NILE RIVER LOW DISCHARGE EFFECTS ON PUMP STATION WATER SUPPLY

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ABSTRACT

Nile water discharges have a relatively wide variation. The observed high flows range up to 150 billion cubic meters per year as observed in 1878-1879 as natural inflow at Dongla gauging station and the lowest observed flows was 42 billion cubic meters per year in 1878-1879. For both high and low flows, some measures have to be considered to avoid any resulted side effects for these circumstances. The side effects of low flows are many, some examples of these side effects are the water supply un-sufficiency, navigation problems, and some local sedimentation problems. The scope of this paper is focused only on the effect of Nile low flows on the pump station water supply. During this research, pump stations along all reaches were reviewed according to their design and critical water level to determine the potential for expected problems due to passing the low discharges in the four reaches. A one-dimensional computer program based on solving the flow equations was developed to compute water levels related to the analyzed discharges. The model was calibrated using the actual water level readings from gauging stations after developing the corresponding rating curve for each station. The computed water levels were compared to the design and critical pump station water level to determine the adequacy of the water level for pump station supply. The frequencies of different discharges were evaluated and the probability of the analyzed discharges was evaluated. The results of this analysis were illustrated at the end of this research.

KEYWORDS: Nile River, Pump Stations, Low Water Levels.

NILE RIVER

Nile River is the second longest river in the world (about 6500 kilometers long). Most of Nile water is coming from the Ethiopian plateau through the Blue Nile and Atbara during the period from August to December.

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Following this period, the major contribution for the rest of the water supply comes from the White Nile and its tributaries (Sobat at first, then the Great Lakes Plateau). Nile flood has a very great variation due to the variety of the different characteristics of the Nile basin. The Nile flood can be as high as 150 (1878-1879) billion cubic meters per year and as low as 42 billion cubic meters per year (1913-1914). Both extreme cases, very low and very high, floods have their own side effects. While the very high floods have their side effects on riverbanks, hydraulic structures and riverbed, very low floods have their own side effects. Some examples of these side effects are the water supply un-sufficiency, navigation difficulties, and some local sedimentation problems. Nile River is divided into different reaches between hydraulic structures. The river length between down stream Old Aswan dam to upstream of Delta Barrage is divided into four reaches. The description of these four reaches is as follows:

1- Reach 1, located from downstream Old Aswan Dam to upstream of Esna Barrages with a total length of 166.65 km,
2- Reach 2 located from downstream of Esna Barrage to upstream of Naga Hammadi Barrage with a total length of 192.80 km,
3- Reach 3 located from downstream of Naga Hammadi Barrage to upstream of Assiut Barrage with a total length of 185.30 km, and
4- Reach 4 located from downstream of Assiut Barrage to upstream of Delta Barrage with a total length of 409.00 km.

Every reach of the four reaches has its own gauging station to measure daily water level corresponding to the passed discharge. Some of these gauging stations were used for the calibration process of the developed model to determine the required model parameters. Table (1) shows the selected gauging stations for the four reaches. It shows the reach and the gauging station number, the gauging station name, and its location measured from Aswan Dam.

Nile River Discharges Down Stream Aswan

Figure (1) shows the frequencies of Nile River discharges down stream Aswan for the period 1985-2002. The discharges range from a minimum value of 60 million cubic meters per day to a maximum value of 270 million cubic meters per day with an average discharge value of 158.71 million cubic meters per day. During this study we have concentrated on the effect of passing the lowest value (60 million cubic meters per day) down stream Aswan on the pump stations along the four reaches. The proposed discharges for the four reaches are shown on Table (2). The computed probability of passing the 60 million cubic meters per day from the frequency occurrence is about 0.79%.

Table 1. Selected water level gauging stations

No.	Site Name	Km	No.	Site Name	Km
R1-1	Gaafra	33.75	R3-5	Sohag	445.95
R1-2	Kom Ombo	49.65	R3-6	Koramata	457.6
R1-3	Ekleet	62.45	R3-7	Maragha	470
R1-4	Salwa Bahry	85.45	R3-8	Khazend	479.1
R1-5	Ramady	102.50	R3-9	Magris	509.5
R1-6	Baselea	131.00	R3-10	Aboteeg	520.5
R1-7	U.S. Esna	166.65	R3-11	Usassiut	544.78
R2-1	Ds Esna	166.65	R4-1	Ds Assiut	544.78
R2-2	Mateena	174.7	R4-2	Maaabda	576.2
R2-3	Armant	203.8	R4-3	Mandra	612.1
R2-4	Luxor	224.1	R4-4	Menia	687.55
R2-5	Hela	255.6	R4-5	Fadl	735.25
R2-6	Sherikia	264.9	R4-6	Beba	789
R2-7	Qena	286.7	R4-7	Baniswafe	808.6
R2-8	Naga Hamadi	346.45	R4-8	Korimate	839.1
R2-9	Us Naga	359.48	R4-9	Lethy	873.7
R3-1	Dsnaga	359.48	R4-10	Eksas	887
R3-2	Dom	363.2	R4-11	Roda	927
R3-3	Baliana	386.6	R4-12	Usdelta	953
R3-4	Gerga	405.1			

Table 2. The proposed discharges for this analysis

Reach	Proposed Discharge (million cubic meters per day
1	60
2	50
3	40
4	37.7

PROPOSED MATHEMATICAL MODEL

Mathematical models are used to predict water levels for different flood conditions. For this study, a mathematical model was derived based on solving the flow equations to compute water levels corresponding to different discharges.

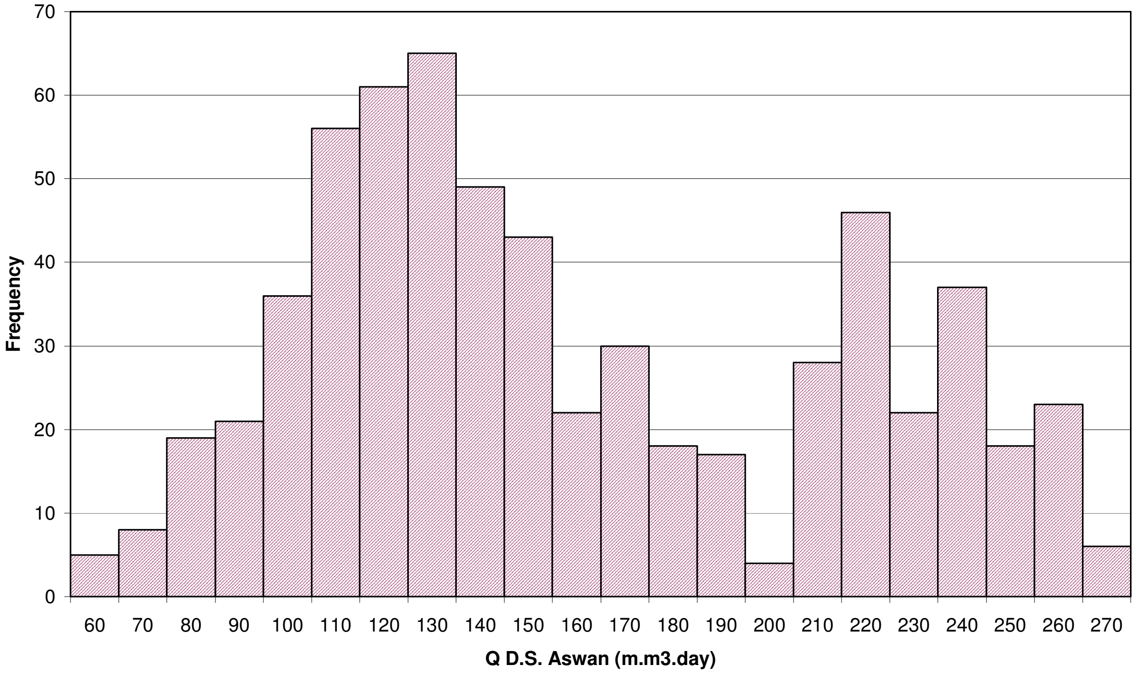

Figure (1) Frequencies of water discharges down stream Aswan (1985-2002)

Water Surface Profile Computations

Water surface profile computations for the developed model are based on solving the energy and the flow equations. The energy equation is described as follows:

$$\frac{V_1^2}{2g} + Y_1 + S_o \Delta L = \frac{V_2^2}{2g} + Y_2 + S_f \Delta L \qquad ...(1)$$

Where:

V_1 = Average velocity at section (1)
V_2 = Average velocity at section (2)
Y_1 = Water depth at section (1)
Y_2 = Water depth at section (2)
S_o = Bed slope
S_f = Energy slope
ΔL = Distance between sections (1) and (2)

The Manning flow equation is described as follows:

$$Q = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} A \qquad ...(2)$$

Where:

Q = Flow discharge,
n = Manning roughness,
R = Hydraulic radius (A / P),
S = Energy slope,
A = Cross sectional area, and
P = Wetted Perimeter.

The energy equation is solved numerically using Standard Step Method iterative procedure (Chow, 1957). The downstream boundary condition is pre-determined from the actual measurements and the water surface profile computations are processed from downstream to upstream.

Model Calibration

The first step for the model calibration is to determine the actual measurements related to the analyzed discharges at the gauging stations. Since the actual measurements are varied from time to time according many factors, it was very important to develop a rating curve for each gauging station to be able to define its actual measurements related to different discharges in a more realistic way. These rating curves were developed for all the gauging stations shown on Table (1). An example of these rating curves for only low discharges is shown on Figure (2) for down stream Esna Barrage gauging station. The results of the calibration process are shown as follows: Figure (3) shows the calibration results for Reach 1, Figure (4) shows the calibration results for Reach 2, while Figure (5) shows the calibration results for Reach 3, and Figure (6) shows the calibration results for Reach 4. From these figures it can be concluded that there is close agreement between the measured and the predicted water levels and the predicted water level can be used for the simulation process and the required analysis.

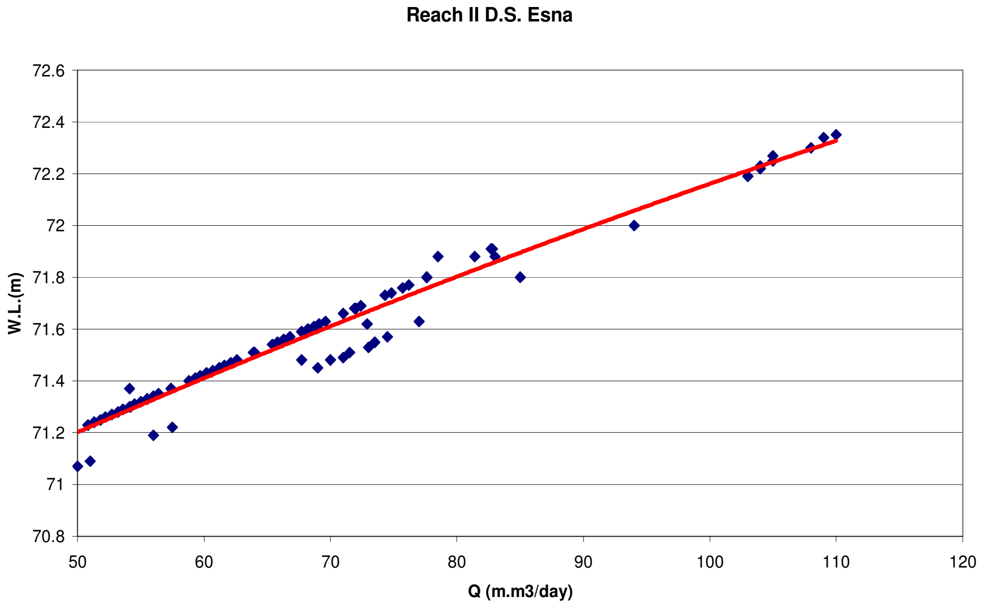

Figure (2) Downstream Esna gauging station rating curve for low discharges

ANALYSIS RESULTS

The analysis results are shown on Figures 7 to 10. Figure 7 shows the results for Reach 1. The computed water levels for a discharge of 60 million cubic meters per day along the reach are illustrated on the figure with the pump station design and critical water level. The critical water level is defined as the minimum water level at which pump stations are able to operate. Some of these stations are floating stations which can not relatively suffer from the low water levels. The stations with critical water higher than the computed water levels are expected to suffer from lack of water head. Figure 8 shows the results for Reach 2. The computed water levels for a discharge of 50 million cubic meters per day along the reach are illustrated on the figure with the pump station design and critical water level. Figure 9 shows the results for Reach 3. The computed water levels for a discharge of 40 million cubic meters per day along the reach are illustrated on the figure with the pump station design and critical water level. Figure 10 shows the results for Reach 4. The computed water levels for a discharge of 37.7 million cubic meters per day along the reach are illustrated on the figure with the pump station design and critical water level. The summary of the results is shown on Table (3). This table shows, for every reach, the analyzed discharge. It shows also the observed number of stations which have a critical water level higher than the computed water levels due to the analyzed discharge in addition to the total number of pump stations. It shows the maximum, minimum, and average head difference between the critical and the computed water level for all pump stations in each reach. It has to be mentioned her, that Reach 3 has the highest percentage,7 out of 9, of 78% and the maximum head difference for both cases maximum and average differences.

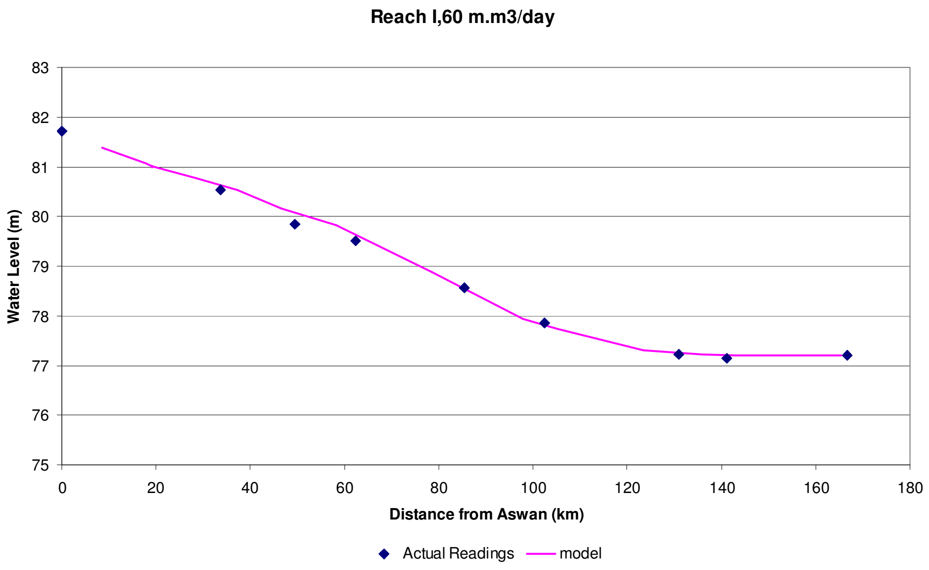

Figure (3) Reach (1) calibration curve.

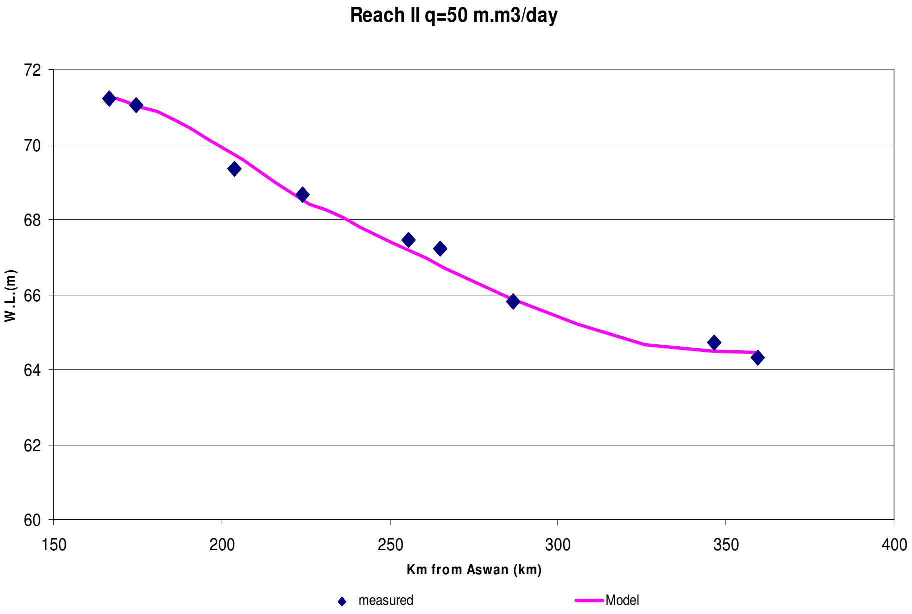

Figure (4) Reach (2) calibration curve

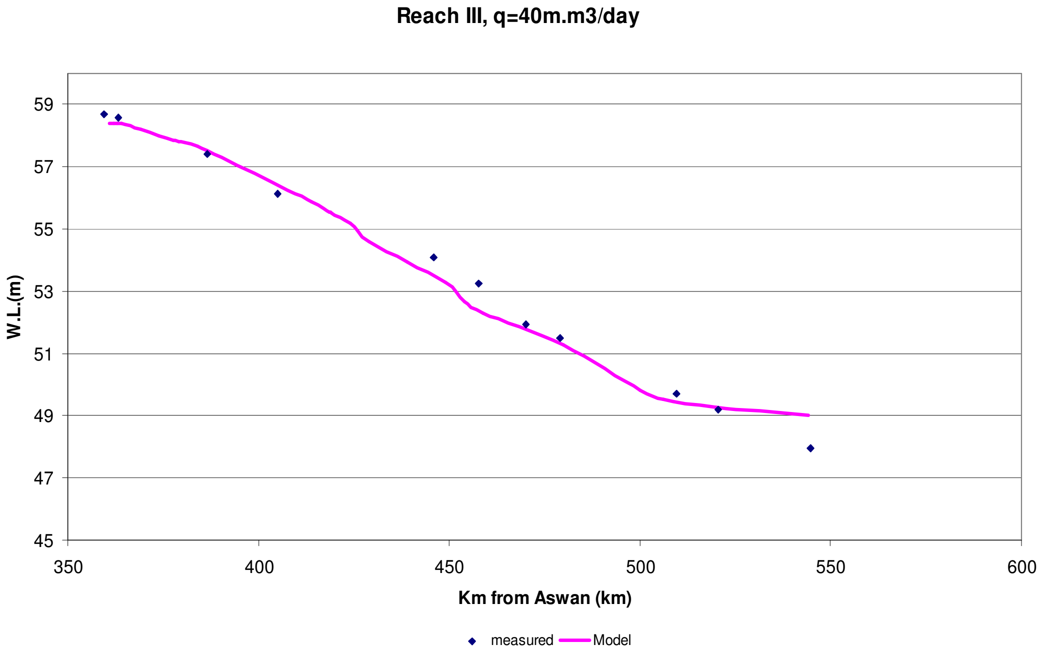

Figure (5) Reach (3) calibration curve

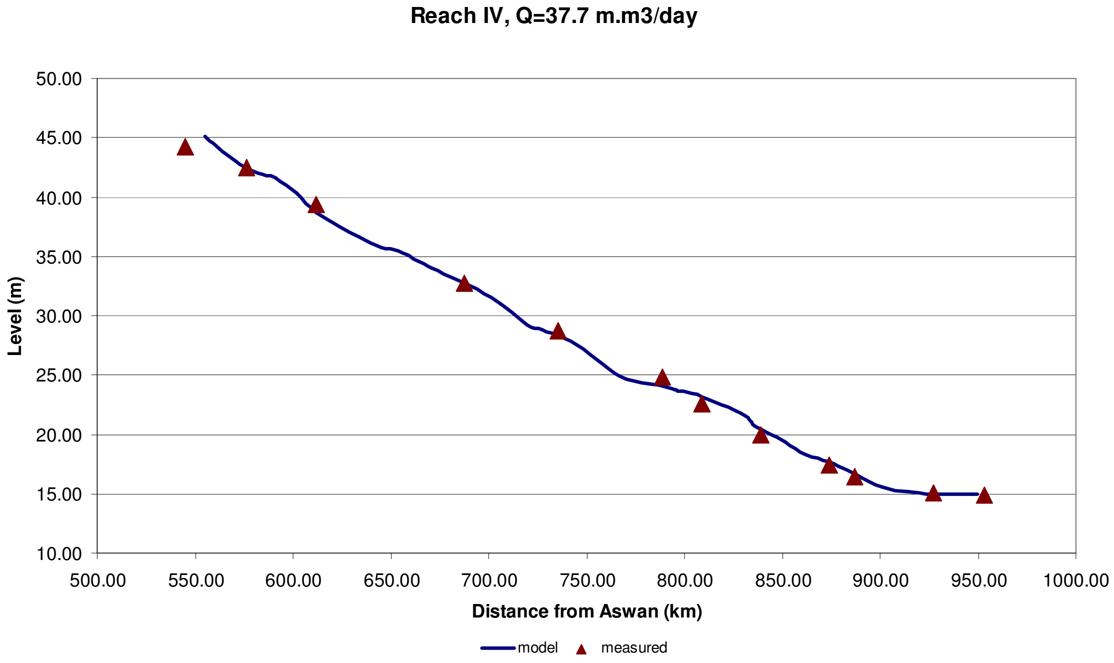

Figure (6) Reach (4) calibration curve

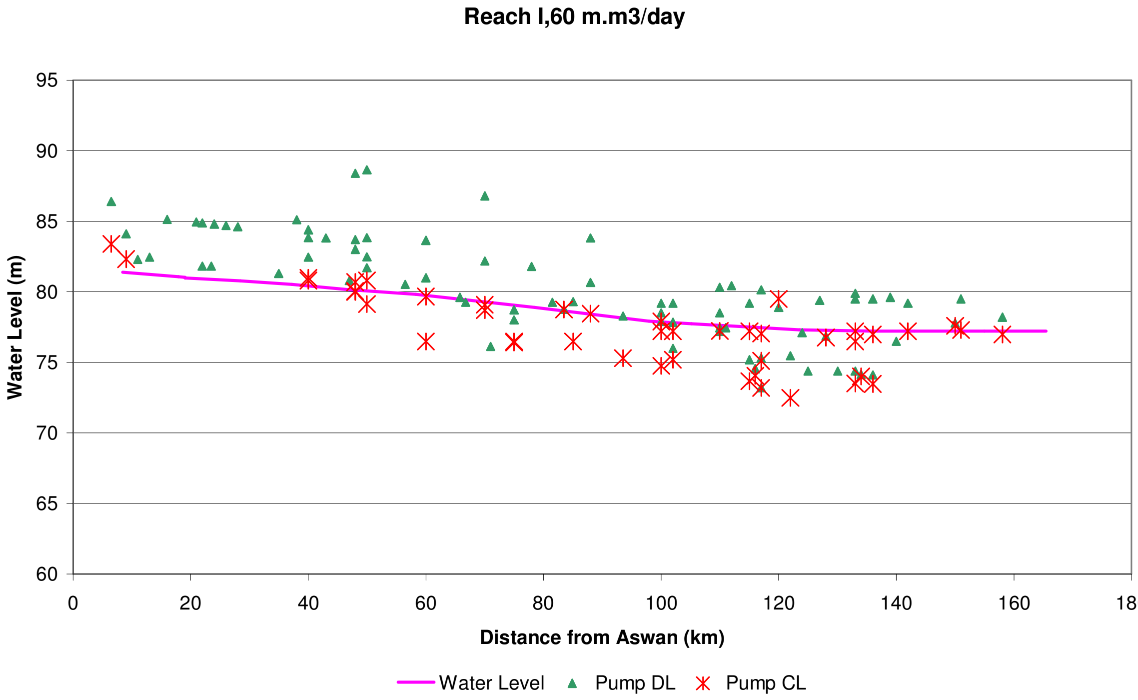

Figure (7) Analysis results for reach (1).

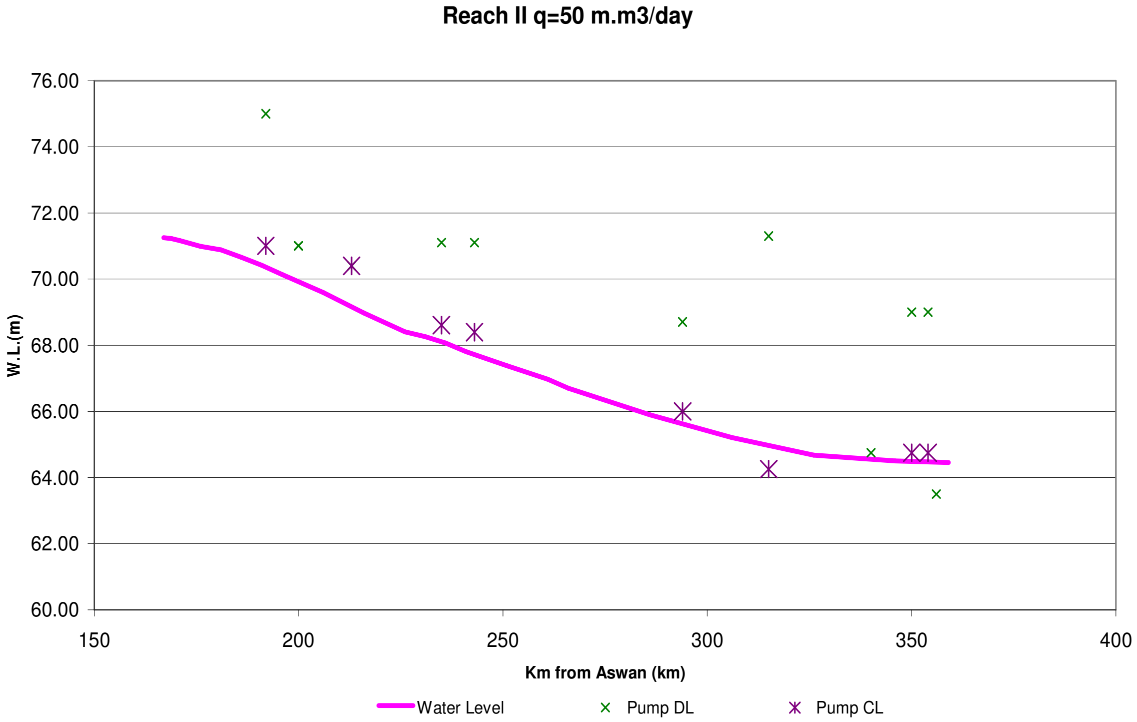

Figure (8) Analysis results for reach (2).

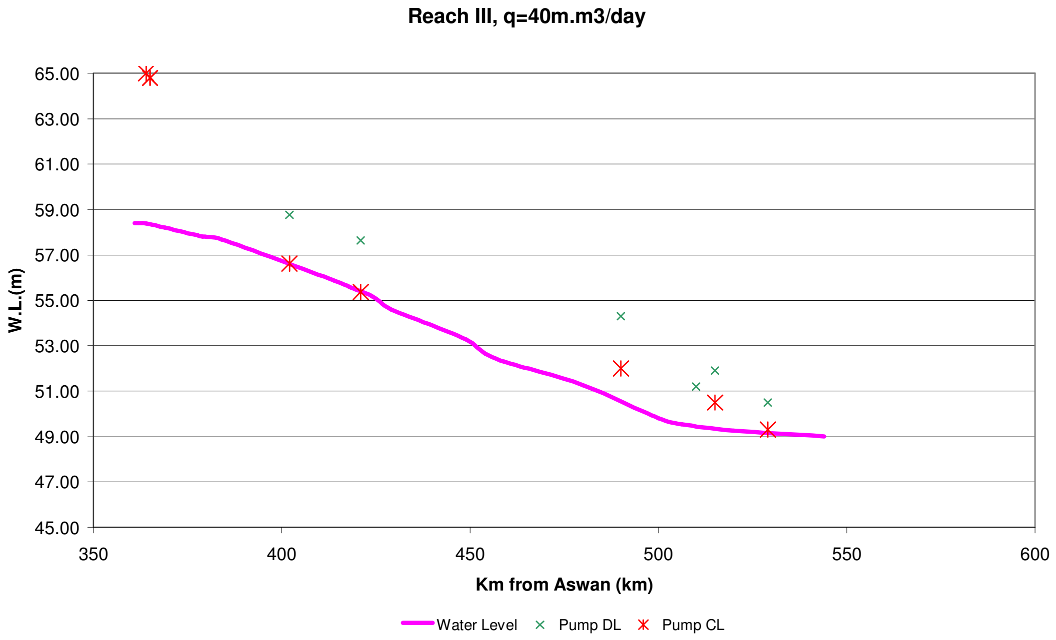

Figure (9) Analysis results for reach (3).

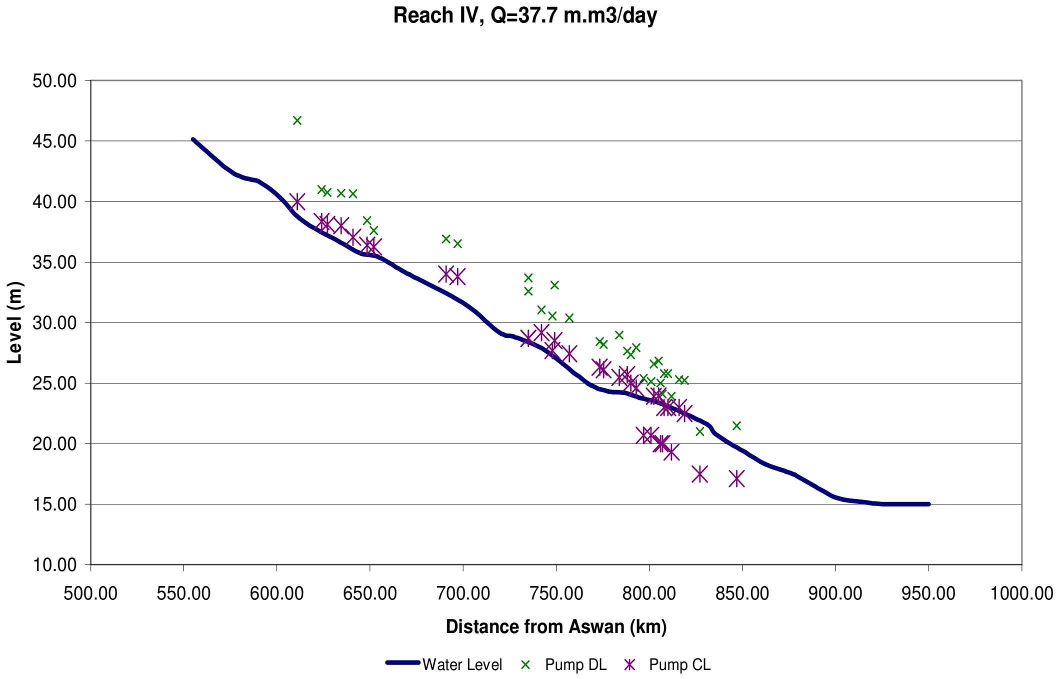

Figure (10) Analysis results for reach (4).

Table 3. Summary of the results for pump stations.

Reach	1	2	3	4
Q (m.m^3/day)	60	50	40	37.7
Observed No. of stations	12	7	7	25
Total No. of stations	81	12	9	36
Maximum Head	2.11	1.24	6.61	1.95
Minimum Head	0.02	0.27	0.03	0.07
Average Head	0.66	0.57	3.18	0.99

CONCLUSIONS

- During this research, pump stations along all reaches from down stream Aswan to upstream Delta barrage were reviewed according to their design and critical water level to determine the potential for expected problems due to passing the low discharges in these reaches.
- A one-dimensional computer program based on solving the energy and flow equations was developed to compute water levels related to the analyzed discharges.
- The model was calibrated using the actual water level readings from gauging stations after developing the corresponding rating curve for each station to obtain more realistic values.
- The computed water levels were compared to the design and critical pump station water level to determine the adequacy of the water level for pump station supply.
- The frequencies of different discharge were evaluated and the probability of the analyzed discharges was evaluates.
- The observed number of stations which have a critical water level higher than the computed water levels due to the analyzed discharge in addition to the total number of pump stations for every reach are shown.
- The maximum, minimum, and average head difference between the critical and the computed water level for all pump stations in each reach are shown.

REFERENCES

Chow, V. T., 1957. *Open Channel Hydraulics*, McGraw-Hill Book Co., 1957.