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Applying Modern Surveying Techniques and Simulation Models for The Rehabilitation of Main Canals in Egypt: Case Study – El-Bagoriya Canal

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ABSTRACT

El-Bagoriya canal is a main canal in the Middle Delta and it is the main water source for West Kafr El-Sheikh irrigation directorate. As originally a natural canal, El-Bagoriya canal has specific characteristics that affected its hydraulic performance, and which resulted in a problem in conveying required water supply to downstream irrigation directorates. With the installation of two new municipal stations on the canal, there was a plan to dredge the canal inside El-Monofiya irrigation directorate to increase its hydraulic capacity. A research project was conducted to help the irrigation directorate implementing the dredging in the best way. The research activities included surveying the cross sections using modern surveying techniques, using ArcMap program to develop contour maps from the surveyed points and derive cross sections from these counter maps. The activities also included using the simulation model to check the original situation, the suggested dredging scenario, and the actual dredging. The results showed that the suggested dredging could improve the flow inside the investigated reach from 53.5 m^3/sec to 64.5 m^3/sec while maintaining minimum water slope inside the reach. Actual dredging could improve the flow inside this reach to 57.5 m^3/sec while maintaining the same water slopes.

Keywords: Main Canals; Water Management, Rehabilitation

INTRODUCTION

Improving the performance of the irrigation system at different levels is a main step to improve water management and water use. The highest level in the irrigation network in Egypt is the main canals, and improving the performance of this level might be the most important step to improve water management. The maintenance of these canals was rare. For instance, there was no previous documentations for the dredging of El-Bagoriya canal in El-Monofiya irrigation directorate before conducting this study. Based on some staff, the last dredging was in 1980s, but there was no available information about such dredging. With a long time of deterioration of the irrigation network, the hydraulic performance of many canals was affected sharply.

One of the reasons for the deterioration of the main canals is the responsibility for the maintenance of these canals. In many cases, the physical problems in some reaches in the main canals are affecting the downstream irrigation directorates. In the Egyptian irrigation system, water distribution system depends mainly on the complaints from the farmers. The reaches of the main canals in upstream directorates are normally “no-complaint reaches” even they have many physical problems as farmers can access water easily. Therefore, upstream irrigation directorates do not feel a real problem from such physical problems, and they do not react to these problems, as there is no complaints from their farmers.

Moreover, many reaches in the main canals are under the responsibility of upstream irrigation directorates, but irrigation-water quota for downstream irrigation directorates are calculated at the beginning of these reaches. In most of the cases, these reaches suffer from low maintenance and high water use as well. As an example, the quota of the irrigation water for Kafr El-Sheikh irrigation directorate from Mit Yazid canal is calculated downstream Beltag regulator (km 21.1), but the reach until El-Wasat regulator (km 34.4) is under the responsibility of El-Gharbiya irrigation directorate. There were many irrigation problems in this reach, and average water use was almost double average water-use rate in the canal (WMRI 2008 & El-Gamal, et al. 2009). Kafr El-Sheikh irrigation directorate is suffering from the same problem in El-Kased canal (downstream Sord regulator), in Bahr Nashart canal (downstream the head regulator) and in El-Qodaba canal (downstream the head regulator). El-Gharbiya irrigation directorate is also suffering from the problem in Bahr Shibin canal (downstream Meleg regulator) and in Tanta Navigation canal (downstream the head regulator). El-Bagoriya could be considered as the most critical example in this category. The canal is mainly a feeder for El-Gharbiya irrigation directorate and it is the main water sources for West Kafr El-Sheikh irrigation directorates. However, the first 74.4 km of the canal is under the responsibility of El-Monofiya irrigation directorate, while its served area by El-Bagoriya canal is only 3000 feddan.

According to above description, the research problem is the low hydraulic performance of El-Bagoriya canal inside El-Monofiya irrigation directorate, due to the big deviation of its cross sections. As the responsible

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irrigation directorate to maintain the first reaches of the canal is not the directorate affect by such maintenance, as described above, there was no dredging for these reaches of the canal since long time ago, and even there was no information about such old dredging. Therefore, a research should be conducted to help the irrigation directorate implementing such dredging in the optimal way.

The main objective of the research is to define the optimal and implantable scenario for dredging El-Bagoriya canal inside El-Monofiya irrigation directorate in order to improve its hydraulic performance.

MATERIALS AND METHODS

The purpose of the current research was to define the best scenario for dredging a specific reach of El-Bagoriya canal that could increase the canal capacity without threating the surrounding buildings or having a big change in the cross sections from a location to the other. The research included the following steps:

A mesh of GPS-based surveyed points were defined in order to derive the cross sections at different points. The Eco sounder with Leica GPS station were used to define the coordinates of these points inside the watercourse or at the banks of the canal. ArcMap program was used to develop contour maps for the entire watercourse and the contour maps were used to derive the cross sections.

Simulation model was used to check different scenarios for the rehabilitation of the canal. The original situation was simulated to define maximum capacity in the original situation. Suggested scenario for dredging the canal was discussed with the irrigation directorate and it was evaluated by the simulation model. After the actual implementation, the simulation model was used again to evaluate the impact of the actual dredging.

The current study used HEC-RAS simulation model. Based on USACE (2006), HEC-RAS contains four components of one-dimensional river analysis to study the following conditions: 1) steady flow water-surface profile computations, 2) unsteady flow simulation, 3) movable boundary sediment-transport computation, and 4) water quality analysis. The current study uses the unsteady flow component. The input data included the canals' geometric data, initial conditions and boundary conditions.

The initial conditions are the values of flow parameters at time zero. In the presence of friction, which is the case in this study, the importance of the initial data decreases and the results will mainly depend on the boundary conditions (Cunge et al., 1980). In HEC-RAS, the initial condition is the expected flow at the beginning of the reach at time zero.

The boundary conditions should add new information to the existing data. Boundary condition values should be defined for all time steps of the simulation. Boundary conditions could be stage hydrograph, discharge hydrograph or discharge-stage relationship. Based on Cunge (1975), Cunge et al. (1980), Vreugdenhil (1989), and Franz et al. (1998), the following restrictions should be considered to choose the boundary conditions type:

The boundary conditions should be independent of the existing data.

The discharge-stage relationship cannot be imposed at the upstream end. In addition, this type of boundary condition could be a source of error at the downstream end if the relationship affects the reach upstream of the boundary with backwater influence.

Regarding discharge hydrograph, using it at the downstream should not impose a flow rate that exceeds the capacity of the channel to deliver water to that node. From the other hand, using the discharge hydrograph at the upstream and the downstream end of the reach is a pitfall error, which makes the results completely dependent on the initial conditions. Using the discharge hydrograph at the upstream boundary implies that the downstream conditions do not affect flow at the upstream boundary. Otherwise, the upstream boundary imposes a certain discharge, which is not a true value.

The stage hydrograph should not be small enough to change the flow from subcritical to critical or supercritical.

The current study used stage hydrograph as upstream boundary conditions (water levels at Shubrabas regulator), and it uses the discharges hydrograph at the tail end (Kafr Rabie regulator).

Study area

El-Bagoriya canal is an old natural branch of the Nile River. Before the construction of Delta Barrage and El-Monofy Rayah, the canal was branching out from the Damietta branch. After the construction of El-Monofy Rayah in 1865, its intake was changed to branch out from El-Monofy Rayah at km 23.1.

Figure (1) presents a schematic drawing of the canal and its branches. The canal length is 90 km and it ended with the intake of another extension (El-Qodaba canal). The design served area of El-Bagoriya canal is 200,000 feddan. The canal is just a carrier canal, and until km 84.0, there are two small branches: Ganabiet El-Bagoriya at km 10.38 and Dalel El-Nahareya at km 80.2. The served area of each of them is 500 feddan. Total length of the canal inside El-Monofiya irrigation directorate is 74.4 km and total served area inside the directorate is 3000 feddan. At the end of El-Monofiya irrigation directorate, there is a main feeder of the El-Bagoriya canal from Tanta Navigational Canal. The canal has two cross regulators inside El-Monofiya irrigation directorate: Shubrabas regulator at 29.8 km, and Kafr Rabie regulator at km 53.55

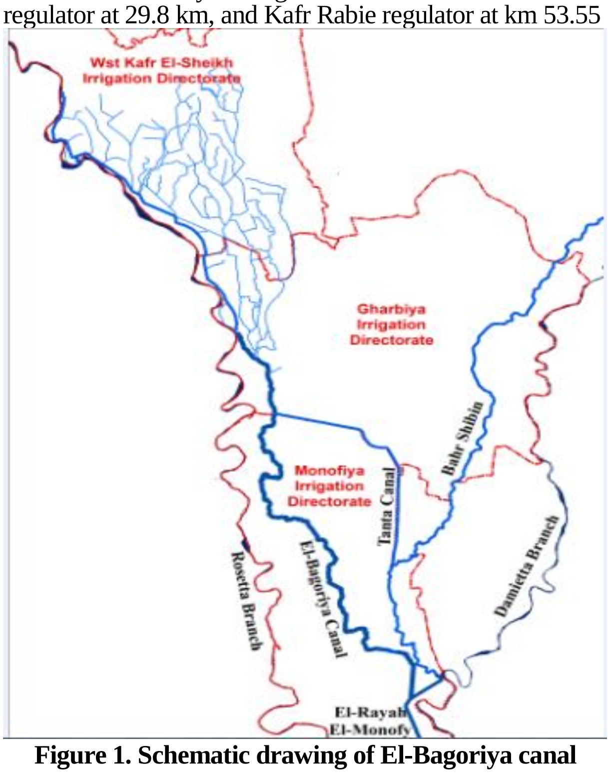

Figure 1. Schematic drawing of El-Bagoriya canal

The preliminary study of the canal

The preliminary investigation of the canal inside El-Monofiya irrigation directorate referred to the following:

There was a physical problem in the weir at the head of the canal (Figure 2A).

As originally a natural stream, El-Bagoriya canal has many bends, which resulted in a deviation of the watercourse from its original location (Figures 2D & 2E). Based on many farmers, most of the collapse on the banks happened when the canal was a navigation canal. The investigation showed high encroachments from the farmers that increased such deviation (Figure 2C)

There was a collapse in the banks, especially at the reach from the head to Shubrabas regulator. Based on collected information, the collapse always happen at the end summer season with the sudden decrease in water levels (Figure 2B).

The canal passes inside urban area, and there were contraction in the cross sections in these areas due to the encroachments (Figure 2C).

As originally a natural canal, the property of canals are not adjacent to the watercourse at many areas, and there were some private fields between the watercourse and canal's property (figures 2D & 2F).

The two cross regulators has no roll in water management and there are open free for most of the time.

From the preliminary survey, it was obvious that the reach between Shubrabas and Kafr Rabie regulators was the worst reach in the canal, and it has its negative impact on the hydraulic performance of the canal.

The preliminary investigation concluded by suggesting a detailed study for the rehabilitated of the reach between Shubrabas and Kafr Rabie regulators.

Figure 2. some characteristics of El-Bagoriya canal

RESULTS AND DISCUSSION

Results

The flow inside El-Bagoriya canal

Water supply at the head of El-Bagoriya canal is affected by change in the general strategy of water distribution in Egypt. During the period from 1998 until 2008, the reservoir in Aswan High Dam was full during many years and there was a necessity to release more water. This results in high water supply to the main canals including El-Bagoriya canal. In 2010, there was big reduction in water supply with the decrease of the flood, and it was the case during last year (2019) with the strategy to rationalize water use. From figure (3 left), and based on the collected data from irrigation directorates, annual water supply at the head of the canal was between 753 million m^3 in 2010 and 1185 million m^3 in 2008.

From figure (3 right), highest daily water supply values were 5.35 million m^3/day during 1996, 5.91 million m^3/day during 2008 and 4.30 million m^3/day during 2019. Highest values were during June month and it extended to July in 2008.

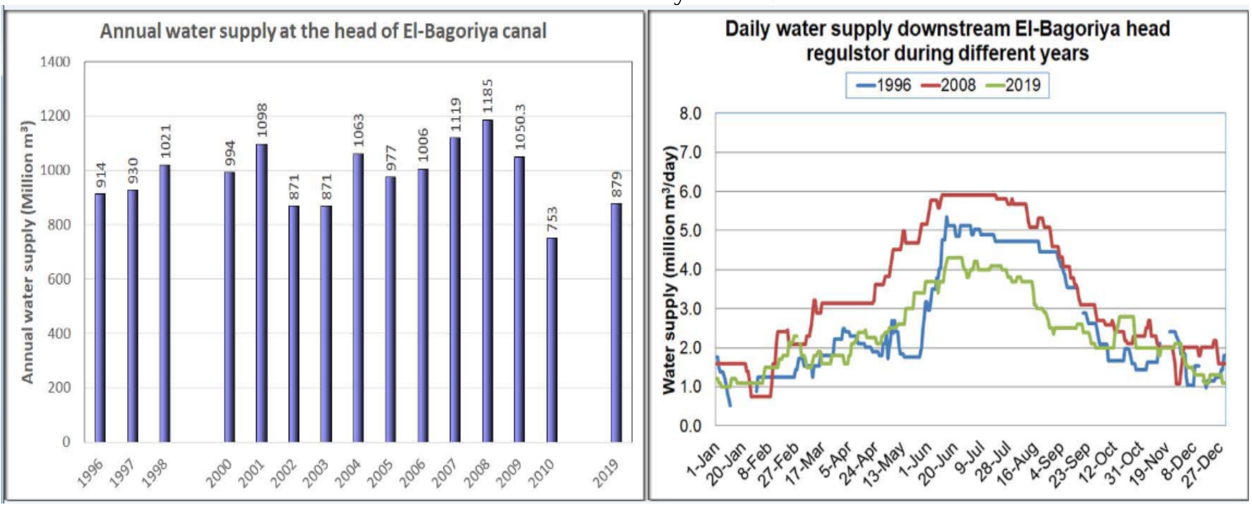

Figure 3. Annual water supply for El-Bagoriya canal during different years

The difference between water supply at the head of El-Bagoriya and Kafr Rabie regulator, based on collected data from El-Monofiya irrigation directorate, reached 1.0 million m^3 during the highest water supply period. This included irrigation water and municipal water use. Regarding irrigation water, the official served area on El-Bagoriya canal inside El-Monofiya irrigation directorate is 3,000 feddan, but there was high amount of unofficial water use. In addition, there were two feeding points for two branches in El-Monofiya irrigation directorate in the reach between Shubrabas and Kafr Rabie cross regulators. Current served area on El-Bagoriya was estimated as 15,000 feddan. Regarding municipal water, there were seven municipal water stations on El-Bagoriya canal inside El-Monofiya irrigation directorate. There was a plan to construct another two stations in the reach between

Shubrabas and Kafr Rabie cross regulators during the time of this study and these stations were the reason for dredging the canal.

The activities included measuring the flow at Kafr Rabie regulator during 2010. Figure (4) presents the direct measurements from March to August 2010, and the calculated flow, based on the developed equation, for summer 2010 (May to August 2010). The maximum measured flow was 54.85 m^3/sec, and maximum calculated flow was 54.3 m^3/sec. Both values were during June month. These values were the guideline for defining flow hydrograph in the simulation model.

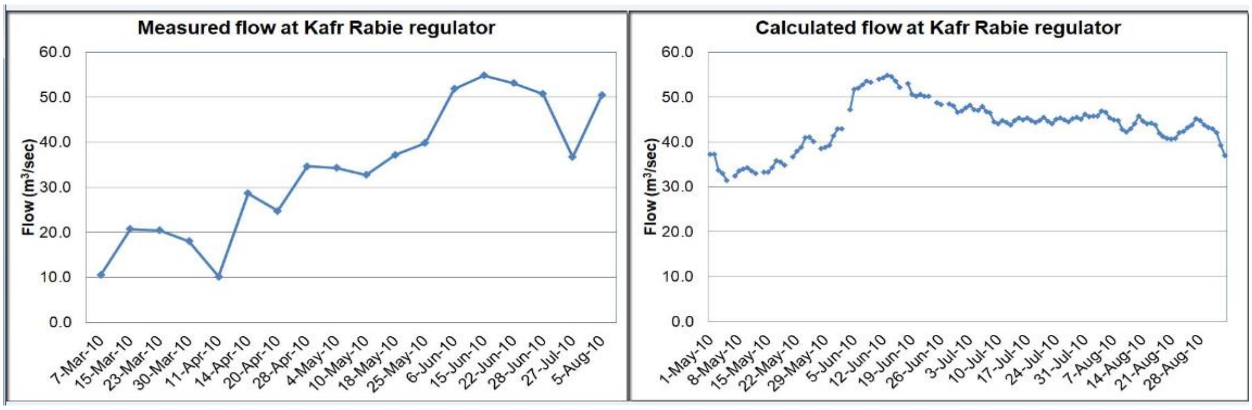

Figure 4. Daily water supply values downstream the head regulator and downstream Kafr Rabie cross regulator during three different years

Water Levels

Water levels were collected from El-Monofiya irrigation directorate for the cross regulators of El-Bagoriya canal during different years. These water levels were the guide for defining upstream stage hydrograph in the simulation model. In addition, water levels were recorded automatically for some points between the two cross regulators during the study, and calculated water slopes were used for evaluating the simulation model.

During 1996 and considering highest consumption period (June and July), water levels downstream Shubrabas regulator were between 8.52 and 9.52 m. Downstream Kafr Rabie regulator, water levels were between 6.9 and 7.78 m. During 2008 and considering highest consumption period, water levels downstream Shubrabas regulator were between 9.6 and 9.94 m. Downstream Kafr Rabie regulator, water levels were between 7.67 and 7.98 m. During 2019 and considering highest consumption period, water levels downstream Shubrabas regulator were between 9.38 and 9.80 m. Downstream Kafr Rabie regulator, water levels were between 7.58 and 8.0 m (Figure 5).

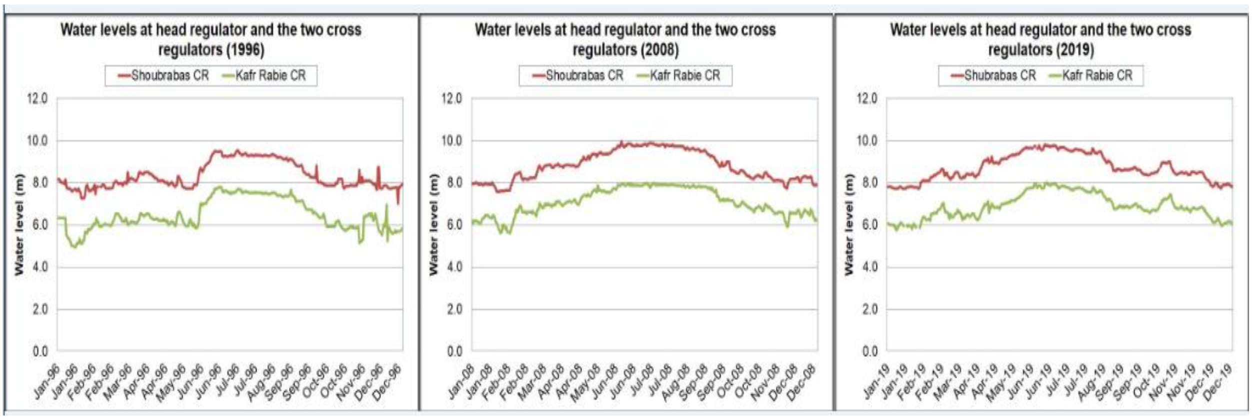

Figure 5. daily water levels downstream the head regulator, downstream Shubrabas regulator and upstream Kafr Rabie cross regulator

Water levels were recorded at three points of the reach between Shubrabas and Kafr Rabie regulators (between km 28.9 and km 53.55) during 2010. Based on the installed recorders, the reach was divided into two sub-reaches and water slopes were calculated for each sub-reach, besides calculating water slope for the whole reach. The first sub-reach was from Shubrabas regulator (km 28.9) until the beginning of Darajil village (km 45.2). The second sub-reach was from the beginning of Darajil village until Kafr Rabie regulator (km 53.55). From figure (6), water slopes at the first sub-reaches were in the average of 6.0 cm/km with little fluctuation. Water slope in the second sub-branch was between 10.0 and 13.0 cm/km for most of the time, which reflects the problem in this reach. Average water slopes between Shoubra Bas and Kafr Rabie regulators were around 8.0 cm/km.

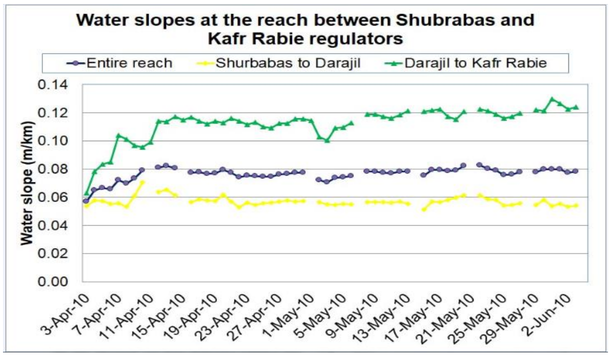

Figure 6. water slopes for different reaches between Shubrabas and Kafr Rabie cross regulators

Define optimal dredging scenario

There was not any documentations about previous cross sections of El-Bagoriya canal before this study. Based on some staff in the administration, last dredging was in 1980s, but there was no any official documents about it. Based on the irrigation directorate, bed width was defined as 35.0 m, and side slope is 3:2. Based on a study of Maintenance Research Institute, the bed width was suggested as 33.0 m. The last value was considered during the rehabilitation of the canal.

Surveying cross sections:

Surveying the cross sections of El-Bagoriya canal has many difficulties due to the increase of the bends, the instability of the banks (figure 7), and the frequent changes in the cross sections from point to the other.

Eco sounder was used with Leica total station to survey the entire watercourse of the investigated reach between Shubrabas and Kafr Rabie regulators. Figure (8 left) presents the Eco sounder during surveying the watercourse of investigated reach, and figure (8 right) presents example about using the surveyed points to derive the cross sections. As presented in the figure, the surveyed points inside watercourse and at the edges were used to develop contour maps for the entire wetted perimeter of the investigated reach. The contour maps were used to derive the cross sections of this reach. The boundary of the canal property was defined from spatial maps and they were used in ArcMap program to define the dredging location.

Figure 7. The banks at some regions of El-Bagoriya canal

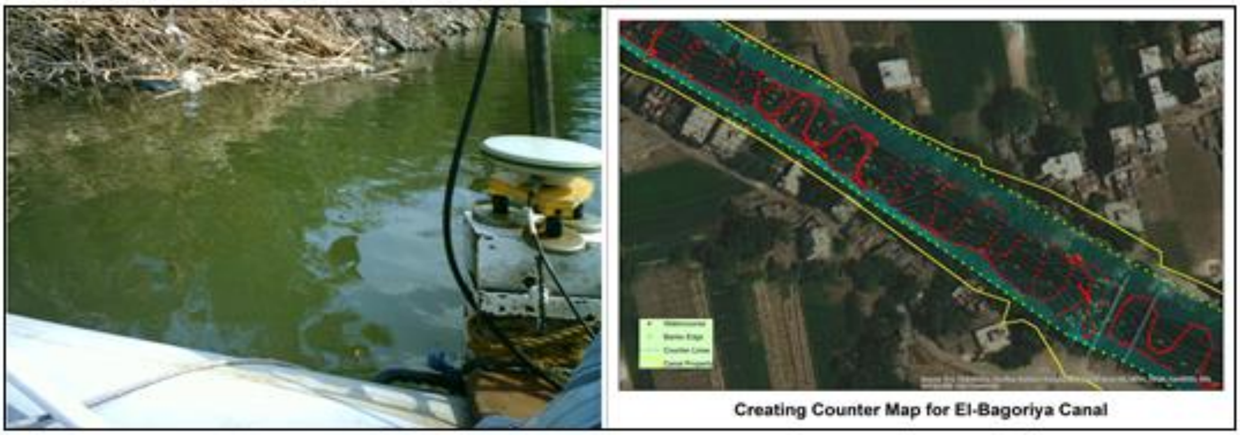

Figure 8. Surveyed points and the developed counter map for El-Bagoriya watercourse

Figure (9) presents as example about the change in the cross sections. Two consecutive cross-sections with a difference 210 m in the location. There is a huge difference in width, and considerably in the bed level, from a section to the other.

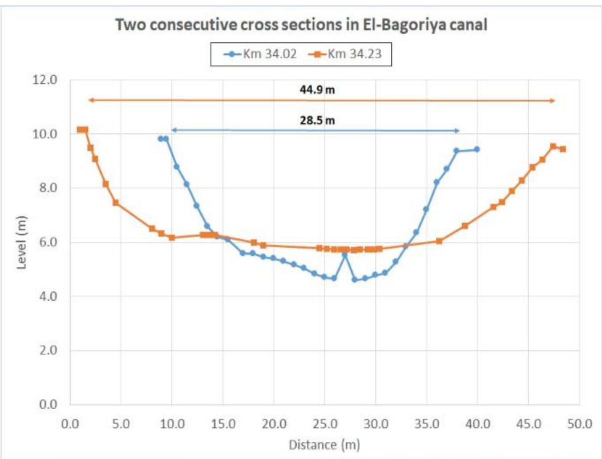

Figure 9. Two consecutive cross-sections in El-Bagoriya with different widths

Define the required dredging:

The suggested dredging was defined based on the derived cross sections and their relation with required (design) cross section. The scenario suggested dredging 93 sections from 124 sections in the reach between Shubrabas and Kafr Rabie. The cross sectional areas of other sections were sufficient to pass the required flow. There were many obstacles on the ground that affected the decision about the suggested dredging. These obstacles prevented dredging these sections to the design cross section, and in their official location. As examples:

The canal was passing through many urban areas. The scenario avoided threating any of the buildings. An example is presented in figure (10). The section is located at km 46.34 (inside Darajil village). There was a sedimentation in the left side, and there were some buildings interfere with the design cross-section on this side. These buildings included a new reinforced concrete building at 21.25 m from the current edge. There was also adobe building at 12.9 m from current bank edge and poultry nest at 10.6 m from the same edge. It was decide to extend the dredging for 12.0 m from bank edge. Therefore, there was no necessary to remove the adobe building. Only a part of the poultry nest building should be removed. The bed width in this section after the dredging will be 29.5 m instead of 33.0, with a recommendation to complete the cross section after removing any buildings inside the property of the canal.

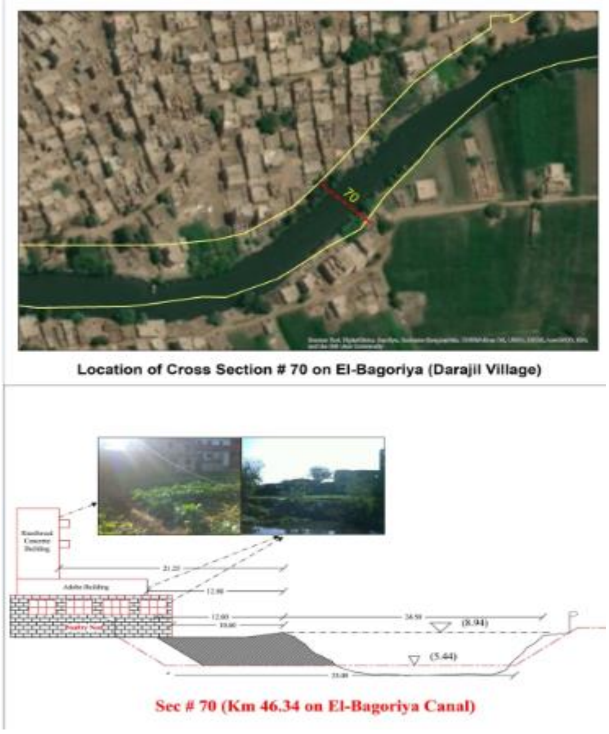

Figure 10. Adapting the required dredging in sec # 70

In many cases, the current watercourse moved outside the borders of official canal's property and there was a collapse in the adjacent private fields. These collapsed parts cannot be refilled without building a retaining wall at the border of the canal. As there was no budget for rebuilding these walls, only a part of the design section was dredged with a recommendation to complete the dredging to the end of the official design cross section and rebuild the part outside the canal property when the fund is available. As an example, and at km 47.45 (cross-section # 80), there was a huge scour in the left side and a sedimentation in the right side (figure 11). The scenario suggested dredging a part of design cross section that complete the required cross section until having a budget to rebuild the whole cross section to fix both scour and sedimentation. Only 12.0 m from the design bed (33.0 m), was dredged. The top width was 45.0 m as required in the design.

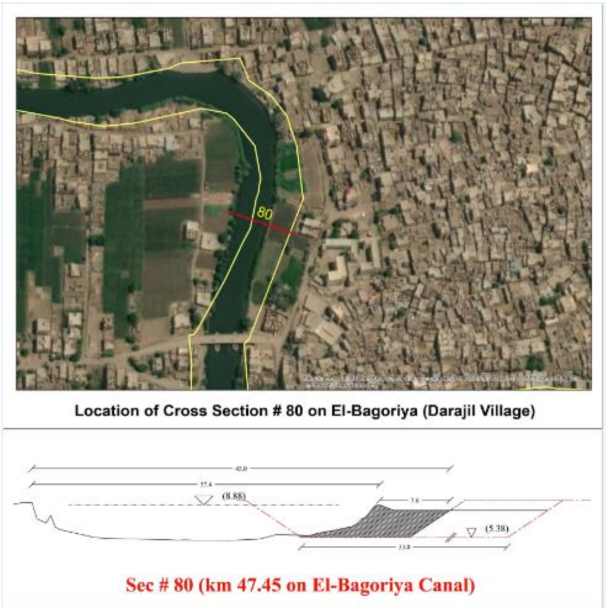

Figure 11. Adapting the required dredging in sec # 80 (Km 47.45)

In some sections, there was a direct change in the dredging side from side to the other. In this case, the section was divided into many sub-sections and a specific part of the design cross section was dredged in each sub-section to have the same width of the watercourse. As example, cross-section number 65 at km 45.13 (figure 2 E) was divided into six sub-sections due to the rapid change of scour and sedimentation from a point to the other. The suggested dredging width was between 7.0 & 17.0 m and it changes from a side to the other in these sub-sections.

Applying the simulation model:

As described in the previous sub-section, and based on the suggested scenario, many sections were not dredged to the design cross section due to the obstacles on the ground. Therefore, there was a necessity to use the simulation model to check the impact of the suggested scenario. The simulation model was used for three different purposes in this study:

The first purpose was to check the maximum discharge that the canal could convey under the original conditions;

The second purpose was to check the impact of implementing the suggested scenario in increasing the hydraulic capacity;

The third purpose was to evaluate the situation after the actual dredging, which was not equivalent to the suggested scenario;

Check the original situation:

The simulation model was used to check the original situation based on surveyed cross sections and with the following assumption:

Stage hydrograph was used as upstream boundary conditions at the beginning of the reach (downstream Shubrabas regulator). Based on collected information, the value 9.85 m was used as stage hydrograph at the upstream end;

Flow hydrograph was used as downstream boundary conditions at Kafr Rabie regulator. Different values were tested to maintain minimum water slopes through the reach, without having a flood at any point.

Manning coefficient value was considered as 0.034 for the all sections except the reach inside Darajil village, where Manning coefficient value was considered as 0.035.

Maximum flow hydrograph value at Kafr Rabie regulator that maintain minimum water slopes through the reach was 53.5 m^3/sec. Water level at Kafr Rabie regulator was 7.88 m. As presented in figure (12 left), water levels hit the banks at some points without any flood. Velocities in the reach from Shubrabas to Darajil were between 0.35 and 0.6 m/sec, and water slope in this reach was 5.87 cm/km. In the reach from the beginning of Darajil to Kafr Rabie regulator, the velocities were between 0.42 and 0.87 m/sec, and water slope in this reach was 11.44 cm/km. Water slopes were very close to the recorded water slopes (figure 6), which refers to the validation of the model.

With the same upstream stage hydrograph, the flow at Kafr Rabie regulator could reach 56.0 m^3/sec, but with rapid increase in water slopes. Increasing downstream flow hydrograph than this value without increasing upstream stage hydrograph resulted in instability of the simulation model. Increasing upstream stage hydrograph permits increasing the flow though the reach, but this will result in a flood at different points of the reach.

In the case of flow hydrograph (56.0 m^3/sec), water level at Kafr Rabie regulator decreased to 6.48 m (figure 12 right). Velocities in the reach from Shubrabas to Darajil were between 0.37 and 0.66 m/sec, and water slope in this reach was 6.90 cm/km. In the reach from the beginning of Darajil to Kafr Rabie regulator, the velocities were between 0.49 and 1.09 m/sec, and water slope in this reach escalated to 25.90 cm/km.

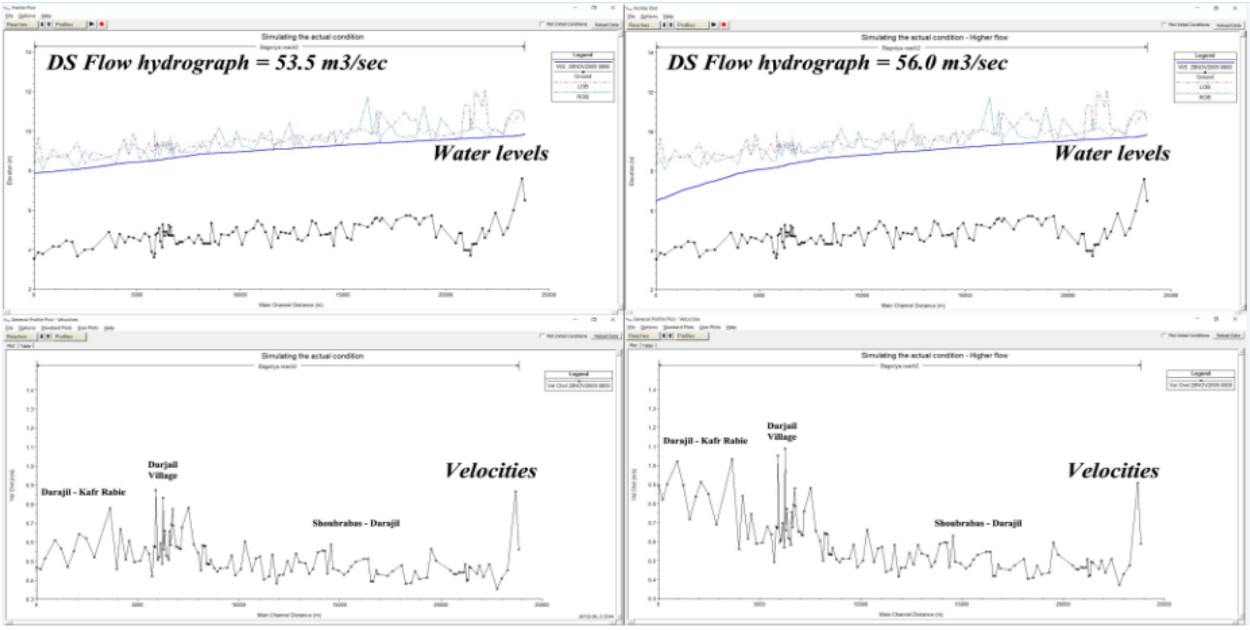

Figure 12. Water levels and velocities in the studying reach under original conditions and with two different flow values

Check the impact of the suggested dredging:

Applying the suggested dredging scenario as explained in the previous sub-sections could increase the flow inside the reach while maintaining the required levels inside this reach. Upstream water level was used as in the previous run (the original situation). Different flow hydrograph values were tried as downstream boundary condition to keep minimum water slopes. It was be able to increase the flow at Kafr Rabie regulator to 64.0 m^3/sec (19.6% more than the original situation). In this scenario (figure 13 left), water level at Kafr Rabie regulator would be 7.91 m. The velocities in the reach from Shubrabas to Darajil were between 0.43 and 0.67 m/sec, and water slope in this reach was 7.02 cm/km. In the reach from the beginning of Darajil to Kafr Rabie regulator, the velocities were between 0.38 and 0.76 m/sec, and water slope in this reach decreased from 11.44 cm/km in the original situation to 8.63 cm/km in this scenario. The flow could be increased in the reach, but this would be associated with an increase in velocities and water slopes and in a decrease in water level at the end of the reach. Increasing flow hydrograph at the end of the reach to 65.0 m^3/sec increased water slopes to 7.34 cm/km at the reach between Shubrabas and Darajil, and 10.27 cm/km at the reach from the beginning of Darajil to Kafr Rabie regulator. Water level at Kafr Rabie regulator decreased to 7.69 m.

Increasing flow hydrograph at the end of the reach to 66.0 m^3/sec increased water slopes to 7.78 cm/km at the reach between Shubrabas and Darajil, and 13.07 cm/km at the reach from the beginning of Darajil to Kafr Rabie regulator. Water level at Kafr Rabie regulator decreased to 7.37 m. If the flow increased to 67.0 m^3/sec (figure 13 right), water slopes increased shapely to 8.36 cm/km between Shubrabas and Darajil and to 19.25 cm/km from the beginning of Darajil to Kafr Rabie regulator. Water levels at Kafr Rabie decreased to 6.75 m. In this case, the velocity increased to 0.98 m/sec inside Darajil village. Increasing downstream flow hydrograph than 67.0 m^3/sec without increasing upstream stage hydrograph resulted in instability of the simulation model.

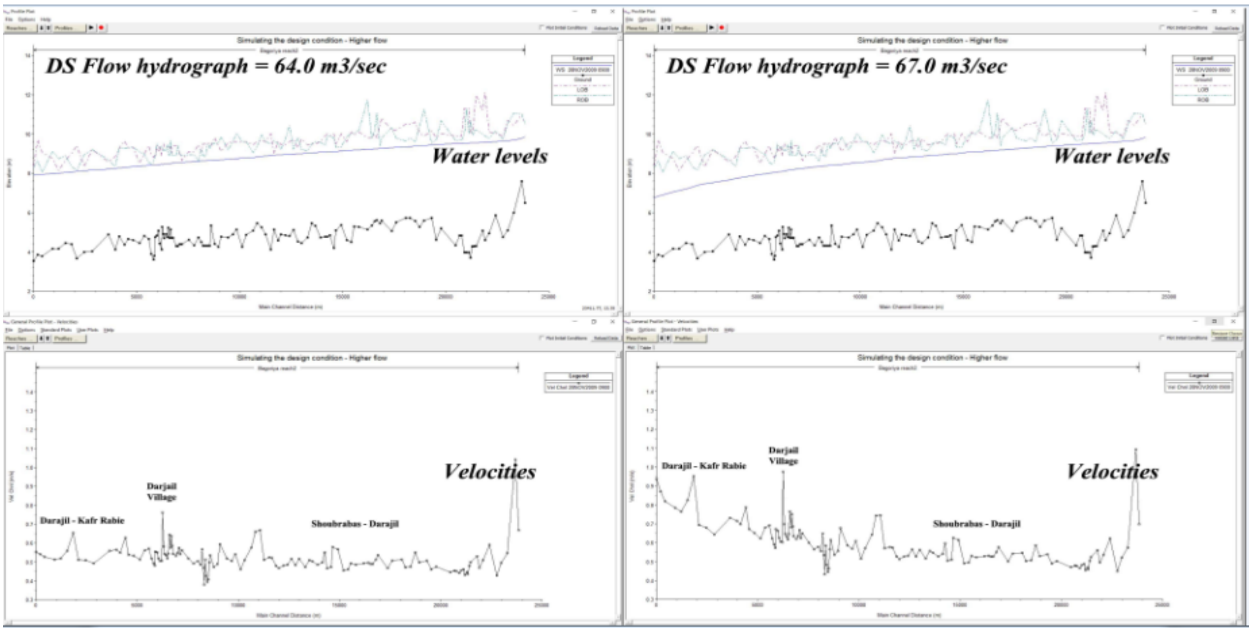

Figure 13. Water levels and velocities in the studying reach under the suggested dredging scenario and with two different flow values

Check actual dredging situation:

The suggested scenario was not performed completely due to some instability conditions during the implementation time. The implementation covered the reach of only 73 sections. Some cross sections in this reach were dredged totally and other were dredged partly, No dredging was performed in other sections. The average dredging ratios for these 73 sections was 38% (figure 14).

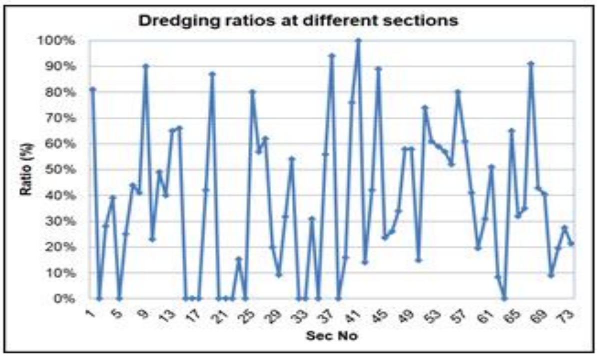

Figure 14. Dredging ratios at different sections

The irrigation directorate wanted to check the impact of such dredging on the increase of the flow in the studying reach before terminating the contract. The simulation was performed again with post-dredging cross sections. Figure (15) presented the results of the simulation model.

Considering the same stage hydrograph at the upstream end (9.85 m), and to maintain the minimum water slopes in the investigated reach, the flow hydrograph at the end of the reach was 57.5 m^3/sec (figure 15 left). This value exceeded the flow under the original condition by 4.0 m^3/sec (345600 m^3/day). This amount was close to the consumption of the two new municipal stations. In this case, water slope in the reach between Shubrabas and the beginning of Darajil increased from 5.87 cm/km in the original situation to 6.60 cm/km in post-dredging situation. Maximum velocity increased from 0.60 cm/sec to 0.66 cm/sec. In the reach from the beginning of Darajil to Kafr Rabie, water slop decreased from 11.44 cm/km in the original situation to 10.62 cm/km in post-dredging situation. Maximum velocity decreased from 0.87 cm/sec to 0.81 cm/sec. From figures (12 left & 15 left), there was a considerable decrease in the velocities inside Darajil village. The velocities in the reach from the end of Darajil to Kafr Rabie was still high, as the dredging did not cover this reach. Increasing the downstream hydrograph to 60.0 m^3/sec decreased water level at the end of the reach to 6.89 m (figure 15 right). Under this condition, water slope increased to 7.7 cm/km in the reach from Shubrabas to the beginning of Darajil and to 20.3 cm/km in the reach from the beginning of Darajil to Kafr Rabie. Maximum velocities were 0.72 cm/sec in the first reach and to 1.02 cm/km in the second reach. Increasing downstream flow hydrograph more than 60.0 m^3/sec resulted in instability in the simulation model.

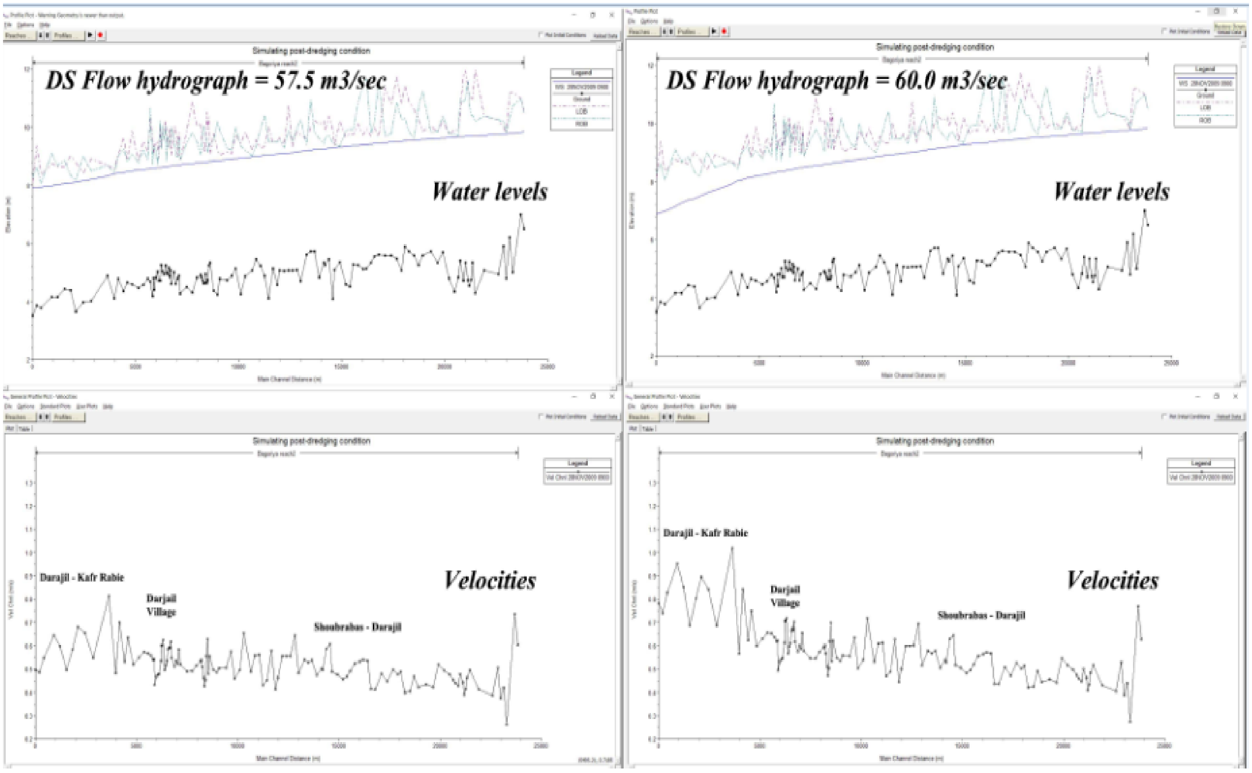

Figure 15. Water levels and velocities in the studying reach for post-dredging situation and with two different flow values

Discussion

A plan for dredging El-Bagoriya canal was conducted by El-Monofiya Irrigation Directorate to increase the hydraulic capacity of the canal. Due to the difficulties of surveying the canal, a research plan was associated with the plan of the irrigation directorate to define the optimal dredging scenario. The research activities included using modern surveying techniques to survey the canal and to derive the cross sections at different locations. Eco sounder and Leica total station were used to generate a mesh of points that cover the water body of the investigated reach. Then ArcMap program was used to generate contour maps from these points, and to drive the cross sections from such contour maps. The investigation generated 124 cross sections, from which 93 cross sections were smaller than the design cross section and required dredging. The activities included using the simulation models as well. Due to different obstacles in the canal, there was no ability to dredge the entire reach to the design cross sections and at their official locations. Therefore, using the simulation models was important to assess the impact of the suggested scenario for dredging the canal.

The simulation model was used to assess three different stages. The first stage was the original situation before the dredging to check the maximum hydraulic capacity before the dredging. The second stage was the suggested dredging scenario. The simulation model was used to anticipate the impact of the suggested scenario on the hydraulic capacity of the canal. The third stage was the actual dredging. Due to some instability conditions during the implementation, the dredging was not performed as planned. The irrigation directorate wanted to check the impact of such dredging on the hydraulic capacity of the canal to terminate the contract. The simulation model was used again for such check. In the simulation model, stage hydrograph was used at the upstream end and flow hydrograph was used at the downstream end. Collected and recorded water levels were used to define stage hydrograph values and to validate the model. Different flow hydrograph values were tested at the end of the investigated reach to maintain lowest water slopes and minimum velocities without having floods at any point in the investigated reach.

The results of the simulation models could be summarized as following:

Under the original condition, the maximum flow at the end of the reach that maintain minimum water slope without having floods at any point was 53.5 m^3/sec. In this case, maximum water slope in the sub-sections of the investigated reach was 11.4 cm/km and maximum velocity in the sub-sections was 0.87 m/sec. With the increase of the flow hydrograph to 56.0 m^3/sec, maximum water slope in the sub-sections of the investigated reach would increase to 25.9 cm/km, and the maximum velocity in the sub-sections would increase to 1.09 m/sec. With any increase of flow hydrograph than 56.0 m^3/sec, the simulation model would turn into instability condition and would stop.

Considering the suggested dredging scenario, the maximum flow at the end of the reach that maintain minimum water slope without having floods at any point was 64.0 m^3/sec. In this case, maximum water slope in the sub-sections of the investigated reach was 8.63 cm/km and maximum velocity in the sub-sections was 0.76 m/sec. With the increase of the flow hydrograph to 67.0 m^3/sec, maximum water slope in the sub-sections of the investigated reach would increase to 19.25 cm/km, and the maximum velocity in the sub-sections would increase to 0.98 m/sec. With any increase of flow hydrograph than 67.0 m^3/sec, the simulation model would turn into instability condition and would stop.

Considering the actual dredging scenario, the maximum flow at the end of the reach that maintain minimum water slope without having floods at any point was 57.5 m^3/sec. In this case, maximum water slope in the sub-sections of the investigated reach was 10.62 cm/km and maximum velocity in the sub-sections was 0.81 m/sec. With the increase of the flow hydrograph to 60.0 m^3/sec, maximum water slope in the sub-sections of the investigated reach would increase to 20.30 cm/km, and the maximum velocity in the sub-sections would increase to 1.02 m/sec. With any increase of flow hydrograph than 60.0 m^3/sec, the simulation model would turn into instability condition and would stop.

CONCLUSION

A research plan was conducted to help El-Monofiya irrigation directorate applying the dredging of El-Bagoriya canal, which is a carrier canal conveying irrigation water to downstream irrigation directorates, in an optimal way. El-Bagoriya canal is originally a nature canal with many steep bends, and without specific property in both banks. The canal suffered from a deviation in its cross sections. The water body moved outside the official property to the adjacent fields in many locations while there was a big sedimentation in other regions / sides. The canal also suffered from passing inside urban areas, and from many encroachments from the adjacent fields. Modern surveying techniques were used to scan the whole water body of the canal. ArcMap program was used to build contour maps from the surveyed points and to derive the cross sections from these contour maps. Due to the difficult conditions in the canal, many obstacles prevented implementing the dredging to the design cross sections and in their official locations. A dredging scenario was suggested to prevent threating any buildings or to extend the cross sections more than the hydraulic requirements. The simulation model was used to check different conditions. It were used to check maximum hydraulic capacity in the original condition. Then, it was used again to anticipate the impact of the suggested dredging scenario. After the actual dredging, which was not equivalent to the suggested dredging scenario, the simulation model was used again to check the actual change in the hydraulic capacity.

The simulation model showed that the suggested dredging scenario could increase the hydraulic capacity of the canal inside the dredged reach by 19.6%, while considering all obstacles on the ground. The actual dredging, which did not complete the suggested scenario, increased the hydraulic capacity of the canal inside the dredged reach by 7.5%.

The study illustrated the importance of using modern surveying techniques and simulation models in the rehabilitation of different watercourses, especially the canals that are originally natural-streams, such as El-Bagoriya canal and Bahr Yousef canal, as these canals are normally suffering from many physical problems.

Conflict of Interest

The authors declare that there is no conflict of interest.

REFERENCES

Cunge J. A., (1975), “Applied Mathematical Modeling of Open Channel Flow,” *Unsteady Flow in Open Channels*, Mahmoud K, and Yerjevich V, ed., Vol. 1, Water Resources Publications, Fort Collins, Co., pp. 379-404.

Cunge, J. A., F. M. Holly, and A. Verwey, (1980), *Practical Aspects of Computational River Hydraulics*, Pitman Advanced Publishing Program, London.

El-Gamal, T. T, M. E. Meleha, E. S. Yassa (2009) "The Effect of Main Canals' Characteristics on Irrigation Improvement project", Journal of agricultural science, Mansoura University, Vol 34 No (11), November 2009

Franz D. D., (1998), *Full Equations (FEQ) Model for the Solution of the Full, Dynamic Equations of Motion for One-Dimensional Unsteady Flow in Open Channels and Through Control Structures*, Water Resources Investigations, Report 96-240, USGS, http://il.water.usgs.gov/proj/feq/feqdoc.

US Army Crop of Engineering (USACE), Hydraulic Engineering Center, "HEC-RAS River Analysis System User's Manual – Version 4.0", November 2006

Vreugdenhil, C. B., (1989), *Computational Hydraulics*, Springer-Verlag Berlin Heidelberg, New York, 1989.

Water Management Research Institute (WMRI), (2008), "Monitoring and Evaluation of Irrigation Improvement Project (IIP1) – Final report"

تطبيق تقنيات المسح الحديثة ونماذج المحاكاة الهيدروليكية لإعادة تأهيل الترع الرئيسية في مصر دراسة حالة ـ قناة الباجورية

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ترعة الباجورية هي أحدي الترع الرئيسية في وسط الدلتا وهي تبدأ من إدارة ري المنوفية وتمر بإدارة ري الغربية وهى أحد مصادر الري الرئيسية لإدارة ري غرب كفر الشيخ. ويعتبر الحبس الأول من ترعة الباجورية داخل زمام ري المنوفية مجرد قناة ناقلة، حيث يبلغ طولها داخل زمام المنوفية 70 كيلومتر، في حين أن الزمام التصميمى هو 3000 فدان فقط. وكأحد مجاري الري الطبيعية في مصر، تتميز قناة الباجورية بخصائص أثرت على أدائها الهيدروليكي، مما أدى إلى مشكلة في نقل إمدادات المياه المطلوبة إلى إدارات الري في نهاية الترعة. ومع تركيب محطتين جديدتين لمياه الشرب على ترعة الباجورية، بدأت إدارة ري المنوفية برنامج لإعادة تأهيل الترعة داخل زمامها من أجل زيادة قدرتها الإستيعابية، وتم إجراء مشروع بحثي لمساعدة إدارة ري المنوفية على تنفيذ ذلك البرنامج بأفضل طريقة. بدأت الدراسة بتحليل بيانات التصرفات والمناسيب على كامل الحبس داخل زمام إدارة ري المنوفية، وتم تحديد الجزء من قنطرة شبراباص (كم 29.8) وقنطرة كفر ربيع (كم 53.55) على أنه الجزء الأكثر تأثيرا على تقليل القدرة الإستيعابية للترعة، ومن ثم بدأت دراسة تفصيلية لإعادة تأهيل هذا الجزء من الترعة. تضمنت الأنشطة البحثية مسح المقاطع العرضية لهذا الجزء من الترعة باستخدام تقنيات المسح الحديثة، واستخدام برنامج ArcMap لتطوير الخرائط الكنتورية من النقاط التي تم مسحها، ثم تم اشتقاق المقاطع العرضية من تلك الخرائط الكنتورية. تضمنت الأنشطة أيضًا استخدام نموذج المحاكاة الهيدروليكية لمراجعة الوضع الأصلي، وتأثير سيناريو التجريف المقترح على زيادة القدرة الإستيعابية للترعة، كما تم استخدام النموذج بعد إنتهاء أعمال التجريف لتحديد تأثير التجريف الفعلي على زيادة قدرة الترعة الإستيعابية. أظهرت النتائج أن التجريف المقترح يمكن أن يحسن التدفق داخل الحبس من قنطرة شبراباص حتي قنطرة كفر ربيع من 53.5 م^3/ثانية إلى 64.5 م^3/ ثانية مع الحفاظ على أدنى انحدار مائي داخل هذا الحبس. ونتيجة لعدم قدرة الإدارة على تنفيذ مقترح التجريف بالكامل، فقد أظهرت نتائج برنامج المحاكاة أن التجريف الفعلي يمكنه تحسين التدفق داخل داخل الحبس من 53.5 م^3/ثانية إلى 57.5 م^3/ ثانية مع الحفاظ على أدنى انحدار مائي داخل الحبس.