EFFECT OF HIGH FLOODS ON NAGA HAMMADI BARRAGES SCOUR HOLE

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ABSTRACT

Local scour is a threat for hydraulic structures, and the removal of material downstream these structures, around piers, abutments, spurs, embankments and in curves affects their safety. Many factors affect local scour downstream barrages, such as the head difference between upstream and downstream, flow conditions, gates' operation, suspended sediment concentration, downstream concrete length, filter length if any and soil characteristics. Scour depth and location differ from one barrage to another according to operating conditions, local soil and geometric conditions. This local scour has a negative effect on the overall stability of the structures.

The purpose of this paper is to study the effect of high floods on Naga Hammadi Barrage scour hole. A mathematical model was used for scour analysis which is based on stream tubes concept to simulate the two-dimensional and three-dimensional effects. It is also used to simulate the response of the scour hole for different high floods with different duration. The calibration results showed close relationship between the measured and the predicted values. Different sediment approaches were used for the calibration analysis and they were compared to show the best approach for this study. Floods of 300, 350, 400, 500, and 600 million cubic meters per day were considered for this analysis and the flood duration ranged from one week up to four months. The average eroded thickness for the scour hole was computed for each case.

INTRODUCTION

Local scour involves removal of material downstream hydraulic structures, around piers, abutments, spurs, embankments and in curves. There are two mechanisms that are causing local scour downstream barrages;

- Local scour resulting from the flowing water due to the flow conditions and deficit of sediment which makes water tend to erode soil particles downstream the concrete flooring. In this case, the fluid characteristics can be described by Reynolds number and Froude number and sediment properties for non cohesive sediments which can be characterized by critical tractive force and the standard deviation. While for cohesive soils, a term of critical scouring velocity should be considered in addition (ASCE, 1975).

- Local scour due to the seepage downstream the barrage which enables seeping water under the flooring to carry soil particles and erode them downstream the flooring. The seepage analysis should be studied to determine the critical conditions for exit gradient to avoid piping and removing of soil particles. The factor of safety against piping is described by the ratio of the actual hydraulic exit gradient and the critical exit gradient at which the soil particles downstream the flooring start to move. There are many factors affecting the seepage forces under the flooring such as the head differences, flooring lengths, filter lengths, soil conditions and layers descriptions. Many studies are performed to measure, analyze the local scour downstream barrages in Egypt by the Nile Research Institute specially downstream Esna Barrage, Naga Hammadi Barrage and Assiut Barrage. An example of these studies is the analysis performed for Naga Hammadi Barrage, which describes and monitor the lowest point movements downstream the barrage and their effect on the barrage for the period from 1979 to 1996 (Aziz, Samuel, and Abdelbary, 1998) and a brief summary is given in this paper.

NAGA HAMMADI BARRAGE

Naga Hammadi Barrage was built during the period 1927-1930 about 359 km downstream Aswan Dam. It consists of 100 openings separated by 99 piers with a total length of 818 meters between abutments. These openings are 6 m wide and are numbered from 1 (at the west) to 100. It has a navigation lock on the western side of a length of 80 m and width of 16 m. The proposed new Naga Hammadi Barrage will have 7 openings each 17.0 m wide. Figure (1) shows the cross section of Naga Hammadi Barrage. The scour measurements are referenced to barrage center line in the horizontal direction. Scour downstream Naga Hammadi Barrage has been a continuing problem. Stones were dumped in the scour holes during the period from 1939 to 1978 and then a monitoring program was established on a regular basis. NRI (1990) concluded that the scour hole was becoming deeper and was not shifting nearer to the barrage. It also concluded that there was not overall shift towards or away from the barrage from 1979 to 1989. A description of Naga Hammadi scour hole is given in Table 1. This table shows the lowest levels for the scour hole during 1979, 1989, and 1996 surveys (Aziz, Samuel, and Abdelbary, 1998).

Table 1 Naga Hammadi Barrage scour hole

Year	Lowest Level (m)	Distance from C.L. of Barrage (m)
1979	49.0	123.93
1989	44.35	129.0
1996	46.5	131.5

THE EFFECT OF HIGH FLOODS ON NAGA HAMMADI BARRAGE

To study the effects of high floods on Naga Hammadi Barrage, flood conditions and scour hole responses have to be simulated using a suitable mathematical or physical model. In this study, the required analysis was simulated by using a mathematical model to overcome scale ratio difference problems such as sediment grain sizes and their motion according to different approaches. The mathematical simulation represents the actual dimensions of the study area and the bed materials.

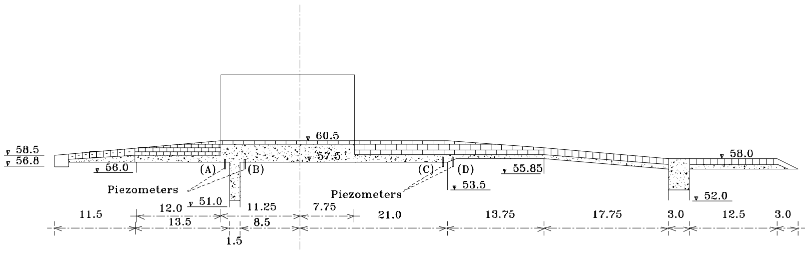

Figure (1) Naga Hammadi Barrage longitudinal section.

THE USED MODEL

In this study, the model GSTARS 2.000, which was developed by U.S. Bureau of Reclamation, 1998, was used for the analysis. The assumptions for this model and its capabilities are shown in the literature review. Flow pipes were used to simulate the three dimensional flow conditions to be able to study the changes in both the transverse and the longitudinal directions without facing the actual three-dimensional calibration difficulties. Figure (2) shows a brief description for the model. Different sediment motion approaches have been used for the model calibration such as:

- Meyer-Peter and Muller's method.
- Laursen's method.
- Toffaleti's method.
- Engelund and Hansen's method.
- Ackers and White's 1973 method.
- Yang's 1973 sand and 1984 gravel formulas.
- Yang's 1979 sand and 1984 gravel formulas.
- Parker's method
- Yang's 1996 modified method.
- Ackers and White’s method with the revised 1990 coefficients.

NAGA HAMMADI SCOUR HOLE MODEL CALIBRATION

The scour hole data for the period 1986 to 1989 were used to calibrate the mathematical modeling analysis. The 1989 data were predicted from 1986 data using the model according to:

- The actual flow discharges and water levels during this period,
- The geometry of the scour hole during 1986,
- The grain size distribution of the bed materials,
- Different sediment computing approaches, and
- The different roughness coefficients.

The predicted data were compared with the actual measured data to determine which sediment approach to be used and how close is the simulation using the model. The comparison of the different methods for the simulation showed that Yang's 1996 modified method is more suitable for the scour hole mathematical simulation. This method was used for the calibration and the prediction. Figure (3) shows an example of the comparison of some of these different approaches to predict one of the cross section in 1989 from 1986 data. Figures (4), (5) and 6 show the comparison of the scour hole cross sections in 1986, 1989, and the predicted 1989 using Yang’s approach. These cross sections are located at 99.00m, 139.00m, and 149.00m from barrage center line (the cross section locations are selected to represent the critical scour hole configuration). It is very complicated to predict the actual changes of the scour hole bed configuration because of many local factors, barrage operation rules, and local flow conditions. For this study, the different comparisons show close relationships between the actual parameters and the predicted parameters using the mathematical model.

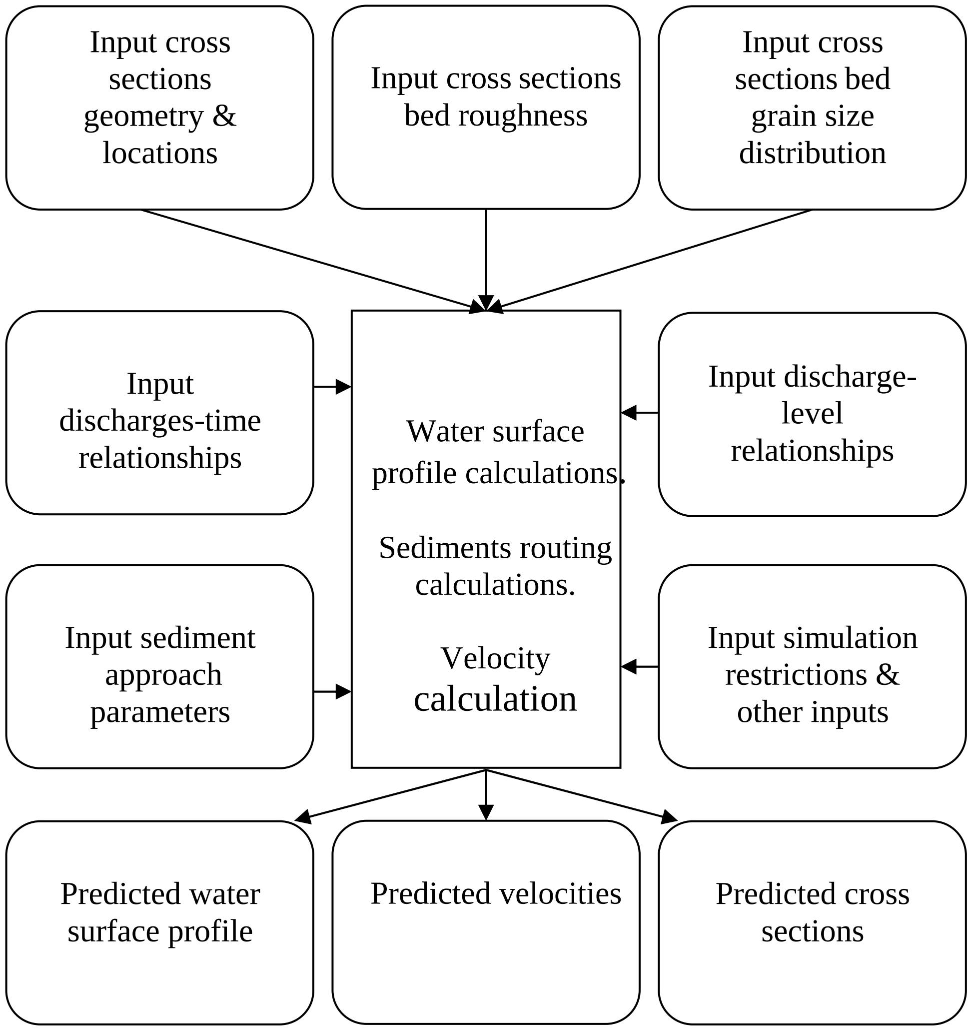

Figure (2) GSTARS 2.000 model brief description

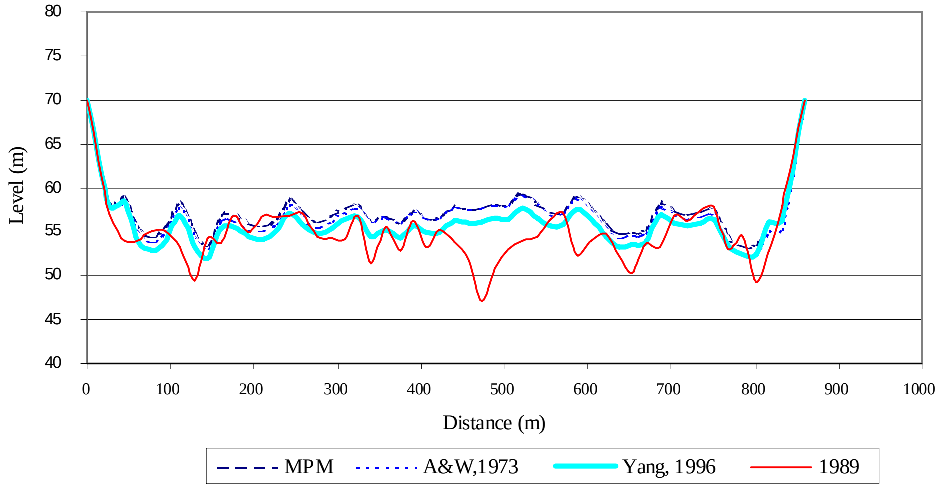

Figure (3) Some of sediment calibration approaches for cross section at distance 109.0 m from Naga Hammadi Barrage

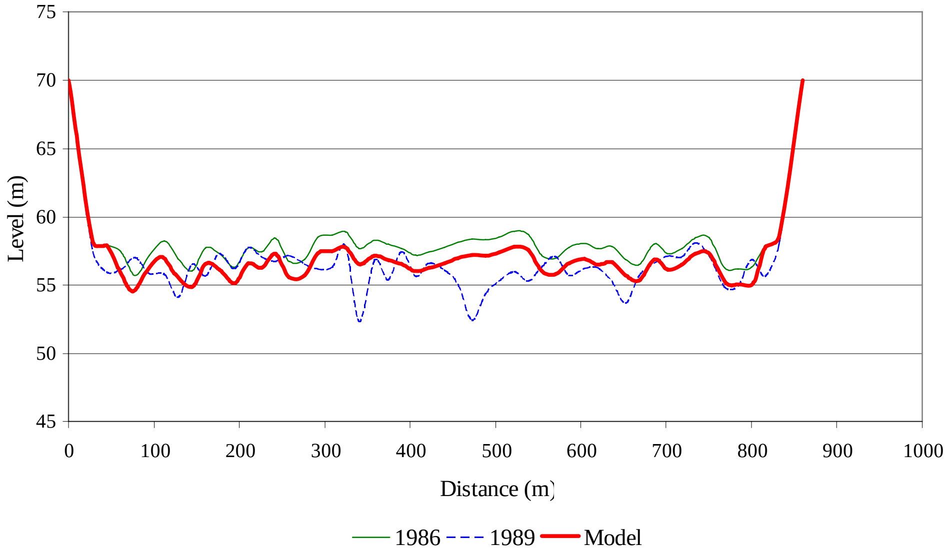

Figure (4) Model calibration for cross section at distance 99.0 m from Naga Hammadi Barrage center line.

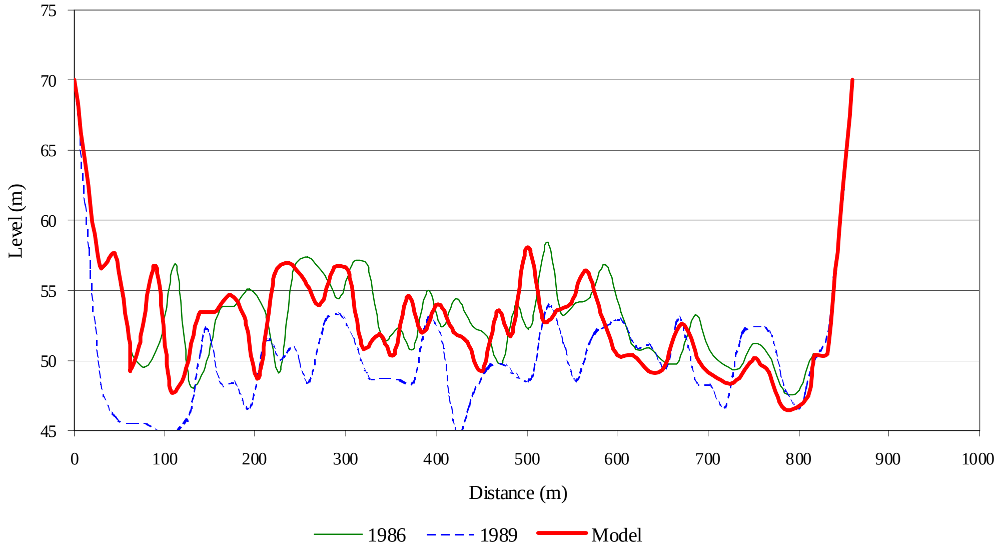

Figure (5) Model calibration for cross section at distance 139.0 m from Naga Hammadi Barrage center line.

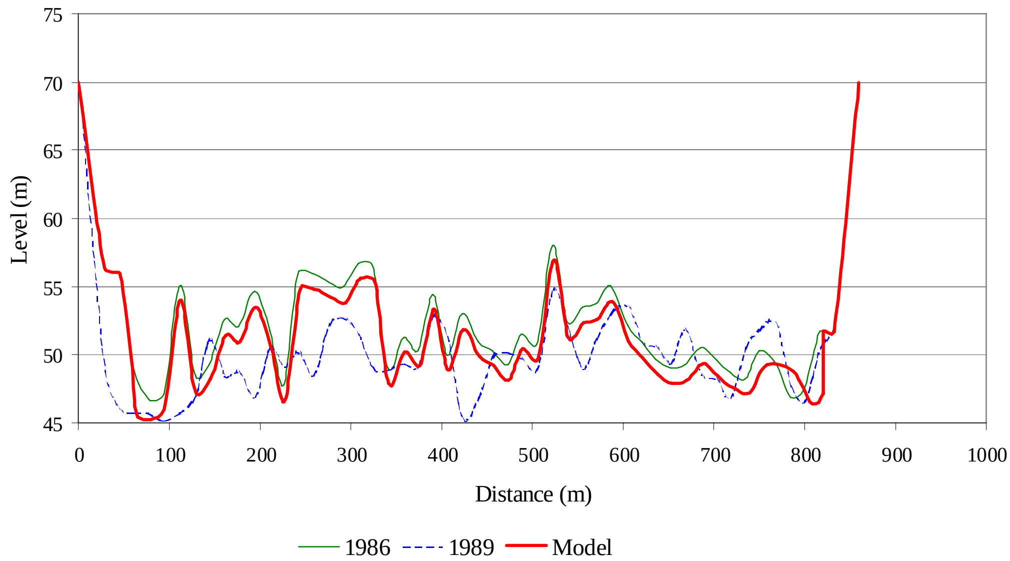

Figure (6) Model calibration for cross section at distance 149.0 m from Naga Hammadi Barrage center line.

NAGA HAMMADI BARRAGE FLOOD ANALYSIS

For the flood analysis, five different high floods were considered for this analysis:

- 300 million cubic meters per day,
- 350 million cubic meters per day,
- 400 million cubic meters per day,
- 500 million cubic meters per day, and
- 600 million cubic meters per day.

These different floods were simulated using the model, and their effect on the scour hole, were analyzed. The duration period for each flood was taken into consideration. For this study different flood duration periods were considered and simulated from one week and up to four months. The results of this analysis are shown on Figure (7) and Table 2. The figure and the table show the average eroded thickness for the scour hole for each flood during the simulation period. The average eroded thickness was selected for this research instead of the lowest point changes because of the following reasons:

- To reduce modeling errors for computation at certain point and increase the accuracy by computation for all points and using their average.
- The effect of the average depth drop on the stability of the barrage may cause more damages than the effect of only one point local scour. From Figure (7) and Table 2 it can be shown that the average eroded thickness is decreasing with the increasing of the flood duration, reaching stability conditions for the same flood and boundary conditions (Ismail, 2001).

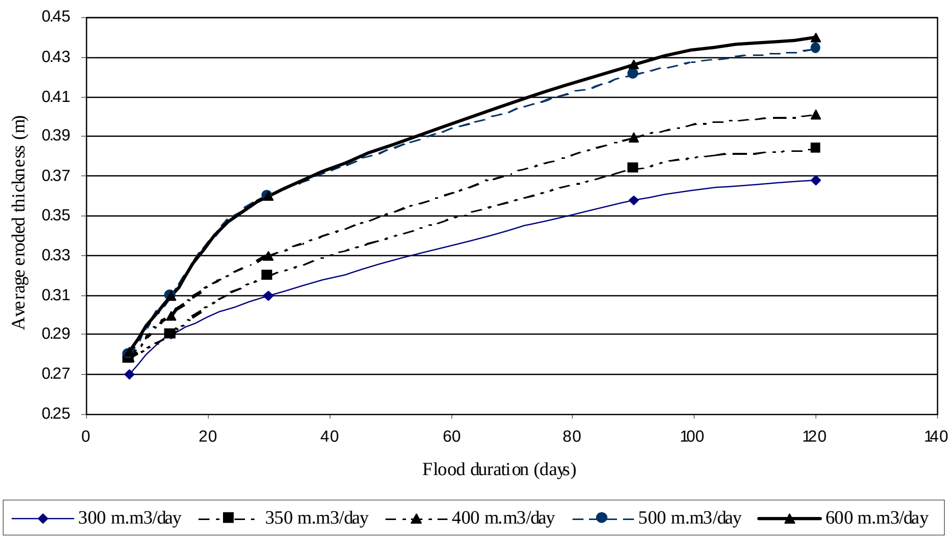

Figure (7) Average erosion prediction downstream Naga Hammadi Barrage for different floods and duration (Ismail, 2001).

Table 2 Average eroded thickness for Naga-Hammadi Barrage flood analysis

Flood Duration (Days)	300 ($m.m^3$/day)	350 ($m.m^3$/day)	400 ($m.m^3$/day)	500 ($m.m^3$/day)	600 ($m.m^3$/day)
7	0.27	0.28	0.28	0.28	0.28
14	0.29	0.29	0.30	0.31	0.31
30	0.31	0.32	0.33	0.36	0.36
90	0.36	0.37	0.39	0.42	0.43
120	0.37	0.38	0.40	0.43	0.44

CONCLUSIONS

Most of Egyptian Barrages are suffering from downstream local scour. To study the effect of high floods on Egyptian Barrages, these flood conditions and scour hole responses were simulated using the model GSTARS 2.000, which was developed by U.S. Bureau of Reclamation (1998). For this study, the different comparisons show close relationships between the actual and the predicted parameters using the mathematical model for Naga Hammadi Barrage. The results of the analysis of the average eroded thickness for Naga Hammadi Barrage show the following:

a) 300 million cubic meters per day flood:
   The results range from 0.27 m for one-week flood period to 0.37 m for four-month flood period.
b) 350 million cubic meters per day flood:
   The results range from 0.28 m for one-week flood period to 0.38 m for four-month flood period.
c) 400 million cubic meters per day flood:
   The results range from 0.28 m for one-week flood period to 0.40 m for four-month flood period.
d) 500 million cubic meters per day flood:
   The results range from 0.28 m for one-week flood period to 0.43 m for four-month flood period.
e) 600 million cubic meters per day flood:
   The results range from 0.28 m for one-week flood period to 0.44 m for four-month flood period.

RECOMMENDATIONS

The recommendations for future studies can be summarized as follows:

- The collection of more calibration data are required in three dimensional models for local scour. This includes different velocity values in different directions and the most recent data about the bed grain size distribution.

- The continuous monitoring and design of suitable solutions for scour hole downstream hydraulic structures are very important to avoid critical conditions.

REFERENCES

1. ASCE, Sedimentation Engineering. ASCE Manuals and Reports on Engineering Practice-No. 54. pp. 745, 1975.
2. Aziz, M., M. Samuel, and M. Abdel Bary. Effect of Scour Holes on the Stability of Hydraulic Structures. pp. 1.7-1 1.7-7, Proceeding of Conference on Coping with Water Scarcity, Hurghada, August, Egypt, 1998.
3. NRI, Pre-feasibility Study of Development for Naga Hammadi Barrage, Nile Research Institute, National Water Research Center. El-Qanater, Egypt, pp. 130, 1990.
4. U.S. Bureau of Reclamation, “Gstars 2.000 Model Manual”, U.S. Bureau of Reclamation, Denver, Colorado. pp. 532, 1998.