The influence of the Mosul dam on the bed sediments and morphology of the River Tigris

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Abstract The Mosul dam and its flow regulating scheme have been constructed 60 km north of Mosul city. A minimum discharge of 330 $m^3 s^{-1}$ is usually released from the dam. The reach of the River Tigris below the dam (about 8.3 km long) investigated in this study serves as a small reservoir for the regulating scheme. The effects of high velocity discharges from the bottom outlet and spillway structures on channel morphology were monitored for two periods using fixed cross-sections. The characteristics of the bed sediments were studied using 32 samples. The results showed that large amounts of sediment (average 0.5 m) were eroded from the bed of the river during a 10 month period. The bed sediments were characterized by a sand:silt:clay ratio of 42.4:50.2:7.4 respectively and it is believed that lining of the bed of the river downstream of the bottom outlet and spillway would reduce the scour downstream.

INTRODUCTION

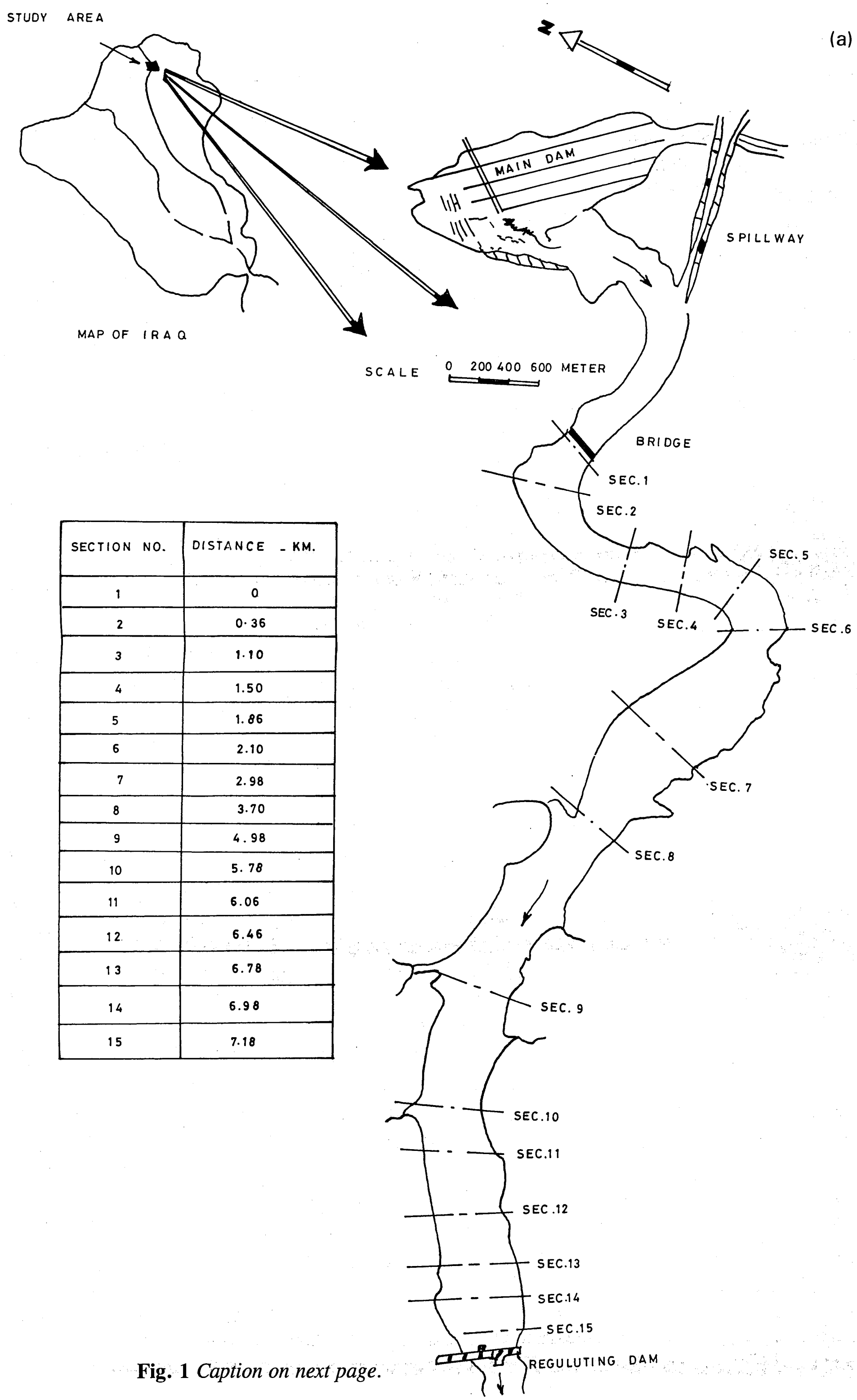
Serious problems arise when river beds are subjected to high velocity water jets downstream of dams. Extremely high rates of scour and erosion can occur below such jets and under certain conditions these could cause structural failure. Furthermore, water jets enhance the downstream movement of sediment both as bed and suspended load. In this study the geometry and bottom sediments of an 8.3 km reach of the River Tigris downstream of the Mosul dam and upstream of the regulating scheme was monitored during the period 1990-1991.

HYDROLOGICAL CONDITIONS

The Mosul dam

The Mosul dam is located 60 km north of Mosul city (Fig. 1). Its capacity is $17.4 \times 10^9 m^3$ at a maximum operating level of 257 m a.s.l. The dead storage is $7.6 \times 10^9 m^3$. Water from the reservoir is discharged through the dam via the power house tunnels, the spillway and/or the bottom outlet of the dam. The use of these outlets depends on the hydrological conditions and water requirements downstream (Al-Ansari *et al.*, 1990, 1992).

The water released is impounded downstream of the Mosul dam and upstream of the regulating scheme in a reach of the River Tigris about 8.3 km long. The amount



SECTION NO.	DISTANCE – KM.
1	0
2	0·36
3	1·10
4	1.50
5	1.86
6	2.10
7	2.98
8	3.70
9	4.98
10	5.78
11	6.06
12	6.46
13	6.78
14	6.98
15	7.18

Fig. 1 *Caption on next page.*

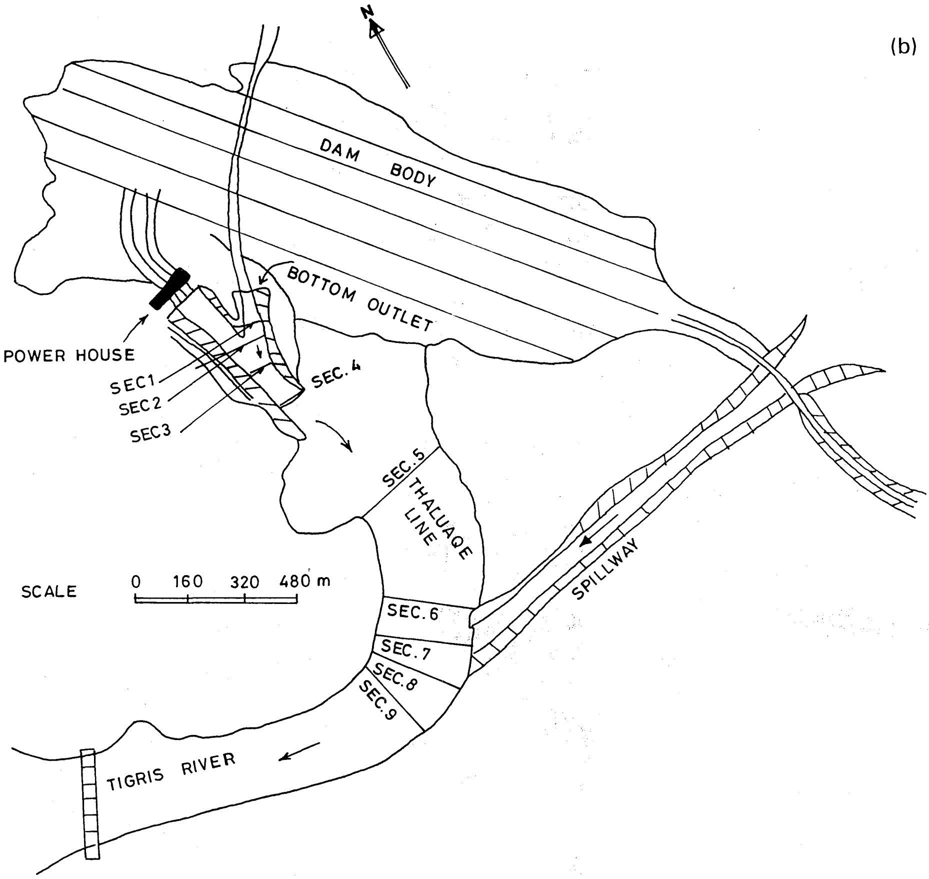


Fig. 1 Maps of the study area showing the location of the bed sampling sites (a), and the measured cross sections (b).

of water released depends on the amount needed for irrigation and power generation. A minimum discharge of 330 $m^3 s^{-1}$ is usually released through the Mosul dam to this reservoir.

The River Tigris

The mean daily discharge of the River Tigris before the construction of the Mosul dam was 663 $m^3 s^{-1}$. The maximum and minimum discharges recorded were 30 $m^3 s^{-1}$ (September 1925) and 7500 $m^3 s^{-1}$ (April 1963) respectively. The mean daily discharge since the construction of the dam is 823 $m^3 s^{-1}$. The maximum and minimum discharge were 5290 $m^3 s^{-1}$ (April 1988) and 117 $m^3 s^{-1}$ (September 1989) respectively for the same period (Al-Ansari *et al.*, 1990, 1992; Ministry of Irrigation, 1990). Large amounts of sediment (about 3500 m^3) were eroded from the river bank opposite the spillway during the high flood of 1988 (Al-Taiee *et al.*, 1990).

Table 1 Areal distribution of sediment on the bed of the River Tigris between Mosul dam and the regulating scheme.

Sediment type	Range (%)	Areal distribution (% total bed of river)
Clay (7.4%)	<1	37.2
	1-10	33.8
	>10	30.2
Silt (50.2%)	0-40	30.2
	40-60	34.8
	>60	34.9
Sand (42.4%)	0-20	46.5
	20-60	37.2
	>60	16.2

METHODOLOGY

During November 1990, 15 cross sections were surveyed across the River Tigris between the Mosul dam and the regulating scheme (Fig. 1(a)). Another nine cross sections were surveyed immediately downstream of the Mosul dam over a distance of 1320m (Fig. 1(b)). The former were used to collect 32 bottom sediment samples. The latter were monitored again in August 1991, to investigate the changes in the geometry of the cross sections.

The cross sections were surveyed using a boat with Raytheon echo-sounder. The positions of the points along each cross section were fixed using sextants. The bottom sediment samples were collected using a Van-Veen grab sampler.

BED SEDIMENTS

The results showed that the average sand:silt:clay ratio was of the order 42.4:50.2:7.4 respectively (Table 1). Furthermore, 29% of the samples were silty sand, 27% sandy silt, 24% silt, 10% sandy mud and 5% sand and mud according to Folk's (1954) classification. The areal distribution of the sediments on the bed of the study area (Fig. 2) indicates that each of the above types covered 24%, 28%, 31%, 13%, 1% and 3% of the total area (Fig. 3).

It is evident that coarse size fractions (mainly sand) cover the upstream reach near the main dam. Here the dominant sand percent is 40-60% followed by silt (0-40 and 40-60%) and clay (<1%). This is due to the relatively high flow velocity in the vicinity of the dam which transports fine sediment downstream. The contrary is true near the regulating scheme where the flow velocity is relatively low. The pattern evidenced by the areal distribution of the sediments indicates that water velocity is the most important factor controlling this distribution. Large sediment particles are confined to the upstream area where the flow velocity of the water released from the dam is high. On the other hand, the downstream areas are dominated by fine sediment particles (clay) due to the lower flow velocity.

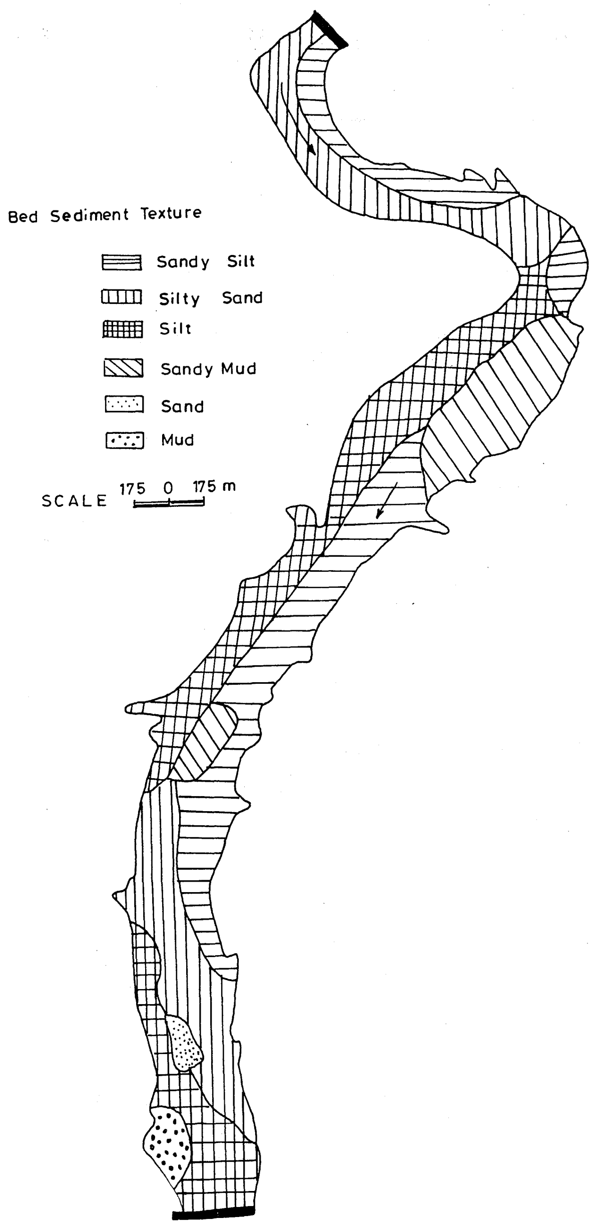


Fig. 2 The areal distribution of the bed sediments of the River Tigris within the study reach.

MORPHOLOGY OF THE REACH

The right bank in the study reach is characterized by steep ridges of alternating gypsum and limestone beds. Alluvial deposits comprise the bulk of the sediments forming the left bank which is characterized by gentler slopes. In general, the banks

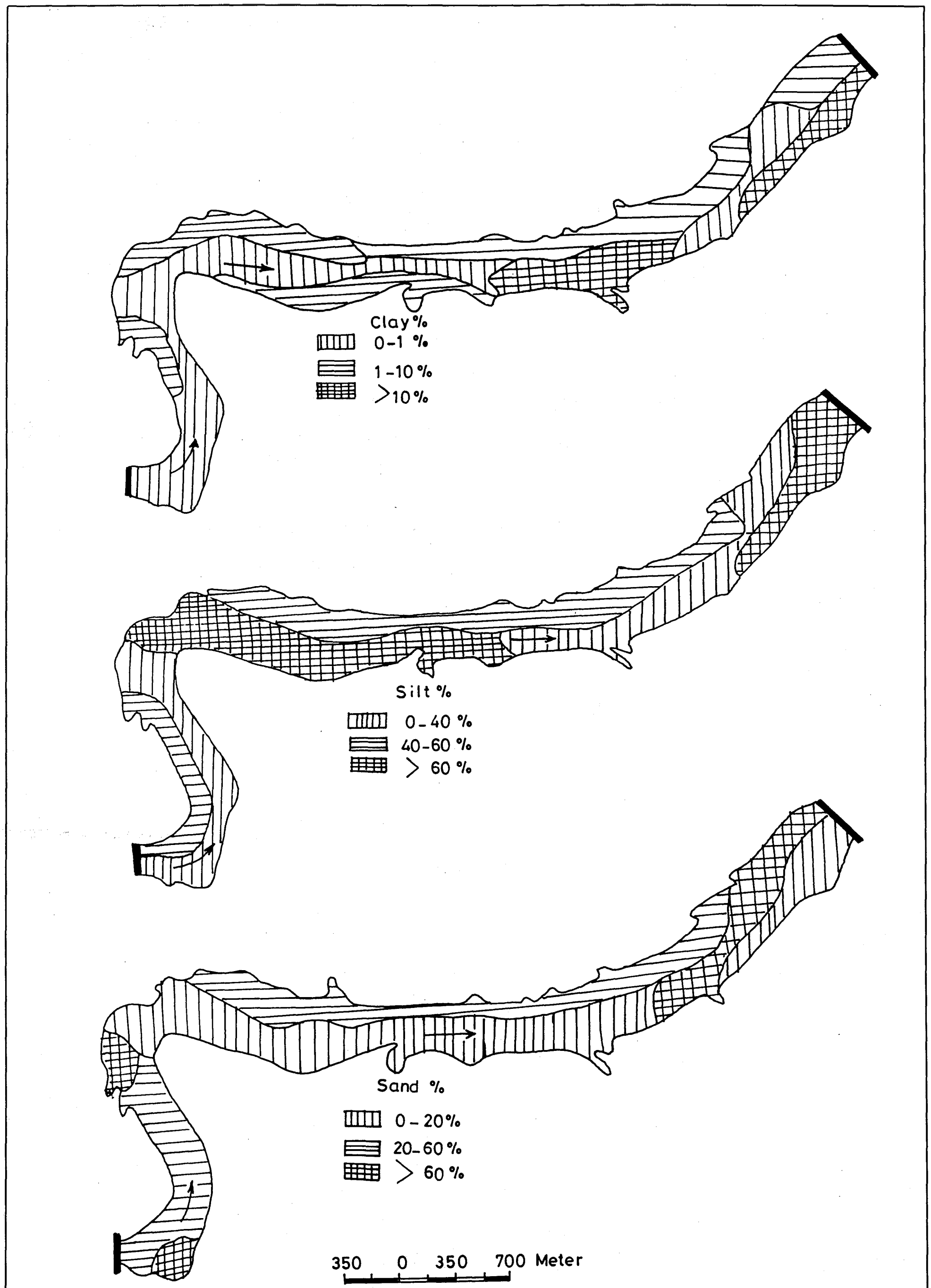


Fig. 3 The areal distribution of clay, silt and sand within the bed sediments of the study reach.

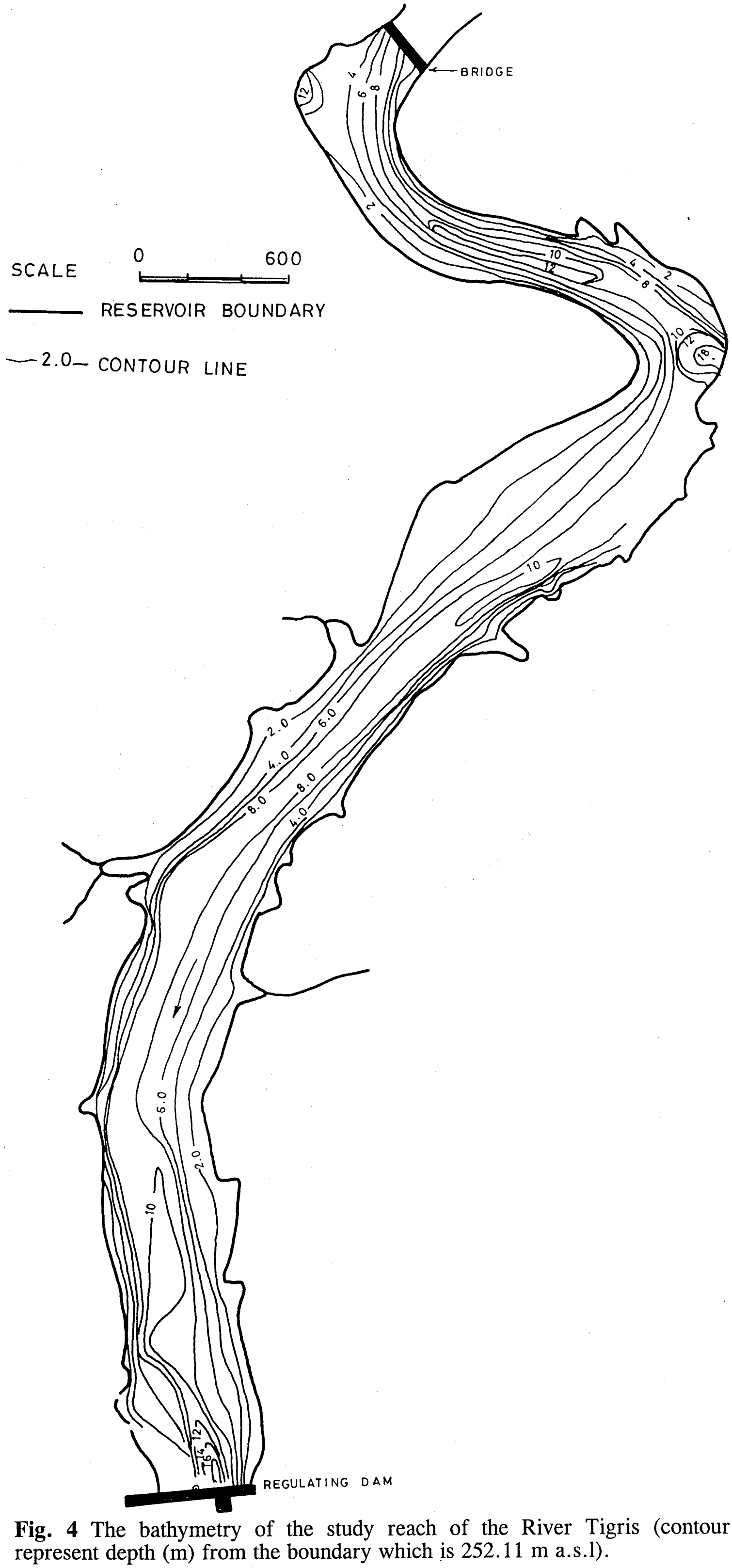


Fig. 4 The bathymetry of the study reach of the River Tigris (contour values represent depth (m) from the boundary which is 252.11 m a.s.l).

of the reach are more stable than the loose sediments of the bed due to the nature of the materials.

The cross sections surveyed at water level 253 m a.s.l (Fig. 4) indicate that the average depth ranges from 4 to 8 m. The maximum depth reached 18 m in cross section 6 (Fig. 1(a)). The average slope measured along the thalweg line reaches 1.5 m km^{-1} but it drops to 0.54 m km^{-1} when using the water surface measurements (Fig. 5). The slope was 0.48 m km^{-1} before the construction of the dam (see Nedico, 1976).

Some of the cross sections surveyed on two occasions (Fig. 6) show high rates of erosion, while others show relatively limited scour. Erosional rates depend on the position of the cross section relative to the dam. Near the bottom outlet high rates of scour are found and these reach 2 m in cross section 1. At cross section 2 (Fig. 6) the width of the river almost doubles causing a decrease in water velocity and consequently sedimentation in parts of the section. The shapes of cross sections 3, 4 and 5 reflect relatively normal erosional rates. The operation of the spillway after March 1991 caused relatively high rates of erosion in cross sections 6, 7, 8 and 9.

Emergency operation of the bottom outlet and spillway structures at the Mosul dam has caused some morphological changes in the river reach downstream of the dam. If the average depth is taken as an indicator of the scour; an increase of 0.5 m exists between the first and second survey (February and April 1991). Due to differences in the distribution of sediment and flow velocity, the rate of scour varied along the surveyed reach. Erosion and scour affected the thalweg line where it shifts in certain places (see Figs 5 and 6). Field observation and survey results suggests that the bed of the river downstream of the bottom outlet and spillway should be protected to reduce scour. In addition the use of riprap on the left bank of the river is recommended to stop or reduce erosion.

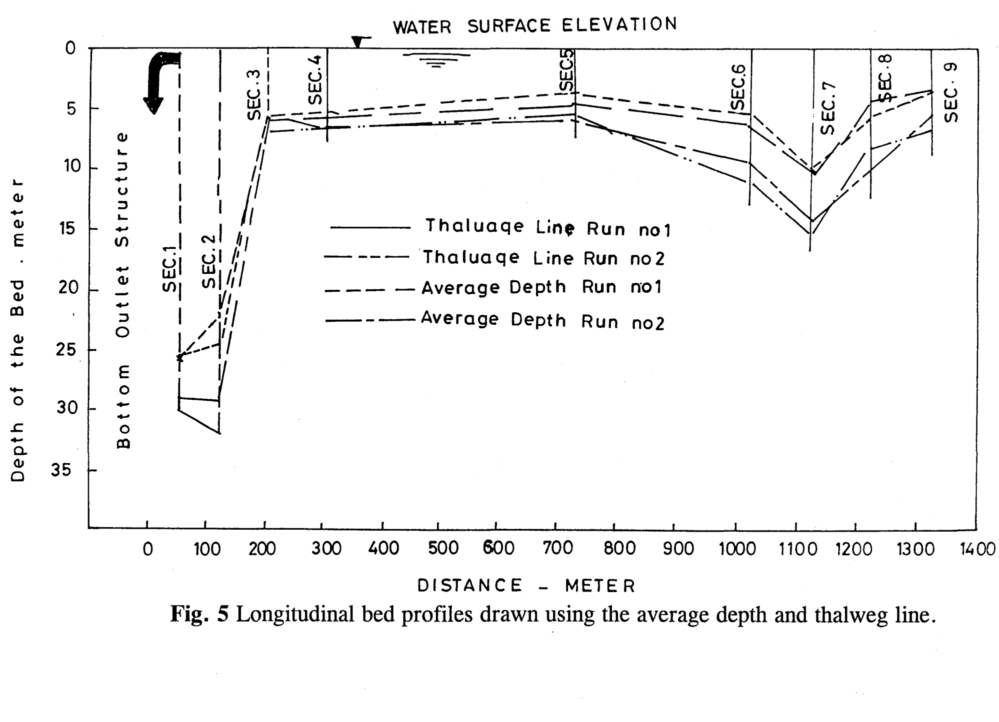


Fig. 5 Longitudinal bed profiles drawn using the average depth and thalweg line.

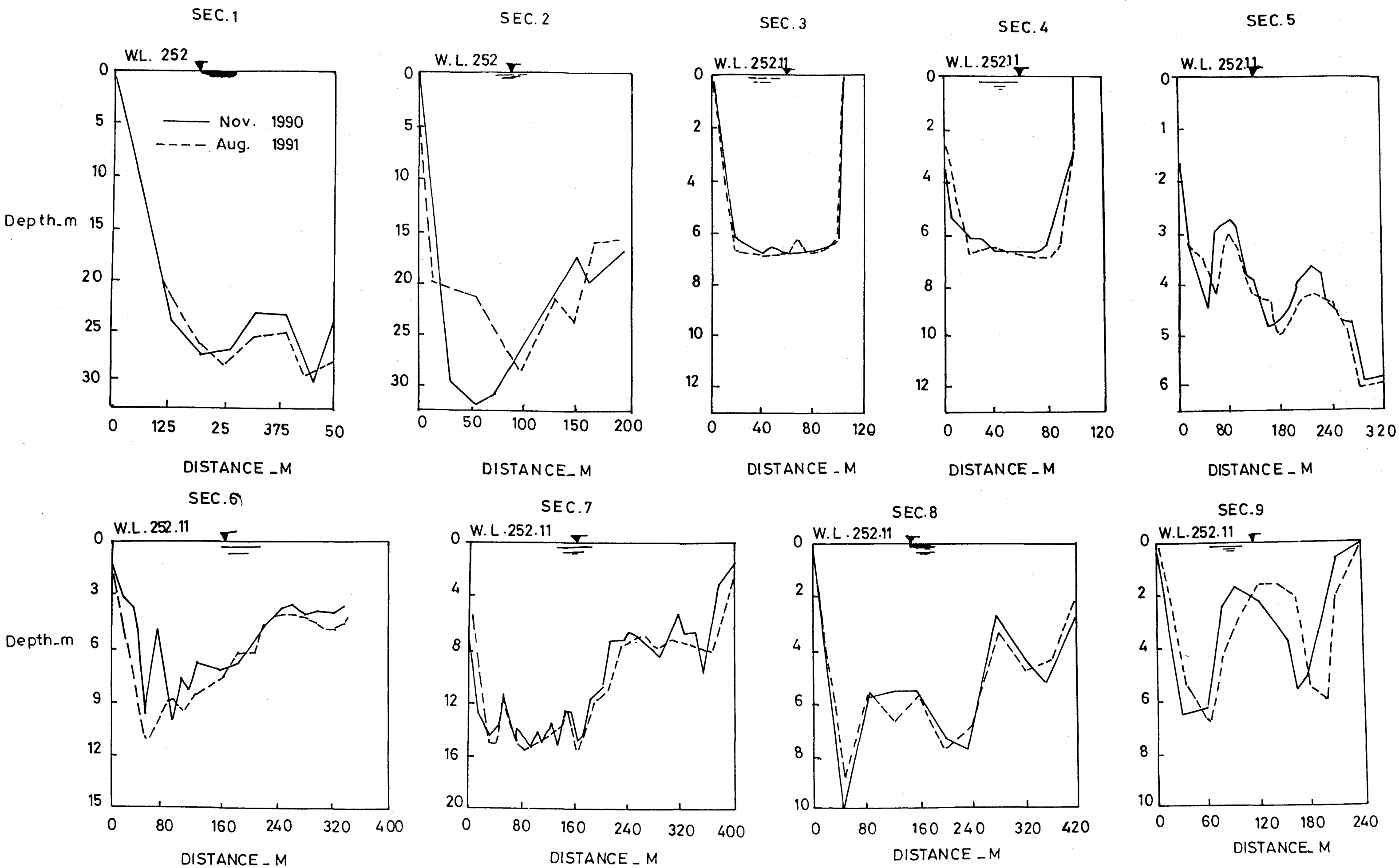


Fig. 6 Variation of the geometry of the river cross sections between November 1990 (____) and August 1991 (....). The location of the cross sections is shown in Fig. 1(b).

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