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HYDRODYNAMIC STUDY OF NILE RIVER USING 1D MODEL

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ملخص البحث

أجريت العديد من الدراسات للتنبؤ بمناسيب مياه نهر النيل خلف سد أسوان، ولكن حتى الآن لم يتم بناء نموذج هيدروليكي موحد لكامل مجرى النهر. لذلك تم عمل هذه الدراسة بهدف استكشاف الخصائص الهيدروليكية لنهر النيل عن طريق بناء نموذج هيدروليكي كامل للأحباس الأربعة من سد أسوان وحتى قناطر الدلتا .

تم استخدام الأرصاد اليومية للتصرفات ومناسيب المياه بالإضافة إلى خرائط الرفع المساحي التي أجريت للأحباس الأربعة في عام 2006 لبناء نموذج رياضي أحادي البعد باستخدام برنامج HEC-RAS .

تم عمل معايرة للنموذج الهيدروليكي إلى أن تم الوصول إلى أقصى اتفاق بين المناسيب الحقيقية والمناسيب الناتجة عن النموذج الهيدروليكي، وذلكفي مواسم الزراعة الثلاثة: أقصى الاحتياجات، الاحتياجات المتوسطة وأقل الاحتياجات وتشير نتيجة المعايرة إلى أن متوسط معاملات الخشونة (ماننج) للأحباس الأربعة كانت 0.029 و 0.029 و 0.028 و 0.033. وهذا يشير إلى أن الحبس الرابع من نهر النيل هو الأكثر تدهوراً والأقل كفاءة وهذا لأنه أكثر الأحباس تعرضاً للتدخلات البشرية.

ABSTRACT

Numerous studies to predict water surface profiles downstream the Old Aswan Dam "OAD" were extensively carried out. However, variation of water surface levels for the whole river downstream of "OAD" with time and location in one single model has not been fully explored. The study in hand was carried out to identify the occurred variations in water surface levels through the four reaches in the Nile valley from downstream of "OAD" to upstream of the Delta barrages.

The daily records of flow discharges and water surface levels in addition to the bathymetric survey along the four reaches for the year 2006 were utilized to build a one-dimensional mathematical model using HEC-RAS software, which was the most suitable to execute the longitudinal water surface profile.

The result revealed a good agreement between the deduced water surface and the observed water levels for all the high, average and low demand periods along the four reaches and indicated that the average Manning coefficients of the four reaches are 0.029, 0.029, 0.028 and 0.033 consequently. The achieved results concluded that the fourth Nile River reach is the roughest as it is the most reach vulnerable to human interventions, which affected its hydraulic efficiency.

Keywords: Nile River, 1D Model, HecRas, Hydraulic Study

INTRODUCTION

The general properties of the flow such as velocity and pressure gradients vary in longitudinal, transverse and normal directions (3- dimensional variation) as well as in the directions of their components. Thus, there are three methods of mathematical modeling according to spatial dimensions which are: one-dimensional, two-dimensional, and three-dimensional modeling. One dimensional model is efficient in simulating heavily controlled reaches with many hydraulic structures where a rapid assessment of water surface profile is required. Two-dimensional model is used where detailed flood plain hydraulics is important or while studying sediment or pollution transport. Three-dimensional modelling is not frequently used due to its high complexity and it is mainly used for very large projects to take advantage of its increased accuracy

Some prior modeling studies of the hydrodynamics of the Nile River were carried out including Krony (1992) who suggested that the Manning's coefficient range from 0.018 to 0.035 in the Nile River. In Krony study, the Manning's coefficient was taken as a linear function of flow depth in the numerical model, where the surface roughness decreases with increase the water depth depending on the ground cover and the density of vegetation.

Noha Kamal (2007) also investigated the effect of different releases on water levels and bank line of the **first** reach between Aswan and Esna Barrages and the fourth reach between Assiut and Delta Barrages by designing a computer model to compute the water surface profile for the study reach with the aid of GIS. She concluded that manning roughness coefficient average values for the first and fourth reaches were 0.038 and 0.02 respectively.

Elmoustafa and A. Moussa (2010) also built a Hydrodynamic 1D model using HEC-RAS for the **fourth** reach extending from Assiut Barrages to Delta Barrages to evaluate the Muskingum hydrologic model parameters for the reach and the calibration process showed an obvious matching between the modeled and the recorded water levels at the water level gagging stations for Manning's roughness coefficient equals to 0.033.

Dalia et al. (2012) conducted a morphological study of the Nile river **fourth** reach by building a one-dimensional mathematical model using GSTARS software. Results revealed that the average manning coefficients of this reach are as in the below table:

From Station	To Station	Manning (n)
545+000	634+000	0.031
634+000	657+000	0.028
657+000	720+000	0.02
720+000	895+000	0.025
895+000	948+000	0.015

Fathy et al. (2013) studied the effect of main barrages failure on the Nile Valley by simulating the river, the main regulators and main lateral off takes on combined SOBEK 1D-2D software package. Their model was calibrated utilizing measurements of water flows and levels of January 2010 depending on Manning's coefficient (n) as a calibration parameter. The estimated manning's coefficient was found to be 0.029, 0.027, 0.024, 0.028 for **first, second, third and fourth** reaches respectively.

Raslan (2013) also built a 2D model using CCHE2D software for a reach of 30 km downstream New Nagaa Hammadi Barrages (**third** reach) with the aim of Predicting morphological changes DS New Naga-Hammadi Barrage for extreme Nile flood flows and found that manning coefficient value of 0.015 best fits the current situation of the study reach.

Reham Elsayed et al. (2019) investigated the **first** reach extending from Aswan to Esna Barrages using 1D unsteady HEC-RAS hydrodynamic model with an intent to evaluate the existing navigational path and she concluded that after intensive calibration, a significant agreement was met between the observed and model-calculated water surface elevations using manning roughness n =0.025 and 0.015 for the banks and channel.

The study in hand was carried out to build a 1D hydrodynamic calibrated model and perform steady and unsteady flow simulation through the four reaches of the Nile River from downstream of "OAD" to upstream of the Delta barrages taking into consideration the lateral outflows and inflows of pump stations and drains. The calibration parameter of the model is Manning's roughness coefficient.

STUDY AREA

The Nile River flows in Egypt from south to the north passing through 9 governorates in upper and middle Egypt then it branches into Rosseta and Damietta branches at the Delta Barrages before it drains into the Mediterranean.

The Nile River from HAD to Delta Barrages is divided into four main reaches between each two barrages, First reach which extends between HAD and Esna Barrages for a distance of 167 km, second reach extends between Esna Barrages and Nagaa Hammadi Barrages for a distance of 192km, third reach extends from Nagaa Hammadi Barrages to Assiut Barrages for a distance of 186km and the fourth reach extends from Assiut Barrages to delta barrages for a distance of 409km.

In addition to the gravity diversion of the Nile water to the canals upstream each structure of the above mentioned, water is also diverted by more than 100 pumping stations distributed along the river.

The area selected for the current study encompasses the Nile River (Valley) from Aswan Dam to Delta Barrages with total length of 954km.

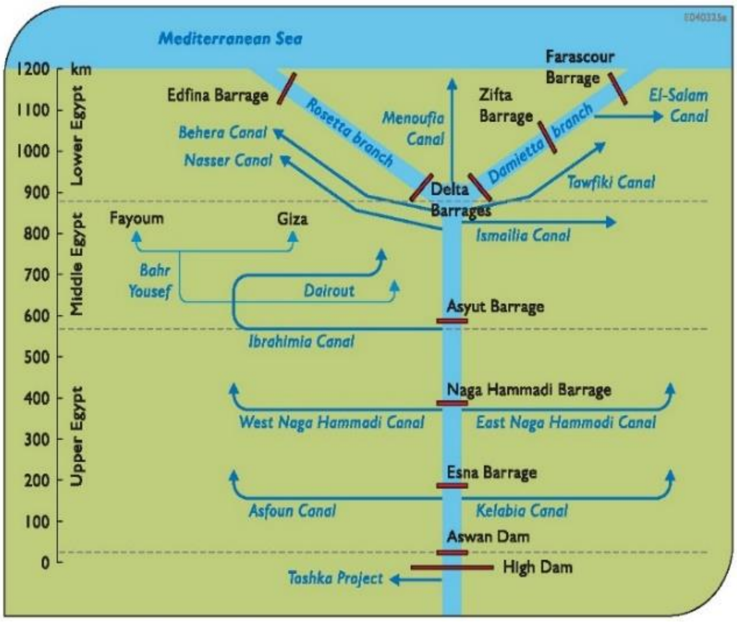


Figure 21: Major Hydraulic Structures along Nile River:

METHODOLOGY

In order to satisfy the objectives of the study in hand, many processes were held. The current research approach is described in brief in Figure 22.

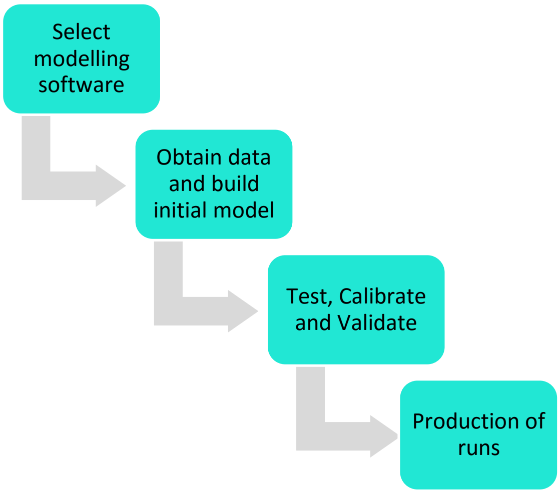


Figure 22: Research approach

Modeling software

HEC-RAS (River Analysis System) was developed by the U.S. Army Corps of Engineers, the Hydrologic Engineering Center; it's considered one of the most popular programs made for Hydraulic Analysis. It has been designed to perform one/two dimensional hydraulic calculations for a full network of natural and constructed channels. This software allows you to perform steady flow, unsteady flow calculations, sediment transport/mobile bed computations and water quality modeling.

Model Description

Considering a few simplifications, an attempt was made to create an accurate one-dimensional, unsteady flow model for the Nile River extending from downstream Aswan Dam till it reaches Delta Barrages. The flow model is analyzed with the aid of widely used modeling program, HEC-RAS. Based on the principle governing gradually varying flow, the flow model is derived from the Saint-Venant equations (Equations (1) & (2).

$$\frac{dA}{dt} + \frac{dQ}{dx} = 0 \qquad (1)$$

$$\frac{dQ}{dt} + \frac{d\left(\frac{Q^2}{A}\right)}{dx} + gA\frac{dH}{dx} + gA\left(S_0 - S_f\right) = 0 \qquad (2)$$

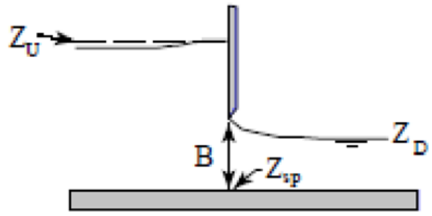
Where A = cross-sectional area normal to the flow; Q = discharge; g = acceleration due to gravity; H = elevation of the water surface above a specified datum, also called stage; S_o=bed slope;
S_f = energy slope; t = temporal coordinate and x = longitudinal coordinate.

Gate Simulation equations

Standard sluice gates in inline structures were used to simulate the main regulators on the Nile River i.e. Esna, Nagaa Hammadi and Assiut Barrages.
The sluice gate uses the orifice equations.
For free flow condition:

$$Q = CWB\sqrt{2gH} \quad (3)$$

for fully submerged condition (more than 80% submergence):



$$Q = C_{Sub}WB\sqrt{2gH_{sub}} \quad (4)$$

$$\text{Submergence ratio} = \frac{Z_D - Z_{sp}}{Z_U - Z_{sp}} \quad (5)$$

Where C is the sluice gate discharge coefficient, C_{sub} is the submerged orifice discharge coefficient, W is the crest length and B is the gate opening.
The head, H, is measured from the headwater energy level, Z_U, to the gate seat elevation, Z_{sp} while H_{sub} is the head differential between the headwater energy, Z_U, and the tailwater elevation, Z_D.

Gate Operation rule

In existing conditions, the gates of the main barrages are opened and closed occasionally to maintain a certain level upstream the structure with no matter of the flow passing by the gate.
The 'Time Series Gate Openings' option in HEC RAS fulfills our requirements in simulating the gates. It is very easy to use as it simply requires a gate opening height for each prescribed time interval over the entire model simulation period.
In the case of our study, the gate openings were roughly calculated prior to the run with the aid of the observed data collected including water flows, upstream water levels and invert levels of the structures as per equations (3) and (4).

Model assumptions

In order to create a big model such as Nile River hydraulic model that precisely represents the actual site conditions and is computationally efficient at the same time, many assumptions are taken into consideration depending on the variable that is targeted by the study and to what level of detail the model could be considered satisfactory.
In this study, the following assumptions are applicable including the assumptions of St. Venant Equations:

- Flow is one-dimensional.
- Inherent assumption of 1D finite difference river modeling is that flow velocities are perpendicular to the cross section.
- Hydrostatic pressure prevails and vertical accelerations are negligible.
- Streamline curvature is small.
- Bottom slope of the channel is small.
- Manning's equation is used to describe resistance effects.
- The fluid is incompressible.
- Channel boundaries are considered fixed and therefore not susceptible to erosion or deposition
- Meandering and local scouring are excluded

Inflow and Outflow Calculation

The flow entering the canals and the outflows from drains on the banks of the Nile river (Lateral structures) is calculated following the below discussed methodology:

1. Area Served was digitized for each canal, pump station and drain in the study area using satellite imagery (Google Earth) – Figure 3 shows a part of the digitized served area
2. Urban areas were then digitized and excluded from the served areas.
3. For calculating the canals flow, an average demand of 35 m^3/fed/day was assumed for the whole served area and the average flow was calculated in units of cubic meters per second, following the equation below:

$$Q=(A\times D)/(24*60*60) \qquad (6)$$

Where,

Q= Canal Flow (m^3/s)

A= Served Area (Fed)

D= Average demand (m^3/fed/day)

4. The drains flow is then assumed to be equal to 1/3 of the canals flow.

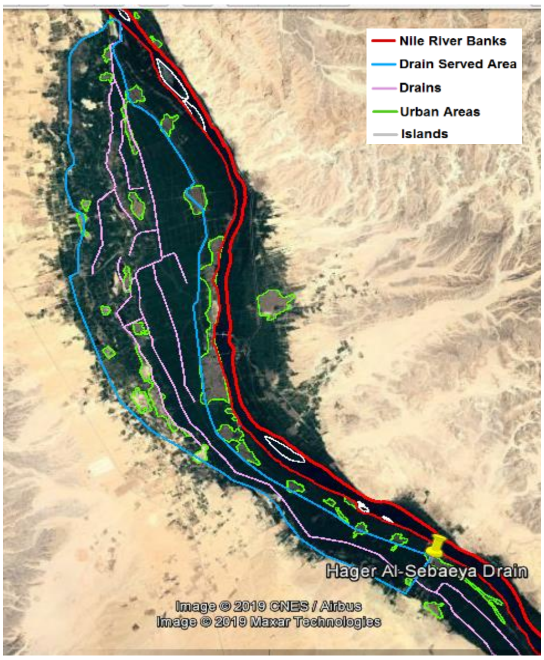


Figure 23: Sample of Digitized Served areas in The Nile Valley

By means of the above-mentioned criteria, the inflows and outflows of drains and canals from and to the Nile River is estimated

Model Building (Geometric Data Entry)

The first step in building the model using Hec-Ras software was entering the geometric data of the modeled river, which consists of a background map layer, connectivity information for the stream system (River System Schematic), cross-section data and the river crossing structures data.

- River System Schematic: The alignment of Nile River was traced with the aid of the free Google satellite imagery then imported to the Hec-Ras through the Hec-GeoRAS tool on ArcGIS. **Error! Reference source not found.** shows the river system schematic after importing it to HEC RAS.
- Cross Sectional Data: The cross-sectional data tables was extracted from the topo-survey using Hec-GeoRAS tool on ArcGIS and imported to the HecRAS and then in geometric data editor window, manning coefficients are entered.
- Bridges data: All Bridges data was entered manually for each one using the Bridge editor. The bridges included in the model are listed in Table 2.

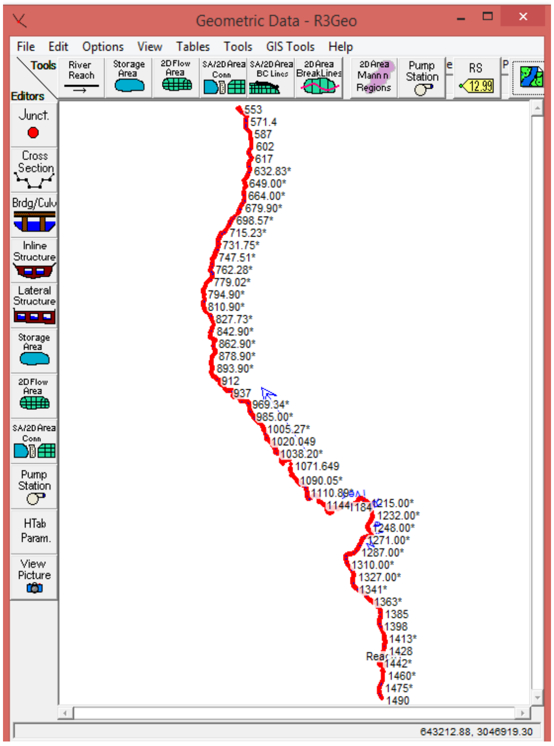


Figure 24: River schematic for four reaches of Nile River in HEC RAS

Table 2: Bridges included in the model

No	Bridge name	Distance from Aswan Dam (km)	No	Bridge name	Distance from Aswan Dam (km)
1	Aswan Bridge	19.000	14	Beni Swaif Bridge	805.000
2	Edfu Bridge	110.000	15	El Waseti Bridge	841.000
3	Old Esna Barrage	164.700	16	Reigonal Ring Road	883.600
4	Luxor Bridge	212.900	17	El Marazeeq Bridge	896.800
5	Dandara Bridge	285.750	18	Ring Road Bridge	920.600
6	Qena Railway Bridge	288.100	19	Abbas Bridge	923.700
7	Nagaa Hammadi Railway Bridge	343.100	20	Cairo University Bridge	925.100
8	Gerga Bridge	407.730	21	El Galaa and Kasr El Nile Bridges	926.500
9	Sohag Bridge	442.900	22	6th October Bridge	927.300
10	Ekhmim Bridge	445.500	23	15th May Bridge	928.600
11	Tema Bridge	493.500	24	Embaba Bridge	930.400
12	El Waseti (Ring Road) Bridge	539.200	25	Rod El Farag Bridge	931.600
13	El Minya Bridge	682.300			

- Cross Regulators Data: Weir and gates option in the inline structures window were used to model the cross regulators structures. Deck dimensions, gates characteristics are entered to be similar to the actual conditions. Table 3 below shows the main barrages structure characteristics as inputted in the model.

Table 3: Main Barrages Characteristics

Hydraulic Structure	New Esna Barrages	Old Nagaa Hammadi Barrages	Old Assiut Barrages
Distance DS Aswan Dam	167.700	359.50	544.70
No. of Vents	6	100	111
Vent Width (m)	12	6	5
Gate Height (m)	13	10	7
Invert Level (m)	67	57	45

- Lateral Structures: No Geometric data were entered regarding the lateral structures, they were only represented by the amount of inflow or outflow they take or give to the system as boundary condition in the steady/unsteady flow data of the model.

Flow Data Entry

Following to the geometric data entry, the flow data is applied for both models, steady flow models and unsteady flow models as discussed below.

1- Steady flow Model

The steady flow simulation was carried out for each reach individually for different discharges (High flow, Average flow and low flow) in order to come up with the calibration parameter, manning's coefficient (n), to be used in further unsteady flow simulations.

Reach 1: Aswan- Esna

The flow release of the Nile first reach from Aswan Dam for year 2006 varies between 80 Mm3/day during low flow periods and 245 Mm3/day during high flow periods, the water levels US Esna barrages corresponding to these flow conditions was found to be 78.00m and 78.5m above msl respectively.

Reach 2: Esna- Nagaa Hammadi

The flow release of the Nile second reach from Esna Barrages for year 2006 varies between 73 Mm3/day during low flow periods and 240 Mm3/day during high flow periods, the water levels US Nagaa Hammadi barrages corresponding to these flow conditions was found to be 64.90m and 65.15m above msl respectively.

Reach 3: Nagaa Hammadi-Assiut

The flow release of the Nile second reach from Nagaa Hammadi Barrages for year 2006 varies between 60 Mm3/day during low flow periods and 220 Mm3/day during high flow periods, the water levels US Assiut Barrages corresponding to these flow conditions was found to be 48.25m and 50.30m above msl respectively.

Reach 4: Assiut - Delta

The flow release of the Nile second reach from Assiut Barrages for year 2006 varies between 57 Mm3/day during low flow periods and 170 Mm3/day during high flow periods, the water levels US Delta barrages corresponding to these flow conditions was found to be 16.68m and 16.20m above msl respectively.

2- Unsteady Flow Model

The geometric data for the four reaches is then connected into one full model to study the hydrodynamics of the whole river as a part, and the following was carried on:

- Simulation Plan

A simulation plan for the high flow conditions which occur in Summer (The month of June is taken as the simulation period) and this simulation plan is mainly used for the validation process of the model.

The Model runs for a period of one month to ensure that the model reaches the steady state condition (the flow entered at the Aswan Dam passed through the four reaches until it reached the downstream end of the simulated river at Delta Barrages).

- Boundary conditions

Boundary conditions are required for the farthest upstream and downstream cross-sections of the river system in addition to the structures such as the inline structures (Cross regulators), Lateral structures (Head regulators of Branch Canals), pump stations and Drains weirs.

The upstream boundary condition – RS 1500 was the inflow hydrograph of Aswan dam in the year 2006, with time step of 1 day (daily flows were obtained).

The downstream boundary condition– RS 552.5 was the stage hydrograph of US Delta Cross Regulator in the year 2006, with time step of 1 day (daily flows were obtained).

Internal boundary conditions were entered as:

1- Flow hydrographs for the gates of the lateral structures representing the main canals branching from the Nile River
2- Lateral outflows of the pump stations lifting from the river
3- Lateral Inflows of the drains discharging into the river

Model Calibration

The objective of the calibration process is to match the output water surface profile of the model with observed water surface elevations at different observed gauging stations. Channel roughness is the most sensitive parameter in development of hydraulic model of a natural river. Hence, in the present study it is attempted to calibrate the model by trying different values for the channel roughness coefficient (Manning's "n" value) along the river and comparing the resulting water surface profile in the model with the actual measurements on different gauges along the river. The values of Manning's roughness coefficients for alluvial waterways can be assessed using references such as Chow (1959) as per Table 4. In this study, Manning's roughness (n) values for all the reaches was assumed initially to be 0.025 for the canal sections and 0.05 for the right and left overbanks, and a steady flow simulation was conducted for each reach. Then, these initial values were modified iteratively during the calibration process until a good agreement is reached between the simulated water levels and the actually observed water levels at the gage stations of Nile River for periods of High, Average and Low Flow of each reach

Table 4: Manning's n for Channels (Chow, 1959)

Type of Channel and Description	Min.	Normal	Max.
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

The final calibrated manning "n" values for each reach are presented in Table 5.

Table 5: Manning's values used in the Mathematical Model Calibration

	Station DS HAD		Manning (n)		Station DS HAD		Manning (n)
	From St.	To St.			From St.	To St.	
Reach 1	10	39	0.031	Reach 3	360	385	0.03
	39	80	0.030		385	433	0.023
	80	109	0.033		433	451	0.031
	109	141	0.027		451	479	0.033
	141	166	0.026		479	520	0.032
Reach 2	166	200	0.026		520	545	0.023
	200	223	0.035	Reach 4	548	586	0.037
	223	246	0.027		586	769	0.032
	246	290	0.036		769	787	0.031
	290	364	0.025		787	808	0.04

According to Chow (1959), the calibrated manning coefficients lie within the logical values for the clean channel with some weeds, and this description is close to the existing situation.

The above-mentioned manning coefficients revealed the water surface profiles represented in figures 5 to 16. It can be observed that the results match well with the field data.

The final calibrated manning coefficients of the study in hand were then compared with manning coefficients resulting from other similar studies. Table 6 shows a comparison between Manning's coefficient in the current study and other studies.

Table 6: Comparison between Manning's coefficient

	Current Study	Other Studies	
Reach No.	Manning (n)	Manning (n)	Author
Reach 1	0.029	0.038	Noha (2007)
		0.029	Fathy (2013)
		0.015	Raslan (2013)
Reach 2	0.029	0.027	Fathy (2013)
Reach 3	0.028	0.024	Fathy (2013)
		0.015	Raslan (2013)
Reach 4	0.033	0.028	Fathy (2013)
		0.026	Dalia (2012)
		0.033	Moussa (2010)
		0.015	Reham (2019)
		0.02	Noha (2007)

DISCUSSION

There is variation between the manning coefficients in the study in hand and the previous studies, this may be due to the reasons discussed below:

- All of the previously discussed studies didn't take into consideration the discharges of the pump stations lifting water from Nile River neither the drains discharging water into the river, while the current study did.
- All of the previously discussed studies neglected the presence of the bridges along the river, while the current study did.
- All of the previously discussed studies except Fathy et al. (2013) didn't include the barrages structures in the model, while the current study did.
- All of the previously mentioned studies except Reham (2019) run a steady flow simulation only while the study in hand included steady and unsteady simulations
- Noha (2007) used cross-sections and flow data of the year 1997, while the current study used that of 2006.

Steady Flow Model Profiles

LEGEND: Mann Wtd Chnl W.S. Elev Min Ch El Obs. WL

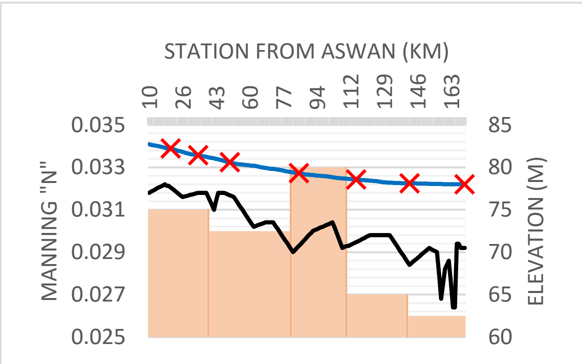


Figure 30: Reach 1 Low Flow

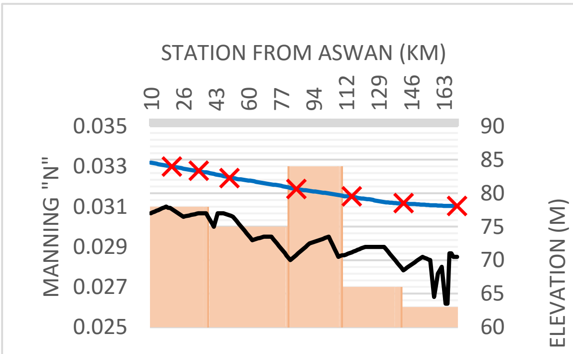


Figure 29:Reach 1 Avg Flow

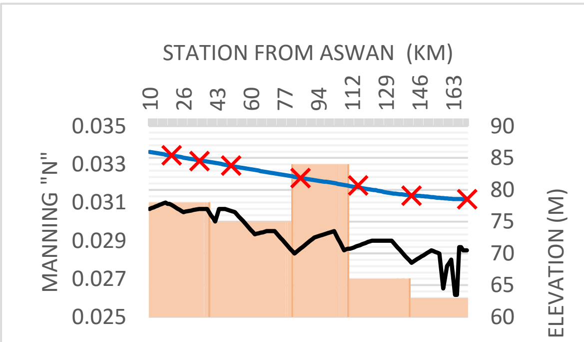


Figure 28:Reach 1 High Flow

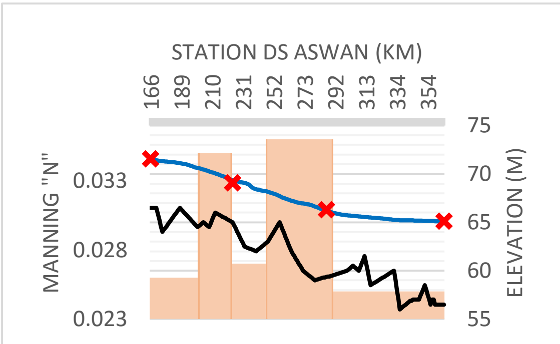


Figure 27:Reach 2 Low Flow

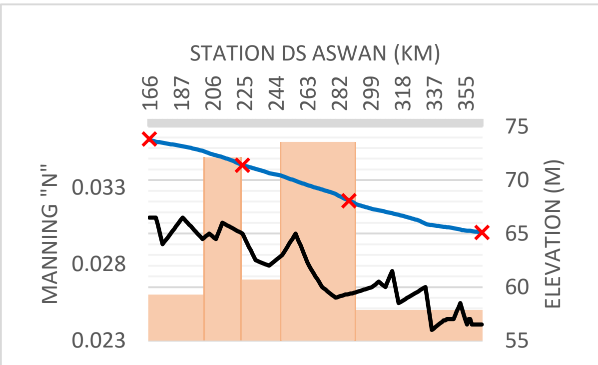


Figure 25:Reach 2 Avg Flow

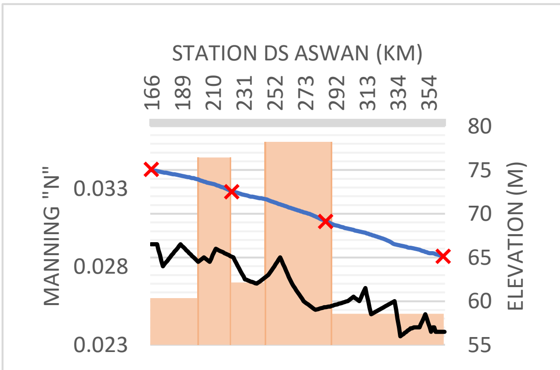


Figure 26: Reach 2 High Flow

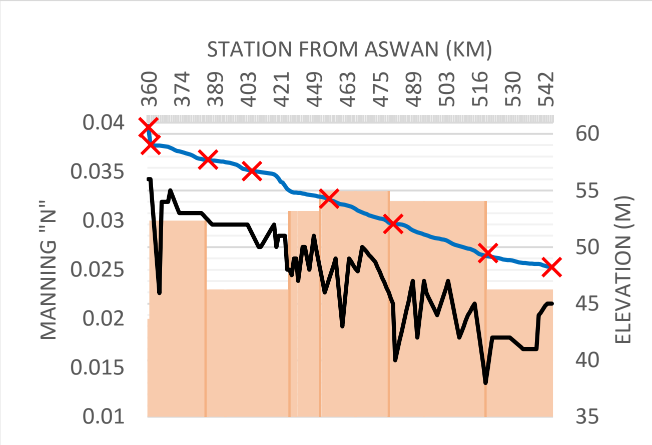


Figure 39: Reach 3 Low Flow

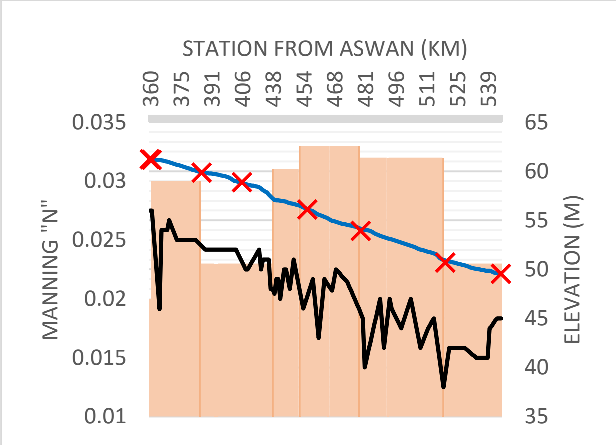


Figure 40: Reach 3 Avg Flow

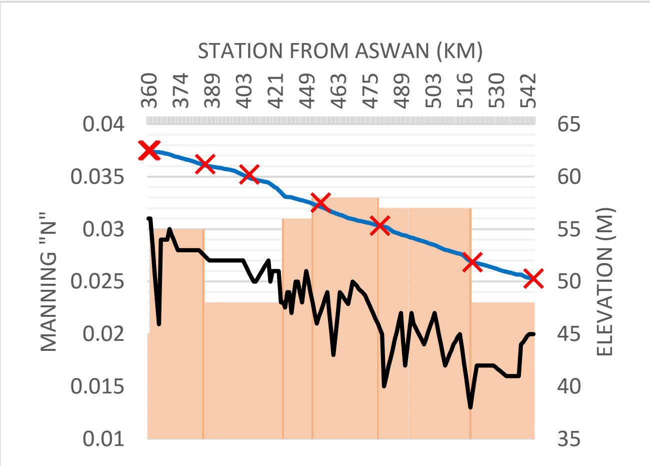


Figure 37:Reach 3 High Flow

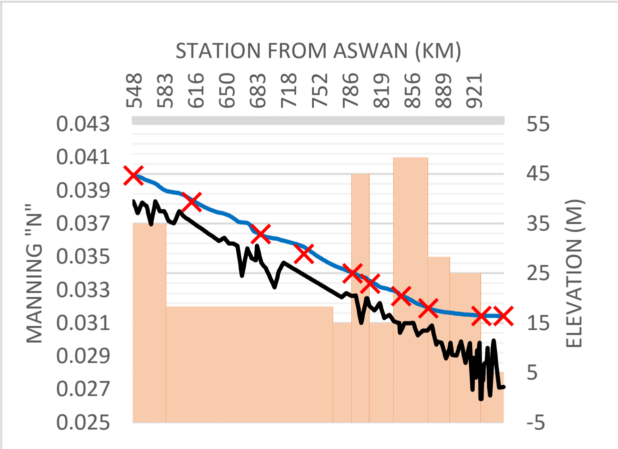


Figure 38: Reach 4 Low Flow

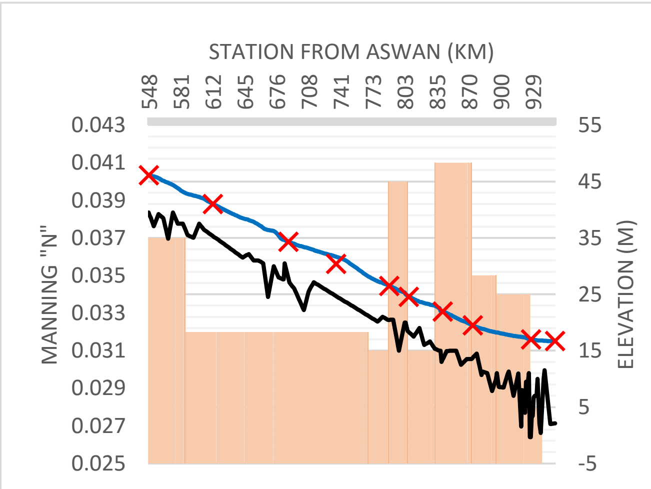


Figure 34:Reach 4 Avg Flow

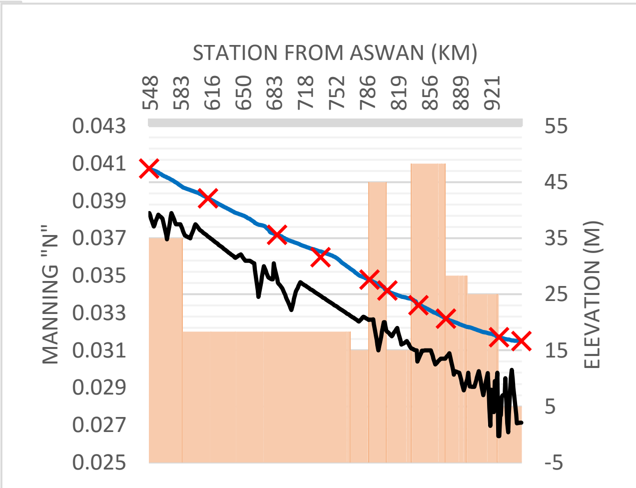


Figure 33: Reach 4 High Flow

MODEL VALIDATION

The final step in the calibration process is validation of the model. This operation is most desirable, but is not always possible, often requiring more data than is available. The verification process is done by using the calibrated model to compute water surface profile from other flood events that weren't used in the calibration process. The objective of this process is to ensure that the built model can be used in all flood cases and give reliable results.

As previously mentioned, the validation of the model in this study is done by combining the four reaches and performing unsteady simulation and it revealed good results with the calibrated parameter. Figure 41 shows the relationship between the model and observed water levels for the whole river profile for the unsteady simulation.

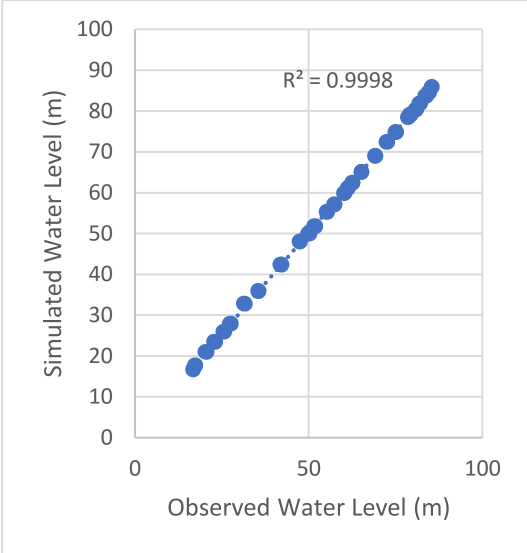


Figure 41: Unsteady Simulation Comparison

Performance evaluation Criteria

The equations below illustrate the statistical performance evaluation criteria used to assess the accuracy of the built model.

- Nash Sutcliffe model Efficiency coefficient (NSE)

$$NSE = 1 - \frac{\sum_{i=1}^{n}(OBS_i - SIM_i)^2}{\sum_{i=1}^{n}(OBS_i - \overline{OBS})^2} \quad (7)$$

- Coefficient of Correlation (Corr)

$$Correl(X, Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} \quad (8)$$

Table 7: Model Performance evaluation

Terminology	Value for Model
NSE	0.9997
Correl	0.9999

It is clear that results show an encouraging coefficient of efficiency as well as excellent correlation. Thus, the model is successfully verified.

CONCLUSION AND RECOMMENDATION

The current study was carried out to build a 1D hydrodynamic calibrated model and perform steady and unsteady flow simulation through the four reaches of the Nile River taking into consideration the lateral outflows and inflows of pump stations and drains.

In the calibration process, a steady state for model for each of the four reaches separately was built by passing the demands for high demand period (June), average demand period (April) and low demand period (January) which are:

- 80, 160 and 245 Mm3 /day through Aswan Dam
- 63, 161 and 240 Mm3 /day through Esna Barrages
- 60, 147 and 221 Mm3 /day through Nagaa Hammadi Barrages

- 57, 112 and 170 Mm3 /day through Assiut Barrages

Validation of the model was then carried out by executing an unsteady flow simulation plan for the complete river (four reaches connected) with a simulation period of 1 month (High demand month)

The result revealed a good agreement between the deduced water surface levels for all the high demand, average demand and low demand periods at various locations and the observed water levels along the four reaches and indicated that the average manning coefficients of the four reaches are 0.029, 0.029, 0.028 and 0.033 consequently. The achieved results concluded that the fourth Nile River reach is the roughest as it is the most reach vulnerable to human interventions, which affected its hydraulic efficiency.

The built model can be then used for further studies on Nile River including:

- Studying the predicted future conditions
- Performing dam break analysis
- Wave propagation studies.
- Planning and Identifying the most efficient control scheme of the regulators
- Evaluation of accidental pollutants spills in the Nile River
- Studying the flow parameters including water depth, velocities, …etc.
- Water resources management

REFERENCES

1- Kamal, Noha. (2007). Computer Model for Evaluating River Nile High Flood Effects.

2- Elmoustafa, Ashraf & Moussa, Ahmed. (2010). Evaluating of Muskingum hydrologic model parameters in reach four of Nile river using 1D model. Scientific Bulletin Cairo University. 57.

3- Elsayed, Reham et al. Evaluation the Existing Nile River Navigation Path in The Reach from Aswan City to Esna Barrage. The Egyptian International Journal of Engineering Sciences & Technology, [S.l.], v. 27, p. 1-11, feb. 2019.

4- Fathy, Heba & El Deen Y. Helal, Esam & A, El-Belasy & M.F, Sobeih. (2013). Effect of Main Barrages Failure on the Nile Valley. Nile Basin Water Science & Engineering Journal. 6. 76.

5- Dalia, El Manadeely & Medhat (2012). Morphological Study of the Nile River Fourth Reach

6- U.S Army Corps of Engineers: HEC-river analysis system user's manual, version 5 (2016)

7- Borah A., Sil B.S. (2017) Flow Analysis in a Meandering River Using HEC-RAS Model. In: Garg V., Singh V., Raj V. (eds) Development of Water Resources in India. Water Science and Technology Library, vol 75. Springer, Cham

8- Chow, V. T., 1957. Open Channel Hydraulics, Mcgraw-Hill Book Co., 1957.

9- Goodell, Christopher R.. "Advanced Gate Operation Strategies in HEC-RAS 5.0." (2016).