SIMULATION OF SEDIMENT TRANSPORT IN HIGH ASWAN DAM LAKE

By

Rajaa Mohammed Sabri

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
IRRIGATION AND HYDRAULICS ENGINEERING

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Title of Thesis:

SIMULATION OF SEDIMENT TRANSPORT IN HIGH ASWAN DAM LAKE

Key Words:
Sediment Transport, High Aswan Dam Lake, GSTARS3, Scenarios, Numerical Model

Summary:
High Aswan Dam is the most important construction on the Nile River for water storage and control. The dam experiences sedimentation problem upstream the lake. The rate of reservoir sedimentation depends mainly on the size of a reservoir relative to the amount of sediment flowing into it. Through this study, a number of scenarios has been tested to numerically study the expected morphological changes that might take place in HADL as a result of the possible reduction of the incoming flow and/ or the sediment loads due to any possible dam construction activities upstream. The mathematical model was first verified to represent the conditions of the lake second; the model was evaluated then applied to the developed scenarios to predict the sediment transport in the longitudinal direction and sedimentation zone extension along the lake and to estimate of the expected total sediment volume.

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Dedication

To My Father's Soul,

Mother,

My Husband

and Lovely Kids

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Nomenclature

A	Cross section area
A_d	Ineffective cross sectional area
As	Volume of sediment in suspension at the cross section per unit length
A_k	Surface area of the reservoir represented by cross section k
ARV	Annual runoff coefficient
$amsl$	Above mean sea level
B	Channel width
BCM	Billion cubic meters
C_{ai}	Concentration at a reference level
Ci	Concentration of sediment in transportation at cross section i
c	Number of particles per unit bed area at time
C_t	Total sediment concentration
$C_{t,i}$	Sediment transport capacity at cross section i
C_v	Suspended sediment concentration by volume, including wash load
d	Sediment particle diameter
d_{50}	Mean bed material size
Dg	Primary grain diameter
E_n	Artificial damping coefficient
g	Gravitational acceleration
G	Specific gravity of sediments in water
H	Elevation of the energy line above the datum
HAD	High Aswan Dam
HADL	High Aswan Dam Lake
h	Water surface elevation
i	Cross section index
j	Time index
K	Total number of size fractions
k	Size fraction index
M_{j}	Mass of particle
$MinF$	Minimizing sedimentation
MAR	Mean annual runoff
MAP	Mean annual precipitation
n	Manning's roughness coefficient
N	Number of size fraction
Q	Water discharge
Q_i	Time weighted discharges
Q_s	Volumetric sediment discharge
$Q_{s,i}$	Sediment transport rate at cross section i
$Q_{s,i,k}$	Computed volumetric sediment discharge for size k at cross section i
q	Discharge of flow per unit width
q_{lat}	Lateral inflow per unit length of channel
q_{bi}	Bed load transport rate for size fraction i
P	Wetted parameter

p_i	Percentage of material of size fraction *i* available in bed
P_i^*	Percentage of material of size fraction *i* incoming to the reach
ppm	Part per million
Rh	Hydraulic radius
r_T	Turbulent diffusivity
$R_{j,t}$	Reservoir release
ROC	Runoff coefficient
S	Specific gravity
S_e	Slope of the energy line
$S_{j,t}$	The largest storage level for the terminal storage state
S_y	Sediment yield
STD	Soil type and drainage
t	Time
u_i	Velocity of particle of class *i*
u_s	Sediment transport velocity
u^*	Shear velocity
u^*_e	Effective shear velocity
u^*_{c50}	Non dimensional critical shear velocity for the d_{50} fraction
V	Flow velocity
VC	Vegetation condition
x	Length along the flow direction
y	Water depth
z	Bed elevation
τ_j	Particle strength
α	Recovery factor
α_d	Recovery factor for deposition
α_k	Recovery factor of sediment size group *k*
α_s	Recovery factor for scour
γ_s	Specific weights of sediment
γ_m	Specific weights of sediment-laden flow
Δt	Time step interval
Δx	Distance between cross sections
Δx_i	Distance between cross section *i* and *i*+1
Δz	Change in bed elevation (positive for aggradation, negative for scour)
ε and ζ	Coefficients for the determination of recovery factor
η	Volume of sediment in a unit bed layer volume (one minus porosity)
$\eta_{i,k}$	Volume of sediment in a unit bed layer for size *k* at cross section *i*
κ	Coefficient for the determination of Manning's *n*
ν	Kinematic viscosity of clear water
ν_m	Kinematic viscosity in a sediment-laden flow
a, b, and c	Weighting factors that must satisfy a +b + c =1
ρ	Fluid density
ρ_g	Sediment grain density
ρ_s	Specific density of sediment particles
ρ_m	Specific density of sediment particles

Φ	Total rate of energy dissipation
Φ_w	Rate of energy dissipation due to water movement
Φ_s	Rate of energy dissipation due to sediment movement
ω	Sediment particle fall velocities in clear water
ω_k	Fall velocity of sediment size *k*
ω_i	Fall velocity of sediment particles *I* with diameter d_i
ω_m	Particle fall velocity in a sediment-laden flow

Abstract

The major and significant morphological changes of any river might be due to the construction of a huge structure across it like the High Aswan Dam (HAD) on the Nile River (NR). At a level of 182m amsl, the High Aswan Dam Lake (HADL) extends 500 km upstream dam location. HADL has a surface area of nearly 6500 km^2 and a capacity of 162 billion m^3.

The objectives of this study:
To simulate the water and sediment transport in HADL using a numerical model and to test the effect of reducing water flow or/and sediment loads on the morphology of the lake bed.

The study presented in this work was undertaken using historical and field data measurements that were utilized in the numerical model (GSTARS3). The one – dimensional, GSTARS3 model was selected because of its capability in carrying out long term hydrodynamics and sediment transport simulations throughout the entire HADL in a semi-two dimensional manner while adopting the stream tube concept.
The model was calibrated and validated using Han's (1980) non-equilibrium sediment transport equation and Ashida and Michiue formula (1972). Generally the model fitted well measurements however; it predicted more deposition than the measured at the lake entrance. The model was used also to simulate a number of probable future scenarios; such scenarios include: repeating the last 40 years records, reducing the flow discharge in flood seasons by 10% and decreasing sediment loads entering the lake by (10, 25, 50 and 75%), decreasing discharge by (10%) in flood seasons and sediment loads by (10, 25, 50%) respectively.
The model results showed that: repetition of the last 40 years flow rates and sediment loads will result in a general increase in sediment deposition at lake entrance and the upstream sedimentation zone will be extended closer to the dam site up to a distance of 105km from the HAD location.

For the case of 10% reduction in flow discharge in flood seasons, it is noted that the deposition of sediment decreased from lake entrance till 394 km from the dam location.

Decreasing sediment loads entering the lake will decrease the depths of deposition at the lake entrance till km122 from the dam. It was notable that decreasing the entering sediment load by 75% will lead to the lowest deposition depths. Decreasing both flow and sediment loads with different ratios (10, 25 and 50%) will cause some erosion zones to appear/emerge in the upstream reach of the lake and deposition depths will reduce till 402 km upstream the dam.