Study of Morphological Changes for the River Nile in El-Dahab Island, Giza Governorate

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Abstract

This study investigates morphological changes in the Nile River in El-Dahab Island, which is located in the metropolitan region of Cairo near the eastern Nile shore near Qorsaya Island, resulting from human interventions and the construction of stream bank protection structures. A two-dimensional model was developed to simulate morphological changes in the area. Results show significant channel changes due to decreased flows and sediment supply, particularly in recent decades. Erosion and deposition areas in the study region are presented in this paper. These findings will aid decision-makers in area development, navigation, and the protection of water structures and riverbanks. The results can also support analyses of sediment transport in the past twenty years and serve as a reference for future predictions of morphological changes in the area. A comparison was made between the measured cross sections of 2003 and the same area in 2020 by using the SMS (Surface-water Modeling System). The model is used to simulate morphological changes in water level, bed elevation, and sedimentation in the study area.

Keywords

Morphology, modeling, sediment, river Nile, SMS (Surface-water Modeling System), and erosion

1. INTRODUCTION

1.1 General

The River Nile, the world's longest river, flows About 6,650 km long, its drainage basin covers eleven countries: the Democratic Republic of the Congo, Tanzania, Burundi, Rwanda, Uganda, Kenya, Ethiopia, Eritrea, South Sudan, the Republic of the Sudan, and Egypt (Elsanabary, 2012) as shown in Fig.(1). The river faces erosion and sedimentation issues in Egypt due to its central location and natural geomorphology. Understanding the impacts of erosion and sedimentation on the River Nile provides valuable insight into the problem in the study area (Ahmed & Fawzi, 2009). Several previous research studies have used numerical models, which are crucial for studying river morphological changes (Abdel-Mageed Badawy, et al., 2021). Morphological changes in river channels are essential for navigation safety, intake structure locations, and scour around bridge piers. Numerical models can predict sediment transport processes and calculate sediment balances.

Figure 1 The River Nile (Elsanabary, 2012) .

This section introduces a literature review of previous studies that presented the effect of the morphological changes on the Nile River in Egypt. M. El-Moattassem et al. presented a two-dimensional model for simulating water flow and sediment transport in the Aswan High Dam Reservoir to predict sediment deposition issues, particularly delta growth. The model's predictions align with field measurements, making it a valuable tool for monitoring future water flow and sediment deposition in the reservoir (El-Moattassem, et al., 2005). Abdel Naby investigated morphological changes in the River Nile at Kasr El-Nile, involving sedimentation, bed degradation, and bank failure. A two-dimensional numerical model was developed using field data from 2000 and 2004. Results showed erosion, deposition, and scour holes, particularly downstream of the Kasr El-Nile Bridge (Abdel Naby, et al., 2007). Another paper described the bathymetry of the lake Nasser bed surface and develops a 2-D hydrodynamic model for its flow fields. The SMS with RMA2 2-D hydrodynamic model is used for lake hydrodynamic analysis (S. EL-Sammany & M. El-Moustafa, 2011). A Python-based application analyzes morphological changes along the Nile River in Greater Cairo, revealing significant changes, especially at El-Dahab Island. The study reveals sediment deposition is more than erosion, with El-Dahab Island experiencing the largest changes. Solutions include dredging, maintenance, safety modifications, bank protection, and three-dimensional modelling for sustainable water resource development (Kamal, 2019). R. Salama used two hydraulic models, SMS modules (FESWMS) and Delft3D, to simulate River Nile hydraulics and morphological changes at KM 633 - KM 645 upstream El-Roda gauge station (Salama & El-Sersawy, 2020). Results show both models predict water surface elevations well, with Delft3D being more logical for mesh resolution.

1.2 Description of the Study Area

The morphology of many regions along the Nile River is undergoing continuous changes after the construction of Aswan High Dam (AHD), such as bank failure, bed degradation and aggradations, and new island formation. These changes resulted from the variation in the water levels and discharges over time. These morphological changes have an environmental impact on the natural view and safety of different structures due to changes in depth. The study area shown in Fig. (2) is El-Dahab Island, which is located near the eastern Nile shore near Qorsaya Island. The island belongs to Giza and has a strong agricultural character. The main objectives of the study are to investigate the changes in channel width, change in cross section, and erosion and deposition in the channel.

Figure 2 The area of study, El-Dahab Island.

1.3 The Main Research Objectives

The study compares cross-sections from 2003 and 2020 to get morphological changes in El-Dahab Island because it is an important area and aims to aid decision-makers in area development, navigation, and water structure protection, thereby enhancing the understanding of channel width, erosion, and deposition.

2. METHODOLOGY

2.1 Data measurements

The water level was measured using traditional surveying equipment and checked with the readings of gauge stations. Actual data on water level and discharge on a daily basis were analyzed by five sections from south to north, respectively, as shown in Fig. (3), which covers the study area to measure cross sections in 2020 by using a survey boat with data collection instruments (GPS and HYPACK software) as shown in Fig. (4). A steel bar was embedded about 70 cm in the ground at both river sides, and a total station instrument was used to establish a base line. Echo-sounder equipment was mounted on a boat to record flow depths along the cross-section. The distance and depth measurements were processed to obtain data, which was then plotted relative to the water level, which was later in this study compared with archived data for 2003 by SMS.

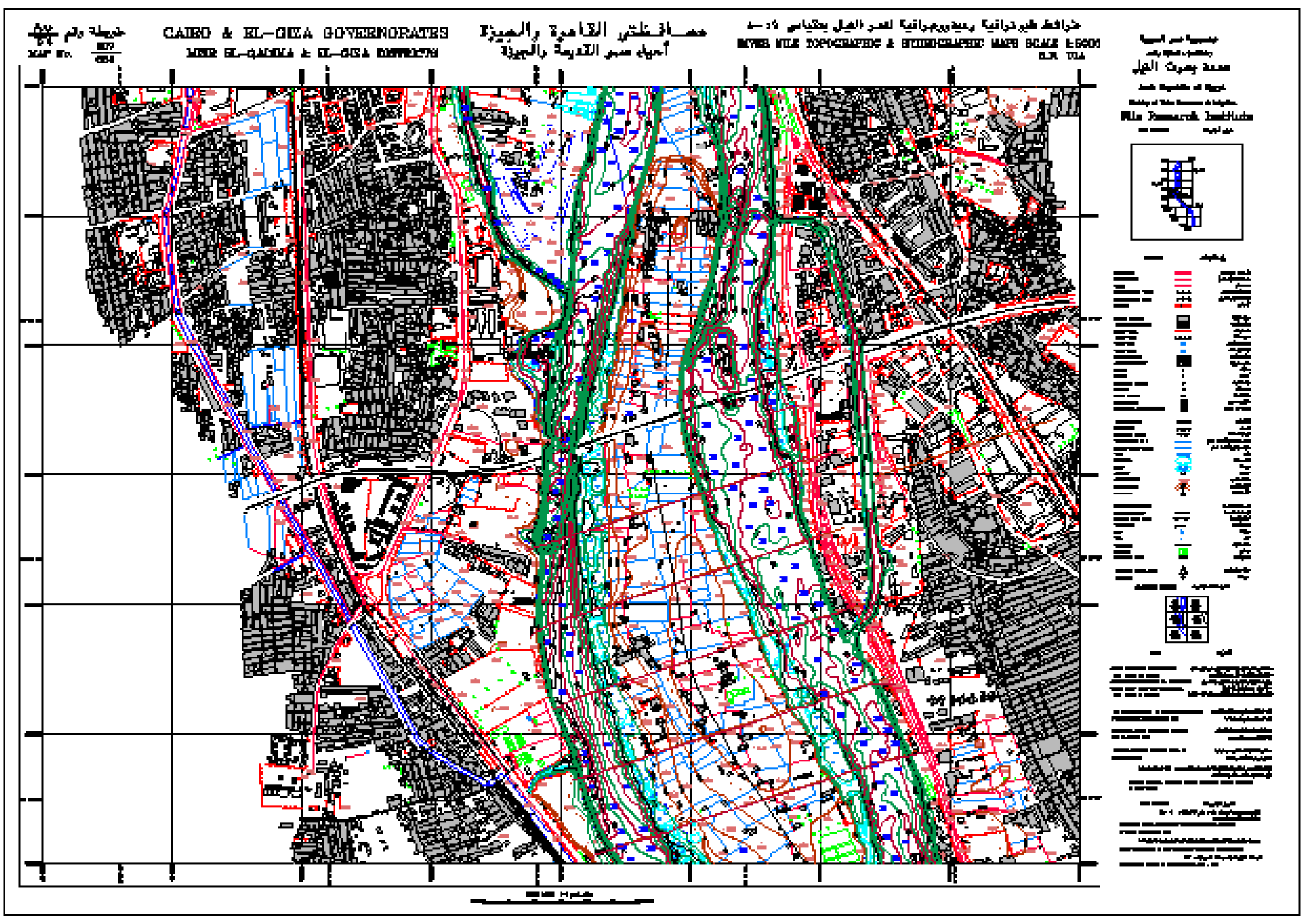


Figure 3 The map of study area 2003 (National Water Research Center, Nile Research Institute, 2003).

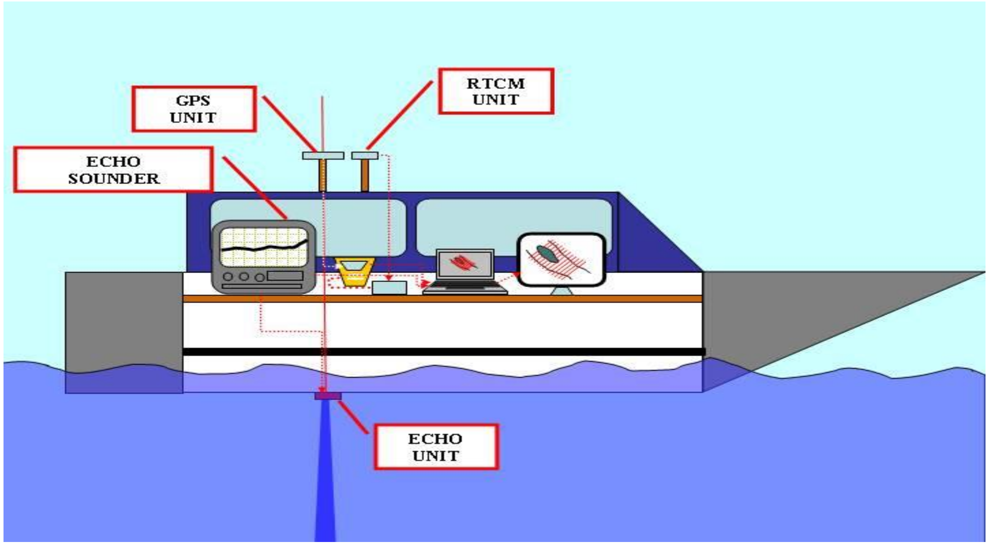


Figure 4 Surveying boat with data collection instruments (GPS and HYPACK software).

3. MODEL IMPLEMENTATION

3.1 SMS MODEL

The SMS (Surface-water Modeling System) 12.1 model (Aquaveo, 2013) is suitable to be used in solving hydraulic behavior, sedimentation, and transport problems in rivers, reservoirs, wetlands, estuaries, and bays. It is used to predict flow patterns and evaluate sedimentation rates in a navigation channel. Therefore, the SMS model was applied to predict the different parameters in the study area. The simulation period was taken for the year 2003 to get the bed elevations of the study reach, and the calibration was done for the year 2020.

3.2 Mesh Generation

A preliminary finite element mesh module was created using SMS 12.1 software (FESWMS model), which is a network of quadrilateral elements constructed from nodes. The study used aerial photographs and landsat satellite images to define the area boundaries. SMS Model generated a grid network from the map module, interpolating bathymetric data into the mesh. The mesh covering approximately 2.2 kilometers as shown in Fig. (5).

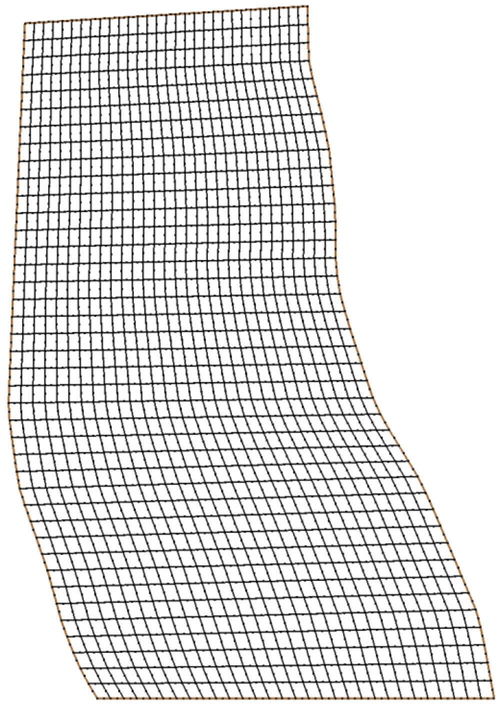
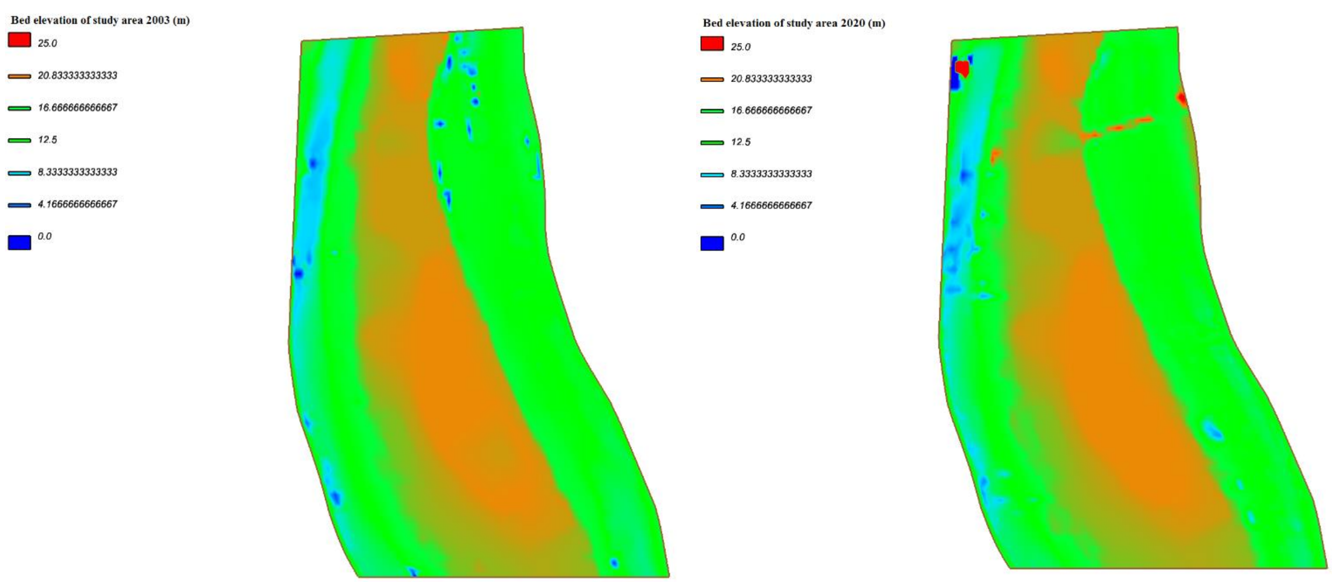


Figure 5 Mesh Representation of the area.

3.3 Model implementation

The simulation period was taken by using the field data for 2003 to get the bed elevations of the study area, as shown in Fig. (6-a). The calibration was done for the year 2020, as shown in Fig. (6-b).



(a) (b)

Figure 6 (a) Bed elevation of study area 2003 (m), (b) Bed elevation of study area 2020 (m).

4. RESULTS and DISCUSSION

The study examines the presentation of morphological changes, comparing cross-sections of 2003 with 2020 measured data as shown in Figs. (7-11), which show the erosion and sedimentation areas.

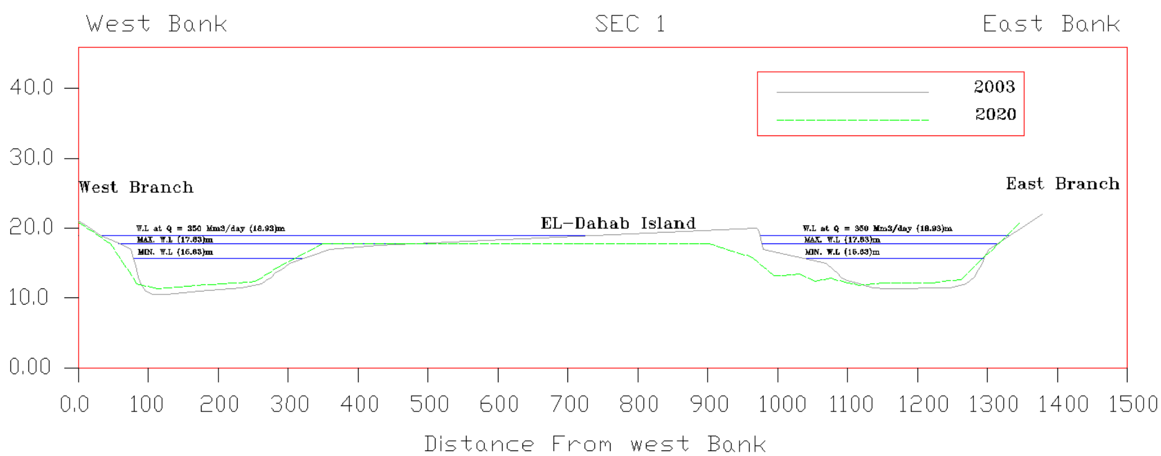


Figure 7 Comparison between year 2003 and 2020 for X. sec. 1.

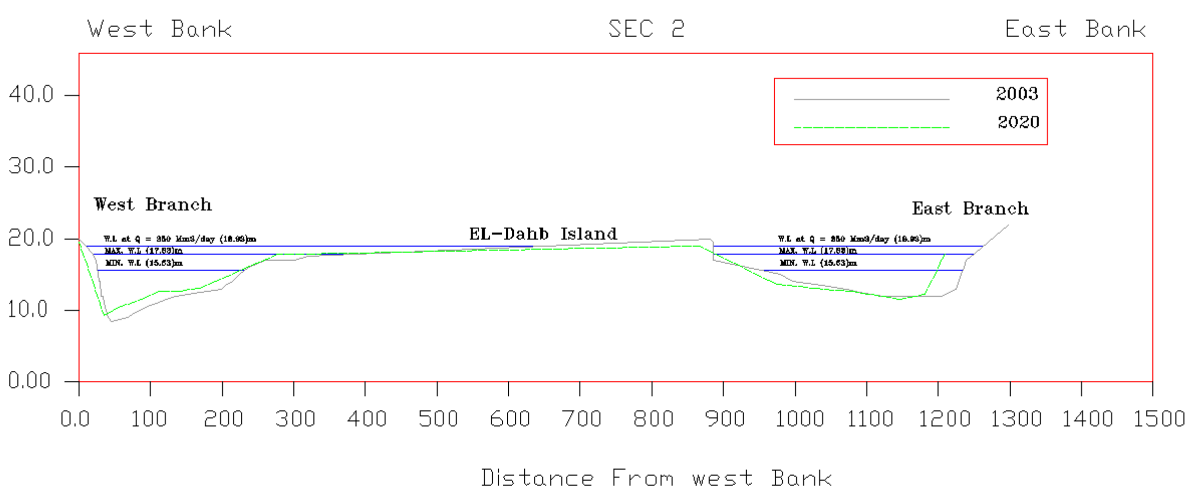


Figure 8 Comparison between year 2003 and 2020 for X. sec. 2.

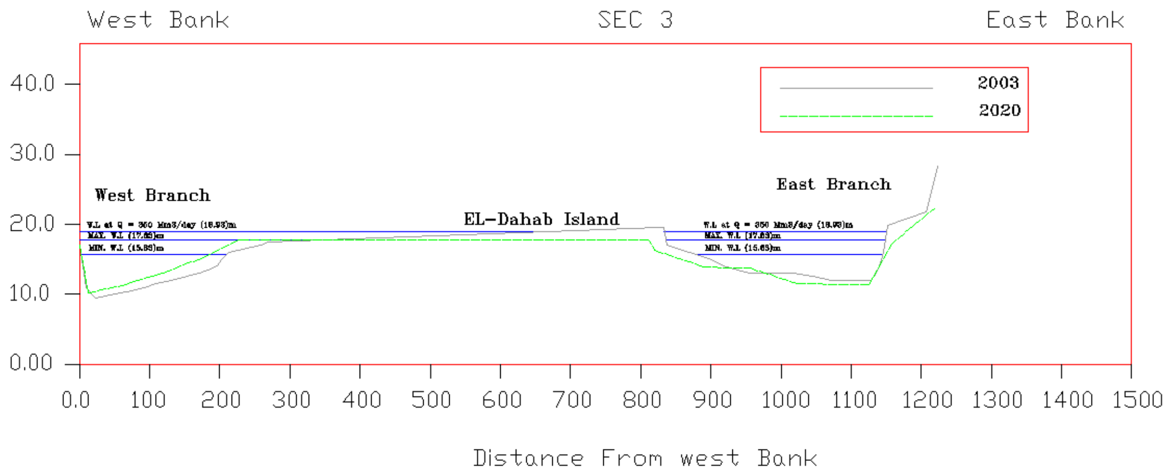


Figure 9 Comparison between year 2003 and 2020 for X. sec. 3.

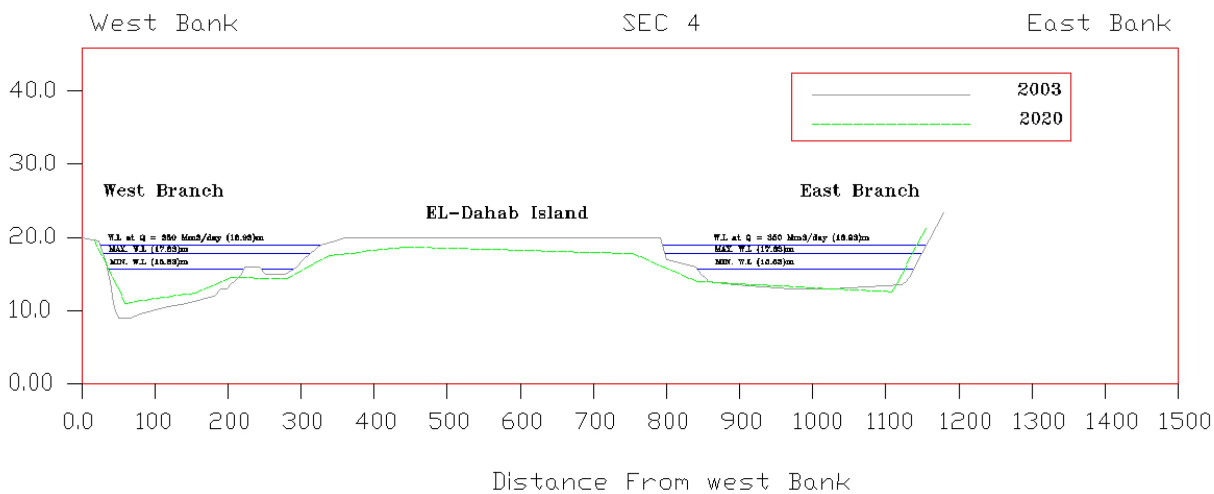


Figure 10 Comparison between year 2003 and 2020 for X. sec. 4.

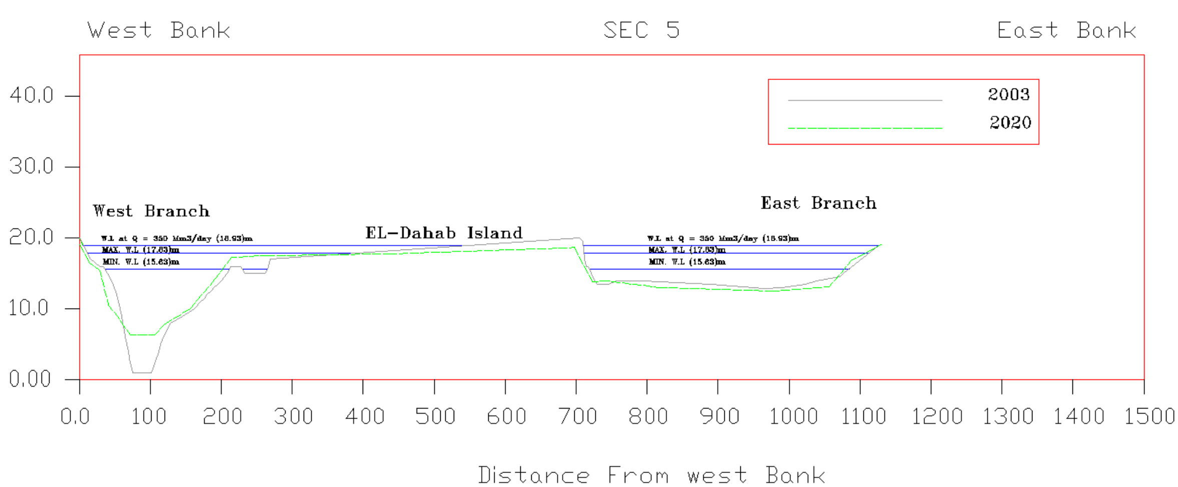


Figure 11 Comparison between year 2003 and 2020 for X. sec. 5.

Sedimentation and erosion rates in the east and west of El-Dahab Island are shown in Fig. (12), where regions of deposition range from 1 to 3 m and regions of erosion range from -1 to -3 m.

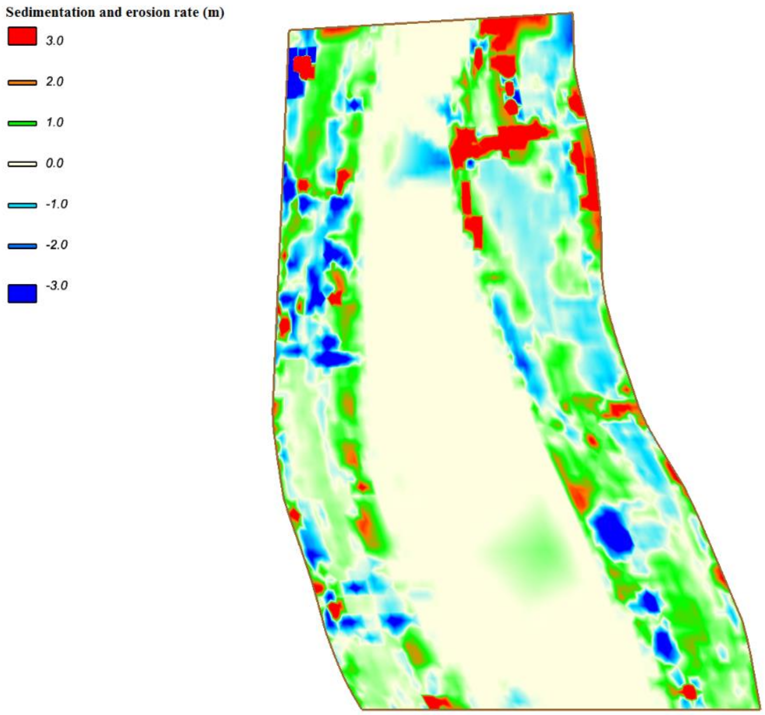


Figure 12 Sedimentation and erosion rate (m) (2020-2003).

5. CONCLUSION AND RECOMMENDATIONS

The study provides information on the Nile River's morphological changes in the greater Cairo region. The analysis of the morphological changes of the study reach reveals that the deposition rate is more than erosion. Based on the results of this study, it was found that the study area had suffered deposition in many places at El-Dahab Island. Also, it suffered erosion at the west side. Additionally, the results showed that the navigation path in the area would be affected.

Accordingly, the following solutions are suggested:

1- Dredging works are proposed to reduce the sediment deposition in El-Dahab Island region.
2- The efficiency of navigational path can be promoted by increasing the maintenance operation rate in front of water intakes to decrease the deposition rate.
3- For navigation safety, a modification study of the navigation path is to be accomplished in the outer curve of El-Dahab island area.
4- Bank protection works should be implemented at the areas suffering from severe erosion to prevent bank failure, maintain the aesthetic and civilized appearance of the study area, and improve navigation conditions.
5- Using three-dimensional modelling instead of two-dimensional modelling, of course, more preferred to obtain better results.

The research provides reliable information on the Nile River morphological changes in greater Cairo for supporting decision makers to design and implement reliable sustainable water resources development programs.

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