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MODIFICATION OF BEDLOAD TRANSPORT CAPACITY IN BRAIDED RIVERS (NOTE)

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The capacity of a river to transport bedload sediment has been shown (Bagnold, 1977) to correlate well with the excess specific stream power, grain size and flow depth:

$$i_b \propto \frac{(\omega - \omega_o)^{1.5}}{\omega_o^{1/2}} \left(\frac{D}{d}\right)^{0.67} \quad (1)$$

Where i_b = bedload transport rate (submerged mass) per unit bed width, ω = stream power per unit bed area = ρgqS, ρ = water density, g = gravitational acceleration, q = discharge/unit width, S = mean energy slope, ω_o = stream power at the onset of bedload motion, d = flow depth and D = grain diameter. The total bedload transport rate Q_b of material of given size is then given by

$$Q_b \propto [(Q - Q_o)]^{1.5} \left(\frac{D}{d}\right)^{0.67} \frac{\rho gS}{Q_o^{0.5}} \quad (2)$$

since total flow rate Q = qb where b = stream width, and S is assumed to be constant for a significant reach of river over a wide range of flow rates.

It is required to estimate the percentage change in bedload transport capacity due to a change in flow regime in a given river; thus S and D are prescribed and no longer variable. In a braided river the variability of flow depth d (however defined) will be much less than that of Q, which fact, together with the lower sensitivity of Q_b to d (indicated by its exponent of 0.67 in (2) as compared with that of 1.5 for $(Q - Q_o)$), suggests that it might be sufficient to rewrite (2) as

$$Q_b = K(Q - Q_o)^{1.5}$$

where K is a constant, embodying S, d and D for the reach in question, and a factor to give Q_b units of volume per unit time.

River flow is not constant; the long-term variability of Q is shown by the flow duration curve for a river, that is, the probability p(Q) that a flow rate Q is exceeded or equalled (Fig. 1). Over a sufficiently long time t, the volume of bedload transported by a small range of flows between Q and $Q + \Delta Q$ is given by the value of Q_b corresponding to $(Q + 0{\cdot}5\Delta Q)$, multiplied by the probability of the flow being in this range $p(Q) - p(Q + \Delta Q)$, and

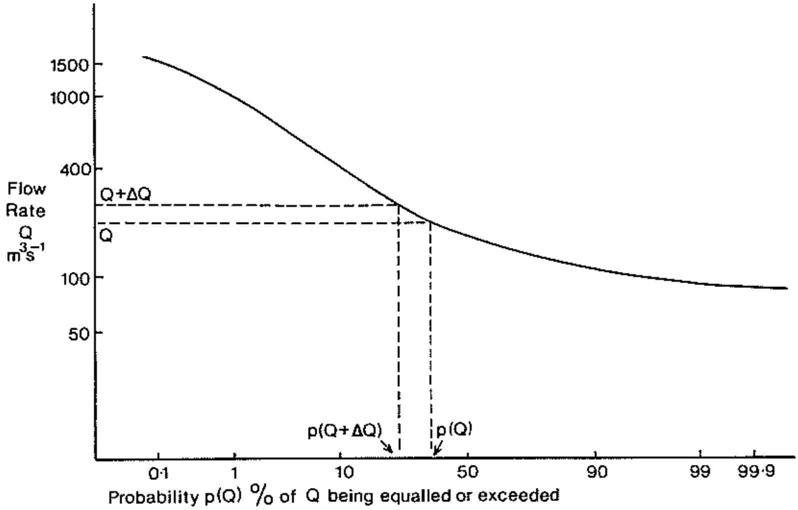

FIG. 1—Flow Duration Curve of the Rakaia River, Gorge Bridge. 1958-70.

t; for any reasonably small value of ΔQ the total bedload volume transported while the flow rate is between Q and Q + 1 is given by

$$\frac{Q_h\,[p(Q) - p(Q + \Delta Q)]t}{\Delta Q}$$

provided that $Q \gg 1$ so that $Q \simeq Q + 0.5\Delta Q$.

Hence the relationship between the volume of bedload transported during a long time t, and discharge, is

$$\mathcal{V}_t = K(Q - Q_o)^{1 \cdot 5}\,\frac{[p(Q) - p(Q + \Delta Q)]t}{\Delta Q} \qquad (3)$$

Since K is unknown, the units of $\mathcal{V}_t$ will be arbitrary but self-consistent, and t on the right hand side of (3) might as well be put equal to one.

An indicator of the capacity of a river to transport bedload over a long period of time can thus be obtained using (3) with t = 1; for a series of chosen values of Q, $\mathcal{V}_t$ can be calculated if the flow duration curve, Q_o and K are known.

The usefulness of this method is demonstrated using the flow duration curve of the Rakaia River, Canterbury, New Zealand (Fig. 1). Q_o for the braided reach of the Rakaia is believed to be about $400 m^3 s^{-1}$; the end result, however, is only weakly dependent on the value of Q_o. K is assumed to be equal to 1. The area under the full curve of Fig. 2 represents the volume of sediment moved by all flows over a long period of time t = 1. It is seen that the flow rate most effective in moving bedload sediment is about $800 m^3 s^{-1}$; this might be thought of as a kind of 'dominant' discharge (Lee

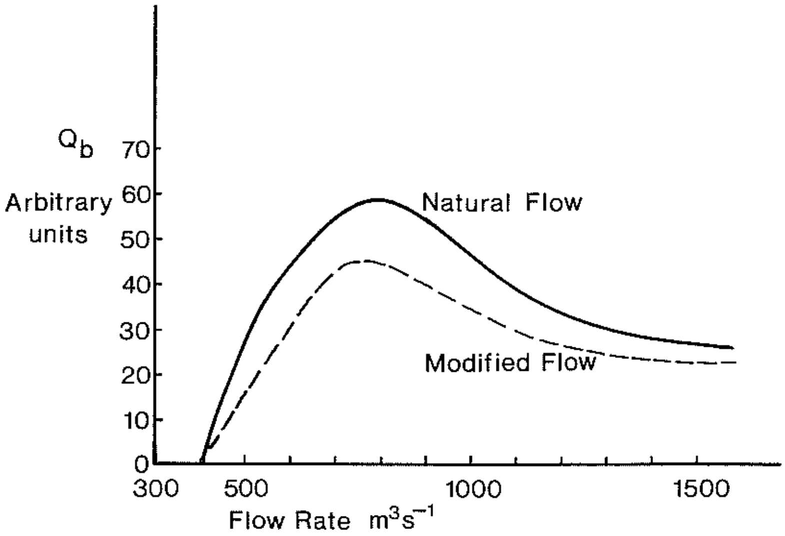

Fig. 2—Bedload Transported by Various Flows; $Q_0 = 400m^3s^{-1}$.

and Davies, 1986), although the flatness of the curve indicates that this dominance is not very distinct. If it is now proposed to abstract water from the river at a rate which varies in time, the modification to the flow duration curve resulting from this abstraction can be calculated and the result is a different set of probabilities p(Q). The new values of $\text{\textcrlambda}_t$ against Q can be drawn (Fig. 2, dashed line). The percentage reduction in bedload transport capacity due to the abstraction can then be calculated by comparing the areas under the full and dashed curves in Fig. 2, and, even if the absolute value of $\text{\textcrlambda}_t$ is quite unknown, will be a useful indicator of the probable magnitude of the effect of any proposed abstraction on the behaviour of the river.

For example, the dashed line in Fig. 2 shows the effect of abstracting 70 m^3s^{-1} continuously from the Rakaia; the approximately 20% reduction in sediment transport capacity suggests a moderate effect on the river and its behaviour, including presumably a degree of long-term aggradation in the vicinity of the offtake(s). If the bedload transported by the Rakaia amounts to 80,000m^3a^{-1} as has been suggested (Bowden 1983), this aggradation would be of the order of 16,000m^3a^{-1}. It is important to note that in general we do not know enough about braided rivers to say what other effects might result, for example how channel pattern, bank erosion and fish habitat might change.

This comparative approach has the merit of allowing the relative effects of various river management stategies to be assessed; for example, the effect of abstracting only water required for proposed irrigation schemes can be calculated.

Dealing only with comparative values also eliminates many problems due to our ignorance of bedload in braided rivers, such as the effects of armouring and sediment supply (Davies, 1987). The validity of (1) in a river such as the Rakaia is unknown, and since the whole approach is quite sensitive to the index of $(Q - Q_0)$ in (1) this should be borne in mind. At our present state of understanding, however, and within its limitations, the method seems to have some practical value.

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