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Impact of Grand Ethiopian Renaissance Dam on River Navigation at Khartoum State, Sudan

Yassin Mohamed Mahmoud Ali[1], Prof. Mustafa Yousif Mohamed[2], Prof. H.S.M. Hilmi[3] and Dr. E. S. Ganawa[4]

[1]**Ministry of Transportation, Road and Bridges, Sudan**
yasin780@gmail.com

[2]**Alzaiem Alazhari University, Sudan**
mustafayousif70@gmail.com

[3]**Future University, Sudan**
hilmi.aau@gmail.com

[4]**Future University, Sudan**
ganawagis@gmail.com

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Abstract

River transport is one of the preferable part of transportation in the country which owns rivers as it is the least expensive and the largest capacity and least impact negatively on the environment, Since Sudan has an extensive network of rivers represented in the Great Nile River, river transport had a great influence in shaping the history of the country. As the river transport vessels are affected by water levels, there is a need to study the effect of the Ethiopian Renaissance Dam on the river navigation in Sudan, taking a specific area in Khartoum state where the Nile tourist berth. The study began by determining the basic depths of the Nile from the lowest level. Here is the concept of depth, which is the distance from the water surface to the bottom of the river. For the purposes of this study we assigned this depth to the level of the earth surface in the vicinity to know the shape of the basin. Geographic Information Systems (GIS) techniques were used in the ARC GIS program and preliminary data collected from the study area were obtained by means of a bathymetric device and the locator (GPS). The program was processed by means of statistical tools for the depth of the study area. By using the Raster calculator and producing the final map. The secondary data was obtained from the study of the Ministry of Irrigation and Water Resources, the Research Hydraulic Center and Studies for River Navigation Authority, Ministry of Transport, Roads and Bridges, for the study of the Berber-Khartoum-Kosti navigational study year 2016. The data represented water levels in the Nile after the dam operation. For the Khartoum area in March, which corresponds to the initial data collection which represents the lowest level of Nile, and was processed by the program and the production of final maps. The results show that after the operation of the dam will increase the navigable area where the increase in the rate of two meters in the lowest level of the Nile in the dry season, which increases the depth of the same value, which facilitates the movement of rivers and reduce the amount of large quantities of removal in the shallow areas proposed in The study was conducted by the Ministry of Irrigation and Water Resources that mentioned above.

Keywords: *Grand Ethiopian Renaissance Dam, Khartoum State, River Navigation.*

1. Introduction

The river navigation means the river utilized for transport with different types of river vessels. For navigation we need depth of water or from this we can say level of water. This point is an important factor for navigation. The river used for transport history that people build the old civilizations that adjacent to it. Rivers are the resource of life because rivers are representing the easiest healthiest resource of water. From born of life at the Earth people used rivers for transportation trade, social and militarist. Blue Nile is the main stream of the Nile. Its charge the Nile about 59% of the total amount of water charges, that gives it the highest effect for the water level at the river. The distance of the river from its source to its confluence has been variously reported as being between 1,460 kilometers (910 mile) and 1,600 kilometers (990 mile). This uncertainty over the length might partially result from the fact that the river flows through a series of virtually impenetrable gorges cut in the Ethiopian Highlands to a depth of some 1,500 meters (4,900 ft.) depth comparable to that of the Grand Canyon of the Colorado River in the United States of America. According to materials published by the Central Statistical Agency, the Blue Nile has a total length of 1,450 kilometers (900 mile), of which 800 kilometers (500 mile) are inside Ethiopia. The Blue Nile flows generally south from Lake Tana and then west across Ethiopia and northwest into Sudan. Within 30 km (19 mile) of its source at Lake Tana, the river enters a canyon about 400 km (250 miles) long. This gorge is a tremendous obstacle for travel and communication from the north half of Ethiopia to the southern half. The power of the Blue Nile may best be appreciated at the Blue Nile Falls, which are 45 meters (148 ft.) high, located about 40 kilometers (25 mile) downstream of Lake Tana. GIS is one of the modern science that developed the concept of traditional maps into digital maps with its possibilities and tools, it was used at this study to develop new concept of river navigation maps and to find a high level of safety on water ways.

2. Boundary of Study Area

Study area is a part from Blue Nile which's located at eastern of Khartoum city with length (5.5km) from southern Elmanshia Bridge to eastern Kobar Bridge with maximum width (320m) at buri beach. Study area have carved shape from south to north and from east to west with boundary (15o 37' 10'' N, 32 o 34' 20''E, 15 o 35' 45''N, , 32 o 35' 30 ''E). Figure 1 shows the study area location and Figure 2shows the study area in polygon with true boundary. Total length is 4.46 km majored from width line on the river and total area is 1543.716 km

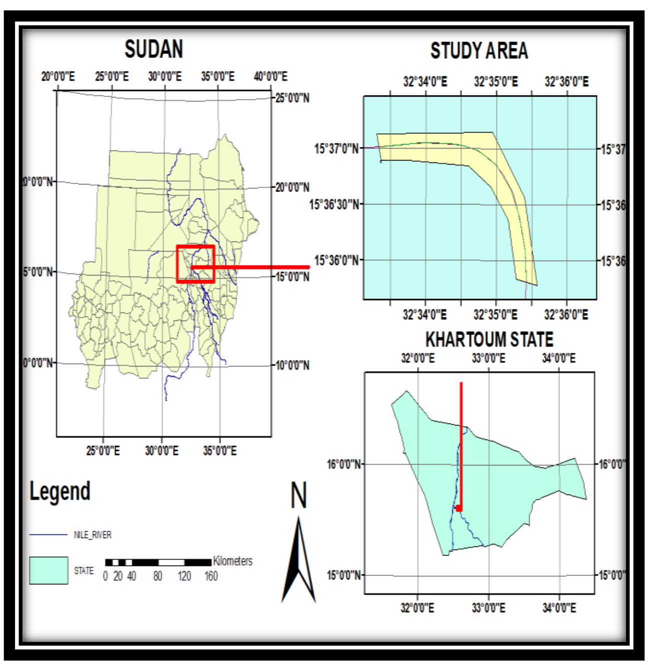

Figure 1: The Location of study area in Khartoum

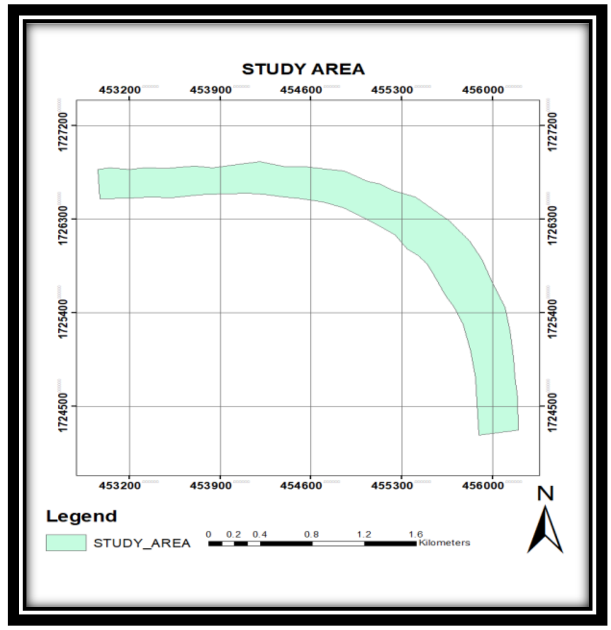

Figure 2: The Location of study area

3. Methodology and materials

The method used to achieve the objective include (a) Field data was collected from study area at 26/3/2018. The data are represents (x,y,z) points about 131 points was measured by RTK GPS & Echo sounder. (b) Water level prediction data was used after the Ethiopian dam work and (c) satellite image to describe areas.

Table 1: The data that used for research

Data	Type	Provider	Projection
Depth data	Vector	Primary data	UTM WGS 1984 36N
Flow prediction after the Ethiopian dam work	Water level	Hydraulic research center	
Satellite image	Multispectral	Google Earth & Base map	

3.1 River bed elevation data

Control point (bench mark) was utilized (x,y,z) (455725.6, 1724515, 383.495)m near Elmanshia bridge by RTK GPS and found other one over the bridge (455813.1, 1724622, 386.26)m to give the portable device good radio signal to cover the target area . Then we put echo sounder at side of the boat near the middle boat beam line the place where more stable and far from engine noises and put GPS antenna nearby. the distance was measured from water level to Echo sounder device (offset) and read it manually with any observed point to correct Echo sounder read. the starting of collection data done by team work (boat driver, one at RTKGPS, one at Echo Sounder, one observes offset, one at note and two persons to replace another team).

3.2. Water level data

The simulated data for water level gathered by Hydraulic research center by request from River Navigation Authority to study river navigation route from Barber to Kosti with total length 725 km. They used hydrodynamic model (Sobek) which used cross section to run and give very accurate result after good calibration by real data from station gauges.

Data was used at this study consist of two parts:

- primary data (field data collection) which is depth data collected by echo sounder from study area
- secondary data acquired from (HRC) ministry of water resources (water level data before and after GRED operation

3.3 Materials

3.3.1 Real Time Kinematic (RTK)

3.3.2 Echo Sounder

3.3.3 Boat:

For collection field data from the river, fiberglass boat was utilized to carry the Echo sounder and GPS with teamwork (L.O.A:7m, B: 2m, d: 0.3m, Eng.:40hp).

Low speed of vessels used when data was taken (3km/h).

3.3.4 Software used

Two softwares were used:

- Excel for pre analysis data at tables (field data).
- ArcGIS for interpolation and layout

3.4 Conceptual Framework

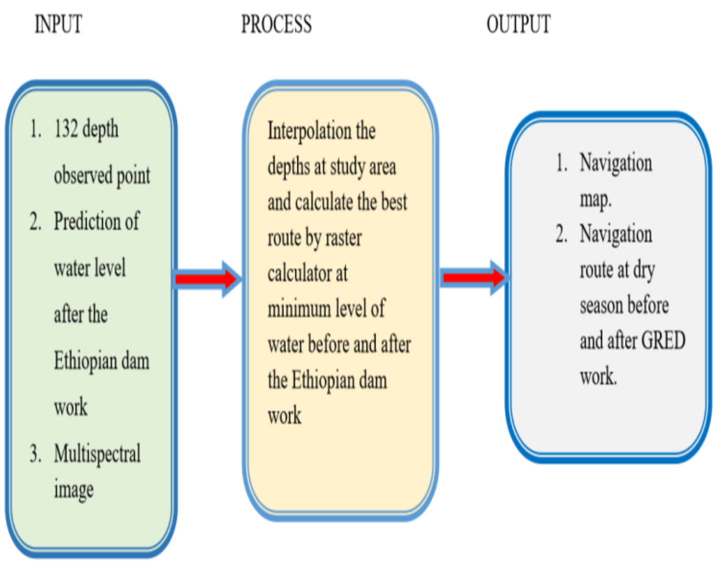

Figure 3: Research Conceptual Framework

3.5 Data Analysis

3.5.1 Primary data:

Arcgis was used for analysis after entering data to Excel sheet and make preproces to add field data by :

a. Add table on Arc GIS by(add x,y data)
b. Export table to shapfile and load it on featuer class
c. Creat new polygon shapfile and edit study area from basemap.
d. Start analysis by geostatistical tools
e. HRC data was used in the study and repeat adding by upove steps

RTK GPS data:

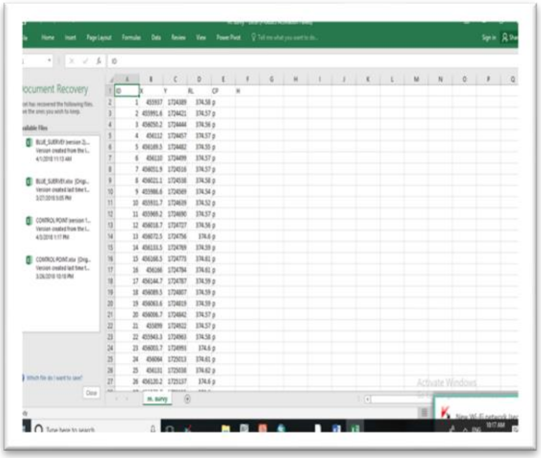

Figure 4: the data loaded from GPS

Echo Sounder Data:

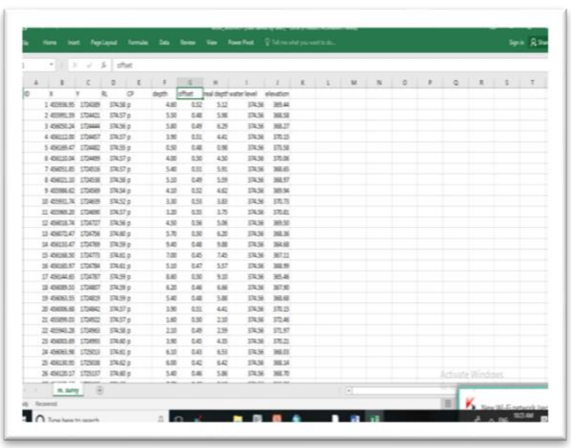

Figure 5: data of echo sounder

At this sheet data loaded as follow :

a. Depth: that was measured by Echo sounder and give the distance between river bed and device. But this values are not real depth becuese there is distance between water surface and Echo Sounder device .
b. Offset:the distance between water level and Echo Sounder. We read it manualy for each boint to correction the depth.
c. Water level: we caculate the avof three GPS reading .
d. Real depth: given by ((offset)+(depth))
e. Elevation: depth converted to elevation that rivers not like sea it have slope and elevation over sea level .it geven by((water_level)-(real_depth)). After completing the table the graphs has been reformed.

1. Add data at ArcMap (add x,y data)

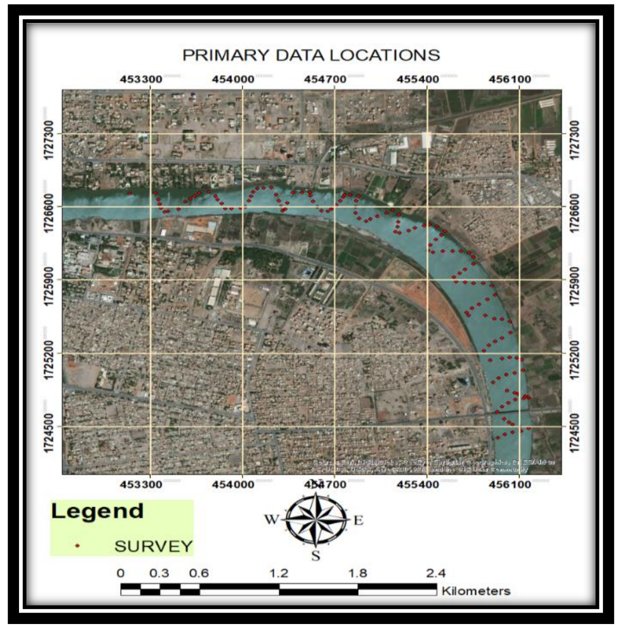

Figure 6: The survey points

2. Add base map and drow polygon around the river to boundring study area.

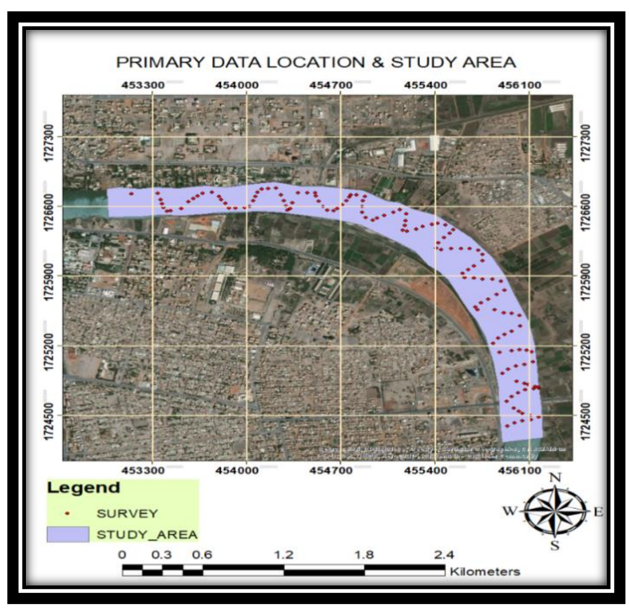

Figure 7: Base map of the study area

The study was clipped by polygon to gurntee to contain the result of interpolation.

3. Befor start analysis we open hitogram on geostatitical tools to shwo detripution of data.

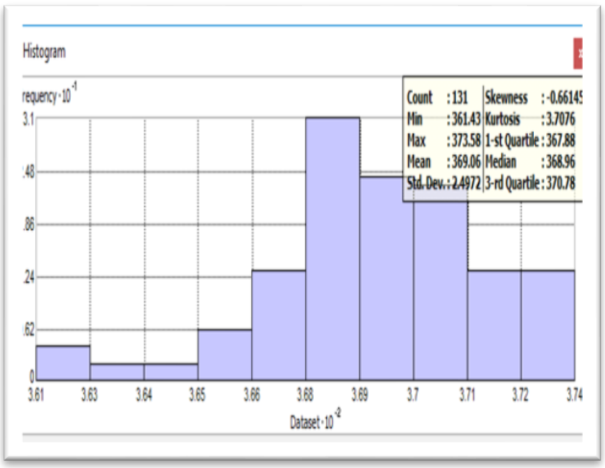

Figure 8: The River bed elevation

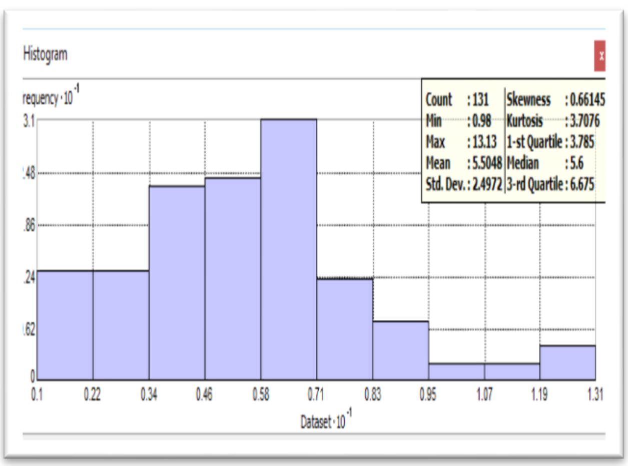

Figure 9: The Real depth histogram

4. Used kriging method to interpolate un sampled area

3.5.2 Secandary data:

GRED data from ministary of water resources (HRC):

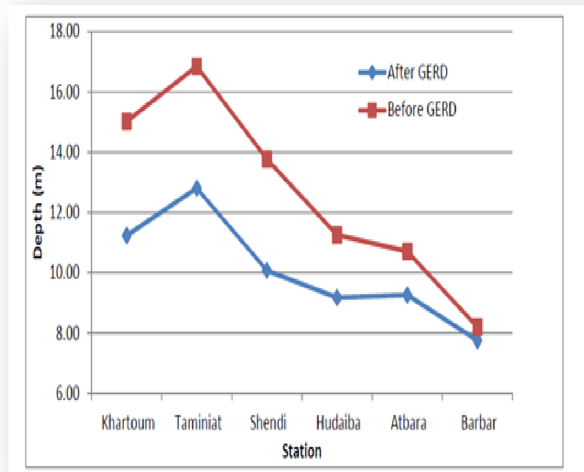

Figure 10: water depth (navigation study 2015 (HRC))

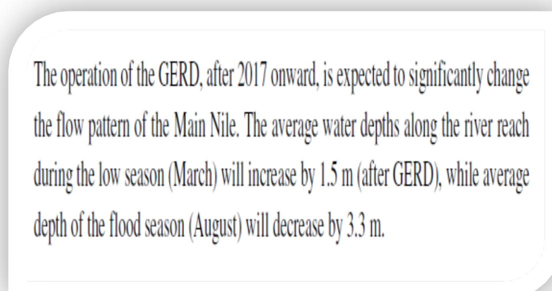
The operation of the GERD, after 2017 onward, is expected to significantly change the flow pattern of the Main Nile. The average water depths along the river reach during the low season (March) will increase by 1.5 m (after GERD), while average depth of the flood season (August) will decrease by 3.3 m.

Figure 11: data of water level from water resources (navigation study 2015 (HRC))

From dataabove we can notic the increasing of water depth at Khartoum is equale to 2m.

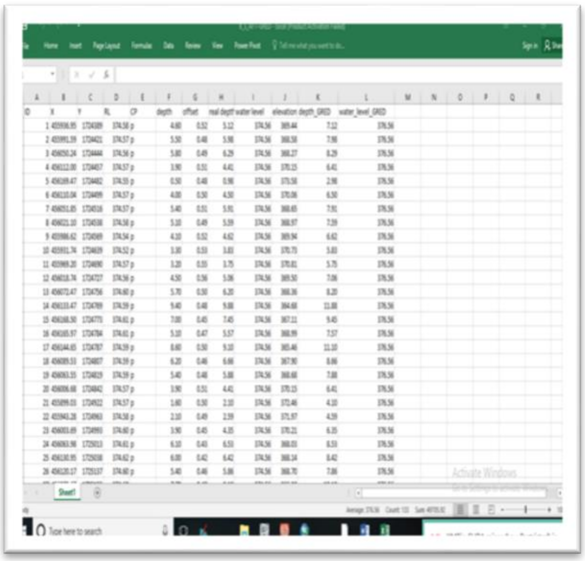

Figure 12: The water level after add 2 meters

At this table we added the (HRC) data to water level and real depth columns (2m+real_depth&water level).

4. Results and Discussions

In this chapter we fined the results of study after we finished analysis. The results consist of graphs that show sample values & water level, and maps which shows depth interpolation and navigation paths.

4.1 Water level & bed elevation

Water level was calculated z value from the average of three reading points by GPS during survey. Water level is the very important factor at bathometric survey and it was linked with the time because water level is variable with time.

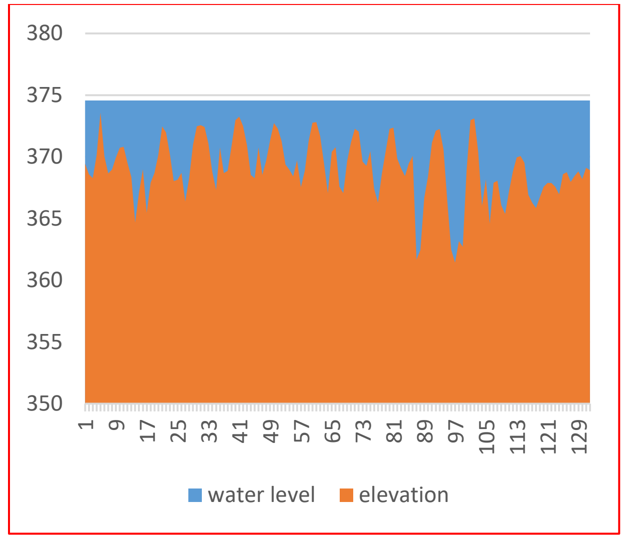

Figure 13: water level & depth

The figure above shows water level at dry season and river depths under it by elevations with 2 dimension seen refers to sample points.

4.2 Real depth

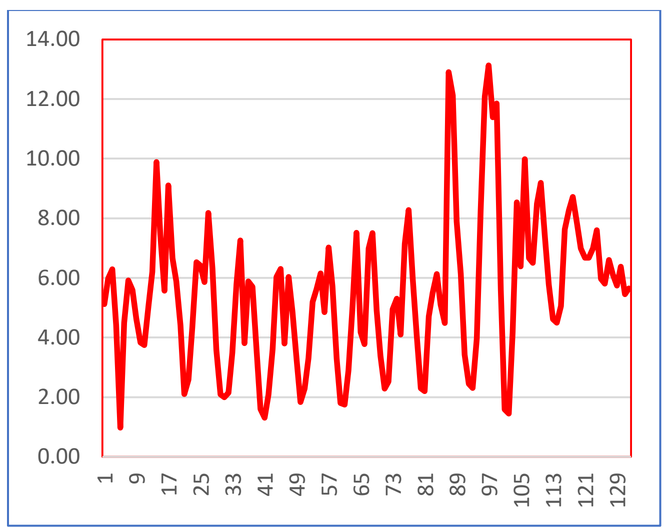

Figure 14: Water depth

At this graph above we can see the real depth from River surface to River bed at x axes we find umber of sample points and at y axes we find depth value.

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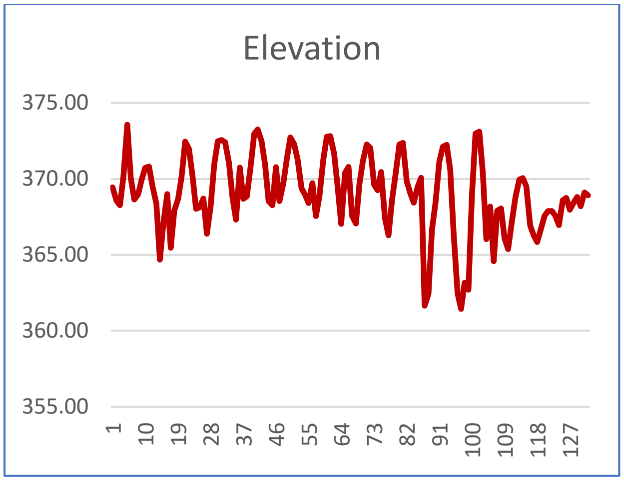

Figure 15: Real depth

At this graph above we can see the real depth from River surface to River bed, at x axes it is found that the number of sample points, and at y axes the depth was represented by elevation. That to show basin by real elevation on study area.

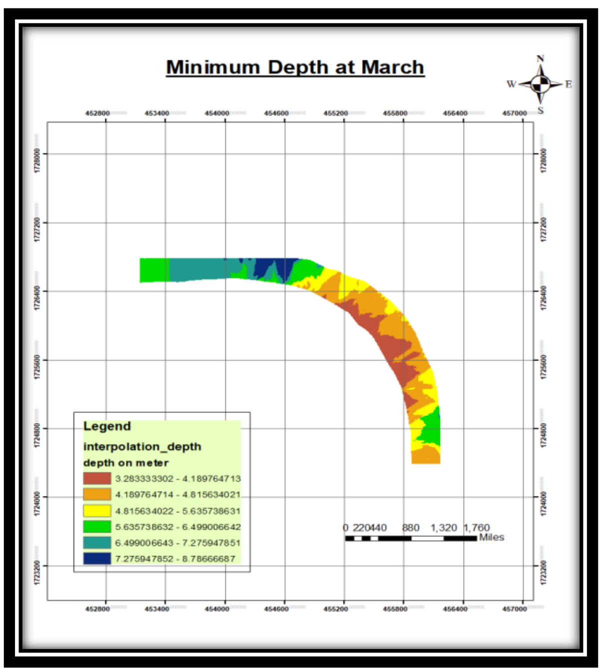

Figure 16: Interpolated depths

Study area covered by depth value, kriging method was used to predict unsampled area.

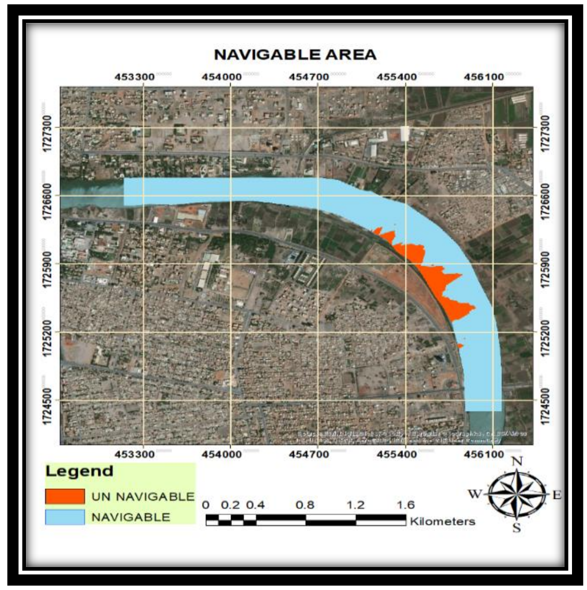

Figure 17: navigation path

By raster calculater area must be(>=4m) to give the navigable area because the maximum river vessels draft is (1.8m) and for safe navigation or sealling they need (1.25m) under the keel and here we put (1m) more for more saftey and remove any expect error from interpolation.

This map is representing the study area at the river by two color, red is mean the depth on this area are less than 4m and it not good for navigation but the blue one is more than 4m and it safe for navigation, this analysis for minimum depth at dry season.

4.3 Water level after GERD

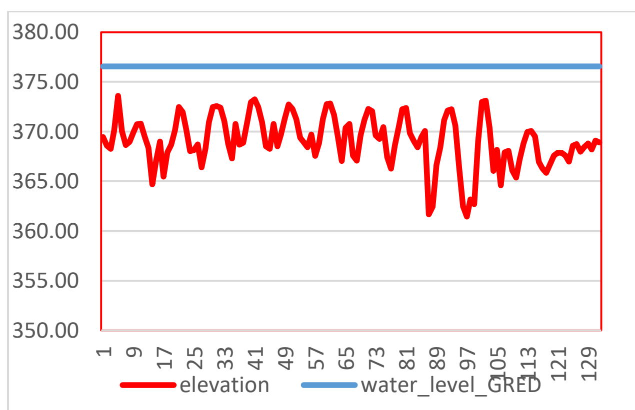

Figure 18: Water level & bed elevation after GRED work

Graph above illustrates the real depth from River surface to River bed at x axes we find number of sample points, and y axes illustrates depth value by elevation after GERD work.

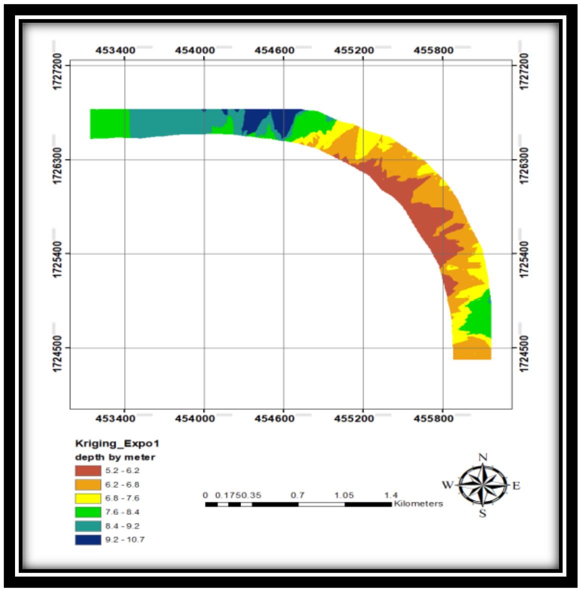

Figure 19: Depth after GRED Operation

At this map above we fine study area covered by depth value, we used kriging method to predict non sampling area but we inter the new sampling value for depth by add 2m for each one.

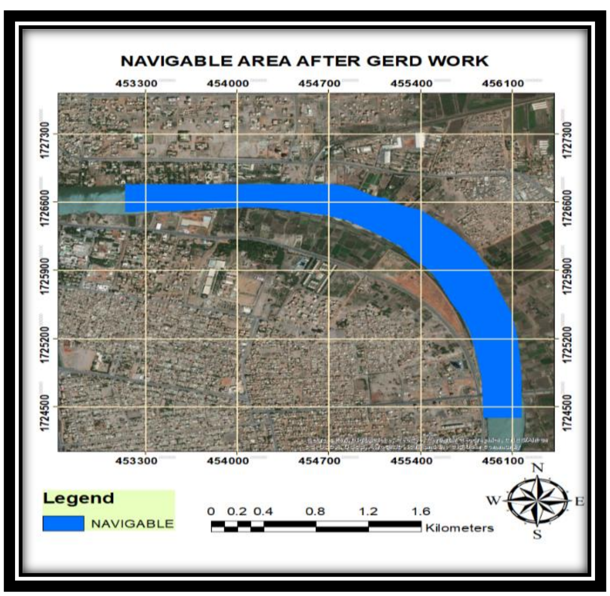

Figure 20: The navigation path after GERD work

This map is representing the study area at the river by blue color and all study aera is navigable.

5. Conclusion

From this study we can conclude the following remarks:

- Throughout this study, the best navigable path was found by calculate the effecting factors that cripple on vessels movement.
- Using navigation maps provides safe and easy river navigation at day and night. Because it gives the vessel's crew the navigable routes and dangerous areas.
- The depth on the navigation map presented by the lowest level of water at dry season which considered the most dangerous time for navigation.
- The studies conducted on the Nile levels were taken into account after the operational period of GERD which resulted in increased the navigable area.
- Compared with previous studies, it was found that the use of interpolation in GIS gives rewarding results for un sampled depth which lead to save time and effort.

6. Recommendations

From the results and findings of this study, following recommendations can be drawn:

- Include the data generated from the water current analysis in the navigation map.
- Include data generated from the difference between the bridges height and the fluctuating water surface elevation in the navigation map.
- This study cab be generalized for all water ways of river Nile at Sudan to provide the navigable route.
- Validate the result navigation map by random samples depth using echo sounder to measure the accuracy of interpolation.

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