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Study of Sediments Accumulated of Tigris River in Al-Kut Barrage and Their Effect on Engineering Criteria of River Sections

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Abstract. The study was conducted on the Tigris River, in front of the Al-Kut Barrage. The study period continued (11 months), where six vertical sections were chosen upstream of Kut Barrage, the distance between one section to another was 100 m. The first section begins at 350 m from the front of Barrage. The result showed that variation in the discharge of Tigris River in upstream of Kut Barrage during the months of the study period, and it is noticed that the values of the discharge of the studied sections ranged from 117.35 m3/sec to 542.71 m3/sec, and the lowest average value of discharge was 217.84 m3/sec on August 2018, and the high average value of discharge was 411.19 m3/sec on February 2019. The values of velocity of the current water of the studied sections ranged from 0.121 m/sec to 0.567 m/sec, and the lowest value of velocity was 0.225 m/sec on August 2018, and the high average value of velocity was 0.402 m/sec on April 2019. The flow area of Tigris River ranged from 295.6 m2 to 2080. 8 m2 during the period of study. The depth of water levels of Tigris River ranged from 1.36m to 4.68 m, the area of accumulated sediments upstream of Al-Kut Barrage ranged from 1069.2m2 to 2854. 4 m2 during the period of study. The volume of the accumulated sediments upstream Al-Kut Barrage ranged from 139000m3 to 257740m3.

Keywords. Sediments, Accumulated, Engineering criteria, Al-Kut dam.

I. INTRODUCTION

Different sediments in rivers, streams, irrigation channels and reservoirs impact on amount of discharges of rivers design, irrigation and channels, as well as they impact on the cross-sections of those rivers, streams and channels. Thus, they effect on their efficiency in providing irrigation water for agricultural lands [1].

The rivers sediments are an important criterion and a good analytical guide for studying the sedimentation pattern. They are containing a mixture of primary and secondary minerals. They passed different regions and exposed to different conditions [2]. When Sediments arrive to dams, they begin to accumulate layers according to the newness of these sediments. Old sediments deposited in order first than the latest ones. They take this order as consistent pattern. Almost of these patterns are depending on the conditions of the river, its speed, water level and climatic conditions as well [3]. The study of these classes and their metal components give some indicators and good evidence in how these sediments contribute in some elements and minerals adding. The benefit of sediments was increasing the soil fertility or harmful ones, such as pollutants as known they are dangerous to public health [4].

The moving of sediment in rivers are occurring in three ways as following:

1. Suspended sediment: It consists of particles that carried by water and moved without touching the riverbed for a long time, and this is known as suspended load.
2. Riverbed sedimentary materials: It consists of materials that roll over on the bottom of the stream most of the time, and this is known as the bottom load or bed load.
3. The moving load: It is a medial case that lies between two limits and consists of suspended particles. They are moving on the bottom of the stream from time to time.

The geotechnical relationship between water and sediments depends on the properties of those sediments compared to the hydraulic properties of the water flow in the channel. Therefore, the properties of sediments in terms of engineering that the size of particles, distribution and movement influence from one location to another.

Sedimentation processes includes three steps:

1. Transferring sediments away from the sources of their emergence through the air media and water.
2. Deposition of the transported materials and their stability in depressions, rivers, streams, etc. Water plays a major role in the mentioned processes [5].

In the rivers, the geological structure of the basin, topography, nature of the soil, climate, natural vegetation, area of the basin and its characteristics have been an important impact on determining the amount of running water [6]. The ability of absorb the quantities of water surplus depends on the size of the river basin. As the occurrence of floods is an indication of the inability of the waterways in the basin to absorb the excess water in it [7]. Other factors that have been an impact on water discharge are suspended materials (sediments) that impact the water flow, as well as their impact on changing the course of the river, carrying capacity of irrigation channel and storage projects [8].

The differences of pressure between two points or a difference and a gradient in energy depends on the speed of the flow of water and its discharge. River flow means the seasonal variation in the amount of water flowing into it. Also, it due to the differences of the amount of rain. The degree of the river slope impact on the river flow and precipitation in the seasons of the year as well. In addition, the seasons of the year contribute to the speed of the flow of the river. Spring season is one of the seasons that contribute most to the speed of flow due to the compatibility between the fall of rain and the melting of the snow. Most of research notes that flow speed has been decrease and the lack of its size increase in its water temperature [9]. In rivers, the flow speed are differences from one section to another, as well as for the same section vertically and horizontally. The main factors that moving the water are gravity, which works vertically. As the velocity of the water speed at the surface is at its maximum and decreases as it moves towards the bottom [8].

The research aims of this study as following:

1. Evaluate the amount of accumulated sediments in the Al-Kut dam and determine how these sediments impact on the shape of the cross-section of the Tigris River and other engineering parameters of the river section.
2. Study the influence of the accumulated sediments of the dam on the discharge design of Al-Kut dam, Also, study its effect on useful age of Al_Kut dam as hydraulic construction was construct for irrigation purposes.

II. MATERIALS AND METHODS

This research has been conducted on the Tigris River (in front of the Al-Kut dam). The study period was (11 months), six sites sections has been selected in advance of the Kut dam. One hundred meters was the distance between one site and another.

The following measurements were taken:

1. Calculating the width of the river section from the top, the discharge of the river Q, and the velocity of the water speed m / s in the studied sections using the M-9 equipment, which is carried on a boat belonging to the Al- Kut dam department.
2. Evaluate the accumulated sediments size in front of the dam (m^3) in the studied sections.

Sediments areas m^2 = design section area m^2 - area of the river cross-section measured by equipment m^2

Sediments size m^3= (sediments area S1+ Sediments area S2/2)* Horizontal distance)

- **Water Samples**

Water samples were taken from the river for each section. These samples have been taken from three sites. The first site is located on the right side of the river, second site is in the middle of the river, and the third site is located on the left side of the river. Two water samples were taken from each location. First sample was taken at a depth of 0.2 from the river's water level, and the second at a depth of 0.8 from the river's water level.

Samples were collected at a rate of one time per month from the study sites, these was starting from August 2018 until June 2019. The time for collecting samples was at the same time (in the morning). Samples were taken by a modelling equipment for the purpose of conducting physical and chemical analyses of river water. For the sample analysis, 1 ml of (manganese sulfate solution) has been added in order to maintain the oxygen level until laboratory work. Also, by using a 2.250L, sealed polyethylene containers after they wished well in river water.

FIGURE 1. M-9 equipment carried on a boat in Experimental study.

- **Statistical analysis**

The data has been analysis by using Genstat programme for found least significant differences L.S.D (0.05) between samples. Also, SPSS programme has been used for regression and correlation.

III. RESULTS AND DISCUSSION

- **Discharge of the Tigris River**

Table (2) has been showed that the variation in the discharge of the Tigris River in upstream of the Al-Kut dam during the months of the study period. It was noticed that the discharge of the river increased on August 2018, as the rate of discharge of the studied sections was 217.84 m^3/ s. In November 2018, it increased to 268.05 m^3/ s during the month. Also, 294.01 m^3/ s on December 2018. The results showed that the highest value reached 411.19 m^3/ s during February 2019, and the river discharge was higher than this value during March 2019. The researcher was not able to measure the river flow during the mentioned month because the water levels of the Tigris River was too high in spring 2019. Also, the Ministry of Water Resources departments are busy following the flood wave and conducting reinforcement of the dam adjacent to the Tigris River to prevent the risk of flooding within the borders of Wasit Governorate.

In the mid- April 2019, the flood began to decrease in Tigris River (down south of Al-Kut city). River discharge rate was decreased to 309.23 m^3/ s on April 2019 in the study area sections. Then, the river discharge has been increased during May 2019, which has been reached 338.6 m^3/ s. It has been increased to 409.86 m^3/ s during June 2019 due to the increase in water released from Mosul Dam and Turkey as a result of the increase in water storage in the Mosul Dam and the Turkish dams. As well as, increased in rainfall rates during 2018/2019 in Iraq.

The results indicate that the velocity average of the water flow of the Tigris River in advance of the Al-Kut dam, starting from August 2018, which reached 0.225 m/ s, then increased to 0.29 and 0.228 m/ s on November and December 2018, respectively (Table 2). It has been reached the highest values, which was 0.36 and 0.402 m/ s on February and April 2019, respectively (Table 2), in which the peak of the river flooding increased on 2019, then the velocity of the water current began to decrease on May and June 2019, which reached 0.26 and 0.276 m/ s, respectively (Table 1).

- **The area of the river flow section**

Table (2) has been noted that an increase in the average area of the flow section during the December 2018 and February 2019, which was 1356.9 and 1180.026 m^2, respectively. It was compared with area of the river flow section during August and November 2018, which was 985.4 and 954.7 m^2. this is because the water levels were increased and the amount of discharge during the peak of the flood for the rainy months of 2018 and 2019. The average of area flow section has been decreased at the end of April 2019. After that, it recorded to increase again during May and June 2019 after increased water releases from Turkey and the Mosul Dam during these months. The depth average in this study was recorded on December 2018 and February 2019 as well, it was 2.84 and 3.36 m, respectively. Then, the average area of river flow has been decreased at the end of April 2019 after flood regression that reached to 770.0m^2.

It has been increased during May and June 2019. The average area of section flow for all sections were 1431.52 and 1511,03 m^2 for those months. This is because the different releases of water from Turkey and Mosul dam during these months.

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Table (2) showed that comparing the area of the flow section of the Tigris River (upstream of the Tigris dam) with the design section of the Tigris River, which is 3150 m^2 (Al- Kut Dam Department 2014). It was noticed that there is a decrease in the cross-section areas compared to the engineering design dimensions of the Tigris River.

TABLE 1. Hydraulic standards for the Tigris River section.

Sections	Date	Water discharge m^3/sec	velocity water rate m/s
S1	12/8/2018	182.73	0.184
S2		205.68	0.178
S3		200.97	0.206
S4		204.54	0.236
S5		199.37	0.195
S6		313.72	0.349
Average		217.84	0.225
S1	9/11/2018	304.96	0.333
S2		208.44	0.195
S3		227.54	0.187
S4		203.82	0.314
S5		325.15	0.336
S6		338.37	0.372
Average		268.05	0.29
S1	15/12/2018	326.89	0.365
S2		193.14	0.121
S3		354.52	0.224
S4		339.41	0.246
S5		359.73	0.269
S6		190.34	0.141
Average		294.01	0.228
S1	18/2/2019	300.62	0.202
S2		291.63	0.265
S3		313.72	0.314
S4		538.88	0.383
S5		507.42	0.431
S6		514.84	0.567
Average		411.19	0.36
S1	27/4/2019	346.6	0.388
S2		331.93	0.376
S3		352.58	0.415
S4		117.35	0.397
S5		347.88	0.395
S6		359.06	0.439
Average		309.23	0.402
S1	25/5/2019	301.97	0.358
S2		326.89	0.365
S3		209.23	0.139
S4		315.18	0.219
S5		310.05	0.189
S6		488.27	0.289
Average		338.6	0.266
S1	14/6/2019	261.62	0.155
S2		287.93	0.191
S3		307.66	0.218
S4		542.71	0.307
S5		523.38	0.390
S6		535.83	0.397
Average		409.86	0.276

The decrease ranges in the cross-section areas during the study period between 52.03% - 75.56%. the lowest percentage of decreasing in the average area of sections during April\2019 was 75.56%. Then, the average area of the

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river sections has been recorded next one (November 2018). It was decreased to 69.69%. Then, the average area of sections during August 2018, has been recorded decrease in the average design section area of the river by 68.72%, and the lowest percentage in the average area of the studied sections of the river compared to the area of the design section of the river. It was 52.03% during June 2019. It has been increased because they released the water from Mosul Dam and the Turkish dams, as mentioned previously.

- **Depth of the flow section**

Table (3) showed that there is a decrease in the hydraulic depth average of the Tigris River compared to the depth of the river design, which is 6m (Al-kut dam Dept. 2020). It has been recorded that hydraulic depth rates in sections during the months of the study ranged between 2.05 -3.35m. The lowest depth average for the sections was 2.05m during the November 2018. The depth design has been decreased to 65.83%, while the highest average depth average for the sections was 3.35m during February 2019. The depth has been recorded 44.17% because the accumulation of sediments provided by the dam in the sections as shown in Table (2).

- **Sediments accumulated upstream Kut-dam**

The sediments accumulated in sections during the months of the study has been ranged between 820260 m^3 on June 2019, and 1198570 m^3 during April 2019. The amount of sediments accumulated upstream of Al-kut dam during, August, November, December\2018 was 3045095m^3them increased during February, April, May, and June months have been recorded 3848370 m^3, with increase of 26.38% in the load of sediments accumulated. This is because the sediments suspended has been increased in flood season 2019. It was 320.02, 209.9, 229.12 and 323.8 kg/s for February, April, May, and June 2019 respectively, while the load of suspended sediments in the river has been recorded 146.24, 180.88 and 199.29 kg/s, for August ,November and December\2018 respectively (Table 4). This study has been agreed with [10].

This is study has been found that the left bank of the Tigris River upstream of the Al-Kut dam, is characterized by the presence of dense growth of reed, sedge and algae plants. This condition causes a decrease in the velocity of the water current and, therefore, increased sedimentation and accumulation of load suspended in the river near this bank. It has been affected on the discharge design of the dam. Also, the amount of accumulated sediments in the Tigris River was estimated at the front of Al-Kut dam and within 350 m from the left side. The quantities of accumulated sediments in the front of the Al-Kut dam during 2018 was 667340.3 m^3 for 500m and 305545m^3 for the same distance for 2013 (Al-Kut Dam Department, 2020) (Table 4). In addition, the estimated accumulated sediments in the bottom of the Tigris River section has been recorded about 560500 m^3 for a distance 500 m in the front of the dam [10], while the accumulated sediments in front of the Al-Kut Dam Department were estimated 1197180 m^3 at a distance of 1 km north of the dam on 2018 (Al-Kut Dam Dept. , 2020).

The accumulated sediments which is recorded from the dam will lead to a decrease of hydraulic depth rate and cross-sectional area of the Tigris River upstream of the dam compared to the original engineering dimensions of the river at the Al-Kut dam. [11], have been found same results in the Al-Musayyib project. The annual increasing of accumulated sediments in the north of the Al-kut dam will reduce the river's capacity to accommodate large discharges during flood seasons. Therefore, reducing the river's ability to absorb the flood wave during rainy [12].This will increase the water levels in the front of Al- Kut dam. The accumulated sediments on the left side of the river causes a high pressure on the section of the gates without the other gates of the dam. It will effect on the stability of the dam structure and as well as the gates movement. Thus, the sediments cause that stored water will decrease in the dam because occupy a large part of the volume of the riverbed upstream of the dam .

- **Concentration of suspended sediments**

The average concentration of suspended sediments in the waters of the Tigris River for the studied sections has been recorded 671.83 mg/L for the studied sections during of August 2018 and 762.83 mg/L for the studied sections during June 2019. The results showed that the concentration of suspended sediments in the waters of the Tigris River at 2019 higher than monthes 2018 (Table 5). The highest concentrations were 674.83 - 676 mg/L at 2018, while 676 - 762.83 mg/L at 2019. It has been found that most of the lands located in the Tigris River feeding basin are poor in their cover. The soils of these lands are subject to erosion [13-15].

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TABLE 2. Amount of sediments (m^3) in front of Al-Kut dam during study period.

Date	section	Design Area (m^2)	Flow area (m^2)	Sediments area (m^2)	Sediment area Average (m2)	Distance (m)	accumulated sediments (m^3)
	S1	3150	993.1	2156.9			
	S2	3150	1155.5	1994.5	2075.7	100	207570
	S3	3150	975.6	2174.4	2084.45	100	208445
	S4	3150	866.7	2283.3	2228.85	100	222885
12/8/2018	S5	3150	1022.4	2127.6	2205.45	100	220545
	S6	3150	898.9	2251.1	2189.35	100	218935
Average			985.4		2156.8		
Total							1078380
	S1	3150	915.8	2234.2			
	S2	3150	1067.9	2081.1	2157.65	100	215765
	S3	3150	1216.8	1933.2	2007.15	100	200715
	S4	3150	649.1	2500.9	2217.05	100	221705
9/11/2018	S5	3150	967.7	2182.3	2341.6	100	234160
	S6	3150	909.6	2240.4	2211.35	100	221135
Average			954.7		2186.9		
Total							1093480
	S1	3150	895.6	2254.4			
	S2	3150	1596.2	1553.8	1904.1	100	190410
	S3	3150	1582.7	1567.3	1560.55	100	156055
	S4	3150	1379.7	1770.3	1668.8	100	166880
15/12/2018	S5	3150	1337.3	1812.7	1791.5	100	179150
	S6	3150	1349.9	1800.1	1806.4	100	180640
Average			1356.9		1746.3		
Total							873135
	S1	3150	1488.2	1661.8			
	S2	3150	1100.5	2049.5	0855.65	100	185565
	S3	3150	999.1	2150.9	2100.2	100	210020
	S4	3150	1407.0	1743.0	1946.95	100	194695
18/2/2019	S5	3150	1177.3	1972.7	1857.85	100	185785
	S6	3150	908.0	2242.0	2107.35	100	210735
Average			1180.0		1973.6		
Total							986800
	S1	3150	893.3	2256.7			
	S2	3150	882.8	2267.2	2261.95	100	226195
	S3	3150	849.6	2300.4	2283.8	100	228380
	S4	3150	295.6	2854.4	2577.4	100	257740
27/4/2019	S5	3150	880.7	2269.3	2561.85	100	256185
	S6	3150	817.9	2332.1	2300.7	100	230070
Average			770.0		2397.1		
Total							1198570
	S1	3150	843.5	2306.5			
	S2	3150	895.6	2254.4	2280.45	100	228045
	S3	3150	2080.8	1069.2	1661.8	100	166180
	S4	3150	1439.2	1710.8	1390.0	100	139000
25/5/2019	S5	3150	1640.5	1509.5	1610.15	100	161015
	S6	3150	1689.5	1460.5	1485.0	100	148500
Average			1431.5		1685.5		
Total							842740
	S1	3150	1687.9	1462.1			
	S2	3150	1507.5	1642.5	1552.3	100	155230
	S3	3150	1411.3	1738.7	1690.6	100	169060
	S4	3150	1767.8	1382.2	1560.45	100	156045
14/9/2019	S5	3150	1342.0	1808.0	1595.1	100	159510

	S6	3150	1349.7	1800.3	1804.15	100	180415
Average			1511.0		1640.5		
Total							820260

TABLE 3. Measured sections during the study periods.

Date	section	Water depth (m)	Water flow area m^2
	S1	1.81	993.1
	S2	2.56	1155.5
	S3	2.35	975.6
	S4	2.59	866.7
12/8/2018	S5	2.32	1022.4
	S6	1.79	898.9
average		2.15	985.36
	S1	1.49	915.8
	S2	1.65	1068.9
	S3	3.52	1216.8
	S4	1.54	649.1
9/11/2018	S5	1.79	967.7
	S6	2.29	909.6
average		2.05	954.65
	S1	1.75	895.6
	S2	2.93	1596.2
	S3	3.06	1582.7
	S4	2.85	1379.7
15/12/2018	S5	3.34	1337.3
	S6	3.59	1349.9
average		2.84	1356.9
	S1	2.81	1488.2
	S2	4.04	1100.5
	S3	3.26	999.1
	S4	3.75	1407.0
18/12/2018	S5	3.13	1177.3
	S6	3.1	908.0
average		3.36	1180.02
	S1	1.77	893.3
	S2	1.83	882.8
	S3	2.48	849.6
	S4	2.78	295.6
27/4/2019	S5	2.28	880.7
	S6	2.58	817.9
average		2.29	769.98
	S1	1.36	843.5
	S2	1.75	895.6
	S3	3.36	2080.8
	S4	3.48	1439.2
25/5/2019	S5	4.68	1640.5
	S6	3.76	1689.5
average		3.07	1431.52
	S1	3.04	1687.9
	S2	3.53	1507.5
	S3	3.26	1441.3
	S4	3.96	1767.8
14/6/2019	S5	2.37	1342.0
	S6	2.69	1349.7
average		3.14	1511.03

TABLE 4. The quantities of accumulated sediments (m^3) of the front of the Al-Kut dam, 2018.

Measured time	Sediments volume accumulated (m^2)	Averag area accupied by sediments m^2	Area accupied by sediments m^2	Distance (m)	section
			1516.34	50	0+0
	71453	1429.06	1341.78	50	0+50
	70522	1410.44	1479.1	50	0+100
	68731.5	1374.63	1270.15	50	0+150
2018	109600	137	1469.85	80	0+230
	101943.8	1456.34	1442.83	70	0+300
	132396	1323.96	1205.08	100	0+400
	112694	1126.94	1048.8	100	0+500
		Total= 667340.3			

TABLE 5. The suspended and sediments of the Tigris River.

Date	section			
	S1	668	122.06	11.2
	S2	673	138.42	11.76
	S3	668	134.25	11.62
12/8/2018	S4	670	137.04	11.34
	S5	676	133.58	11.62
	S6	676	212.07	12.02
average		670.83	146.24	11.59
	S1	675	205.85	12.25
	S2	673	140.28	11.80
	S3	671	152.68	12.10
9/11/2018	S4	670	136.56	11.76
	S5	676	219.8	12.35
	S6	680	230.09	12.72
average		674.16	180.88	12.16
	S1	676	220.65	12.20
	S2	668	129.98	11.52
	S3	681	241.43	12.52
15/12/2018	S4	680	230.8	12.3
	S5	683	245.7	13.38
	S6	668	127.15	11.37
average		676	199.18	12.25
	S1	676	202.92	12.63
	S2	676	196.85	12.60
	S3	676	212.07	13.75
18/2/2019	S4	876	472.06	14.25
	S5	818	415.07	13.86
	S6	818	421.14	14.23
average		756.3	320.02	13.55
	S1	678	234.99	12.42
	S2	678	225.05	12.26
27/4/2019	S3	681	240.11	13.08

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	S4	666	78.16	11.80
	S5	680	236.56	12.48
	S6	681	244.52	13.13
average		677.3	209.9	12.53
	S1	675	203.83	12.63
	S2	676	220.98	12.9
	S3	671	194.07	12.41
	S4	676	213.06	12.9
25/5/2019	S5	675	209.28	12.65
	S6	683	333.49	13.39
average		676	229.12	12.9
	S1	673	176.07	12.04
	S2	673	193.78	12.20
	S3	675	207.67	12.85
	S4	886	480.84	14.25
14/9/2019	S5	835	437.02	13.64
	S6	835	447.42	13.72
average		762.83	323.8	13.12

IV.CONCLUSION

Form these results, this research has been calculated that the volumes of sediments accumulated in the study sections during the period has been recorded between 820 260 – 1198570 m^3. The accumulated sediments in the studied sections during 2019 increased by 26.38% compared to the volume of accumulated sediments in the studied sections during 2018. It has been found that increasing the load of suspended sediments in the Tigris water during 2019 compared to the load of sediments suspended in the river during 2018. Finally, the accumulation of sediments in the left bank of the river effects on the gates movements and exerts high pressure on the other gates, which leads to operational problems of the origin of the dam.

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