The Use of the Geographic Information Systems (GIS) in Networks Analysis of Water using (Geometric Network) Application Area Alazhari - Khartoum State

Maha Ali Ibrahim Yagi[1], Alwalid Bashier Gism Elseed Ahmed[2], Samni A. Talab[3]

Abstract: ***The aim of this paper is to apply the concept of geographic information systems to solve the problem of distribution of potable water network in Alazhari region. The problem of the study was the lack of sufficient geographical data for the network, which leads to a high dropout rate in the network which is one of the biggest concerns and challenges facing network administrators. The large number of faults caused by the cracking and erosion of network components is a great challenge to reach an ideal network. We can also learn how to manage and maintain water networks using this technology to help decision-makers reach solutions at the lowest cost and in a timely manner by collecting, introducing and addressing the spatial and descriptive management of water networks. The geometric network of the Azhari water network was used to explain its advantages. A geographical database was created, which included the construction of layers (buildings, squares, localities and state) and a layer of water networks with their accessories and linking them to the Orcale program and then using this application to solve problems Located in the area.***

Keywords: Network Analysis, Spatial Commands, Geometric Networks, Geo-database, Trace Downstream, GIS,Trace Upstream, Find connected, Find disconnected, Find loop, Find path, Utility Network Analyst.

1. Introduction

Public facility networks and infrastructure, together with other services provided to citizens, are considered as the most important elements of urban structure by which the level of civilization is measured, and the lack thereof is considered one of the principal obstacles to economic, social and urban planning development of cities and suburbs altogether. And the most important networks are drinking water supply networks (water networks).

Making good use of water resources available in the area requires maintaining it and transporting it to use, treatment or storage places through proper networks executed at the required standards using proper materials in order to provide what follows:

Maintaining water and preventing leakage because that causes a lack of drinking water and leads to water contamination as often happens at the study area, or it can lead to stagnation on the surface and lead to insects reproduction which results in spreading diseases, or it might leak beneath roads and sidewalks which leads to their breaking. And since water supply projects cost the state hundreds of millions, this mechanism needs to be executed with high accuracy. And since that the success of the project of analyzing the water supply network (geometric network) of Alazhari, Khartoum depends on its quality, then the appropriate engineering rules need to be applied, then document the network's data.

GIS can be used as a tool for analyzing the water supply network in Alazhari, Khartoum to help in making the right decisions regarding the maintenance of the network and the best way to distribute water and cutting down the leakage. The aim of this study is to apply GIS using (geometric network) to analyze the water supply network in Alazhari, Khartoum. And to achieve this goal network analysis was used for it's the most important function GIS provides.

This paper was designed to have many chapters after this one: Second Chapter which is an introduction to the use of GIS in network analysis. Third Chapter will discuss the area selected for the study and why it has been selected and Forth Chapter explains the concept of network analysis. Fifth Chapter contains results and discussions obtained from the application of GIS and finally the Sixth Chapter includes the conclusion.

This study aims to what follows:

1) Developing a GIS model for managing water supply networks in Alazhari, Khartoum and provide more consistent and advanced assistance in decision making in regards of water supply networks development and operation.
2) All the information and data pertaining water supply network of Alazhari, Khartoum then putting a numerical description of the collected data and information, and after that developing a model and translating it using ArcGIS database for all the contents of the network.
3) Explaining the use of GIS software as an integrated tool for preparing the comprehensive spatial data and increasing the water supplied to residents of the project area through the proper management of the current water supply network by using geometric networks.

The study methodology:

GIS was used in this study and it followed the analysis methodologies then used Oracle database system to create a database then use GIS with its three 3 software tools; Arc Map, Arc Tools, Arc Catalog), as Arc Map is the central software of Arc GIS and it includes a number of important operations in dealing with maps, such as addition and analysis & deletion and analysis, and it provides different ways to exhibit spatial data such as watching geographic data and watching water supply networks.

Used Tools: ArcGIS 10.2.2 software and Oracle database.

Study Limits:

Spatial Limits: the spatial limits of the study are in the geographic area of Alazhari, Khartoum, Sudan and for developing the management of water supply network there as a model for the use of GIS in the area.

Temporal Limits: from the beginning of 2016 until 2019.

Use of GIS for network analysis
In fact, most of water supply networks in Alazhari, Khartoum don't have constant supply of water, and it works in an interrupted manner, and still there is no significant care taken in designing and managing these networks. And as it is known that the design of water supply networks is done on the assumption that water flows inside the network continuously, which is not true in the ground in all of the networks in Alazhari, Khartoum, and GIS was suggested in the recent years as a way to collect information about the networks and systems used to provide urban services such as water, cooking gas and electricity distribution networks in addition to sewage collection systems.

GIS can be used to manage water supply as an information tool to operate and maintain the water supply network in Alazhari, Khartoum. The key advantage of this system is the possibility of keeping detailed numbers and records of water distribution in the study area and that it can be easily updated, also it can answer some important questions like questions about pipes, valves and storage tanks and other things, for example. Also administrative employees can access and use the system without needing to know the complexities of GIS programming.

Network analysis process in one of the most important functions that GIS can do very efficiently. Network analysis process provides a variety of ways to study any network, and presenting that digitally. And after that the process of dealing with that network begins through a group of commands known as spatial commands which calculates the needed tracks and displays it to the user in an understandable manner.

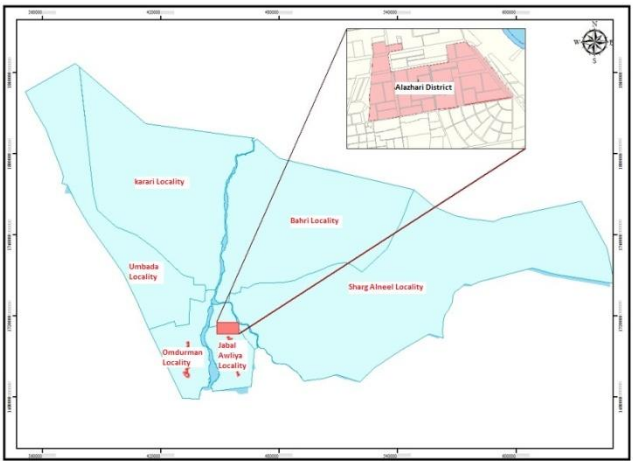
One of the most important problems that network analysis system studies and provides solutions for: the process of finding the most suitable track that connects two or more points. This would be the track with minimum cost. And one of the most vital processes to be done when studying or analyzing one of the facilities' networks, knowing the parts of the network connected with each other at a certain point, or when there's a break or defect in any part of the network.

2. Study Area

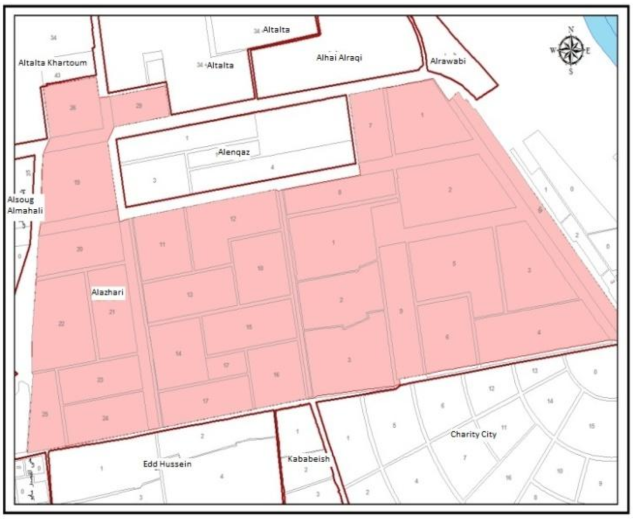
2.1 The geographic location of the study area:

Alazhari is located in the Republic of the Sudan, Khartoum State, JabalAwliya Locality, between the longitudes (32' 57' 898') degrees east and the two latitudes (15' 50' 73') degrees north.

On the western side it's bounded by AlsougAlmahali and on the northern side by Alenqaz neighborhood and on the southern side by Edd Hussein and the Charity City as shown in the map no. 1.

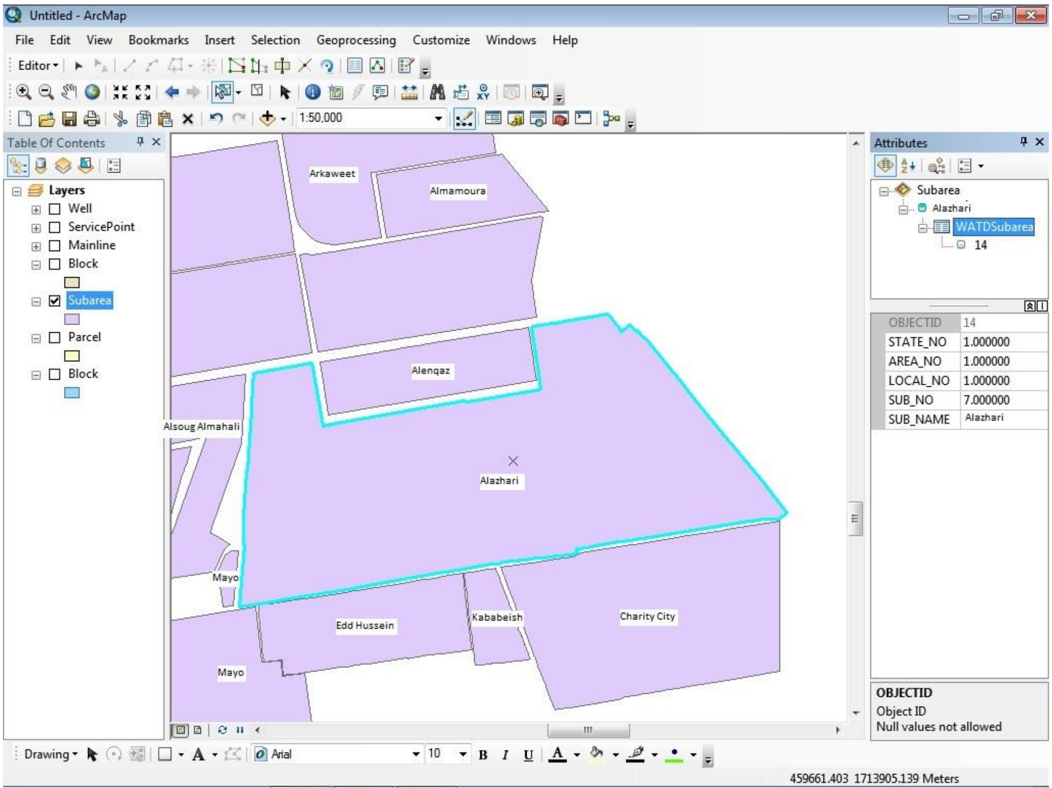


Shape 1-2



Shape 2-2

Block 24 was selected as a case to study as it includes the block area which is 380,016 square meters (380 kilometers), and the number of buildings included is 791 buildings, and the number of the water supply lines included is 60 lines.

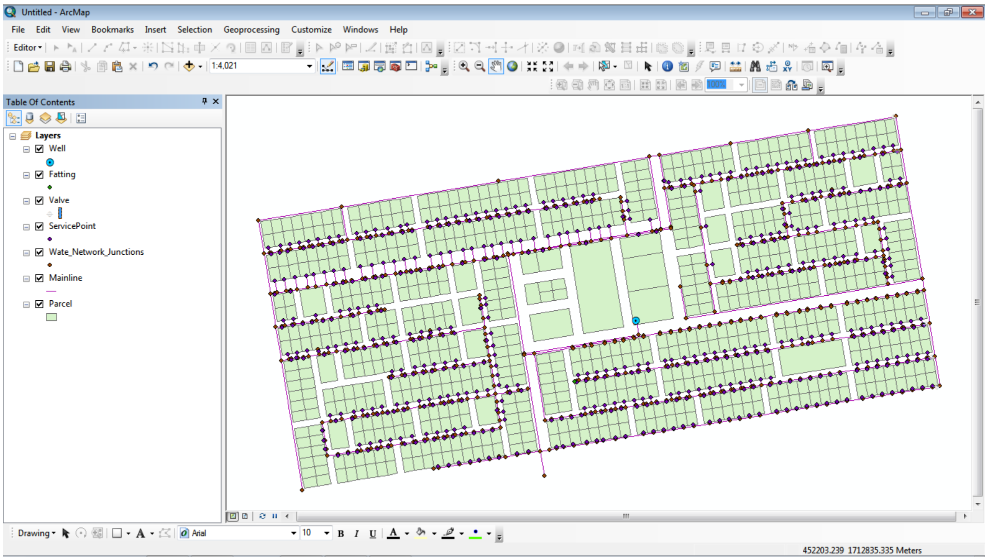


Shape 2-3: Shows the study area: Block 24 Alazhari

2.2 Water Distribution Network

The water distribution network in Block 24 comprises of many types of pipes in accordance with their function as follows:

1) The Source: which is the water storage place, such as tanks, stations and wells, and the source in the study area is a well in a services yard.
2) Water Lines: and these are divided into three types:
   a. Supply Line
      - A line that comes out of the well with a diameter of 12 inches to supply water for blocks 23-24-25 Alazhari and Block 1 Edd Hussein.
      - 12 inches line heads north to become an 8 inches line and it decreases until it becomes 6 inches of diameter.
   b. Distribution Line: the lines available are 4 inches of diameter and are always between neighborhood streets which supplies water to service lines that supplies water to houses.
      - The area isn't fully constructed so the supply lines are made according to the existing buildings.
   c. Service Lines: and these supply water from the distribution lines to buildings.
3) Network Attachments: and these are T and Bend joints and dead caps and valves and the total number of these is 8.
4) Service Point (Consumer):



Shape 2-4: Shows the distribution of water supply networks

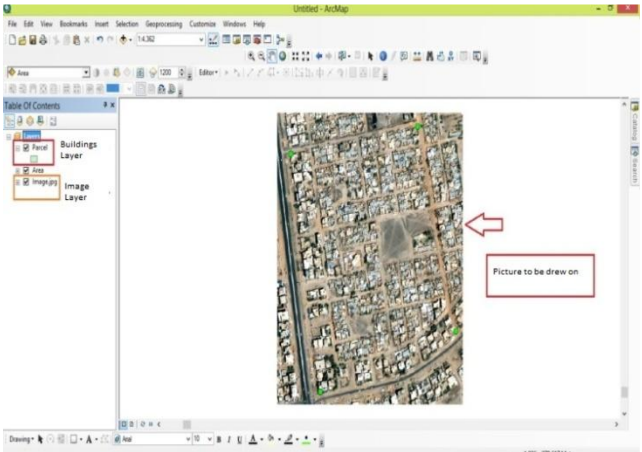
2.3 The use of GIS for network analysis

There has become a great increase in the use of GIS software in water supply networks analysis, and this part explains how to deal with water supply systems using information systems.

ArcGIS 10.2.2 was used to analyze the water supply network and generate the required geometric network to develop the Goe-database, also the Utility Network Analyst was used.

2.3.1 Use steps

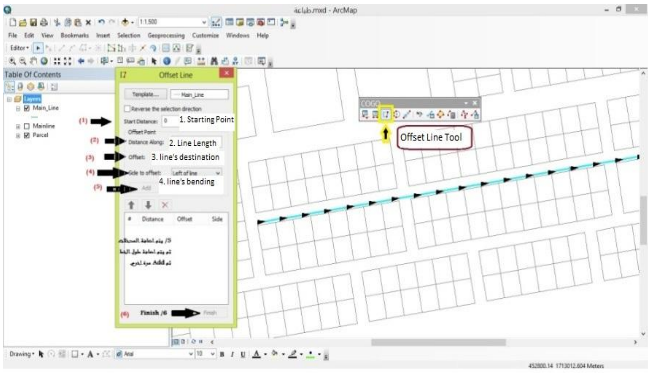
1) The coordinates of the area were taken using Google Earth software to produce a map for the area,



Shape 3-1

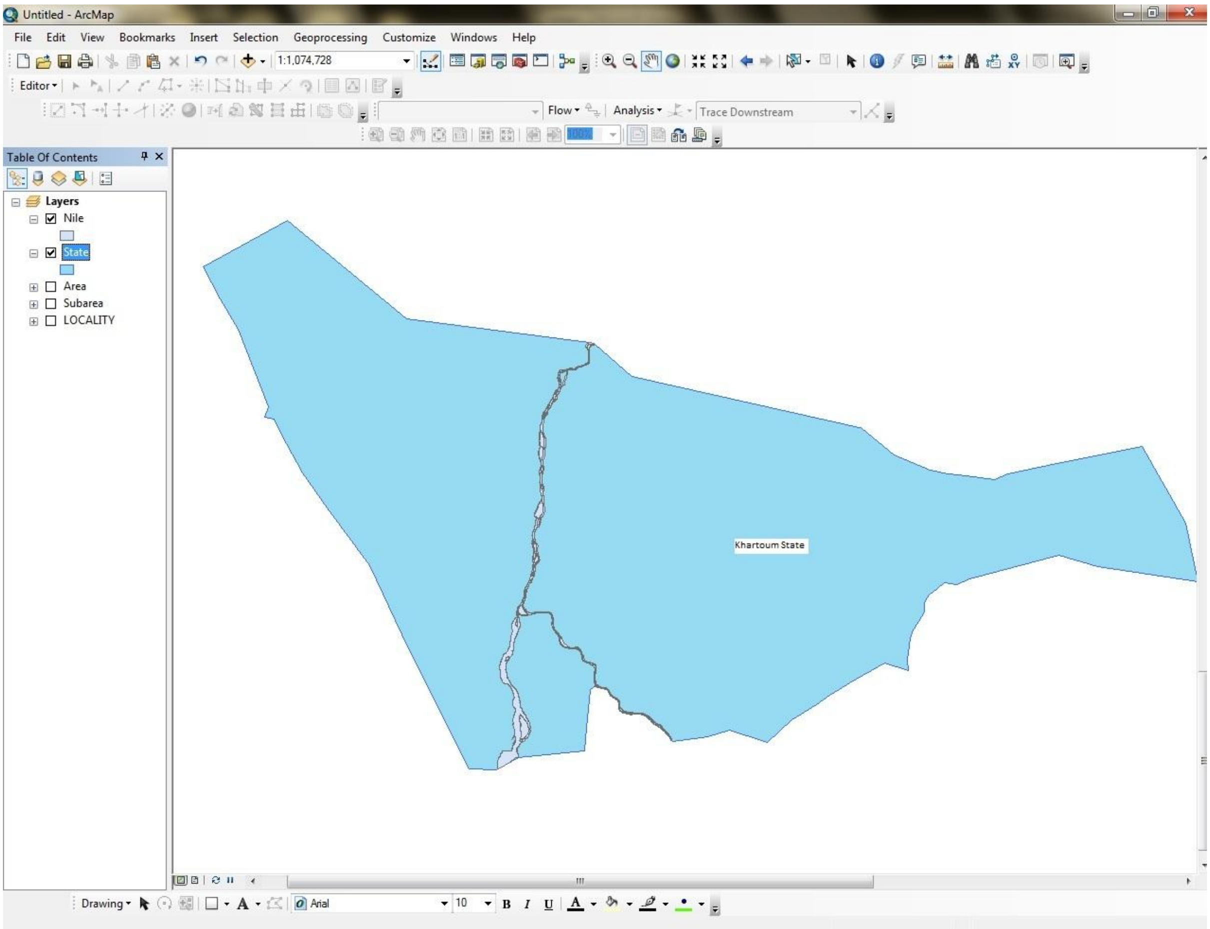
Shape 3-2

2) Drawing water supply networks and their attachments (valves, water supply lines, wells…etc.)

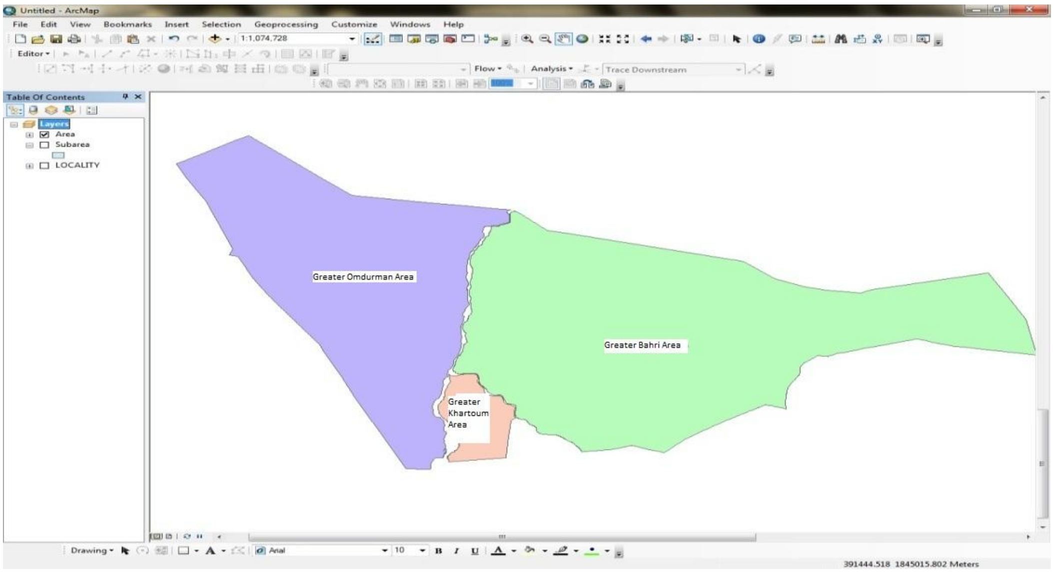


Shape 3-3

3) Developing a Geo-database for buildings, localities, blocks, neighborhoods, state, greater areas, water supply networks (valves, water supply lines, attachments, sources, consumption points) through Catalog Arc.

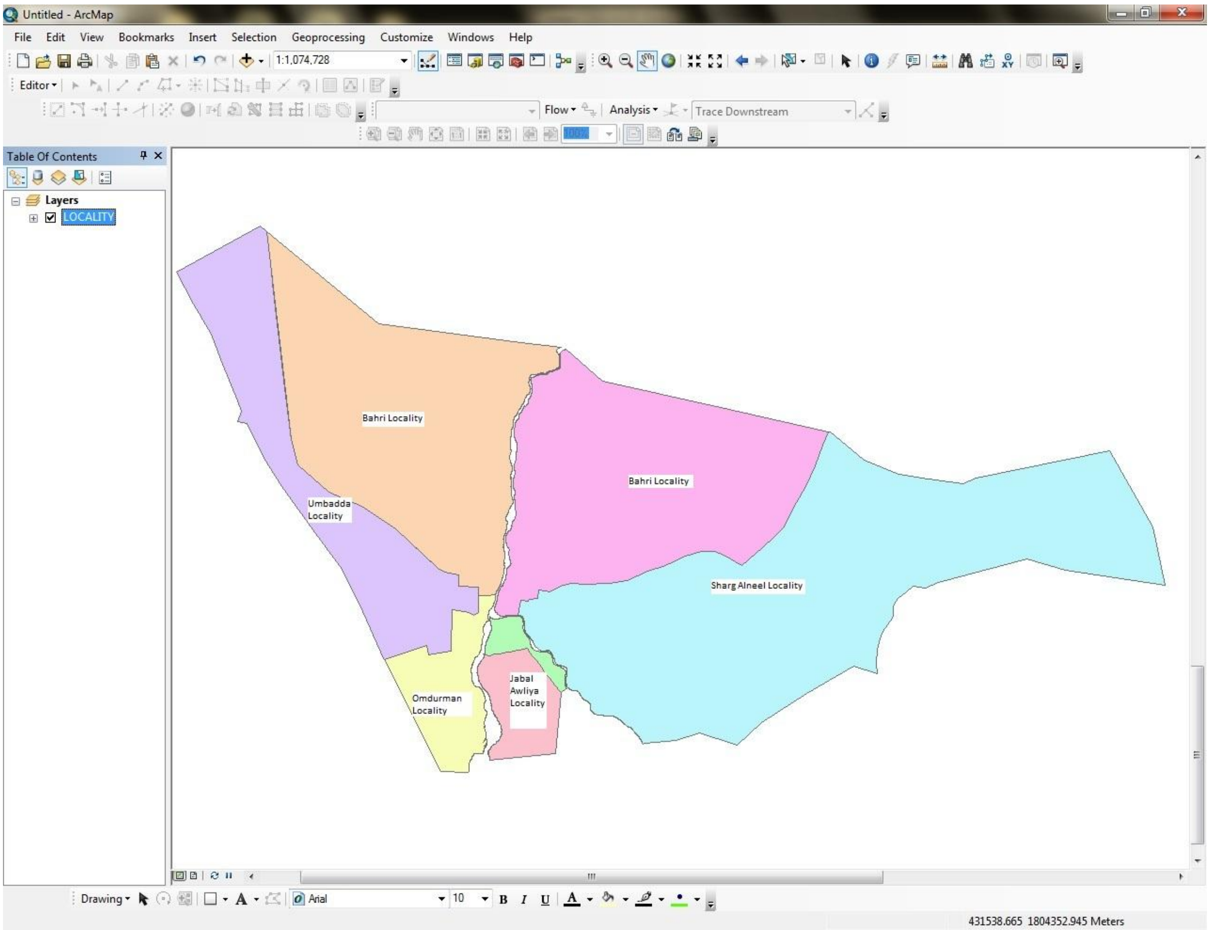


Shape 3-4: Shows states layer

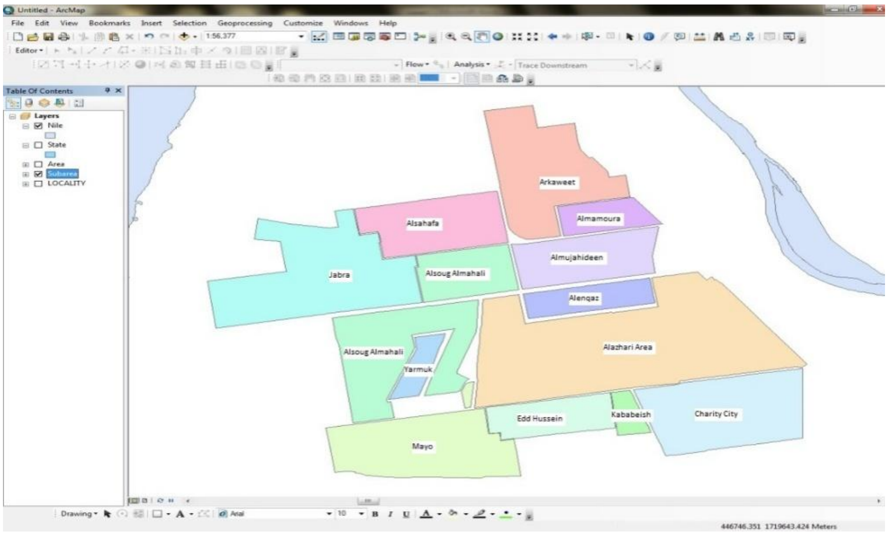


Shape 3-5: Shows greater areas layer

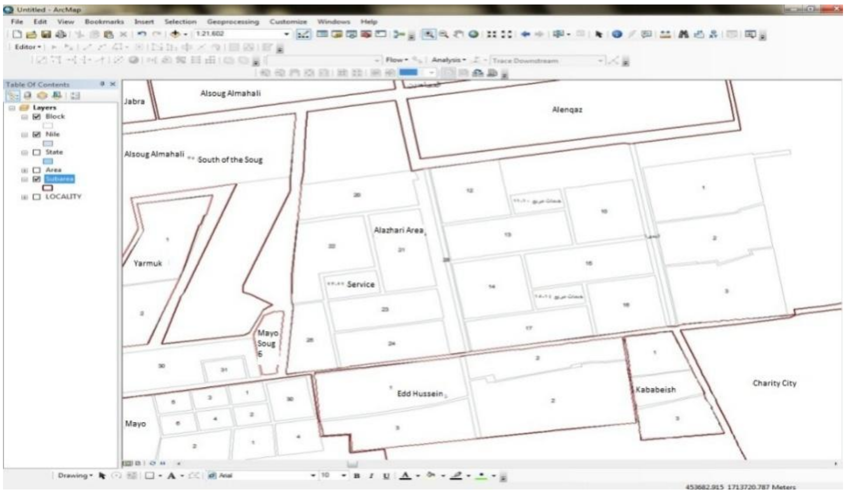
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296



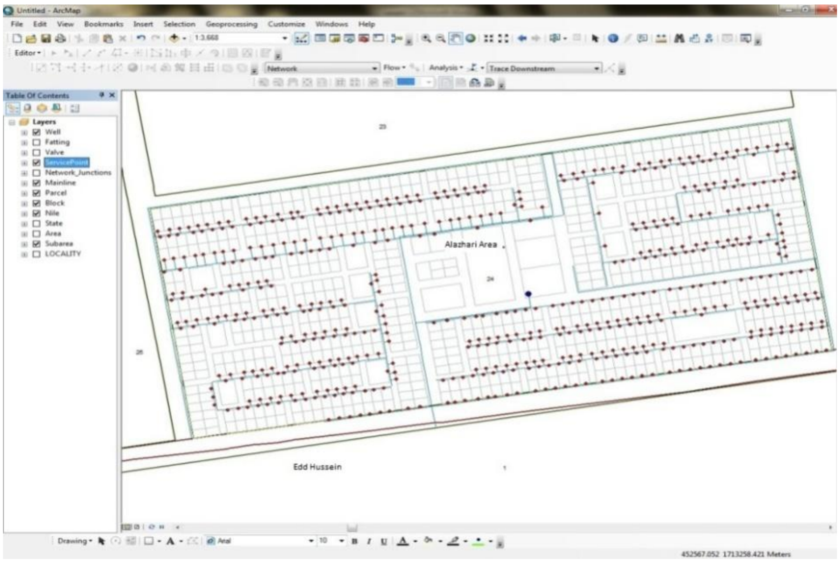
Shape 3-6: Shows localities layer



Shape 3-7: Shows sub areas layer



Shape 3-8: Shows the blocks layer



Shape 3-9: Shows water supply networks distribution

4) A database was made using Oracle software to enter the descriptive data of the water supply network and that includes (customers accounts, localities, neighborhoods, etc.) and then connecting them to GIS.
5) Drawings of buildings and the borders of blocks, neighborhoods and localities using ArcMap software then drawing water supply networks and their attachments.

2.3.2 Database tables

1) Userstable

Table 3-1

Field Description	FIELD	DATA TYPE	PK/FK
User number	user_id	number(2)	PK
Username	user_name	varchar2(50)	
Password	pass_w	varchar2(50)	

2) States table

Table 3-2

Field Description	FIELD	DATA TYPE	PK/FK
State number	state_no	number(2)	PK
State name	state_name	varchar2(50)	

3) Greater area table

Table 3-3

Field Description	FIELD	DATA TYPE	PK/FK
State nu,ber	state_no	number(2)	FK-PK
Area number	area_no	number(3)	FK-PK
Area Namer	area_name	varchar2(30)	PK

4) Localities table

Table 3-4

Field Description	FIELD	DATA TYPE	PK/FK
State number	state_no	number(2)	FK-PK
Area number	area_no	number(3)	FK-PK
Locality number	local_no	number(3))	PK
Locality name	local_name	varchar2(30)	

5) Sub areas table

Table 3-5

Field Description	FIELD	DATA TYPE	PK/FK
State number	state_no	number(2)	FK-PK
Area number	area_no	number(3)	FK-PK
Locality number	local_no	number(3))	FK-PK
Sub area number	sub_no	number(3)	PK
Sub area name	sub_name	varchar2(30)	

6) **Blocks table**

Table 3-6

Field Description	FIELD	DATA TYPE	PK/FK
State number	state_no	number(2)	PK-FK
Area number	area_no	number(3)	PK-FK
Locality number	local_no	number(3))	PK-FK
Sub area number	sub_no	number(3)	PK-FK
Block number	block_no	number(3)	PK
Block name	block_name	varchar2(30)	

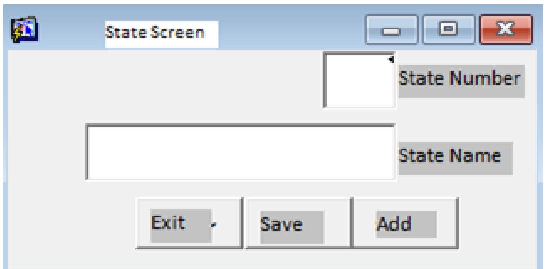
7) **Customer information table**

Table 3-7

Field Description	FIELD	DATA TYPE	PK/FK
State number	state_no	number(2)	PK-FK
Area number	area_no	number(3)	PK-FK
Locality number	local_no	number(3))	PK-FK
Sub area number	sub_no	number(3)	PK-FK
Block number	block_no	number(3)	PK-FK
Building number	build_no	varchar2(10)	PK
Username	costomer_name	varchar2(100)	
National ID No.	national_id	varchar2(30)	
Account/meter No.	acc_no	number(20)	
Floor	floor	number(3)	
Line/ account size	acc_size	number(1)	
Phone No.	tel_no	number(10)	
Source type	source_type	varchar2(30)	
Line type	line_type	varchar2(30)	
Width	width	number(3)	
Raw materials	row_material	varchar2(100)	
Depth	depth	number(3)	
User number	user_id	number(2)	

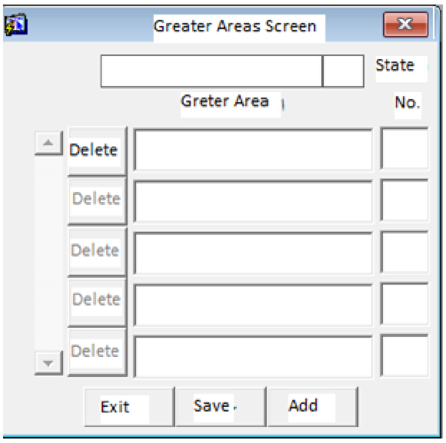
2.3.3 Screens

1) **State screen**



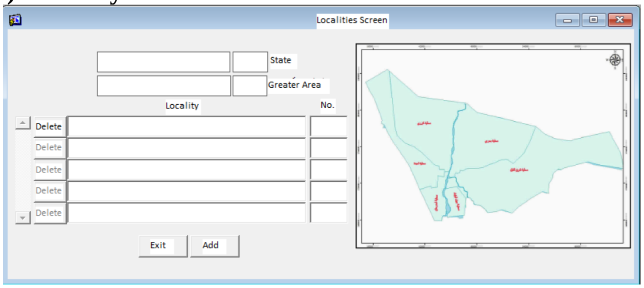
Shape 3-10

2) **Greater area screen**



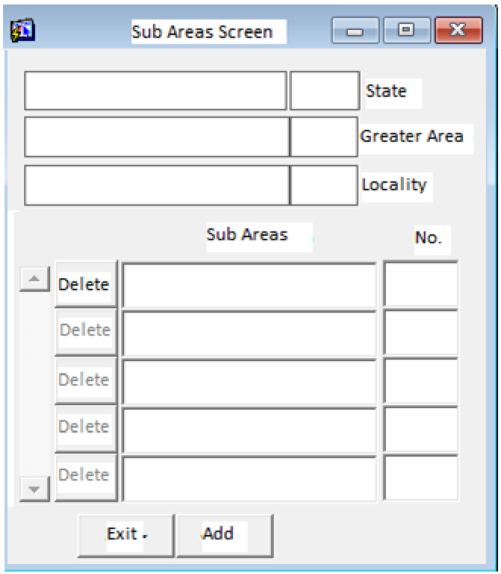
Shape 3-11

3) **Locality screen**



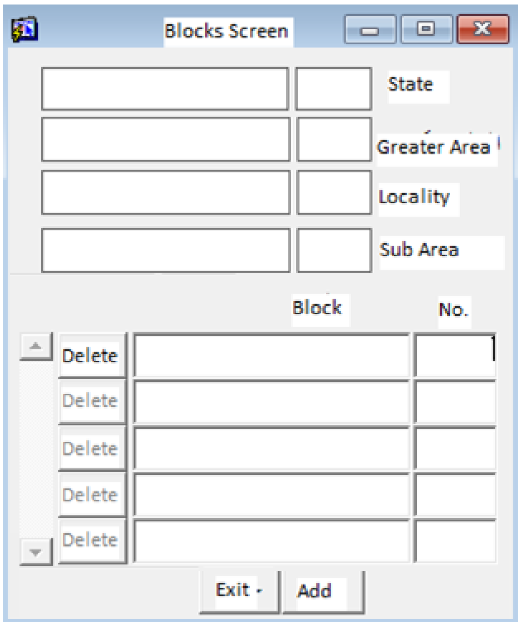
Shape 3-12

4) **Sub area screen:**



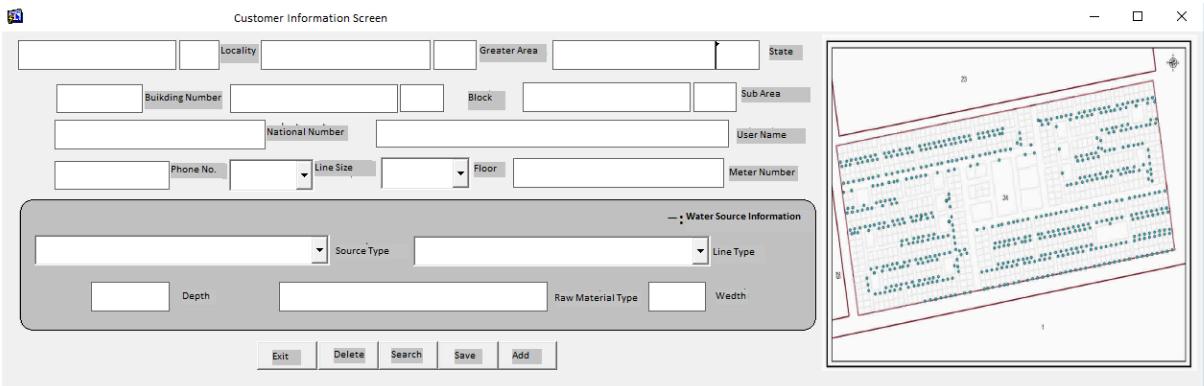
Shape 3-13

5) **Block screen**



Shape 3-14

6) **User information screen**



Shape 3-15

2.3.4 Digital Evaluation Model (DEM)

It's a data file with digital presentation of data in the form of (Raster) as each pixel in it has a digital value that represents the average height of surface in the area of the pixel, these files exist within the GIS software and are usually of big size and it's useful for planning purposes.

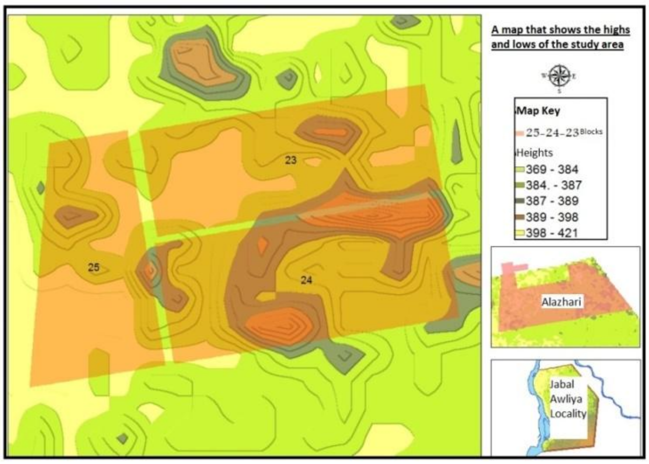
This model either uses geographic coordinates network, the network of longitudes and latitudes and especially if there's data that changes due to surface bending, or uses UTM network in case there is common data, so if the DEM was small we use geographic coordinates and if it was big then we can use either of them, DEM always shows the height of the terrains and the height of plain land that doesn't have plants or human made buildings in contrary of Digital Surface Model which shows the height of tree tops, house rooftops, towers and other things.

And it's resulting from areal images and satellite footage and there are many models of DEM files, some are free like SRTM which is used in this paper with an accuracy of 90 meters, and some are paid.

This classification depends on the resolution, as the resolution of the free data is 1:1000 meters while the resolution of the paid data is 1:30 meters.

Ways to get DEM:
1) Survey and land measurement devices (Total Station/GPS)
2) Contour maps
3) Areal imagery
4) Satellite footage
5) Free international DEM on the internet4

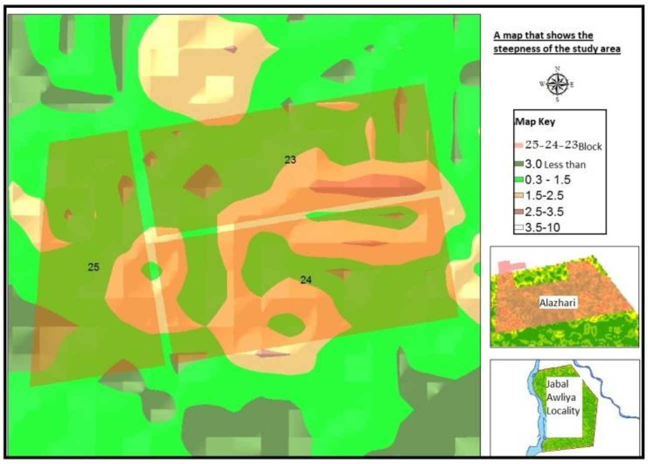
2.3.5 A map that shows the DEM of Alazhari, Khartoum (study area)



Shape 3-16

Looking at the shape we find that the height of the area ranges between 384-398 meters. Which means that the area height increases with the increase of the level.

2.3.6 Steepness: the steepness of the study area ranges between 0.3-3.5 degrees.

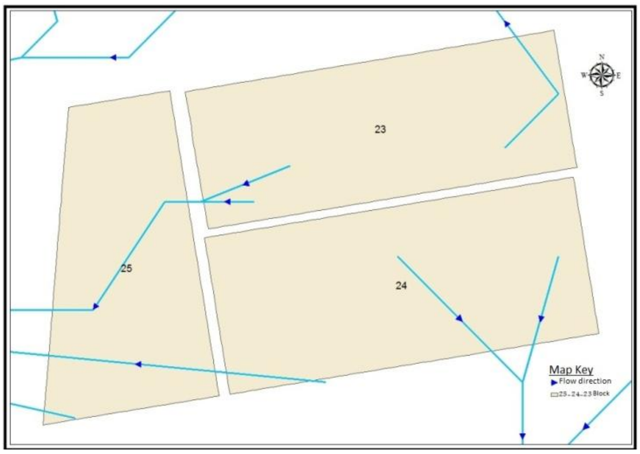


Shape 3-17

Which shows that the area isn't very steep and is a low area and whenever the slope increases steepness increases as well as shown in the shape.

2.3.7 Flow direction from the source

It is generated from "flow direction" layer to determine water flow direction.



Shape 3-18

2.3.8 Excavation and landfill amount

It's calculated after putting the water supply lines on the ground to know the amount of land filling needed.

Amounts calculation is the sum of the road work and it's the end those whose working in the sector are trying to achieve and it's the basis for negotiation and contracting, and it's the basis for construction work.

The advancement in tools and software used in amounts calculation happened and new more expensive and more accurate software came up lately.

Factors that affect quantities calculation

There are three main factors that affect quantities calculation:

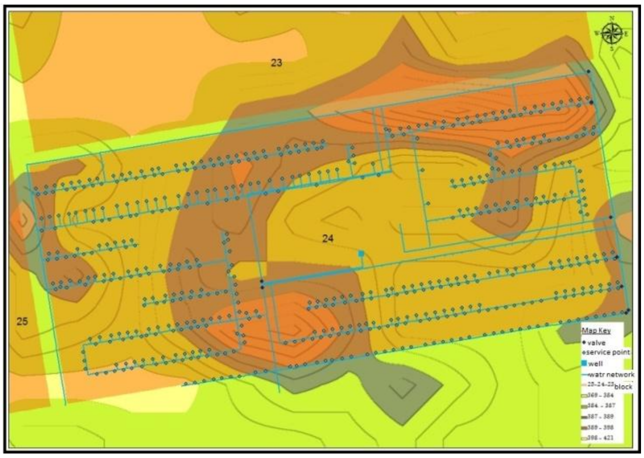
1) The road's cross-section.
2) The natural land readings of the road.
3) The design line or the construction line of the design.

These factors enable us to calculate the quantities and the change of any factor changes the resulting quantities. The direction of water supply networks is determined after applying the geometric network through "flow".

2.3.9 Water supply network high and low parts

We find that the source of water (the well) is at a height of 283-287 meters and for the water to be pumped out we need water pumps because the location of the lines ranges between 384-398 meters, also we find that the valves that control the water flow direction are at a height of 389 – 398 degrees and that shows that the height of the valves is higher than the water source.

Note: the well operates for 20 hours a day and it operates on electricity and needs a water pump so it can pump the water to the network and doesn't depend on the height of the area.



Shape 3-19

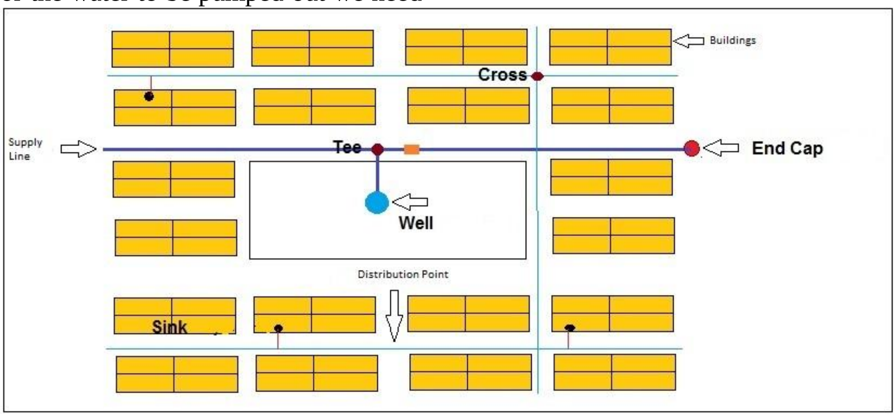
2.3.10 A table that shows the coordinates of the network components

Table 3-8

Water networks	X	Y
Water source (well)	452809.758179	1712986.30108

3. Water supply network analysis using geometric networks

The geometric networks comprise of the Network Edge Features and Network Junction Functions. And one of the examples of the edge function is the water mains, and an example for the junction feature is the valves. The edges need to connect to other edges through junctions. The features of the edges are related to the elements of the edge and the network and the features of the junctions are related to the elements of the junctions of the network. Shape 4 illustrates the elements of the water supply network.

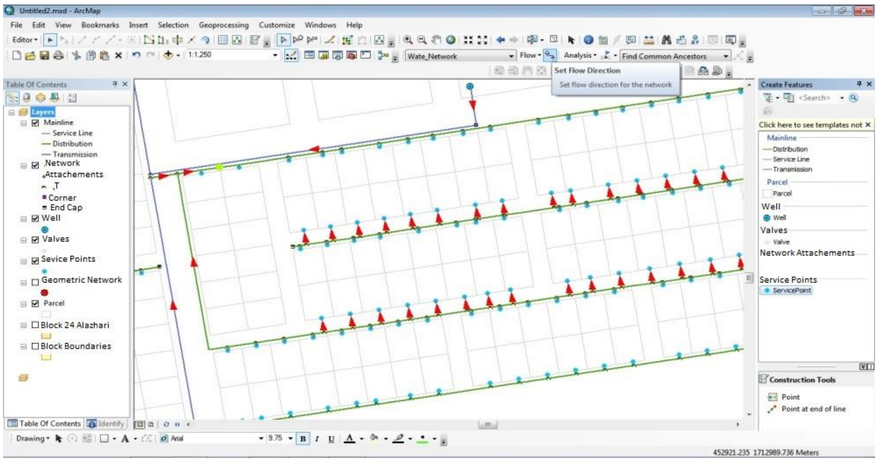


Shape 3-20: Water supply network elements model

The importance of building geometric networks

1) Having a strong database for all parts of the network that includes the network update
2) Easier control of the network through a group of main valves which allow us to avoid dealing with all the valves of the network.
3) Adding new outlets such as the fire valve.
4) Altering the track of the network from a point to another in the beak times.
5) Flow directions and altering them.
6) Determining the goals and achieving them.
7) Quick and active repair teams for the breaks.

In the applications of water supply networks, knowing the direction of the water flow along the lines or the edges is necessary. The water flow direction in the geometric network determines the water flow direction in every line in the network, knowing that the flow direction is determined through connecting the network lines and determining the location of the water sources and water flow parts of the network in addition to determining the possible and impossible features. The water flow direction in the water supply lines is determined.



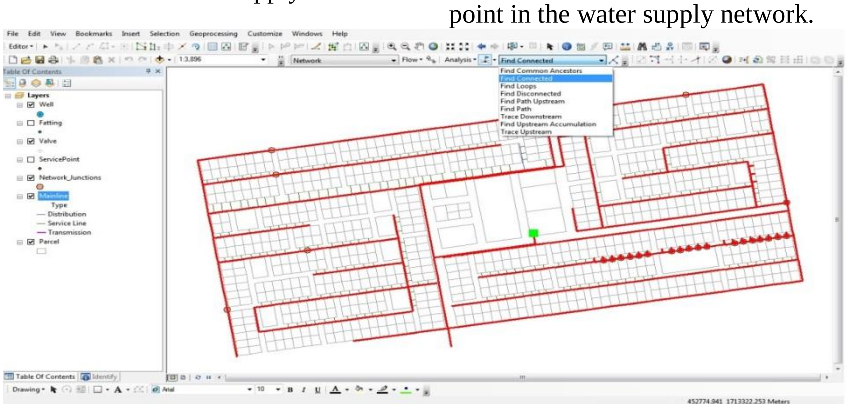
Shape 3-21 the water flow direction after determining the source and the drainage

4. Managing Water Supply Networks

We can use the utility network analyst and the water distribution network on the GIS software to do a number of missions through which the current water supply network can be analyzed and managed through a number of commands on the software as follows:

1) Connected Task

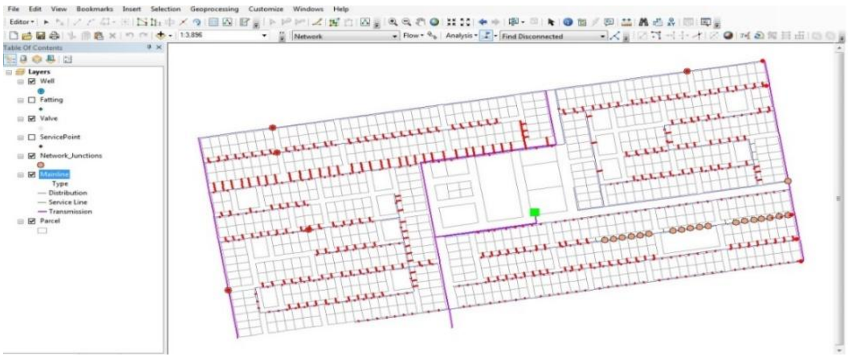
To find all the features that are not connected to a certain point in the water supply network.



Shape 3-22

2) Disconnected task

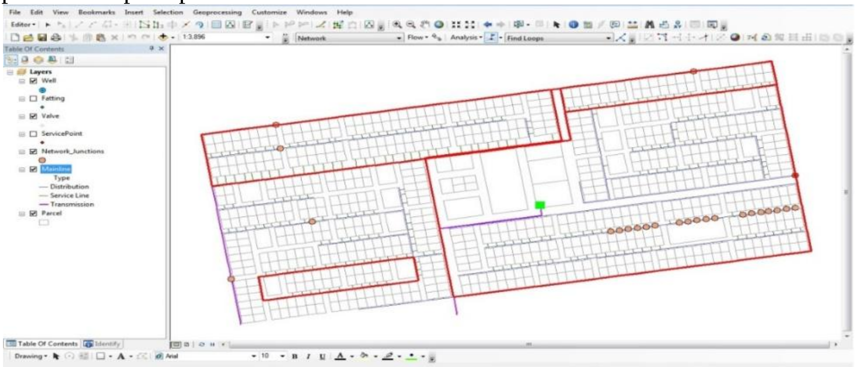
Knowing the disconnection of network's elements with each other.



Shape 3-23

3) Finding loops

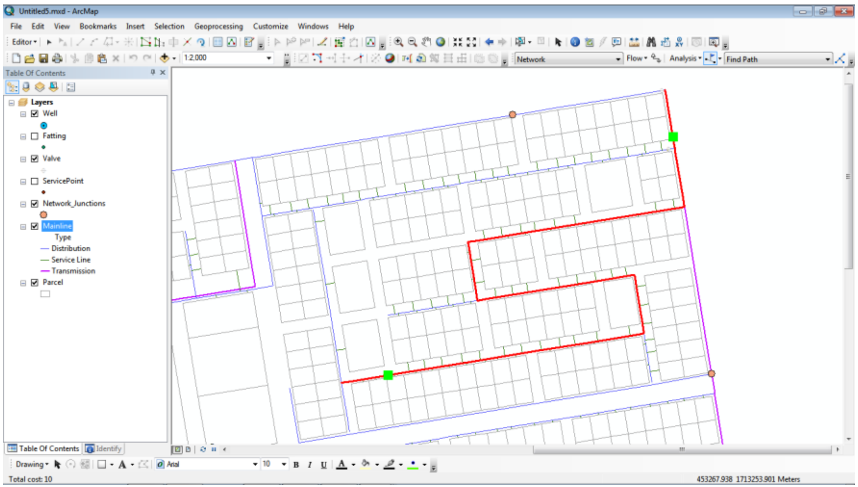
Knowing if there are pipes in a loop shape that leads to a conflict in the water flow direction which leads to a water shortage.



Shape 3-24

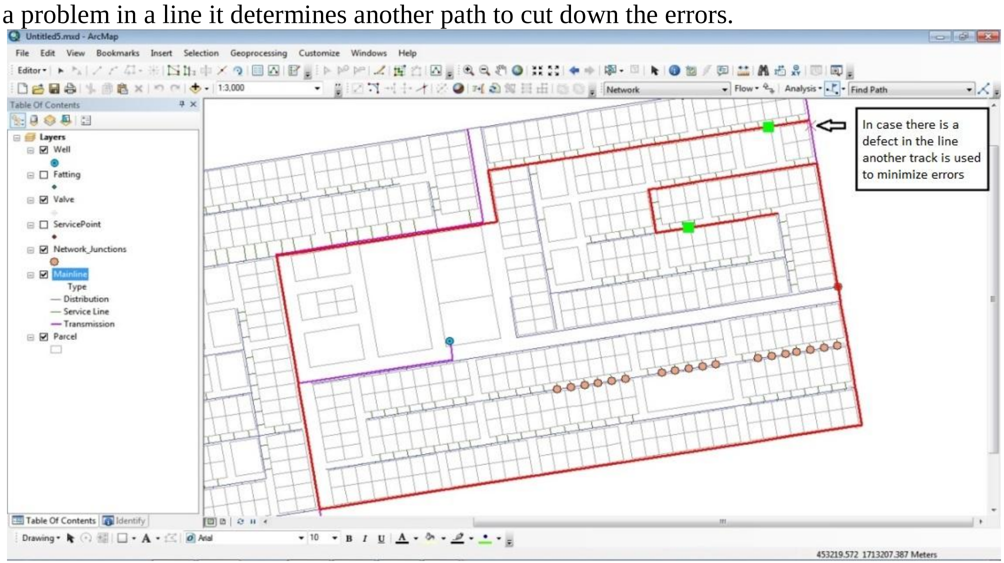
4) Finding the path

Determines the water flow direction between two points in the same network



Shape 3-25

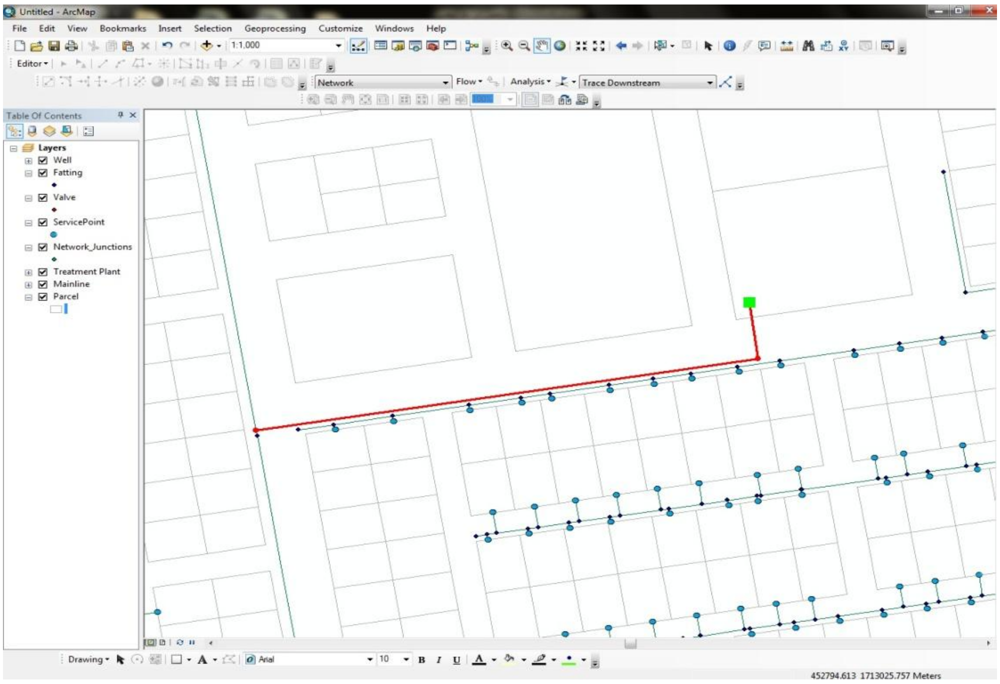
Or when there's a problem in a line it determines another path to cut down the errors.



Shape 3-26

5) Tracing downstream

Determines the direction of a certain point inside the network from its beginning to its end



Shape 3-27

5. Results

GIS was used to manage the water network and this model was applied to the water distribution network in Alazhari, Khartoum as a case to study. And as for the conclusions that we reached to are as follows:

1) The big increase in the inhabitants number in the developing countries in relation with the severe lack of the water reserves pressured engineers into rethinking and coming up with ways that are more efficient ways to manage the water supply networks.
2) The suggested project helps the authorities in monitoring and managing and operating the water supply networks with high efficiency, and in developing a long term plan for the financial expectations for improving the network and maintaining it as a part of an operation that makes continuous updates for the network.
3) GIS allows the possibility of providing a basic map of the state or the country which helps in determining the geographic locations of the water supply network and its attachments and the possibility to analyze this network and connecting it to the database management system such as Oracle and SQL and others to achieve an ideal network.
4) GIS enables us to know the expected age of the network to know when to change the network.
5) The application of the geometric networks helps officials in taking the right decisions.

6. Recommendations

1) Applying technology of GIS in the designing and management of the water supply networks is important for developing countries and it helps in the areas that suffer of the lack of water.
2) We recommend the application of GIS mobile for smartphones for the workers in the maintenance and emergency departments to help them to get to the damage area with the least time and effort.

7. Conclusion

The authorities are supposed to make use of GIS technology. This research studied the water supply network in that area in terms of its type, efficiency and growth plans, in addition to the evaluation of water pumping to users in the study area, and GIS was used to evaluate the evaluation of the efficiency of the network in addition to putting a scenario of how to manage the network using GIS which makes decision making in the least time possible.

References

[1] Anand, S. and Vairavamoorthy, K. (2005), "GIS in Design and Asset Management of Intermittent Water Distribution Systems", City and South Bank Universities: London, England.
[2] Principles of Geographical Information Systems Paperback– June 23, 2015by Peter A. Burrough , Rachael A.McDonnell , Christopher D. Lloyd .
[3] GIS Technology Applications in Environmental and Earth Sciences, 1st Edition, BaiTian,Published September 20, 2016
[4] Khartoum State Water Authority.
[5] Dr. Mohamed Ahmed Mayas (2018) - Foundations of Remote Sensing and Aerial Image Processing.
[6] Ismail Youssef Ismail (2008). GIS Applications: Knowledge Facility Alexandria- Galal Hazzi & Partners.
[7] Gomaa Mohammed Daoud - Foundations of spatial analysis in the framework of geographic information systems - first edition 1433-2012.
[8] Hossam Mohamed Saber - Applied Study of Geographic Information Systems (Surface and Engineering Networks), Wadi Library, Damlhur 2013.
[9] Hossam Mohamed Saber - Applications of Geographic Information Systems https://www.4shared.com/office/XIPiM4vq

[10] Wikipedia Free Encyclopedia, Water Distribution Network, https://en.wikipedia.org/wiki
[11] https://www.iasj.net/iasj?func=fulltext&aId=17610
[12] https://www.facebook.com/MshrwKlyhAlsnhAlthdyryhBnatJamhNjran/posts/498969996886388
[13] https://file.scirp.org/pdf/JGIS_2013061911443910.pdf
[14] www.uobabylon.edu.iq/uobColeges/lecture.aspx?fid=11&lcid=33662