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DOMINANT DISCHARGE IN THE INDUS RIVER FROM DOWNSTREAM OF THE KOTRI BARRAGE DAM

WYZNACZENIE WARTOŚCI PRZEPŁYWU KORYTOTWÓRCZEGO PONIŻEJ ZAPORY KOTRI NA RZECE INDUS

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Abstract. Hydraulic data of the Indus River, downstream of Kotri Barrage dam are analyzed. An attempt has been made to determine the dominant discharge, which is defined as that discharge which over a long time period transports the most sediments and could be used to predict the shape of river cross-section. For dominant discharge calculation Wolman and Miller's approach has been applied. Since the transport of sediment concentration could be a more effective variable for forming the shape of the river cross-section, suspended sediment concentration has been introduced, because more than 85% of total load is in suspension. We show in the paper that water discharge $Q = 1000\ m^3 \cdot s^{-1}$ of water is a frequent discharge and carries maximum sediment load. This discharge we call here the dominant discharge (Q_{dd}) for the Kotri dam cross section.

Streszczenie. W pracy określono wartość przepływu korytotwórczego dla rzeki Indus w przekroju zapory Kotri Barrage. Wykonano próbę analizy przepływu dominującego jako tego, który jest zdefiniowany jako trwający przez długi okres oraz transportujący największą ilość rumowiska i może być stosowany do przewidywania kształtu przekroju poprzecznego

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rzeki. Do obliczenia przepływu korytotwórczego zastosowano metodę Wolmana and Miller. Wykazano, że przepływ wody $Q = 1000\ m^3 \cdot s^{-1}$ wody jest wartością, przy której następuje maksymalny przepływ rumowiska. Ten przepływ określa się jako przepływ dominujący (Q_{dd}) w przekroju zapory Kotri Barrage.

Key words: dominant discharge, dam, river

Słowa kluczowe: przepływ dominujący, zapora, rzeka

INTRODUCTION – THE AIM OF THE STUDY

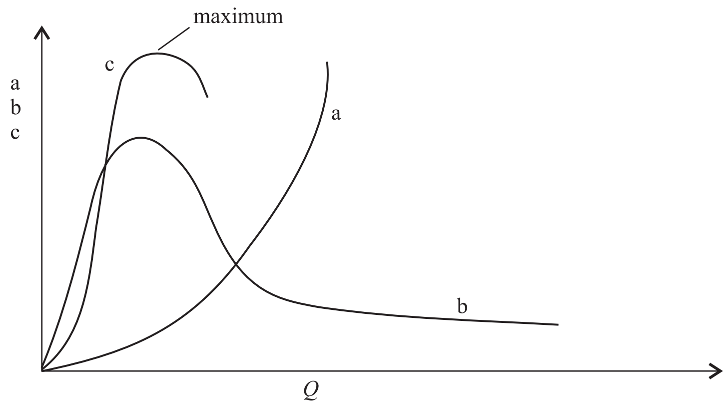
A river regime must be described by a common discharge which occurs frequent in the flow course, in order to have an applicable variable to transport most of sediment over a long time period therefore, the river morphology and its stretch as a consequence of river activity could be predicted. Hence the concept of dominant discharge has been introduced. There are many ideas and definitions connected with dominant discharge (Q_{dd}), some of which are reproduced below [Andrews 1979, Radecki-Pawlik 2000, 2011]:

1. The range of flows which, over a period of time, transport most of the bed-load.
2. The 1.58 year flood on the annual series used as a statistical definition of bankfull discharge.
3. The effective discharge – the increment of discharge that transports the largest fraction of annual sediment load over a period of years.

Also there are many methods for the determination of dominant discharge, including Makkaveev, Roshe, Schaffernak, Rzanicyn, van Berkelon, Laval, Gluszkow, Ljudin and Wierzbicki [Radecki-Pawlik 2011]. Having so many methods to approaching the dominant discharge yields results which are too different to allow conclusions to be drawn. It seems that this study needs further development. In order to develop the definition of dominant discharge, it is necessary to know the process of river formation. Suppose that the river has formed a stable single channel. The channel will be frequently overflowed by floods and the flood plains on either side of the channel will frequently have to carry this flood flow at quite low depths and velocities. Over-the-berm flow will therefore have much lower transporting power than the deeper, faster flow in the channel, and material will be deposited on the berm, slowly raising their surface level. This is how flood plains are built up [Wolman and Leopold 1957]. Erosion also has a significant influence. Therefore, frequency will play an important role in defining the dominant discharge. Magnitude and frequency of geomorphic forces were conceptualized by Wolman and Miller [1960]. They noted that in many instances land features were formed by relatively frequent geomorphic forces and not by rare catastrophic events. Figure 1 shows Wolman and Miller concept.

The magnitude or relative significance of a given discharge is represented by its sediment rate curve „a". The sediment transport rate T commonly varies proportionally with discharge Q to a power n rather than 1.

$$T = Q^n$$



a – suspended sediment transport curve
b – frequency of flood discharges
c – product of frequency and suspended sediment curve

Fig. 1. Wolman and Miller curve for explanation dominant discharge concept
Ryc. 1. Wykres klasyczny Wolmana i Millera objaśniający pojęcie przepływu dominującego

The frequency is given with curve „b" which is a distribution of stream flows. It can be easily seen that the largest discharges are rare. When combining them with frequency of occurrence and plotting on the curve „c" which is a product of „a" and „b" they aren't as important as lower floods which transport sediment more frequently. Radecki-Pawlik [2011] proposed the bed load transport variable instead of shear stress. However this study proposes frequent discharges and introduces suspended sediment concentration following Wolman and Miller [1960] foundings, because the major portion of sediment load is in suspension which could be a parameter responsible for forming the river bed.

The aim of the present study is to calculate the dominant discharge below the Kotri Barrage dam on the Indus River in Pakistan. To do so, hydraulic data of the Indus River – downstream of Kotri Barrage dam were analyzed. Since the transport of sediment concentration could be a more effective variable for forming the shape of the river cross-section, suspended sediment concentration has been introduced, because more than 85% of total load is in suspension. We show in the paper that water discharge $Q = 1000 \ m^3 \cdot s^{-1}$ of water is a frequent discharge and carries maximum sediment load.

MATERIALS, METHODS AND RESULTS

Data of suspended sediment concentration and water discharge for the years 1991–1993, during monsoon period from June–September, for the Indus River at the downstream of Kotri Barrage dam cross section, have been collected from the Irrigation Department, Sindh Province. These data have been used to determine the dominant discharge which could be applied for predicting the river shape. It is noteworthy that the Indus River is one of the biggest rivers in the world (21st in rank) rising in Himalaya in Kashmir and Tibet, receiving the Kabul River at Attack, and at Mithankot, 700 kilometers from its mouth, receiving the Punjnad, the combined waters of the five Punjab rivers. From Mithankot it flows as one great river to the sea. The collected data are shown in Table 1 which is given below. All calculations of sediment transport and dominant discharge are done according to Wolman and Miller concept [1960] in the figures 3, 4 and 5.

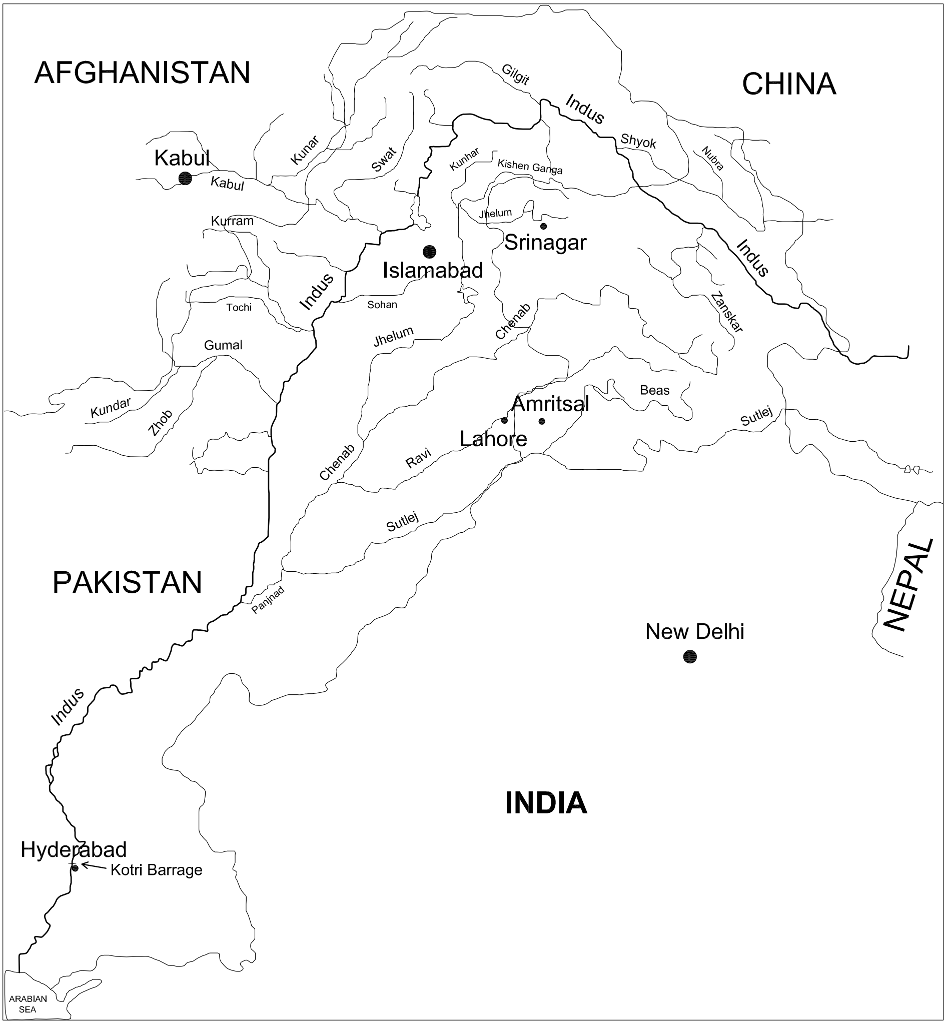


Fig. 2. Indus River and the Kotri Barrage dam
Ryc. 2. Rzeka Indus i zapora Kotri

Table 1. Hydraulic data of the Indus River at the downstream of Kotri Barrage dam
Tabela 1. Dane hydrauliczne dla rzeki Indus w przekroju zapory Kotri

No. Nr	Period Okres	Discharge Przepływ Q $m^3 \cdot s^{-1}$	Suspended load Rumowisko zawieszone Q_s $g \cdot l^{-1}$		
			S	M	B
1	1991	153.83–7677.41	1.12–2.50	1.14–2.56	1.16–2.62
2	1992	34.71–19094.80	0.44–2.60	0.57–2.64	0.62–2.68
3	1993	21.45–11037.23	1.148–2.61	1.164–2.68	1.198–2.78

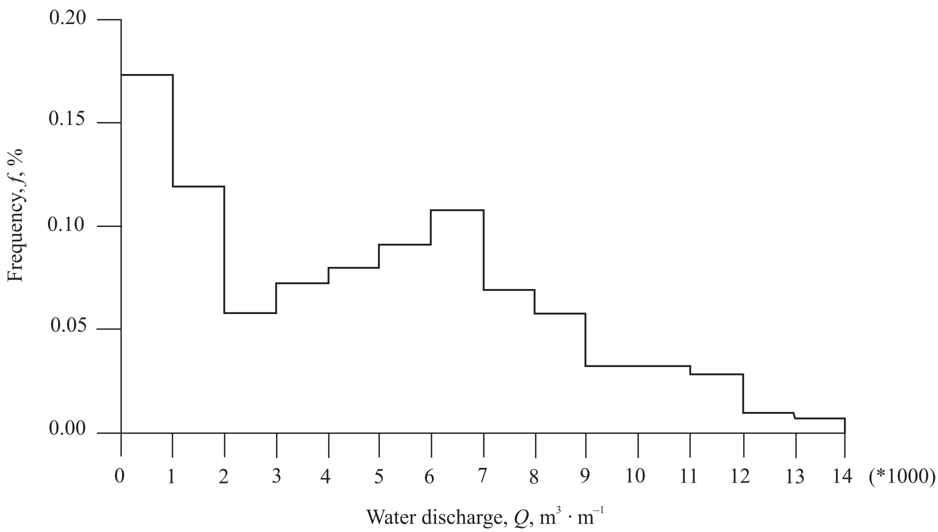


Fig. 3. Frequency graph in the Indus River and the Kotri Barrage dam cross section
Ryc. 3. Wykres częstości dla rzeki Indus w przekroju zapory Kotri

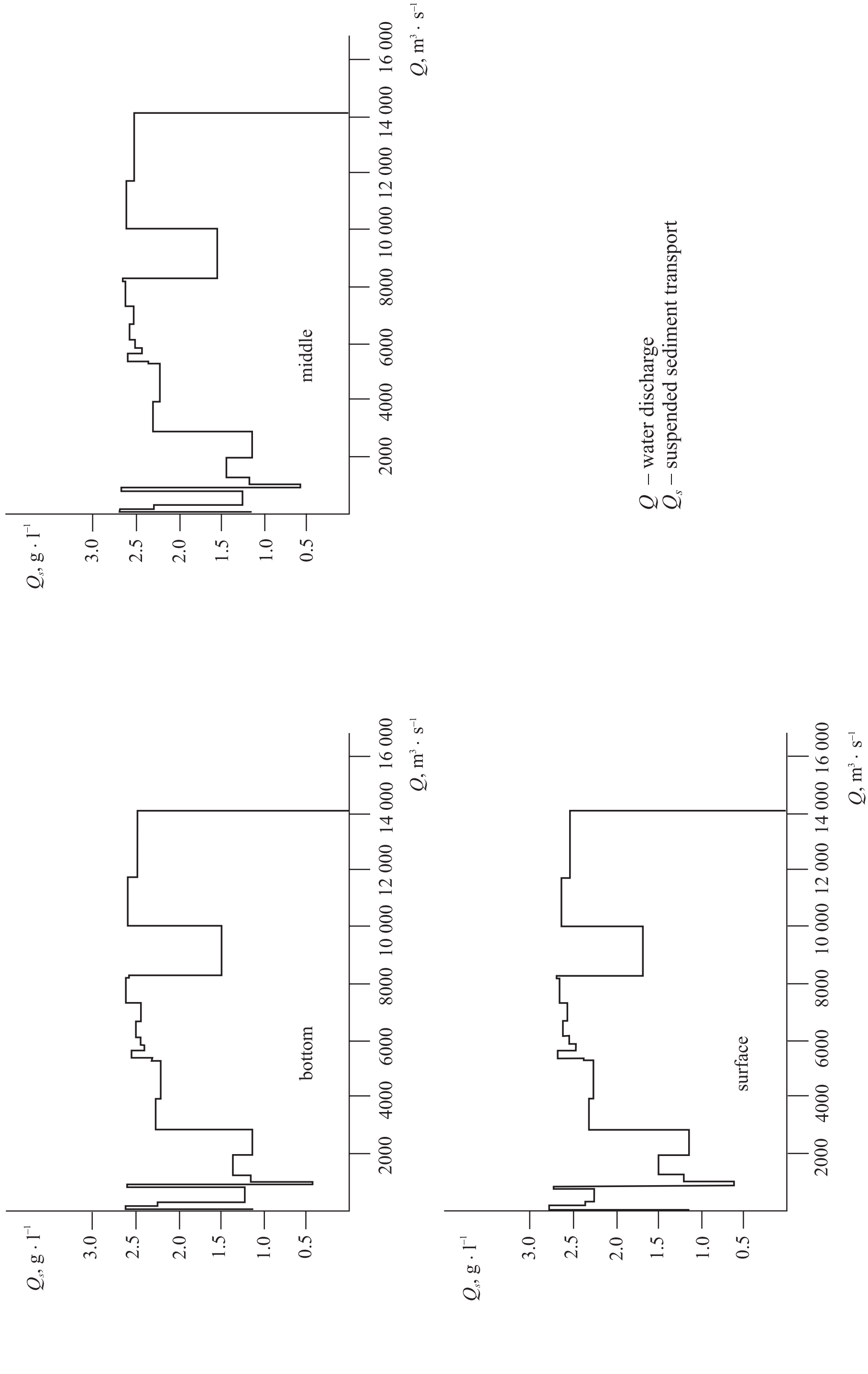


Fig. 4. Sediment graph in the Indus River and the Kotri Barrage dam cross section
Ryc. 4. Sedymentograf dla rzeki Indus w przekroju zapory Kotri

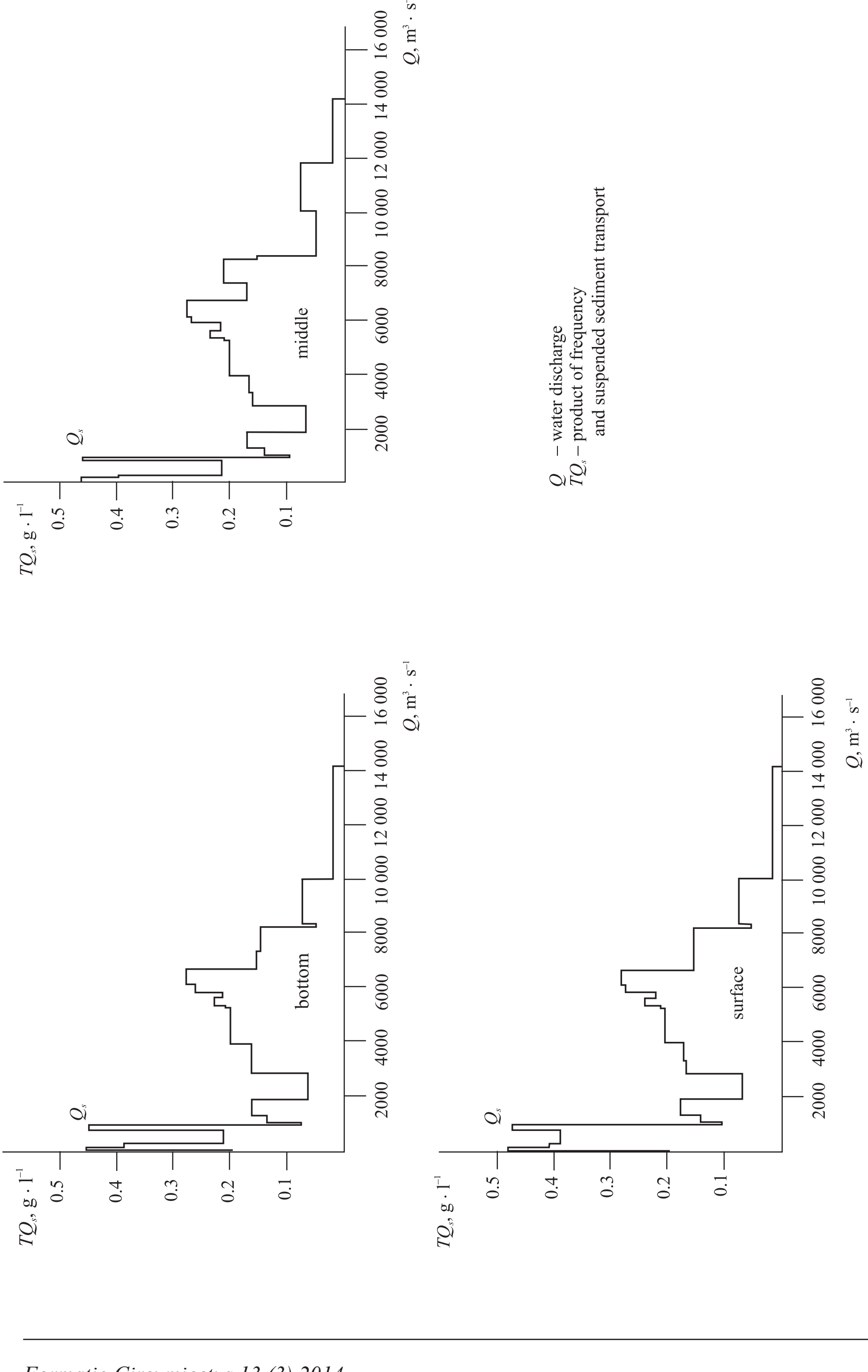


Fig. 5. Dominant discharge graph in the Indus River and the Kotri Barrage dam cross section
Ryc. 5. Wyznaczenie przepływu brzegowego dla rzeki Indus w przekroju zapory Kotri

CONCLUSIONS

From the above presented table and figures the following conclusions might be redrowned:

1. A flood frequency curve has been developed and is shown in Figure 3 and gives the frequency for in the Indus River and the Kotri Barrage dam cross section.
2. Water discharge and suspended sediment concentration in the Indus River and the Kotri Barrage dam cross section has been correlated and depicted in Figure 3 which shows that 1000 $m^3 \cdot s^{-1}$ of water carries maximum sediment load at all three stages.
3. Product of suspended sediment concentration and frequency versus water discharge has been plotted and illustrated in Figure 5 which shows that the same 1000 $m^3 \cdot s^{-1}$ of water carries maximum sediment load and is a frequent discharge. Therefore it may be concluded that 1000 $m^3 \cdot s^{-1}$ is a dominant discharge. This flow of water is often in the main stream of the Indus River from downstream of the Kotri Barrage dam.
4. Calculation based on catastrophic floods is inappropriate to determine the shape of river cross-section, because these occur very rarely. But the dominant discharge is a frequent discharge which may be more responsible for changing the river morphology.

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