

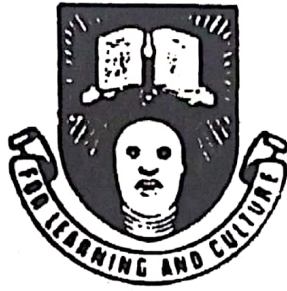


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Department of Geography
Faculty of Social Sciences Obafemi Awolowo University, Ile-Ife, Nigeria.

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GIS Application to Water Resources Monitoring and Management in Kwara State, Nigeria

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Abstract

The need for proper decision making on problems of water resources necessitated this study. The aim is to create a system that allows comprehensive database to respond flexibly and effectively to water provision. The database management developed was tagged Water Resources Information System (WRIS) basically to answer questions about water resources problems. To achieve this, the study developed a framework for capturing spatial data relating to water within Kwara State. The bulk of the data used for this work were secondary and were sourced for from satellite imagery SPOT5 XS, 2005 Dec. and existing data from Federal Ministry of Water Resource. To create the WRIS, all the related spatial features were vectorised using ArcGIS software. Information about all these features were stored in the attribute table as the databank. All the databanks were linked together to form database that can handle GIS operation. Moreover, series of operations were performed to carry out GIS findings on area of settlements having water accessibility and those areas that are not. Many other tests were carried out on the database built, by subjecting the system to different searches and queries and the results are displayed for proper decision making on water issues. The study recommends the factors that can speed up the implementation of this type of system within the state and other area of the country.

Introduction

Water is a vital resource for human survival and economic development, proofs from scientists show that water plays a key component in food digestion which aids nutrient absorption for survival of any living creature, both plant and animal. As populations and economies grow; water demand increases while the availability of the resource remains constant. Shortages engender water use conflicts, both in terms of quantity and quality.

The increase in water demand and limited nature of resources for adequate supply of water calls for monitoring, management, and maintenance of the available ones. The source for availability of water in the societies is not limited to a single unit, and this can be broadly divided into two. The first is the natural water source i.e. availability of water without human effort e.g. river, stream, spring,

rainfall and natural dam. The second category is the artificial water sources i.e. provision of water with little or full effort of man e.g. artificial dam for pipe born water, well water, and borehole.

From US Urban Water Resources Management (www.gdrc.org/uem/water), it is affirmed that "there is considerable variation across countries in laws and institutions related to water planning and project implementation ability is not uniform. Therefore the Eighth General Increase in the Financial Resources of the World Bank calls for guidelines that are flexible enough to be tailored to

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different situations involving institutions, legal instruments, and the technical means to achieve an integrated approach to planning that considers all sources and uses of water in a given basin". In addition to this, effort must also be directed toward supporting water resources planning, policy making and management through development and application of GIS. as a strategy that considers several issues associated with the core problem of developing multiple sources and managing multiple uses (municipal, industrial, irrigation etc) of water so that, over time, more efficient water resource supply systems and use patterns emerge, while maintaining or improving ambient water quality. Moreover, the achievement of any effort(s) to improve water resources in term or monitoring, management and maintenance can be achieved by the application of Geographic Information System (GIS) either at global or local level. This dissertation was based on application of this tool (GIS) to access water resources for monitoring, management and maintenance in Kwara State.

The evidence of water insufficiency in Kwara State is real, most especially during the dry season because of the inadequacy of water resource provision for the citizen. Also, the available water resource is faced with poor monitoring and management due to improper record keeping that serves as databank for them. Boreholes are dug within the cities and villages without provision by the facilitators or agencies in charge to maintain them. Pipe borne water are installed with no provision for adequate management, settlements are left with no care for water availability and accessibility. "A research problem is an intellectual stimulus calling for a response in the form of scientific enquiry" (Abler, et.al.1972).

This study is targeted to solve problems about monitoring for management and maintenance of water resources, with particular emphasis on boreholes, public wells, streams and rivers in Kwara State. The identified problems can be summarised thus:

- Insufficient availability of Kwara State Digital map to water resource management organization.
- Location and identification problem of public water resources.

- Lack of current information about the condition of water resources.

- Lack of adequate spatial database in Kwara State.

- Problems associated with rural water resources and accessibility of rural dweller to water.

The study was thus set to develop a Water Resource Information Sysytem (WRIS) for effective monitoring and management of water distribution in Kwara State. In order to achieve this, the following objectives were pursued. (i) Obtaining and digitizing Kwara State Map. (ii) Identifying the water resources and their location in Kwara State. (iii) Gathering of geometric data on the available water resources. Creation of Database for Water Resources Information System by linking ii & iii above together to make possible easy maintenance and management. (iv) Identifying major settlements in the rural area and measuring their water resource accessibility. (v) Conducting spatial searches that are useful for effective monitoring and management of Water Resources.

Study Area

The study area, Kwara State, Nigeria, is geographically located between latitude 8° 00" and 9° 00" North and longitudes 2° 45" and 6° 40" West (Figure 1). It lies in North-West of Nigeria but it falls into North-Central geopolitical zone. The state has sparse hills and valleys in parts of Baruten, Kaiama and Moro local government areas. It has river Niger as its boundary both in its North and East sides, while it shares boundaries with Oyo, Osun and Ekiti State in the South. It shares the boundary with Kogi State in the East, and international boundary with Republic of Benin in the west. Kwara state is located in the middle belt of Nigeria, at the beginning part of Guinea savanna. It has both wet and dry seasons with each season lasting for about six months. The wet season starts about the end of March and ends around late October while the dry season starts early October and ends at early March. Kwara State has sixteen (16) Local Government Areas (Figure2) with total population of *Two million, three hundred and seventy-one thousand and eighty-nine* people

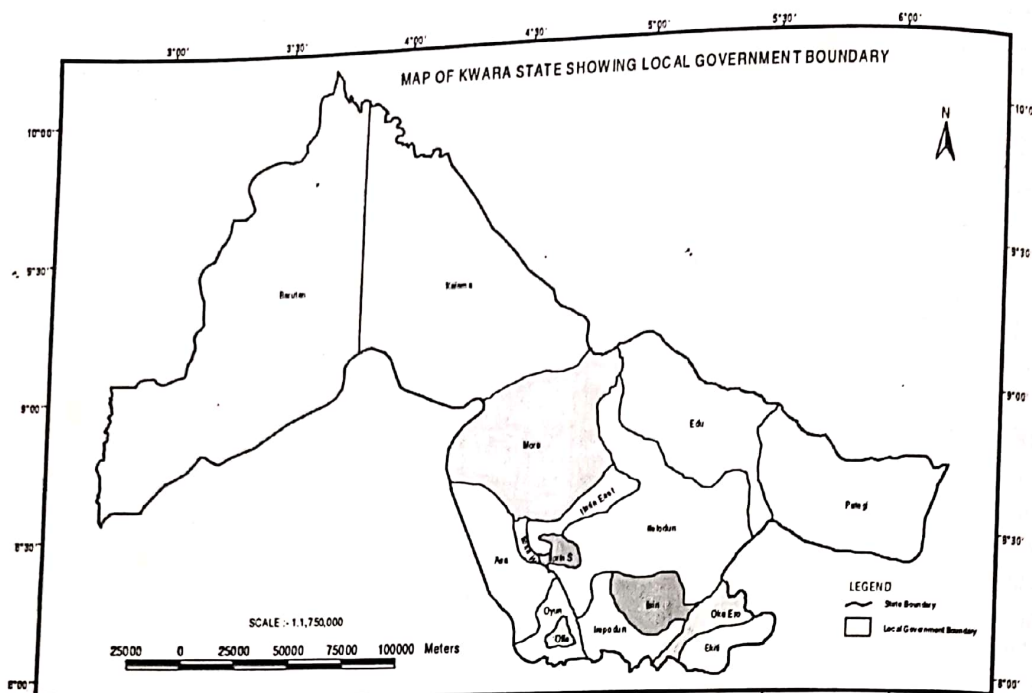


Fig 1: Boundary Map of Kwara State (Source: World Health Mapping, 2000).

(2,371,089) (NPC, 2006), out of which the number of Female is 1,149,908 and Male is 1,220,581.

Barbour et al (1982), described the drainage system of Nigeria in three ways, *Short Swift-flowing Coaster Rivers, The Inland Drainage System of the Chad Basin and The Long Plateau Rivers*. Kwara State drainage system falls on the first class (Short Swift-flowing Coaster River) of these three. The spread of river and stream within the state can be said to be evenly distributed and this implies that the state has good drainage system. The largest land use in Kwara state is Agricultural Land Use (farming and grazing), both mechanized farming and subsistence farming are found in every part of the state. Other recognized land uses (for example; residential, commercial, industrial) are joining together to form the built-up area either as city, towns, settlements and villages. Major industries are found in the city of Ilorin, the capital city of the state while local industries are also available in other towns and villages scattered over the state.

Methodology

Data required and data sources

The quality of data integrated into the database is the foundation of good and reliable results. The required data for the design and creation

of water resources information system (WRIS) are as follows:

- Administrative map of Kwara State
- Drainage map of Kwara State
- Road map of Kwara State
- Satellite Imagery of Kwara State
- Global Positioning Coordinates of Public Water Resources (Geometric Data)
- Field Information on Physical Developments (Attribute Data)

These were obtained from secondary sources and this was complimented with primary data. While water resources locations were obtained through the use of Global Positioning System (GPS), features on the satellite image were identified through *ground truthing*. Table 1 shows the list of the primary data that was used in this study and their sources. The secondary data include available information about spatial features, for example, hard copy maps (Administrative Map, Road Map, Drainage Map and Satellite Image).

Data Pre-processing

The acquired maps were scanned as windows bitmaps, georeferenced and digitized. The map vectorization was done in such a way that different layers (themes) were created. These include boundary of the study area; COGO Conversion of Cartesian Coordinates to vector point

Table 1: Data Set and Data Sources

Data Set	Data Source
Primary Data	
Coordinates of public Boreholes and Wells in the State.	Global Positioning System (GPS)
Attribute data on some physical developments of the state. e.g Village Name, Village Status, Road Name, etc.	Various Existing Cartographic data.
Secondary Data	
Administrative Map of Kwara State	World Health Mapping 2000
Road Map of Kwara State	Kwara State Ministry of Land and Survey
Drainage Map of Kwara State	World Health Mapping 2000
Satellite Imagery of Kwara State	SPOT 5 form SPOT Corporation processed by Infotera Consult.

Source: Authors Fieldwork

data; and the creation of different layers for individual physical developments within the study area.

Data Processing /Analysis

In this section, the method of operation, the process of data integration, and all the GIS operations given in the previous section were followed simultaneously to design a Water Resources Information System (WRIS) to provide intelligent result, which can be used for decision making in solving water related problems. Firstly,

data collection strategy was set and the process commenced immediately after the certainty of the project. Followed by this, is data structure and quality control, whereby the accuracy of data was determined. The spatial features needed for the GIS operations and analysis was captured using ArcGIS vector tool at the scale of 1/15,000m based on the nature and their characteristics. The digitizing was carried out using edge and vertices mode on feature class selection system (layer by layer). After this, the cartographic finishing and map properties were

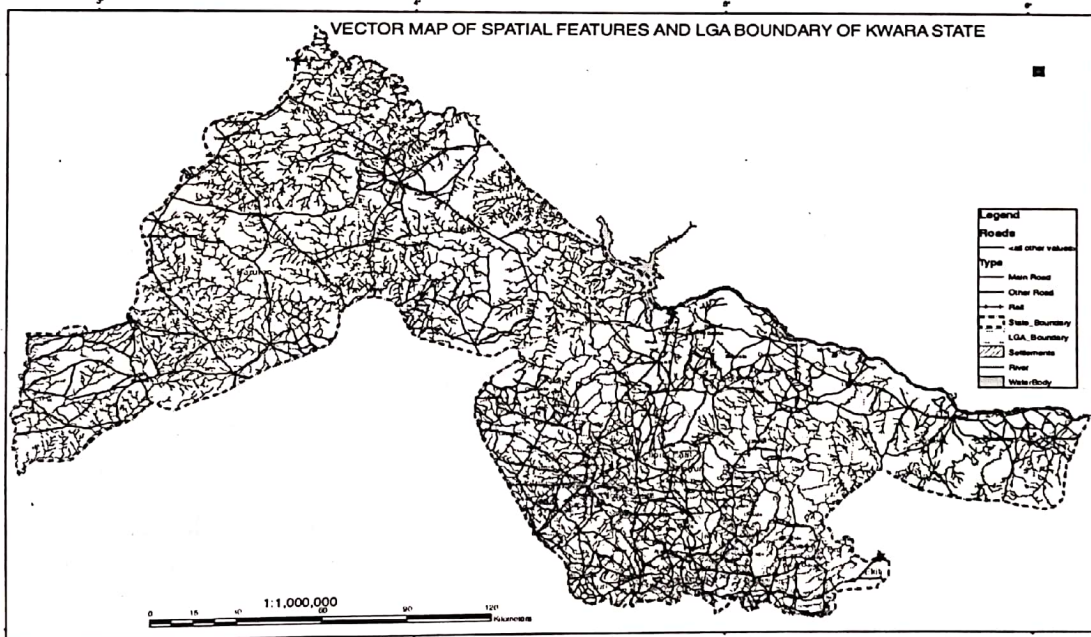


Figure 2: Vector Map of Spatial Features and LGA Boundary in Kwara State •Source: SPOT 5 (2006)

Result and Analysis

Geometric Data on the Available Water Resources

The coordinate file of Global Positioning System (GPS) location of Boreholes and Public Wells were extracted from the data collected from the Ministry of Water Resources of Nigeria in 2007, using WGS 84 Geographic Coordinate System format with Decimal Degree mode. The properties (attributes) of all these features were collected from the ministry. This text data was collected in soft copy (Microsoft Word file), this was converted to tabular data with the help of data exchange machine into excel worksheet. From the worksheet table a re-conversion operation was carried out to change to dBase format (dBase IV .dbf), which is compatible to adopted GIS software engine (ArcGIS 9.2).

Another relevant data to water resources is the settlements where water is needed. The distribution of settlements in Kwara State is not uniform, their representation in the satellite image shows that there are concentration in some parts than others. The reason for this may be due to land use pattern, landform or climatic factors. It is obvious that man settles close to where their day to day activities are found and the more the concentration of human activities in an area, the higher the increase in number and size of settlements. The broad definition given to settlements in Kwara State is urban and rural and the measure for the definition was based on the size of development.

Moreover, because the coordinate system chosen for the projection of the map area was "Geographic; WGS 1984", there was the need for the introduction of customized program that will convert centroid value of "degree" into "kilometer" for area computation of settlements. To assign the status of settlement (Urban or Rural) a query operation was performed using "Shape_Area" as selection factor. For a settlement with area size less than 1kilometer square, it was considered rural ($\text{size} < 1\text{Km}^2$) and settlement with area size greater than one kilometer ($\text{size} > 1\text{Km}^2$) square was considered to be urban, then the database was updated accordingly. The total number of settlements captured is One thousand one hundred and seventy-two all together, the smallest area out of all these is 0.821m^2 while the maximum area is approximately 327.712km^2 and that is Ilorin Township (Fig 3).

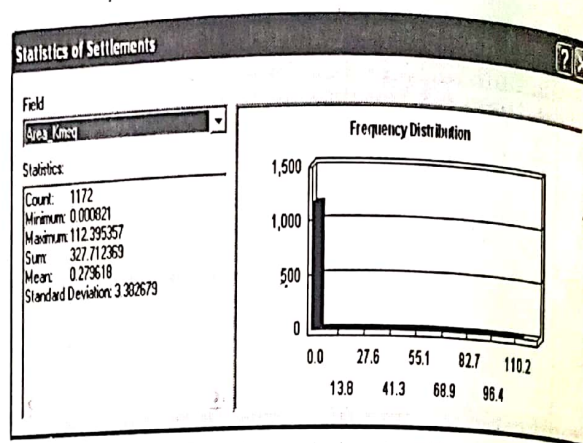


Fig 3: Statistics of Settlement's Area in Kilometer Square.

Water Resources Location in Kwara State

The concentration of settlements in the south-eastern part of the state is extremely higher than that of any other part, which means the population of the state dwellers is concentrated in the eastern part, most especially, south-eastern part (Fig 4)

After the text data conversion from word file to worksheet and from worksheet file to Dbase file, the result table was used as an interface to create point feature that represented the location of boreholes within Kwara State. The table was structured following ArcGIS default design and the arrangement was set by putting the identification number (ID) first and this served as unique characteristics for strategic counting. This was followed by the feature class representation called "Shape" that specified the nature of object as point.

The condition for computer mapping of points is that each must have latitude and longitude column (Olayinka 2001). Based on this, "GPS_Longitude" that holds geographical coordinate of X direction; and "GPS_Latitude" that holds the geographical coordinate of Y direction were created. Others are "Scheme Code" (a predefined registration number by the Ministry), "Scheme Name" (the name given to the borehole or public well and the settlement or area of location), "Ward" (political ward number), "LGANAME" (Name of local Government Area), "Name_Prov" (the name of organization, body or individual that facilitated the provision). There were several field created for information upload and the Relational Table was design to accept all types of data by setting the domain to desired option

The first Four (4) can be classified as default fields or topology on which the relational

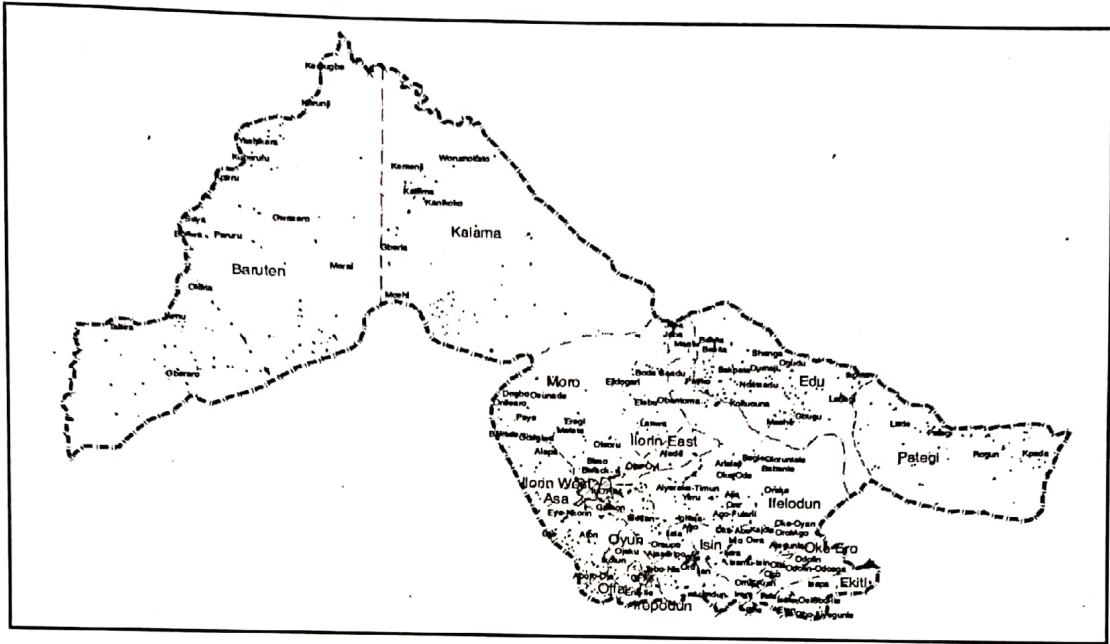


Figure 4: Settlement Distribution Pattern in Kwara State (Source: SPOT 5, 2006)

table was built. These fields have a key relation to other fields and graphic features in the design view. In actual sense, it is the factor on which the "Link" was established. After the strategic structure of the table, an operation was performed to carry out data conversion from text to graphic. During the operation, ArcGIS was for the basis of conversion and the coordinate system for the source data, in this case, the two fields longitude and latitude were

used by specifying the column of "GPS_Longitude" in the X direction and "GPS_Latitude" in the Y direction of the dialogue box. The result of conversion operation is given in Fig 5.

Surface water (stream and rivers), which is the major source of water for rural dwellers within Kwara State must be captured to examine the network and their distribution pattern. The graphic data captured for surface water were directly from

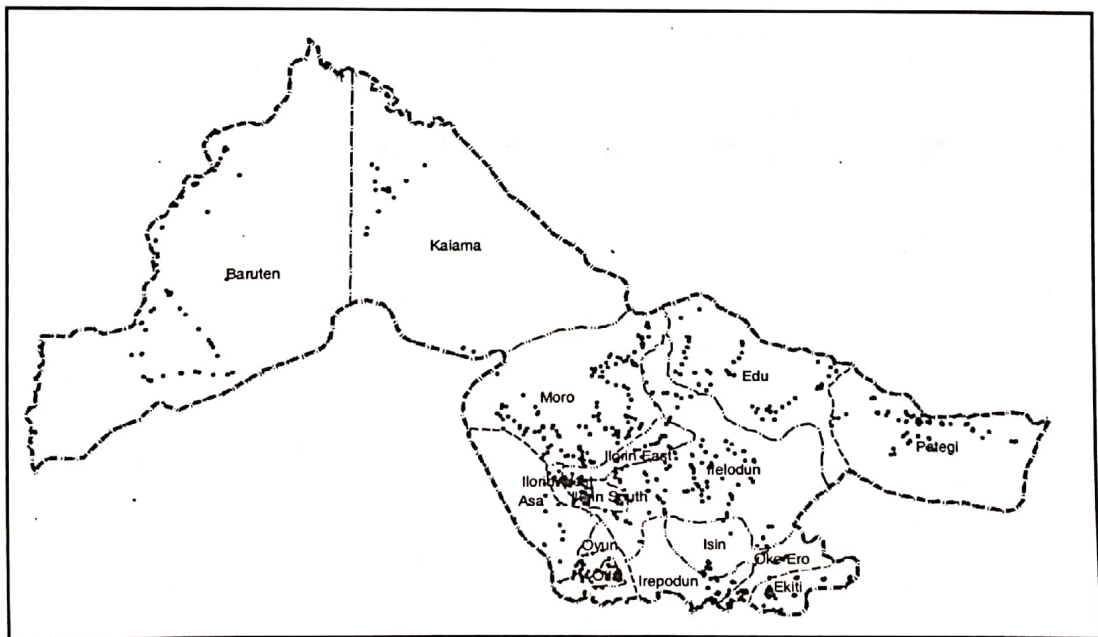


Figure 5: Data conversion Result (Borehole Locations)

SPOT 5 imagery by tracing the streams and small rivers in the mode of line format. The edges and vertices that make up a river were placed at the observed centre of the water course.

The other category of surface water was captured as water body and this was introduced to represent big river and other lakes or dams that cannot be put as linear feature. In doing this, rivers in this class were digitized as polygon and their banks were traced in a close circuit. Other challenging formation on surface water is the manifestation of island and sandy surfaces on some big rivers like river Niger and others. This was taken care of using donut polygon operation in ArcGIS module. Figure 6 shows the nature, network and pattern of surface water in Kwara State. On this issue of surface water, the area of little challenge was the area prone to

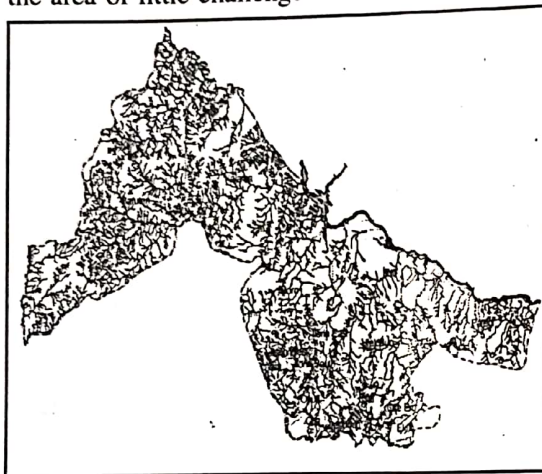


Figure 6 Surface Water (Rivers and Streams) in Kwara State
Source: SPOT 5 (2006)

flood or swampy area. Any small river or stream that flows into it may have its course vanished or split into small and indefinite units. Therefore, the rivers or streams that were found in this situation were terminated at their visible spot or point during digitizing e.g. stream entering River Niger flood plain or irrigation area.

Database Creation for WRIS

Creating a new personal geodatabase involved creating a mdb file on disk. A geodatabase can be structured fully-relational, object-relational, network, or hierarchical geographic database that provides services for managing geographic data. These services include validation rules, relationships, and topological associations. A geodatabase contains feature datasets as well as feature classes that can be stored inside a feature dataset or maintained independently. A personal geodatabase is stored inside a relational database management system (RDBMS) and this was performed using ArcCatalog. Figure 9 shows the representation of the geodatabase, feature dataset and feature classes used for this work.

The graphic data in vector data format was linked to the default data set by their attribute table. This link operation was carried out in two ways; for the data with pre-design third party table (Excel table or Dbase table), the link was carried out by introducing common field in the two tables. For those data without pre-design database, the default ArcGIS tables were used. Table 3 shows the typical Database Relational Table for water point.

Table 2. Typical Relational Database Table for Water Point.

Attributes of Water Facility													
DB ID	Shape	SCHEME_CODE	GPS_LONGIT	GPS_LATITU	TOWNSHIP	WARD	LGNAME	NAME OF PR	TYPE OF PR	CAPACITY_L	CAPACITY_U	TREATMENT	CONNECTION
337	Point	KVSHAI14V01	8.36301	4.82771	KIBAJA HA	14	FELOOLUN	KWADP	STATE	12	8	1	
338	Point	KVSHAI14V01	8.37928	4.88183	KIBAJA I	14	FELOOLUN	CELTEL	DONOR	120	75	1	
339	Point	KVSHAI14V01	8.53888	4.81428	ATIRANTA HA	15	FELOOLUN	DFRRI	DONOR	12	8	1	
340	Point	KVSHAI14V01	8.5008	4.8242	GORRI HAN	15	FELOOLUN	DFRRI	STATE	12	8	1	
341	Point	KVSHAI14V01	8.4847	4.82781	BALOOIN O	15	FELOOLUN	KVSRWISA	STATE	12	18	1	
342	Point	KVSHAI14V01	8.48488	4.82891	BALOOIN O	15	FELOOLUN	DFRRI	STATE	12	33	1	
343	Point	KVSHAI14V01	8.46548	4.82863	BALOOIN O	15	FELOOLUN	UNCEP	STATE	12	50	1	
344	Point	KVSHAI14V01	8.53225	4.81398	ELUREJU M	15	FELOOLUN	LOWER NO	FOR	120	48	1	
345	Point	KVSHAI14V01	8.53001	4.5853	ORORI OJA	16	FELOOLUN	DFRRI	DONOR	12	8	1	
346	Point	KVSHAI14V01	8.50748	4.85478	TONGOLO	16	FELOOLUN	DFRRI	DONOR	12	8	1	
347	Point	KVSHAI14V01	8.52513	4.82084	OKOLO MO	16	FELOOLUN	DFRRI	DONOR	120	33	1	
348	Point	KVSHAI14V01	8.46445	4.82288	MOSUNDO H	16	FELOOLUN	DFRRI	STATE	12	8	1	
349	Point	KVSHAI14V01	8.44498	4.85877	AGO HAND	16	FELOOLUN	DAN MUSA	DONOR	12	33	1	
350	Point	KVSHAI14V01	8.43472	4.88383	AGO HAND	16	FELOOLUN	DFRRI	STATE	12	8	1	
351	Point	KVSHAI14V01	8.48541	4.88318	YARU HAND	16	FELOOLUN	DFRRI	FOR	12	41	1	
352	Point	KVSHAI14V01	8.38087	4.71027	IOFIN HA	17	FELOOLUN	DFRRI	DONOR	12	8	1	
353	Point	KVSHAI14V01	8.37706	4.70988	IOFIN HA	17	FELOOLUN	DFRRI	DONOR	12	8	1	
354	Point	KVSHAI14V01	8.37641	4.71072	IOFIN HA	17	FELOOLUN	DFRRI	DONOR	12	8	1	
355	Point	KVSHAI14V01	8.36498	4.74824	ALAKURU I	17	FELOOLUN	KWALCP	STATE	12	8	1	
356	Point	KVSHAI14V01	8.06216	4.7802	ALAKURU I	17	FELOOLUN	COMMUNITY	LOA	180	0	1	
357	Point	KVSHAI14V01	8.35223	4.75026	ALAKURU I	17	FELOOLUN	GOVT	LOA	25	0	1	
358	Point	KVSHAI14V01	8.36512	4.71193	IOFIN HA	17	FELOOLUN	KWALCP	STATE	12	260	0	1
359	Point	KVSHAI14V01	8.41778	4.80837	GAMMO MOI	18	FELOOLUN	LOWER NO	FOR	120	79	1	
360	Point	KVSHAI14V01	8.41188	4.80841	GAMMO HAN	18	FELOOLUN	UNCEP	DONOR	12	50	1	
361	Point	KVSHAI14V01	8.4118	4.8182	GAMMO HAN	18	FELOOLUN	KWALCP	STATE	12	25	1	
362	Point	KVSHAI14V01	8.41985	4.80807	GBADEDE H	18	FELOOLUN	UNCEP	DONOR	12	8	1	
363	Point	KVSHAI14V01	8.41421	4.81808	GBADEDE H	18	FELOOLUN	KWALCP	STATE	12	33	1	
364	Point	KVSHAI14V01	8.41304	4.81812	KABBA KAJ	18	FELOOLUN	DFRRI	STATE	12	33	1	
365	Point	KVSHAI14V01	8.3823	4.8785	KABBA DM	18	FELOOLUN	DFRRI	FOR	12	41	1	
366	Point	KVSHAI14V01	8.58834	4.73746	KAA ELEPO	01	LORIN EA	DFRRI	FOR	12	33	1	
367	Point	KVSHAI14V01	8.51851	4.78224	ABEJU HAN	01	LORIN EA	GOVT	LOA	12	8	1	
368	Point	KVSHAI14V01	8.51856	4.78891	OLOMOYOVO	01	LORIN EA	KWALCP	STATE	12	33	1	
369	Point	KVSHAI14V01	8.54828	4.73586	BUJO OYO	01	LORIN EA	DFRRI	STATE	12	41	1	
370	Point	KVSHAI14V01	8.58118	4.80484	KV STATE	01	LORIN EA	GOVT	STATE	12	374	1	
371	Point	KVSHAI14V01	8.58118	4.80484	ABADEDE H	01	LORIN EA	GOVT	STATE	12	374	1	
372	Point	KVSHAI14V01	8.58027	4.82958	OBADAMU H	01	LORIN EA	UNCEP	DONOR	12	25	1	
373	Point	KVSHAI14V01	8.58055	4.82955	OBADAMU H	01	LORIN EA	DFRRI	STATE	12	25	1	
374	Point	KVSHAI14V01	8.49891	4.5504	ITA ABA	02	LORIN EA	GOVT	STATE	12	8	1	

Settlements' Accessibility to Water Resources

Criteria: GIS design requires some predefined conditions or specifications that serve as guide for its analysis and operation. These predefined conditions are basically subject to the principles of profession or discipline on which the design is applied. In WRIS, there is the need for predefined condition or specifications that come from life realities which will guide the search judgment and justification of the operator for provision of adequate result or information, which decision maker will use to solve spatial problem. The criteria for this design and manipulation were based on the following (Giancarlo B. et al 2009):

- (a) The definition for villages and towns was based on the built-up area extent of the settlements; any settlement having the size above one kilometer square ($<1\text{Km}^2$) is considered to be town while any settlement having size less than one kilometer square ($>1\text{Km}^2$) is taken to be village. In this case, Ilorin metropolis was considered a city.
- (b) All developments within five hundred metres (500m) away from public boreholes and wells are considered to be 'Served Area' in the towns and city centre while in the villages; one kilometer (1Km) from river or stream is taken to be maximum distance for serviced settlement.
- (c) The parameter for distributing new boreholes and wells will be based on spatial search and result of the GIS operation engine not on political basis. The areas or settlement with proximity disadvantage will be first considered during decision making for sharing new boreholes.
- (d) The degree of water availability within the state will be based on the total area of water proximity advantage and the area of the state in general.

Analysis: Under this analysis, evaluation was made on the degree of water proximity to the citizen of Kwara State by calculating nearness to surface water and water point location. There is no consideration for the condition of the water resources; the interest of the researcher is to check whether there are available water sources within the reach of a particular settlement, town or area.

Moreover, to carry out this analysis, there is need for proximity operation on two spatial

features (Borehole and River). Proximity tools can be divided into two categories depending on the type of input the tool accepts: feature or raster. The feature-based tools vary in the types of output they produce. For example, the buffer tool outputs polygon features, which can then be used as input to overlay tools. To perform buffer operation on any feature, ArcGIS has a customized engine, which was designed to work directly on personal geodatabase with an interface through which the file that contain the feature dataset can be specified, input value for buffering distance with the unit of measurements (Kilometer, meter, Decimal Degrees etc.) and the automatic output file will be generated. The buffering operation dialogue box and various parameters for this analysis are shown in Figure 7.

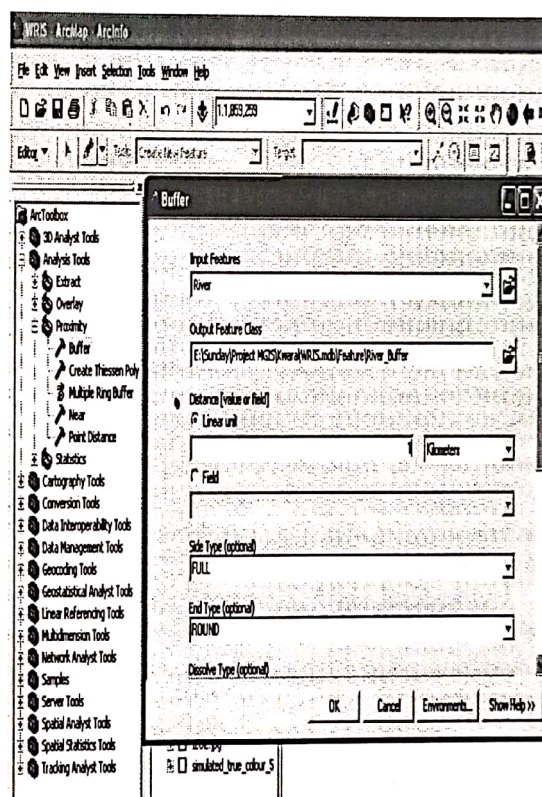


Figure 7. Arc GIS Interface for Buffer Operation.

The buffering operation was based on the specified distance in the stated criteria that is, 500m for boreholes and 1km for rivers. The result of this operation (Figures 8 and 9) was used for further operation to get accurate result. Fig. 8 is the result of buffer operation carried out on water points by using 500m as buffering value. Also, Figure 9 shows the result of buffer operation carried out on the rivers

Settlements' Accessibility to Water Resources

Criteria: GIS design requires some predefined conditions or specifications that serve as guide for its analysis and operation. These predefined conditions are basically subject to the principles of profession or discipline on which the design is applied. In WRIS, there is the need for predefined condition or specifications that come from life realities which will guide the search judgment and justification of the operator for provision of adequate result or information, which decision maker will use to solve spatial problem. The criteria for this design and manipulation were based on the following (Giancarlo B. et al 2009):

- (a) The definition for villages and towns was based on the built-up area extent of the settlements; any settlement having the size above one kilometer square ($<1\text{Km}^2$) is considered to be town while any settlement having size less than one kilometer square ($>1\text{Km}^2$) is taken to be village. In this case, Ilorin metropolis was considered a city.
- (b) All developments within five hundred metres (500m) away from public boreholes and wells are considered to be 'Serviced Area' in the towns and city centre while in the villages; one kilometer (1Km) from river or stream is taken to be maximum distance for serviced settlement.
- (c) The parameter for distributing new boreholes and wells will be based on spatial search and result of the GIS operation engine not on political basis. The areas or settlement with proximity disadvantage will be first considered during decision making for sharing new boreholes.
- (d) The degree of water availability within the state will be based on the total area of water proximity advantage and the area of the state in general.

Analysis: Under this analysis, evaluation was made on the degree of water proximity to the citizen of Kwara State by calculating nearness to surface water and water point location. There is no consideration for the condition of the water resources; the interest of the researcher is to check whether there are available water sources within the reach of a particular settlement, town or area.

Moreover, to carry out this analysis, there is need for proximity operation on two spatial

features (Borehole and River). Proximity tools can be divided into two categories depending on the type of input the tool accepts: feature or raster. The feature-based tools vary in the types of output they produce. For example, the buffer tool outputs polygon features, which can then be used as input to overlay tools. To perform buffer operation on any feature, ArcGIS has a customized engine, which was designed to work directly on personal geodatabase with an interface through which the file that contain the feature dataset can be specified, input value for buffering distance with the unit of measurements (Kilometer, meter, Decimal Degrees etc.) and the automatic output file will be generated. The buffering operation dialogue box and various parameters for this analysis are shown in Figure 7.

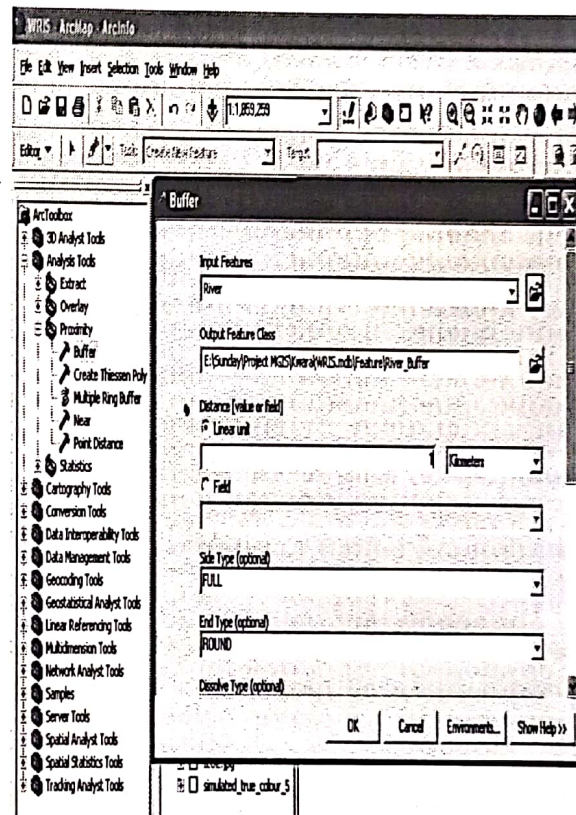


Figure 7. Arc GIS Interface for Buffer Operation.

The buffering operation was based on the specified distance in the stated criteria that is, 500m for boreholes and 1km for rivers. The result of this operation (Figures 8 and 9) was used for further operation to get accurate result. Fig. 8 is the result of buffer operation carried out on water points by using 500m as buffering value. Also, Figure 9 shows the result of buffer operation carried out on the rivers

by using 1km as buffering value. The system design is flexible, incase the proximity value is different from what was specified in the criteria. The Analyst will just change the value in dialogue box while repeating the operation in the spatial analyst command.

After the successful buffering operation, the next one was overlay operation. This placed two spatial features on each other based on spatial reference to give their spatial locational relationship. The overlay operation was performed with buffer of river and buffer of water point on the settlements and result of overlay is shown in Fig. 10.

The need for the above operations is the intelligent steps toward achieving water availability and accessibility analysis. The buffer result of water points (public boreholes and wells) at first stage came out as units of several objects, also the buffer result of rivers and stream. To compute the percentage rate of accessibility and availability, there are two ways to it. First, is by combining the units of object {(buffer of each river and stream (1)), {buffer of each water point (2)} and the units of feature (the result of 1&2) together and total result will be related to the settlement in the whole state. Secondly, is by relating each result (1) and (2) separately on the settlements and the percentage relationship will be generated differently. The first option was used in this analysis and this manipulation will give a single polygon object representing the total coverage area of water availability or area that has water accessibility (served area) Fig 9.

Moreover, the result of coverage area of water availability was overlaid on settlements' layer and the intersection region was discarded to have non serviced area as polygon theme (Fig 13). After this, the mathematical results of non serviced area and settlements area were computed as follow:

$$\begin{aligned} \text{Total Area of settlements} &= 327.712 \text{ km}^2 \\ \text{Total Area of settlement not serviced} &= 67.495 \text{ km}^2 \\ \text{Total Area of serviced settlement} &= 260.217 \text{ km}^2 \\ \text{Percentage of serviced Area} &= \frac{\text{total area of settlement} - \text{total area not served}}{\text{total area of settlement}} * 100 \\ &= \frac{327.712 - 67.495}{327.712} * 100 \\ &= \frac{260.217}{327.712} * 100 \\ &= 79.4 \% \end{aligned}$$

This implies tha 80% of the settlements have access to water without consideration for seasonal effect. 20% of the whole developed area (both urban and rural) has low degree of water

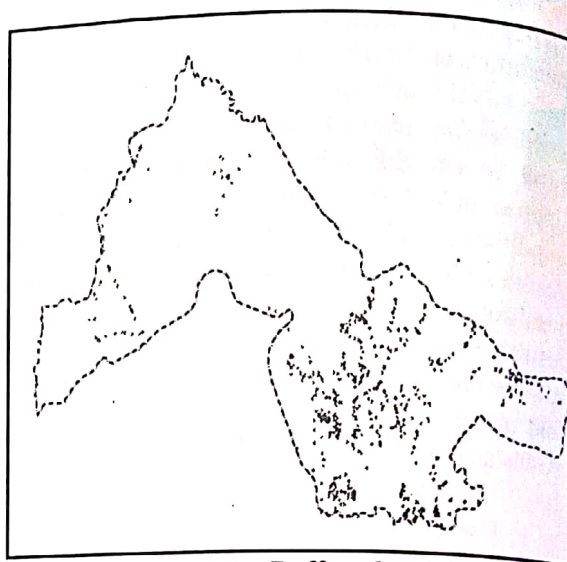


Figure 8 500 Meter Buffer of Water Point

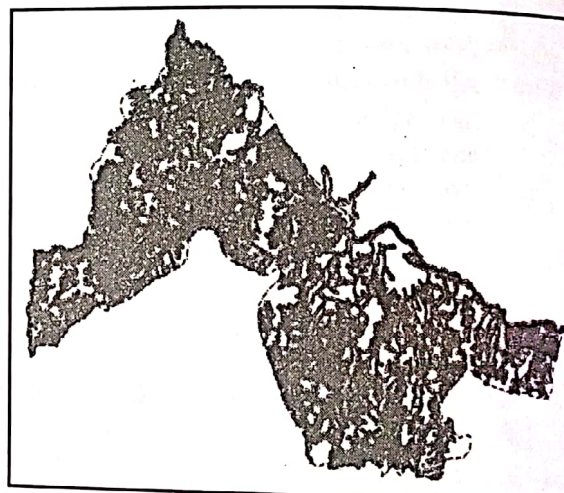


Figure 9 One (1) Kilometer buffer of River and

access or availability, this 20% is the sum of unit parts of settlements scattered all over the area of the whole state, which were shown in red in Fig 14. This type of analysis can be reduced down to individual settlement and the percentage degree of availability and accessibility can be computed separately. The usefulness of the result is to organize the distribution pattern and strategy of locating new boreholes within the state to avoid irregularities.

Furthermore, there are many other computations that are possible with the designed database depending on the requirement and manipulation strategy of the user. For example, this type can be performed on the whole state area (not only the land use or settlement area).

Spatial Searches

To test the geospatial database created for this work, it was subjected to some spatial search. Fig. 13 shows water facilities presently under bad conditions. Most of the facilities in this group are either not working. This query was issued to show the capability of this database to answer question pertaining to the condition of the facilities under consideration. This could help the ministry in charge to mark out those facilities for necessary rehabilitation, repair and or reproduce.

Furthermore, Fig. 13 shows water facilities owned by the state government and which are in bad conditions. This is a further query that combined more than one condition and the possibility of it lies on the strength of database. The two results (Fig 13 and 14) are different ways of showing search operations. The first, (Fig 13) was shown with the query expression while the latter (Fig 14) was a result without the query expression. Other aspect of search operation that GIS operation can handle is unique identifier, a situation whereby an object is pointed to and the information about it will be given. This was tested on the water facility, one unit of water point was identified through this tool and the information about it was shown in Fig 15.

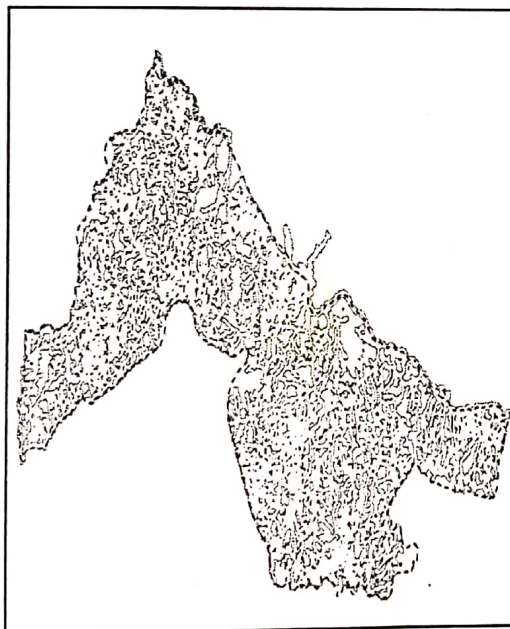


Figure 10 Combination of Buffer from all Water Source

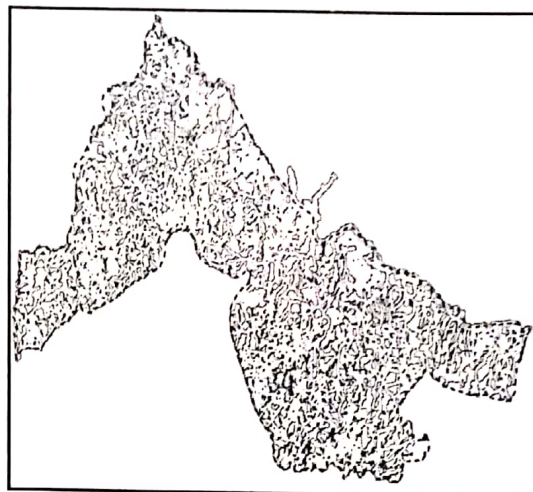


Figure 11. Overlay of Combined Buffer on Settle

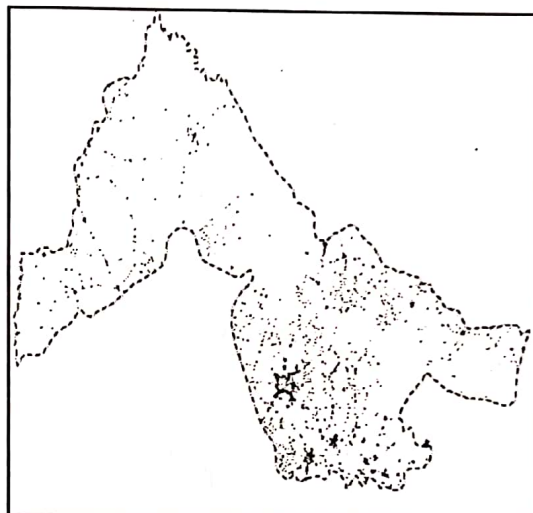


Figure 12. Area with Low Degree of Water Availability

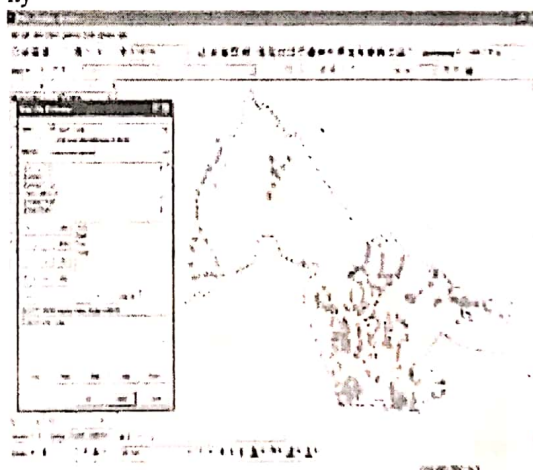


Figure. 13: Spatial Search Result Showing Water

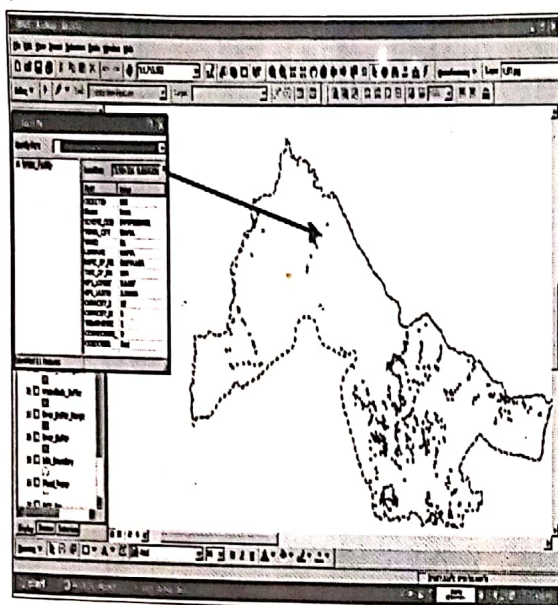


Figure 15: Unique Identifier Result

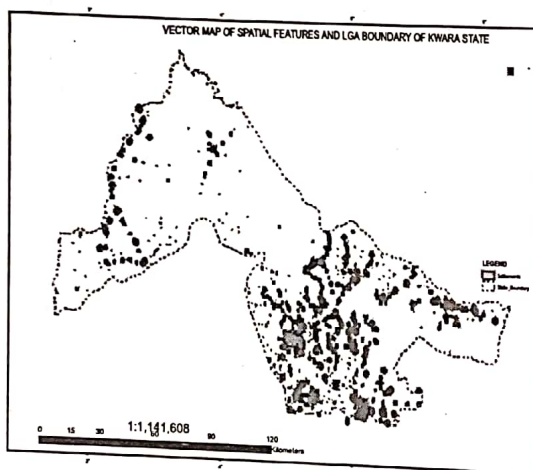


Figure 14: State Owned Water Facilities in Bad Conditions

Conclusions and Recommendations

The most important part of GIS work is the database, the database of this project was created on three (3) distinct features of Water Point (public boreholes and wells), Surface Water (Stream and River) and Settlements (Towns and Villages). The three (3) databank were relationally link together to perform series of operations. All these operations were analyzed and the result were given for spatial decision making on water resources in Kwara State.

The study revealed that it is possible to evaluate the degree of water accessibility by using GIS techniques. By this, any developed area of the state (rural or urban) that has no enough water for human consumption can be easily determined and a solution will be provided for them. Also, the system makes it simple to share and install water resources within the state without waste of resources or misappropriation. Moreover, the system serves as information base, through which different searches can be.

The capacity of this type of water information system makes the solution about spatial problem on water simple. Therefore, it is recommended that:-

- That the government of Kwara State should adapt the use of modern technology (GIS) to handle the production, distribution and management of water resources for effective water availability to the citizen.

- That there should be further analysis by people in charge of water provision on this type of system and more result be generated on degree of water accessibility even up to individual settlement's level.

- The searches and questions about water information system should be performed through WRIS.

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