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Research Article

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River Nile Restoration due to Man-Made Interventions and its Morphological Impacts

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Abstract The River Nile has experienced main morphological changes during previous times decades. Irresponsible human interferences and their actions change the connections between the river channel and its contiguous floodplain as shown at Al Wasta City waterfront which located on the west bank of the River Nile, south of Cairo, Egypt. The main objectives of the research are to analyze the historic and present river geomorphic and morphologic changes. The hydraulic modeling approach was proposed to evaluate several alternatives for river restoration, identify the most and the best feasible solutions. The number of restoration alternatives was recognized as temporary solutions (dredging) and permanent solution (super dikes) to be able to control and sustain the chosen (water levels, water flow velocity, and hydraulic channel situations). The results shown that the combination between dredging and super dikes the best solution where given min erosion and deposition and its positive effects affect the river. The main thrust of this research is the proposal of a new strategic plan for river restoration not based exclusively on qualitative assessment but developed using numerical analysis.

Keywords River Restoration, Human Interventions, Dredging, Super dikes, Hydraulic Modeling

1. Introduction

River restoration was and still a focus of human actions and interest throughout the ancient and modern decades. It has been also a subject of study for both engineers and scientists who have been bewitched by the geometric shapes which are self-formed and their reactions to alterations in nature and human interventions [5-9]. Engineers are interested in water supply, design, navigation improvement, river regulation, and flood control. Plus, engineering, understanding river actions are necessary also for environmental improvement. The study of morphological alterations in the River Nile is important in the practical areas when it is linked to human interferences [4-5-7].

Human interventions' effects on rivers and improving our knowledge of human dimensions became an important piece of incorporated river research. Human interferences (river course canalization, use of river sediments, dam construction, and reforestation) also share in altering river courses [15]. Knowledge of morphological modification in alluvial channels needs careful respect of the interactions between a set of variables explaining fluvial procedures and fluvial morphology extrinsic supervision (that supplies the input evacuation and sediment load differences and put physical bonds onto the nature of adjustments) [16], and intrinsic supervision (due to an Internal interaction between operating processes–flow velocity, evolving morphology within the fluvial system and flow stage and sediment transport characteristics [9].

For these targets, a two-dimensional hydrodynamic limited element pattern is utilized to describe the flow velocity field within the study field and to gain a better insight into the flow manners and potential techniques of the sediment deposition. The research employed the Finite Element Surface Water Modelling System (FESWMS) computer program, which developed by the Federal Highway Administration, to chart the flow manners within the river channel. The standardized numerical model was enforced to estimate the hydrological and hydrodynamic conditions for the different schemes to find advantageous restoration measurements[4-6-10].

Organizational works are necessary to deliver suitable water conveyance within the river system, as well as to affect other essential aids to mankind as navigation and irrigation. By keeping this in mind, several engineering works could be installed permanently as dams, , weirs, bend way weirs, spur dikes, barrages, and submerged vanes, while in specific situations some works are needed temporarily as dredging and vandals. Yet, temporary river works are essential to be occasionally repeated by artificially taking out deposits from places where adequate flow depth is required [11]. This effect could be positively reached by submerged vanes or vandals which can be done for only one or two years. These temporary organizational works are proper more for rivers with once [6].

After building of Aswan High Dam. The extreme discharge flow was diminished and the unsettled sediment concentration was greatly reduced consequently, the Nile River has undergone morphological alterations in many locations along its path, principally along with the distance between Aswan and Cairo [8-9].

The main objectives of the research are:

1- Analyzed the historic and present river geomorphic and morphologic characteristics.
2- Developed the hydraulic approach to detect river changes using a two-dimensional hydraulic model.
3- Proposed four restoration alternatives to increase the hydraulic efficiency of the river channel.
4- Evaluated these alternatives to identify the best and the most feasible solutions.

2. Materials and Methods

2.1. Study area

The study area clarifies the sequels of man-made interferences on Nile River. The study reach location is at the waterfront of Al Wasta city, Beni Suef governorate south of Cairo, Egypt. The location is between (km 81.0) and (km 87.0) from El Roda gauge station (west bank of Nile river) with a total length of 7.00 kilometer which shown in figure (1). In the south study region, there is an immersed island in the west side of the main channel with a 1.15 Km length and 200 m width. The range of main channel width is (380 – 650) m. In consideration to the Egyptian Water Resources Plan. Channel in the west bank. Al Wasta Bridge which located in the north of the study area is representing the end of the study area. Nile River flows from south to north, with a median bed slope of 0.06% as shown in figure 1.

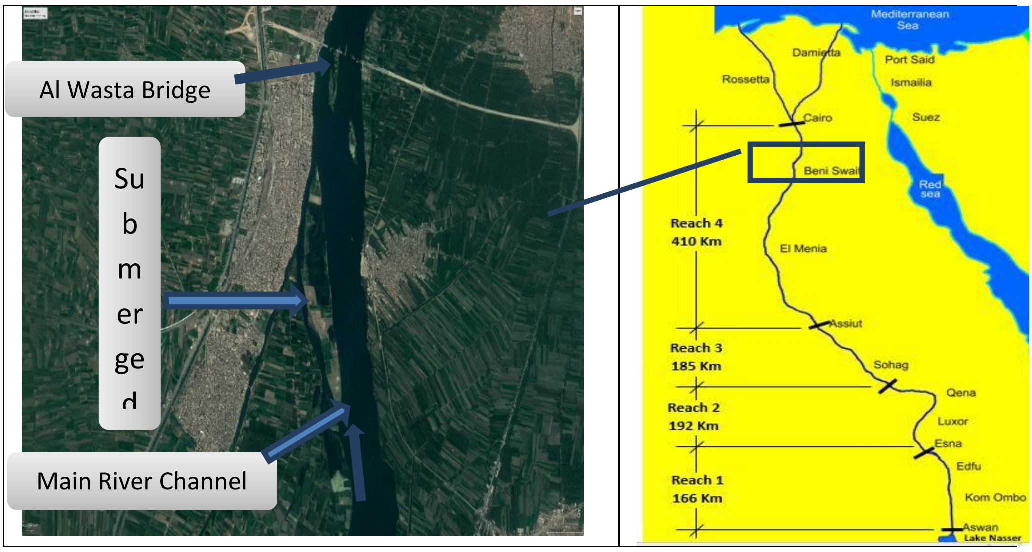


Figure 1: Study Area Location Map

2.2. Methodology

The current study is targeting to develop the approaches for simulation of the flow in Nile River, determine the current and future safe navigation, expect the sediment transport, and suggest the appropriate solutions to solve issues associated with the navigable channel. In addition, a modeling base flow map would be presented to give decision-maker the necessary information related to the morphological and hydrological alterations in the river and enable solutions and prediction of the navigation bottleneck issues associated with the alterations in water management policy in figure 3.

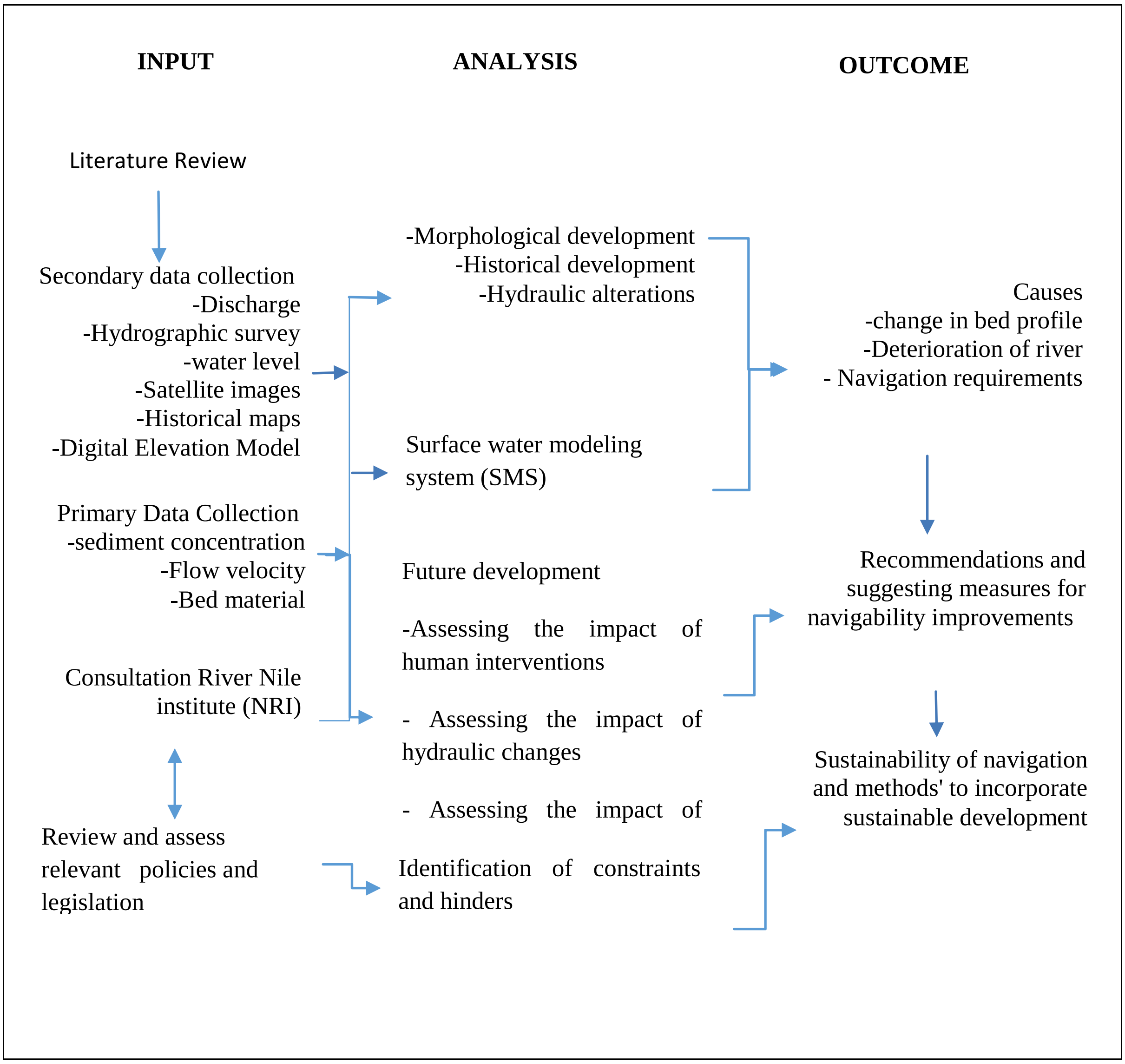


Figure 2: Study Methodology Flow Diagram

2.3. Data collection

To set up the (SMS) model, it required discharge, water level and cross section data. We collected all these necessary data of the river for different stations and time periods. Data collected for the setup of model are shown in table1

Table 1: *Data Collection*

Data	Location	Period	Source	Usage
Bathy Metry Survey	Fourth Reach at wasta city length of 7 km	2013	NRI	Grid Development
U/S discharge	Down Stream assuit barrage	2003 to 2013	NRI	Boundary condition(BC)
Water level	ElRoda water station	2003 to 2013	NRI	Boundary condition(BC)
Velocity Measurements	5-cross sections at(82-83-84-85-86-)km	2013	NRI	Calibration & Verification
Bed Sample	3-Bed samples (west-middle-east)at the velocity cross section	2013	NRI	Roughness

3. Modeling Application Approach

3.1. The Surface Water Modeling System (SMS)

The (SMS) model was utilized for the current study. The system involves a family of numerical pattern which gives multidimensional solutions to open the channel flow. The SMS pattern is proper for utility in solving transport and sedimentation problems of rivers, reservoirs, hydraulics behavior, estuaries, West lands and lakes. The SMS package involves Finite Element Surface Water modeling System (FESWMS). The FESWMS is a two-dimensional, depth-averaged hydrodynamic model employed to compute depth averaged velocities and water levels. The FESWMS model was hired to compute a time history of water depth and the depth averaged velocity at every node in the mesh.

The FESWMS model resolves depth-integrated equations of momentum and mass a conservation in a two horizontal directions. The equations of depth-averaged surface water flow are delivered by integrating the 3-D mass and momentum. Transport equations in resection to vertical coordinate from bed to water surface, acting as if that vertical velocities and accelerations are unpretentious.

The momentum equations that vertically integrated are written as:

$$\frac{\partial(HU)}{\partial t} + \frac{\partial}{\partial x}\left\{\beta_{uu}HUU + (\cos\alpha_x \cos\alpha_z)^2 \frac{1}{2} gH^2\right\} + \frac{\partial}{\partial y}(\beta_{uv}\mathrm{HUV}) + \cos\alpha_x gH\frac{\partial z_b}{\partial x}$$
$$-\Omega HV + \frac{1}{\rho}\left[\tau_{bx} - \tau_{sx} - \frac{\partial(H\tau_{xx})}{\partial x} - \frac{\partial(H\tau_{xy})}{\partial y}\right] = 0 \qquad (1)$$

$$\frac{\partial(HV)}{\partial t} + \frac{\partial}{\partial y}\left\{\beta_{vv}HVV + (\cos\alpha_y \cos\alpha_z)^2 \frac{1}{2} gH^2\right\} + \frac{\partial}{\partial x}(\beta_{uv}\mathrm{HVU}) + \cos\alpha_y gH\frac{\partial z_b}{\partial y}$$
$$+\Omega HV + \frac{1}{\rho}\left[\tau_{by} - \tau_{sy} - \frac{\partial(H\tau_{yx})}{\partial x} - \frac{\partial(H\tau_{yy})}{\partial y}\right] = 0 \qquad (2)$$

$$\frac{\partial H}{\partial t} + \frac{\partial(HU)}{\partial x} + \frac{\partial(HV)}{\partial y} = q \qquad (3)$$

For flow in the x direction, and for flow in the y direction:

where H = water depth, U = horizontal velocity in the x-direction, and V = horizontal velocity in the y-direction, , z = vertical direction, zb = bed elevation, HU = unit flow rate in the x-direction, HV = unit flow rate in the y-direction, q= mass inflow rate (positive) or outflow rate (negative) per unit area, ρ is water mass density, Ω is the Coriolis parameter, β is isotropic momentum flux correction coefficient that accounts for the variation of velocity in the vertical direction, g = gravitational acceleration, τbx, and τby = bed shear stresses acting in the x and y directions, respectively, τsx and τsy = surface shear stresses acting in the x and y directions, respectively, and τxx, τxy, τyx, and τyy = shear stresses caused by turbulence.

3.2. Mesh Generation and Boundary Conditions

Conditions the finite element mesh is known to be a network of quadrilateral and triangular elements built from nodes. The study area is known by means of an unstructured grid consisted of triangular and quadrangular elements. The water depths are fixed at the vertices (nodes) of each element giving rise to the mesh. The ingredients of velocities and the water surface rise are computed at the nodes. Fig. 4 illustrates the finite element mesh generation. In the fields of concern as the area in front of the floating jetty, the mesh ingredients are compressed to give much more sense for these areas. The interpolation between mesh nodes and bathymetry survey (which obtained from the field data), helped in calculating the bed levels of the mesh nodes.

The hydrodynamic model in addition to mesh geometry demands input data explaining initial and boundary conditions. The initial conditions are known as the initial bed elevations for the overall network nodes, which were gathered at the time of the field survey. The boundary conditions composed of 3 types which are inflow, outflow, and side boundary conditions. The inflow boundary condition is known to be the inflow discharge to the study area. The outflow boundary condition is known to be the upstream water level in the study area. The initial bed gradation for the programmed reach of the study based on the analysis of the gathered samples.

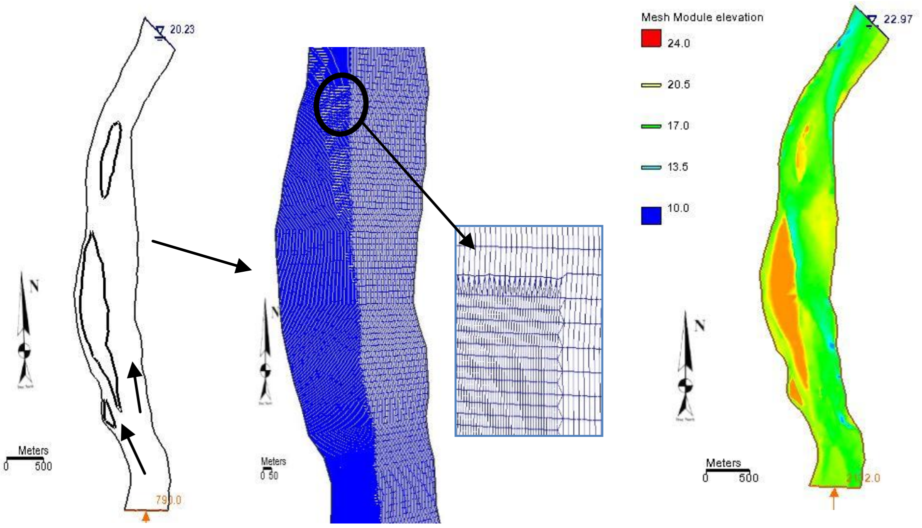


Figure 3: The finite element mesh generation and bed elevation at study area

3.3. Model Calibration

Calibration phase is counted the most significant stages which are confirmed to match the model to the condition in nature and its potentiality to mimic water flow custody subject of the study. Calibration is performed to guarantee a proper prognosis of hydrodynamic conditions during the procedure of instituting a numerical model to represent an offered study area. The model was verified and calibrated by using of field measurements (river bed samples, water velocities and unsettled solids measurement of the study area). The model is calibrated by using an inflow discharge of (790 m^3/s) and the water level (20.23) m at the downstream boundary condition which was presenting the river condition during the field data measurements.

The initial roughness values were overestimated were adjusted accordingly, it shows acceptable model calibration and verification process as shown in figure (4) and figure (5).

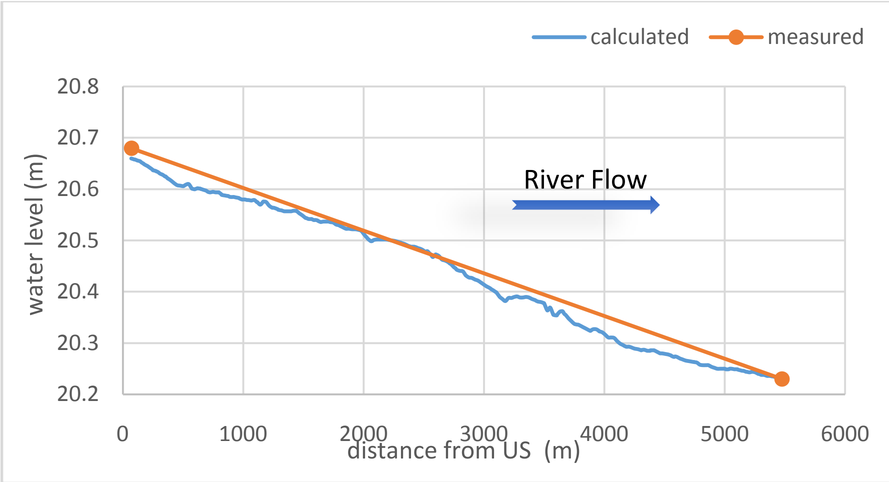


Figure 4: The observed and simulated Water Surface Profiles (Calibration Process)

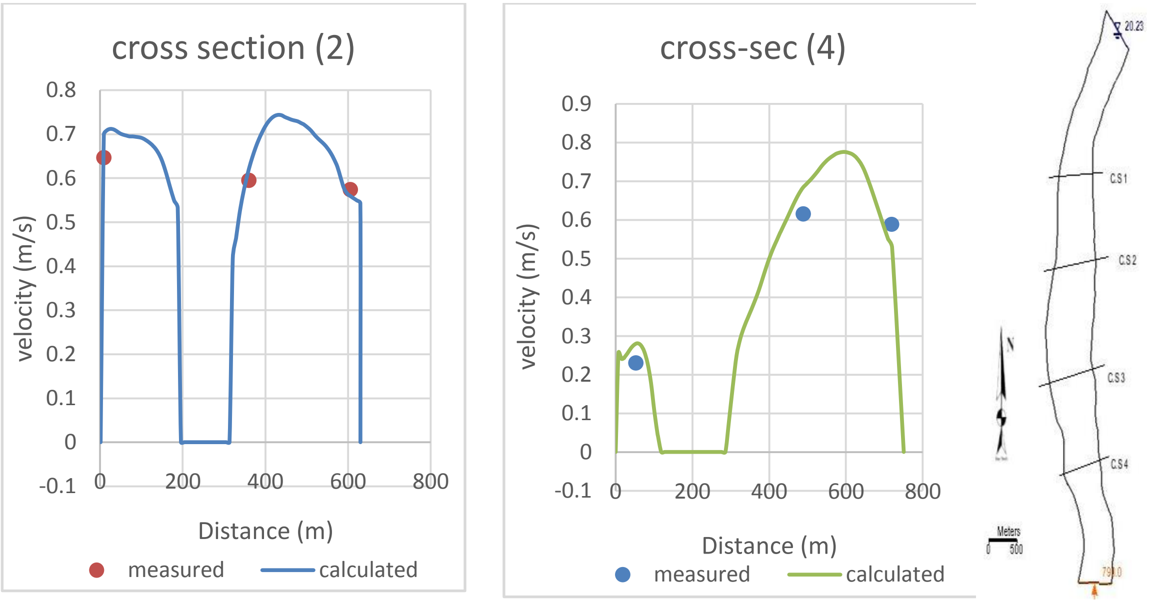


Figure 5: Depth average velocities calibration and the cross sections location

3.4. Hydrological Analysis and Scenarios:

The hydrological study was carried out to determine the different stages of the water levels and discharges of the study area using the data from the gauge stations .The reach of this study is placed at the waterfront of Al Wasta city, Beni Suef governorate south of Cairo, Egypt. The reach is between (km 81) and (km 87) from El Roda gauge station (west bank of Nile River), as shown in table (2).

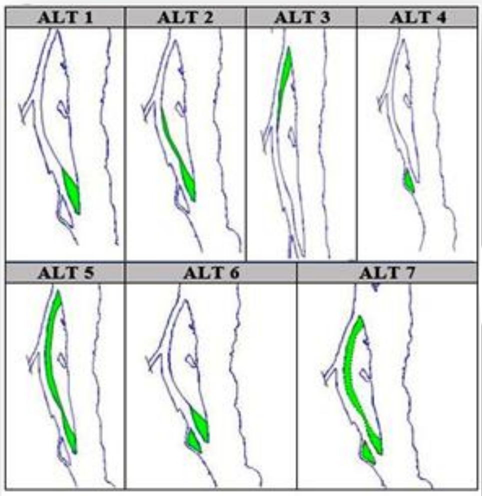
Table 2: Describing the different discharges used in the study area

River flow	Discharge		Water level (m)
	million.m³/day	m³/sec	
min	29.20	338	19.40
max	184.28	2132	22.97
flood	350	4060	23.94

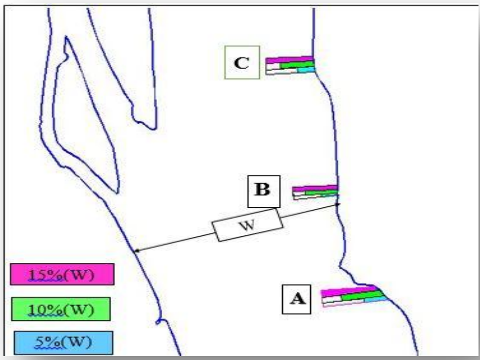
Three scenarios have been created to solve the problem of logic, which are dredging and super dikes and their combination as shown in table (3).

Table 3: The River Restoration scenarios

			Volume of dredging (m^3)	Length of super dikes (m)
Case 1 (dredging)		Alt1	57580	
		Alt2	99844	
		Alt3	38610	
		Alt4	24846	
		Alt5	138454	
		Alt6	82426	
		Alt7	196034	
Case 2 (super dikes)	S(A)	Alt a1		33
		Alt a2		66
		Alt a3		100
	S(B)	Alt b1		33
		Alt b2		66
		Alt b3		100
	S(C)	Alt c1		40
		Alt c2		80
		Alt c3		120
case 3(combination)	Super dikes (a3+b3+c3)			
	Alt5 + super dikes			
	Alt7 + super dikes			



Case 1



Case 2

4. Results and Analysis

During this study, a morphological and hydraulic analysis of alternatives was made the proposal which are dredging and super dikes and their combination.

4.1. River Morphology Results:

The river morphological changes at the study area were analyzed by two sets of bathymetric survey of the river bed levels data which was surveyed at years 2003 and 2013.We concluded that there is a balance relative between erosion and sedimentation processes in the study area but it the sediment deposition increase at the west side of the river. The comparison of the cross sections of river main channel and secondary channel for year 2003 to year 2013 showed that there are intensive sediment deposition inside the secondary (khor) channel. In addition, it is observed that there are erosion and deposition process occurs in the river main channel especially at the west side of the river as shown in figure 6.

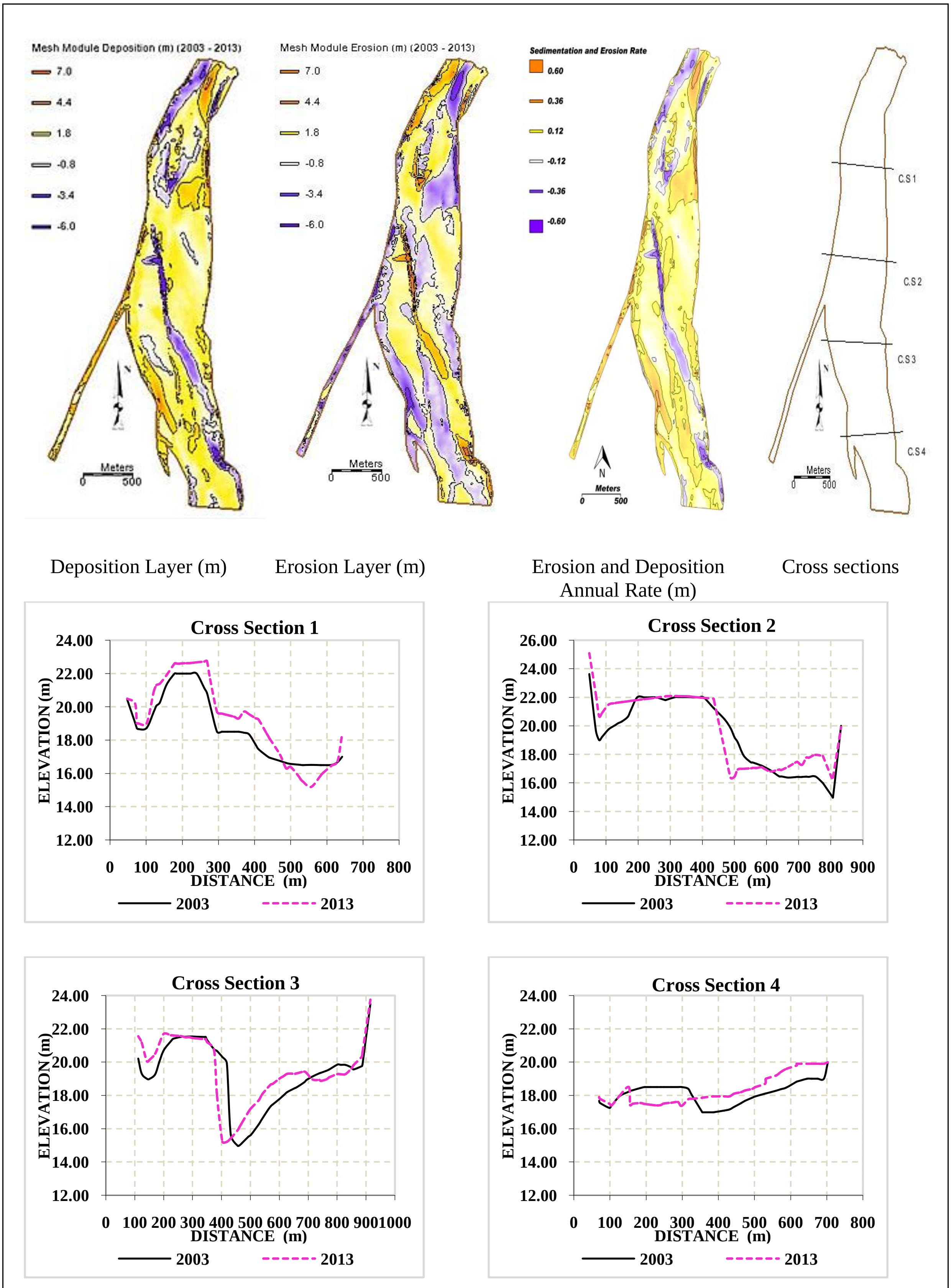
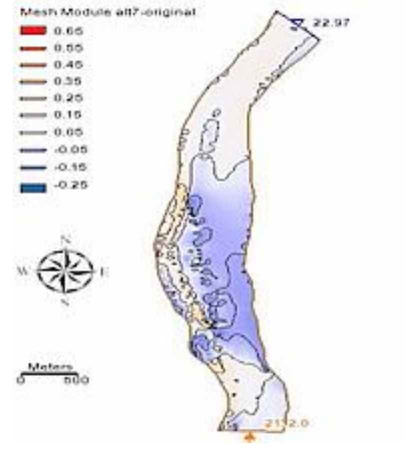


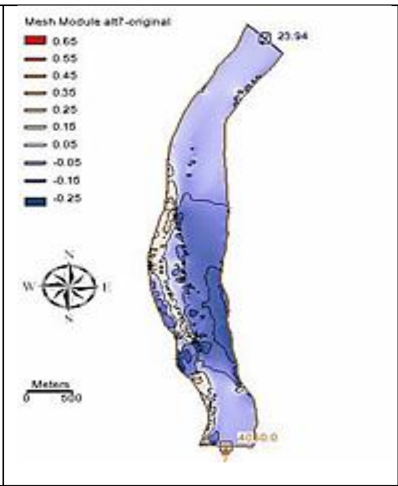
Figure 6: Deposition and Erosion layers and its cross sections at study from year 2003 to year 2013

4.2. Hydraulic analysis for the proposed alternatives

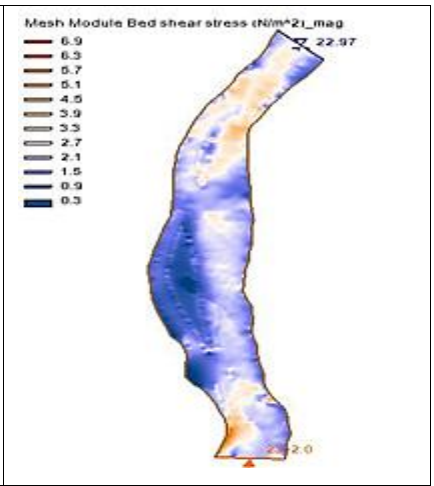
A hydraulic analysis of the alternatives has been made under different discharges and found to be in figure7-8.



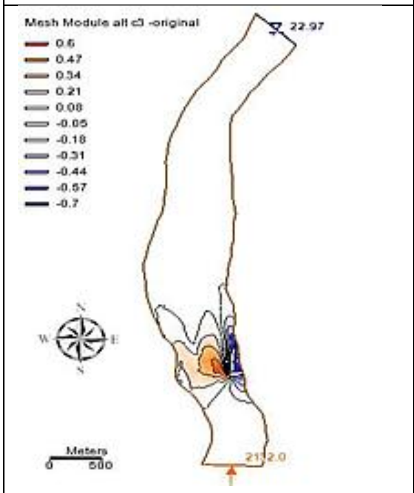
mean velocity for(alternative7-original case) at max flow



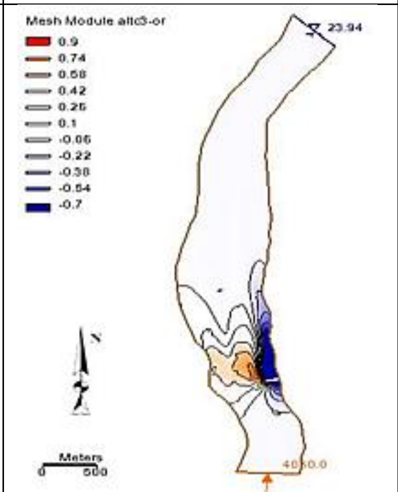
mean velocity for(alternative7-original case) at flood flow



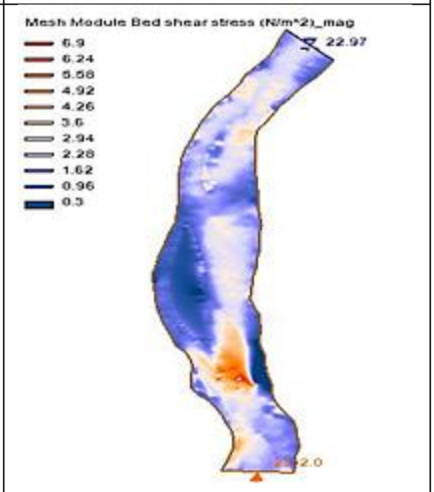
Bed Shear Distribution Maximum Flow at Alternative 7



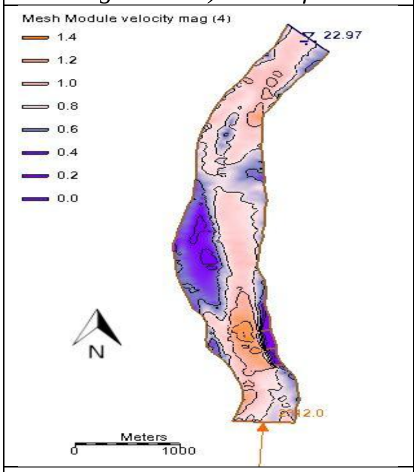
mean velocity for(alternative c3-original case) at max flow



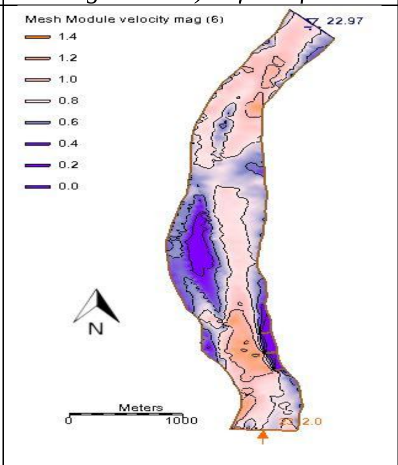
mean velocity for(alternative c3-original case) at flood flow



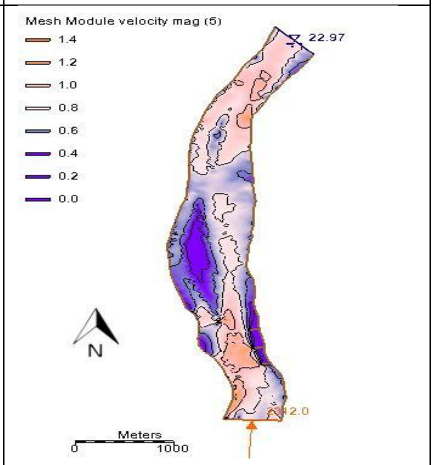
Bed Shear Distribution Maximum Flow at Alternative c3



mean velocity at maximum flow for alt super dikes



mean velocity at maximum flow for alt5+ super dikes



mean velocity at maximum flow for alt7+ super dikes

Figure 7: Hydraulic analysis for all scenarios

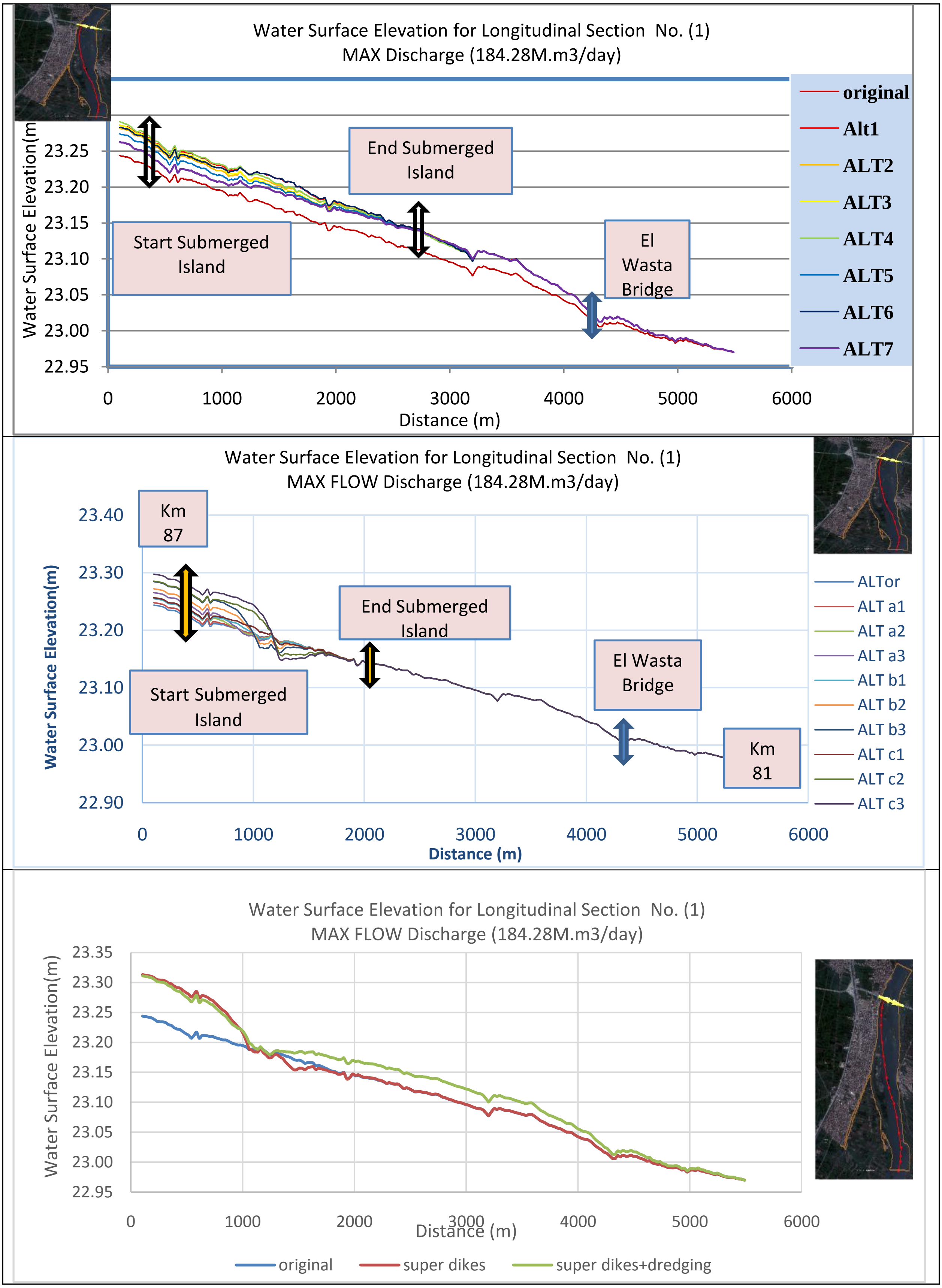


Figure 8: Water surface for scenarios

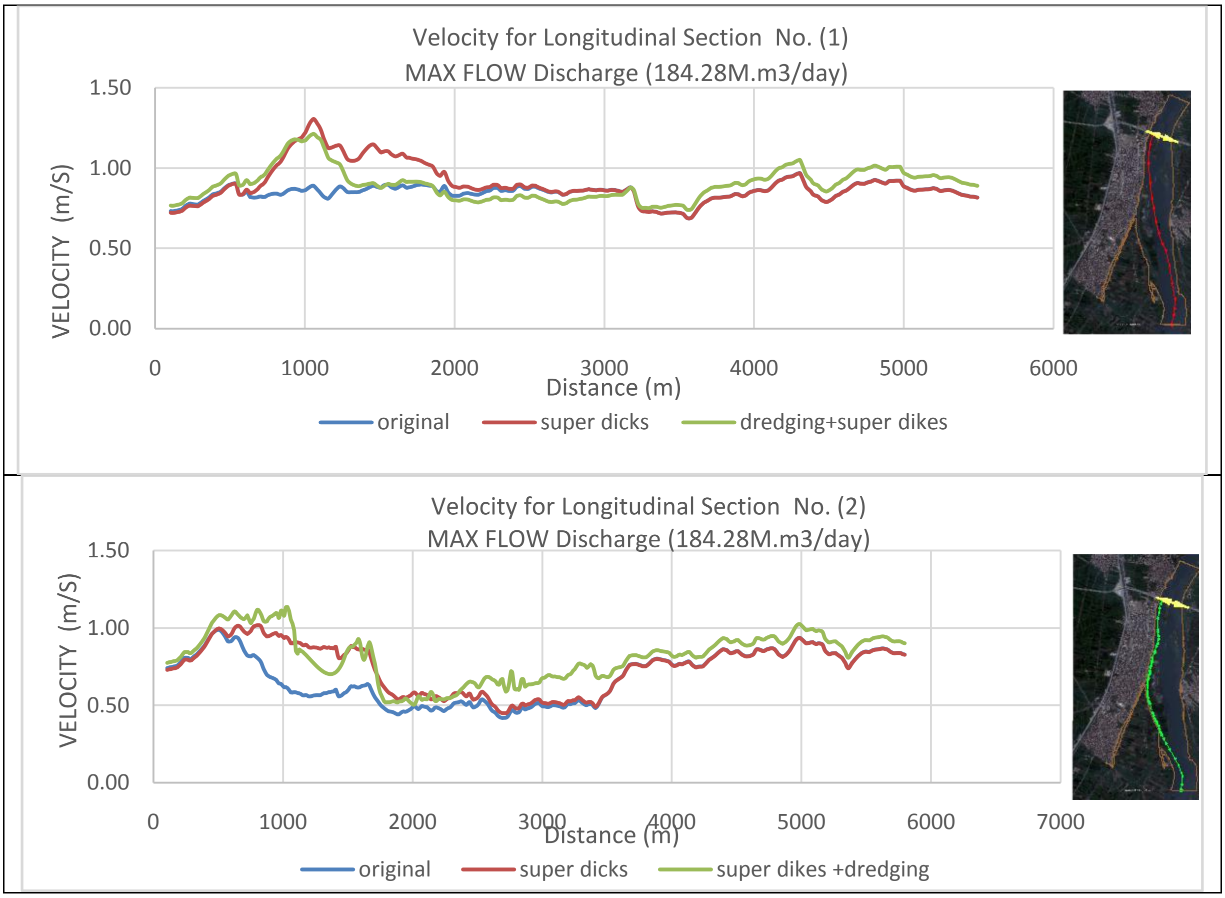


Figure 8: Mean velocity for scenarios

Table 4: The difference between different alternatives

Alt	River Flow	Main branch		Secondary branch		Water surface at Upstream (m)		Diff (cm)
	Q(m³/s)	Q(m³/s)	Percent%	Q(m³/s)	Percent%	max	flood	
Original case	2132	1936	90.8	196	9.2	23.244	24.438	
Dredging (Alt5)	2132	1785	83.8	347	16.2	23.274	24.421	3
Dredging (Alt7)	2132	1712	80.4	420	19.6	23.263	24.406	1.9
Super dike(c3)	2132	1885	88.5	247	11.5	23.298	24.545	5.4
Super dikes(abc)	2132	1896	89	236	11	23.313	24.555	6.9
Dredging(Alt5) +super dikes	2132	1727	81.1	405	18.9	23.322	24.496	7.8
Dredging (Alt7) +super dikes	2132	1642	77.1	490	22.9	23.311	24.486	6.7

5. Conclusions

In this research work, the following conclusions were reached:

-River restoration is the process of managing rivers to reinstate natural processes to restore hydraulic efficiency of the river channel.

-To solve the problem of encroachment on the West Bank in its study area that there have been interventions those have been made with three proposals: dredging and super dikes and their combination.

-For dredging options, seven alternatives have been created for a different location in the study area, it was concluded that there is an increase in velocity and discharges on the secondary channel.
-For super dikes options, nine alternatives have been created for different locations and lengths in the study area, conclude that there is a local effect, the effect on speeds is smaller.
- For the combination of dredging and super dikes options, was found the best solution because Increase in velocity and decreased on the water surface this will increase bed shear stress and reduce sediment transport.

References

[1]. Barnes, H. H., (1967),"Roughness Characteristics in Natural Channels," U.S. Geological Survey Water Supply Paper 1849.
[2]. Holmes, N. T. H. (1998). The River Restoration Project and its demonstration sites. In: de waal, L. C., Large, A. R. G. and Wade, P. M. (Eds.), Rehabilitation of Rivers: Principles and Implementation. Wiley, Chichester, 133-148.
[3]. Sadek, N., Mohamed, M.S., and Mohamed, R. (1999). "Nile River Morphological changes; case Study Rosetta Branch". ASCE Middle East Regional Conference and International Sympoiums Environmental, 16 - 18 May, 1999, Cairo, Egypt.
[4]. Sadek, N., Rafeek, M., Abdel Bary, Talaat A., and Aly, A. (2001). "Morphological Changes Impact On Water Surface Profile Predicted For The River Nile". Eighth International Symposium on River Sedimentation, (ISRS 8), Cairo, Egypt, Nov, 2001.
[5]. El Sersawy, H., (2001), "Modeling of the Morphological Processes in the Navigation uses". Thesis submitted to a PH. D., Cairo University, Faculty of Engineering.
[6]. Yang C. T., Francisco J. M., (2002). "Generalized Sediment Transport model for Alluvial River Simulation Version 3 (GSTARS3)". U.S. Bureau of Reclamation, Technical Service Center, Denver, Colorado, December, 2002.
[7]. Nile Research Institute, (2003). "Hydrographic and Topographic Maps of the River Nile".
[8]. Attia, K., and El Sersawy, H. (2004), "Realignment of West Side of the River Nile Downstream New Esna Barrages Using Mathematical Models", NRI Technical Report in Arabia.
[9]. Attia, K. M. and El-Saied, N.,(2004), "Plan Form Geometry of River Meander at Damietta Branch" Scientific Bulletin, Faculty of Engineering, Ain Shams University, ISSN 1110-1385, Vol. 39, No. 1, pp.359-379, March 31, 2004.
[10]. Sadek, N. and Aziz, M. (2006). "Analysis of Different Floods on River Nile Fourth Reach" Third Regional Conference on Perspectives of Arab Water Cooperation Challenges, Constraints and Opportunities, Cairo, Egypt, 9 -11 Dec., 2006.
[11]. Wael A. Fahmy, (2006). "Improving Flow Conditions Along Inner Curve of River Bends." Master's Degree Thesis, Faculty of Engineering, Shobra, Banha University.
[12]. NRI (2005-2007). "Water Budget (2003- 2007) to the Completion of Great National Projects in Egypt". Between the Nile Research Institute and the Academy of Scientific Research and Technology. This project Introduced 4 reports, in April. 2005, October 2005, August.2006, and March. 2007.
[13]. Raslan, Y., Sadek N., and Attia k. "Impact of Navigation Development on Damietta Branch" Water Research Center Journal, March, 2008, Cairo, Egypt.
[14]. Wael M. Ziada, (2009). "Effect of Man Made Interventions on River Nile Hydraulic Characteristics." Master's Degree Thesis, Faculty of Engineering, Shobra, Banha University.
[15]. Nile Research Institute (2013), "Development of Waterfront of Al Wasta, Beni Suef Governtore, Egypt". Technical Report.
[16]. El Sersawy, H. and El Barbary, Z, (2016), "Hydraulic Evaluation of River Restoration Using Numerical Modelling Approach" international journal of scientific & engineering research, volume 7, issue 10, october-2016.