Long-Term Morphological Changes along the 2nd Nile River Reach through Half Century after "HAD" Construction

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Abstract

With the progress of High Aswan Dam "HAD" construction and filling the upstream reservoir, out of an average annual sediment load of 125 million tons, only about 26.3 million tons passed downstream of the Old Aswan Dam "OAD" in year 1968 which was enormously decreased to about 2.0 million tons in year 2000. This led to conclude that, the average annual suspended sediment downstream "HAD" is enormously decreased from 1600 ppm before "HAD" construction to about 50 ppm. So far, several studies anticipated general degradation along the four Nile River reaches and sever local scour downstream the main hydraulic structures. Therefore, the present study aimed to explore the variation of water surface levels with time and location along the second river reach since the construction of "HAD" till year 2010. The daily records of flow discharges and the corresponding water surface levels along the second reach from year 1962 to 2010 were utilized to deduce the matching stage discharge rating curves.

Following a similar study for the first Nile River reach, assessment of the attainable water surface levels for various periods and locations along the second river reach - at passing 200 million m^3 / day – revealed that El-Mataana and El – Shanhoria gauge stations were the only sites subjected to water surface level decline and possible degradation after "HAD" construction. The decrease reached its maximum value of 0.225 m and 0.115 m at El-Mataana and El-Shanhoria gauge stations respectively at years 1979 and 1980 then turned over to increase and possible sedimentation at year 1992 for El-Shanhoria gauge station which reached 0.18 m and 0.355 m in years 2000 and 2010 respectively. On the other hand, the downstream part of the study reach from El-Sheikheya to Qena gauge stations did not subject to any decrease in water surface levels since "HAD" construction till year 2010. The monitored increase in water surface levels in year 2010 revealed a maximum value of 0.675, 0.355, 0.575 and 0.460 m at Luxor, El-Shanhoria, El-Sheikheya and Qena gauge stations respectively with respect to the condition before "HAD" construction. Moreover, the attained results for the condition before and after "HAD" construction revealed narrow distinction for the variation in longitudinal water surface slope which ranges between maximum and minimum values of 5.51 cm/km and 4.98 cm/km respectively. Therefore, unlike the concluded results for the first reach, the second one was not subjected to significant or considerable variations in the longitudinal water surface slope after "HAD" construction. Considering the increase in water surface level is due to general sedimentation of 0.516 m as an average value in year 2010, a total deposited material of 49.16 million m^3 was worked out along the represented river reach. This led to conclude that the second River Nile reach is being subjected after "HAD" construction to general regular sedimentation and not degradation as expected from several studies.

Keywords: High Aswan Dam Side Effects, Degradation, Sedimentation, Stage Discharge Rating Curves

1. INTRODUCTION

It is nearly half a century since the Nile River annual flood water was first stored upstream "HAD" in 1968 which was completed in 1970 with the installation of the twelfth turbines. According to the early project documents, three basic functions were specified which are; (1) to store the annual floods by detention to allow regulated release for irrigation and other purposes throughout the year; (2) to generate hydroelectric power; and (3) to control high floods through the Nile River reaches which are shown in Fig.(1). Since the project completion, several changes within the Nile River and its valley in Egypt emerged. Consequently, an immense side effect points were raised, such as bed degradation; less of fisheries; massive bank erosion; water logging and salinity; aquatic weeds; reduction in brick industry; loss of fertility by loss of deposited sediment on the land; and erosion of the seashore of the delta. Most of those side effects were successfully remedied to guarantee such mitigated impact. However, variation of river bed and water surface levels with time and location since the construction of "HAD" till now has not been fully explored.

Figure 1: Location of Main Nile River Barrages in Egypt

In order to review the previously attempted researches within the current subject, a distinction should be made between the general scour (degradation) and the local scour. Degradation can be considered as the river response to any morphological or hydrological changes in its boundary conditions such as accelerated bank erosion, cutoffs of river bends. While localized scour can be distinguished in a number of different types such as downstream of the hydraulic structures, around bridge piers, river constrictions, near spur dikes and guide banks.

Among the early investigation that was made in (1976) by El-Ansary, A.E. to evaluate the degradation that is likely to take place under the maximum discharge downstream of "HAD" which was assessed by deduction from what has actually taken place under present discharges. The "Critical Tractive Stress Theory" was used under the condition that the Nile River downstream "OAD" is permanently fed with clear water after "HAD" construction. Knowledge of the critical tractive stress - in this case - together with the hydraulic relationships for any reach of the Nile River would enable to determine the ultimate stable slope in that river reach under any anticipated conditions. The corresponding bed drop downstream any barrages can be then worked out when the distance to which degradation is likely to extend is known. The achieved results of degradation downstream the main Nile River barrages at year 1974 and the results of the estimated ultimate values as well as the corresponding affected distance downstream each barrage are listed in Table (1).

Table 1: Estimated Degradation after "HAD" Construction

No.	Location	Estimated bed lowering (m)		Affected distance (km)	
		1974	Future**	1974	Future**
1	D.S. of Esna barrages	0.60	5.20	43	193
2	D.S. of Naga-Hammady barrages	0.45	5.20	50	180
3	D.S. of Assuit barrages	0.75	7.80	185	190

In the above Table, [Future**] means the ultimate values after several years of "HAD" operation. Bearing in mind that the total length of the 2nd, 3rd, and 4th Nile River reaches are 193.9, 181.8 and 408.7 km long respectively, this means that the ultimate anticipated degradation would cover 100%, 100% and 46% of the mentioned three reaches respectively. However, such estimation seems to be unrealistic and illogic with respect to the real facts and the actual conditions.

Richardson, E.V. and Clyma, W. in (1979) revealed that the release of sediment – free water from "HAD" has lowered the river bed and the change in flow regime has increased bank erosion. These effects were anticipated during the design of the dam, but calculations indicated that the existing barrages would cause backwater upstream and the flat slope of the Nile River (0.4 ft per mile) [equivalent to 7.6 cm / km] would not be of immediate concern and could be dealt with in time. Moreover, the study also demonstrated that the measurements made since 1964 confirmed that the expected degradation would not be excessive because in large rivers such as the River Nile, it is difficult to conclude a certain assessment for bed erosion. These because from the hydrographic survey, one can find for example erosion in one five kilometer reach and deposition in the following five kilometer reach and so forth. For this reason, the study concluded that the drop in water level can be an indicator of degradation which consequently would be the result of bed erosion, bank erosion and change in channel roughness.

Moreover, from the rating curves of the gauging stations which are located downstream of "OAD", the drop in water levels during the period from 1964 to 1978 for 100 million m^3/day flow discharge was determined by Gasser et al (1978) as listed in Table (2).

Table 2: Estimated Drop in Water Surface Levels

No.	Site	Expected drop	
		(m)	(ft)
1	El-Gaafra	0.40	1.3
2	D.S. of Esna barrages	0.81	2.6
3	D.S. of Naga-Hammady barrages	0.62	2.0
4	D.S. of Assuit barrages	0.35	1.1

The study revealed that most of the determined drop in water surface elevation occurred during the construction of "HAD" when sediment was trapped upstream the coffer dam and the non-regulated high sediment-free flow passed on towards the downstream. Additional study was presented by Ismail, H.M. (1990) who stated that as the average annual suspended sediment was reduced from 1600 ppm before "HAD" construction to 50 ppm, and the change occurred in the flow regime, river bed was eroded. Different national and international experts expected lowering of the river bed and water surface level downstream the existing barrages from 3 to 20 m. Measurements at fixed cross sections were periodically taken along the Nile to monitor the change in water surface and bed levels. Observations indicated that the total drop in water surface level ranges between 0.5 and 1.0 m which is due to the flat slope and self armored river bed.

More efforts to evaluate the expected degradation downstream the main hydraulic structures along the Nile River after the "HAD" construction were carried out by El-Moattassem, M.M. (1998 and 2001). The studies revealed that some of 95% of total annual sediment load is deposited in the upstream regions of lake Nasser upstream the "HAD", while only 5% of sediment reaches Aswan. The study also indicated that about 60% of the deduced drop in water surface levels downstream the main barrages have occurred due to the large volumes of nearly clear water that were discharged during dam construction. The actual drop in water surface levels until year 1997 at five locations along the river from Aswan to Cairo was worked out from the gauging discharge relations as listed in Table (3).

Table 3: Estimated Drop in Water Surface Levels Due to Degradation

No.	Site	Distance D/S of "OAD" (km)	Discharge (million m^3/day)			
			80	100	150	200
			Drop in water surface level (m)			
1	El-Gaafra	34	1.0	0.8	0.6	0.4
2	Esna Barrages	167	1.0	0.9	0.7	0.3
3	Naga-Hammady Brgs.	360	1.0	0.9	0.8	0.6
4	Assuit Barrages	540	0.8	0.7	0.6	

The study observed that erosion downstream the barrages were noticed in the wider shallow sections to fill the narrow deeper ones. For example, erosion of the bed was observed in the first 7 km reach downstream of Esna barrages with 0.60 m average height and 790 m bed width during the period from 1963 to 1977 while the water surface slope was decreased from 7.0 cm /km to 4.0 cm /km. The following 3 km in the downstream direction, sedimentation was noticed in narrower cross sections with 0.25 m average height and 500 m bed width and the water surface slope was decreased from 5.1 cm /km to 4.6 cm /km. Moreover, Wail, A.F. (2010) revealed in his Ph.D. study that the daily water surface level corresponding to flow discharge of 233 million m^3/day at km 93.5 downstream of "OAD" in years 2004 and 2005 is 0.97 m higher than that before “HAD” construction in years 1963 and 1964. This result contradicts the previously conducted and published studies which indicated general degradation along the four river reaches downstream of "OAD" as a direct impact of "HAD" construction.

The most recent and relevant study was carried out by Ahmed, et al (2014) which focused on the first Nile River reach from downstream of "OAD" till upstream of the new Esna barrages. The deduced water surface levels for various periods and locations along the reach - at passing 200 million m^3 / day – revealed that El-Gaafra and Kom - Ombo gauge stations were the only subjected sites to degradation since "HAD" construction. This degradation turned over and recovered to sedimentation at years 2002 and 1991 for El-Gaafra and Kom – Ombo respectively and reached to a maximum sedimentation of 0.011 and 0.315 m at El- Gaafra and Kom – Ombo in year 2010. On the other hand, the downstream part of the first river reach has not been subjected to any degradation since "HAD" construction until the year 2010. The monitored sedimentation (deposition) within such reach in year 2010 reached a maximum value of 0.760, 0.989 and 1.405 m at Selwa – Bahary, El – Ramady, and Edfu gauge stations respectively with respect to the condition before "HAD" construction. Moreover, water surface slope at passing 200 millions m^3 /day was reduced from 5.84 cm/km in year 1962 to 4.05 cm/km in year 2000. The achieved results led to conclude that the first Nile River reach is being subjected to sedimentation and not degradation after "HAD" construction.

Therefore, so far, numerous hydraulics and morphological studies to classify the side effects of "HAD" constructions were carried out. Most of those studies indicated general degradation along the four river reaches downstream of "OAD" as a direct impact of "HAD" construction (El-Ansary, 1976). This because most of the provided studies were limited to the emerged local conditions downstream the main hydraulic structures after "HAD" construction rather than analysis of real data that covers adequate time and along reach (i.e. as function of distance). Consequently, no comprehensive study for any materialized degradation or sedimentation developments in time and locations along the River Nile since "HAD" construction has been attempted. The only detailed study was carried out by Ahmed et al (2014) which focused on the first Nile River reach. For this reason, the current study would employ the daily recorded observations for water surface levels and the corresponding flow discharges along the second reach to produce the stage discharge rating curves leading to work out the resulted variations in bed and water surface levels along the study reach since "HAD" construction up to the year 2010.

2. METHODOLOGY

As the main objective of the current investigation is to illustrate the development of Nile River water surface levels as an indicator for bed degradation or sedimentation since "HAD" construction until now, the daily records of flow discharges and the corresponding water surface levels would be utilized. The study would be limited to the second river reach which extends from downstream of the new Esna barrages at km 167.830 downstream of "OAD" until upstream of the new Naga - Hammady barrages at km 362.820 downstream of "OAD". Variations of daily flow discharges and the corresponding water surface levels along a steady flow condition part of the second river reach would be examined from the year 1962 before "HAD" construction up to the year 2010. On the other hand, as such hydrological information is of a stochastic nature, long time-series data records of at least one year would be demonstrated (Jansen et al, 1979). For this reason, the analyzed flow discharges and the corresponding water surface levels records would cover two successive years each ten years within the study period of almost 50 years. The available hydrologic data would be used to establish stage-discharge relationships (rating curves) which would be utilized to determine the corresponding water surface levels at an adopted flow discharge.

With this in mind, the estimated drop in water surface level can be utilized as an indicator of degradation which consequently could be the result of one or more reasons such as bed erosion, massive bank failure and decreasing in cross section width or change in channel roughness. While the increase in water surface level can be utilized as an indicator of sedimentation which consequently could be the result of one or more reasons such as general sedimentation, possible external source of sediment supply by wind and/or flash flood flows, bank erosion or change in channel roughness. This consequently means that any achieved variations in water surface levels could be more often than general sedimentation or degradation.

3. COLLECTED DATA

The present study would be focused on the second reach which extends for 194.990 km between the new Esna barrages at km 167.830 and the new Naga - Hammady barrages at km 362.820 downstream of "OAD". Daily records of flow discharges downstream the new Esna barrages and the corresponding water surface levels at 6 installed gauging stations from year 1962 to year 2010 were utilized as listed in Table (4).

Table 4: Available Data for the Hydrological Study

No.	Year	Daily Isna Discharge (mm^3/day)	Daily Water Surface Levels (m) at Gauging Stations					
			El-Mataana Km 174.700	Luxor Km 223.800	Shanhoria Km 245.000	Sheikhiya Km 264.900	Qena Km 286.750	Deshna Km 316.600
1	1962	•	•	•	•	•	•	X
2	1963	•	•	•	•	•	•	•
3	1979	•	•	X	•	•	•	•
4	1980	•	•	X	•	•	•	•
5	1989	•	•	•	•	•	•	•
6	1990	•	•	•	•	•	•	X
7	1999	•	X	•	•	•	•	X
8	2000	•	X	•	•	•	•	X
9	2009	•	X	•	•	•	•	X
10	2010	•	X	•	•	•	•	X

Where: **X** Unavailable Data
- Available Data

The sites of these gauging stations are indicated in Figure (2). Selection of the used gauge stations was carried out in such a way as not being influenced by the generated flow turbulence downstream of the new Esna barrages and the formed backwater curve "BWC" upstream the new Naga-Hammady barrages. The used gauge stations cover 141.900 km which is equivalent to 72.8% of the total length of the second river reach with maximum and minimum spacing of 49.100 and 19.900 km respectively. To produce the water surface profile along the study reach, the corresponding hydrological data at the case of minimum and maximum flow discharges downstream the new Esna barrages were utilized as listed in Table (5). The 1-D numerical model SOBEK - Sloff, C.J. et al (2004) - was then applied to perform the water surface profile corresponding to the two provided flow conditions as shown in Fig.(2).

Table 5: Actual Data to Perform Water Surface Profile

Flow condition	Date	Flow discharge (mm^3/day)			Water surface level (m)	
		DS of Esna Brg.	N. Hammady canals	DS of N. Hammady Brg.	DS of Esna Brg.	US of N. Hammady Brg.
Min. discharge	13/1/2014	62.919	18.919	44.000	(71.08)	(65.90)
Max. discharge]	28/5/2014	226.804	19.304	207.500	(74.75)	(65.30)

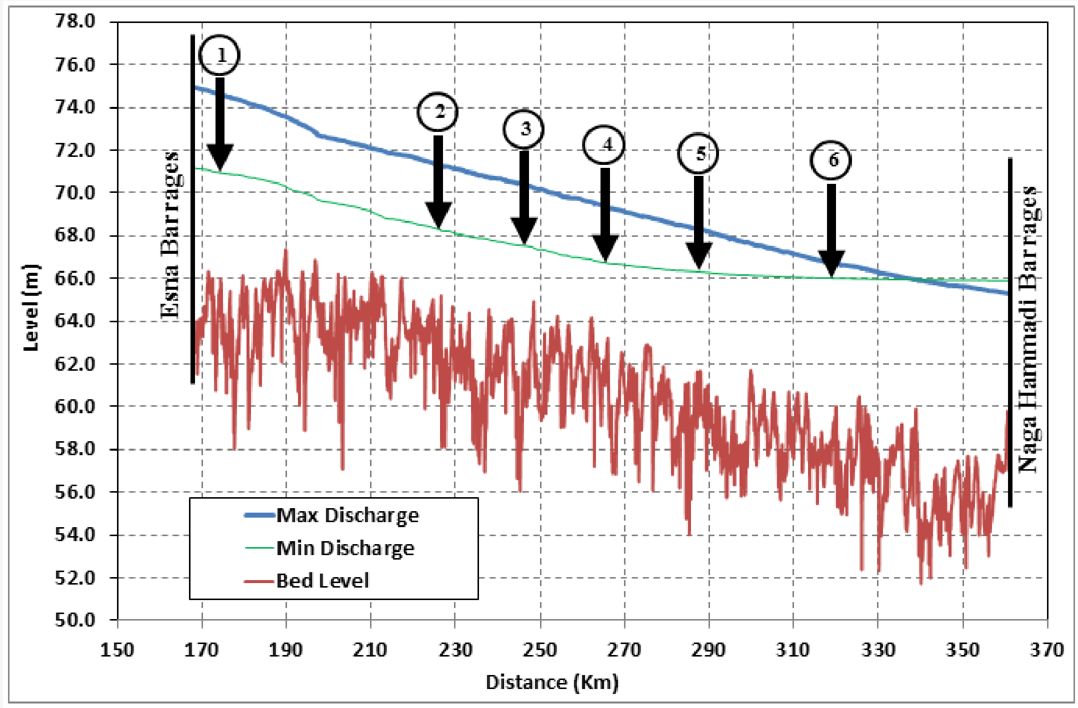


Figure 2: Location of Gauge Stations along the Study Reach

Figure (2) revealed that the backwater curve "BWC" extends for about 52 km upstream the new Naga - Hammady barrages at passing the minimum flow discharge downstream the new Esna barrages. This means that Deshna gauge station which is situated at km 316.600 would be located within the backwater curve during passing low flow discharges.

The collected data for the daily flow discharges downstream of the new Esna barrages and the corresponding water surface levels at the 6 gauge stations covered about 50 years in steps started before "HAD" construction in year 1962 to about 40 years after "HAD" construction in year 2010. On the other hand, it can be seen from Table (4) that some data were not available such as the last four years for El-Mataana gauge station, two years for Luxor gauge station and six years for Deshna gauge station. Additionally, some of the attainable records for the daily flow discharges and water surface levels were uncompleted for different causes. For this reason, the actual recorded data for each study year and gauge station were documented as listed in Table (6). This comprised that the total unavailable daily flow discharge and water surface level records reached 33 and 5458 daily data records respectively which is equivalent to 0.90% and 24.9% of the required daily records respectively. For this reason, the total number and percentage of unavailable daily data records for the flow discharges and water surface levels were analyzed with respect to each of the site and year as illustrated in Table (6). This exposed that the maximum unavailable daily data records reached 2344 days at Deshna gauge station which equivalent to 42.69% of the unavailable records and 9.2% of the total needed data for conducting the current research.

Table 6: The Unavailable Daily Data for the Hydrological Study

No.	Year	Unavailable daily flow discharge and water surface level records (days) at							Total	Percent
		Daily flow discharge (mm^3/day)	Mataana Km 174.700	Luxor Km 223.800	Shanhoria Km 245.000	Sheikhiya Km 264.900	Qena Km 286.750	Deshna Km 316.600	(days)	(%)
1	1962	-	-	-	79	81	-	365	525	9.56%
2	1963	-	-	-	74	57	-	-	131	2.38%
3	1979	-	-	365	-	-	-	-	365	6.62%
4	1980	-	-	366	-	-	-	-	366	6.62%
5	1989	-	-	-	-	23	-	153	176	3.22%
6	1990	2	-	-	-	23	-	365	390	7.09%
7	1999	-	365	-	-	-	-	365	730	13.33%
8	2000	-	366	-	-	-	-	366	732	13.34%
9	2009	31	365	-	62	62	62	365	947	17.24%
10	2010	-	365	123	123	123	30	365	1129	20.60%
Total (days)		33	1461	854	338	369	92	2344	5491	
Percent (%)		0.61%	26.63%	15.55%	6.15%	6.70%	1.67%	42.69%	100.0%	100.0%

4. HYDROLOGICAL STUDY

The hydrological study was carried out to determine the corresponding water surface level at passing flow discharge of 200 millions m^3/day at each of the used gauge station sites during various selected years. The adopted flow discharge was arbitrary chosen to suit the condition through the second Nile River reach before and after "HAD" construction. Stage-discharge rating curves which perform the relationships between the daily recorded flow discharges downstream the new Esna barrages and the corresponding water surface levels at each gauge station were deduced. In doing so, a lag time between the released flow discharges downstream of new Esna barrages to reach the 3rd and 4th gauge stations at El-Shanhoria (km 345.000) and El-Sheikheya (km 294.900) respectively was considered one day time; and the lag time to reach the 5th and 6th gauge stations at Qena (km 286.750) and Deshna (km 316.600) respectively was considered two days. While no lag time was applied for the released flow discharges to reach the 1st and 2nd gauge stations at El-Mataana (km 174.700) and Luxor (km 223.800) respectively. The attained results for some selected gauge stations and years are shown in Figures (from 3 to 8). Regression analysis to determine the best fitting mathematical expression for the attained scatter data – which is known as the least square line or curve - was worked out for all adopted sites and years as listed in Table (7). This because applying such regression minimizes the squared residuals and consequently deviation of the determined mathematical expression from the real measure.

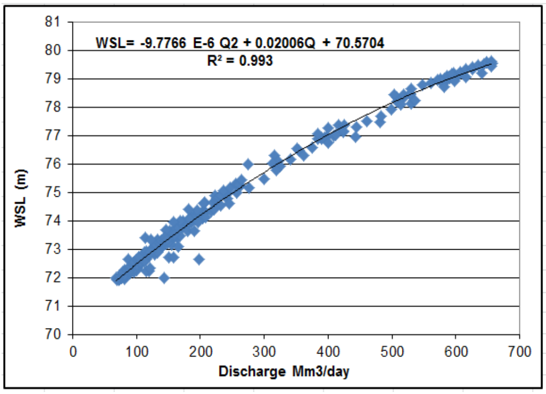


Figure 3: Rating Curve at El-Mataana (1963)

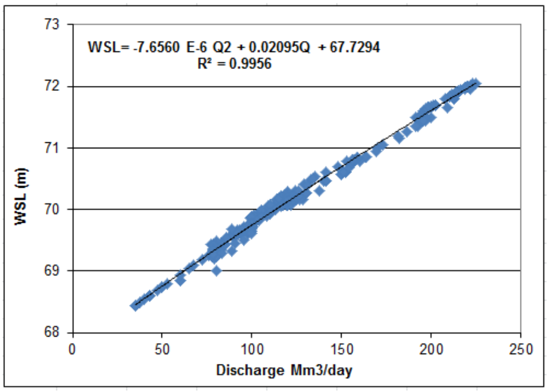
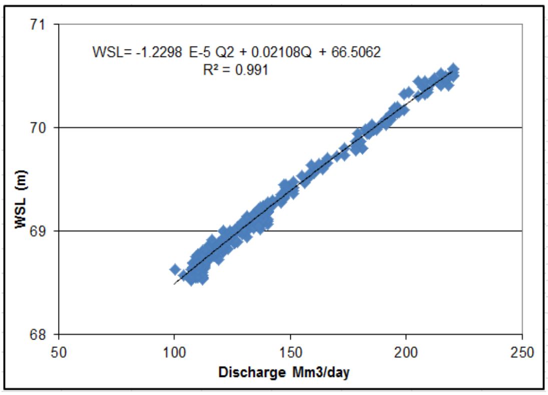


Figure 4: Rating Curve at Luxor (1990)



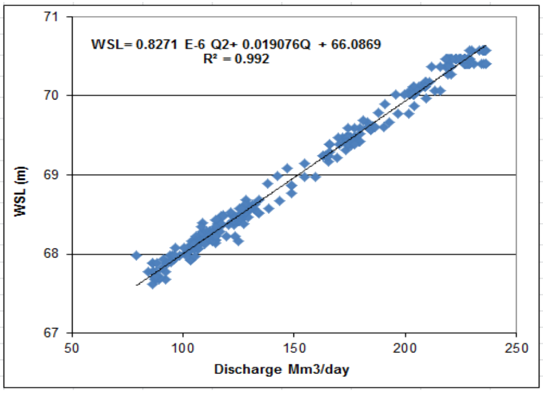
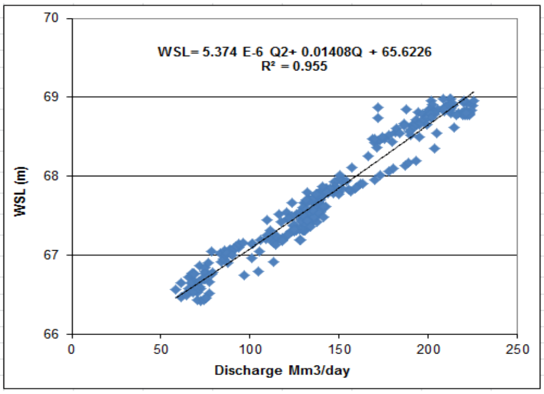


Figure 5: Rating Curve at Shanhoria (1980) **Figure 6: Rating Curve at El - Sheikhiya (2000)**



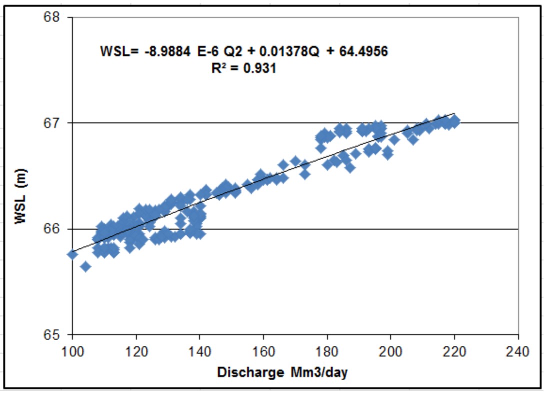


Figure (7): Rating Curve at Qena (2010) **Figure (8): Rating Curve at Deshna (1980)**

Table 7: Produced Stage Discharge Relationships Numbers

Years	Derived rating curve equations at gauging stations :					
	El-Mataana Km 174.700	Luxor Km 223.800	Shanhoria Km 245.000	Sheikhiya Km 264.900	Qena Km 286.750	Deshna Km 316.600
1962	Eq. No. (1)	Eq. No. (11)	Eq. No. (21)	Eq. No. (31)	Eq. No. (41)	-
1963	Eq. No. (2)	Eq. No. (12)	Eq. No. (22)	Eq. No. (32)	Eq. No. (42)	Eq. No. (52)
1979	Eq. No. (3)	-	Eq. No. (23)	Eq. No. (33)	Eq. No. (43)	Eq. No. (53)
1980	Eq. No. (4)	-	Eq. No. (24)	Eq. No. (34)	Eq. No. (44)	Eq. No. (54)
1989	Eq. No. (5)	Eq. No. (15)	Eq. No. (25)	Eq. No. (35)	Eq. No. (45)	Eq. No. (55)
1990	Eq. No. (6)	Eq. No. (16)	Eq. No. (26)	Eq. No. (36)	Eq. No. (46)	-
1999	-	Eq. No. (17)	Eq. No. (27)	Eq. No. (37)	Eq. No. (47)	-
2000	-	Eq. No. (18)	Eq. No. (28)	Eq. No. (38)	Eq. No. (48)	-
2009	-	Eq. No. (19)	Eq. No. (29)	Eq. No. (39)	Eq. No. (49)	-
2010	-	Eq. No. (20)	Eq. No. (30)	Eq. No. (40)	Eq. No. (50)	-

To guarantee the validity of the generated equations, the coefficient of determination (R^2) - which represents the percent of the data that closest to the line of best fit – were determined. The best mathematical relationship form was determined through fitting regression analysis for all sites and years as listed in Tables (8 and 9). This revealed that the produced regression equations to determine the corresponding water surface levels are mainly of second degree with a maximum and minimum coefficient of determination (R^2) equale to 0.999 and 0.890 respectively.

Table 8: Regression Results for the Four Upstream Gauge Stations

No.	Station and year		Eq. No.	Rating curve equations	R^2	W.S.L. (m)**
1	El-Mataana	1962	1	WSL= -6.5403 E-6 Q^2 + 0.01729Q + 71.1389	0.981	(74.34)
2		1963	2	WSL= -9.7766 E-6 Q^2 + 0.02006Q + 70.5704	0.993	(74.19)
3		1979	3	WSL= -1.9464 E-5 Q^2 + 0.02461Q + 69.9194	0.997	(74.06)
4		1980	4	WSL= 4.5473 E-6 Q^2 + 0.01709Q + 70.4206	0.999	(74.02)
5		1989	5	WSL= 0.9548 E-6 Q^2 + 0.01972Q + 70.2735	0.999	(74.26)
6		1990	6	WSL= -8.4180 E-6 Q^2 + 0.02194Q + 70.1307	0.995	(74.18)
7	Luxor	1962	11	WSL= -1.2274 E-5 Q^2 + 0.02108Q + 67.8228	0.981	(71.55)
8		1963	12	WSL= -8.5615 E-6 Q^2 + 0.01816Q + 68.0602	0.996	(71.35)
9		1989	15	WSL= 6.5563 E-6 Q^2 + 0.01787Q + 67.9041	0.998	(71.74)
10		1990	16	WSL= -7.6560 E-6 Q^2 + 0.02095Q + 67.7294	0.995	(71.61)
11		1999	17	WSL= 5.0072 E-6 Q^2 + 0.01846Q + 67.7591	0.996	(71.65)
12		2000	18	WSL= -1.3623 E-6 Q^2 + 0.02059Q + 67.5936	0.998	(71.66)
13		2009	19	WSL= 7.1804 E-6 Q^2 + 0.02028Q + 67.6783	0.982	(72.02)
14		2010	20	WSL= -2.7960 E-5 Q^2 + 0.03115Q + 67.1164	0.975	(72.23)
15	El--Shanhoria	1962	21	WSL= 5.5919 E-5 Q^2+ 0.0014 Q + 67.8999	0.932	(70.41)
16		1963	22	WSL= -6.6226 E-6 Q^2 + 0.01931Q + 66.7443	0.988	(70.34)
17		1979	23	WSL= -3.9203 E-5 Q^2+ 0.02988Q + 65.8830	0.984	(70.29)
18		1980	24	WSL= -1.2298 E-5 Q^2 + 0.02108Q + 66.5062	0.991	(70.23)
19		1989	25	WSL= 5.3911 E-6 Q^2 + 0.01672Q + 66.8134	0.987	(70.37)
20		1990	26	WSL= 3.0210 E-5 Q^2 + 0.00855Q + 67.3886	0.990	(70.31)
21		1999	27	WSL= 1.4193 E-5 Q^2 + 0.01433Q + 67.1163	0.978	(70.55)
22		2000	28	WSL= 1.4700 E-5 Q^2 + 0.01435Q + 67.0973	0.987	(70.56)
23		2009	29	WSL= 1.3482 E-5 Q^2 + 0.01586Q + 67.0424	0.978	(70.75)
24		2010	30	WSL= -1.1797 E-6 Q^2 + 0.02005Q + 66.7471	0.978	(70.71)
25	El-Sheikhiya	1962	31	WSL = -1.3021 E-6 Q^2 + 0.0165 Q+ 66.2239	0.934	(69.47)
26		1963	32	WSL= -1.1510 E-5 Q^2 + 0.01998Q + 66.1022	0.981	(69.64)
27		1979	33	WSL= -2.5112 E-5 Q^2 + 0.02523Q + 65.5512	0.982	(69.59)
28		1980	34	WSL= -5.8651 E-6 Q^2 + 0.01914Q + 66.0227	0.990	(69.62)
29		1989	35	WSL= 1.1310 E-5 Q^2 + 0.01413Q + 66.3676	0.990	(69.65)
30		1990	36	WSL= 8.2373 E-6 Q^2 + 0.01450Q + 66.4658	0.972	(69.70)
31		1999	37	WSL= -0.2199 E-6 Q^2 + 0.01936Q + 66.0687	0.980	(69.93)
32		2000	38	WSL= 0.8271 E-6 Q^2+ 0.019076Q + 66.0869	0.992	(69.94)
33		2009	39	WSL= 9.450 E-6 Q^2 + 0.01711Q + 66.3448	0.970	(70.14)
34		2010	40	WSL= -5.167 E-6 Q^2+ 0.02119Q + 66.0869	0.975	(70.12)

Where:
WSL (W.S.L.) is the water surface level (m)
Q is the passing flow discharge (million m^3/day)
R^2 is the coefficient of determination
$(m)^{**}$ is the water surface levels coresponding to the "HAD" release of 200 million m^3/day

Table (9): Regression Results for the Two Downstream Gauge Stations

No.	Station and year		Eq. No.	Rating curve equations	R^2	W.S.L. (m)**
35	Qena	1962	41	WSL= -1.250 E-5 Q^2 + 0.02014Q + 64.6986	0.975	(68.23)
36		1963	42	WSL= -1.306 E-5 Q^2 + 0.02008Q + 64.6704	0.988	(68.16)
37		1979	43	WSL= -1.419 E-5 Q^2 + 0.01968Q + 64.8324	0.972	(68.20)
38		1980	44	WSL= 5.497 E-6 Q^2 + 0.01326Q + 65.3655	0.980	(68.24)
39		1989	45	WSL= 1.111 E-6 Q^2 + 0.01538Q + 65.1864	0.986	(68.31)
40		1990	46	WSL=1.536 E-5 Q^2 + 0.01085Q + 65.5182	0.991	(68.30)
41		1999	47	WSL= 1.397 E-5 Q^2 + 0.01255Q + 65.4228	0.989	(68.49)
42		2000	48	WSL= 1.545 E-5 Q^2 + 0.01220Q + 65.4935	0.995	(68.55)
43		2009	49	WSL= 1.248 E-5 Q^2 + 0.01223Q + 65.7197	0.974	(68.66)
44		2010	50	WSL= 5.374 E-6 Q^2+ 0.01408Q + 65.6226	0.956	(68.65)
45	Deshna	1963	52	WSL = -2.7652 E-6 Q^2 + 0.0109Q + 64.6101	0.992	(66.68)
46		1979	53	WSL=0.326 E-6 Q^2 + 0.0112Q + 64.5916	0.940	(66.85)
47		1980	54	WSL= -8.9884 E-6 Q^2 + 0.0138Q + 64.4956	0.931	(66.89)
48		1989	55	WSL = -4.2878 E-6 Q^2 + 0.0097 Q + 64.8069	0.890	(66.58)

Using each of the deduced regression equations, the dependent variable of the water surface level at passing 200 millions m^3/day flow discharge was predicted at each gauge station and adopted year as listed in Tables (8 and 9). Table (7) did not contain the four equations numbers (from 7 to 10) for El-Mataana gauge station, the two equations numbers (13 and 14) for Luxor gauge station and six equations numbers (51, 56, 57, 58, 59 and 60) for Deshna gauge station which is due to the unavailability of daily water surface levels data at these locations.

5. ANALYSIS OF THE ACHIEVED RESULTS

The average water surface level at passing 200 millions m^3/day flow discharge in Tables (8 and 9) were utilized to work out the average corresponding values for every two successive years at the 6 gauge stations as listed in Table (10). In this Table the mean value of water surface level during the successive years 1962 and 1963 at each gauge station was assigned as the condition before "HAD" construction. While the mean values for each two other successive years at each of the used gauge stations were worked out to demonstrate the water surface level after "HAD" construction up to year 2010. Therefore, considering that the mean values of water surface level at each gauge station before "HAD" construction as the reference line for the expected variations after "HAD" construction, the difference in the calculated average water surface level with respect to the reference level at each gauge site was determined as listed in Table (10). In this Table, the negative and positive signs signify lower and higher water surface levels with respect to the condition before "HAD" construction. This means that the increase in water surface level can be interpreted as an indicator of sedimentation and could be the result of one or more reasons such as general sedimentation, possible external source of sediment supply by wind and/or flash flood flows, bank erosion or change in channel roughness. While the decrease in water surface level can be utilized as an indicator of degradation and could be the result of one or more reasons such as general degradation, massive bank failure and increase in river width or change in channel roughness.

Table 10: Variation in Water Surface Level Calculations

No.	Gauge station and year	Average W.S.L. of each two successive years (m)	Difference in W.S.L. (m)
1	El-Mataana (1962 & 1963)	(74.265)	0.00
2	El-Mataana (1979 & 1980)	(74.040)	- 0.225
3	El-Mataana (1989 & 1990)	(74.220)	- 0.045
4	El-Mataana (1999 & 2000)	No DATA	No DATA
5	El-Mataana (2009 & 2010)	No DATA	No DATA
6	Luxor (1962 & 1963)	(71.450)	0.00
7	Luxor (1979 & 1980)	No DATA	No DATA
8	Luxor (1989 & 1990)	(71.675)	+ 0.225
9	Luxor (1999 & 2000)	(71.655)	+ 0.205
10	Luxor (2009 & 2010)	(72.125)	+ 0.675
11	El-Shanhoria (1962 & 1963)	(70.375)	0.00
12	El-Shanhoria (1979 & 1980)	(70.260)	- 0.115
13	El-Shanhoria (1989 & 1990)	(70.340)	- 0.035
14	El-Shanhoria (1999 & 2000)	(70.555)	+ 0.180
15	El-Shanhoria (2009 & 2010)	(70.730)	+ 0.355
16	El-Sheikhiya (1962 & 1963)	(69.555)	0.00
17	El-Sheikhiya (1979 & 1980)	(69.605)	+ 0.050
18	El-Sheikhiya (1989 & 1990)	(69.675)	+ 0.120
19	El-Sheikhiya (1999 & 2000)	(69.935)	+ 0.380
20	El-Sheikhiya (2009 & 2010)	(70.130)	+ 0.575
21	Qena (1962 & 1963)	(68.195)	0.00
22	Qena (1979 & 1980)	(68.220)	+ 0.025
23	Qena (1989 & 1990)	(68.305)	+ 0.110
24	Qena (1999 & 2000)	(68.520)	+ 0.325
25	Qena (2009 & 2010)	(68.655)	+ 0.460
26	Deshna (1962 & 1963)	(66.680)	0.00
27	Deshna (1979 & 1980)	(66.870)	+ 0.190
28	Deshna (1989 & 1990)	(66.580)	- 0.100
29	Deshna (1999 & 2000)	No DATA	No DATA
30	Deshna (2009 & 2010)	No DATA	No DATA

The attained results in Table (10) were utilized to demonstrate the occurred variations in bed and water surface levels along the studied reach through investigated time between years 1962 and 2010. This was carried out with respect to the location along the river reach and since "HAD" construction till now according to the following two aspects:

1. The mean value of water surface level - at passing 200 millions m3/day at each of the studied gauge stations before "HAD" construction – was considered as the reference line. Then the determined mean values for each two other successive years at each of the used gauge stations would be plotted as function of time to demonstrate the variation in river bed and water surface level at those years after "HAD" construction till year 2010. This – in other words – can demonstrate the developed variation in water surface levels as indicators of degradation or sedimentation along the second river reach after "HAD" construction till year 2010.
2. Considering mean values of bed and water surface levels before "HAD" construction - at each installed gauge station – as reference level point, variation of degradation or sedimentation along the reach (i.e. as function of distance) after "HAD" construction can be independently worked out at each gauge station location with respect to the applied years up to 2010.

The listed results in Table (10) were utilized to demonstrate various variations in bed and water surface levels with respect to each gauge site and its location which can be demonstrated as follows:

5.1. Water Surface Level Variations

The reached calculations in Table (10) were utilized to demonstrate the average water surface level variations as function of time at each gauge stations as shown in Figure (9) and listed in Table (11).

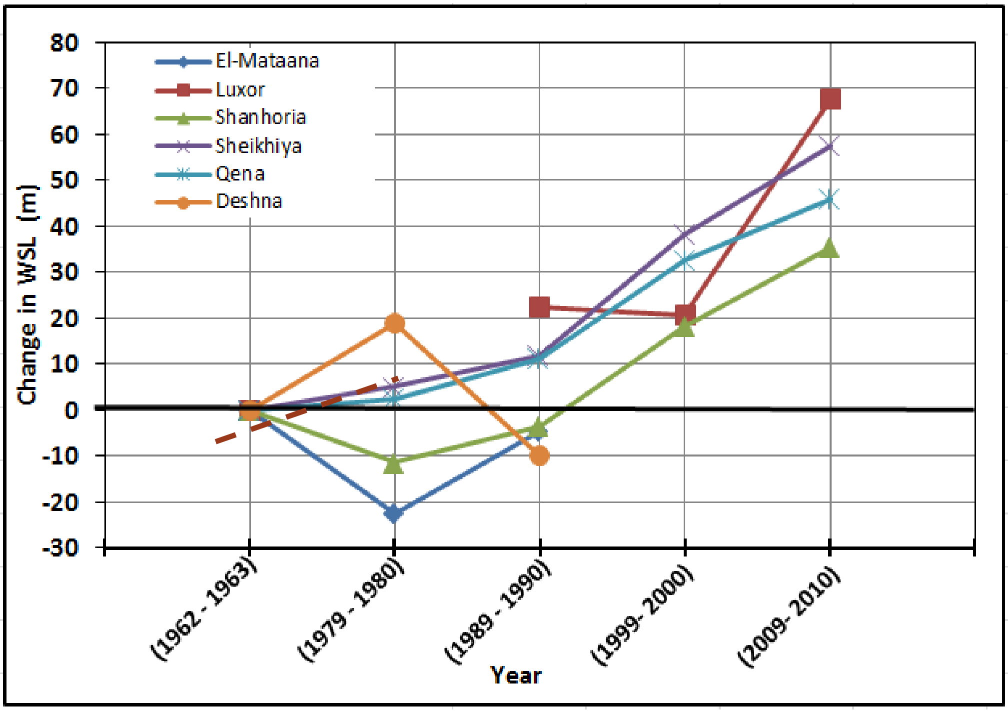


Figure 9: Water Surface Level Variations at Different Gauge Stations

Table 11: Average Water Surface Level Variations along the Reach

Years	Average water surface level variation (cm) at gauging stations :					
	El-Mataana Km 174.700	Luxor Km 223.800	Shanhoria Km 245.000	Sheikhiya Km 264.900	Qena Km 286.750	Deshna Km 316.600
(1962 & 1963)	0.00	0.00	0.00	0.00	0.00	0.00
(1979 & 1980)	- 22.5	NA	- 11.5	+ 5.0	+ 2.5	+19.0
(1989 & 1990)	- 4.5	+ 22.5	- 3.50	+ 12.0	+ 11.0	- 10.0
(1999 & 2000)	NA	+ 20.5	+ 18.0	+ 38.0	+ 32.5	NA
(2009 & 2010)	NA	+ 67.5	+ 35.5	+ 57.5	+ 46.0	NA

[NA] in the above Table is related to unavailable water surface level data at El-Mataana, Luxor and Deshna gauge stations.

Figure (9) and Table (11) signify that only the upstream parts of the study reach at El-Mataana and El – Shanhoria gauge stations were subjected to water surface level decline and possible degradation which took place since "HAD" construction till year 1990. Bearing in mind the unavailable recorded data for Luxor station in years 1979 and 1980, one could expect that Luxor site could be also subjected to water surface level decrease and possible degradation due to its location at 49.100 km distance downstream of El-Mataana station and 21.200 km distance upstream of El – Shanhoria gauge station. The average decrease in water surface level reached its maximum value of 0.225 m and 0.115 m at El-Mataana and El-Shanhoria gauge stations respectively at years 1979 and 1980 as listed in Table (11) and shown in Figure (9). The recorded decreases were significantly reduced to 0.045 and 0.035 m at El-Mataana and El-Shanhoria gauge stations respectively at years 1989 and 1990. On the other hand, the performance at Luxor gauge station showed increase in water surface level and possible deposition of 0.225 m at years 1989 and 1990 with respect to the condition before "HAD" construction.

Also Figure (9) indicates that the recorded water surface level declines through the upstream gauge stations then turned over and progressively recovered to increase in water surface levels and possible sedimentation which reached to a maximum value of 0.675 m and 0.355 m at Luxor and El–Shanhoria stations respectively in years 2009 - 2010. This in other words means that the water surface level at the upstream parts have been subjected to a limited decrease then increase and possible sedimentation starting from years 1989 – 1990 till years 2009 - 2010. On the other hand, Figure (9) and Table (11) show that the rest of the studied river reach from El-Shiekheya to Qena gauge stations were not subject to any decrease in water surface levels and possible degradation since "HAD" construction till year 2010. Moreover, the monitored increase in water surface levels and possible sedimentation within such reach in year 2010 - as listed in Table (11) and shown in Figure (9) - reached a maximum value of 0.675, 0.355, 0.575 and 0.460 m at Luxor, El-Shanhoria, El-Sheikheya and Qena gauge stations respectively with respect to the condition before "HAD" construction. While the condition at each of El-Mataana and Deshna gauge stations could not be definitely defined due to unavailable recorded data at the two sites.

Also Table (11) and Figure (9) illustrate some unexpected variations in the attained results at Luxor and Deshna gauge stations. The reached variations at Deshna gauge station – in spite of the unavailable daily records of water surface level from year 1990 to year 2010 – revealed 0.19 m increase in water surface level in years 1979 and 1980 which was followed by 0.10 m decrease in years 1989 and 1990. Such trend disagrees with the achieved results at the other sites and could be due to the gauge station location which is situated within the backwater curve upstream the new Naga-Hammady barrages during passing low flow discharges as indicated in Figure (2). Also the unavailable water surface level data at Luxor gauge station from year 1989 till year 2010 led to indecisive conclusions. This because the calculated average water surface levels at this site - as listed in Table (11) and shown in Figure (9) – declined from 0.225 m in year 1989 and 1990 to 0.205 m in years 1999 and 2000 then sharply increased to 0.675 m in years 2009 and 2010. Examining such decrease in water surface levels during years 1999 and 2000 proved that the dredging activities for navigation are not the cause.

Therefore, to justify the reached results at Luxor gauge station, an endorsement study was carried out. The daily records for the passing discharges and the corresponding water surface levels during the five years 1994, 1998, 2001, 2003 and 2006 were embloyed as endorsement information. Stage discharge rating curves at Luxor gauge station for the added five years were then deduced as listed in Table (12). Those data were then merged with the previously worked out calculations in Table (10) to produce the average corresponding water surface level at Luxor gauge station for various years as listed in Table (13).

Table 12: Regression Results for the Endorsement Study

year	Eq. No.	Rating Curve Equations	R^2	W.S.L. (m)**
1994	16.1	$WSL = 1.3071\ E\text{-}5\ Q^2 + 0.01451\ Q + 68.0795$	0.977	(71.50)
1998	16.2	$WSL = -2.0012\ E\text{-}5\ Q^2 + 0.02671\ Q + 67.0571$	0.995	(71.60)
2001	18.1	$WSL = -0.9201E\text{-}5\ Q^2 + 0.02453\ Q + 67.2279$	0.998	(71.77)
2003	18.2	$WSL = -1.1941E\text{-}5\ Q^2 + 0.02460\ Q + 67.2658$	0.948	(71.71)
2006	18.3	$WSL = -1.4291E\text{-}5\ Q^2 + 0.02536\ Q + 67.3831$	0.974	(71.88)

Table 13: Regression Results for Luxor Gauge Station

No.	Equation No.	Year	W.S.L. Variation (cm)
1	Eqs. No. (11& 12)	(1962 & 1963)	0.00
2	Eqs. No. (13& 14)	(1979 & 1980)	NA
3	Eqs. No. (15& 16)	(1989 & 1990)	+ 22.5
4	Eq. No. (16.1)	1994	+ 5.0
5	Eq. No. (16.2)	1998	+ 15.0
6	Eqs. No. (17& 18)	(1999 & 2000)	+ 20.5
7	Eq. No. (18.1)	2001	+ 32.0
8	Eq. No. (18.2)	2003	+ 26.0
9	Eq. No. (18.3)	2006	+ 33.0
10	Eqs. No. (19& 20)	(2009 & 2010)	+ 67.5

The reached calculations in Table (10) were merged with the endorsement study for the variation in water surface levels at Luxor gauge station that listed in Table (12) and Figure (9) to produce the total variations at Luxor gauge station as listed in Table (13) and shown in Figure (10).

The attained results at Luxor gauge station – as shown in Figure (10) – showed nearly similar trend to the concluded water surface level condition at El – Mataana and El - Shanhuria gauge stations which are situated upstream and downstream of Luxor site respectively. Such clear tendency at Luxor gauge station could not be precisely demonstrated due to unavailable and limited daily recorded data at the site before year 1989. This led to expect that Luxor gauge station could be also subjected to water surface level decrease and possible degradation due to its location at 49.100 km distance downstream of El-Mataana station and 21.200 km distance upstream of El – Shanhoria gauge station.

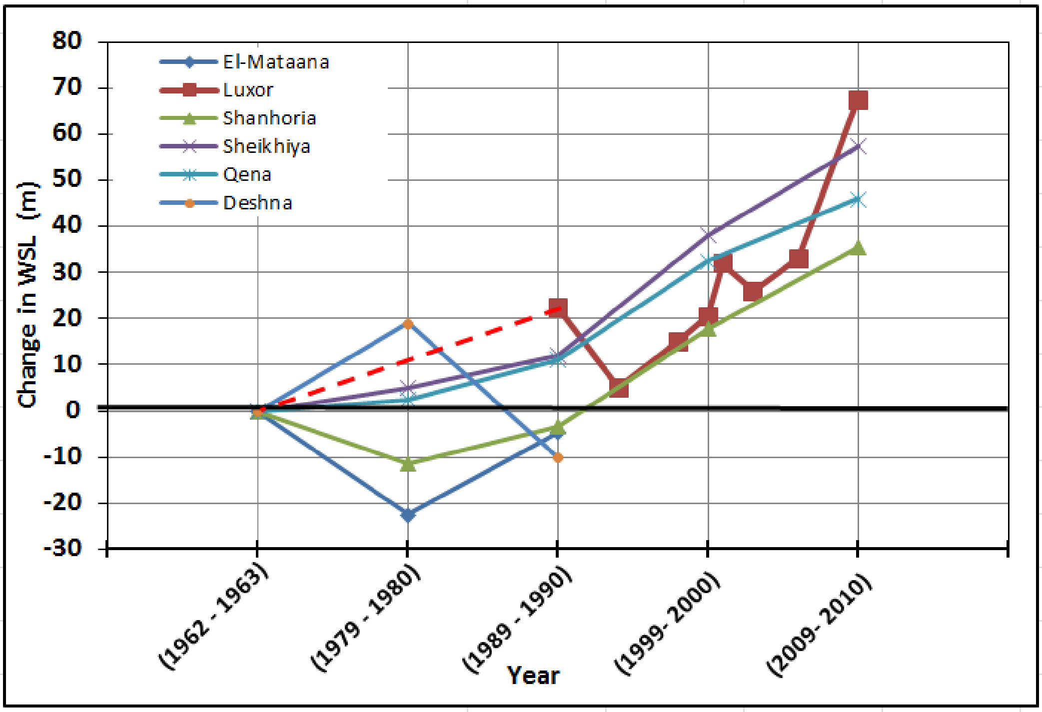


Figure 10: Combined Results after the Endorsement Study at Luxor Gauge Station

5.2. Longitudinal Surface Profiles

The reached calculations in Table (10) were also utilized to demonstrate the variations in water surface levels at each gauge stations for all years as listed in Table (14) and shown in Figure (11). While Figure (12) demonstrates the variation in water surface levels as an indicator for sedimentation and degradation developments with respect to time and space as a vertical coordinate along the studied reach.

Table 14: Longitudinal Water Surface Profile Developments

Years	Variation in W.S.L. at different gauges (m)					
	El-Mataana Km 174.700	Luxor Km 223.800	Shanhoria Km 245.000	Sheikhiya Km 264.900	Qena Km 286.750	Deshna Km 316.600
(1962 & 1963)	(74.265)	(71.450)	(70.375)	(69.555)	(68.195)	(66.680)
(1979 & 1980)	(74.040)	NA	(70.260)	(69.605)	(68.220)	(66.870)
(1989 & 1990)	(74.220)	(71.675)	(70.340)	(69.675)	(68.305)	(66.580)
(1999 &2000)	NA	(71.655)	(70.555)	(69.935)	(68.520)	NA
(2009 & 2010)	NA	(72.125)	(70.730)	(70.130)	(68.655)	NA

[NA] in the above Table (14) is related to unavailable water surface data records at El-Mataana, Luxor, and Deshna gauge stations.

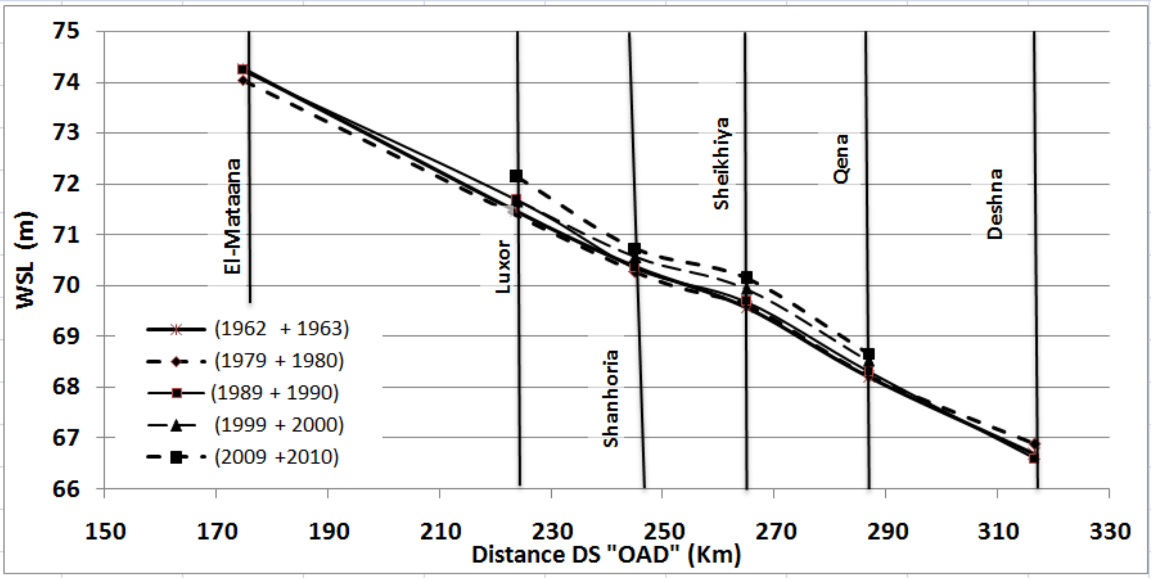


Figure 11: Water Surface Profiles Development along the Study Reach

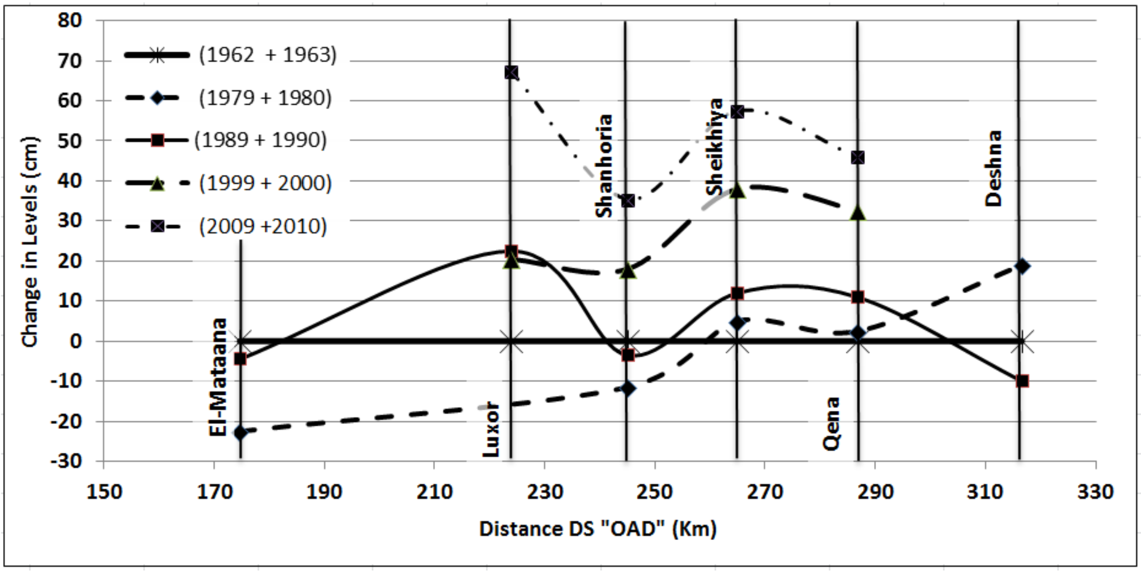


Figure 12: Variation of Water Surface Levels along the Study Reach

The achieved results in Figure (11) for water surface profiles development along the study reach illustrate some increase and possible sedimentation after "HAD" construction till year 2010. This is very clear especially through about 62.950 km of the second river reach between Luxor and Qena gauge stations. This revealed an increase in water surface level which reached a maximum value of 0.675, 0.355, 0.575 and 0.460 m at Luxor, El-Shanhoria, El-Sheikheya and Qena gauge stations respectively in year 2010 with respect to the condition before "HAD" construction. While the condition at each of El-Mataana and Deshna gauge stations could not be defined due to unavailable recorded data at the two sites. This increase in water surface level can be utilized as an indicator for sedimentation and could be the result of one or more reasons such as general sedimentation, possible external source of sediment supply by wind and/or flash flood flows, bank erosion or change in channel roughness. Therefore, considering that the increase in water surface level is possibly due to general sedimentation which results in an average value of 0.516 m along a 141.900 km reach length between El-Mataana and Deshna gauge stations, and with an average width for the second river reach of 671.43 m (Wail, A.F. 2012), the total deposited materials on the bed along the represented river reach would be worked out as 49.16 million m^3. This led to conclude that the second River Nile reach is being subjected after "HAD" construction to sedimentation and not degradation as expected from several earlier studies.

The above results in Figures (11 and 12) also emphasize the anticipated variations in water surface slopes along the monitored gauge stations sites. Considering the condition before "HAD" construction which is represented by years 1962 and 1963, the average water surface level at El-Mataana and Deshna were (74.265) m and

(68.195) m respectively. As the distance between the two mentioned sites is 141.900 km, the corresponding longitudinal water surface slope would be 5.35 cm/km. Subsequently, considering the condition after "HAD" construction in years 1980 then 1990, the water surface levels at El-Mataana and Deshna were (74.040) m and (66.870) m in year 1980 then (74.220) m and (66.580) m in year 1990 respectively. The corresponding longitudinal water surface slope can be then worked out as 5.05 cm/km then 5.38 cm/km for the same distance during years 1980 and 1990 respectively. Moreover, to avoid any possible effect due to the location of Deshna gauge station with respect to the backwater curve upstream the new Naga - Hammady barrages, the longitudinal water surface slope between El – Mataana and Qena of 112.050 km distance was worked out for various years. The results for the condition before and after "HAD" construction till year 2010 revealed such narrow differences with ranges between maximum and minimum values of 5.51 cm/km and 4.98 cm/km respectively.

Therefore, as the similar study for the first river reach revealed an apparent reduction in longitudinal water surface slope from 5.84 cm/km in year 1962 to 4.05 cm/km in year 2000, this led to conclude that unlike the concluded results for the first reach, the second one was not subjected to significant or considerable variations in the longitudinal water surface slope after "HAD" construction. This seems to be due to the location of the first reach with respect to "OAD" which led to the establishment of the long term morphology changes – due to "HAD" construction – along the first river reach before the second one. This led to the expectation that the long term morphological variation along the second Nile River reach is still under progressing and not totally established its final condition due to "HAD" construction.

6. CONCLUSIONS

I. Numerous hydraulics and morphological studies to justify and quantify the side effects of "HAD" constructions - concerning river bed degradation and sedimentation – were reviewed and summarized which anticipated general degradation downstream of the main barrages. However, so far no results for specific time and locations have been materialized along the second Nile River reach.

II. To monitor such variations in water surface levels and consequently possible sedimentation or degradation through the second Nile River reach after "HAD" construction, the daily recorded observations for water surface levels and the corresponding flow discharges along the study reach were employed to produce stage discharge rating curves as the best and accurate technique to fulfill such purpose.

III. Some of the daily essential records for conducting the planed research were unavailable and difficult to be attained especially those before year 1985. Moreover, some collected record sheets were incomplete and lacked of entire months which reached 0.90% and 24.9% of the daily flow discharge and water surface level respectively.

IV. El-Mataana and El – Shanhoria gauge stations were the only sites subjected to water surface level decline and possible degradation after "HAD" construction which reached its maximum value of 0.225 m and 0.115 m at El-Mataana and El-Shanhoria gauge stations respectively at years 1979 and 1980. The decrease was turned over and recovered to increase in water surface level and possible sedimentation at year 1992 for El-Shanhoria gauge station which reached 0.18 m and 0.355 m in years 2000 and 2010 respectively.

V. The unavailable recorded data for Luxor station in years 1979 and 1980 - which is located between El-Mataana and El – Shanhoria gauge stations - led to expect that Luxor site could be also subjected to water surface level decrease and possible degradation after "HAD" construction. Later, the results showed an increase in water surface level and possible deposition of 0.225 m at years 1989 and 1990 with respect to the condition before "HAD" construction.

VI. The downstream part of the study reach from El-Sheikheya to Qena gauge stations was not subject to any decrease in water surface levels since "HAD" construction till year 2010. The monitored increase in water surface levels within such reach reached a maximum value of 0.575 m and 0.46 m at the two sites respectively in year 2010 with respect to the condition before "HAD" construction.

VII. The monitored increase in water surface levels and possible sedimentation within the second reach in year 2010 revealed a maximum value of 0.675, 0.355, 0.575 and 0.460 m at Luxor, El-Shanhoria, El-Sheikheya and Qena gauge stations respectively with respect to the condition before "HAD" construction. While the condition at each of El-Mataana and Deshna gauge stations could not be defined due to unavailable recorded data at the two sites.

VIII. The conducted endorsement study at Luxor gauge station proved nearly similar trend to that concluded at El – Mataana and El - Shanhuria gauge stations which are situated upstream and downstream of Luxor site respectively. Such clear tendency at Luxor site could not precisely demonstrated due to unavailable and limited daily recorded data before year 1989.

IX. Considering that the increase in water surface level is due to general sedimentation of 0.516 m as average value along a 141.900 km reach length between El-Mataana and Deshna gauge stations, and an average width for the second river reach of 671.43 m, the total deposited materials on the bed along the represented river reach would be 49.16 million m3. This led to conclude that the second River Nile reach is being subjected after "HAD" construction to sedimentation and not degradation as expected from several studies.

X. The attained results for the condition before and after "HAD" construction revealed narrow differences for the variation in longitudinal water surface slope which ranges between maximum and minimum values of 5.51 cm/km and 4.98 cm/km respectively. Therefore, unlike the concluded results for the first reach, the second reach was not subject to significant or considerable variations in the longitudinal water surface slope after "HAD" construction.

XI. This led to conclude that the second River Nile reach is being subjected after "HAD" construction to increase in water surface level which can be utilized as an indicator of sedimentation and could be the result of one or more reasons such as general sedimentation, possible external source of sediment supply by wind and/or flash flood flows, bank erosion or change in channel roughness.

XII. Providing the historical hydrological information for water surface levels and passing discharges at different gauge stations and hydraulics structures are very essential and fundamental to conduct such research.

7. RECOMMENDATIONS

I. Digitalizing the historical records for daily flow discharges downstream "OAD" and other major barrages as well as the corresponding water surface levels at different gauge stations is very essential. Such effort is in progress but limited to some of the daily records that took place after year 1985. However, extending digitizing efforts to year 1960 which is former to "HAD" construction would be compulsory and essential.

II. Providing the necessary data for conducting Nile River hydraulics and morphological investigations should be more straightforward and effortless especially for the research staff within and outside of the Ministry of Water Resources and Irrigation.

III. The resulted increase in water surface level through the second river reach can be utilized as an indicator of sedimentation which consequently could be the result of one or more reasons such as general sedimentation, possible external source of sediment supply by wind and/or flash flood flows, bank erosion or change in channel roughness. Therefore, such completing study would be carried out to analyze the real cause for the changes in water surface level.

IV. Corresponding studies should be carried out to investigate the impact of "HAD" construction on the third and fourth Nile River reaches which could be achieved similar to the applied technique in the present study.

V. The recorded sedimentation downstream "OAD" after "HAD" construction – which is against all the previous studies – should be investigated in more details. Such study can be carried out by focusing on the variation in river bed and water surface levels at only El-Mataana gauge station site for a long period and successive years before and after "HAD" construction.

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REFERENCES

1. Ahmed, A.F. and Wail, A.F., 2014, *"Long-Term Morphological Changes in the Nile River since High Aswan Dam Construction to Year 2010",* Nile Water Science & Engineering Journal, The Nile Basin Capacity Building Network for River Engineering, Delta Barrages, Egypt, Volume No. 7, Issue No. 1, December 2014.
2. El-Ansary, A.E., 1976, *"Evaluation of the Future Degradation in the Nile River Channel in Egypt",* Faculty of Engineering, Alexandria University, Alexandria, Egypt, Vol. XV: 1-1976.

3. El-Mottasem, M., (1998), *"River Nile Characteristics Pre-and Post the Aswan High Dam (AHD) and its Protection and Development"*, International Conference on Coping with Water Scarcity, Herghada City, Red Sea, Egypt, August 26- 28, 1998.
4. El-Mottasem, M., 2001, *"Protection and Development of the River Nile – An Overview – Keynote Address"*, the Eighth International Symposium on River Sedimentation, Cairo, Egypt, 3-5 November, 2001.
5. Gasser, M.M., Hassan, W.M.A. and Helmy, M.S., 1978, *"State of the Nile River between 1964 and 1977"*, Hydraulics and Sediment Research Institute, Ministry of Irrigation, Delta Barrages.
6. Ismail, H.M., 1990, *"State of the Nile after the High Dam"*, National Seminar on Physical Response of the River Nile to Intervention, Cairo, November, 1990.
7. Janson, P. Ph., Bendegom, L. Van, Berg, J. Van den, de Vries, M., and Zanen, A., Eds., (1979), "*Principals of River Engineering, The Non-Tidal Alluvial River"*, Pitman Publishing Ltd, London, England.
8. Richardson, E.V. and Clyma, W., 1979, *"Egypt's High Aswan Dam Progress of Retro Gradation"*, Egypt Water Use and Management Project "EWUP", Colorado State University, Fort Collins, Colorado, USA.
9. Sloff, C.J., Ogink, H.J.M. and Janssen, A.P.A.M., 2004, *"SOBEK - Nile schematization, calibration and verification"*, Technical Report, Work Package 1.6, WL| Delft Hydraulics, Report No. Q3181.
10. Wail, A.F., 2012, *"Effect of Barrage Components on Navigation Waterway"*, A Thesis Submitted for the Fulfillment of the Requirements for the Ph.D. Degree in Civil Engineering, Benha University, Shoubra Faculty of Engineering, 2012

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