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Rehabilitation of the Nile River Morphological Characteristics For Navigation Considerations

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Abstract: The Nile River is recognized as an alluvial river with high morphological changes. Sedimentation is a key issue affecting the management of water resources. Concerning navigation, the problem of lack of appropriate depths for the movement of ships is observed, especially in periods of lower water levels. This study aims to investigate the morphological changes, improve the flow characteristics, and solve sedimentation issues in front of a proposed navigation dock in the Nile River. Sediment buildup causes a decrease in water depth and flow rates, making navigation more difficult and raising maintenance expenses. This study discussed the evaluation and implementation of solutions to enhance flow velocities, minimize sediment deposition, and improve the navigability and sustainability of the riverine transportation system. A built and calibrated two-dimensional mathematical model SMS was used to simulate morphological changes at the studied river reach affected by deposition. The solutions can be summarized as dredging around the study area in front of the navigation dock to solve the problem of the lack of appropriate depths for anchoring the units, using spur dikes on the western bank to direct the flow to the study area, and combinations of both dredging and using spur dikes. Twenty-two alternatives were studied in the case of average discharge. Two best solutions including both dredging and using spur dikes were concluded. The two best alternatives were studied in the cases of max. and min. discharges and proved to be effective solutions.

Keywords: Nile River, Morphology, Navigation, Dredging, Spur dikes.

1. INTRODUCTION

Sedimentation can have major negative economic and environmental effects on water resources management due to its contribution as an obstacle on the riversides, leading to the reduction of water velocity on its sides and deposition. Waterways that frequently require dredging are one example. Negative effects of sedimentation tend to become more and more relevant globally due to human intervention.

The consequences of climate change on the hydrology and morphology of River Basins have to be evaluated [1]. Also, it is important to study the sedimentation pattern (distribution and rate) at the river estuary at the existing and ultimate conditions [2].

Using a skimming wall and a combination of skimming wall and spur dike was proved experimentally to be effective for sediment control for lateral intakes [3]. To protect El-Kurimat Power Station intake in Cairo, Egypt from excessive bed sediment, an undistorted movable hydraulic scale model 1:30 was used to investigate the effectiveness of using the sediment deflector system, which comprised a sediment barrier and submerged bottom vanes [4].

Delft3-D software was used to simulate and predict the effects of building an open theater supported by piles and an extended boardwalk inside the Nile River [5]. Delft3-D was used to improve sedimentation issues at pipe intakes on the Nile River employing submerged vanes [6].

Combined with a GIS approach, Delft3-D was used to evaluate the navigational conditions and morphological changes over a 100 km section of the Nile River [7].

SMS 2-D simulated dredging regions and combinations of groins to conclude the best and most cost-effective solution for sedimentation control around three intakes of the Road El-Farag drinking water treatment facility in Cairo, Egypt [8].

Engineering control works are performed on waterways and rivers to change their morphological characteristics including permanent and temporary control works. Temporary control works such as dredging are better appropriate for rivers that experience one yearly flood during a specified period [9].

The most typical varieties of permanent control works are weirs, submerged vanes, groins, and spur dikes which shield banks from erosion and lessen channel sedimentation. However, many solutions can be adapted to control sedimentation as dredging processes [10_11]. Also, spur dikes are efficient tools against sedimentation [12_13_14_15].

2. MATERIALS AND METHODS

2.1 SITE DESCRIPTION

The main objective of this study is to enhance flow velocities and minimize sediment deposition in front of the proposed river navigation dock which is located on the eastern bank of the Nile River in Beni Suef. The study reach of the Nile serves a region with a length of 2 Km starting from Beni Suef Upper Bridge to the Monastery of the Virgin Mary. The studied river reach will be on the eastern bank at kilometer 118.800 in front of Rawda Gauge and opposite kilometer 808.200 behind the Aswan Reservoir. The stream width of the study area ranges between 500 and 660 meters, and the pathway of the Nile River in this area takes a path in the northeast direction, at an angle of 52 degrees in the north direction. As shown in Figure 1, the general plan for the study area includes the construction of a tourist walk, a tourist hotel, a commercial area, a tourist mall, a restaurant area, and green areas that will be established around the navigation dock.

FIG 1. Google Earth Image of the Study Area and the Region exposed to Deposition

2.2 PROBLEM IDENTIFICATION

In the event of the construction of the proposed river navigation dock, the problem of a lack of appropriate depths for ships to be docked and moved to and from the river navigation dock without obstruction is observed, especially in periods of low water levels. On the other hand, the region in front of the river navigation dock is an area of deposition due to the low flow velocities.

2.3 CALIBRATION RESULTS EMPLOYING SMS 2-D MATHEMATICAL MODEL

Brigham Young University, the U.S. Army Corps of Engineers, the Engineering Research and Development Center (ERDC), and the Federal Highway Administration (FHWA) collaborated to develop the "SMS" 2-D mathematical model. The SMS-2D model family is an integrated program for modeling and analyzing free surface flows, sediment transport, and morphological processes. This family also contains a mesh generator (SMS-2D Mesh Generator). Under the SMS interface, the Finite Element Surface Water Modeling System (FESWMS) is a complete environment for two-dimensional flows in a horizontal plane model. This model can simulate both steady and erratic 2-D surface-water flows, including sub- and super-critical conditions. The vertically integrated equations of FESWMS are solved.

To get the best agreement between the measured and model-generated values, many model runs were performed. The model calibration included two cross-sections (Vel. 1 and Vel. 2) with the matching values for the velocity sections. These results were obtained for the case of an average discharge of 1968 m^3/sec and a surface water level of (26.00) m downstream of the study reach. The real data was used to compare the outcomes of the SMS-2D model. The real data were in close agreement with the results of the SMS-2D Model, as indicated in Figures 2 and 3, with an average difference ranging from -3.5% to 3%.

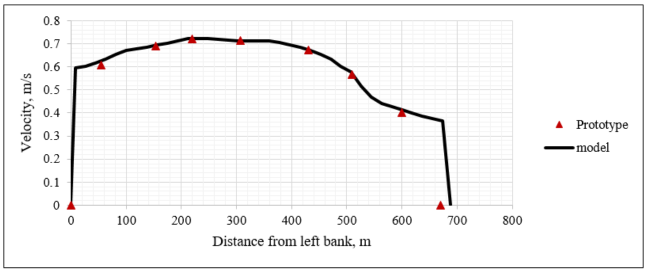

FIG 2. Calibration of Flow Velocity at Cross-section (Vel. 1)

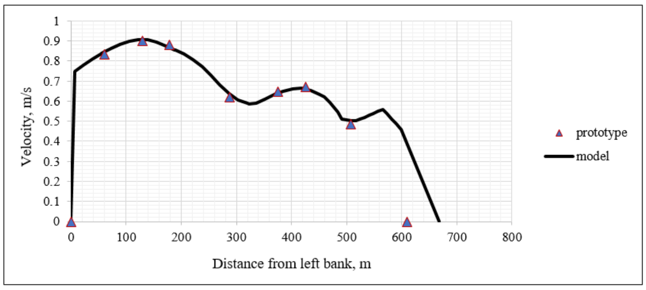

FIG 3. Calibration of Flow Velocity at Cross-section (Vel. 2)

3. RESULTS AND DISCUSSION

To reduce sedimentation, there are several methods such as dredging works in sedimentation areas to increase the flow rate in front of the river navigation dock where the deposition takes place.

Another solution may be using spur dikes to increase the flow velocities, which have great importance in protecting banks and working to repel sediment away from the area exposed to deposition. Regardless of the different types of spur dikes, they redirect flow from the river bank and affect the flow regime, flow velocity, and sediment transportation.

The main objective of this study is to solve the problem of deposition around the study area and increase the flow velocity around it. So, the sequence adapted in this study was as follows:

- 7 alternatives from the first group of dredging were studied, as shown in Figure 4 and Table 1.
- 3 alternatives from the second group of dredging were studied, as shown in Figure 5 and Table 2.
- 4 alternatives using spur dikes were studied, as shown in Figure 6.
- 8 combined alternatives including dredging and using spur dikes were studied, as shown in Figure 7 and Table 3.
- 2 best alternatives were found among 22 previous alternatives.
- The 2 best alternatives were studied in the cases of max and min discharges.

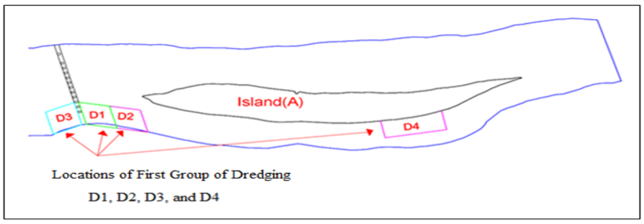

FIG 4. Locations of First Group of Dredging

TABLE 1. First Group of Dredging Alternatives

Alternative	1	2	3	4	5	6	7
D1	√				√	√	√
D2		√			√	√	√
D3			√			√	√
D4				√			√

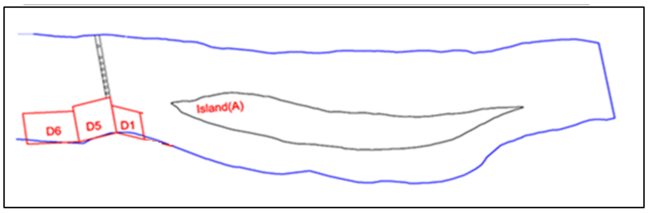

FIG 5. Locations of Second Group of Dredging

TABLE 2. Second Group of Dredging Alternatives

Alternative	1	2	3
D1	√	√	√
D5		√	√
D6			√

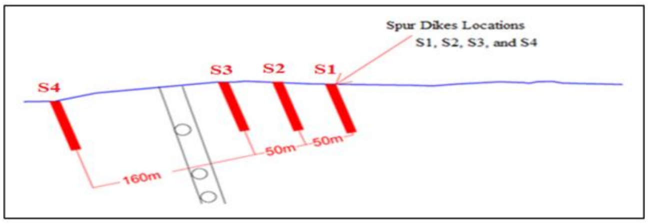

FIG 6. Locations of Spur Dike Alternatives

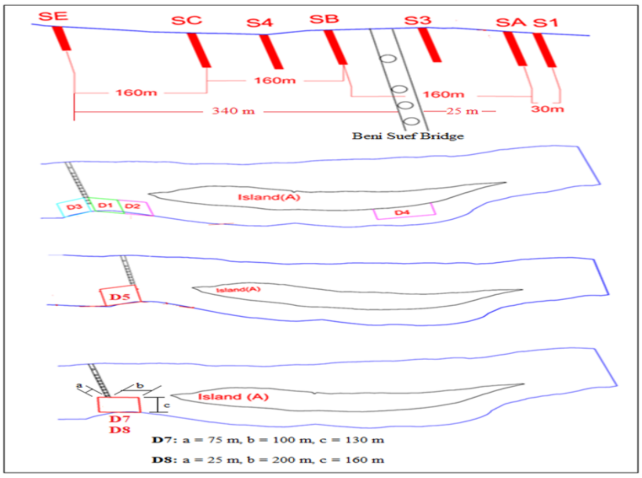

FIG 7. Combined Alternatives Employing Both Dredging and Spur Dikes

TABLE 3. Different Combined Alternatives

Alternative	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
D1	√	√	√	√	√	√		
D2	√	√	√	√	√			
D3				√				
D4				√	√			
D5					√	√		
D7							√	
D8								√
S1	√		√					
S2								
S3		√						
S4			√					
SA				√	√			
SB				√	√			
SC				√	√	√		
SE							√	√

The previous 22 alternatives were studied concerning the flow velocity, discharge distribution on both sides of Islands A and B, and discharge distribution between bridge piers in the case of average discharge. From the results obtained, 2 alternatives were the best. These best alternatives were D7 with SE and D8 with SE from the different combined alternatives. In the case of average discharge, the effects of the best alternatives on the flow velocity are shown in Figures 8 and 9, discharge distribution on both sides of Islands A and B is illustrated in Table 4, and discharge distribution between bridge piers is shown in Figures 10 and 11.

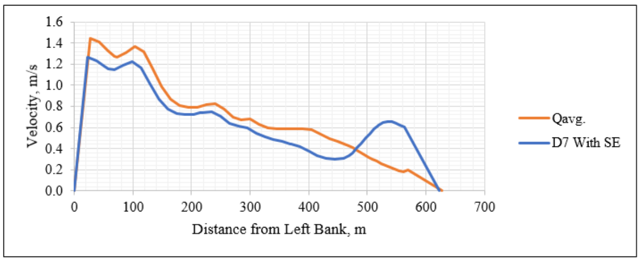

FIG 8. Flow Velocity for Average Discharge with and without (D7 With SE)

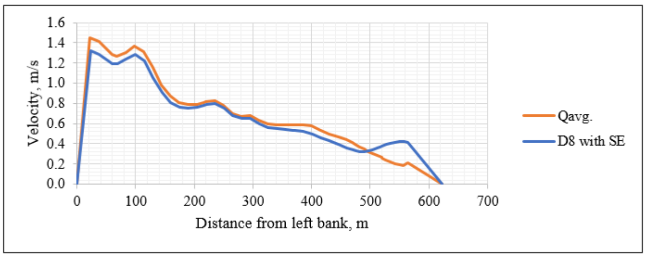

FIG9 Flow Velocity for Average Discharge With and Without (D8 With SE)

Employing (D7 with SE), as shown in Figure 8, the velocity decreased from 1.42 to 1.24 m/s at a distance of 40 m from the left bank with an average decrease of 13%. Then, the velocity decreased gradually to the distance of 480 meters from the left bank. In the study area, employing this alternative increased the velocity significantly from 0.22 to 0.65 m/s with an average increase of 195%.

Employing (D8 with SE), as shown in Figure 9, the velocity decreased from 1.42 to 1.28 m/s at a distance of 40 m from the left bank with an average decrease of about 10%. Then, the velocity decreased gradually to the distance of 480 meters from the left bank. In the study area, employing this alternative increased the velocity significantly from 0.20 to 0.42 m/s with an average increase of 110%.

TABLE 4. Average Discharge Distribution on both sides of Islands A and B

Alternatives	Island A		Island B	
	Qwest	Qeast	Qwest	Qeast
Without	65.04%	34.96%	78.88%	21.12%
D7 with SE	64.32%	35.68%	78.65%	21.35%
D8 with SE	64.28%	35.72%	78.65%	21.35%

As shown in Table 4, the effects of 2 alternatives on discharge distribution on both sides of islands A and B were negligible.

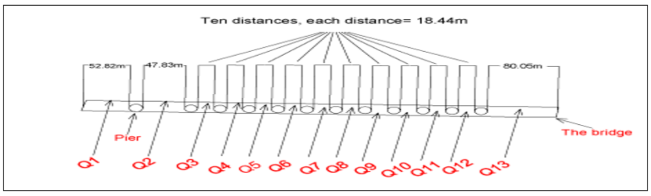

FIG 10. Discharge Distribution between Bridge Piers

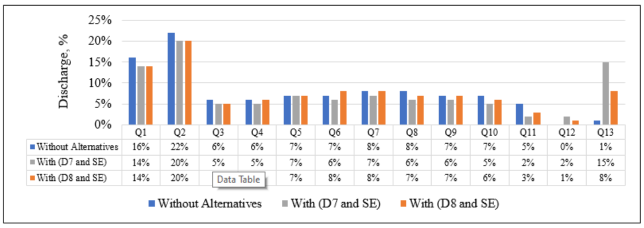

FIG 11. Average Discharge Distribution between Bridge Piers

As shown in Figure 11, it was concluded that employing the alternatives (D7 with SE) and (D8 with SE) significantly improved the discharge distribution between the bridge piers near the study area without changing the river morphology. Q12 increased from 0% to 2% and 1%, while Q13 increased from 1% to 15% and 8% for (D7 with SE) and (D8 with SE), respectively.

In the case of max discharge, the effects of the best alternatives on the flow velocity are shown in Figures 12 and 13, discharge distribution on both sides of Islands A and B is illustrated in Table 5, and discharge distribution between bridge piers is shown in Figure 14.

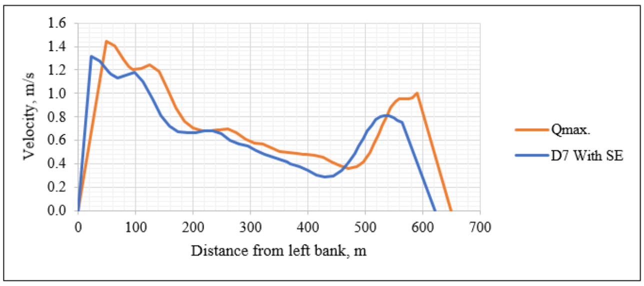

FIG12. Flow Velocity for Max Discharge with and without (D7 With SE)

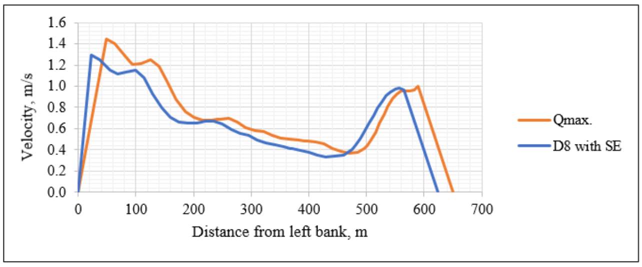

FIG13. Flow Velocity for Max Discharge with and without (D8 With SE)

As shown in Figure 12, employing the alternative (D7 with SE) decreased the velocity from 1.42 to 1.16 m/s at a distance of 60 m from the left bank with an average decrease of 18%. The velocity decreased gradually to the distance of 460 meters from the left bank and increased again. In the study area, the velocity decreased from 0.96 to 0.76 m/s with an average decrease of 22%.

Employing the alternative (D8 and SE), as shown in Figure 13, the velocity decreased from 1.42 to 1.28 m/s at a distance of 60 m from the left bank with an average decrease of 10%. The velocity decreased gradually to the distance of 460 meters from the left bank and increased again. In the study area, this alternative did not affect the velocity which was 0.96 m/s.

TABLE 5. Max. Discharge Distribution on both sides of Islands (A) and (B)

Alternative	Island A		Island B	
	Qwest	Qeast	Qwest	Qeast
Without	68.15%	31.85%	73.31%	26.69%
D7 with SE	68.05%	31.95%	72.41%	27.59%
D8 with SE	66.78%	33.22%	72.25%	27.75%

As shown in Table 5, concerning the effect on discharge distribution on both sides of Islands (A) and (B), the alternative (D8 with SE) had more effect.

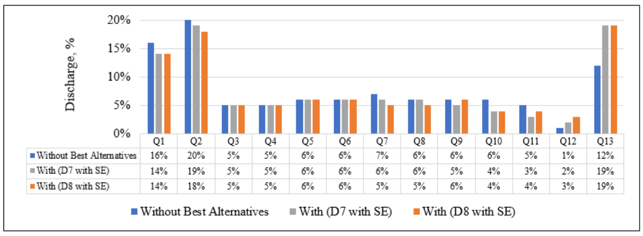

FIG 14. Max. Discharge Distribution between Bridge Piers

As shown in Figure 14, the 2 alternatives had almost the same effect on discharge distribution between bridge piers.

In the case of min discharge, the effects of the best alternatives on the flow velocity are shown in Figures 15 and 16, discharge distribution on both sides of Islands A and B is illustrated in Table 6, and discharge distribution between bridge piers is shown in Figure 17.

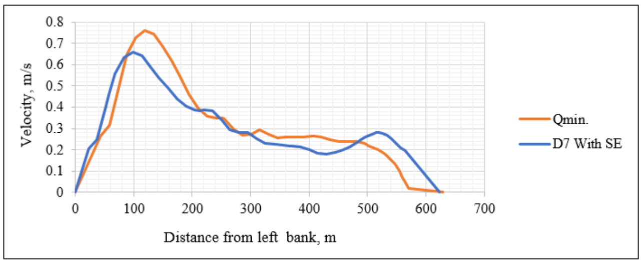

FIG 15. Flow Velocity for Min Discharge with and without (D7 With SE)

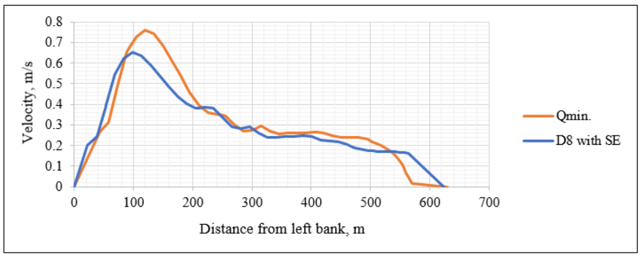

FIG 16. Flow Velocity for Min Discharge with and without (D8 With SE)

As shown in Figure 15, employing the alternative (D7 with SE) decreased the velocity from 0.76 to 0.62 m/s at a distance of 120 m from the left bank with an average decrease of 18%. The velocity decreased gradually to the distance of 480 meters from the left bank. In the study area at a distance of 540 m from the left bank, the velocity increased significantly from 0.16 to 0.26 m/s with an average increase of 63%.

Employing the alternative (D8 with SE), as shown in Figure 16, the velocity decreased from 0.76 to 0.62 m/s at a distance of 120 m from the left bank with an average decrease of 18%. The velocity decreased gradually to the distance of 540 m from the left bank. In the study area at a distance of 560 m from the left bank, the velocity increased significantly from 0.07 to 0.16 m/s at a distance of 560 m from the left bank with an average increase of 128%.

TABLE 6. Min. Discharge Distribution on both sides of Islands (A) and (B)

Alternative	**Island A**		**Island B**	
	Qwest	**Qeast**	**Qwest**	**Qeast**
Without	62.61%	37.39%	91.11%	8.89%
D7 with SE	61.93%	38.07%	90.24%	9.76%
D8 with SE	61.92%	38.08%	90.35%	9.65%

As shown in Table 6, the effects of 2 alternatives on discharge distribution on both sides of islands A and B were negligible.

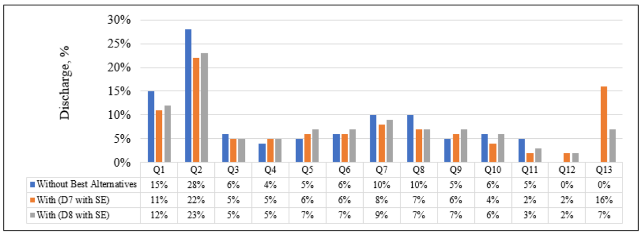

FIG 17. Min. Discharge Distribution between Bridge Piers

As shown in Figure 17, the (D8 with SE) had more effect on discharge distribution between bridge piers.

From the previous study, the 2 alternatives (D7 with SE) and (D8 with SE) were the recommended alternatives. These alternatives solve the problem of sedimentation in the study area by increasing the flow velocities near the study area according to the allowable limits and consequently solving the navigation problems.

5. CONCLUSIONS

A river navigation dock is proposed on the eastern bank of Beni Suef in an area of deposition due to the low flow velocities. The problem of a lack of appropriate depths for ships to be docked and moved to and from the river navigation dock without obstruction is observed, especially in periods of low water levels. The studied river reach is on the eastern bank at kilometer 118.800 in front of Rawda

Gauge with a length of 2 km starting from Beni Suef Upper Bridge.

A two-dimensional mathematical model SMS was built, calibrated, and used to simulate morphological changes at the river reach affected by deposition.

Twenty-two alternatives including dredging only, using spur dikes only, and employing both dredging and spur dikes were studied in the case of average discharge. Two best alternatives were found including both dredging and using spur dikes. The two best alternatives were studied in the cases of max and min discharges and proved to be effective solutions

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