Prediction of Breach Formation Through the Aswan High Dam and Subsequent Flooding Downstream

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Abstract

All over the world, there are many dams failure due to many different reasons. These reasons range from structural instability to some hydraulic conditions. The dam failure may occur due to overtopping, seepage or piping through the dam body or its foundation. There are some situations which may cause sudden failure to the dam like earthquakes, landslide or even possibility of terrorist attacks. Failure of dams can result in loss of life, property and environmental damage, and have economic repercussions. The Aswan High Dam, (AHD) plays an important role in the main system of Egyptian irrigation system, hydropower, flood control, drinking water. This importance is related to that, the population majority of Egypt is located downstream the dam site accompanied with the high portion of the national economic activities as agriculture and industries.

The present paper assesses the risk of the Aswan High Dam breaching due to overtopping, numerically. All related data were collected and analysed. A suitable numerical dam breach model was chosen and selected to be implemented. Three scenarios were designed to represent minimum, normal and maximum flood flow to the lake at normal water level, respectively. Other three scenarios represent the same flood configuration flow to the lake at maximum water level conditions, respectively. The six scenarios were simulated using the dam breach model. The expected impacts of the Aswan High Dam failure, due to overtopping, were analysed.

Outflow hydrographs due to the failure were obtained. The Nile River downstream Aswan High Dam until Delta Barrage was simulated using 1D 2D model. The obtained results from dam failure of the scenario of maximum inflow to normal Nasser Lake water level were applied to 1D2D model. A risk assessment to the dam breaching was achieved. Results of the calculated show the flood wave propagation in terms of inundations maps, flows, water levels, flood arrival time, and flow velocities along the water course from Aswan High Dam to delta Barrage. The results of this investigation could be further applied and could assist decision makers to set a plan to confront the risks of the Aswan High Dam failure.

***Key words**: Dam Breach, Outflow hydrograph, Aswan High Dam, flood flow, overtopping*

1. INTRODUCTION

The Aswan High Dam (AHD) was built in 1968 to protect Egypt against flood and draught of the Nile River. It also secures a sustainable supply of water demands in the Nile River. The location of the Aswan High Dam is 6.50 km south of the Aswan Old Dam (AOD). This location was considered as the most suitable and appropriate location due to the relative narrowness of the course of the Nile.

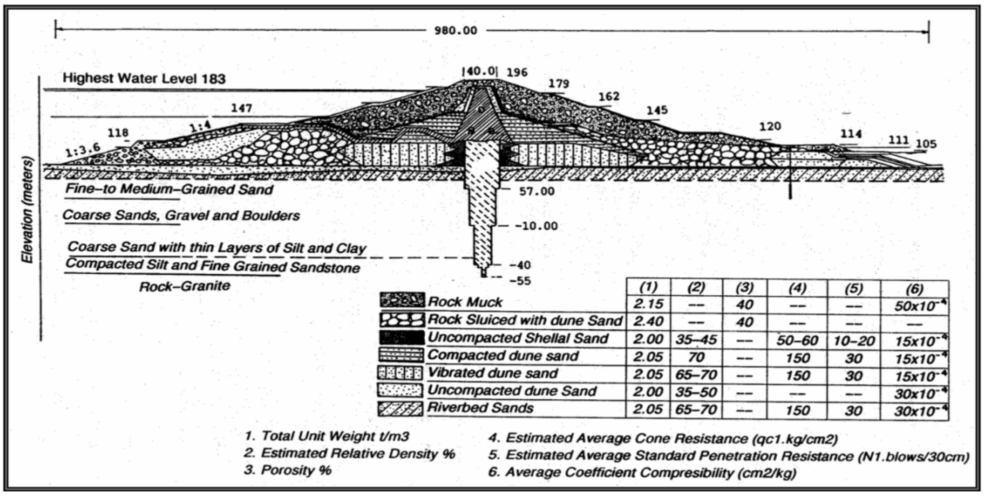
The AHD is a rock-fill dam with a length of 3820 m of which 520 m are within the river channel and the rest is in the shape of two wings at both sides of the river. The length of the right wing is 2520 m, while the left wing is 780 m. The dam width at the bottom of the river bed is 980 m, and 40 m at the crest. The height of the dam above the river bed is 111 m. The bulk volume of materials used in building the AHD is about 43 million cubic meters, (MCM) which is about 17 times the size of the great Giza pyramid, "Cheops". The body of the dam is constructed of granite blocks, sand and clay, in the midst of which is a clay core to prevent seepage of water. The core is connected at the upstream part with a horizontal blanket of clay for the same purpose. Figure (1) shows the cross section of the dam and its materials.

Since the Nile bed, on which the dam was built, consists of sedimentary deposits, it was provided with a vertical injected curtain extending 170 m under the main core until it reaches the solid impermeable layer.

The injected curtain has been built of special materials like Aswan clay and other chemical materials to prevent the seepage of water. The width of the injected curtain is 40 m under the main core, and decreased until it reaches 5 m at the point where it meets with the solid layer. The core was penetrated by three galleries, constructed with reinforced concrete. During construction, the galleries were used in completing the vertical injected curtain, while they are being used now for inspection and maintenance purposes. Various measuring devices have been installed in these galleries to measure vertical and horizontal movements, pore pressure in clay and seepage, if any. The dam was provided before the end of its toe with a row of vertical relief wells to drain the water which may seep through the dam. See Abdel Azim Abul-Atta, 1978.

The AHD formed a large artificial lake of 500 km length, with an average width of 12 km. the surface area of the lake is 6000 km^2. It was considered one of the largest man-made lakes in the world. Its maximum capacity, which mounts to 162 Billion Cubic meter, (BCM) is divided into three parts as follows:

a) Dead storage capacity of 31.6 BCM up to 147 meter above Mean Sea Level, and designed for the silt deposition over 500 years.
b) Live or working storage capacity between the levels 147, and 175 m above MSL, mounting to 90.4 BCM, which guarantees the annual requirements of water.
c**)** Flood control capacity of 40 BCM between levels 175 and 182 m above MSL. Figure (2) shows the Nasser Lake elevation-storage curve



	(1)	(2)	(3)	(4)	(5)	(6)
Rock Muck	2.15	--	40	--	--	$50x10^{-4}$
Rock Sluiced with dune Sand	2.40	--	40	--	--	--
Uncompacted Shellal Sand	2.00	35–45	--	50–60	10–20	$15x10^{-4}$
Compacted dune sand	2.05	70	--	150	30	$15x10^{-4}$
Vibrated dune sand	2.05	65–70	--	150	30	$15x10^{-4}$
Uncompacted dune Sand	2.00	35–50	--	--	--	$30x10^{-4}$
Riverbed Sands	2.05	65–70	--	150	30	$30x10^{-4}$

Figure 1: The Aswan High Dam Cross section, Abdel Azim Abul-Atta, [1]

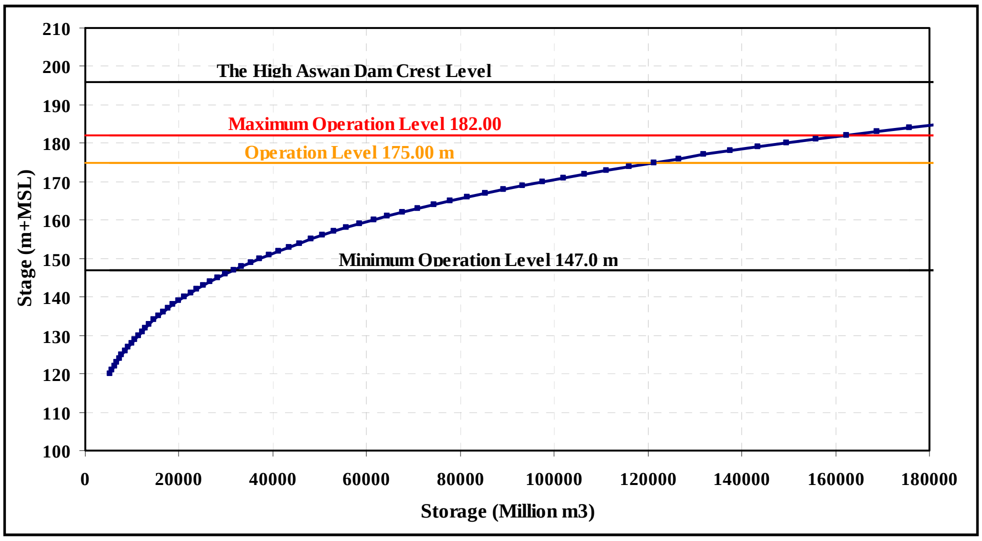


Figure 2: Nasser Lake Elevation-storage curve

From the reviewed literature in the field of dam breaching, it was clear that several researchers dealt with dam breaching, worldwide, while the Aswan High Dam did not gain any interest from researchers. Due to the importance of the dam in the Egyptian lives, this study was initiated in order to assess the breaching risks. During the recent decades several catastrophes have happened due to the failure of dams at various locations in the world. The number of significant dam failures that occurred in the period from 1900 to 1990 are about 123 in which many people died, ICOLD, 1995.

The measurements data was collected from different sources. These data described the water levels in the Nasser Lake and the inflows as well as the outflows of the dam. Also, metrological data were collected. All these data were analyzed in order to perceive an insight to the physical properties of the breaching process. The analyzed data were a guide in the design of the simulated scenarios.

2. THE BREACH MODEL

One dimensional model, (1D) is needed to predict the outflow hydrograph, and breach characteristics due to dam failure. In the present study the HR-Breach Model was applied using runs that represent the simulation of expected breach development of the AHD. In our case the bottom level of the breach gap will start from the lake water level. However, since the (final) bottom level of the breach remains well above the water level downstream of the AHD, the flow through the gap will remain modular all the time, which means that the discharge through the gap is independent of the water level downstream of the AHD. In this case, it is therefore justifiable to operate the breach development model and the flood propagation model downstream of the dam separately.

2.1. Model Description

Info Works-RS incorporates parts of the HR-BREACH model developed by HR Wallingford. The HR BREACH model is a 1D model that can simulate the failure of homogeneous or composite embankment dams by overtopping or piping. The HR BREACH model takes into account the soil mechanics principles in the breaching process and is based upon the principles of hydraulics and sediment transport. The effect of plain grass, and riprap as protective layers was also incorporated into the model. The model predicts the outflow hydrograph from a breached embankment dam. It also simulates the erosion processes involved in the breaching process and predicts the growth of the breach in the longitudinal and the transverse directions. To simulate the flow over the crest and on the downstream face of the dam, the 1D Saint-Venant equations for unsteady flow, and momentum correction coefficients are used. The model is based on the principles of hydraulics, sediment transport, soil mechanics, the geometric properties of the dam, and the reservoir characteristics. A detailed description of the model is given in, Mohamed, et al., 2002. It is worth to mention that, in most of the model test cases, the model has showed a better performance than other breach models that were used to model similar cases.

2.2. Breach Morphology

In this model, the breach shape is controlled by two common assumptions. The first mechanism assumes an initial rectangular shape. The following relationship governs the width of the breach:

$$B_o = B_r\, y \tag{1}$$

Where, B_o is the width of the breach, B_r is factor based on the optimum hydraulic efficiency and y is the depth of flow in the breach. The second mechanism is derived from the stability of soil slopes. The initial rectangular shaped channel changes to a trapezoidal channel when the sides of the breach channel collapse, as shown in Figure (3).

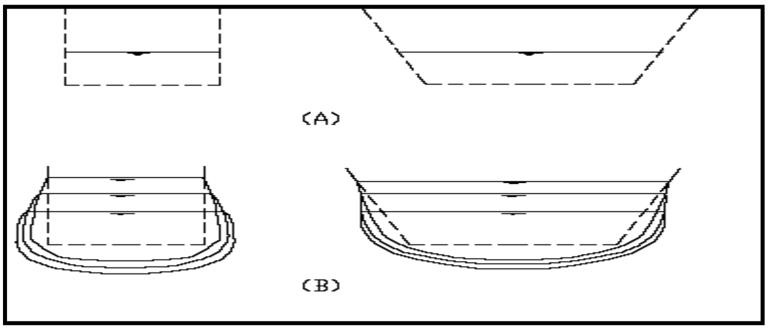


Figure 3: A) initial breach shape, B) Hypothetical breach shape.

2.3. Hydraulics of Flow through the Breach

For an overtopping failure, the reservoir water level must exceed the top of the dam before any erosion occurs. Erosion is assumed to occur only along the downstream face of the dam. The flow through the breach (Q_b), can be computed using the broad crested weir formula under modular flow conditions, which is independent of the downstream water level. In our case, since the water level in the lake (the initial level of the gap breach) is always lesser than the AHD crest level (196 m AMSL), the equation used in the model to compute this component is as follows:

$$Q_b = C_d\, B_b\, H_b^{3/2} \qquad (2)$$

Where, Q is the discharge , B_b is the breach width, C_d is the discharge coefficient and H_b is the total head over the breach.

2.4. Limitations

The HR BREACH model has the following limitations:

- Composite dams in the model is simulated as only two layers (i.e. outer and core layer)
- Limited selection of erosion formulae
- Assuming uniform erosion along the sides and bottom of the breach

2.5. Model Schematization

To set up the HR BREACH model, it is necessary to define the network of nodes and branches. The network presents the upstream boundary, (Inflow hydrograph), the storage area, (Nasser Lake), the spill unit, (Aswan High Dam), and the downstream boundary, (water levels). The water levels vary according to the studied scenario. The dam data were provided to the model as the dam geometry and material properties. The data comprised crest level, length, and width, foundation level, downstream and upstream slopes. The dam material properties comprised median diameter (d_{50}), porosity, dry unit weight, friction angle, cohesion, shear and tension strength, and Manning coefficient. In the model, One year was considered as a simulation period during each failure scenario. One year was selected by trial and error to be suitable to the annual inflow to Nasser Lake.

3. DAM BREAK MODEL SCENARIOS

For dam break studies, three types of dam failure are considered:

- A dam failure can occur under "fair-weather" conditions, i.e. under normal operation condition. This can happen due to structural failure, piping under the dam, or any unmanageable external causes.
- A dam failure under external flow conditions due to climatic events (tropical storms, severe rainfall events), this happen when the critical design water levels are exceeded and cause structural instability or dam erosion.
- A dam break can be caused by overtopping due to the passage of a large wave from an upstream to a downstream.

HR BREACH model gives the outflow hydrograph due to the expected failure of the Aswan High Dam. Six (6) dam break scenarios were designed and are summarized in Table (1). These scenarios were simulated. The inflow conditions, (upstream boundary of dam break model) are considered to be maximum, average, and minimum flood hydrographs. The head water level at the AHD is set to be at maximum operational level (182.00 m), or normal operational level (175.00), as shown in Table (1). Figures (4) and (5) show the inflow hydrographs and downstream water level of the AHD.

Table 1: Designed scenarios of the Aswan High Dam Breach

No	Failure Mode	Initial Breach (m)	Flood type / year	Flood inflow (BCM/y)	Lake Level (m)	Lake contents BCM
1	Overtopping	10.0 m x 21.0 m	Minimum, Year (2002-2003)	41.79	Normal, (175.00)	121.3
2		10.0 m x 21.0 m	Average, Year (1999-2000)	81.45	Normal, (175.00)	121.3
3		10.0 m x 21.0 m	Maximum, Year (1964-1965)	119.08	Normal, (175.00)	121.3
4		10.0 m x 14.0 m	Minimum, Year (2002-2003)	41.79	Maximum, (182.00)	162.3
5		10.0 m x 14.0 m	Average, Year (1999-2000)	81.45	Maximum, (182.00)	162.3
6		10.0 m x 14.0 m	Maximum, Year (1964-1965)	119.08	Maximum, (182.00)	162.3

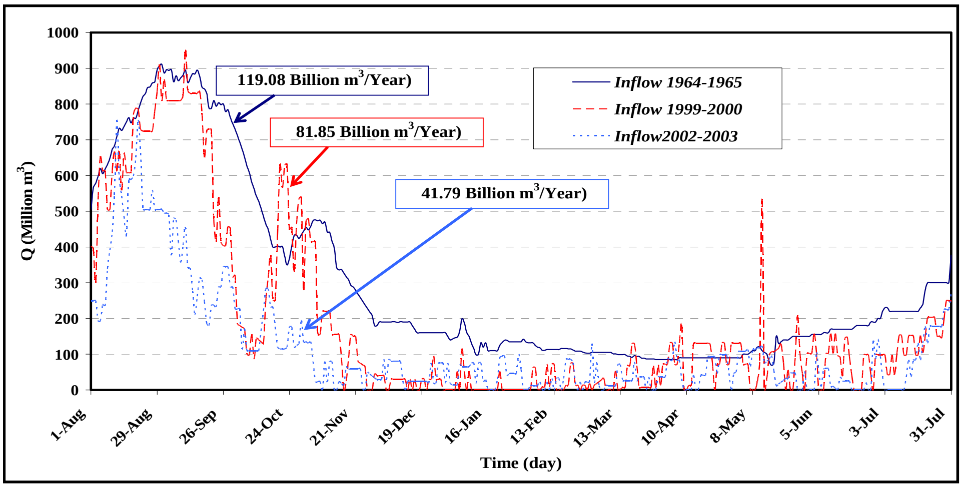


Figure 4: Inflow hydrographs of the Nasser Lake

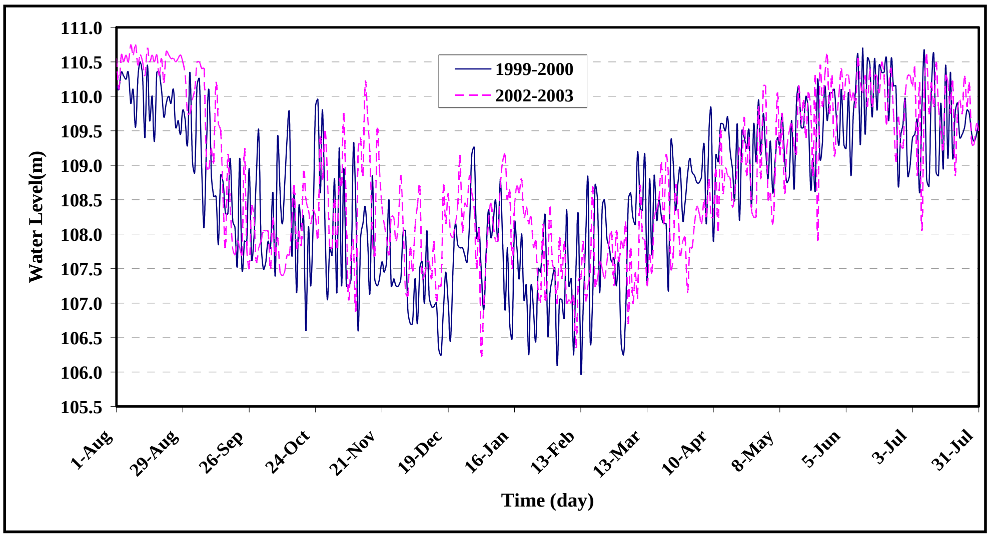


Figure 5: downstream water level of the AHD

4. RESUILTS OF THE BREACH MODEL

The failures due to overtopping are treated here. The initial breach is developed as soon as the water level reaches the level of the initial breach gap of the AHD. Although we are applying overtopping's equation 2, the initial upstream water level is the lake level and not the crest level of the AHD. The power plant of the AHD was built on the right bank with water intake embedded in solid rock. A failure of this structure is not considered for the simulation in the present study.

Results of Overtopping Failure Scenarios

Regarding the overtopping failure mode, we considered a breach in the rock-fill of the dam from the crest to the bottom. The breach characteristics are given in Table (2).

For the first scenario, the inflow hydrograph considered the hydrograph of year 2002/2003, the initial breach is assumed as 10.0 m width and 21.0 m depth in the rock-fill part of the AHD, The breach developed progressively in 42 hours and reached a depth of 26.28 m, and a width of 333.30 m, at level 169.72 m+ MSL, (bottom level of the breach). The peak flow reached was 11068.82 m^3/s. The water level of Nasser Lake decreased from level 175.0 m+ MSL, to 169.72 m+ MSL.

For the second scenario, the inflow hydrograph considered the hydrograph of year 1999/2000, the initial breach is assumed as 10.0 m width and 21.0 m depth in the rock-fill part of the AHD, The breach developed progressively in 51.50 hours and reached a depth of 27.81 m, and a width of 380.60 m, at level 168.19 m+ MSL, (bottom level of the breach). The peak flow was 15473.22 m^3/s. The water level of Nasser Lake decreased from level 175.0 m+ MSL, to 168.19 m+ MSL.

For the third scenario, the inflow hydrograph considered the hydrograph of year 1964/1965, the initial breach was assumed to be 10.0 m width and 21.0 m depth in the rock-fill part of the AHD. The breach developed progressively in 70.50 hours and reached a depth of 31.21 m, and a width of 444.55 m, at level 164.79 m+ MSL, (bottom level of the breach). The peak flow was 29569.42 m^3/s. The water level of Nasser Lake decreased from level 175.0 m+ MSL, to 164.79 m+ MSL. Figures (6) and (7) show the outflow hydrograph and water levels in Nasser Lake resulting of scenarios 1, 2 and 3, respectively.

Table 2: Overtopping Breach Characteristics

Scenario No.	Failure Mode	Peak Outflow (m^3/s)	Breach depth (m)	Breach width (m)	Lake water Level (m + MSL)	Formation time (hours)
1	Overtopping	11068.82	26.28	333.30	169.72	42.00
2		15473.22	27.81	380.60	168.19	51.50
3		29569.42	31.21	444.55	164.79	70.50
4		374309.84	61.50	490.50	134.50	76.00
5		377957.19	61.94	580.00	134.06	83.00
6		389009.69	62.11	666.30	133.89	95.00

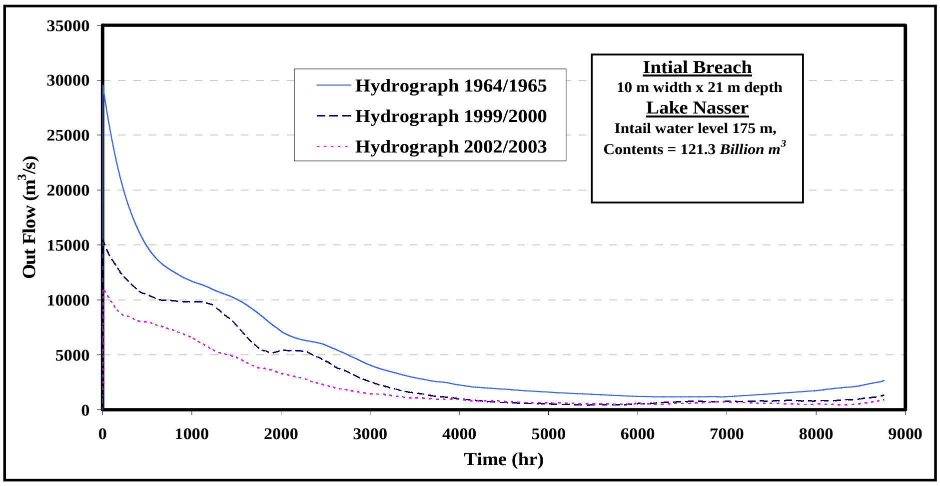


Figure 6: Outflow hydrograph of scenarios No. 1, 2, and 3

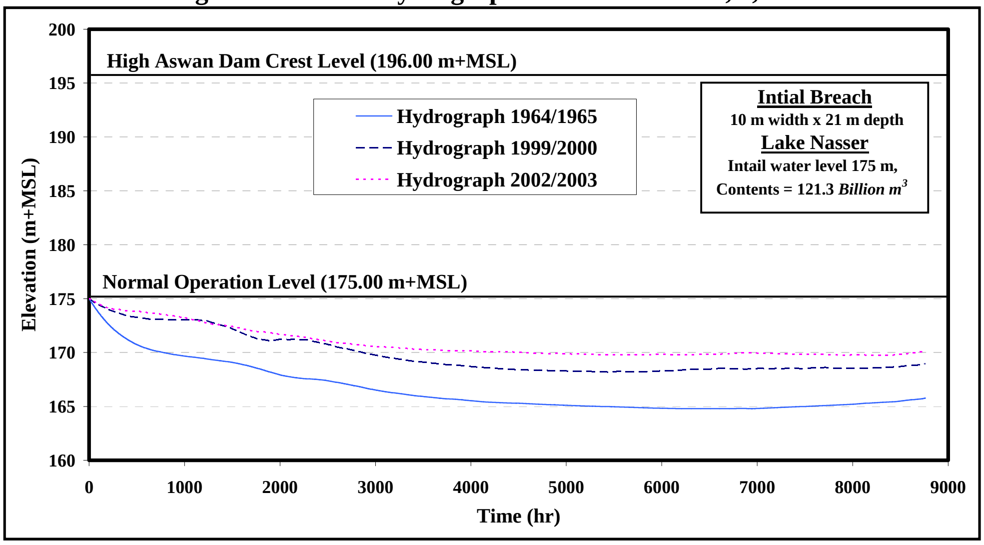


Figure 7: Water level of the Nasser Lake for scenarios No. 1, 2, and 3

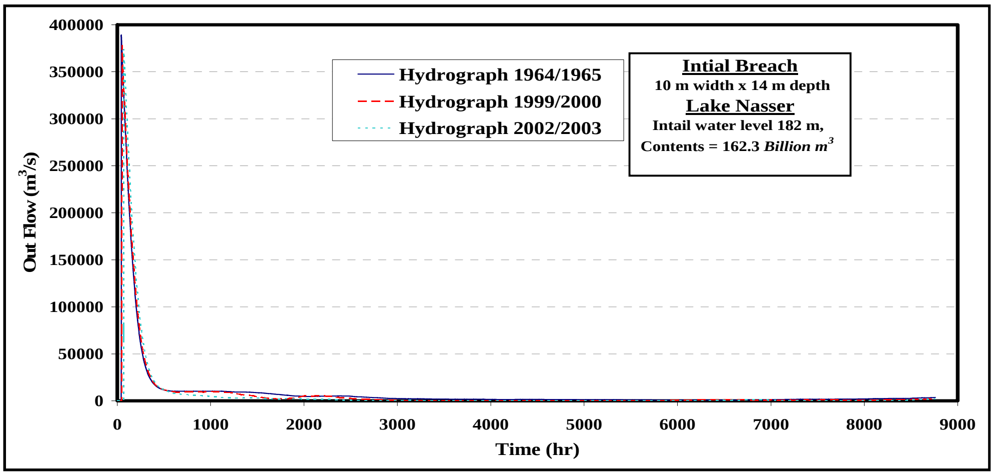


Figure 8: Outflow hydrograph of scenarios No. 4, 5, and 6

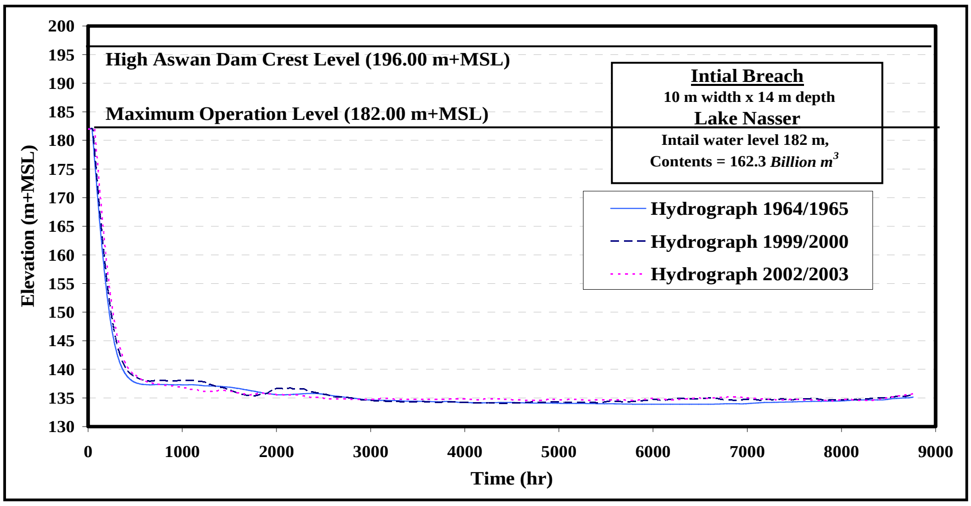


Figure 9: Water level of Nasser Lake for scenarios No. 4, 5, and 6

For the fourth scenario, the inflow hydrograph considered the hydrograph of year 2002/2003, the initial breach is assumed as 10.0 m width, and 14.0 m depth in the rock-fill part of the AHD, The breach developed progressively in 76 hours and reached a depth of 61.50 m, and a width of 490.50 m, at level 134.50 m+ MSL, (bottom level of the_breach). The peak flow was 374309.84 m^3/s. The water level of Nasser Lake decreased from level 182.0 m+ MSL, to 134.50 m+ MSL.
For the fifth scenario, the inflow hydrograph considered the hydrograph of year 1999/2000, the initial breach is assumed as 10.0 m width, and 14.0 m depth in the rock-fill part of the AHD. The breach developed progressively in 83 hours and reached a depth of 61.94 m, and a width of 580.00 m, at level 134.06 m+ MSL, (bottom level of the breach). The peak flow was 377957.19 m^3/s. The water level of Nasser Lake decreased from level 182.0 m+ MSL, to 134.06 m+ MSL

For the sixth scenario, the inflow hydrograph considered the hydrograph of year 1964/1965, the initial breach is assumed as 10.0 m width, and 14.0 m depth in the rock-fill part of the AHD, The breach developed progressively in 95 hours and reached a depth of 62.11 m, and a width of 666.30 m, at level 133.89 m+ MSL, (bottom level of the breach), The peak flow was 389009.69 m^3/s. The water level of Nasser Lake decreased from level 182.0 m+ MSL, to 133.89 m+ MSL. Figures (8) and (9) show the outflow hydrograph and water levels in Nasser Lake resulting of scenarios 4, 5 and 6, respectively, Fahmy, et al. 2011.

5. SIMULATION THE RIVER DOWNSTREAM AHD

The downstream river reach can be well simulated using one-two dimensional, (1D2D) flow model. Thus a model was schematised based on the numerical SOBEK software package, Delft Hydraulics, 2010 which is:

- The 1D analysis along the modelled reaches of the river.
- The 2D unsteady formulations of the full dynamic equations along overland water flooded flow.

The high water levels along the valley, flood arrival times, as well as stage and discharge hydrographs at specified locations can be obtained from the results of the SOBEK model. Primarily, assumptions were put forward to initiate the computation. During the computations the following assumptions were made:

- Bank failure does not occur due to excessive discharges.
- The debris, present in the barrages fore-bays that could obstruct the vents during the passage of the flood wave, is absent.
- All the gates of the main barrages, downstream the AHD, were opened when the flood wave reaches them. These gates are sabotaged when the flood discharge reaches 7000 m^3/s, the computation will continue assuming that there is no barrage at this location.
- The bridges, along the Nile, are sabotaged when the water level reaches their deck
- Erosion does not take place during the simulations.
- The lateral off-takes, all side canals and Rayahs upstream the barrages worked with their maximum capacity during the flood.

5.1. 1D2D Model Schematization

The Nile River is described through 4 reaches. Figure (10), shows the schematization of the Nile, with its nodes, branches and its main structures. The model schematization will be concerned with the four reaches to simulate the 1D modeling of the river flow and concerned with 2D over flow land.

Up-stream conditions were set as the hydrograph obtained by HR BREACH, and the downstream boundary conditions were set as the maximum water level upstream Delta barrages. Lateral in/outflow were specified for both point discharges (m^3/s) for the main canals and all pumps that directly withdraw off the river, all minor abstraction canals and all drains returning water to the river within the reach under consideration. Every reach was spilt into segments bounded by two calculation nodes 200 m apart. The calculations were executed to the segments, structures and the intermediate nodes to produce the water levels, depths, velocities, discharges and some hydraulic characteristics. The simulation period is considered six months period after failure.

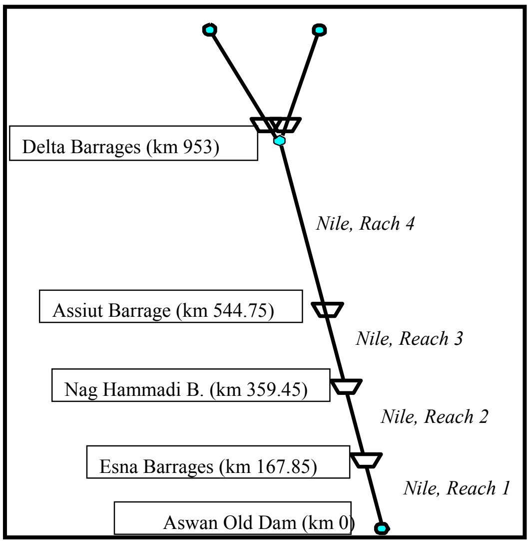


Figure 10: Schematization of the Nile River

5.2. Model Calibration and Validation

Calibrations of the model were done based on real measurements of inflows, discharges, and water levels. The measurements were carried out by the Hydraulics Research Institute at January 2010.
To validate SOBEK model, the data of flood seasons 1998/1999 were used. The validations were done in two schemes as follows:

- Validating water profiles along the different reaches.
- Comparing the results of the hydraulic flow characteristics at a number of hydrometric stations.

Several model runs were made to achieve the best agreement between measured and computed values from the model. This was carried out by adjusting roughness coefficients at various locations along the modelled reaches, for 1D model (the Nile River), but for 2D model (the Nile Valley) we considered the areas at the river sides of bed level higher than the water level at Aswan Lake). The modelled areas were classified to urban, rural, building, and mountains. The roughness of each type was taken according US ARMY CORPS MANUAL.

5.3. Scenario 3 Simulation Using 1D2D Model

This scenario was chosen to be simulated by 1D2D model because it represents the maximum inflow and normal water level of the Lake. This is considered the closest condition to reality. This scenario used the hydrograph obtained by HR BREACH as an upstream boundary condition for SOBEK 1D2D.

6. IMPACT OF THE ASWAN HIGH DAM FAILURE

The hypothetical failure of the AHD due to scenario 3 caused huge damages along the Nile River. These results are presented in Table (3). A breach was initiated at t =0 in the rock-fill part of the AHD. The breach developed progressively in 70.50 hrs and reached a depth of 31.21 m and a width of 444.55 m at a level of 164.79 m+MSL (bottom level of the breach). The maximum flow at the breach was 29569.42 m3/s. The flood wave reached Aswan Old Dam almost instantly. A maximum flow reached Aswan Old Dam was 29582.93 m3/s. After the AHD failure, the water level increased more than 12.0 m. The flood wave reached the Aswan City after 60 minutes. The maximum discharge was 29571.17 m3/s . The water level increased more than 15.0 m. A maximum velocity reached 3.04 m/s.

The water level at the New Esna Barrage is increased by 14.0 m with velocities ranged between 1 and 1.5 m/s. The flood wave arrived at the New Esna barrage after 12 hours. The maximum discharge of 12920.64 m3/s was attained. Luxor City was first touched by the flood wave after 13 hrs. The maximum flow of 12,261.84 m3/s was attained. The flow was associated with a water level increase of 18.0 m. Qena City was first touched by the flood wave after 17 hrs. The maximum flow 11715.09 m3/s, was attained. The water levels increased by 14.0 m.

Table 3: Hydraulics characteristics along the Nile River, (Scenario 3)

Distance from AOD (Km)	Description	Initial Water Level (m)	Max. Water Level (m)	Time of wave arrival(hour)	Max. Flow (m^3/s)	Max. Velocity (m/s)	Time of Max. water Level(hour)
0.00	US Aswan Old Dam	88.50	101.46	0	29,582.93	3.85	220
0.10	DS Aswan Old Dam	85.70	100.93	0	29,582.93	3.85	220
7.00	Aswan	85.28	100.92	1	29,571.17	3.04	222
50.00	Kom Ombo	83.20	100.03	2	24,775.95	1.62	250
111.00	Idfu	79.80	96.76	5	20,917.91	1.57	379
167.85	US New Esna Br.	79.00	93.58	12	12,920.64	1.02	545
167.95	DS New Esna Br.	73.93	93.38	12	12,920.64	1.02	545
223.00	Luxor	71.62	89.64	13	12,261.84	1.41	689
285.50	Qena	68.70	83.45	17	11,715.09	2.78	881
363.00	US Naga Hamadi Br.	65.40	74.21	23	11,051.16	1.81	1214
363.10	DS Naga Hamadi Br.	61.26	74.14	23	11,051.16	1.81	1214
405.00	Girga	58.76	71.49	26	10,141.75	1.14	1320
443.00	Sohag	55.74	67.21	29	9,918.06	1.99	1523
544.75	US Assiut Br.	49.50	57.18	39	9,691.54	1.43	1854
544.85	DS Assiut Br.	47.74	57.16	39	9,691.54	1.43	1854
684.00	El Menia	35.91	39.51	85	9,100.39	1.05	2477
805.00	Beni Suef	26.00	32.77	104	8,879.90	1.09	2900
907.00	Helwan	18.65	25.94	125	8,542.33	1.27	2906
930.00	Cairo	17.60	22.97	138	8,131.24	1.42	2911
953.50	US Delta Br.	16.28	21.88	143	6,440.98	1.84	2917

The flood wave reached New Naga Hammadi Barrage after 23 hrs. The maximum flow of (11051.16 m3/s) was attained. The water levels increased more than 8.0 m in the fore-bay. Sohag City was first touched by the flood wave after 29 hrs. The maximum flow of (9918.06 m3/s) was attained. The water levels increased by 11.0 m. The flood wave reached Assiut Barrage after 39 hrs. The maximum flow (9691.54 m3/s) was attained after 1854 hrs. The water levels increased by 7.0 m in the fore-bay. El-Menia City was first touched by the flood wave after 85 hrs. The maximum flow reached to (9100.39 m3/s). The water levels increased by 3.0 m. The flood wave reaches the Beni Suef City after 104 hrs. The maximum flow (8879.90 m3/s) was attained. The water levels increased by 6.0 m. Cairo was first touched by the flood wave after 138 hrs. The maximum flow (8131.24 m3/s) was attained. The water levels increased by 5.0 m.

The flood wave reached Delta Barrages after 143 hrs. The maximum flow (6440.98 m3/s) was attained. The water levels increased by 5.0 m in the fore-bay. Figure (11), shows the flow hydrographs at the hydraulics structures along the Nile River.

In general, water velocity ranged between 0.5 to 4.5 m/s according to the natural bed slopes, and the Nile cross-section width. After the failure, the velocity increased dramatically during the first few days. This increase in velocities extended from the failure site up to 400 km downstream the AHD. The first propagation wave takes about 143 hrs to travel a distance of 953 km downstream the AHD, while under the normal flow conditions, the time of water movement from AHD to the Delta Barrages takes 280 to 295 hrs, as shown in Figure (12).

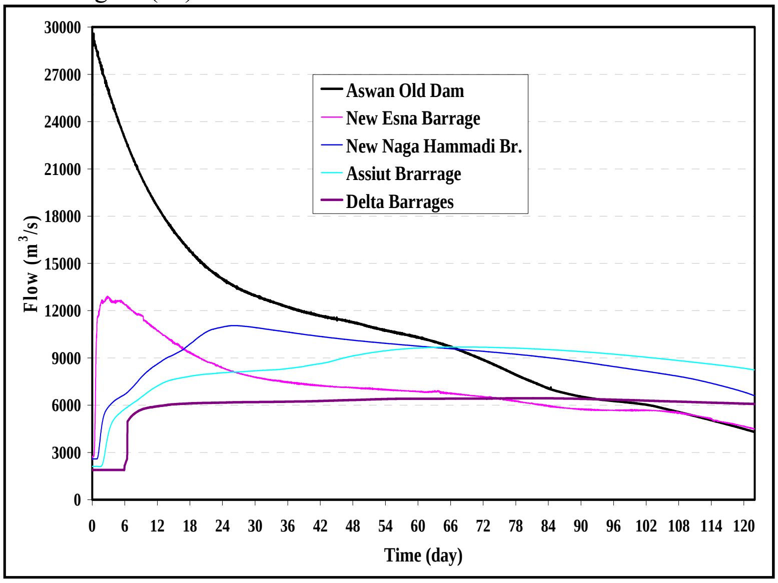


Figure 11: Hydrographs at hydraulics structures

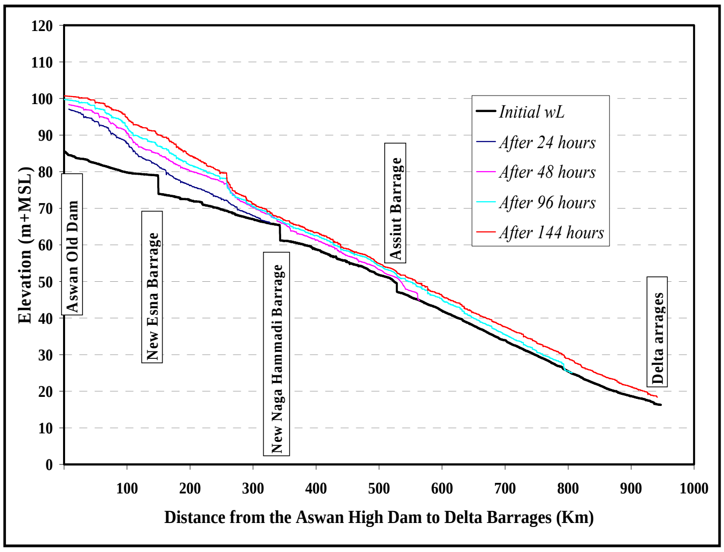


Figure 12: longitudinal profile of flood wave propagation

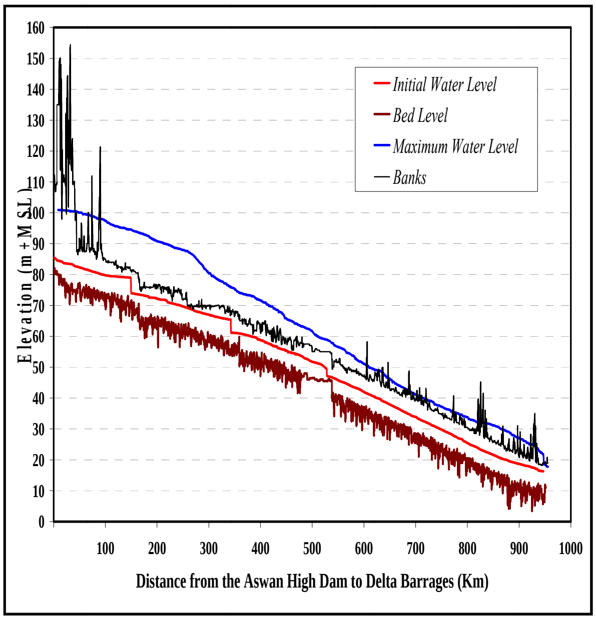


Figure 13: Peak water profile on the Nile River

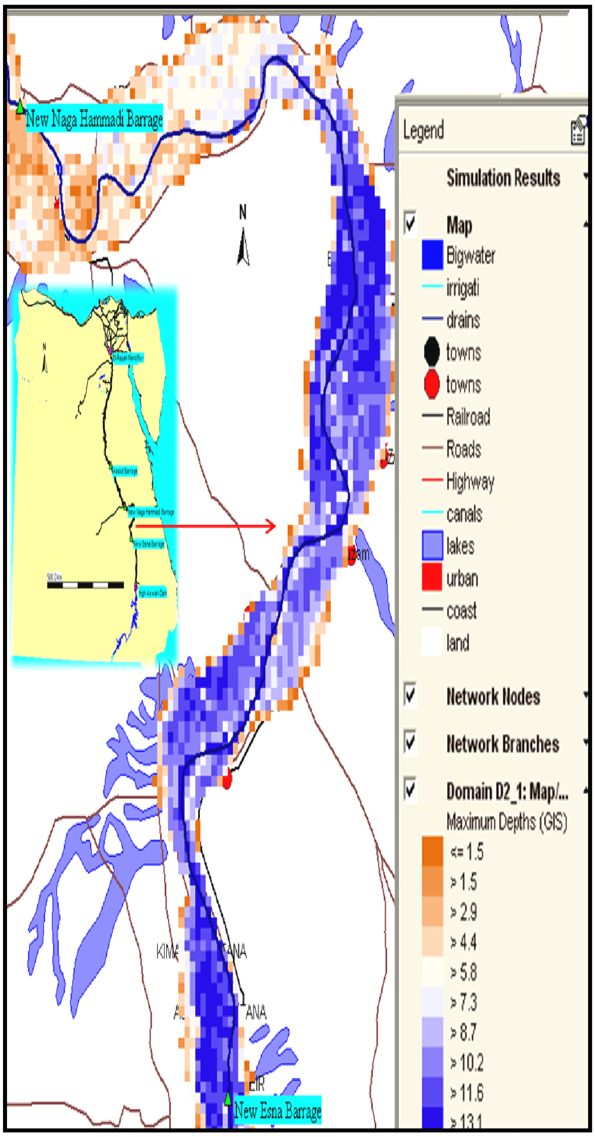


Figure 14: GIS map of inundated areas of reach 1

6.1. Banks Overtopping and Violation Sites

The model showed that, the overtopping occurred after about 5 hrs. The flooding continued for 4 months until the water level profile gets down. The banks were overtopped at all sites downstream the AHD, except some small areas between AHD, and Kom Ombo town at the first reach. Figure (13), shows the maximum water profile on the Nile River.

6.2. Inundated Areas and Maps (GIS database)

The total gross flooded area resulted from this scenario is about 13466.10 km2, all of it within the Nile Valley borders. Figure (14) shows the GIS maps of inundated areas, and the inundated depths for the second reach.

7. CONCLUSIONS

The following was concluded:
1- Aswan High Dam breach was simulated. Six breach scenarios were planned and simulated with HR BREACH model. These scenarios represent the three expected floods (minimum, average and maximum) to the lake at normal and maximum water level. The results of outflow hydrograph and the water levels of each scenario during the dam failure were obtained.

2- The maximum peak outflow of the AHD failure is 389009.69 m^3/s. This was in case of overtopping failure when, the inflow of hydrograph of year 1964/1965 was considered. The Nasser Lake contents and water level are 162.3 BCM and 182m +MSL respectively; the assumed initial breach is 10.0 m width, and 14.0 m depth in the rock-fill part of the AHD. The breach developed progressively in 95 hours and reached a depth of 62.11 m, and a width of 666.30 m, at level 133.89 m+ MSL.

3- Scenario (3) was chosen to be simulated by 1D2D model because it represents the maximum inflow and normal water level of the Lake. This is considered the closest condition to reality. In the case of the Aswan High Dam failure, major damages can be expected along the Nile Valley. The resulting flood wave propagated down the Nile causing the failure of all other dams by overtopping. The calculated flows were much larger than the discharge capacities of the main barrages except delta barrages. The wave travels down the Nile with a velocity that ranged between 0.5 and 4.5 m/s. The first propagation wave takes about 143 hrs to travel a distance of 953 km downstream the AHD. The total gross flooded area resulted for this scenario was about 13,466.10 km^2. All of it was within the Nile Valley borders.

8. ABBREVIATIONS

1D : One dimensional,
AHD : Aswan High Dam,
AOD : Aswan Old Dam.
BCM : Billion Cubic Meters,
d50 : Median grain size of sediment,
MCM : Million Cubic Meters, and
MSL : Mean Sea Level.

9. REFERENCES

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