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RESEARCH ARTICLE

DEVELOPMENT OF WATER DISTRIBUTION NETWORK USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS IN HAWATA AREA – EASTERN SUDAN

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Abstract

The study explored Hawata and Wad Alegali Water Distribution Network in the Hawata area which is located at the state of Gedaref in eastern Sudan. The area is suffering from water shortage of during summer in particular, due to the increasing population and the weak and of insufficient water supplies. In addition to the absence of effective water network that could cover all towns and neighboring villages. The study carried out through analyzing of the water network and its main components, in terms of identifying the villages and towns in the area compared to the population numbers and the per capita water consumption using Geographic Information Systems (GIS) and Remote Sensing (RS). The main objective of the study was to highlight the vital role of GIS in terms of developing and managing the water projects and facilities using spatial analysis for collecting the results in the designated area, as well as focusing on groundwater characteristics as a main source of drinking water. Landsat8 satellite images were used to study the geographical features and phenomena in the area and their impacts upon water supply network as well as background information for the wells/boreholes water and reservoirs. Villages' information in the study area was used to recognize the villages with most dense population and less water consumption, and those villages of less population and more water consumption. Moreover, villages with more livestock population were identified as well. The study also collected samples and identified the water quality for the study area. The study investigations revealed that the main water network is insufficient to avail water for all population of the project area. Furthermore, GIS was used to improve the accuracy of network asset data to avoid any impact on service delivery. Accordingly, new water network extensions have been proposed in order to solve this problem and distribute water to the nearby villages and using GIS to improve management within the Hawata and Wad Alegali Water Corporation.

Key Words: *: Water, Network, Remote Sensing, GIS*

1.1: INTRODUCTION

Enormous population in the world are suffering from inadequate water supply system. Approximately 80% to 85% of the cost of a total water supply system is contributed toward water transmission and the water distribution network (The UN and Water, 1992). GIS used to be an excellent tool for managing water and wastewater utility information and for improving the operation of these utilities (Clark, 2004).

The Sudanese government officially applied to the government of the Federal Republic of Germany during the period 1981-1988 for technical and financial assistance to solve the pressing drinking water shortage in Hawata area. The United Nations High Commissioner for Refugees contributes by US Dollars of 500,000 and the remaining investment cost was covered by the German KFW Bank on behalf of the government of Federal Republic of Germany (MUPGS, 1990).

In this research GIS has been used as a tool for studying drinking water services network in Hawata area. The benefit of the research is to contribute to the development for better management for the water network by changing the old operation systems by making use of the advanced capabilities of the GIS.

1.2: The Study Area

Hawata locality is situated within Rahad River Basin in eastern Sudan (Gedaref State), between latitudes 12.8º N and 14.4º N and longitudes 33.9º E and 35.4º E.

From topographic point of view the study area is characterized by flat surface and some low live outcrops in the east and valleys in the south wait. Rahad River represents the main drainage feature that flows out of the Ethiopian plateau from the south and descends towards the eastern Sudan's plains till it meets the Blue Nile River at North of Wad Madani city in Abu Haraz (HWWC, 2020).

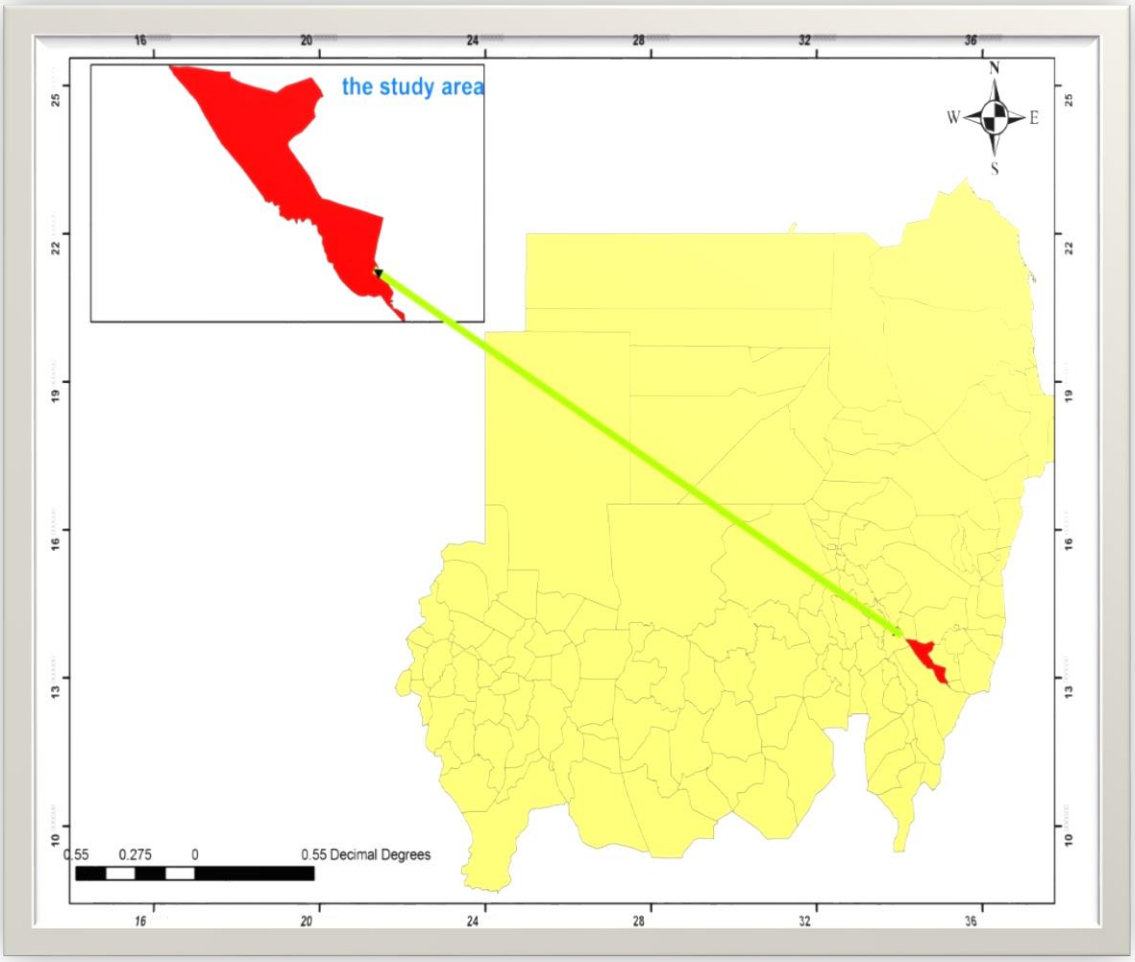

Figure 1.Location of the study area

1.3: Problem and justification

Hawata Wad Alegali areas were suffering acute water shortage due to the rapid population growth and expansion of the towns and villages in the locality. In addition to that the water network is very old and there is lack of information about the ratio of population to water supply. Therefore, this study endeavor to introduce the implementation of modern techniques of remote sensing and GIS to assist the Hawata water corporation to achieve the goal of proper development and management and planning of the water distribution network , together with suggestions for improving the network by designing new extension to meet the increasing water demand.

1.4: OBJECTIVES

1.4.1: General Objective:

The overall objective of the study is to establish water distribution network using GIS that help in the development, management, and planning of Hawata Water Corporation.

1.4.1: Specific Objectives:

- Introducing modern remote sensing and GIS techniques for the development and management and planning of the water distribution networks in Hawata area.
- Updating the data for Hawata Water Distribution Network.

- Proposed new extensions of water network based on the actual needs of the area.
- Investigate the water quality of the area (chemical and physical properties).

2: METHODOLOGY

2.1: Data Acquisition and Tools

2.1.1: Data and Materials

The following tools, software and material during the course of the present study: Satellite Image showing the study area of Hawata and Wad Alegali wells/boreholes; CAD drawing to show the study area buildings, blocks, and streets.; Land use classification map (image format), showing the land use types in the study area such as commercial, green area, public, and residential; Water networks shape file, showing the different components of the water network in the study area of Hawata; Attribute tables, containing description of the types of materials used for manufacturing the pipes in addition to the diameters of the different pipelines; Mainline (transmission line, distribution line); and fitting (bend, cross. end cap, reducer, repair clump, tee), Service line, Service points a Valves (Richards,1990). Then ArcMap and ERDAS Imagine 2014 programs were used to view, edit, create, and analyze the geospatial network data. The GPS Navigator also used in data collection (http://www.esri.com).

2.1.2: Methods

The methodology was based on the division of work into an official data such as, as satellite images, built up and historical maps; and the GPS field work collected to update the old data, ground trothing of the satellite images, direct observation of the system of the network and population data. The reason behind, updating the date of the wells of Wad Alegali and Hawata, is to a quire a profound information of the data i.e. (the wells production, and the water consumption, as well as, the depth and the pumps type). Monitoring all these components will enhance the performance of the plant and help in meeting the user requirements in a quicker and consistent way (Harris, 1993).

The satellite image was Landsat 8 downloaded from usgs.org website site that used to analyze and build the database for the project components and the study area. A layer stack, mosaics and band ratio (5/7) were created to determine clay minerals and map showing the villages included the Hawata Water Corporation Distribution Network. Maps showing the location of the nine productive water wells, distribution network and main pipelines were produced (Fig. 2). Also maps showing the high population density and high water consumption areas were produced.

Then the water distribution lines and wells fields were put in topology system so that the piping networks are of circular and rectangular shapes as used by Ganawa (2009). The water system had been outlaid to secure any one of the three sections of water production and discriminate the main fails or those need repair so that section could be isolated without disrupting all users on the network.

It has been assumed that at least three wells out of nine must be under operation with three submersible pumps to produce about 115 m^3 in the average. They discharge into one main collector reservoir at well no. (8), where the main pipe line of water network proceed eastward to the Hawata town. The length of the main pipeline from Hawata to Wad Elageili is about 35 Km. The well chambers were constructed for all of the nine (9) production wells to house the mechanical and electrical equipment for operation, monitoring the pump unit and they were fenced to safeguard these important plant components. For creating the design for the new extensions in the study area, the following thematic layers were produced which represent the required components for building the necessary water network system of Hawata and Wad Alegali, the information needed that include necessary cadastral information in the area (example, block number, type of parcel use commercial, green area, industrial, public, residential).

With regard to water quality, the chemical and physical data were collected from 7 wells, representing the main producing well for the entire Hawata and Wad Alegali Network. The interpolated parameters include the chemical analysis of PO_4, P and the Total Dissolved Solid (TDS), while the temperature represents the only interpolated physical parameter. Then spatial analysis has been made utilizing the spatial analyst module of ArcGIS namely interpolation tools mainly Inverse Distance Weighted (IDW) was used to interpolate the chemical analysis data, whereas the (Kriging) tool was implemented to in interpolate the physical parameters (Verbyla, 2002).

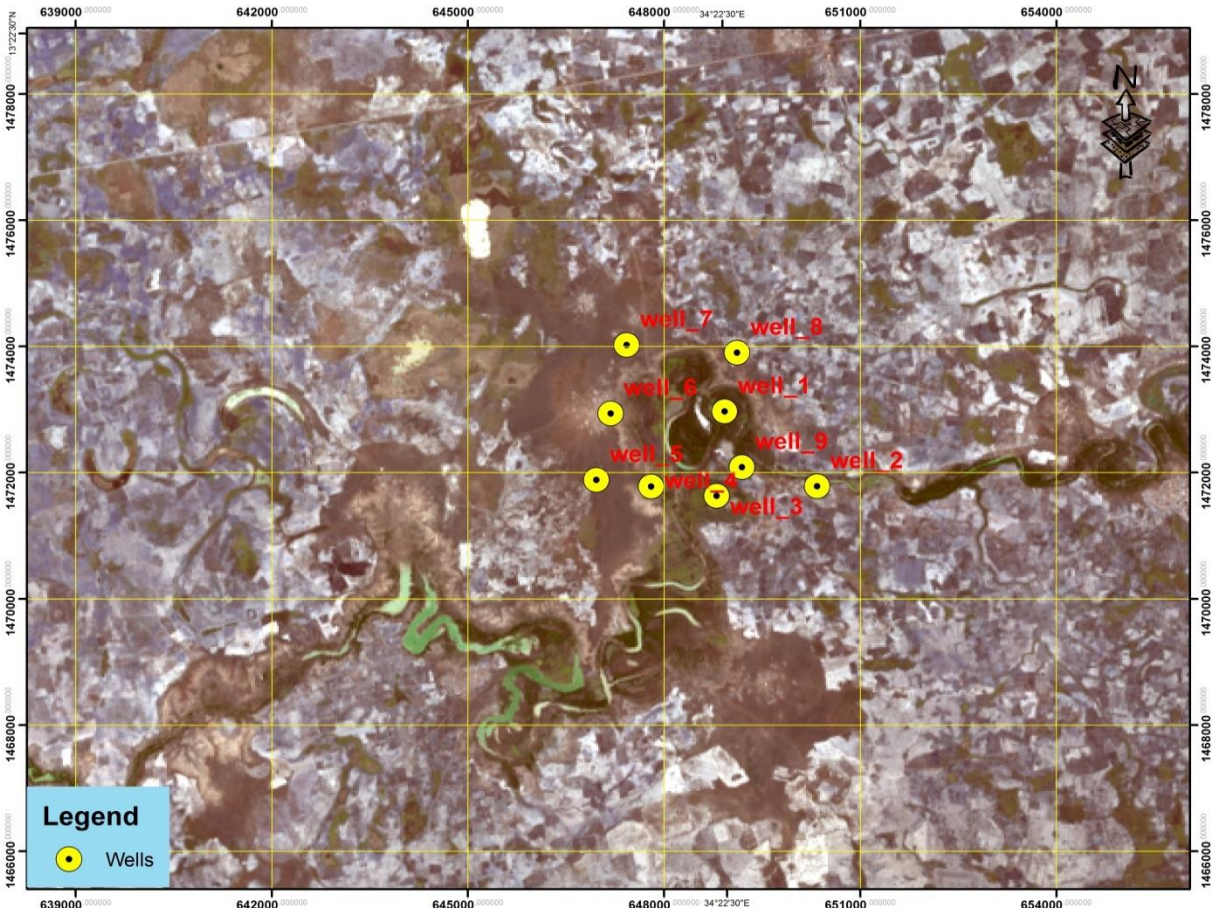

Figure 2: Productive wells in the study area

Moreover, a field visit and surveying has been conducted to all (53) villages and (2) towns Hawata and Qala En Nahal for personal and public interviews with the authorities and key persons from Census Bureau, Urban Planning and Planning Departments.

Finally, the database of the main water network of the project (wells, stations, main network lines, distribution lines, and main reservoirs) has been developed in addition to population and water consumption relationship (Figure 4).

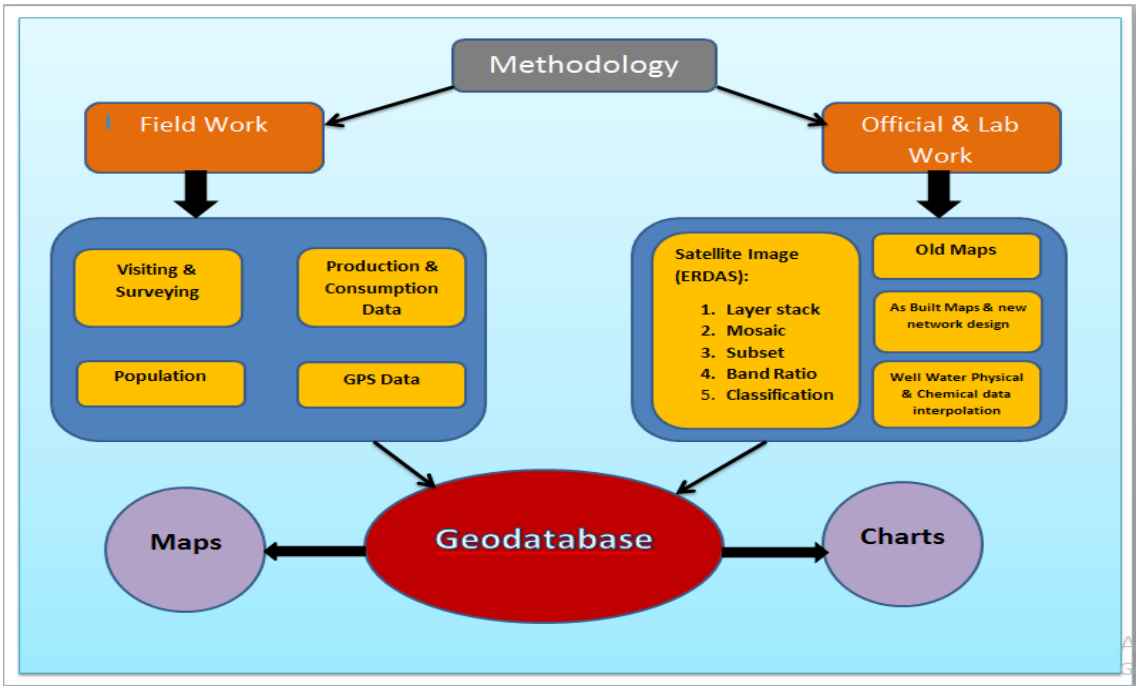

Figure4. Research activities and methods flow chart

3: RESULTS AND DISCUSSIONS

The results and discussions of the study fulfill the overall objective of the research study that is to establish a geospatial database using GIS for development, management, and planning of Hawata and Wad Alegali Water Corporation Distribution Network as the main goal. The main objective was followed by three specific challenges ‘or goals which had been divided into categories for facilitating the discussions of the results as output of the research study showed that, with regard to updating of the Hawata and Wad Alegali Water Corporation Network Data, it has been found that the total length of transmission, distribution lines networks (different diameters ranging from 2 to 48 inches) in Hawata is about 97.07 linear meters and in the study area is about 40.88 linear meters. These networks exist in several forms of materials such as (asbestos cement, glassed reinforced plastic, reinforced concrete and steel), Figure 5. The distribution process subjected to many determinants such as the shortest path, the nearest valve as well as the nature of the land covers types. The system needs a designated employee in every

distribution station, to manage and run the facility. With regard to analysis of water production and consumption of Hawata and Wad Alegali Water Corporation Network as compared to the population density; it has been found that Hawata town district east and west Rahad riverside has the highest population of 43,328 inhabitants of the total population (81,178 persons) and consumed more water as compared to the rest of the area (Figure, 6).

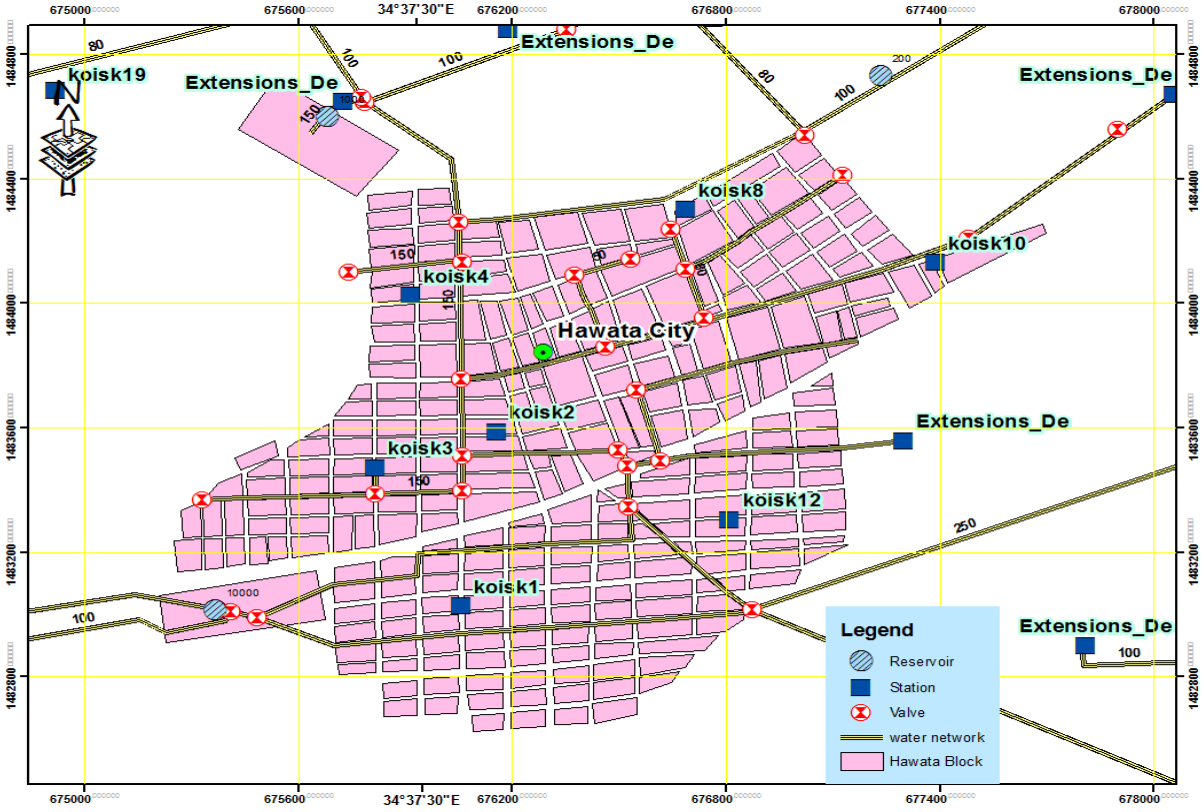

Figure 5: Hawata town water distribution network

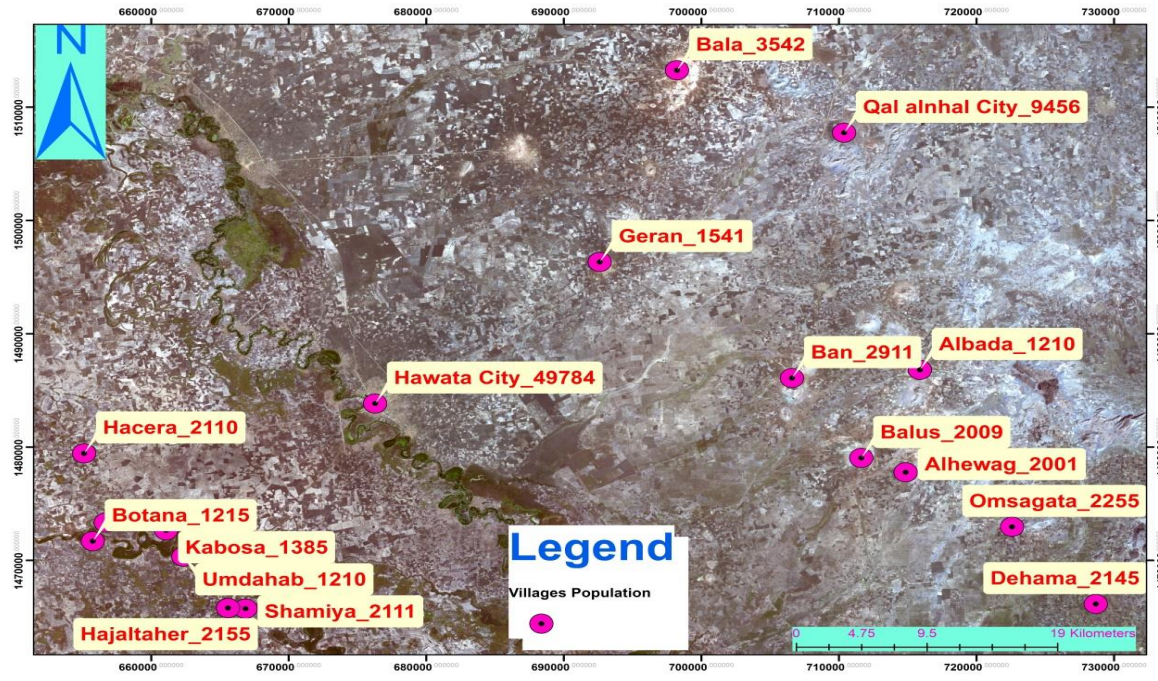

Figure 6: Hawata Population Distribution

With Regard to the water quality, in the chemical analysis a distribution map of PO_4 concentration has been produced (Figure, 7). It is clear from the map that the high concentrations of PO_4 were found in well No. 3 that reaches a peak of 6.3 mg/L. Nevertheless, the concentration of this chemical group is moderate in wells No. 4, 5, and 7 and 2, while well No. 1 recorded the minimum value within the investigated wells that counts only to 0.2 mg/L.

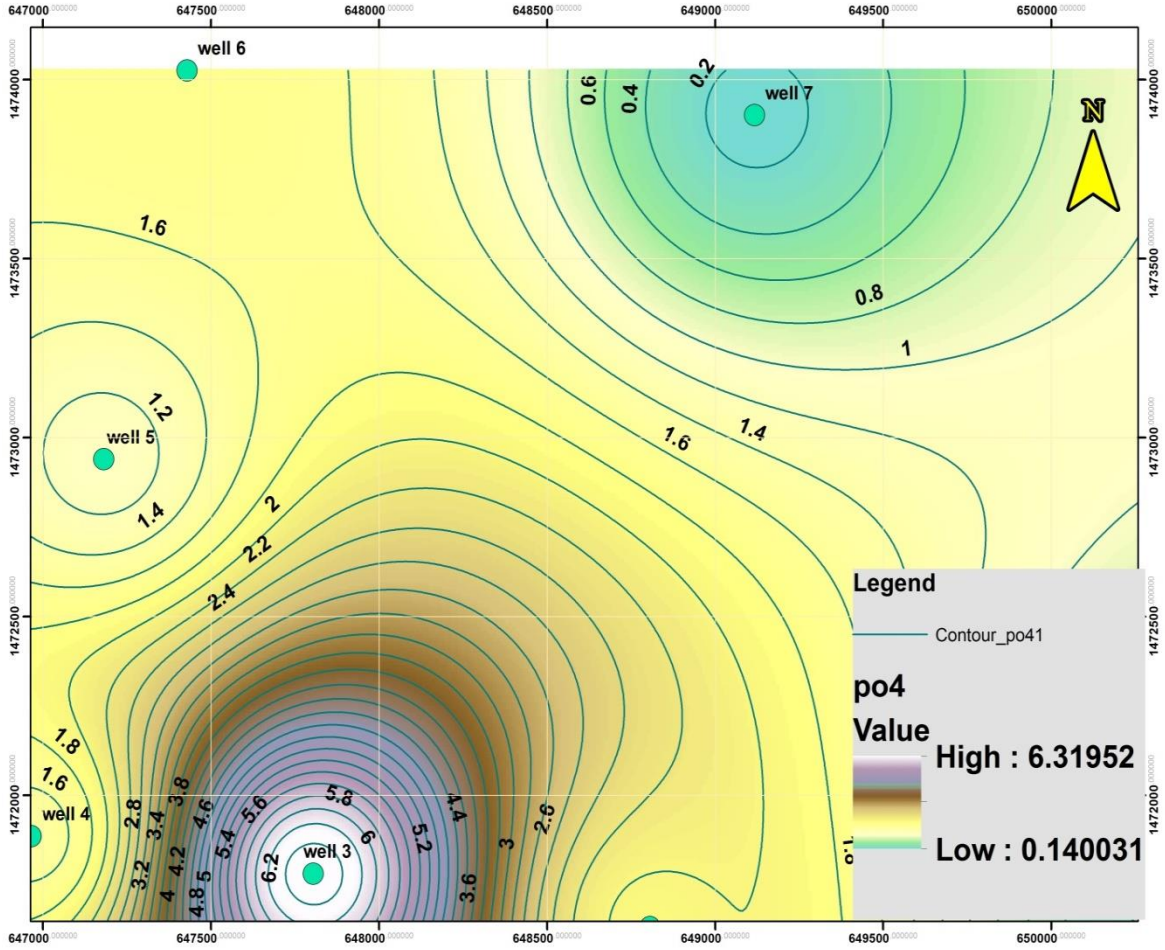

Figure 7: PO_4 Spatial Distribution

For Phosphor (P) it has been found that it was concentrated in wells No 5 and 3 to reach 0.7 unlike well No.4 and 2 where phosphor concentration was 0.05 (Figure 8). Furthermore, the water physics characteristics (conductivity) result showed more concentration in well No.2 by about 6.5 S/m and low well No. 3 with about 3.0 S/m (Figure 9).

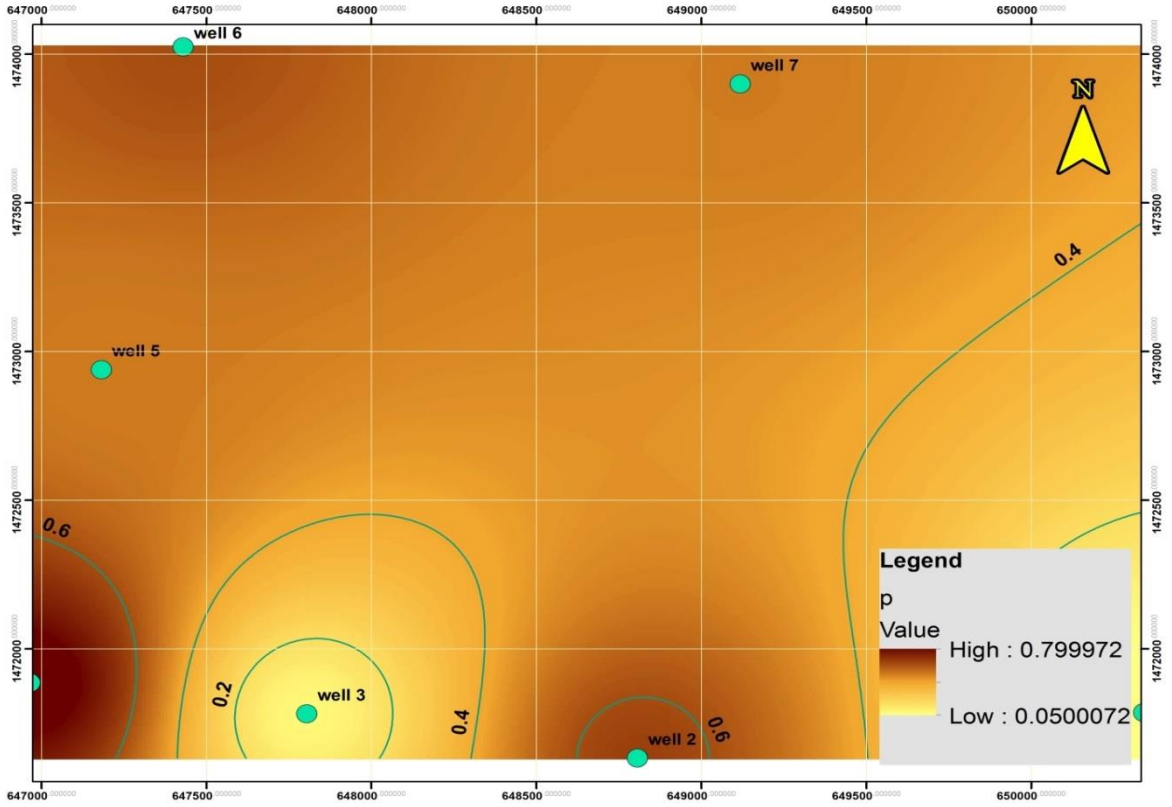

Figure 8: P Chemical analyses and distribution

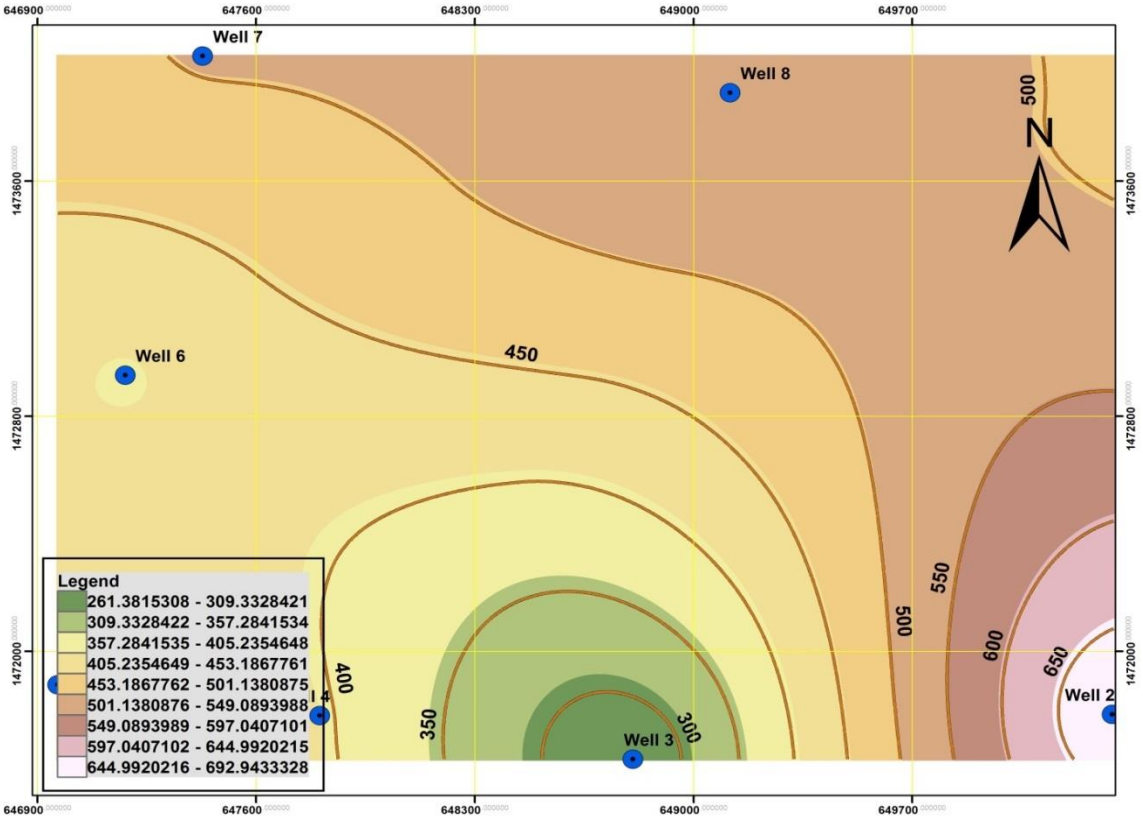

Figure 9: Conductivity distribution in the wells.

Clay minerals have been extracted from the image through the spectral rationing technique (Figure 10) in order to sort out the clayey soils to pave the way for the construction of the network (digging operations). The Clay minerals playing a pivotal role in the installation of the water networks lines, in addition to facilitate the instillation of the water networks decision making.

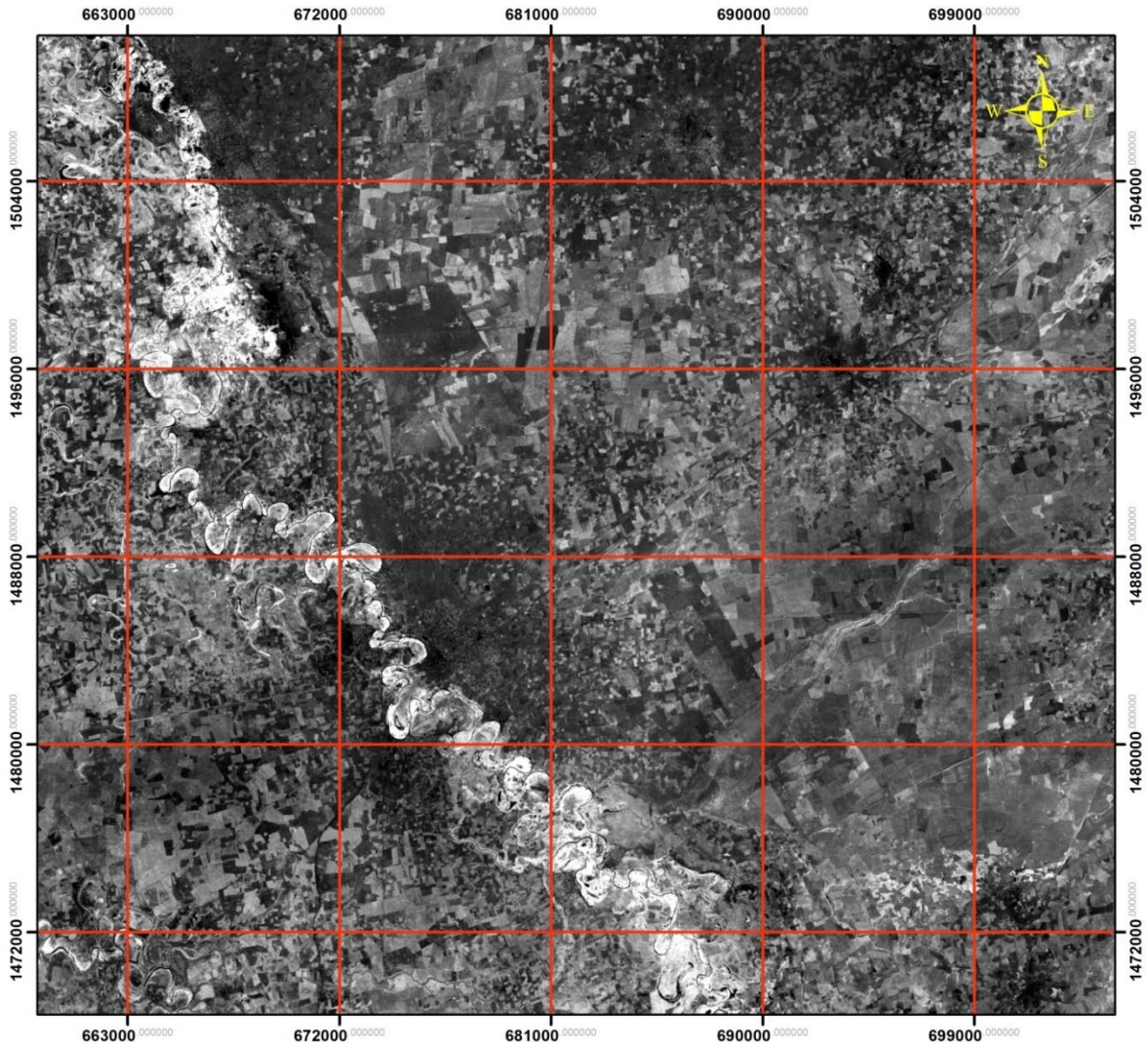

Figure 10: Band ratio of band 5/7 showing the clay minerals in area as light tones.

4: CONCLUSIONS

The study concluded that GIS and remote sensing could be used to develop the water network in the area and could support the management system. Also the findings assured the info of great link between population increase and water consumption. The study showed possibility of better assessment and evaluation water quality if there is a good database. Accordingly, the study highly recommends the use of GIS and remote sensing technology for water distribution network.

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