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Morphological Changes of Reach Two of the Nile River

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ABSTRACT: This research will focus on studying the hydraulic impacts such as erosion, sedimentation and overtopping. For studying these impacts study area on the Nile River is determined between Esna barrage and Naga Hammadi barrage 192 km, at the period from 1982 to 2005. Two main sets of data were used in the analysis, includ the contour maps for the Nile River bed between Esna and Naga Hanmmadi barrages for the year 1982 and 2005. Cross sections were deducted from these maps at space of 4 kilometers. These cross sections were used to compare the 1982 and 2005 cross sections in order to calculate erosion and sedimentation quantities of 26 cross sections which are selected along the study reach. On the other hand, cross sections of year 1982 were input to the numerical model GSTARS in order to predict the flow stage corresponding to different discharges along the reach and sediment routing was performed. Finally, 2005 cross sections were used to develop water surface profile and to map the overtopping areas by future discharge of 4051m3/s using topographic maps. 16 sectors were affected by overtopping and it could be noted that the total areas are 794.82 feddans were mapped the major areas are in river islands as 531 feddans are mapped.

Keywords: Morphology, Overtopping, Erosion and sedimentation

1 INTRODUCTION

The Nile River in Egypt consists of four reaches from Aswan to Cairo and bifurcates into Rosetta and Damietta branches that discharge into the Mediterranean Sea.

There are five structures across the Nile River in Upper Egypt. They control the water levels and flow for considerable upstream distance. These structures are:

- High Aswan Dam
- Esna Barrage
- Naga Hammadi Barrage
- Assiut Barrage
- Delta Barrage

The main function of these barrages is to raise the water level and to provide additional head to the irrigation canals that supply the cultivated areas in Upper Egypt.

The Ministry of Water Recourses and Irrigation (MWRI) is constructing new barrages to replace the existing structures and to ensure the constant supply of water to the downstream. The new barrages incorporate as hydropower annex to utilize the natural resource of the Nile River for hydropower generation. They also improve the navigation in the Nile River via new locks. On the other hand, for any new barrage there are probable negative impacts such as:

Inundation of Agricultural land on river islands and areas adjacent to the river by overtopping

Impacts on river morphology by erosion and sedimentation

2 OVERVIEW ON ESNA BARRAGE

It exists across the river. It was constructed in 1908, 170 km downstream of Aswan, and 61 km upstream of Luxor to guarantee basin irrigation in the southern reaches of Upper Egypt.

The barrage is composed of 120 gates each 5.00 m in width separated by piers 2.0m thick to enable the conversion of the surrounding area to a perennial irrigation regime.

The barrage was remodeled between 1945 and 1947 to increase the available head from 2.5m to 5.0m.

In 1994, the New Esna Barrage was constructed, 1.2 km downstream of the existing structure and the objectives of the new Esna barrage were to:

Ensure improved water regulation for irrigation purposes

Avoid major repair works and maintenance on the old barrage

Maintain upstream water levels required for feeding both Asfoun and Kalabaya Canals without the requirement for pumping

Generate electric energy by utilizing the discharges and the corresponding heads on the barrage

Improve navigation facilities by constructing a new lock with large dimensions (160 x 17m)

Construct an alternative access road for the new barrage.

The power plant dimensions are 92 m long and 59.5 m wide, with six turbines and a maximum power output (installed capacity) of 13 MW each. The water levels upstream of Esna barrage fluctuate between 79.50 m and 77.0 m during the year while the downstream levels fluctuate between 75.50 m and 74.60 m.

3 STUDY OBJECTIVES

The objectives of the present research are to:

Evaluate the erosion quantity in the reach two.

Compute the sedimentation quantity in the reach two.

Determine the overtopping and land overflow quantity in the reach two.

4 IMPLEMENTED MODEL (GSTARS 2.0)

The implemented mathematical model for this analysis is GSTARS 2.0 Model. It is developed by the U.S. Bureau of Reclamation in 1998.

This model uses the flow pipes to simulate the effect of the two and three dimensional flow.

5 CAPABILITIES OF GSTARS 2.0

GSTARS could simulate generalized flow and sediment routing (U.S. Bureau of Reclamation, 1998). GSTARS 2.0 solves the energy equation based on the standard step method for backwater computations. The momentum equation is used for cases of change from subcritical to supercritical flow conditions.

It has a number of capabilities such as:

1. It has the proficiency of computing hydraulic parameters for open channels with fixed and movable bed boundaries.
2. It has the aptitude of computing water surface profiles for subcritical, super critical and mixed type flows.
3. It has the capability of predicting and simulating hydraulic and sediment variations in longitudinal and transverse directions.
4. It has the skill of predicting and simulating the change of alluvial channel profile and cross sectional geometry.
5. It has the competence of including special conditions such as channel side stability and erosion limits.

6 STUDY METHODOLOGY

To achieve the above objectives, a study methodology was set. The steps of this methodology were as follows:

Review the literature in the field of river engineering (i.e. morphological changes in the vicinity of structures in the rivers, impacts of barrages).

Accumulate data concerning the existing barrages (i.e. flow, topography, site conditions, socio - economic conditions, topographic so as contour maps, discharges so as water levels, cross sections, geometry, locations and bed grain size distribution).

Analyze the accumulated data and represent them.

Calculate water surface profiles, upstream and downstream the barrage under different scenarios, using a mathematical model.

Study the effect of sedimentation and erosion on a number of cross sections along the Nile River.

7 A. ASSEMBLYING REQUIRED DATA FOR GSTARS 2.0

Two main sets of data were assembled. The first set included the contour maps for the Nile River bed between Esna and Naga Hanmmadi barrages for the period 1982 and 2005. This data were produced by the Nile Research Institute. Cross sections were deducted from these maps at space of 4 kilometers. These cross sections were used for comparison purposes to calculate erosion and sedimentation quantity of 26 cross sections which are selected on the study reach. On the other hand, cross sections of 1982 were used in the mathematical model GSTARS.2 as input data to predict the flow stage corresponding to different discharges along the reach and sediment routing is performed. Cross sections of year 2005 were used to develop water surface profile and calculate overtopped areas by future discharge of 4051 m^3/s using topographic maps.

The second groups of data are water level at different gauging stations along the study reach and discharge downstream Esna Barrage of 10 days for the period from 1982 to 2005.

The discharge was measured at downstream Esna Barrage and the water level at downstream end (upstream Naga Hammadi Barrage) corresponds to minimum, average, and maximum water levels were used as boundary conditions.

Finally, average grain size distributions for study reach are used.

7 B. THE CALIBRATION RESULTS FOR WATER LEVELS

The discharge released through Esna barrage during the period from 1982 to 2005 was ranged from 550 m^3/s to 2830 m^3/s. The model calibration includes two scenarios 1000 and 2500 m^3/sec. The results of the model were compared by the actual data. Figures (1) and (2) show that the computed water surface profile of Gstars Model are close with the actual data.

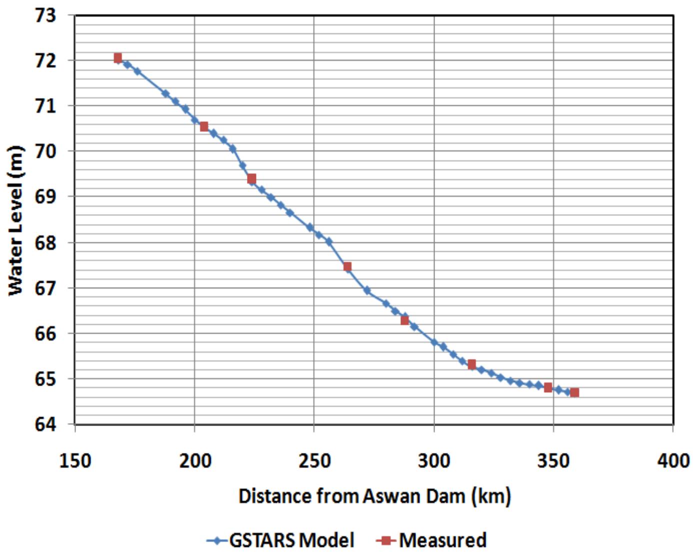

Figure 1. water level calibration for a flow of 1000 m3/sec

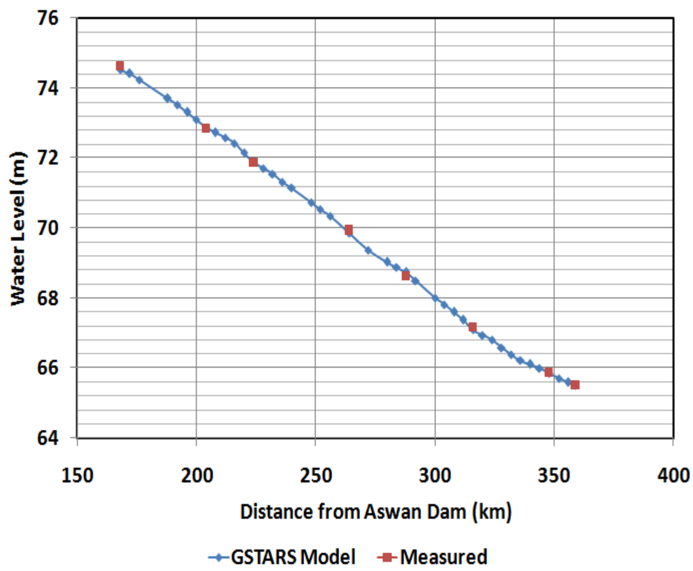

Figure 2. water level calibration for a flow of 2500 m3/sec

7 C. MODEL CALIBRATION FOR CROSS SECTIONS

The cross sections calibration is the second step of model calibration. The cross sections surveyed in 1982 used as an input file and compare the results of the model by the cross sections surveyed in 2005 to make sure that the model gives acceptable results.

From literature review it can be found that three methods, for predicting bed-material load discharge, are applicable to the Nile River and are widely accepted, (A. Moustafa and M. Aziz). These are Ackers-White (1973), Yang (1973) and Engluned and Hansen.

The method of Engluned and Hansen is used here. This method is based on the energy-balance concept.

Figures (3), (4), show some examples of the cross sections that are distributed along the reach under consideration. it is found that both the trend and values are very close. This means that the model could be suitable for simulation.

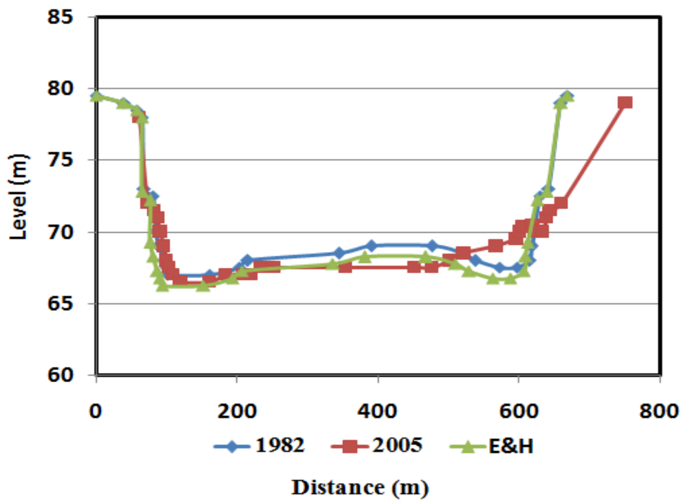

Figure 3. Cross section calibration for GSTARS 2 (km 188 from Aswan)

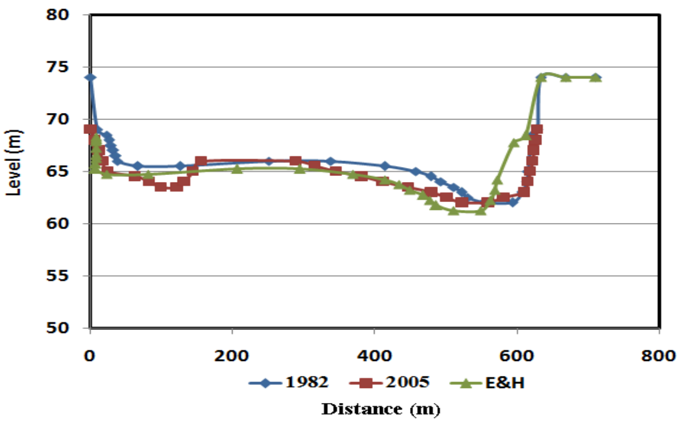

Figure 4. Cross section calibration for GSTARS 2 (km 264 from Aswan)

8 AREAS AFFECTED BY OVERTOPPING

To study the overtopping two sets of maps were used (i.e. contour maps for the Nile River bed between Esna and Naga Hanmmadi barrages and the topographic maps). Cross sections were deduced from these maps at 4.0 kilometers spacing's. These cross sections were used as input data to develop water surface profile corresponding to a future discharge of 4051 m^3/s in order to calculate and map the overtopping areas.

According to the water surface profile of 4051 m3/s, overtopping was detected. The study reach was divided into sectors 4.0 km apart, 16 sectors were affected by overtopping and it could be noted that the total areas are 794.82 feddans were mapped. The locations of affected sectors are shown on Figure (5).

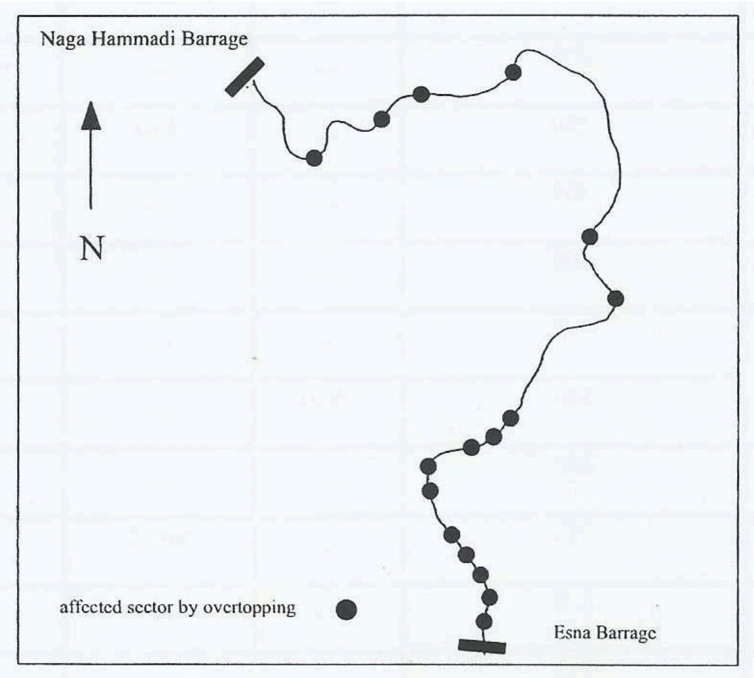

Figure 5. location of sectors affected by overtopping

8.1 *Land use of areas affected by overtopping*

To study the land use features for areas affected by overtopping, satellite images by Google map and topographic maps for study reach are used as shown in figure (6). Table (1) presents detailed description for the affected areas by overtopping.

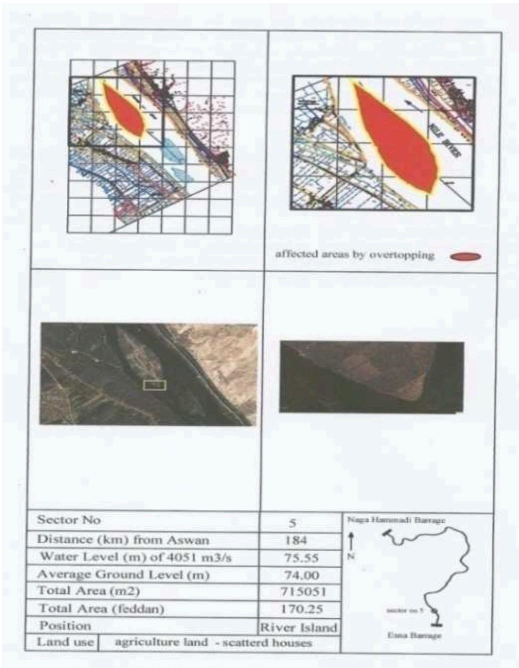

Figure 6. River Island that were full overtopped

Table 1. Land use of affected areas by overtopping

site	Sector No	Distance from Aswan Dam (km)	Land use
1	2	172	Wet land
2	3	176	Wet land
			Agriculture land
			Berth for boats
3	4	180	Agriculture land
			Water treatment plant
4	5	184	Agriculture land
			Scattered houses
5	6	188	Agriculture land
6	8	196	Wet land
			Agriculture land
7	9	200	Agriculture land
8	11	208	Agriculture land
			Scattered houses
9	12	212	Agriculture land
			Scattered houses
			Residential area
10	13	216	Residential area
11	20	244	Wet land
12	23	256	Wet land
13	34	300	Agriculture land
			Scattered houses
14	38	316	Agriculture land
			Berth for boats
15	40	324	Residential area
			Agriculture land
16	44	340	Agriculture land
			Scattered houses

9 SEDIMENTATION AND EROSION ANALYSIS

To study the impacts of erosion and sedimentation, two sets of maps were used (i.e. contour maps for year 1982 and the contour maps for year 2005). 26 cross sections were selected to study the erosion and sedimentation, Figure (7) Table (2).

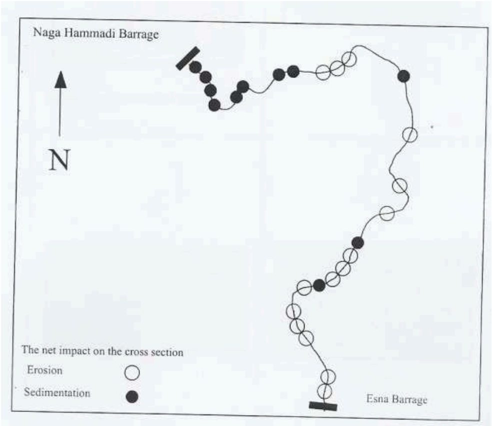

Figure 7. locations of cross sections that were affected by erosion and sedimentation

Table 2. erosion and sedimentation quantity for cross sections

Sec no	Distance (km) from Aswan	Area $_{1982}$ (m^2)	Area$_{2005}$ (m^2)	Area of Sedimentation (m2)	Area of Erosion (m2)	Net impact
1	172	3424.9	3463.3	549.1	587.5	E
2	176	2911	3342.7	208.9	640.6	E
3	188	2934.2	3232.7	168.6	467.2	E
4	192	3006.3	4298.5	132.5	1424.7	E
5	196	2591.6	3294.4	213	920.5	E
6	204	2634.5	2750.8	248.1	364.4	E
7	208	4690	4332	845.4	487.1	S
8	212	3488.8	3601.4	325.2	437.7	E
9	216	3234	3507	617	890	E
10	220	2500.8	2917.2	204.8	621.2	E
11	224	2808.3	2801.6	468	461.3	S
12	236	2632.6	2864.4	804.2	1036	E
13	248	2996.6	3014.1	280.4	297.8	E
14	264	2918.6	3432.6	23.7	539	E
15	280	3652.9	3355.5	575.9	277.8	S
16	300	2980.7	3189.7	331.3	540.3	E
17	304	2897.8	2951.1	112.2	165.6	E
18	308	3150.9	3220.5	286	355.7	E
19	316	2791.3	2482.9	335.5	27.2	S
20	320	3669.9	3515.5	329.4	204.9	S
21	332	3404.5	2607.9	851.5	54.9	S
22	336	3187.4	3013.8	560.2	386.6	S
23	344	3302.8	3246.2	161.9	105.2	S
24	348	3925	3800	606.3	482.5	S
25	352	3954.9	3386.3	656.2	87.9	S
26	356	3437.7	3062	528.2	152.3	S

E=erosion
S=sedimentation

10 IMPACTS OF VELOCITY DISTRIBUTION ON SEDIMENTATION AND EROSION

By studying the location of erosion and sedimentation, it was found that:

Degradation occurred at the downstream the hydraulic structure. (i.e. Esna Barrage) the velocity is ranged between 0.57 to 0.77 m/s at discharge 1000 m3/s and 2500 m3/s respectively.

Aggradation would occur upstream the hydraulic structures (i.e. Naga Hammadi Barrage) the velocity is ranged between 0.42 to 0.7 m/s at discharge 1000 m3/s and 2500 m3/s respectively.

The barrages disturbed the equilibrium of the stream due to velocity change Figure (8).

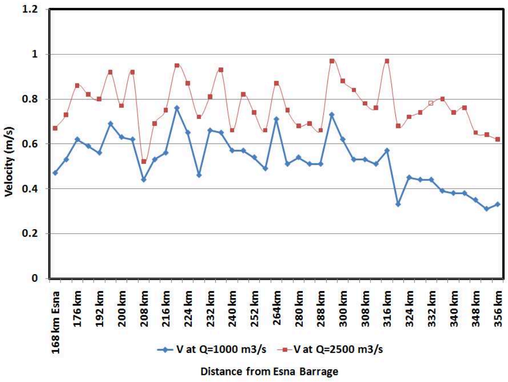

Figure 8. velocity distributions along the study reach

11 IMPACTS OF BEND CURVATURE ON EROSION PROCESS

As a river curves to follow the terrain, silt carried in the current is deposited on the inner edge of the curve due to the relatively slower currents. The current, at the outer edge of the curve, causes the river bank to erode and tends to widen the river at this point. Silt deposited on the inner curve section builds up to form a beach. The effect shifts the river very slowly in the direction of the eroded bank. Silt from the eroded bank travels on to be deposited at the next curve and so the river starts to meander, Figure (9).

It is clear that the erosion could be on the right bank, Figure (10) so as on the left bank, Figure (11).

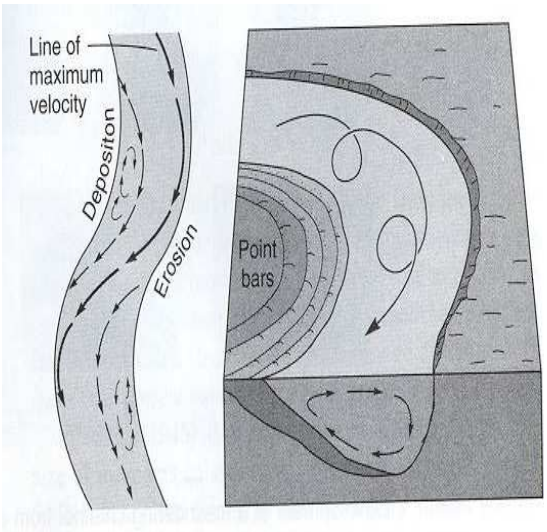

Figure 9. Impacts of bends on bank erosion

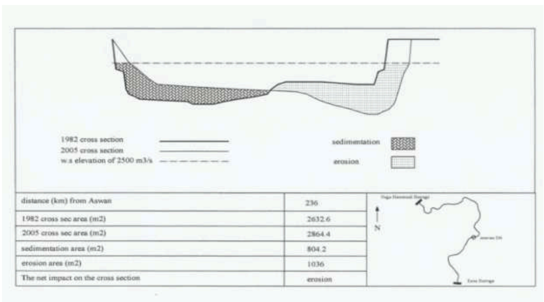

Figure 10. Impacts of bend curvature on bank erosion

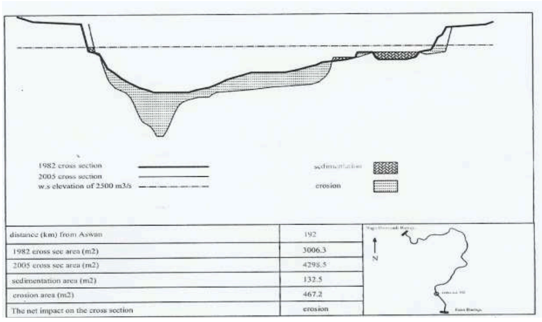

Figure 11. Impacts of bend curvature on bank erosion

12 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the present investigation, the following were concluded:

6. According to the water surface profile of 4051 m3/s (future discharge will be released from Esna barrage) the affected areas by overtopping were detected.
7. As the study reach is divided into 4.0 km apart sectors, 16 sectors are affected by overtopping and can be noted that the major areas are in river islands as 531 feddans are mapped.
8. The features of overtopping caused inundation for river islands, agriculture land and residential zones.
9. The barrages disturbed the equilibrium of the stream causing aggradation in the downstream reaches. This occurred at the upstream of the hydraulic structures due to velocity change. The length of the aggradation will extend for 47.45 km Upstream Naga Hammadi Barrage. The total volumes of sedimentation for the whole of the study reach equal 74.6 Million m3.
10. Degradation occurred due to the lack of sediment supply from upstream. The length of the degradation will extend for 38 km Downstream Esna Barrage. The total volumes of erosion for the whole of the study reach equal 86.78 Million m3.
11. Due to the river a curve, the current is deposited the sediments along the inner edge of the curve due to the relatively slow current.
12. The fast current at the outer edge of the curve eroded the river bank and tended to widen the river.
13. Silt deposited on the inner curve section builds up to form a beach.
14. The river shifted very slowly towards the direction of the eroded bank.
15. Silt from the eroded bank travels on to be deposited at the next curve and so the river starts to meander.

Also, some recommendations were given forward for future researches:

It is recommended to investigate the overtopping for study reach using different discharges with different boundary conditions.

It is advised to study the impacts of future discharge (4051m3/s) on erosion and sedimentation process for study reach using different time periods.

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