintain the quality of water by preventing the growth of nuisance

Table 3.7 Chemical Analysis of Treated Water from the Otamiri Headworks

Item	Units	Value
Colour	Mg Pt/L	5
pH		7.2
Turbidity	NTU	5
Conductivity	us/cm	63
Total Alkalinity	mg/L	13
Acidity	"	0
Total Hardness	"	32
Calcium Hardness	"	30
Calcium Ca^{++}	"	12
Iron (Total)	"	0.04
Manganes	"	NIL
Aluminium	"	2.0
Chloride	"	NIL
Sulphate	"	10
Total chlorine	"	0.45
Free (residual) chlorine	"	0.25

Source of Sample	Otamiri pumping station
Submitted by	Scientific Officer
Date submitted	20 - 10 - 86
Date of Analysis	10 - 9 - 86
Place of Analysis	Otamiri Headworks Lab.
File number	IWR/OT/LAB/1

micro-organisms. Distance affects the level of residual chlorine in the distribution network.

Results of chemical analysis of the treated water from the Otamiri Headworks represented in Table 3.7, show that the physical parameters like colour, turbidity, pH, etc. have been corrected within acceptable limits.

Other chemical parameters in the table were corrected with a view to meeting the international standards represented in Appendix E. The water could be classified as very good for drinking based on Table 3.8, adapted from Walker (1978).

Table 3.8 Classification of Drinking Water Quality based on Hardness (after Walker)

Quality classification	Mg/L $CaCo_3$
Very good	< 80
Good	81 - 120
Fair	121 - 180
Poor	>180

< = less than

> = greater than

3.2.5 Distribution network

After chlorination, the water is pumped into the 15,000 m^3 Elevated Water Tank (EWT) from the high lift pumping station (see Fig 3.5). This is distributed to the city by gravity. The design of the Otamiri EWT is represented in Appendix G.

The high lift pumping stations houses four vertical spindle pumps. They are electrically powered with a capacity of 830m^3/hr each. Only three pumps were in use by September 1986. Steel pipes were used to distribute the water from the Otamiri EWT to the major Ground Level Reservoirs (GLR) and Elevated Water Tanks (EWT) as shown on the map (see Fig. 3.6).

The system has four EWT and four GLR. The capacity and locations of the EWT are as follows:

(1) Otamiri Headwork, with a capacity of 15,000 m^3 and at about 48 m above the ground (see Appendix G.).

(2) Orji/Junction EWT, has a capacity of 750m^3 and at approximately 31m above the ground (see Appendix H).

(3) Ubomiri EWT, with a capacity of 500m^3. The height is about 30m above the ground (see Appendix 1).

(4) AVU EWT, with a capacity of 230m^3. The height is about 30m above the ground (see Appendix J).

The GLR capacities and locations are as follows.

(a) North East Ground Level Reservoir (NEGLR) is located at the Water Board premises along the Okigwe Road (see Plate III). The capacity is 20,000m^3, height at 11m and diameter 50.60m.

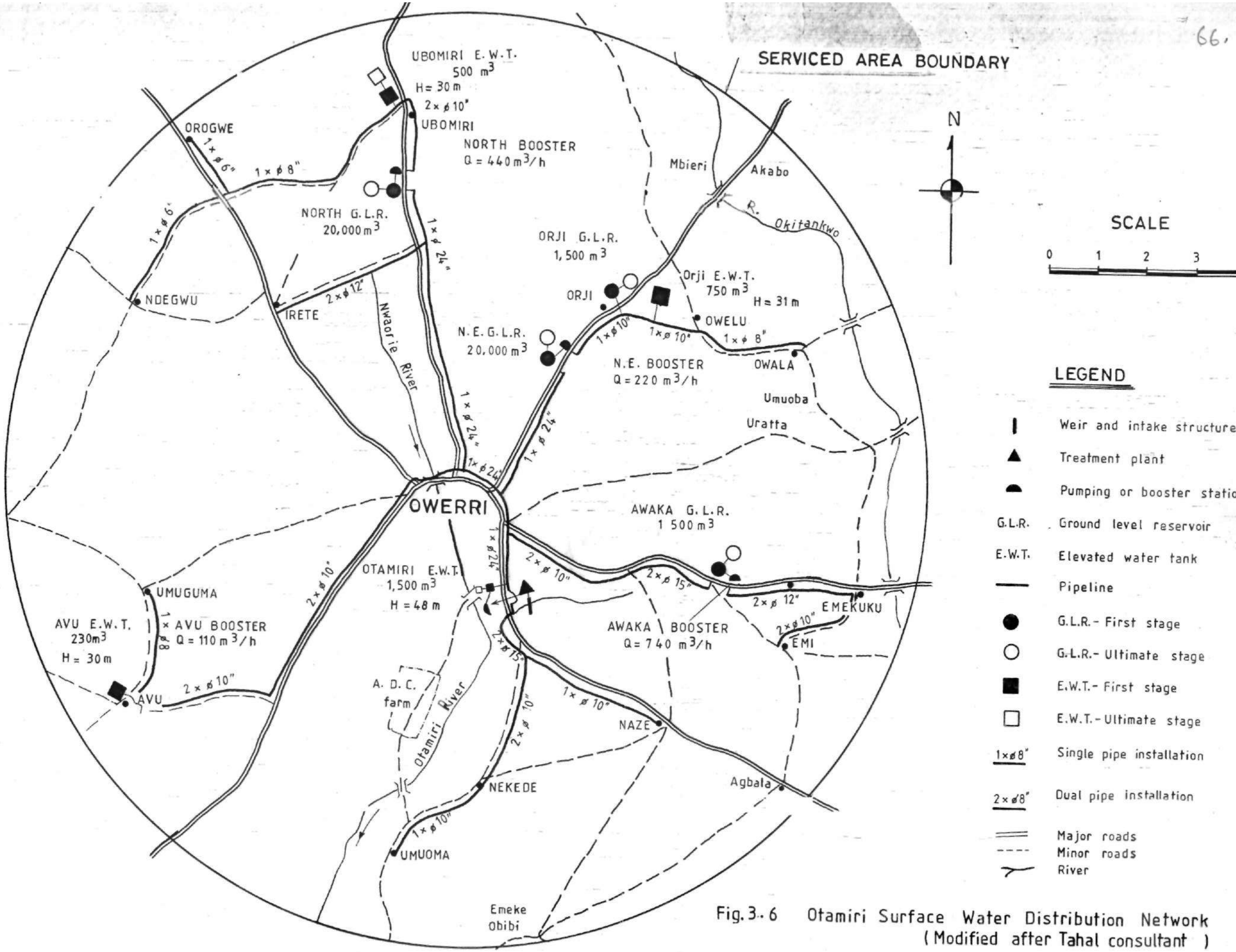


Fig. 3. 6 Otamiri Surface Water Distribution Network
(Modified after Tahal consultant)

(b) North GLR located at Ubomiri, has a capacity of 20,000m^3 with dimensions as in (a).

(c) Orji GLR located at Orji, has a capacity of 1,500m^3 with a diameter of 17.50m and height 8m.

(d) Awaka GLR located at Awaka, has a capacity of 1,500m^3 with dimensions as in (c).

Booster stations were installed at some locations along the network system to enhance the pumping of water to the tower and reservoirs. According to Walker (1978), these are usually installed to increase the head, particularly in water transmission pipelines where friction losses or increases in elevation necessitate an increase in pressure or in distribution systems at higher elevations.

Distribution from the water towers and the ground level reservoirs is by gravity and through asbestos cement pipes. The sizes used include 450 mm. to 100 mm AC pipes and these form the secondary network system. However, small galvanised iron pipes of various sizes are used for household connections which is the final phase of the distribution network.

The services area boundary is 10 km. radius from the Headworks. Towns and communities within this radius and slightly beyond, enjoy the Otamiri surface water scheme (see Fig. 3.6).

3.3 Number of Connections

The total number of connections are usually considered in any water supply scheme. Connections are based on the number of service pipes from the water mains to the buildings of Structures They are classified into the following: domestic, public, commercial, industrial, agricultural and fire service connections.

(a) Domestic: concerns connections into private houses for drinking, cooking, cleaning, flushing of toilets, bathing, gardening etc. They constitute well over 90% of the total connections in the system.

(b) Public: This includes street washing, public stand pipes, schools, hospitals, market places etc.

(c) Commercial: include hotels, slaughter houses and laundry.

(d) Industrial: connections in any sort of industry

(e) Agricultural: Connections for livestock production, machinery, plant watering etc.

(f) Fire service: This concerns fire fighting.

During a fire, the rate of demand of water is high, an important consideration when selecting the size of pipes, pumps and supply pressures (Al-Layla et al., 1977). Also, the total quantity of water required for fire fighting may be a small fraction of the total consumption in large cities. In Owerri, the Fire Service Station is located very close to the Otamiri Headwork in light of the above requirement.

The available records in Owerri indicated the following number of connections:

(1) From 1972 to 1975,

commercial registration		2
private	"	300
		302

(2) From 1976 to 1977,

School registration		1
Commercial	"	1
Private	"	801
		803

(3) From 1978 to 1985,

Office registration		5
Hospital	"	1
School	"	7
Commercial	"	20
Slaughter house	"	1
Private	"	3194
		3228

(4) From January to November 1986

private registration 547

The number of public stand pipes in Owerri urban from 1960 to 1980 amounted to 58. The installation of public stand pipes have been stopped in Owerri Urban. Therefore, the total number of connections in Owerri Urban registered as at November 1986, amounted to ±4,938, excluding the pre-war connections. Most registrations for commercial and public connections were done with private addresses instead of the business address. This accounts for the low number of commercial and public connections. The connections are not metered. The possibility of illegal connection is not ruled out.

Chapter 4

FUTURE DEVELOPMENT

4.1 Plans for Future Extension

Official plans for future extension has been made based on the Otamiri Surface Water Scheme. The extension has been envisaged from the Low Lift Pumping Unit, through the treatment to the storage and distribution sections.

In November 1986, three vertical spindle pumps were operational at the low lift pumping station as against the four installed. When the scheme is eventually extended, the four pumps will be operated at full capacity to increase the volume of abstraction.

At the treatment section, provision has been made at the filtration unit. This unit as earlier stated, consists of four twin filter beds which work on parallel basis (see Fig. 3.5). Only three twin filter beds were used as at November 1986. The fourth bed will be put into use when the need arises.

Provisions were also made for the storage section. Reference to the legend and the distribution network pattern in Fig. 3.6, would enable one to appreciate the extent of the provisions made. The ground level reservoirs and the elevated water tanks were planned for first and ultimate stages. Only the first stage reservoirs and towers were used at the time of this report. However, the ultimate stages may not be constructed until the period of proposed extension. The first

stage provision for EWT with a capacity of 750m^3 was made for Awaka town, but has not been executed. The same applied to Avu GLR of 1,500m^3.

The Ultimate stage EWT was planned for Ubomiri and Awaka with 500m^3 and 75m^3 capacity respectively. Also, 1,500m^3 ultimate GLR - was planned for Awaka, Avu and Orji. While 20,000m^3 was designed for Ubomiri and NEGLR.

The first stage of the scheme was designed to supply 48,400 m^3/d to an estimated population of 203,000 people. Currently, about 40,000 m^3/d is supplied. The second stage was proposed to supply 96,000 m^3/d to about 400,000 people by the year 2,000 AD. The current yield of the river was estimated at 1.3m^3/s. The average daily withdrawal by November 1986, was 0.46 m^3/s to an estimated population of 226,325 people (see Table 2.1).

The plant was designed and engineered on the basis of daily capacity of 61,000 m^3/d and maximum hourly capacity of 2,541 m^3/hr. The projected 96,000 m^3/d may not be realized because

(1) There will be a short fall of 35,000m^3/d to the projected 96,000 m^3/d, since the daily capacity of the whole plant is 61,000 m^3/d. The economic base of the state may not be viable enough to construct another treatment plant.

(2) The downstream discharge beyond the weir and intake has drastically declined with the result that grasses have grown along some portions of the velley.

Therefore, increased abstraction beyond an estimated value of 65,000 m^3/s will definitely jeopardize the ecology of the river. The need for an alternative supply obviously, should be given a serious thought for the economic wellbeing of the state.

4.2 Recommendations for Future Development

Recommendations for future development have been considered under the following: (a) choice of scheme (b) treatment and (c) pipes. Recommendations in the light of the present operational capabilities are essential. The discharge of Otamiri River may not meet the future demand of the expected growth rate in population alongside with living standards.

(a) Choice of Scheme

The choice will centre on surface and subsurface developments. Surface development will definitely come from rivers in the area. The discharge of Nwaorie River is estimated at $0.3m^3/s$, Okitankwo River is highly influenced by the seasons and the discharge at Mba River is equally low (Fig. 1.1). Surface water development in Owerri should therefore be discouraged and discontinued in future.

The Water Board should consider groundwater scheme for the future development of water supply to Owerri as a matter of commitment towards the welfare of the people.

Some of the abandoned boreholes should be rehabilitated and kept on standby basis in case of a breakdown at the Headworks. The equipment at the Headworks is complex and it may take weeks to rectify any fault in event of a breakdown.

It is recommended that the ultimate stage of the Avu GLR, be completed in future. Boreholes should be drilled to make

use of the Avu GLR for storage and the EWT for distribution to Avu and the adjoining towns. The conversion will reduce overdependence on the Otamiri surface water scheme and increase the litre per capita day (lpc d) of the citizenry (see Fig 3.6)

The ultimate stages of the Ubomiri EWT and GLR should be completed, and a groundwater scheme be developed to use the two GLR for storage and two EWT for distribution to Ubomiri, Amakohia, Orogwe, Irete, Ndegwu etc. It is envisaged to increase the Lpcd of the people and boost agricultural production.

Major industrial establishments should be provided with private boreholes to avoid the risk of under production due to water shortage.

The boreholes should not be very close to one another to avert possible well interference.

(b) Treatment

The use of free chlorine for disinfection should be continued pending the advancement of our indigenous technological base towards the preparation of Ozone in sufficient quantity for water treatment.

There should be improvement and uniformity in the method of water sample analysis and expression of results between the Chemical analysts at the Otamiri Headworks and the Water Board headquarters at the Okigwe road, especially at the headquarters.

Regular sampling and analysis of treated water from private

homes and industries should be carried out to monitor the elemental and TDS concentrations of the supplied water for safety.

Water circulating in the distribution system, whether treated or not, should not contain any organism that may be of faecal origin. The frequency of bacteriological examination for hygienic control of the supply, and the location of the sampling points at pumping stations, treatment plants, reservoirs, booster pumping stations, and in the distribution system should be such as to enable the bacterial quality of the water supply to be properly controlled (WHO, 1971).

The maximum interval between successive sample analysis in the distribution system should be at least once a day. The installation at the chlorine, Alum and Lime chambers should be regularly maintained to avert possible breakdown.

The management must take care to prevent quality deterioration and if possible, contribute to an improved quality of the final drinking water.

The chemicals used for water treatment at the Otamiri Headworks are imported, and the prices of imported goods are quite expensive due to the present economic situation in the country. The economy will most probably not improve in the near future. There is a likelihood that some time in future the water from the Otamiri river will not be adequately treated due to lack of chemicals which are imported. It is recommended that in anticipation of such situation the Water Board should enlighten the public, that water from the distribution network in Owerri should be boiled before drinking. For the purpose of

enlightenment, churches, schools, radio and dailies should be used.

(c) Pipes

Many people have expressed fears over the use of asbestos cement pipes for water distribution due to health hazards associated with asbestos fibres, resulting from corrosion of pipes.

According to Zielhuis (1977), experience from drinking water authorities has not shown any relation between the prevalence of gastrointestinal tumors and the presence of asbestos fibres in drinking water. At this moment, there is no evidence that there exists any increased health risk from asbestos fibres present in drinking water. Therefore, the use of asbestos cement pipes should continue pending the availability of an alternative type of pipe.

One of the greatest advances in reducing costs both for well casings and for water distribution lines has been in the development and use of thermo-plastic pipes (Biswas, 1978). The commonest thermo-plastic pipe used in water supply is polyvinylchloride (PVC). It has good chemical resistance, is non-absorbent and resists corrosion and build up of deposits (BISWAS, 1978). The PVC should be used if manufactured locally., It could be used as service pipes for experimental purposes before final incorporation into the distribution network.

Chapter 5

SUMMARY AND CONCLUSION

The history of the water supply scheme to Owerri town can be divided into two periods: an earlier groundwater period and a later surface water period. The available records show that during the groundwater period, the serviced area boundary was small that at present when the only source is surface water.

There is a likelihood that the change from groundwater to surface water was prompted by the belief that the groundwater aquifer will not be sufficient for the growing town, and most probably, out of pressure from the citizenry, borne out of traditionally held view that they were used to surface water. Generally, the treated water quality is good when compared with recommended international drinking-water standards.

However, the rural water supply scheme around Owerri town is based on groundwater, and clearly shows that the Coastal Plains Sands aquifer is high yielding to provide a sufficient source of water for Owerri town up to the foreseeable future. Unfortunately, the available data are not sufficient to support this statement with figures. It is recommended that Owerri town should in future return to groundwater as the main source of supply for drinking water.

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APPENDIX A

MEAN MONTHLY MAXIMUM TEMPERATURE FOR OWERRI STATION FROM 1976 - 1985
UNIT - $^{\circ}$C, LAT. 05°29'N, LONG. 07°05'E, ALT. 91M.
NIGERIAN METEOROLOGICAL SERVICES, OWERRI

JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
X	X	X	X	X	X	27.6	27.8	29.7	29.6	31.0	32.6	1976
31.7	34.2	34.1	33.3	32.6	29.7	28.8	29.1	30.0	30.7	33.2	32.7	1977
34.0	34.5	33.3	31.7	31.7	30.6	29.0	29.1	29.7	30.7	32.2	33.9	1978
34.5	33.9	33.4	33.1	32.4	30.3	29.7	28.7	32.4	30.7	31.8	32.6	1979
34.0	35.1	33.5	32.8	30.7	29.6	29.0	29.1	29.9	30.4	31.7	32.3	1980
32.1	34.4	33.8	33.6	31.6	31.1	29.0	29.0	29.8	30.6	31.9	33.6	1981
32.9	34.2	33.5	33.0	31.9	30.9	29.0	28.6	29.5	30.4	31.7	32.7	1982
36.4	36.2	36.7	35.0	32.5	30.4	29.3	28.2	30.0	31.3	32.8	32.1	1983
33.7	35.4	33.6	32.9	32.1	31.6	30.3	30.8	30.2	29.6	32.2	32.8	1984
33.0	35.2	34.7	32.5	32.3	30.8	28.4	30.0	X	31.0	31.9	32.4	1985
302.3	313.1	306.6	297.9	287.8	275	290.1	290.4	271.2	305	320.4	327.7	TOTAL
33.59	34.79	34.07	33.1	31.97	30.56	29.01	29.04	30.13	30.5	32.04	32.77	AVERAGE

X = Not Recorded

APPENDIX B

MEAN MONTHLY MINIMUM TEMPERATURE FOR OWERRI STATION FROM 1976 - 1985
UNIT ^{o}C, LAT. 05^{o}29'N, LONG 07^{o}02'E ALT. 90.91M.
NIGERIAN METEROROLOGICAL SERVICES, OWERRI

JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
20.7	28.8	23.1	23.1	23.1	22.5	21.9	21.9	22.4	22.9	22.9	26.6	1976
23.2	23.3	23.9	24.1	23.4	22.6	22.5	22.7	22.9	22.9	23.7	21.9	1977
20.3	24.1	23.5	23.4	23.3	23.0	22.3	22.8	22.2	22.2	22.1	22.9	1978
22.9	23.6	23.6	23.8	23.4	23.0	23.0	22.6	24.1	23.0	23.6	20.6	1979
23.7	24.5	24.0	24.1	23.7	23.3	23.0	23.6	22.7	22.7	23.1	22.2	1980
21.2	23.5	23.7	23.7	23.4	23.0	22.0	23.0	22.4	22.8	22.4	22.1	1981
23.4	23.6	23.4	23.1	23.3	23.2	22.6	22.6	22.5	22.8	23.6	23.3	1982
20.8	24.2	25.8	24.7	24.2	23.2	22.8	22.6	22.8	23.3	24.1	23.1	1983
22.6	24.3	24.1	23.7	23.3	22.9	22.7	22.8	22.3	22.6	23.5	21.7	1984
24.2	23.6	24.6	23.8	23.5	22.8	22.1	22.7	22.7	22.9	23.7	21.8	1985
223	243.5	239.7	237.5	234.6	229.5	224.9	226.3	227	228.1	231.7	221.3	TOTAL
22.3	24.35	23.97	23.75	23.46	22.95	22.49	22.63	22.7	22.81	23.17	22.13	AVERAGE

APPENDIX C

Data on Borehole Depth and Yield

Borehole No.	Borehole Depth (M)	Borehole Yield (L/S)
1	x	x
2	x	x
3	x	x
4	x	48.01
5	94.49	48.36
6	91.44	44.16
7	91.44	53.62
8	91.44	53.62
9	91.44	x
10	103.63	10.72
11	86.87	16.82
12	86.26	12.6
13	93.88	42.1
14	57.91	6.31
15	92.05	26.18
16	85.04	26.18
17	86.6	25.85
18	90.22	42.74
19	90.22	48.01
20	85.34	48.00
21	91.44	42.74
22	182.9	15.17
23	46.00	x
24	43.00	x
TOTAL	1775.61	611.19
Average	88.78	33.96

APPENDIX D

Estimate of Daily average Water demand in Owerri

Year	Lpcd	Average Estimate (m^3/d)
1975	54	9,248.69
1980	142.26	28,000.47
1985	196	44,359.7
1990	230.6	60,068.76
1995	270.5	81,176.24
2000	300	103,852.2
2005	350	139,852.3

APPENDIX E

International Drinking Water Standards and Objectives
(after Walker 1978)

Chemical	Objective (Minimum) mg/L	Acceptable (Maximum) mg/L
Ammonia as N	0.01	0.5
Calcium as Ca	75	200
Chloride as Cl	250	250
Copper as Cu	0.01	1.0
Iron (dissolved) as Fe	0.05	0.3
Magnesium as Mg	50	150
Manganese as Mn	0.01	0.05
Phosphate as PO_4	0.2	0.2
Total Dissolved Solids	500	1,000
Total Hardness as $CaCO_3$	120	
Sulphate as SO_4	250	500
Sulphide as H_2S	Not detectable	0.3
Zinc as Zn	1.0	5.0
Nitrate + Nitrite as N	10.0	
Arsenic as As	Not detectable	0.01
Lead as Pb	"	0.05
Barium as Ba	"	1.0
Boron as B	"	5.0
Cadmium as Cd	"	0.01
Cyanide as CN	"	0.01

APPENDIX F

Logs of Selected Boreholes in Owerri

BH. 10

	From (M)	To (M)	Thickness (M)
Red earthy sand	0.00	12.19	12.19
Medium dirty sand	12.19	15.24	3.05
Medium - Coarse sand	15.24	18.29	3.05
Grit	18.29	24.38	6.09
Medium clean sand	24.38	27.43	3.05
Grit	27.43	33.53	6.1
Medium - Coarse sand	33.53	39.62	6.09
Medium - V. Coarse sand	39.62	48.77	9.15
Fine sand	48.77	51.81	3.04
Fine-Medium sand	51.81	57.91	6.1
Medium - Coarse sand	57.91	60.96	3.05
Fine sand	60.96	70.10	9.14
Fine - medium sand	70.10	35.34	15.24
Medium sand	85.34	91.44	6.1
Fine sand	91.44	94.48	3.04
Medium - Coarse sand	94.48	97.53	3.05
Grit	97.53	105.15	7.62

*Grit Angular fine or medium grained sand

	From (M)	To (M)	Thickness (M)
Dark brown sandy soil	0.00	0.61	0.61
Red Laterite earth	0.61	16.76	16.15
Water-Warm quartz pebbles	16.76	18.29	1.53
Red Laterite earth	18.29	19.81	1.52
Medium Pink sand and grit	19.81	22.86	3.05
Fine Pink Sand	22.86	25.91	3.05
Medium and Coarse light pink grit	25.91	30.48	4.57
Fine and medium golden yellow grit sand	30.48	35.05	4.57
Fine sand and Medium grit, light brown - yellow in colour	35.05	53.34	18.29
Fine yellow sand and white coarse grit with water worn quartz pebbles at the base	53.34	56.39	3.05
Fine and medium yellow grit and sand	56.39	60.96	4.57
Very fine to fine yellow sand	60.96	86.86	25.9

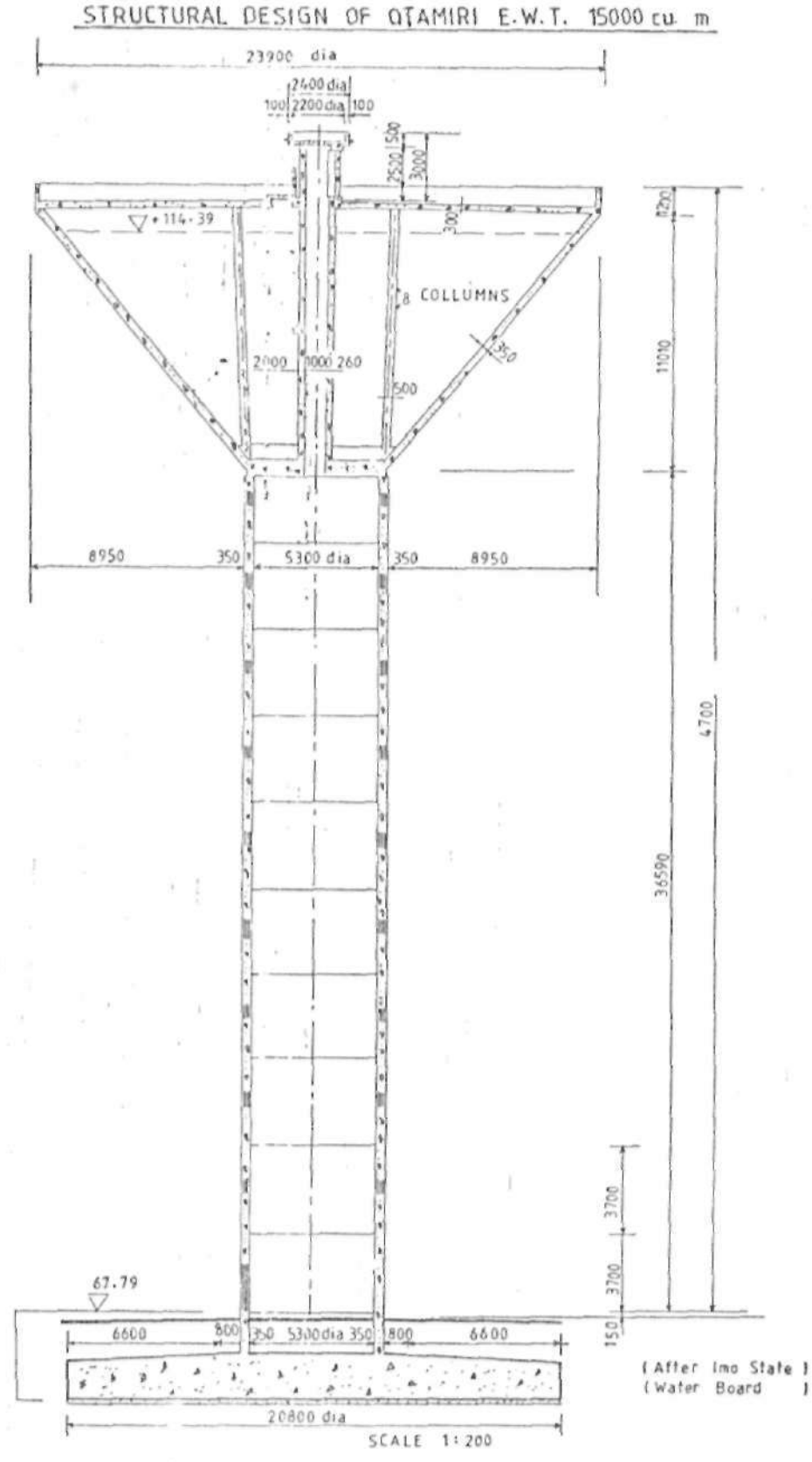
BH.12 (GSN.BH. 3145)

Clayey sand with red, medium to coarse grained pebbles towards base	0.00	16.76	16.76
Red cobble gravel, very coarse	16.76	23.16	6.4
Yellowish sand, very coarse grained, silty or clayey	23.16	31.09	7.93
White, very coarse silty granule gravel	31.09	39.32	8.23
Yellowish sand, medium to coarse grained			

	From (M)	To (M)	Thickness (M)
Fine grained reddish sand	0.00	15.24	15.24
Coarse grained reddish sand	15.24	39.62	24.38
Medium-Coarse grained white sand	39.62	97.53	57.91
Medium grained whitish sand	97.53	118.87	21.34
Brownish clay	118.87	124.96	6.09
Fine grained sand with clay	124.96	140.20	15.24
Fine grained whitish sand	140.20	167.63	27.43
Pinkish fine grained sandy clay	167.63	182.87	15.24
BH. 23 (OW/BD4/81/85)			
Clay and sand, Reddish brown	0.00	8.00	8.00
Gravel and clay, Reddish brown	8.00	15.00	7.00
White sand and gravel	15.00	18.00	3.00
White gravel and sand	18.00	27.5	9.50
White sand	27.5	33.5	6.00
White gravel	33.5	36.5	3.00
White sand	36.5	43.00	6.5
White gravel	43.00	46.00	3.00
BH. 24 (OW/BD4/23/84)			
Brownish clay and sand	0.00	12.00	12.00
Brownish sand and clay	12.00	15.00	3.00
Brownish sand and gravel	15.00	21.5	6.50
White sand and gravel	21.5	27.5	6.00
White sand	27.5	43.00	15.50

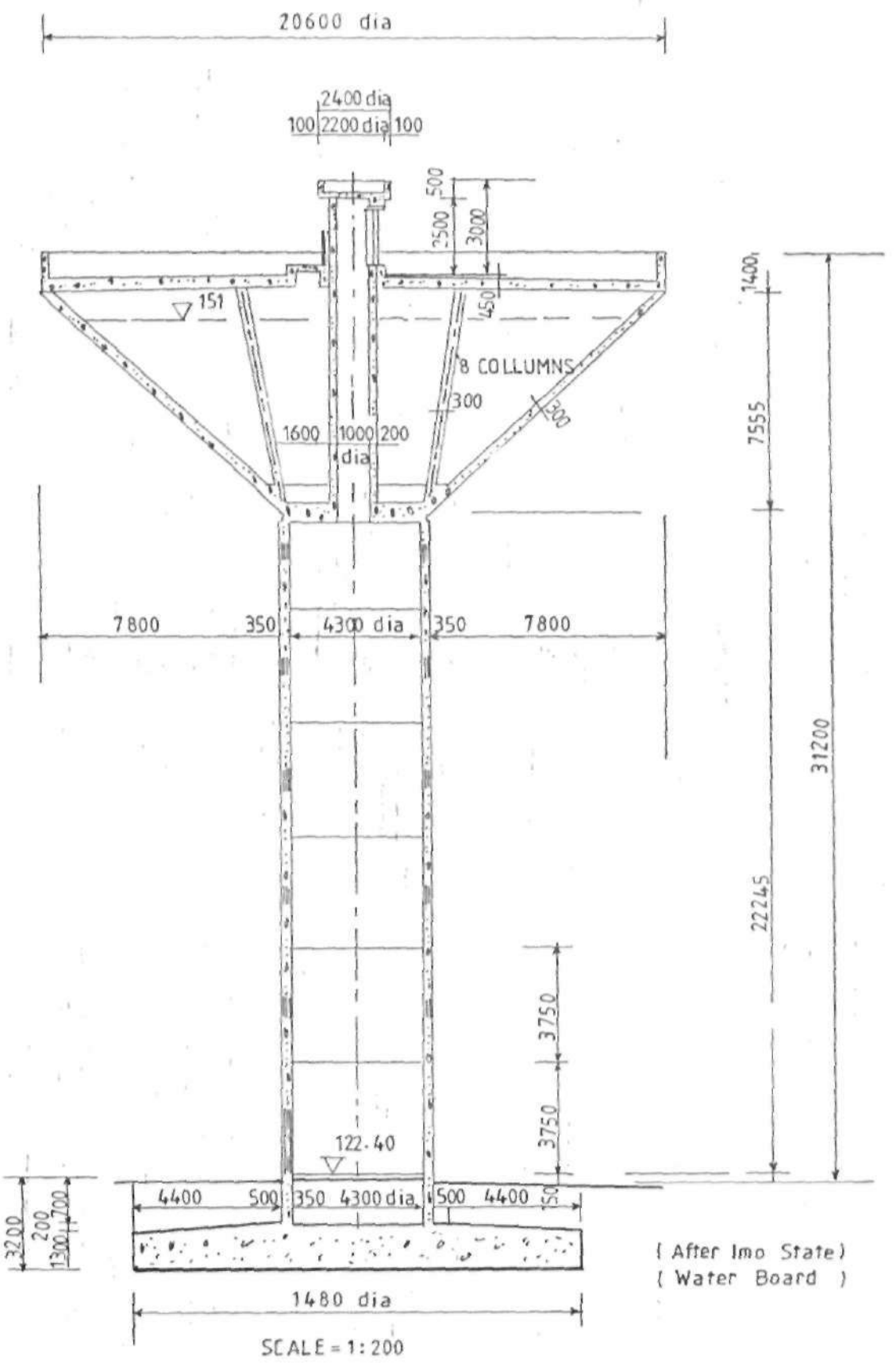
Appendix G

STRUCTURAL DESIGN OF OTAMIRI E.W.T. 15000 cu. m



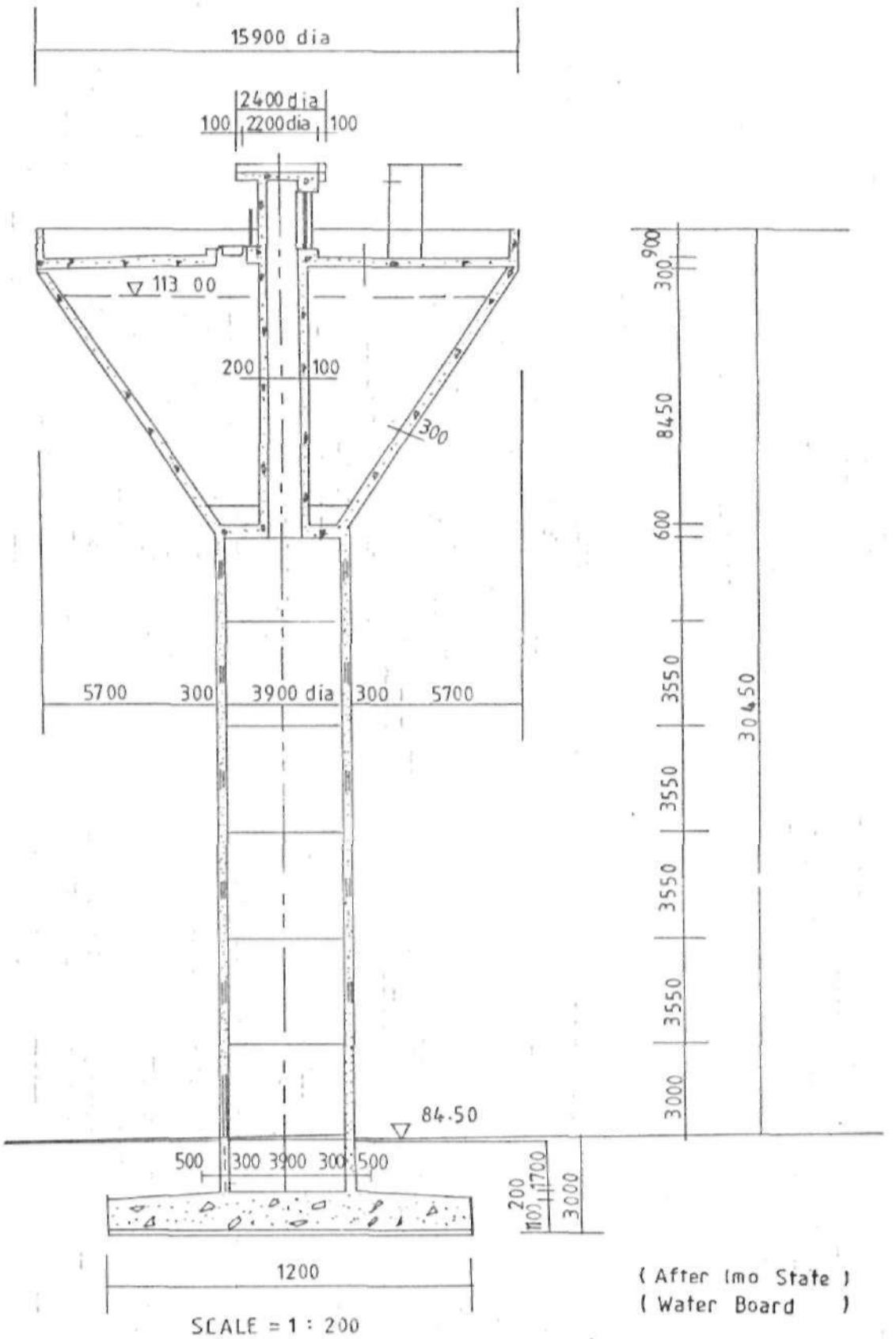
Appendix H

STRUCTURAL DESIGN OF ORJI/JUNCTION E.W.T. 750 m^3



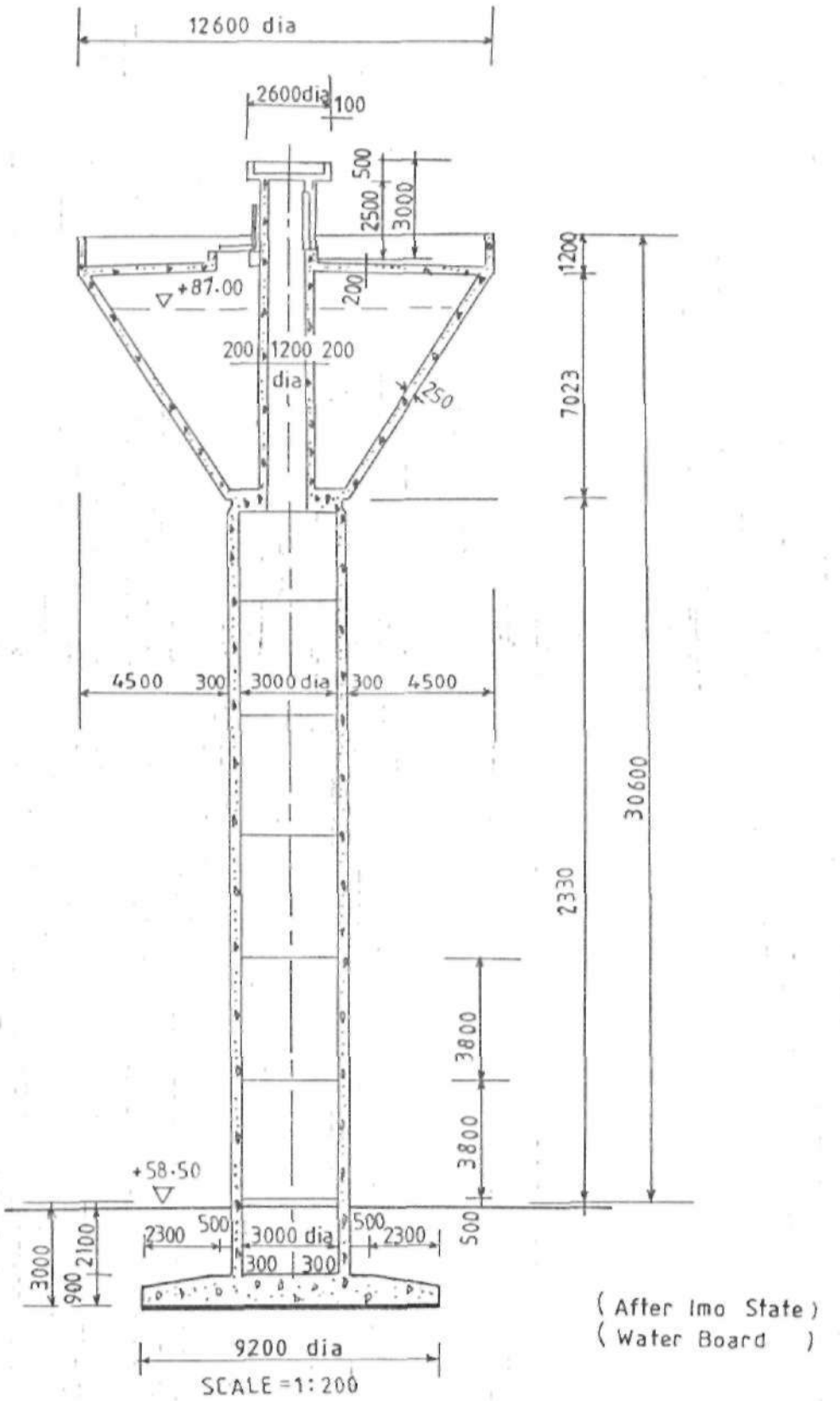
Appendix I

STRUCTURAL DESIGN OF UBOMIRI E.W.T. 500 m3



(After Imo State)
(Water Board)

Appendix J
STRUCTURAL DESIGN OF AVU E.W.T. 230 m^3



(After Imo State)
(Water Board)



Plate I. Front view of a borehole connected with a flowmeter at the Okigwe road groundwater Scheme.

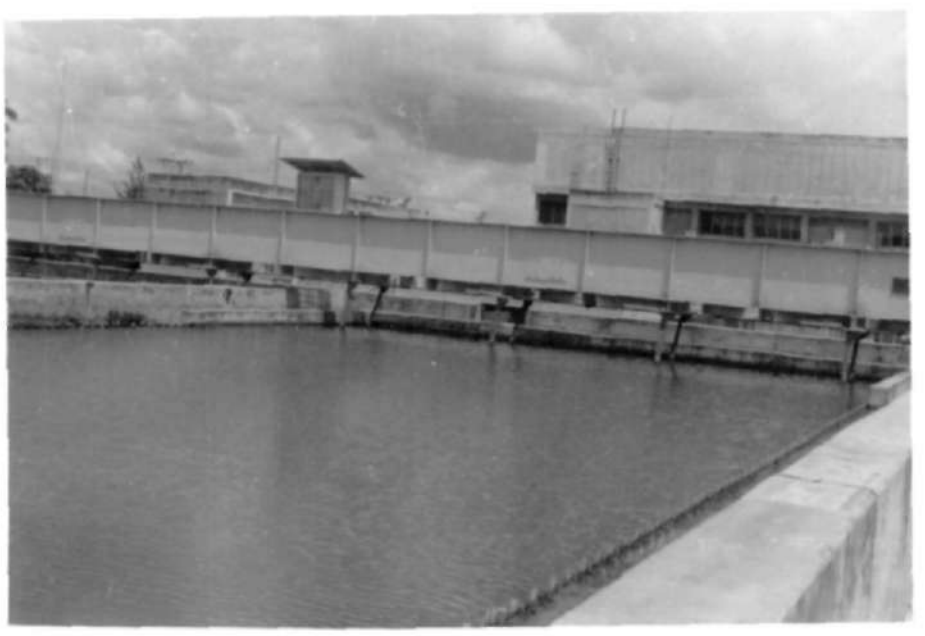


Plate II. Side view of the sedimentation tank filled with water at minimum turbulence and provided with the scraper bridge at the Otamiri treatment Headworks.



Plate III. Front view of the 20,000 m^3 North East Ground Level Reservoir (NEGLR) at the Water Board premises, Owerri.