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Research Article

The mitigation measures of sediment deposition in-front of El Kuraimat power plant intake

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Abstract The objectives of the current research were to mitigate the sedimentation problem in front of thermal power plant intakes, case study, El Kuraimat thermal power plant, also investigate the effectiveness of a set of alternatives to solve this problem. Several sorts of data were collected including, velocity measurements, hydrographic survey data, water levels and discharges in several years and seasons.
2-D numerical model, iRIC "international River Interface Corporative" was utilized to simulate the study area and test the set of alternatives to meet the optimum solution, the model was calibrated and verified using the field velocities and water levels. The set of alternatives were used to improve the flow pattern inside the eastern channel, where the plant intake was located. The model results were revealed that connecting the small formed island and the downstream tip of El Kuraimat island to bed level 23.00 m, was the optimum solution from both the hydraulic and economical point of view.

Keywords Hydrodynamic, Water Intake, Flow Distribution, Power Plant, River.

Introduction

Most of the Nile River sediment loads have been deposited in Nasser Lake, upstream the Aswan High Dam. In turn, the river almost sediment- free downstream the dam. Local scour and deposition in the Nile River were observed at many locations. Several sources of sediments were developed from wind-blown sands, bank failures, dredging operations, flash floods and the river bed. Most of the intakes of the power plants facing problems especially at power plants that use river water for cooling, the sedimentation problems in front of its plant intake, as the sediment entering causes blockage of the trash rack and the associated vibration and wearing of the pump impellers.

Many researches were involved in studying and solving the sedimentation problems in front of power plants intake; 2D hydrodynamic model was applied to investigate the distribution of velocities at an existing water intake along the River Nile west bank at Assuit. Demolishing of stone peaks from the central island (alternative 1) showed an increase of the velocities magnitudes [1]. The river morphological changes were studied using 2-D numerical model to analyze the problem of sedimentation at water intake of Rowd El-Farag pump station, the study shows significant morphological change in this reach due to hydraulic Structures (Imbaba and Rowd El-Farag Bridges). Several scenarios were presented and many alternatives were tested to control sediment, the study concluded dredging the pump intake area to the level 14 m was less compared to dredging to the level 12.5 m [2]. An experimental study was executed to enhance the sediment distribution in the vicinity of New Tebbin power plant using double rows of submerged vanes placed vertically at an angle of 60º to the main flow direction. The function of vanes were to generate a secondary flow in order to modify the flow near the bed pattern also for re-distribute the flow and the sediment transport within the channel [3]. It was found that using submerged vanes led to minimizing the bed sediment entering the intake effectively.

Two flumes were constructed using four vanes placed in one row, sixty runs were conducted including four runs without vanes to be used as a reference case. It was demonstrated to minimize the sediment transport that entered the intake channel by 40% to 75 %; the position of the single row of vanes should be at $b_v/b_d = 0.5$,(

where: b_d: Intake channel width and b_v: Distance from the centerline of the intake to the centerline of vane's row) and the vanes angle equal to 40º with the main flow direction, and the height of vanes was 0.4 m of the tail water depth so volume that entered the intake channel was the least quantity among the tested cases [4]. Eighty-one experiments were executed in a laboratory open-channel of cross-section dimensions 20*50 cm and 10 m long to solve the change in bed level and corresponding water level of rivers due to its deposition on the river bed. The experiments used three heights of sharp crested weir placed in the last third part of the channel; they found the sediment reduction ratio increased with the increase of weir height [5].

Focusing on previous studies related to sediment transport process and water intakes, it was stated that sediment transport is the set of processes that mediates between the flowing water and the channel boundary as the amount and size of sediment moving through a river channel are determined by three fundamental controls: competence, capacity and sediment supply [6]. It was defined that the coarse sediment moving as bed load and the fine sediment moving as suspended load, If coarse sediments reach the pump, may cause pump impeller damage and erosion of piping. Fine suspended sediments at high concentrations tend to cause siltation inside the pump intake structure which adversely affecting the cooling water system [7].

Ijok intake was studied which facing sedimentation problem at inlet that reduced the flow capacity into Ijok canal with CCHE2d a two dimensional model According to the sediment patterns which measured after running 3 hours in the physical model and 11 hours in the numerical model the L-shape dike and the combination between the 90º dike and the L-shape dike in front of intake structure , the analysis showed that the construction of dike can be useful as it can reduce and control the sediment in river water intake [8]. Submerged vanes was used in preventing bed load transport from entering water intakes. By generating a secondary circulation in the flow, the vanes change the magnitude and direction of the bed-shear stresses and cause a redistribution of the flow and sediment transport in the area affected by the vanes [9]. It was described that, how the sediment problem was successfully controlled by means of modifications to the area in front of the intake and the upstream riverbank. The modifications comprised erosion-promoting vanes and a skimming wall, which enabled the intake and power station to continue operating while the modifications were being installed [10].

Study Objectives

A 2-D numerical model, iRIC "international River Interface Corporative" will be utilized to develop a clear understanding for the river morphology and the flow distribution in the vicinity of the plant and also investigate the effectiveness of a set of alternatives for solving the sedimentation problems in front of the intakes of the thermal power plant intakes.

Site Description and Problem Definition

EL Kuraimat power plant is located on the East Bank of the River Nile, approximately 95 km south of Cairo. It comprises of two 627 MW gas/oil fired units generating power into the National Unified Power Grid System (NUPS) through a 500/220kV switchyard and associated transmission system [11].

Figs (1 and 2) show the layout of the general feature of the Nile River at the proposed location of the thermal power station. It is noticed that the river boundary within the surveyed reach is comprised many islands. The biggest one, is called El Kureimat Island, is about 4300m long with average width of 1300m. The downstream boundary of this island is located about 500m upstream of the proposed site for the plant.

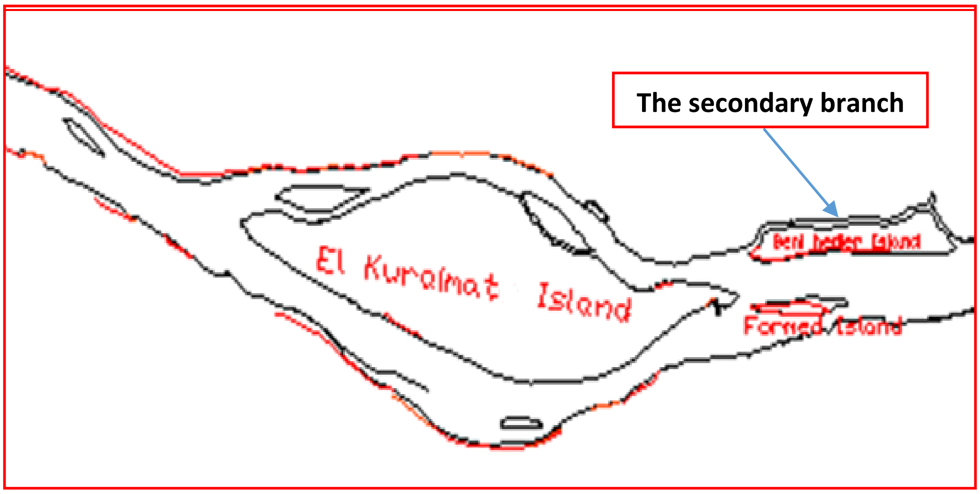

Figure 1: General layout of the modeled reach

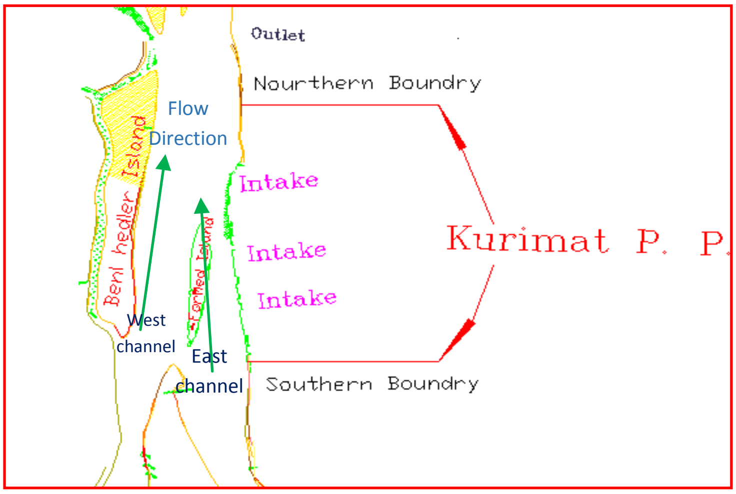

Figure 2: General layout of the modeled reach

Beni-hideir island divides the river into two branches. The secondary one, which is located in the lift side of the river, is about 95 m wide full of weeds. The active width of this branch is about 50 m, and carries about 50 m^3/s which is equivalent to 3 % of the total discharge

The main channel, in the right side of the river, with an average active width of 600 m. Due to the change in the morphology of the river, a new island is formed in front of the southern part of the site (See Fig.1), Due to the formation of the new island, the width of the main channel is divided into two parts. The east channel which is in front of the power plant intake and the west channel that is between the formed island and Beni Hideir island.

So, a large amount of sedimentation formed in front of the existing intake, the sediment sizes penetrating to the pump are ranging from coarse sand to gravel of median size of 7mm [12].

The sediment that entering causes blockage of the trash rack and associated vibration and wearing of the pump impellers; hence the pump impellers should be changed every 2 to 3 years and during high flows the incoming sediment forces a maintenance process to 1 to 2 quarters of the condenser. In addition to floating vegetation, due to decreased velocities, have been accumulated and thus increasing the deposition in this region acts as sediment traps:

The sedimentation problem is due to morphological features of the river at the location of the intakes:

1. The intakes located on the side of the river where the river will naturally deposit sand.
2. A small island in the river outside the plant, is formed over time to naturally stabilize the channel,

Model Development And Calibration:

Bathymetric survey of the River Nile [13] and velocity measurements at selected locations were analyzed .The field data survey were used the hydrodynamic simulations, water surface elevations and discharges measurements in the vicinity of El Kuraimat Island, which are:

- The maximum water levels and discharges at the power plant site were 23.37m MSL and 2245m^3/s.
- The dominant river flow was equal to 21.63m MSL and 1190 m^3/s.
- The minimum river flow was equal to 20.05m MSL and 550m^3/s.

The model was developed in two dimensional horizontal scheme to cover an area of 8.5km length and 2 km as average width, Fig. (1). The length of the simulated area was set to the most suitable length, which not affect the results accuracy. A grid from polygonal line and width was designed to simulate the whole reach of the studied area where the grid size was set to give much more accurate results through the simulated area. The model boundary conditions were set by giving a convenient hydraulic parameter upstream and downstream the modeled reach based on the field measurements. The discharge was used as an upstream boundary while the water level as a downstream boundary.

For the time frame, the suitable time step and the total simulations time were defined in such a way to reach the steady state condition for the hydrodynamic simulations.

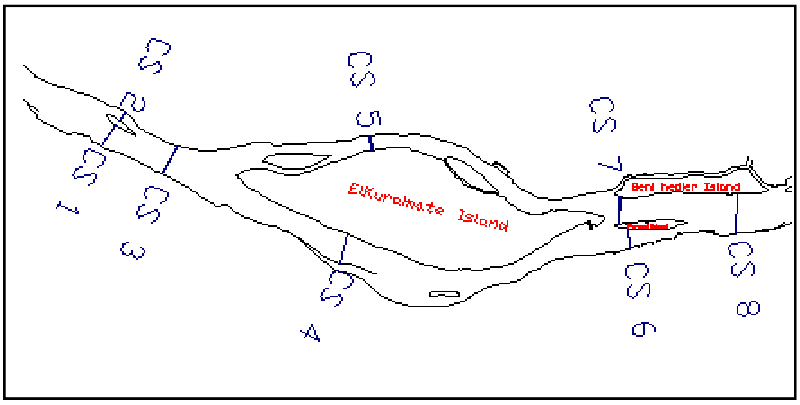

Figure 3: shows the locations of measured velocities cross sections

The discharge used in the calibration process was 1127 m^3/s, the upstream water level was 22.4m and the downstream water level was 21.6m. The calibration of the hydrodynamic model was carried out by comparing the water surface elevations and the velocity data around El Kuraimat Island obtained from the 2-D model with the field measurements, Fig. (3) shows eight measured velocity cross sections distributed along the simulated area. The differences between the measured and the calculated values, showed good agreement between the velocities obtained from the used model and field measurements at different cross sections, Figs (4-6).

Velocities:

<u>For sec No. (1):</u>

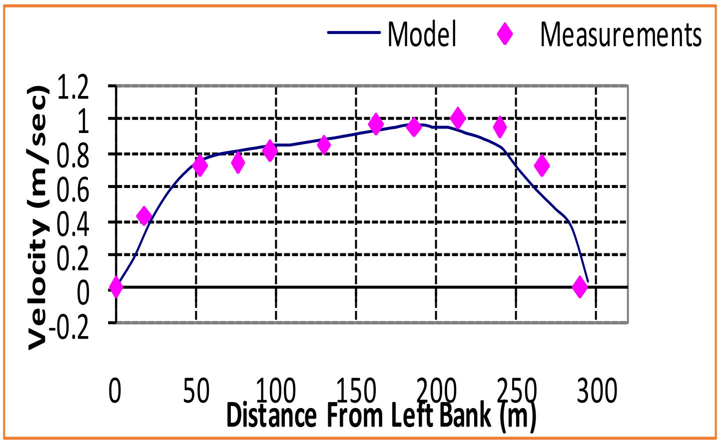

Figure 4: The comparison between the measured and the calculated velocity in cross section 1

<u>For sec No. (4):</u>

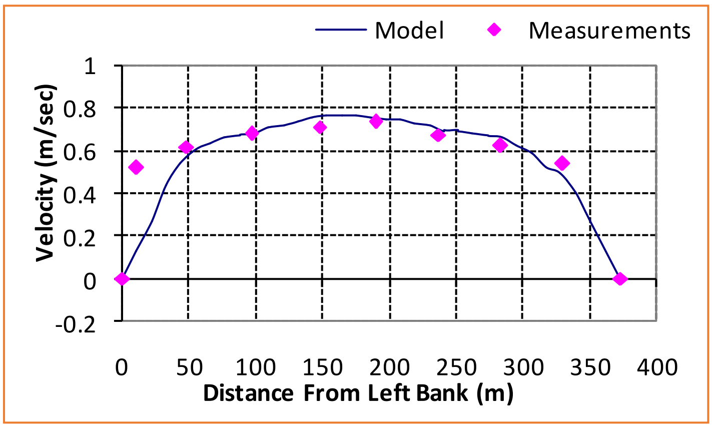

Figure 5: The comparison between the measured and the calculated velocity in cross section 4

For sec No. (7):

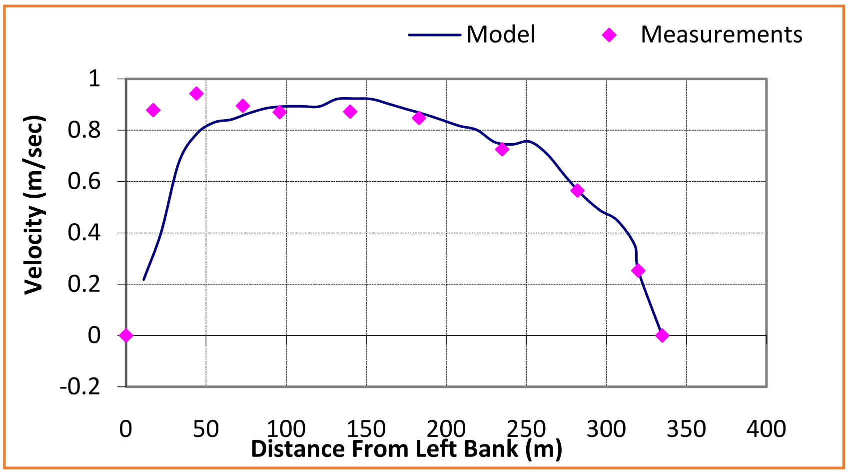

Figure 6: The comparison between the measured and the calculated velocity in cross section 7.

Model Scenarios

Different model scenarios had been carried out to overcome the sedimentation problems at the area of the intake structure, different alternatives with eighteen runs were conducted including three runs for the basic case were tested in the way to assess the optimum solution. Each was tested through different scenarios related to the river flow condition, the maximum river flow, the dominant river flow and the minimum river flow, the model results were compared to the basic case. Two cross sections presented in Fig. (8), (A-A) and (B-B) represent the discharge of the east and west channel of the small formed island. The description of each alternative and the model result are discussed below.

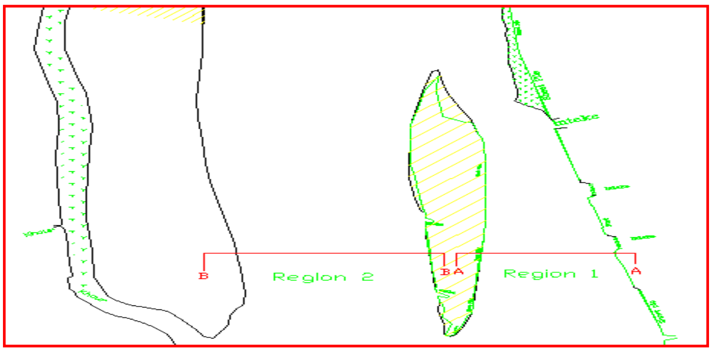

Figure 7: The locations of SECs (A-A) and (B-B)

Model Simulation:

Model simulations were performed according to the following alternatives:

- **Basic Case:** It considered the base line case to be used as a reference for comparison.

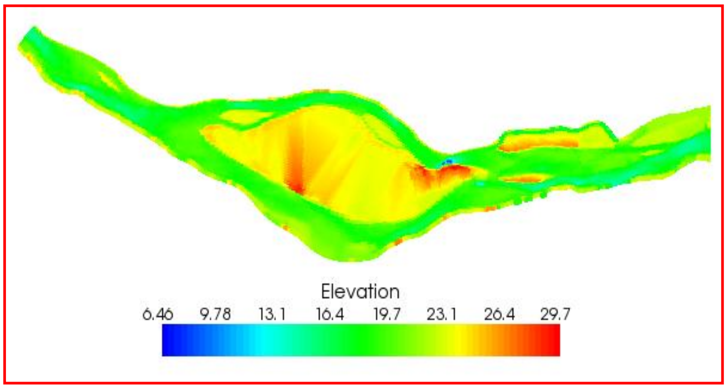

Figure 8: The basic case

- **Alternative One:** One deflector with 100 m length was proposed to be constructed and located at the west channel.

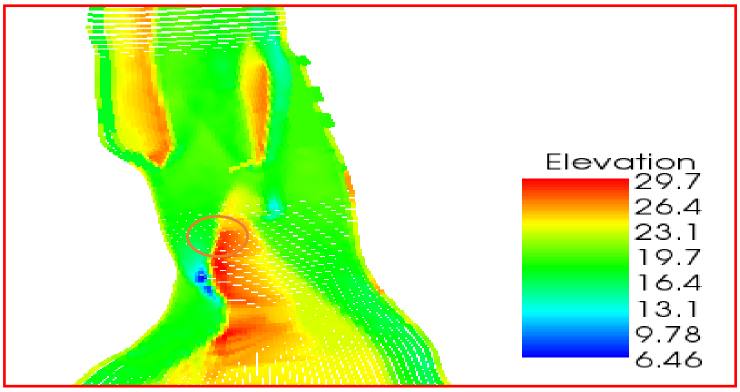

Figure 9: The bed elevation for the location of the deflector

- **Alternative Two:** Dredging the bed level in the eastern channel in front of the intake up to 17.5 m.

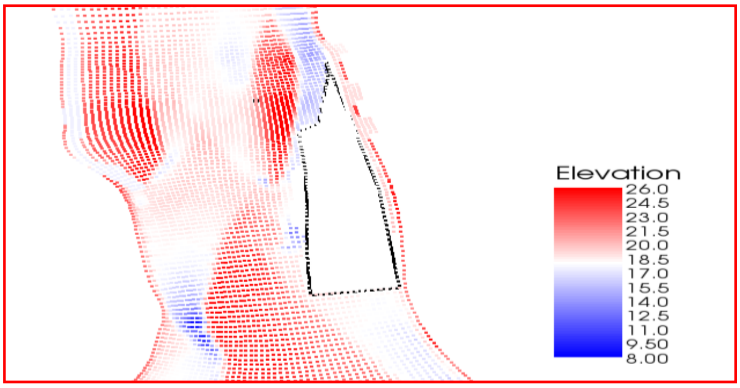

Figure 10: The dredged area

- **Alternative Three:** Connect the small formed island and the downstream of El Kuraimat Island to bed level 23.0 m.

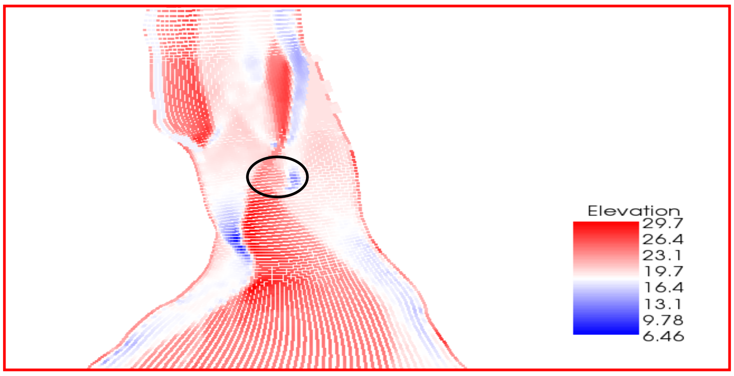

Figure 11: The connected area between the two islands

- **Alternative Four:** Trim the small island according to the following concept; increasing the conveyance of the east channel, by increasing the opening width at the downstream end of the small formed island in front of the power plant intake due to the reduction of the flow in the west channel. The cut area would be dredged to 16m.

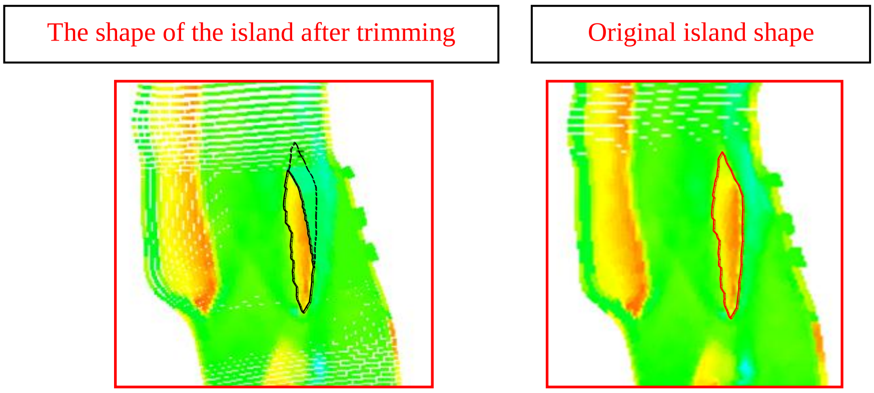

Figure 12: The shape of the original island and the shape of the island after trimming

- **<u>Alternative Five:</u>** It is considered to be the combination between alternative one and alternative two, by using one deflector of 100 m length constructed in the western channel and dredging the area between the small formed island and the right bank to bed level 17.5 m in front of the intake at the eastern channel.

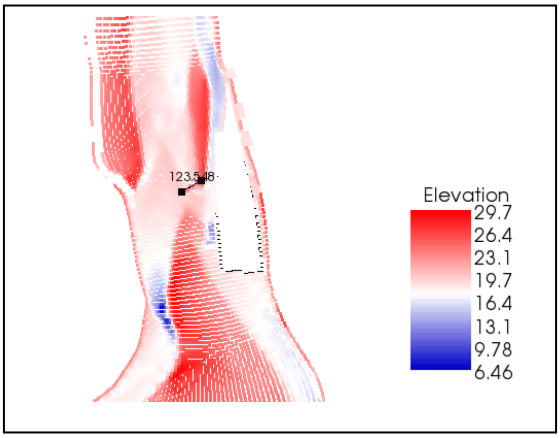

Figure 13: The combination between alternative one and alternative two

For all alternatives, three model scenarios were carried out for each alternative, this model scenarios included the different river flow condition (Min, Dom and Max Flow) as shown in table (1).

Table 1: Shows the River Hydrograph

Case	**Maximum Discharge**	**Dominant Discharge**	**Minimum Discharge**
Discharge (m^3/s)	2245	1190	550
Water Level (m)	23.37	21.63	20.05
Duration (month)	2	9	1

Model Results and Analysis:

The model analysis results were performed based on the improvement of the flow pattern and the total discharge approaching the eastern branch, Where the intake of the power plant located, To assess the effect of each alternative on the flow discharge, and the velocity distribution; a comparison between the studied alternatives and the basic case was carried out, Figs (14-18) show the results of the model simulations of flow velocity with the case of dominant discharge compared with the basic case, as it is noticed that, the flow pattern close to the area of intakes was improved in case of connecting the small formed island with the downstream tip of El Kuraimat island to bed level 23.0 m (Alter-3) where, the flow velocity at such area was increased by 13 % compared with the basic case. This increase in flow velocity close to the area of intakes will lead to reduce the probability of deposition process to occur, and as a result reducing the frequency of the dredging works on front of the intake area from the economical point of view.

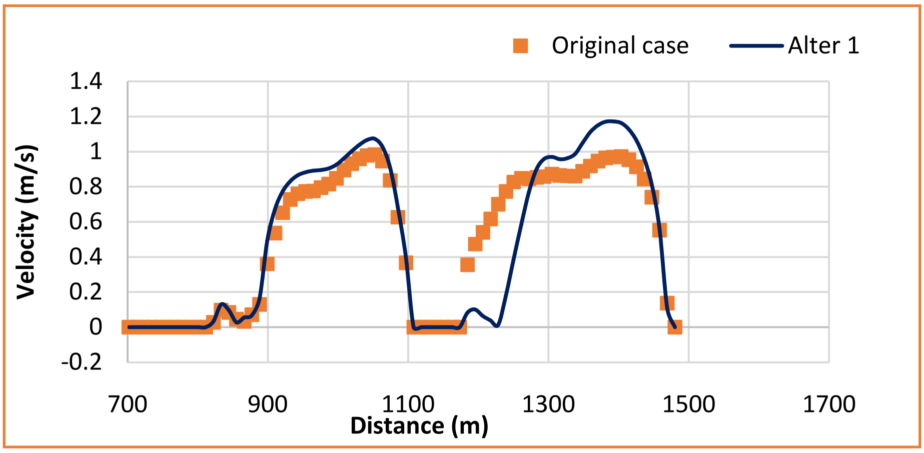

Figure 14: The velocity distribution for Alter (1) and the basic case

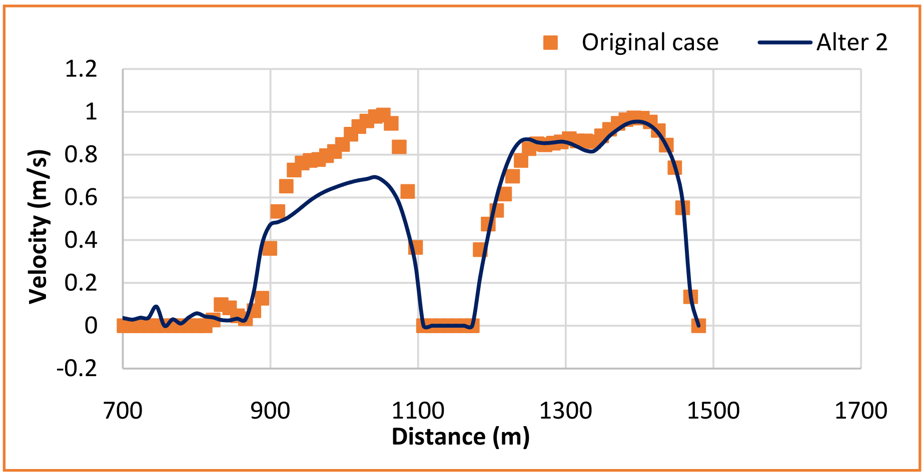

Figure 15: The velocity distribution for Alter 2 and the basic case

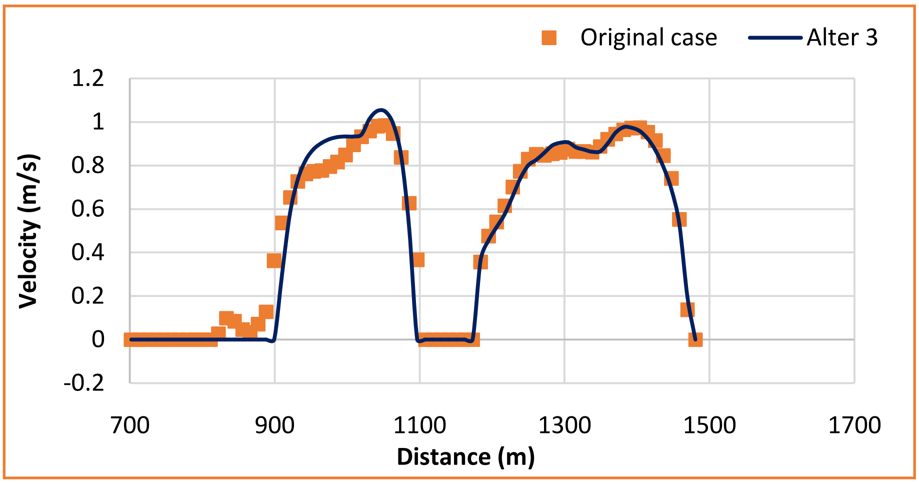

Figure 16: The velocity distribution for Alter 3 and the basic case

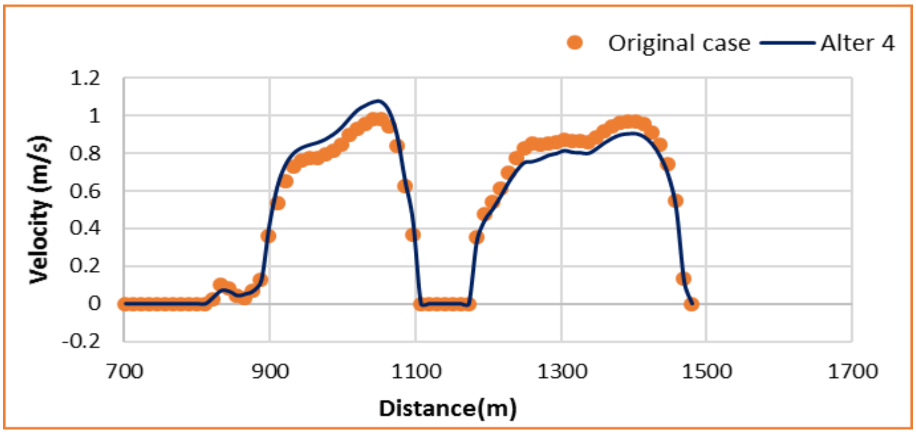

Figure 17: The velocity distribution for Alter 4 and the basic case

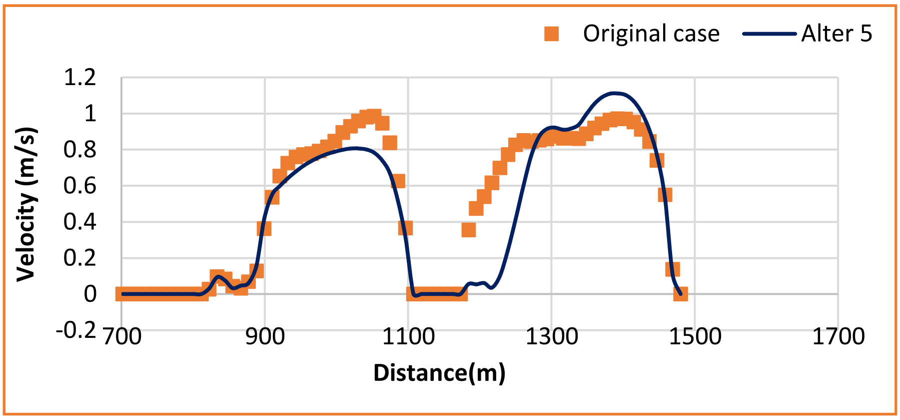

Figure 18: The velocity distribution for Alter 5 and the basic case

Table (2) shows the flow distribution through the eastern and western branches of the small island at El Kuraimat intake vicinity for the original case and the five studied alternatives with different river flow conditions. It can be seen that, connecting the two islands (the downstream tip of El Kuraimat island with the small formed island) to bed level 23.00 m as indicated in alternative 3 or constructed only one deflector in the west channel in addition to dredge the east channel to bed level 17.50 m as indicated in alternative 5 increases the flow discharge passing in front of the intakes of the power plant with 7% and 25% respectively (case of minimum flow), 16.9% and 15.9% respectively (case of dominant flow) and 15.8% and 14.6% respectively (case of maximum flow) comparing to the original case.

Table 2: Shows the discharge comparison between the five alternatives

	Alternatives	**Passing discharge In East branch m^3/s**			**Passing discharge in West branch m^3/s**			**Passing discharge in the Secondary Branch m^3/s**		
		Min flow	**Dom flow**	**Max flow**	**Min flow**	**Dom flow**	**Max flow**	**Min flow**	**Dom flow**	**Max flow**
0	Basic case	285	523.5	906.96	242.5	611.5	1199.7	20.2	50.3	130.3
1	One deflector in the west channel	310.17	567.73	1037.64	230.28	602.27	1084.2	8	20	120.16
2	Dredging to bed level 17.5m	317.1	550.5	953.68	200	569.1	1129.6	30.9	65	155.72
3	Connecting the two islands to bed level 23.00	305.17	612	1050.68	238.57	533.93	1032.3	5.26	40	150.02
4	Trimming island	269.6	557.7	957.5	233.15	544.6	1134.2	45.25	75.7	140.3
5	One deflector in the west channel + Dredging to bed level 17.5 in the east channel	358.4	606.97	1039.45	167.35	515.58	1081.7	23.25	58.45	115.3

Conclusions

Improving the hydrodynamic processes in the vicinity of El Kuraimat power plant intakes was investigated in the way to minimize the sedimentation problems in front of the power plant intakes. The hydrodynamic model simulations were carried out ,using 2-D numerical model IRIC , to asses a number of different alternatives to solve such problem, Based on the model analysis results for each alternative individually, and comparing these results to the basic case, it is concluded that; connecting the small formed island with the downstream tip of El Kuraimat island to bed level 23.00 m is considered the best solution for minimizing the sedimentation problems in front of the vicinity of El Kuraimat thermal power plant where, the discharge passing through the eastern branch in front of the plant intake was increased by 7% in case of Min Flow, 16.9% in case of Dom Flow and by 15.8% in case of Max Flow compared to the basic case. In addition to increasing the flow velocity at the eastern branch of the small island; consequently reduce the opportunity of sediment deposition process in front of the intake, in turn improving the efficiency of the intake withdrawal of water for the cooling system and the efficiency of the power plant electrical production as well.

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