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APPROVAL PAGE

This project have been read and approved by the undersigned as having met the requirements for presentation of project by the department of Agricultural Engineering, Federal University of Technology, Minna.

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ACKNOWLEDGEMENT

I acknowledged the Almighty God, relatives and friends who have contributed towards the successful end of it.

I would like to express my gratitude to my supervisor Engr. Bashir Mohammed for his great effort and patience. My special thanks goes to all the PGD students and the lecturers of the department for their support. My special thanks also goes to my elder brother, Mr. Godwin Ikpe and younger brothers and sisters. And finally, my late mother who died during the compilation and writing of this project.

ABSTRACT

Suitability of groundwater resources in five local government areas of Niger State were evaluated with respect to their quality and availability for dry season irrigation farming. Samples were chosen from five representative boreholes from each of the local government areas and evaluated for physico-chemical properties in terms of quality, and quantity estimated by use of borehole depth and static water level with the estimation of yield per second of each borehole. The total dissolve solids (TDS) were generally less than 250mg/l, which shows that irrigation can be carried out on all soils. The waters generally have low electrical conductivity, which shows that irrigation can be carried out on, with most crops with little likelihood of soil salinity developing. The pH value in 60percent of the samples is worrisome as this level can build-up the acidic content of the soil. The level of nitrate and phosphate are generally very low, that additions of fertilizer are required for optimum growth.

Yield level of the boreholes ranging between 0.4 – 1.8l/s, with dynamic water level ranging between 1.2 - 6m, which implies the groundwater can be utilized for irrigation demands particularly with tubewells in Fadama areas with a high success. Ground water resources in Chanchaga, Agaie, Lapai, Paikoro and Bosso Local Government Areas are suitable for dry season irrigation farming especially in the Fadama areas.

1.2 DESCRIPTION OF STUDY AREA

1.2.1 LOCATION

The study area comprises five local government areas in the southeastern part of Niger State of Nigeria; they are Chanchaga, Minna, Paikoro, Lapai, Agaie and Bosso Local Government area. They are located on longitude 6°28'E and latitude 11°N.

1.2.2 CLIMATE

The climate of the area is the same as that of middle belts of Nigeria. the major wind direction is normally along south-west and North-East axis. The rainy season lasts between 190 – 200 days, with annual rainfall of about 1200mm with September recording the highest rains of 300mm. Mean monthly temperature is March at 37oC and lowest in August at 25°C.

1.2.3 GEOLOGY

The geology of the area is characterized; by Nupe sand stone in Agaie and some part of Lapai Local Government areas, and basement complex in the other three areas of Chanchaga, Paikoro and Bosso. These two formations have been known to contain good aquifers.

1.2.4 ECONOMIC ACTIVITIES

Major occupation of the people within the area is farming. The land is arable for the cultivation of food. Like Yam, rice, guinea corn, groundnut, maize, cassava, vegetable and fruits.

The dry season after harvest people engage in auxiliary works except in the inland valleys where irrigation takes place or along the river banks

1.3 GENERAL OBJECTIVE

The general objective is to determine the suitability of groundwater in Niger State in terms of its quality and availability to dry season irrigation farming.

1.4 SPECIFIC OBJECTIVE

The specific objectives are to;

- Assess the physico-chemical properties of the ground water resource in the five local government in focus.
- Estimate the probable yield potential of the boreholes examined and use this to evaluate the availability of the groundwater for irrigation purpose.
- Determine the suitability's of the ground water resources in Minna, Bosso Paikoro, Lapai and Agaie for irrigation farming.

1.5 JUSTIFICATION

Rainfed agriculture, account for most of the food and fibre grown in Niger State. The seasonal impact of variations of climate on farming allow no continuous production thereby making dry season irrigation farming a necessity in view of the ever increasing population.

The people has practiced irrigation on subsistence scale for a long time and with time improvement can be made in different aspect to increase output, a sound knowledge of the quality and availability of the water to be used and its suitability for crops grown and soil being used is of extreme importance. Irrigation water must be sufficient to meet the crop water requirement and must not contain toxic compound to the crops or harmful to the soil being cultivated.

1.6 SCOPE OF STUDY

The scope of this study is limited to five Local government areas in the state, Minna, Bosso, Paikoro, Lapai and Agaie, using only five representative samples from each local government area.

The borehole yield was estimated, due to lack of yield data during construction and development of the boreholes.

made by nature and some of these have capacities to store much more water that what artificial man-made reservoirs can hold. The only problem in case of underground storage is that the water has to be lifted artificially through pumps or other suitable devices. However, the recent developments in countries such as Israel where artificial underground cut-offs have been constructed to raise the water table have helped considerably in reducing the cost because of the reduction in the pumping head. In many places the underground water lies under artesian conditions and once the water bearing strata is pierced through, water flow out of the well under the natural hydrostatic pressure head.

The greatest advantage of groundwater is its flexibility of use. In the case of surface irrigation, a farmer has to draw his share irrespective of his actual need at the given point of time. But in the case of groundwater, there is no such compulsion. A farmer can operate his pump any time and for any duration which suits him best. Most of the surface irrigation schemes operate at a very low efficiency (about 15 to 20%) due to colossal losses in convergence, application and improper management. The efficiency of ground water irrigation is considerably high about (80 to 90%) because of little losses and better control, (Mazundu, 1983).

2.2 HISTORICAL BACKGROUND

Groundwater development dates from ancient times. The Old Testament contains numerous references to groundwater springs, and well other than dug wells, groundwater in ancient times was supplied from horizontal wells known as

During drought crops perish in Northern Nigeria, surface water resources all but disappears in many areas. Emergency measures of many types are usually instituted to sustain public water supplies and irrigation, but the drilling of thousands of tube wells in the Fadama areas became a key factor in meeting restricted water demands during the critical periods.

Practically all groundwater originates as surface water. Principal sources of natural recharge include precipitation, stream flow, lakes and reservoirs. Other contributions, known as artificial recharge, occur from excess irrigation, seepage from canals and water purposely applied to argument groundwater supplies. Even seawater can enter underground along coasts where hydraulic gradients slope downward in an inland direction. Water within the ground moves downward through the unsaturated zone under the action of gravity, where as in the saturated zone its moves in a direction determined by the surrounding hydraulic situation. Discharge of groundwater occurs when water emerges from underground. Most natural discharge occurs as flow into surface water bodies, such as streams, lakes, and oceans; flow to the surface appears as a spring. Groundwater near the surface may return directly to the atmosphere by evaporation from within the soil and by transpiration from vegetation.

2.4 QUALITY OF GROUNDWATER

It is now generally recognized that the quality of groundwater is just as important as its quality. All groundwater contain salts in solution that are derived conductance. Depending on the purpose of a water quality investigation, partial analysis of only particular constituents will sometimes suffice. Illustrative chemical analyses of ground waters from a variety of geologic formation are shown in table 1 (according to White).

Properties of ground water evaluated in a physical analysis include temperature, color, turbidity, odour, and tastes. Biological analysis include tests, and defect the presence of coliform bacteria, which indicate the sanitary quality of water for human consumption. Because certain coliform organisms are normally found in intestines of humans and animals the presence of these in ground water is tantamount to its contact with sewage sources.

The American Public Health Association and others specify standard methods of water analysis, most laboratories conducting water analysis follows these procedures.

2.6 WATER QUALITY CRITERIA FOR IRRIGATION

The suitability of groundwater for irrigation is contingent on the effects of the mineral constituents of the water on both the plant and the soil (Richards, 1954). Salts may harm plant growth physically by limiting the uptake of water through modification of osmotic processes, or chemically by metabolic reactions such as those caused by toxic constituents. Effects of salts on soils, causing changes in soil structure, permeability, and aeration, indirectly affect plant growth. Specific limits of permissible salt concentrations for irrigation water cannot be stated because of the wide variations in salinity tolerance among different plants; however, field plots studies of crops grown on soils that are artificially adjusted to various salinity levels provide valuable information relating to salt tolerance.

In table 2 relative tolerances of crops to soil-water salt concentrations are listed for major crop divisions. The criterion applied was the relative yield of the crop on a saline soil as compared to its yield on a non-saline soil under similar growth conditions. Within each group, the crops are listed in order of increasing salt tolerance; electrical conductance values at the top and bottom of each column represent the range of salinity level at which a 50% decrease in yield may be expected. It should be noted that these concentrations refer to soil water, which may contain concentrations from five to ten times that of applied irrigation water. Soil type, climatic conditions, and irrigation practices may influence the reactions of a given crop to the salt constituents; therefore, the position of each crop in table 2 reflects its relative salt tolerance under customary irrigation condition.

TABLE 2: RELATIVE TOLERANCES OF CROPS TO SALTS CONCENTRATIONS (AFTER RICHARDS)

Crop Division	Low Salt Tolerance	Medium Salt Tolerance	High Salt Tolerance
Fruit crops	Lemon Strawberry Peach Almond Plum Prune Grapefruit Orange Apple Pear	Date Olive Fig	Date palm
Vegetable crops	3000 ΦS/cm Green bean Celery Radish 4000 ΦS/cm	4000 ΦS/cm Cucumber Squash Peas Onion Carrot Potato Sweet corn Lettuce Cauliflower Bell pepper Cabbage Broccoli Tomato 100,000 ΦS/cm	10,000 ΦS/cm Spinach Asparagus Kale Garden beet 12,000 ΦS/cm

SUITABILITY OF GROUND WATER RESOURCES OF NIGER STATE FOR IRRIGATION

(CHANCHAGA, BOSSO, PAIKORO, LAPAI AND AGAIE LGA'S)

BY

ELIAS OKEDE IKPE

(PGD/AGRIC. ENG/99/2000/91)

A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING, FEDERAL UNVIERSITY OF TECHNOLOGY, MINNA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE POSTGRADUATE DIPLOMA IN AGRICULTURAL ENIGINEERING (SOIL & WATER OPTION)

TABLE 5 GUIDELINES FOR INTERPRETATION OF WATER QUALITY OF IRRIGATION .

IRRIGATION PROBLEM		DEGREE OF PROBLEM	
	No Problem	Increasing Problem	Severe Problem
(1) Salinity – affect water availability to crop Ec (mm hos/cm).	<0.75	0.75-3.0	>3.0
(2) Permeability - affects rate of infiltration of the water into and through soil.	70.5	0.5-0.2	<0.2
(3) Specific 1 on Toxicity – affect sensitive crops			
a. Sodium (meq/l	<3	3-9	>9
b. Chloride (meq/l)	<4	4-10	>10
c. Boron (mg/l)	<0.75	0.75-2.0	>2.0
(4) Miscellaneous effects- affect sensitive crops			
(a) $NO_3 - N$	<5	5-50	>30
(b) HCO_3 (meg/c) (Overhead sprinkling)	<1.5	1.5-8.5	>8.5

Source: Westcott , 1970

2.8. GROUND WATER QUALITY AND AVAILABILITY FOR IRRIGATION.

Groundwater quality has to match the availability and the required quality that will satisfy crop water requirement. The quantity of water that can be available in a particular area will depend on the geologic formation. A geologic formation that will yield significant quantities of water has been defined as an aquifer. Many types of formation serve as aquifers (Black and Sehroeder, 1973).

Irrigation water samples are collected from each sampling borehole with detailed labeling to identify each sample.

Identification record were kept on water samples in the format below:

1. LGA - Local Government Area
2. ID - Identification number
3. Village - Village from which borehole is located were sample was collected.
4. Zone - Part of Niger State
5. Date of collection.
6. Date of analysis.

Table 6: The location of sampling points and dates analysed

L.G.A.	Village	ID	Date Collected	Date Analysed	Zone
Chanchaga					
1	FGC, Minna (Old site)	C1	11/1/2001	12/1/2001	South East
2	Minna Prison yard	C2	11/1/2001	12/1/2001	South East
3	Gidan Mangoro	C3	11/1/2001	12/1/2001	South East
4	Gidan Kora	C4	11/1/2001	12/1/2001	South East
5	FGC, Minna (New site)		11/1/2001	12/1/2001	South East
Paikoro					
1	Kafin Koro	P1	16/1/2001	17/1/2001	South East
2	Tunga Samari	P2	16/1/2001	17/1/2001	South East
3	Asakadara	P3	16/1/2001	17/1/2001	South East
4	Shapere	P4	16/1/2001	17/1/2001	South East
5	Baidna	P5	16/1/2001	17/1/2001	South East
Agaie					
1	Yekowuna	A1	18/12001	19/1/2001	South East
2	Yeko-Badeggi	A2	18/12001	19/1/2001	South East
3	Yeso-yesa	A3	18/12001	19/1/2001	South East
4	Yelwa str	A4	18/12001	19/1/2001	South East
5	Aguie Town	A5	18/12001	19/1/2001	South East
Lapai					
1	Jannarai I	L1	18/12001	19/1/2001	South East
2	Jannarai II	L2	18/12001	19/1/2001	South East
3	Dauda Maza	L3	18/12001	19/1/2001	South East
4	Jantabbo	L4	18/12001	19/1/2001	South East
5	Liman Badegi	L5	18/12001	19/1/2001	South East
Bosso					
1	Rafin yashi	B1	23/1/2001	23/1/2001	South East
2	Gami	B2	23/1/2001	23/1/2001	South East
3	Kuri	B3	23/1/2001	23/1/2001	South East
4	Rampala	B4	23/1/2001	23/1/2001	South East
5	Bako	B5	23/1/2001	23/1/2001	South East

The meter is turn on by pressing ON/OFF button.

- The meter first perform an LCD self diagnostic test by displaying a full set of figures.
- Then it will show a scrolling C100 message.
- P1 then appears on the secondary LCD to inform that the parameter measurement can be performed.
- The programme number is then selected, through the programme button.
- Then the measurement procedure for each parameter was then adopted.

Total chlorine: Adaptation of the EPA recommended DPD method 330.5 was used. The reaction between the chlorine and the DPD reagent causes a pink tint in the sample. The result are presented in mg/l

Colour of water: Adaptation of the colorimetric platinum cobalt method was used. The result is presented in PCU (Platinum Cobalt Unit).

Cupper: Adaptation of the EPA approved method. The reaction between cupper and the bicinchoninate reagent causes purple tint in the sample.

Fluoride: Adaptation of SPADS methods. The reaction between fluoride and the liquid reagent causes a red tint in the sample.

Calcium: Adaptation of the standard methods for the Examination of water and wastewater, 18th Edition, Calmagite method. The reaction between Ca and reagents causes a red tint in the sample.

Magnesium: Adaptation of the standard methods for the Examination of water and wastewater, 18th Edition, EDTA colorimetric method. The reaction between mg and reagents causes a violet tint in the sample.

Iron: Adaptation of the phenantroline EPA recommended method 315B for natural and treated waters. The reaction between iron and reagent causes an orange tint in the sample.

Manganese: Adaptation of the standard methods for the Examination of water and waste water, 18th Edition, Per sulfate method. The reaction between manganese and reagents causes a violet tint in the sample.

Nitrate: Adaptation of the cadmium reduction method. The reaction between nitrate – nitrogen and the reagent causes an amber tint in the Sample.

Dissolve oxygen: Adaptation of the standard methods for the Examination of water and wastewater 18th Edition, azide modified winkler method. The reaction between dissolve oxygen and the reagent causes a yellow tint in the sample.

pH : Adaptation of the phenol red method. The reaction with the reagent causes a red tint in the sample.

Information about the depth of borehole was sourced from RUWATSAN and Niger State Ministry of Water Resources and Rural Development Minna.

The static water level depth was subtracted from the depth of the boreholes to give us the dynamic water level. This water level gives an insight into the available water within each borehole and by implication water that is available for abstraction.

3.7. CHEMICAL EQUIVALENCE

Weight-per-volume units report concentrations of the common irons found in groundwater and for the spectrophotometer and conductivity meter used for these analysis, the weight – per – volume units is expressed in milligram per liter (mg/l). The total ironic concentration (total Dissolve solids) is also expressed in this manner.

Positively charged cations and negative anions combine and dissociate in definite weight rations. By expressing ion concentrations in equivalent weights, these ratios are readily determine because one equivalent weight of a cation will exactly combine with one equivalent weight of an anion. The combining weight of an ion is equal to its formular weight divided by its charge. When the concentration in milligram per litre is divided by the combining weight, an equivalent per litre (meq/l) results.

Table 5 Shows the conversion factors for chemical equivalent

Wilcox (1955), classified irrigation water quality as excellent, good, permissible, doubtful, or unsuitable depending on their percent sodium, the electrical conductance, and Boron concentrations. This classification is shown in table 4.

TABLE 4: QUALITY CLASSIFICATION OF WATER FOR IRRIGATION

			Boron, mg/1		
Water Class	Percent Sodium	Specific Conductance, ΦS/cm	Sensitive Crops	Semitolerant Crops	Tolerant Crops
Excellent	<20	<250	<0.33	<0.67	<1.00
Good	20-40	250-750	0.33-0.67	0.67-1.33	1.00-2.00
Permissible	40-60	750-2000	0.67-1.00	1.33-2.00	2.00-3.00
Doubtful	60-80	2000-3000	1.00-1.25	2.00-2.50	3.00-3.75
Unsuitable	>80	>3000	>1.25	>2.50	>3.75

Source: Wilcox, 1980

2.7. GUIDELINES FOR EVALUATION OF WATER QUALITY FOR IRRIGATION.

Guidelines to evaluate water quality for irrigation using the problem approach are given in table 5. They are limited to various aspects that are normally encountered and materially affect crop production. The focus is on the long-term dominating influence of water quality on the soil-water-plant system as it affects crop production and soil-water management. These guidelines are usable in general irrigated agriculture for evaluation of common constituents in surface, underground and drainage waters as well as sewage effluents.

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A key requirement is their ability to store water in the rock pores. The roles of various geologic formations as aquifers are briefly described in the following subsection.

2.8.1. SANDSTONE

Sandstone and conglomerate are cemented forms of sand and gravel. As such the cement has reduced their porosity and yield. The best sandstone aquifers yield water through their joints.

2.8.2. CLAY

Clay and coarser materials mixed with clay are generally porous, but their pores are so small that they may be regarded as relatively impermeable.

2.8.3. IGNEOUS AND METAMORPHIC ROCKS:

In solid form these rocks are relatively impermeable and hence serve as poor aquifers.

2.8.4. STORAGE COEFFICIENT

Water recharged to, or discharged from an aquifer represents a change in the storage volume within the aquifer. For unconfirmed aquifers this is simply expressed by the product of the volume of aquifer lying between the water table at the beginning and at the end of a period of time and the average specific yield of the formation. In confirned aquifers, however, assuming the aquifer remain's saturated, changes in pressure produce only small changes in storage volume. Thus, the hydrostatic pressure within an aquifer partially supports the weights of the overburden while the solid structure of the aquifer provides the remaining support.

A storage coefficient (or storativity) is defined as the volume of water that an aquifer releases from or takes into storage per unit charge in the component of head normal to that surface.

The storage coefficient for an unconfirmed aquifer corresponds to its specific yield. (Todd, 1980).

2.10. TESTING WELLS FOR YIELD

Following development of a new well, it should be tested to determine its yield and draw down. This information provides a basis for determining the water supply available from the well, for selecting the type of pumps and for estimating the cost to pumping. A test is accomplished by measuring the static water level, after which the well is pumped at a maximum rate until the water level in the well stabilizes. The depth of water is then noted. The difference in depths is the draw down, and the discharge-draw down ratio is an estimate of the specific capacity of the well. Any several measuring devices connected to the discharge pipe can estimate the discharge.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1 INTRODUCTORY NOTES

As is the practice with any irrigation water evaluation and quality control programme, a water sample analysis should be conducted to ascertain whether the existing irrigation water(s) would have any detrimental effects on the soil or crop or not. And whether or not it is sufficient to meet the water requirement of the crops to grow in the study area.

This chapter deals with the methods adopted in the course of the work; the procedure, precaution and problems encountered and how it was overcome are discussed fully. It looks into the sampling locations, laboratory analysis of the water samples, and estimation of boreholes yield.

3.2. SAMPLING LOCATIONS

The sampling locations covers five boreholes each, in each of the five local government areas under study. These are Chanchaga, Paiko, Lapai, Bosso and Agaie Local Government Areas. The boreholes are not equally spaced as they where constructed bearing in mind the settlements locations in the local government areas. However the five sampling areas that were chosen were spread around each of the local government areas, not necessary considering density of the boreholes in a particular place.

Forage crops	2000 ΦS/cm Burnet Ladino clover Red clover Alsike clover Meadow foxtail White Dutch clover 4000 ΦS/cm	4000 ΦS/cm Grass Oats (hay) Wheat (hay) Rye (hay) Alfalfa Sudan grass	12,000 ΦS/cm Barley (hay) Western wheat grass Bermuda grass Nattall alkali grass Salt grass Alkali sacaton 18,000 ΦS/cm
		Perennial rye grass Yellow sweet clover	
Field crops	4000 ΦS/cm Field beam	6000 ΦS/cm Castor bean Sunflower Flax Corn (field) Sorghum (grain) Rice Oat (grain) Wheat (grain) Rye (grain) 10,000 ΦS/cm	10,000 ΦS/cm Cotton Rape Sugar beet Barley (grain) 16,000 ΦS/cm

Note: Electrical conductance values represent salinity levels of the saturation extract at which a 50 percent decrease in yield may be expected as compared to yields on nonsaline soil under comparable growing conditions. The saturation extract is the solution extracted from a soil at its saturation percentage.

Sodium concentration is important in classifying an irrigation water because sodium reacts with soil to reduce its permeability. Soils containing a large proportion of sodium with carbonate as the predominant anion are termed

Information about the depth of borehole was sourced from RUWATSAN and Niger State Ministry of Water Resources and Rural Development Minna.

The static water level depth was subtracted from the depth of the boreholes to give us the dynamic water level. This water level gives an insight into the available water within each borehole and by implication water that is available for abstraction.

3.7. CHEMICAL EQUIVALENCE

Weight-per-volume units report concentrations of the common irons found in groundwater and for the spectrophotometer and conductivity meter used for these analysis, the weight – per – volume units is expressed in milligram per liter (mg/l). The total ironic concentration (total Dissolve solids) is also expressed in this manner.

Positively charged cations and negative anions combine and dissociate in definite weight rations. By expressing ion concentrations in equivalent weights, these ratios are readily determine because one equivalent weight of a cation will exactly combine with one equivalent weight of an anion. The combining weight of an ion is equal to its formular weight divided by its charge. When the concentration in milligram per litre is divided by the combining weight, an equivalent per litre (meq/l) results.

Table 5 Shows the conversion factors for chemical equivalent

Calcium: Adaptation of the standard methods for the Examination of water and wastewater, 18th Edition, Calmagite method. The reaction between Ca and reagents causes a red tint in the sample.

Magnesium: Adaptation of the standard methods for the Examination of water and wastewater, 18th Edition, EDTA colorimetric method. The reaction between mg and reagents causes a violet tint in the sample.

Iron: Adaptation of the phenantroline EPA recommended method 315B for natural and treated waters. The reaction between iron and reagent causes an orange tint in the sample.

Manganese: Adaptation of the standard methods for the Examination of water and waste water, 18th Edition, Per sulfate method. The reaction between manganese and reagents causes a violet tint in the sample.

Nitrate: Adaptation of the cadmium reduction method. The reaction between nitrate – nitrogen and the reagent causes an amber tint in the Sample.

Dissolve oxygen: Adaptation of the standard methods for the Examination of water and wastewater 18th Edition, azide modified winkler method. The reaction between dissolve oxygen and the reagent causes a yellow tint in the sample.

pH : Adaptation of the phenol red method. The reaction with the reagent causes a red tint in the sample.

Phosphate: Adaptation of the standard methods for the Examination of water and wastewater (18th Edition), amino acid method. The reaction between phosphate and reagents causes a blue tint in the sample.

Turbidity, temperature and conductivity: These were determined with conductivity meter that automatically displays the readings.

Hardness, sulphate, chloride, potassium and sodium.

These were determined using Lovibond Mini Kit, test tablet corresponding to the parameters are chooses and the readings taken to have the values in mg/l.

3.5. ESTIMATION OF BOREHOLE YIELD

Ideally the yield information could have been collected during the construction and development of these boreholes. This information became unavailable anywhere, probably the contractors are more interested striking water that will be sufficient before the boreholes were being commissioned. In view of the above, an estimation of borehole yield was therefore made, using the direct field method.

This method involves pumping water at a constant rate, since all the borehole are fitted with hand driven pumps, the pumping was done by one individual at the same rate for five minutes for all the boreholes. A stop watch was used to record the five minutes period, and two plastic bucket of 20litres capacity were used to collect the discharge water, the number of buckets collected are recorded. From this the rate of discharge of water was estimated.

Ideally a yield test is accomplished by measuring the static water level, after which the well is pumped at a maximum rate until the water level in the well stabilizes. The depth to water is then noted. Th discharge is then determined by any of the several measuring devices connected to the discharge pipe.

This method adopted will therefore give us a good estimate of the yields of these boreholes and each can be a basis for knowing the availability of water within these aquifers.

3.6. DEPTH OF STATIC WATER LEVEL

An estimate of the depth of static water level is very important in determining the safe yield of a well and also in quantifying the amount of water the borehole can deliver over a range of time.

For the boreholes under study, the static water levels was evaluated by first removing the hand pump using set of 16mm spanners with a clearance from the village heads or users of the borehole. There after a steel tape was immersed inside the borehole until it reaches the bottomless pit of the borehole. That is the area where gravel packs are constructed. The depth of water from below the tape to last water level in the tape is thereafter recorded.

3.3 PRE-TREATMENT OF WATER SAMPLES

On arrival from each field trip, water samples already collected in clearly marked plastic containers were kept in an air-conditioned room to maintain room temperature, which did not exceed 25^{0}C. The idea of doing this was purposely to reduce microbial activities, as much as possible to the bearest minimum. Immediately sampling exercise was over and pretreatment accomplished water samples were conveyed to the laboratory for series of physico-chemical analysis.

3.4 LABORATORY ANALYSIS OF WATER SAMPLES

As is the practice with any irrigation water sampling and quality control programme, a water sample analysis should be conducted to ascertain whether the existing irrigation water would have any detrimental effect on the soil or crop or not.

As soon as sampling was accomplished, water samples were forwarded to the laboratory for chemical analysis. The most important parameters that are capable of affecting the quality of irrigation water were carefully noted, borne in mind and formed part of bulk of parameters being analysed for in each of the water samples. They include:-

pH value (activity/alkalinity determination at temperature of 25^{0}C

Total dissolve solids (TDS)

Proportions of sodium (Na+) irons to other cations such as Ca2+ (an calcium) and Mg2+ (magnesium)

Hardness, Bicarbonate (HCO_3) concentration.

Analysis also included both macro and micro nutrient elements which included:-

Nitrate NO_3 - Nitrogen

Phosphate PO_4 - Phosphorus

Poltasium - K^+

Calcium - Ca^{2+}

Magnesium - Mg^{2+}

In addition to these parameters, samples were subjected to further analysis to determine salt containing compounds or elements such as:

Sulphate SO_4

Chloride Cl^-

Bicarbonate HCO_3

Water samples Wet similarly tested for some micro elements levels bearing in mind that their toxicity might hinder the performance of crops if found to be in large qualities in irrigation water and these substances included.

Iron Fe^{2+}

Manganese Mn^{2+}

Boron

Analysis for hardness and electrical conductivity were also performed on all the water samples.

3.4.1 METHODS OF ANALYSIS

The water analysis were based on FAO and WHO guidelines and procedure as specified by Water and Waste Water Analysis Association 8th Edition.

Electrical conductivity meter was used to determine the following physical parameters on site.

Temperature 0C

Total dissolve soils TDS (mg/l)

Electrical conductivity in µhos/cm

A multi parameter spectrophotometer was used to determine the concentration in water of all the other parameters.

3.4.2 WATER MEASUREMENT PROCEDURE

Power connection

The 12V DC adaptor was plugged into the DC socket. And the adaptor was plugged into the outlet.

Measurement procedure.

The meter is turn on by pressing ON/OFF button.

- The meter first perform an LCD self diagnostic test by displaying a full set of figures.
- Then it will show a scrolling C100 message.
- P1 then appears on the secondary LCD to inform that the parameter measurement can be performed.
- The programme number is then selected, through the programme button.
- Then the measurement procedure for each parameter was then adopted.

Total chlorine: Adaptation of the EPA recommended DPD method 330.5 was used. The reaction between the chlorine and the DPD reagent causes a pink tint in the sample. The result are presented in mg/l

Colour of water: Adaptation of the colorimetric platinum cobalt method was used. The result is presented in PCU (Platinum Cobalt Unit).

Cupper: Adaptation of the EPA approved method. The reaction between cupper and the bicinchoninate reagent causes purple tint in the sample.

Fluoride: Adaptation of SPADS methods. The reaction between fluoride and the liquid reagent causes a red tint in the sample.

Table 5: CONVERSION FACTORS FOR CHEMICAL EQUIVALENCE (Concentration in mg/l Times the Conversion Factor Yields Concentration in mea/l).

Chemical Constituents	Conversion Factor
Bicarbonate (NCO_3-)	0.01639
Calcium (Ca^{2+})	0.04990
Carbonate (CO_3^{2-})	0.03333
Chloride (Cl-)	0.02821
Magnesium (mg^{2+})	0.08226
Manganese (mn^{2+})	0.03640
Nitrate NO_{3-}	0.01613
Phosphate PO4-	0.03159
Potassium K+	0.02557
Sodium Na+	0.04350
Sulphate SO_4^{2-}	0.02082

Source Hem, (1970)

3.8. COMPUTATION OF PERCENTAGE SODIUM AND SAR

Sodium concentration is important in classifying irrigation water because sodium reacts with soil to reduce its permeability. Sodium content is usually expressed in terms of percent sodium (also known as sodium percentage and soluble – sodium percentage, this was evaluated using equation 1.

$$\% Na = \frac{(Na + K)\,100}{Ca + Mg + Na + K} \quad (1)$$

Where all concentration are expressed in milli equivalent per litre.

The salinity laboratory of U.S Department of Agriculture recommends the Sodium Adsorption Ratio (SAR) because of its direct relation to the adsorption of sodium by soil. This is defined by equation 2.

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}} \quad (2)$$

where the concentrations of the constituent are expressed inmilliquivalents per litre.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSIONS

4.1. INTRODUCTION

In this chapter results of water analysis carried out on all water samples are presented, the depth and yield of all the boreholes are also presented and discussed, the implication of these findings are analysed and discussed.

4.2. INTERPRETATION DISCUSSED

The results of laboratory water analysis carried out are presented in table 4.2(a), 4.2(b),

4.2.1. pH VALUE

The pH value represents the concentration of hydrogen ion (H+) in water. In other word it is the logarithm of the reciprocal of the hydrogen ion concentration. Thus a value pH below 7 indicates acidic concentration, while pH above indicates alkaline character of water.

However, from the results of water analysis the pH values of 12 sample shows acidic levels, this is very worrisome, as this will make the soils after some period of time become acidic, lime fertilizers will be required to reduce the acidic content after prolong irrigation in the area.

4.2.2. NITRATE (NO_3^-)

As widely known, nitrate is the chemical form in which nitrogen is absorbed by plants in the soil. This compound (NO3-) was found to be relatively low in most samples ranging from 0.04 mg/l to 0.8mg/l, but in P1, P2, P3 P5 L1, and L3 were found to be very high from 3mg/l – 77mg/l. While this compound may be acceptable as nitrogen supplying compound in irrigation water with regard to crop production, it is usually regarded as a deleterious substance in construction and municipal water supplies.

4.2.3. PHOSPHATE (PO_4-)

As in the case of nitrate above, phosphate is the chemical form of phosphorus when in solution i.e. the ionic form of phosphorus in solution. Phosphorus as widely known is one of the three primary nutrient elements required in large quantities by plants for growth. Analysis of phosphate shows that phosphorus content is generally very low in all the water samples ranging from 0.3 – 1.42mg/l. There is therefore the need to supplement phosphorus by applying fertilizers to the crops in the field during irrigation season in order to raise its level in the soil solution.

4.2.4. POTASSIUM (K^+)

This substance is one of the basic nutrients elements plants require for better morphological performance in the field. From the results of analysis potassium contents in all but two of the water samples were found to be high and desirable, they range between 0.2 – 55mg/l. This is quite appreciable for irrigation purposes but not desirable for municipal water supply. In C3 the potassium level was zero and A5 were the level was 16.

4.2.5. SODIUM (Na^+)

Sodium is one of the undesirable elements or substances in irrigation. This is because of its ability to destroy the structure of the soil and its tendency to build-up salts in the root.

TABLE 4.2.(b) **RESULTS OF LABORATORY WATER ANALYSIS**

Sample	L4	L5	A1	B2	A3	A4	A5	B1	B2	B3	B4	B5
PH	6.4	6.5	5.6	8.5	8.5	5.6	5.6	6.8	6.7	7.1	6.9	6.9
Temp 0C	30.2	31.0	30.0	30.0	26.6	25.8	30.0	31	30.7	31.7	32	31.6
Colour NTU	30	200	30	400	300	350	600	0	0	0	55	10
Turbidity N/V	5.0	35	20	25	2.0	1.0	20	0	0	0	12	5
Cond. Ec m/ws/cm	0.0	1	16	0.35	15	0.62	0.13	33.2	22.9	22	22	21.2
Calcium (mg/l)	21.2	13.2	24.8	42.4	5.0	39.6	9.6	30	15.6	11.6	9.6	17.6
Magnesium (mg/l)	24	43.7	7.3	19.4	8.0	11.2	4.13	11.6	9.96	14.3	12.15	7.05
Sodium (mg/l)	33.6	0	3.2	3.8	4.0	3.4	2.4	0	0.0	0	0	0
Potassium (mg/l)	2.8	3.6	5.0	0.3	2.4	3.0	1.6	3.0	2.4	1.9	2	2.4
Sulphate (mg/l)	0	10	5.0	0.3	2.4	3.0	16.1	0	3	0	4	0
Chloride (mg/l)	0	0.5	0	0	0	0	0	20	5	4	3.5	10.0
Bicarbonate (mg/l)	0	0.6	0	0	0	0	0	61	118	112	115	90
Carbonate (mg/l)	0	0.2	0	0	0	0	0	0	0	0	0	0
Nitrate (mg/l)	0.04	0.02	0.8	0.04	0.04	17.6	0.35	2.64	0.44	3.5	2.2	4.4
Phosphate (mg/l)	0.3	0.0	0.4	1.2	0.25	0.3	0.42	0.4	0.6	0.4	0.65	0.3
Iron (mg/l)	0	0	0	0	0.04	0.03	0.02	0.02	0.1	0.2	0.9	0.3
Chlorine (mg/l)	0.08	0.25	0.01	0.18	1.20	1.15	1.0	1.0	1.25	1.25	1.2	1.2
Manganese (mg/l)	0.3	0	0.2	1.0	0.1	0.3	0	0.06	0.7	1.0	0.6	0.8
Copper (mg/l)	0.1	0	0.05	0.02	1.0	0.2	0.08	0.08	0.12	0	0.06	0.02
Boron (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0
Hardness (mg/l)	22	28	30	25	18	16	20	25	30	32	40	28
TDS (mg/l)	150	213	0	0	0	0	0	-	-	-	-	177

zone of the soil.

Most water sample collected from the field and analysed have their sodium (Na+) contents lying between 0-4mg/l, these fall within low sodium, water class (S1) and so can be used safely for irrigation, on almost all soils, with little or no danger of the development of harmful levels of sodium salt accumulation and sodium hazard. However L4 level of sodium makes it unsuitable for use.

4.2.6. CALCIUM AND MAGNESIUM ($Ca^{2+,}$ Mg^{2+})

Precipitation of calcium carbonate (CaCO3) and magnesium carbonate (MgCO3) in lateral line and sprinkler nozzles will reduce sprinkler system flow rate over tine. But whether these precipitates will form depends largely upon the concentrations of carbonate and bicarbonate in the irrigation water supply.

Similarly, formation of white precipitates also depends on the pH level of the water supply. For instance, the pH level exceed 8.0, calcium and magnesium carbonates will precipitates. This usually occurs when concentrations of calcium and magnesium are greater than 50mg/l or 50ppm. Where it is found to exceed 50ppm acid treatment might be needed but professional advice must be sought before embarking on acid treatment for pH control of the water.

Ca and mg concentrations of the majority of water samples are found to fall within permissible limit. Generally, from agricultural point of view, calcium and magnesium are some of the basic and secondary nutrient elements required for tissue formation and production of healthy fruit in the tree crops. And when found to be grossly inadequate, they must be supplemented through the use of Ca and Mg containing fertilizer materials.

4.2.7. CHLORIDE (Cl-)

In terms of chloride contents, majority of the water samples are satisfactory in quality. Because the highest desirable level of chloride in any water is 200mg/l, all water samples examined were found to contain quantities of chloride much below this level, and so chloride toxicity could not be a problem to the crops and soils in the field.

4.2.8. SULPHATE (SO_4-)

The desirable limit of sulphate in any irrigation water is 200mg/l. But from the results water analysis for this parameter, the maximum concentration of 1.1mg/l was found in A5, which is indicative of good quality for irrigation purposes for the were fact that their sulphate contents lie within desirable level for sulphate in any irrigation water.

4.2.9. CARBONATE (CO_3) AND BICARBONATE (HCO_3)

Carbonate generally is not encountered in all the water samples from the results of water analysis carried out. This condition therefore suggest that there is little tendency for calcium and magnesium to form chemical precipitate except with the little quantities of free bicarbonate (HCO_3) which was recorded in most of the samples.

However, it may be worthwhile to note that high concentration of HCO_3 ions may result in precipitation of calcium and magnesium bicarbonate from the soil solutions, thereby increasing the relative proportion of Na+ (Sodium) ions and causing sodium hazards. Consequently sodium hazards have unfavourable effects on the structural properties of the soil as well as on the infiltration and permeability rates of the soil during irrigation periods. Basically, chemical precipitation can only occur when pH of water solution exceeds 8.0.

4.2.10. IRON (Fe^{2+})

The chemical effect of iron is that it can become a problem at concentration as low as 0.1ppm as it has ability to cause iron rust in some sprinkler or overhead irrigation systems. Although pressure, temperature and pH are the most important variables that determine iron solubility and precipitation, concentrations of 0.5ppm or 0.5mg/l Fe can be considered severe and must be corrected. This can be achieved by applying appropriate corrective measures. But then the highest desirable level of Fe is 0.1mg/l and the maximum permissible level is 1.0mg/l.

Iron was not detected in some of the water samples, but they range between 0.01mg/l to 1.15mg/l were they are detected. The level of

1.15mg/l in C2 is worrisome, however this can be corrected to make it suitable for irrigation purpose.

4.2.11. MANGANESE (Mn^{2+})

The severity of manganese is not noticed in most samples from the results of water analysis. The range of manganese is between 0 – 1.3mg/l, these values are within the permissible limits. For now there appears not to be any serious chemical effect of (Mn2+) based on the analytical results, but there may be the need to correct it if found to be on the increase in the future.

4.2.12. BORON

Boron is essential to normal plant growth, but the amount needed is very small. The occurrence of Boron in toxic concentration in certain irrigation waters makes it necessary to consider Boron concentrations in water samples. Boron was found to be absent in most of the samples, where they were detected C1, C2, C3, C4, C5, they were within the permissible limits, ranging between 0.0 – 0.15mg/l.

4.2.13. TOTAL HARDNESS

The highest desirable level of total hardness, which in most cases comprises of CaCo3 or MgCo3 and HCO3, is 400mg/l while the maximum permissible level of total hardness in any water is 500mg/l. However, from water analysis result it was discovered that total hardness values for most water samples fall for below even the highest desirable level of 400mg/l

CaCo3. This then implies that they are of acceptable qualities with respect to hardness. They are also observed to be very low in turbidity, ranging from 0 – 35NTU.

4.2.13 TOTAL DISSOLVE SOLIDS (TDS)

The total quantity of dissolved solids (TDS) present in water may indicate the suitability of water for irrigation purposes. For example, when present in large quantities they purport to increase osmotic pressure of the soil solution hereby causing high soil moisture stress in the root zone which inturn may hinder the plant growth and affect crop yield. But the injurious effects of salts on plant growth depends primarily on the concentration of salt left in the soil.

The generally accepted limits to asses the suitability of water based on TDS and pH indicate that water containing TDS up to 400mgle or less at pH value below 8.0 are generally quite suitable for irrigation purposes.

From the result of the analysis carried out all the water sample have their TDs less than 250mgle which makes them quite suitable for irrigation's.

4.2.14 ELECTRICAL CONDUCTIVITY (Ecx10^6 mhos/cm)

The salt concentration in any water is easily measured by determination of Electrical conductivity (fc). It measures the ability of any water to conduct electricity and is expressed in mhos/cm. Ec and salt concentrations are proportional to each other. Electrical conductivity, International values of water quality ratings are given as

Class one : 0 – 100mhos/cm

1. Water sample can be used for irrigation with most crops as the samples have Electrical conductivity with low salinity hazard.
2. Little likelihood of soil salinity developing.
3. Leaching due to irrigation can handle presence of salts (except soils with extremely low permeability).

Class two: 200 – 400mhos/cm

1. Water sample can be used with moderate amount of leading.
2. Salinity control required

Class three: 400 – 800mhos/cm

1. Water samples cannot be used on soils with restricted drainage.
2. Management of salinity control required

Class four; 800 – 1600 mhos/cm

1. Water samples for irrigation under ordinary conditions
2. Not suitable for irrigation under ordinary conditions
3. Soils must be permeable, very good drainage available
4. Irrigation water must be applied in excess to provide considerable leaching
5. Only tolerant crops yield satisfactorily.

From the results of the water samples analyzed, it can be seen that all values given fall in the class one rating.

4.2.15 CHLORINE CONCENTRATION (cl2)

High values of chlorine are unsuitable in irrigation waters. The following standard are used in classifying chlorine content in irrigation waters.

Class one: 0 – 3 meq/l

Low chlorine hazard, irrigation water suitable for most crops.

Class two: 3.0 – 6.0 meq/l

Slightly hazardous on plants, Irrigation water can be used with care.

Class three: 6.0 – 10.0 meq/l

Median hazard values

Class four: 10 -20meq/l

Values in this range can have adverse effects on plants use of samples not recommended for irrigation.

It can be seen that all samples analyzed fall within the class one rating, and are therefore suitable for irrigation with little harm caused by their chlorine content.

4.3 CHEMICAL ANALYSIS AND CLASSIFICATION OF THE ANALYSED WATERS.

The result of the classification of water from five boreholes from each local government are presented in tables 4.3.1, 4.3.2, 4.3.3, 4.3.4 and 4.3.5

Table 4.3.1 Result of Chemical Analysis and Classification of ground water in Chanchaga Local Govt Area.

Sample	Ec mhos/cm	B Mg/c	Ca Mg/c	Mg (*)	Na (meg/l)	Co3 +HCo3 (mg/l)	Cl ¯ (mg/l)	SAR	%Na	water class
C1	61.5	0.12	2.69	0.799	0	33.5	6.0	0.0	1.59	Excellent
C2	59.2	0.16	2.60	1.71	0	32.5	5.0	0.0	1.34	Excellent
C3	21.2	0.13	0.99	0.46	0.08	0.01	96.0	0.0	5.36	Good
C4	27.2	0.14	1.38	0.76	0	140	3.0	0.0	2.56	Excellent
C5	56.9	0.10	2.79	0.74	0	150	0	0.00	1.28	Excellent

This implies that groundwater in Chanchaga Local Government is suitable for irrigation purpose, if lime fertilizers can be used to reduce the acidic nature of the waters.

4.3.2 Classification and analysis of ground water in Paikoro Local Government area are presented in these sections, table 4.3.1 shows this in detail.

This implies that groundwater in A4 is to be used with caution, while A3 and A5 are unsuitable for irrigation purpose except where there are excellent salt tolerant crops and highly drained soils. A1 and A2 are however suitable for irrigation.

4.3.5 Classification and Analysis of government in Bosso Local government area are presented in this section table 4.3.5 shows these results in detail.

Table 4.3.5 Results of chemical Analysis and classification of groundwater in Bosso Local Government Area.

Sample	Ec mhos/cm	B Mg/c	Ca Mg/c	Mg (me a/l)	Na	Co_3+H CO_3 (Mg/c)	Cl -	SAR	%Na	Water class
B1	33.9	0	1.49	0.95	0			0	3.03	Excellent
B2	22.9	0.06	0.78	0.82	0			0	3.7	Excellent
B3	22.0	0.02	0.58	1.17	0			0	2.69	Excellent
B4	22.0	0.02	0.47	0.99	0			0	3.34	Excellent
B5	21.2	0.12	0.87	0.57	0			0	4.04	Good

This implies that the water in Bosso Local government area are suitable for irrigation purpose.

4.4 ANALYSIS OF BOREHOLE YIELD AND STATIC WATER LEVEL.

The result obtained for each of the boreholes examined for yield and static water level are presented in table 4.4

Table 4.4 Result of Borehole depth, yield and static water level

Borehole No	Borehole depth (m)	Static water level (m)	Yield (L/S)
C1	35	8	0.9
C2	45	6	0.6
C3	28	16	1.4
C4	32	12	0.7
C5	30	5	0.8
P1	31	6	0.5
P2	25	8	0.7
P3	32	9	0.6
P4	40	6	0.8
P5	28	4	0.4
A1	30	9	1.2
A2	25	5	0.8
A3	18	10	1.2
A4	16	4	0.9
A5	20	8	1.0
L1	25	10	0.8
L2	30	6	0.9
L3	40	4	0.4
L4	22	3	0.6
L5	28	8	0.8
B1	25	15	1.6
B2	30	5	0.6
B3	32	10	0.9
B4	40	6	0.9
B5	28	4	0.8

Yield in most of the borehole is indeed very appreciable bearing in mind the time of observation which is already onset of the dry season, except in some cases like L3, P5 and P1 where the yield levels are 0.4, 0.4 and 0.5 l/s respectively. The minimum depth of borehole that will make it safe from being contaminated is 30meters, however some of these boreholes were less than this value in height, that height have been responsible for their contamination with time.

The static water levels makes the quantity of water available for irrigation satisfactory, more over if one consider that some of these aquifers might be recharged by supplies from other areas that are kilometers away. The water availability can also be looked at from the angle that if these are sighted in inland valley areas or Fadama areas, there is likelihood that the yield levels will improve appreciably. Making these underground waters satisfactory in terms of water quantity and availability.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

Water samples were collected from 5 boreholes each of the five local government areas in south eastern part of Niger State, Chanchaga Paikoro, Lapai Agaie and Bosso Local Government. Results of the Analysis shows that the water are suitable for irrigation purposes, except in Agaie local government area, where the percentage sodium make the water unsuitable, except when there is high level of drainage soil and crops that are tolerable to high sodium salt level. The total dissolve solids fall below 400mg/l in all sample which shows that water can be used in most soils, the sodium adsorption ration is within the class one rating for all the samples considered which implies, salt non-tolerant crops can be grown without much problems. The level of nitrate and phosphate are generally low, which is good for drinking purposes but because of their nutrient status additional input of N and P based fertilizers are required for optimum growth. The level of acidity in the water is generally worrisome as if the waters are used continuously without the addition of lime fertilizers acidic content of the soil will continue to build up. The yield of the boreholes as estimated gives up so much potential for development with the exception of Paikoro local government were yield level were poor. On the overall ground waters in the south eastern part of Niger State Chanchaga, Paikoro Lapai Agaie and Bosso Local Government are suitable for irrigation farming with some minor modification for liming, the yield level in most of the well make them available to satisfy the water requirement of large hectarage of lands particularly in the inland valley and Fadama areas.

With the increasing other sectorial usage of surface water, couple with the unfavourable climatic conditions recently noticed in these areas, government has to as a matter of urgency tap the potential ground water resources that abound in these areas to supplement rainfed agriculture and therefore make food available in our homes.

5.2 RECOMMENDATIONS

From chemical point of view it has been observed that most of these ground waters are of satisfactory quality for irrigation purposes. This is based on the results of analysis conducted on their samples except in few cases where iron and percentage sodium and some other undesirable chemical substances were encountered. But then this does not prevent their ample use in the field. It is however recommended as follows

The pH of most of the sample are generally not satisfactory, addition of lime fertilizers should be made on timely basis wherever they are to be used for irrigation.

At any rate it is recommended that waters where iron Fe^{2+} are observed to be relatively severe should be carefully monitored and if possible be given the appropriate chemical treatment that will prevent the build up of iron, if not drastically reduced.

Where percentage sodium has made the water unsuitable for use the soil must be properly drained and subsoiled to make the water usable and prevent the build up of sodium.

Borehole water in Lapai township areas should be flushed out and treated with chlorine treatment with chlorine will prevent further build up of iron and other undesirable elements. The chlorination is also required to prevent the build-up of algae growth and some undesirable odour, which are predominant in the presence of all these elements.

Work should continue on other parts of the state Southwest, Northeast and North West to cover all the local government areas of the state. These will serve as a data bank for those that are responsible for the exploitation of these untapped groundwater resources for irrigation purposes or other sectorial users.

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