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IMPROVING THE EFFICIENCY OF RIVER ACTIVITIES BY REFORMING ISLANDS

(Case study: El Kurimat Power Plant)

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ABSTRACT

This paper presents the effect of reforming the islands on enhancing the performance of a main river activity with minimum influence on the other activates. Nile River from Km 802 to Km 812 was selected for this study, as this part of the Nile River has two main activates isolated by two separate Islands. The main activity is a power generation by a thermal Power Plant, (El Kurimat Power Plant) which is suffering from sedimentation problems in front of its intake. The other activity is river navigation pass. 3D Mathematical model, Delft 3D, was used to simulate the study area and test the different scenarios of the study. Field measurements using advanced equipments were carried out to cover a distance of 10 km of the River Nile at study area. Intensive bathymetric survey around the existing structures within the surveyed area (groins, intakes or outfalls structures, Islands, etc) was implemented. The model constructed and calibrated using the measured data. Different flow condition of the Nile River; minimum, dominant and the maximum discharges were tested. The model showed that the connecting of the two Islands by a submerged weir with crest level lower than the minimum water level by 30 cm will reduce the sedimentation problem at the power plant intake by more than 40% with minimum significant changes on the navigation pass.

تقدم هذه الورقة البحثية دراسة تأثير إعادة إستخدام الجزر والبيئة المحيطة في رفع مستوى الإداء لانشطة النهر مع الحد من التأثير على الأنشطة الأخرى. تم اختيار جزء من نهر النيل من كم ٨٠٢ إلى كم ٨١٢ ، ويستخدم هذا الجزء من نهر النيـل في توليد الطاقة الكهربائية بواسطة محطة الكريمات الحرارية الموجودة فى البر الشرقى والتى تعاني من مشاكل الترسيب أمام مأخذها، كما يستخدم الفرع الغربى كممر ملاحى، وتفصل بينهما جزيرتان منفصلتان. ولتحقيق الغرض من هذه الدراسة تم إستخدام نموذج رياضي ثلاثى الابعاد (Delft 3D) ، لمحاكاة منطقة الدراسة واختبار السيناريوهات المقترحة. كما إجريـت القياسات الحقلية لنهر النيل فى منطقة الدراسة. وشمل الرفع المساحى الروس الحجرية، المآخذ ، المخارج والجزر. تم معايرة النموذج باستخدام البيانات الحديثة المقاسة وإختبار السيناريوهات مع ظروف مختلفة للسريان (أقصى وأدنـى الأحتياجـات). وأظهرت نتائج النموذج عند ربط الجزيرتين بإستخدام هدار مغمور بمنسوب عتب أقل من المنسوب الأدنى للمياه بمقدار ٣٠ سم سوف يقلل من مشكلة الترسيب أمام ماخذ محطة الكهرباء بمقدار ٤٠٪ مع أقل تغييرات ممكنة بالنسبة للمسار الملاحى.

***Keywords*: Power Plants, Navigation pass, River Islands, Numerical Model.**

1. INTRODUCTION

The Nile River at El kurimat City is one example of the dynamic river changes where the bed levels rise and severe sedimentation problems have been observed. , (Plate 1), The Nile River at this location was divided into to part; Eastern part and Western part which are separated by two islands with 200 m apart. The main activity of the Western part is river navigation, while the main activity of the Eastern part is the power generation, (total capacity of 2756 Mw), by El Kurimat power plant which depends on the Nile River for its cooling system with two neighboring intake units of 20 m³/s each and a downstream outlet discharge unit about 500 m from the intake units. There is an intensive local sediment transport and deposition in this region. The year 2000 river survey revealed that the bed level of the river reached from 18.5 m to 19.5 m in the vicinity of the intake structure.

Based of the recorded five years data, the water levels and discharges at the site are as follow:

Maximum river flow= 181.31 Mm^3/day at water level 23.52 m+ MSL

Dominant river flow= 89.65 Mm^3/day at water level 21.79 m +MSL

Minimum river flow= 63.30 Mm^3/day at water level 20.46 m +MSL.

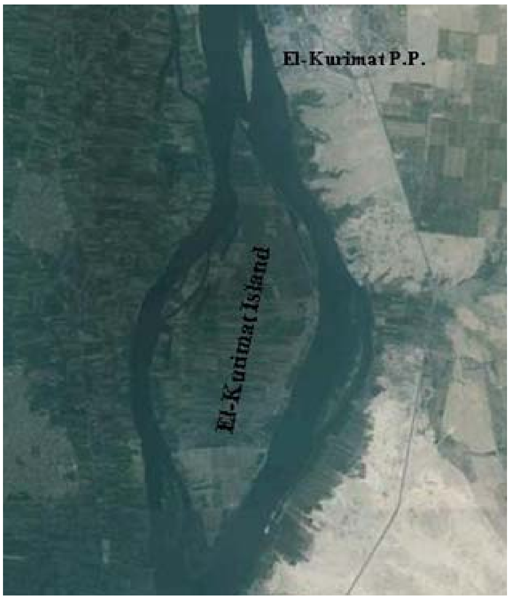

Plate (1): Nile River at El-Kurimat City

1.1 Problem definition:

Clearly this situation constitutes a major problem to the operation of the power plant pump unites which withdrawing water from the intake structure. A second issue is that extension of the current power plant by adding new units having an inflow of 33.75 m³/s was established. A huge amount of sedimentation exists in front of the existing intake and further upstream at the inlet of the eastern channel. The sediment sizes penetrating to the pump are ranging from coarse sand to even gravel of median size of 7 mm. This sediment causes blockage of the trash rack and associated vibration and wearing of the pump impellers. The pump impellers had to be changed every two to three years and during high flows the incoming sediment forces a maintenance process to 1 to 2 quarters of the condenser. In addition floating vegetation, due to decreased velocities, had been accumulated and thus increasing the deposition in this region as they act as sediment traps.

2. PREVIOUS STUDIES

The Upper Egypt Electricity Production Company assigned the Hydraulics Research Institute (HRI) to select the optimum location of the new units and to ensure that no sedimentation problems exist for both the current and future units based on the hydrographic survey data which was carried out by HRI in (2003).

The study was carried out on a hydraulic movable bed model with scale 1:30 and Final results of the study can by summarized as follow

-The sediment barrier “submerged sill” and submerged bottom vanes with crest level 18.85m +MSL, (plate 2), have a very good effect in preventing the accumulation of bed load in front of the intake.

-Dredging the bottom of the eastern channel is required to increase the conveyance in the channel, which will reduce sediment deposition in the channel.

-Groin of 100m at the tip of EL-Kurimat Island” in addition to groin of 50m at upstream the small island , (figure 1), increase the discharge of Eastern channel from 15% to 35% of total river flow.

Thus it was decided to apply the suggestions of these studies in site and mentoring the behavior of the Nile River after the construction works.

3. Site mentoring:

The river bed was mentored in August 2009 after the end of the construction and dredging works to see the effect of the proposed solutions on the river performance. The results show

- Increasing of the flow discharge of the eastern channel to 44% of total river flow, and it was more the expectations of the Models.

Plate (2): Submerged Vans in front of the intakes

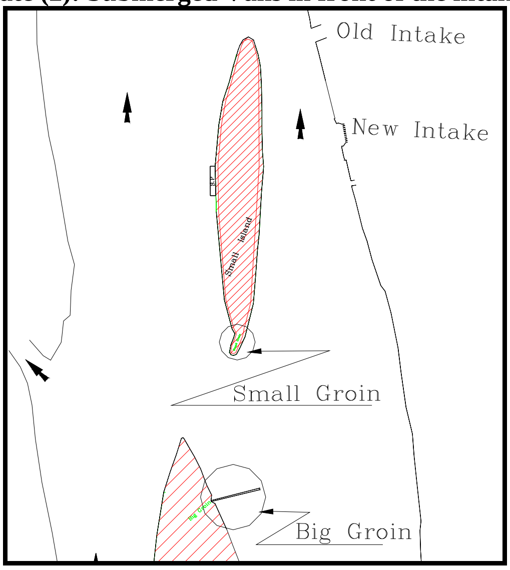

Figure (1) : The proposed groins

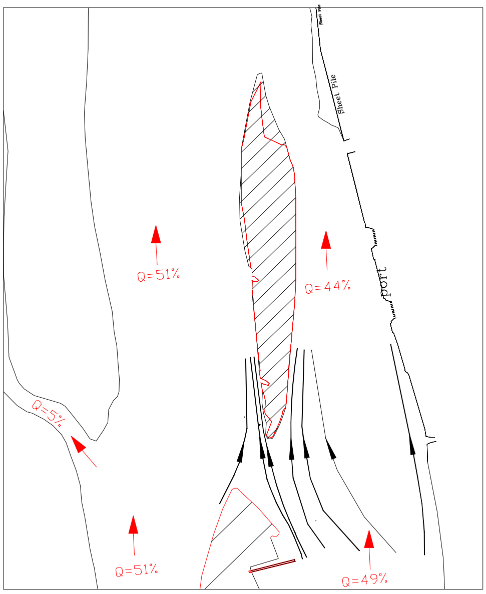

Figure (2): Flow pattern and discharge ratios around the small island

The measured surface flow pattern around the island, as shown in figure (2), shows concentration of the flow discharge beside the boundary of the small island and beside the right bank of the eastern channel

- The bed levels at the entrance of the easting channel starts to increase at the middle of the channel, (sand deposition), and decrease beside the boundary of the small island, (scour), as shown in Figure (3) and Plate (3). This means that the increasing of the flow discharge was concentrated beside the small island and not uniformly distributed over the channel width.

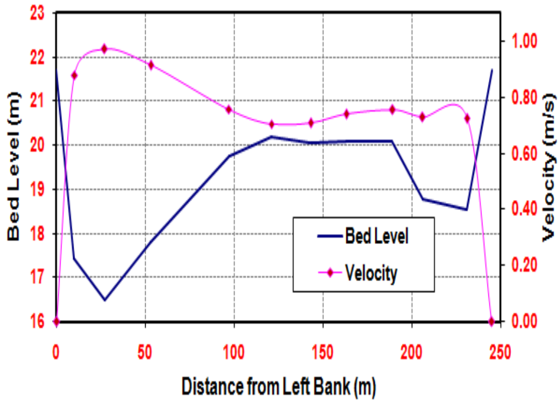

Figure (3) Flow velocity distribution and bed configuration at the entrance of the Eastern channel

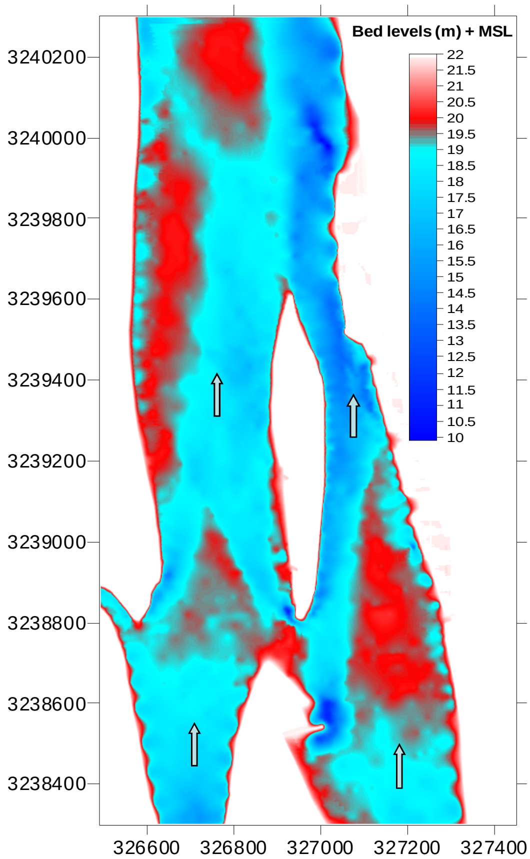

Plate (3): River bed levels, Aug 2009

Aim of the Research:

The main objective of research is to apply a solution that guarantees no sand deposition at the western channel. This can be done by increasing the flow discharge passes through the channel with uniform flow velocity distribution over its width.

4. PROPOSED SOLUTION

The optimal scientific solution for the problem has depended on the investigation of the problem reasons. In addition, it has investigated the problem effects on the Nile River morphology and the necessary steps for the problem elimination. The suggested solution is to connect the two islands by a submerged groin with crest level of (13.50)m which is 0.2 m over the minimum water level in addition to the big groin which suggested by the previous studies.

5. APPLIED MODEL

Delft3D Software Package of Delft Hydraulics the Netherlands was used to develop the hydrodynamic numerical flow model which simulates the flow pattern in the vicinity of the proposed plant. The model will enable the study of recirculation, transport and advection of the thermal plume and the cross flow. Delft3D is integrated, powerful and flexible software. It can carry out simulations of two- (either in the horizontal or a vertical plane) and three-dimensional flows, sediment transports, waves, water quality, morphological developments and ecology. The Delft3D package is used for the modeling of coastal, river and estuarine areas. It encompasses a number of well-tested and validated modules, which are linked to and integrated with one-another. These modules are flow, waves, water quality, ecology, particle tracking and sediment transport. Since this study focuses on hydrodynamic simulations and river morphology, the hydrodynamic module (flow module) of Delft 3D was used. For more details on the Delft3D –Flow Module, reference is made to Delft3D Manual.

The Delft 3D Software Package is supported by two other modules to enable the computational grid generation (Delft-RGFGRID) and bathymetric schematization at the grid points (Delft-QUICKIN).

5.7 Number of computational points

The total number of computational cells should be minimized, in order to have an acceptable computation time. The generated computational grid of the depth-averaged model comprises 592×51=30192 points.

5.9 Boundary conditions

In the flow simulations of a specific reach in a river with two open boundaries it is preferable to setup one boundary as a discharge boundary and the other one as a water level boundary. In this model the open boundary upstream the El-kurimat island was selected as a discharge boundary. The boundary downstream the small Island was selected as water level boundary. During the calibration phase the discharge and water level measurements at the location of the open boundaries were used in the model. In the model scenarios (production simulations) the discharge data imposed in the upstream boundary is based on the flow condition. The water levels associated with these discharges were used in each scenario as downstream boundary. The relevant water levels associated to these discharges were obtained from the results of 1D model SOBEK, see HRI report (49/2011).

5.12 Model calibration

In the calibration phase, various parameters may be adjusted within the limits of their uncertainty to achieve the best model results compared with the measurements data. In the calibration the model open boundaries (discharge and water level boundaries) were obtained from the measurements which were carried out by HRI in the framework of the study. The upstream discharge boundary was 1127m^3/s and downstream water level boundary was 21.56 m MSL. In the calibration phase the model was run in its 2-D mode (Depth-averaged mode). The model was calibrated against 10 measured flow velocity cross sections. The locations of these cross section are shown in Figure (4).

During the model calibration the measured depth averaged flow velocities along the measuring cross sections were compared with the model results. The measured and computed water surface slope was also obtained. Tuning of the roughness parameter in the model was carried out to obtain the best matching between the model and the field measurements. Manning Roughness Coefficient was varying between 0.02 and 0.03 along the model area to give the best matching between the measurements and model computations. Figure 5 shows the comparison between the measured and computed water levels.

Figures 6 to 8 show samples of the measured and computed flow velocities at the measuring cross sections. The figures show that there is a good agreement between the model and the measurements which confirms that the model

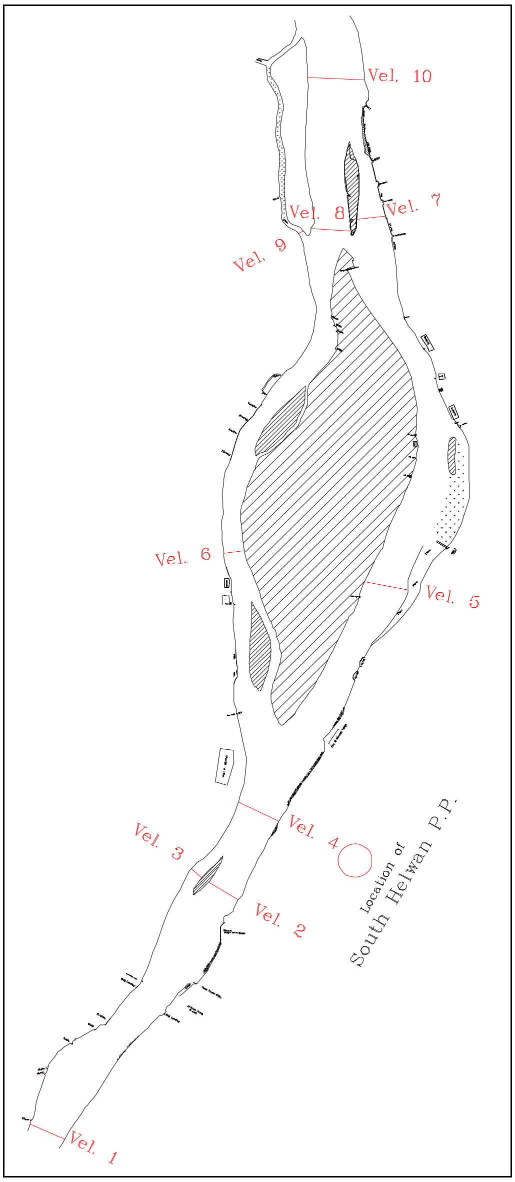

Figure 4: Location of the measured flow velocity cross sections

During the model calibration the measured depth averaged flow velocities along the measuring cross sections were compared with the model results. The measured and computed water surface slope was also obtained. Tuning of the roughness parameter in the model was carried out to obtain the best matching between the model and the field measurements. Manning Roughness Coefficient was varying between 0.02 and 0.03 along the model area to give the best matching between the measurements and model computations. Figure 5 shows the comparison between the measured and computed water levels.

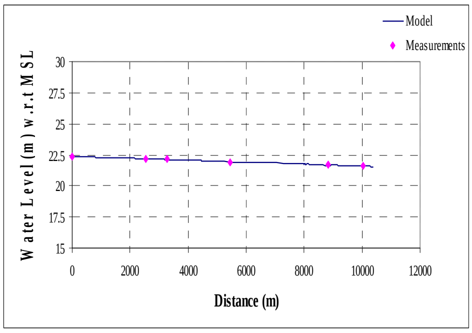

Figure 1: Measured and computed water levels

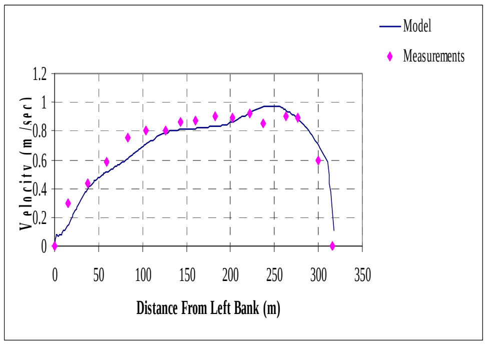

Figure 2: Measured and computed flow velocities at cross section (1)

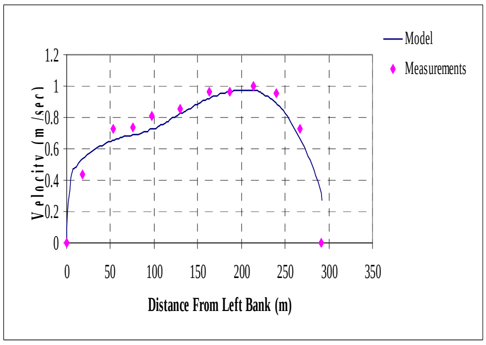

Figure 3: Measured and computed flow velocities at cross section (2)

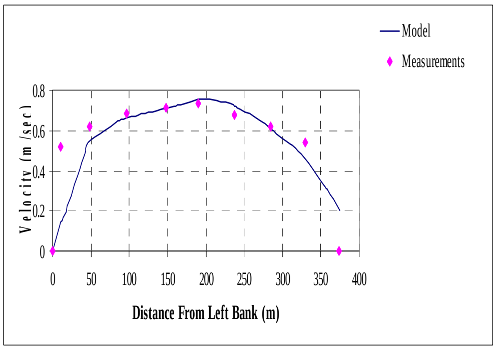

Figure 8: Measured and computed flow velocities at cross section (5)

6. RESULTS AND DISCUSSION

Comparison between the flow discharge distribution after and before applying the proposed solution can presents the efficiency of the solution to reduce the sedimentation problem at the eastern channel. The results show:

- Increasing of the flow discharge of the eastern channel to 49% of total river flow,
- Enhancing the flow distribution over the cross section width with slightly increasing of the flow velocity beside the eastern bank more than the western bank, as shown in Figure (9) which shows a comparison between the flow velocity distribution at the eastern channel with and without the proposed solution.
- The minimum flow velocity will be 0.5 m/s during the closure period which is 1.5 times more than the critical flow velocity, (0.3 m/s), as shown in Figure (10) which shows the flow velocity distribution at the eastern channel the during closure period.

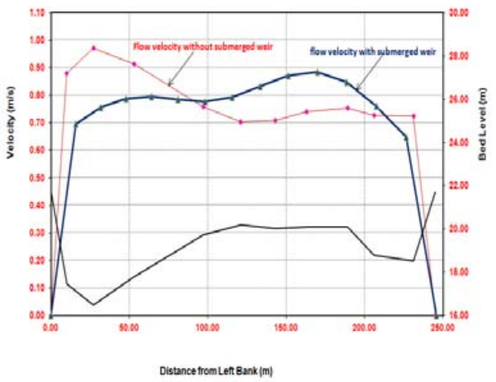

Figure (9) a comparison between the flow velocity distribution at the entrance of the Eastern channel with and without the proposed solution

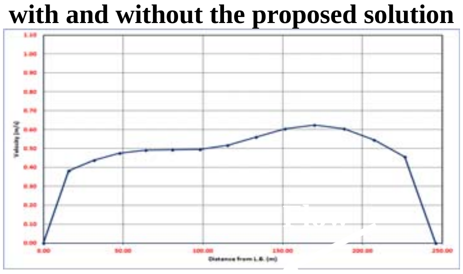

Figure (10) Flow velocity at the entrance of the Eastern channel during the closure period

7. CONCLUSION

The study demonstrated the utility of approach to the solution of a sediment management problem, Field Surveys, Channel stability Analysis, and Numerical Simulations. The Nile River from Km 802 to Km 812 was selected for present study, as this part of the Nile River has two main activates isolated by two separate Islands. The main activity is a power generation by El Kurimat Power Plant which is suffering from sedimentation problems in front of its intake. The other activity is river navigation pass. A lot of studies were implemented to ensure that no sedimentation problems exist for both the existed and future units. Through out this paper the effect of reforming the islands on enhancing the performance of main river activity with minimum influence on the other activates was investigated numerically.

3D Mathematical model, Delft 3D, was used to simulate the study area and test the different scenarios of the study. The models results showed that, the connecting of the two Islands by a submerged weir with crest level lower than the minimum water level by 30 cm will reduce the sedimentation problem at the power plant intake by more than 40% with minimum significant changes on the navigation pass, enhancing the flow distribution over the cross section width with slightly increasing of the flow velocity beside the eastern bank more than the western bank, this solution is believed to provide the best chance of long term success.

8. ACKNOWLEDGMENTS

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