Developing a Computer Simulation to Study the Behavior of Factors Affecting the Flooding of the Gash River

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***Abstract*—In recent years, the city of Kassala has suffered from frequent flooding disasters in the Gash River, which is the city's lifeblood. But the problem of frequent flooding of the river has made it a life-threatening nightmare. The importance of research lies in the fact that it is one of the few attempts to discuss and study the causes and effects of the Gash River floods. It aims to identify the factors affecting river floods. It proposes an algorithm to simulate flooding by randomly generating different factors that effectively affect river flooding. The descriptive analytical approach, the analytical, inductive approach, and the analytical deductive approach to desk research were used, taking advantage of the primary statistical method in its observation and evaluation, which relies on primary and secondary information to help make scientific, practical, and objective. The research came out with significant results related to the problems that threaten the town of Kassala from the frequent floods of the Gash River. The study's results proved that there is a deviation and discrepancy between the floods rate during the year, which gives a negative indication, and that deposited quantities vary in different proportions from one period to another, which causes a significant threat in the future. The research suggests other solutions that help reduce the problems and their effects. In addition to the above, the study proposes various recommendations that will be the basis for future studies to reach the required solutions and goals.**

***Keywords*—Gash river; flood simulation; influencing factors to flood; simulation**

I. Introduction

Floods frequently result in significant economic losses and harm to people and the community [1]. Flood forecasting and management have thus always been difficult for the government and local governments [2, 3]. As more and more computer models are used for flood management [4], there is an increasing need for innovative and effective ways to visualize large amounts of data about floods. In addition, because interaction is one of the most critical factors in modern decision-making tools, simulation effectiveness has become a significant factor [5, 6]. Flooding in urban contexts is typically associated with a complex landscape involving technical, social, economic, and environmental issues [7]. The Gash River is a seasonal river that descends from the Eritrean plateau and reaches the Sudanese border, 30 km south of Kassala. It passes through the city of Kassala, passing through the Gash Delta Agricultural Project, to end at the Gash Delta, about 91 km north of the area of Kassala [8]. The natural features of the Gash River are unique characteristics, including the steep slope, which is six times the sharpest stream in Sudan, as its slope within the Sudanese borders is 1.3 m / km at Kassala city, which gave it the ability to bring high loads of siltation [9].

Soft, sandy soils and fragile banks characterize the riverbed banks. It is easily eroded by high currents and fragmentation and change course from one place to another. These factors combined lead to the occurrence of flood phenomenon [7]. The area of the basin of the Gash River is estimated at 21.000 km2. Most of it is located within the Eritrean lands and at contour heights ranging between 2000 and 1100 m above sea level. This basin is located between longitudes 36.5 and 39.5 east and latitudes 14 and 15.5 north. The river in Eritrean territory has a steep slope that reaches 5.5 meters per kilometer. The transition from about 2000 meters above sea level at its source to only about 550 meters at the Sudanese border [9] makes the flood waves rush very quickly. It reaches 2 meters/sec sometimes [8]. Therefore, the Gash is among the fastest rivers in the world [10]. The river's slope within the flat Sudanese plain is estimated at 1.3 m / km.

The importance of the study lies in the fact that it reveals the role of technical means in reducing water losses due to Flooding and benefiting from them in drinking, agriculture, and creating new projects in the agricultural field. And this study takes a fresh look at the country's flood management, and explores methods for lessening the likelihood of flooding and the damage it might cause [11].

In addition to reflecting technical progress, designing a computer simulation model for the behavior of factors affects flooding.

The Gash River has become a source of fear and anxiety because it floods and damages the economy, society, and environment. These floods are caused by many factors work together. Which is difficult to predict and control, and whatever the matter is, floods are a natural phenomenon that spreads in all parts of the world, and this is not the dilemma, but rather the difficulty remains in that we avoid its occurrence and prevent the disaster before it occurs and to what extent we contribute to it [12].

The study is concentrated in Kassala State. Kassala State, its capital, is the city of Kassala. The area of Kassala State is 55.374 square kilometers, and it is located between latitudes 12-34 and 36-57 east and longitudes 12-14 and 12-17 north. In the east, the state's borders are shared with the country of

Eritrea. Internally, it borders the Red Sea, Gezira, and Gedaref states [13]. The state enjoys a prominent geographical location that helped its growth and made it a center for many commercial and investment activities. It provides essential services and all factors that help investment. It is known for its beautiful scenery and lush gardens, which make it the most important place for tourists to visit. There are many agricultural projects, such as sugar cane production, corn and wheat too. The populace also engages in trading and pastoral work.

II. Morphology of the Gash River

The Gash River is known from the morphological point of view as a cascading river, where the river is wide and shallow. In this type of river, the current takes several directions, is unstable, and constantly changes its course and characteristics [8].

The Gash River carries large quantities of Silt (primarily fine sand and Silt). Due to the sharp decrease in the river's slope when it crosses the Sudanese lands, these quantities exceed the river's ability to transport it. It is deposited along the course of the river until its end, which caused the river's steadily reducing capacity and inability to transport it Passing High Floods Safely [9].

III. Methodology

The research method used in the study is the descriptive analytical method, and this approach is also called the in-depth descriptive method. In this method, the research describes various scientific phenomena and problems in detail, allowing good explanations and results. Using the descriptive-analytic approach, different things are compared to similar items. This allows data to be collected about the differences and similarities between things, which are the most important things that make the descriptive-analytical approach different from other scientific approaches [15].

The descriptive-relational approach is also used because it is related to the nature of the study. It also relies on analyzing the existing system and using diagrams, graphs, flowcharts, algorithms, design, and software to create a more accurate and efficient system. According to the explanatory method, relational studies define problems and analyze them into their essential elements [15] by presenting events and facts and analyzing them. Also, the inductive-analytical approach involves immersing in the details and reasoning behind the points to identify significant patterns, themes, and interrelationships, after which the results are confirmed using analytical principles rather than rules [14]. The study also follows the deductive analytical desk research approach, in which the literature related to the subject of the study is reviewed.

IV. Model Description and Algorithm

To study the current situation, the study dealt with the problem of the Flooding of the Gash River by simulating the factors affecting the Flooding in the form of randomly generated variables within the program environment.

A. Factors Affecting the Flooding of the Gash River

There are many factors affecting the Flooding of the Gash River. Still, they can be limited to natural, technical, and other artificial causes attributed to some harmful practices.

B. Flood Estimate

The Gash River is distinguished for its wide fluctuations in its water revenue throughout and between seasons (Table I). Evidence indicates changes in the river's hydrology as a result of changing the natural properties of the upper river basin in the State of Eritrea, especially the removal of vegetation and soil erosion, which made the flood wave more severe and shorter in time. This is in addition to the global climatic changes that began heralding the high precipitation rates in 2007 AD [9].

TABLE I. Shows the River's Discharges from 1997-2010 (Al-Jira station) [8]

Year	Total Revenues Upstream - Million Cubic Meters	Year	Total Revenues Upstream - Million Cubic Meters
1997	111.58	2009	452.57
1998	565.21	2010	680.69
1999	1386.66	2011	1007.41
2000	1240.00	2012	704.04
2001	1007.41	2013	888.89
2002	704.04	2014	1313.09
2003	1449.49	2015	1300.66
2004	874.97	2016	440.00
2005	1101.00	2017	760.00
2006	1207.75	2018	663.80
2007	1760.00	2019	450.85
2008	665.20	2020	673.02

We note from the above table the great variation in the river's revenues during the season. We also notice the difference in the discharges and returns of the river during a number of selected years at the Al-Jira monitoring station at the source (Fig. 1) illustrates this.

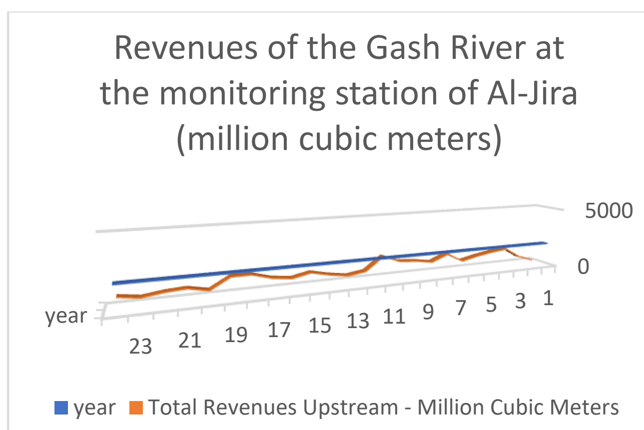

Fig. 1. Shows the discharges and revenues of the river at the Jira station upstream.

Flood estimation methods aim at modeling the relationship between falling rain and the resulting surface runoff. In general, these methods can be divided into three groups. The first group is called simple methods - such as the logical method and implicit equations - from which the value of the peak behavior can be estimated quickly and based on a Small amount of information. The CN Curve Number method is one of the methods of the second group or group of medium complexity [16]. The third group includes straightforward or more complex methods, which depend on the study of each element involved in the phenomenon, the transformation of rain into a surface runoff, and detailed and in-depth analysis. The number curve method is the most prevalent in engineering studies and natural resource management projects, especially in the US states [17].

C. The Nature of the Gash River (The Strength of the Gash River Current)

The significant fluctuation represents the characteristics of the Gash River in the flow, the steepness, the high speeds, high loads of Silt, the broad stream, and the fragile banks combine to form a community that threatens the river's bridges and its widths.

D. Silt

Problem of Silt is one of the most important problems associated with irrigation, drainage, floods, and natural rivers. Generally, dredged Silt represents about 5 to 25% of the total Silt carried, but its importance is that it affects the roughness and stability of the stream. Table II shows the quantities of dredged Silt during periods of years from 2010 to 2020.

As can be seen in Table III, the amounts of Silt vary significantly not only from season to season, but even within a season.

TABLE II. SHOWS THE QUANTITIES OF DREDGED SILT DURING THE PERIOD FROM 2010 TO 2020

Year	Total - mm3	The upper limit is 3 mm
2010	1290	470
2011	0930	385
2012	0810	370
2013	1430	870
2014	0400	205
2015	0535	365
2016	1165	575
2017	1010	395
2018	0960	290
2019	0540	295
2020	0540	295

TABLE III. SHOWS THE DIFFERENT AMOUNTS OF SILT

Date	Attributed	Suspended Silt (ppm)
21/08/2020	508.0	1753.7
22/08/2020	507.0	1450.5
25/08/2020	506.9	13458
27/08/2020	506.8	13300
29/08/2020	506.6	11976

The table shows that silt quantities vary seasonally and within seasons.

The amount of Silt in the water decreases according to the amount of water (water levels). The higher the group, the higher the amount of Silt attached to the water. We find the rise of the stream bed in the two divided sectors of the river, in front of and behind the network of bridges and wide's, receiving their share of the Silt carried from the upper reaches of the river [9].

E. Various other Reasons

There are many harmful practices carried out by the population that affects negatively, including some activities around the river basin have adverse effects such as planting trees around bridges, erecting buildings, constructing bridges and beams inside the bay, taking soil from bridges, or digging latrines and wells in the areas adjacent to the bridges [18].

F. Elevation of the Levels of the Gash River

This is due to three main reasons:

First: the climatic and hydrological changes represented in the disappearance of the vegetation cover and the increase in water and silt discharges, the engineering works that prevented the natural venting that was occurring in the Tajuj region at high levels, and the collapse of the dams built on the Gash River in the State of Eritrea.

Second: Weakness of the conveying capacity of the gutter as a result of the presence of suffocating facilities such as bridges and bridges.

Third: the morphological changes that led to the rise of the riverbed due to sedimentation due to the lack of slope.

All these reasons combine to cause a catastrophe, as happened in 2003. Climate change is a global phenomenon that warns of more variation in precipitation and high waves of floods. The rise in the river water level as result of heavy rains was accompanied by the collapse of some dams in the country of Eritrea, which exacerbated the severity of the floods [8].

Program algorithm generating random numbers to simulate the factors influencing Flooding

```
1. Start
2.1   let I= 1
2.2    sum=0
2.3    pita=300
3.     Let          Z=random (10)
4.     If (z = 0)
{x=0}
Else
{x=pita*Z}
5.     Near the value x to an integer
6.     If (x=0)
{M=pita/4 Go to 8}
7.     Let M=ceil(x)*1/4
8.     Sum = sum + ceil(x)
9.     Print value ceil (m), ceil(x)
10.    Let I=I+1
11.    If (I<=10)
{Go to 3}
12.    Print Report
13.    End
```

In the algorithm

I: represents the loop counter.

Pita: means the amount of water.

Z: represents the randomly generated number from the random function. The random process generates random numbers for unrelated events; the Ceil function approximates the correct number.

M: represents the amount of Silt, which is calculated by the formula m=pita/4.

Fig. 2 shows the sequence of steps of the above program and algorithm through the following flowchart.

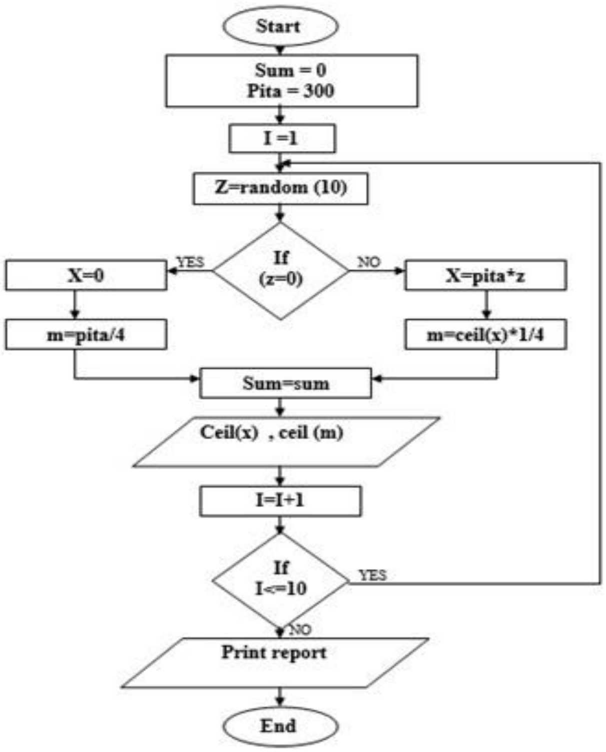

Fig. 2. Flow chart of algorithm.

Fig. 3 illustrates the implementation of the program, and we find that the sediment quantities vary in different proportions from one period to another, which causes a great threat in future periods.

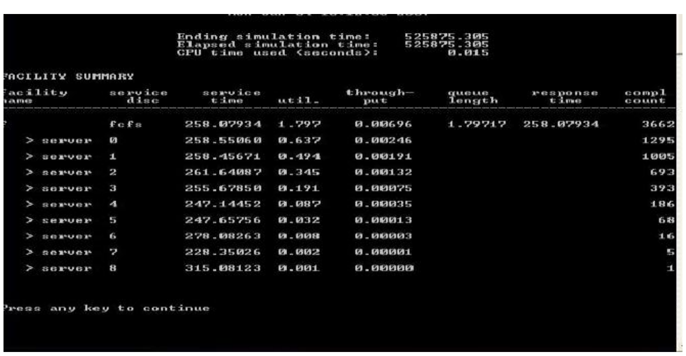

Fig. 3. Shows the program execution screen.

TABLE IV. SHOWS THE OUTPUT OF THE PROGRAM

Year	M (The amount of clay)	X (Quantity of Water)
1	1800	450
2	2400	600
3	0300	075
4	1800	450
5	1200	300
6	2400	600
7	0600	150
8	1800	450
9	0300	075
10	1800	450

Table IV shows a reflection of the implementation of the program shown in (Fig. 3) and shows the relationship between the amount of water in the river and the amounts of suspended silt for ten consecutive years generated randomly.

The total amount of Silt after 10 years is 3600 m.

V. IMPLEMENTATION

A Markov distribution was used to generate random numbers and compare unrelated cases with equal probability distribution using the beta parameter calculated from the entire population.

A sample of 10 years was taken to take the average from the actual reality of the cascade generation that occurs annually starting from the base year. Table V shows the average level of the river level during specific years at the Al-Qash Gash Bridge monitoring station in the city center, as well as the lowest rate, highest rate and the standard deviation.

By comparing the result of the program and the actual reality, we find the relationship between the level and the Silt is correct.

Benefit from the program in calculating the amount of Silt deposited after each number of years.

TABLE V. AVERAGE RIVER LEVEL DURING SELECTED YEARS - AL-GASH BRIDGE MEASURING STATION

Year	The Lowest Rate	Highest Rate	Standards deviation
1990	15.00	210.00	31.2842
1999	504.00	506.00	0.3167
2003	504.00	505.90	0.2563
2005	504.05	505.95	0.3553
2008	505.40	506.01	0.2986
2010	504.70	505.95	0.1951
2015	504.90	506.10	0.2346
2019	504.19	506.45	0.3481

The results of the study proved that there is a large deviation and variation between sedimentation rates during the year, which gives a negative indicator, and that the amounts of sediment vary in varying proportions from one period to another, which causes a great threat in future. It is also expected that the amount of Silt deposited by this algorithm will be about 8.450 mm3 in the year 2035 AD. Different river speeds, revenues, and flows reveal a clear relationship between the volume of water and its rate and the amount of Silt drifting and traveling from one place to another within the same season. The study also proved that the annual average of rain is not considered a good factor for the strength of the rainstorm in estimating the severity of the flood, as it is possible for the power of one of the rainstorms to exceed this annual average.

The study also concluded that increased sediment quantities over the years led to a rise in the river level higher than the level of agricultural lands. This was one of the primary reasons and systematic risks that allowed the river to stray from its intended path. Changing the course of the river may pose a danger in the future.

VI. Conclusion

Developing this model includes all elements have an indirect effect, such as evaporation, soil type, and wind.

The model works on developing a distant understanding, a broad horizon, and an open mind in the applied aspects at all administrative levels, especially about the applications of simulation models.

Also, this model benefits in the field of forecasting and future estimates of the quantities of silt and water for the Gash River.

The application of this model in the investigation and exploration of the river is a powerful technique through which we can provide planners of water resources with an acceptable estimate of the amount of running water and the quantities of suspended Silt that are expected to be deposited.

The results of the model can also be used to help city planners and decision-makers make plans for the future of Kassala city; applying this modern technical method (simulation models) in flood management in the country.

The researcher suggests that there will be future studies that follow the technical method on the basin's area, the mainstream's length, and the peak discharge.

It is also suggested that there be studies of the geological formation, soil permeability, and type of land use around the course of the Gash River to avoid the risks of floods in the future.

Similarly, more in-depth studies reach more detailed results to advance this region and develop it in the future in terms of economic and social aspects.

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