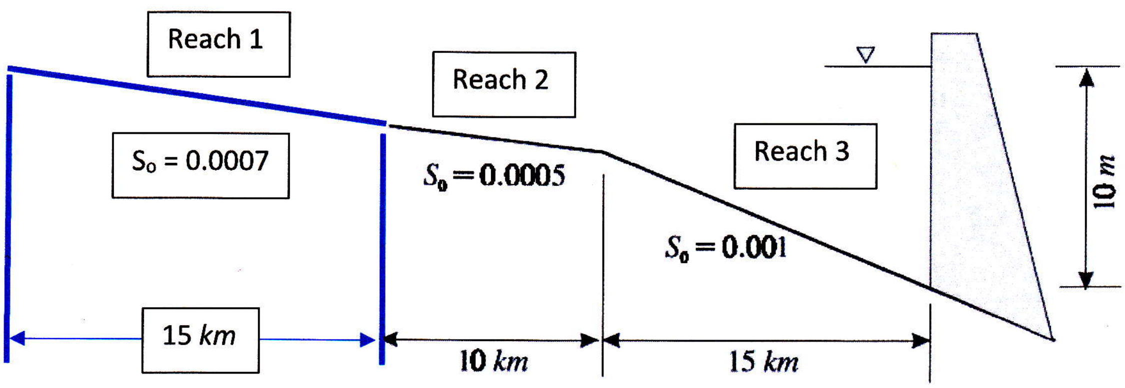
Problem A

Given: Using the channel geometry previously defined in Computer Problem #1, the rigid channel boundary was replaced with uniform bed material with a median grain diameter of 0.4 mm. The sediment inflow at the upstream end was given as steady-uniform flow and the bed elevation was fixed at that point. At the downstream end, the remaining water and sediment discharges were set to be conveyed downstream of the dam such that there is no change in flow depth in the reservoir.

Provide: diagrams demonstrating the following:

(1) the expected type of bed form
(2) Manning n
(3) the water surface profile with bedforms
(4) values of the transport parameter T
(5) the total shear stress in Pa. Discuss the results in comparison with the water surface profile and shear stress calculation in the first computer problem

CP1 Input Parameters:



Given:		
So, 1	0.0007	m/m
So, 2	0.0005	m/m
So, 3	0.001	m/m
L, 1	15	km
L, 2	10	km
L, 3	15	km
H, dam	10	m
q	3.72	m^2/s
n	0.025	
d	0.4	mm

- Wide rectangular channel (R_h = d)
    - q = 3.72 m^2/s

CP2 Problem A Solution:

Van Rijn's chart is provided in Figure 1. A d* of 10.1 is computed using the following relation with a d_{50} of 0.4 mm:

$$d_* = d_{50}\left[\frac{(G-1)g}{v_m^2}\right]^{1/3}$$

The transport-stage parameter was computed as low as 0.2 in the immediate vicinity of the dam, thereby increasing to 15.2 at the upstream end of the reach. The region of interest falls within the red region circled in Figure 1. Ripples are anticipated within proximity of the dam. Thereafter, dunes are anticipated, with the possibility of lower-regime plan bed entering the transition region at the in the upstream reach.

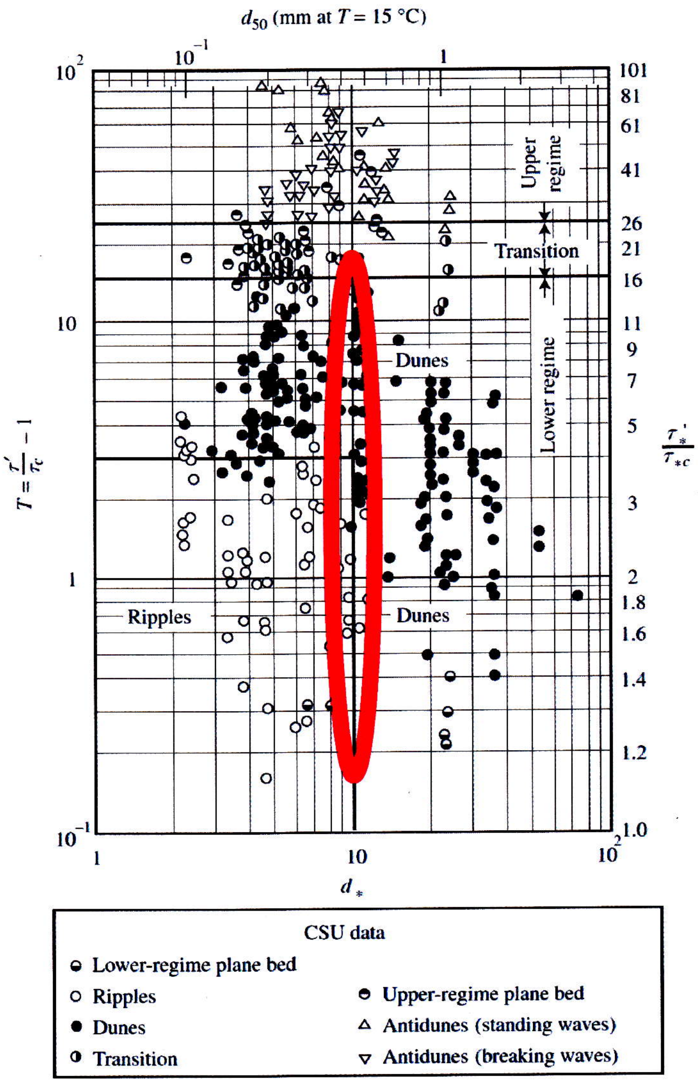


Figure 1: Modified Figure 8.9, Bedform classification (after van Rijn, 1984b)

To compute roughness, the following relationships were used:

$$f = f' + f'' \qquad (8.13e)$$

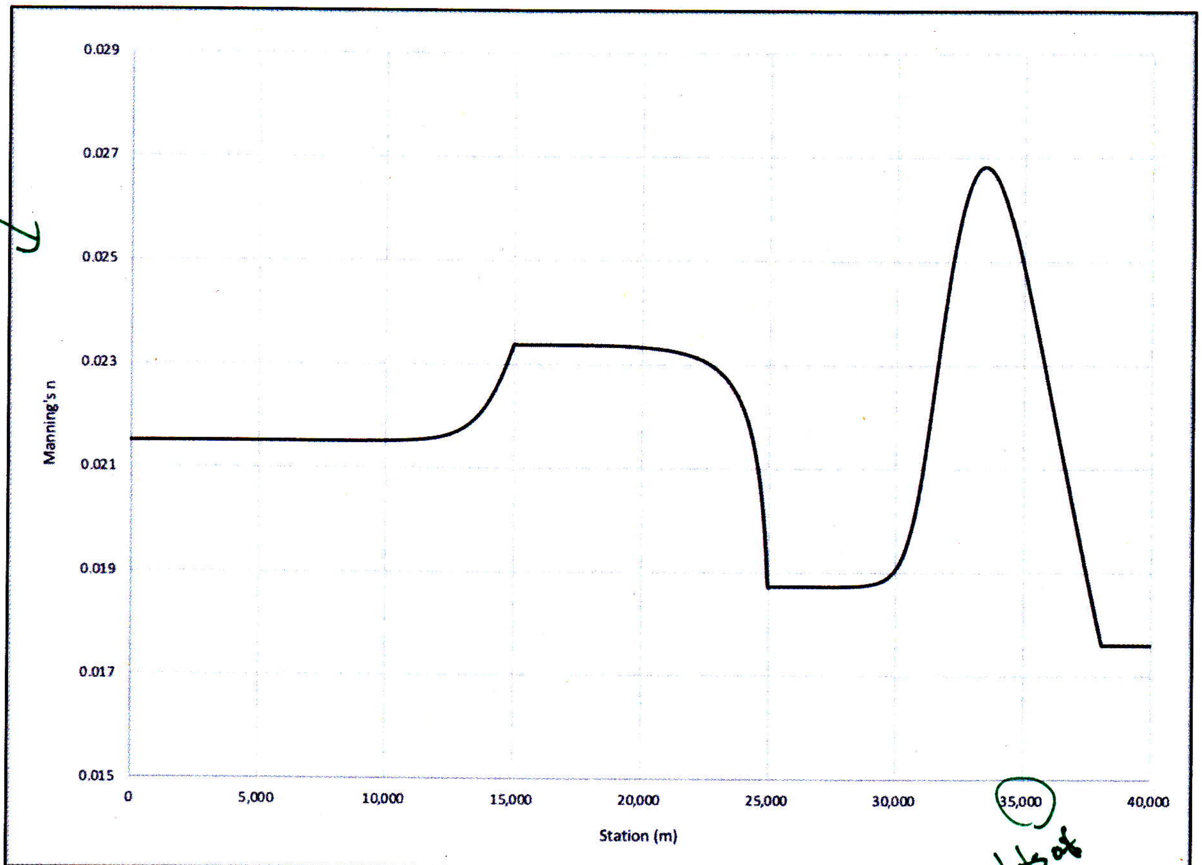
$$f' \cong 0.32\left(\frac{d_{50}}{h}\right)^{1/3} \qquad (8.18b)$$

$$f'' \approx \frac{\Delta}{\Lambda} \qquad (8.21)\blacklozenge$$

$$\sqrt{\frac{8}{f'}} \equiv \frac{R_h^{1/6}}{n'\sqrt{g}} \qquad (6.18)$$

Figure 2 provides a longitudinal profile of channel roughness along the reach, as Manning's n. The variability in the parameter is considerable, however only a brief region exceeds the Manning's n of 0.025 that was assumed in CP1.

Quite small

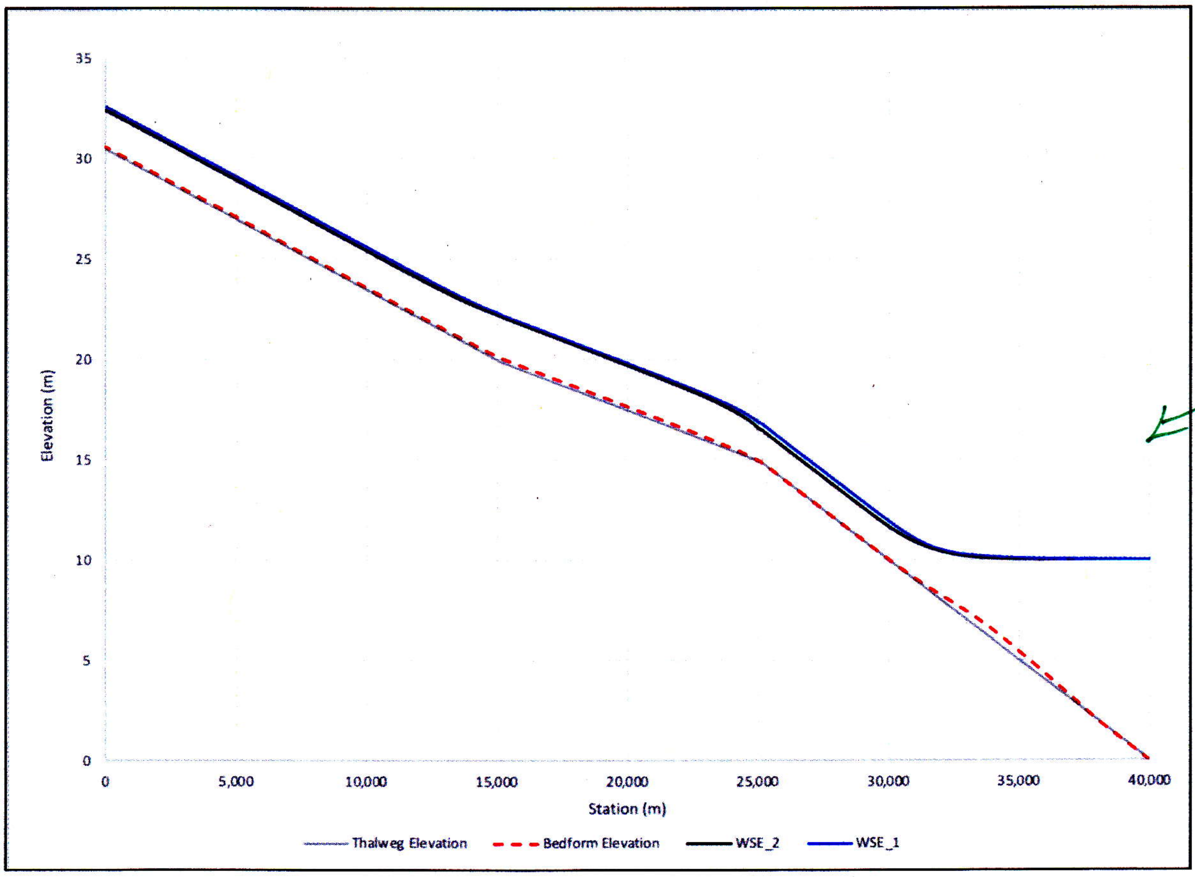


lots of zeros

Figure 2: Manning's n along the longitudinal profile

Figure 3 provides a longitudinal profile of the channel invert elevation overlain by the elevation of the bedform elevations, water surface elevations from the CP1 and CP2 assignments. Dune height was computed using equation 8.11a, shown below. Bedform elevation was computed by summing dune height and the channel invert elevations. Water surface elevation computed in CP2 (WSE2) is the water surface elevation computed when considering bedforms. WSE1 is larger than WSE2 because Manning's n is generally larger in CP1 (0.025) than CP2 (approximately 0.0175 – 0.027).

$$\frac{\Delta}{h} = 0.11\left(\frac{d50}{h}\right)^{0.3}\left(1 - e^{-0.5T}\right)(25 - T) \qquad (8.11a)$$



← to landscape

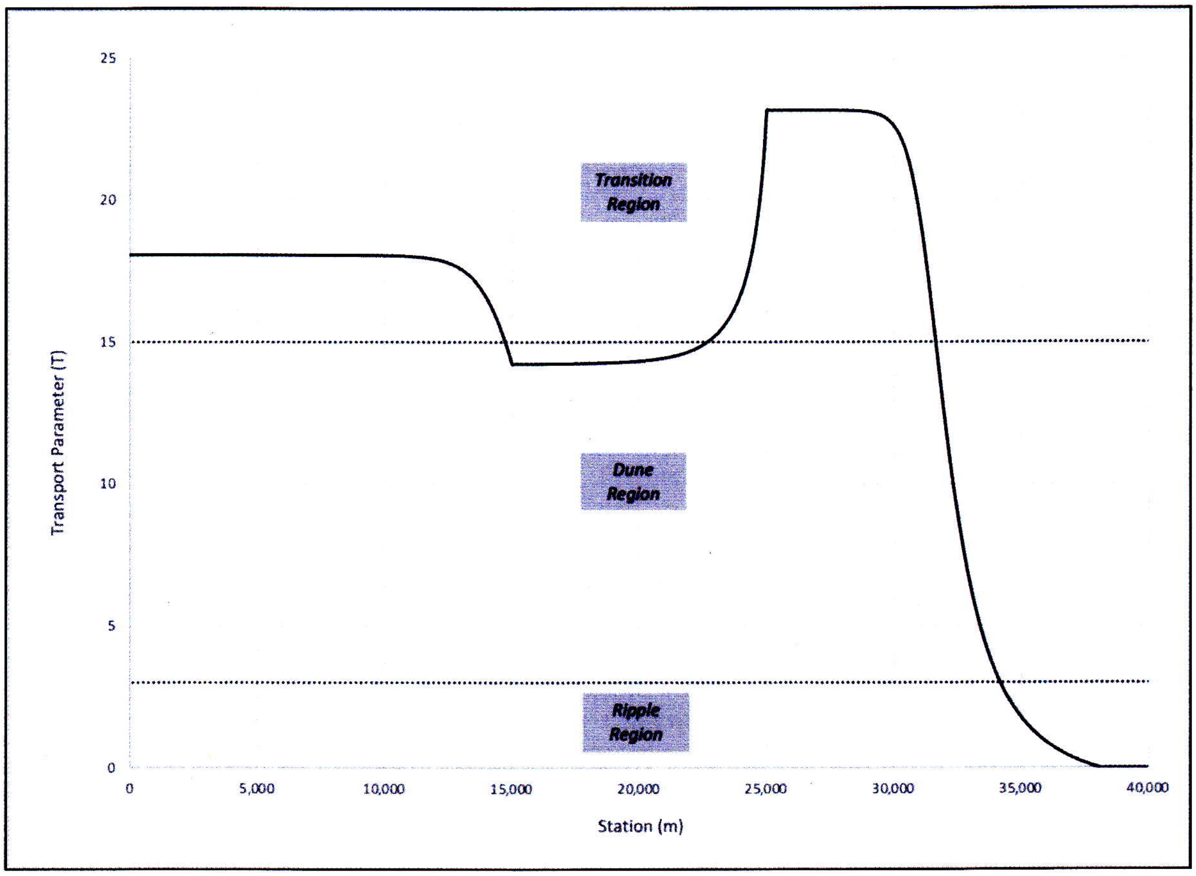
Figure 3: Water surface and channel invert elevations along the longitudinal profile

The transport-stage parameter is defined as

$$T = \frac{\tau'_* - \tau_{*c}}{\tau_{*c}} = \frac{(u'_*)^2 - u_{*c}^2}{u_{*c}^2} = \frac{\rho_m V^2}{\tau_c \left(5.75 \log \frac{4R_b}{d_{90}}\right)^2} - 1 \qquad (8.9b)$$

Figure 4 provides a longitudinal profile of the transport parameter along the reach. The three regions are based on van Rijn (1984b), in which it is asserted that ripples may form when both d* < 10 and T < 3. Dunes are present at T < 15, and washout within the transition region, when 15 < T < 25.

Based on this threshold criteria, ripples are present in the immediate vicinity of the dam. Thereafter, there is a reach of dunes and then a transition region in which bedforms are in the process of transitioning from lower regime plane bed to upper regime plane bed. In the center reach, the transport parameter then recedes, exiting the transition region and reentering the dune region. At the beginning of the upstream reach, however, the dune region again deviates back to the transition region.



ok. ✓

Figure 4: Transport Parameter

Shear stress was computed using the below relationship for both CP1, using flow depths and friction slope that excluding bedform considerations, and CP2, using the flow depths and friction slopes that include bedform considerations.

$$\tau = \gamma h S_f \quad (1)$$

Figure 5 provides a longitudinal profile of the total shear stress along the reach for both cases of excluding and including bedforms. Shear stress is found to be greater in the computation that excludes bedforms from consideration. Conceptually this makes sense because a higher Manning's n was generally used in CP1 (0.025), whereas in this problem, roughness varies from approximately 0.0175 to 0.027 as shown graphically in Figure 2.

Good. ✓

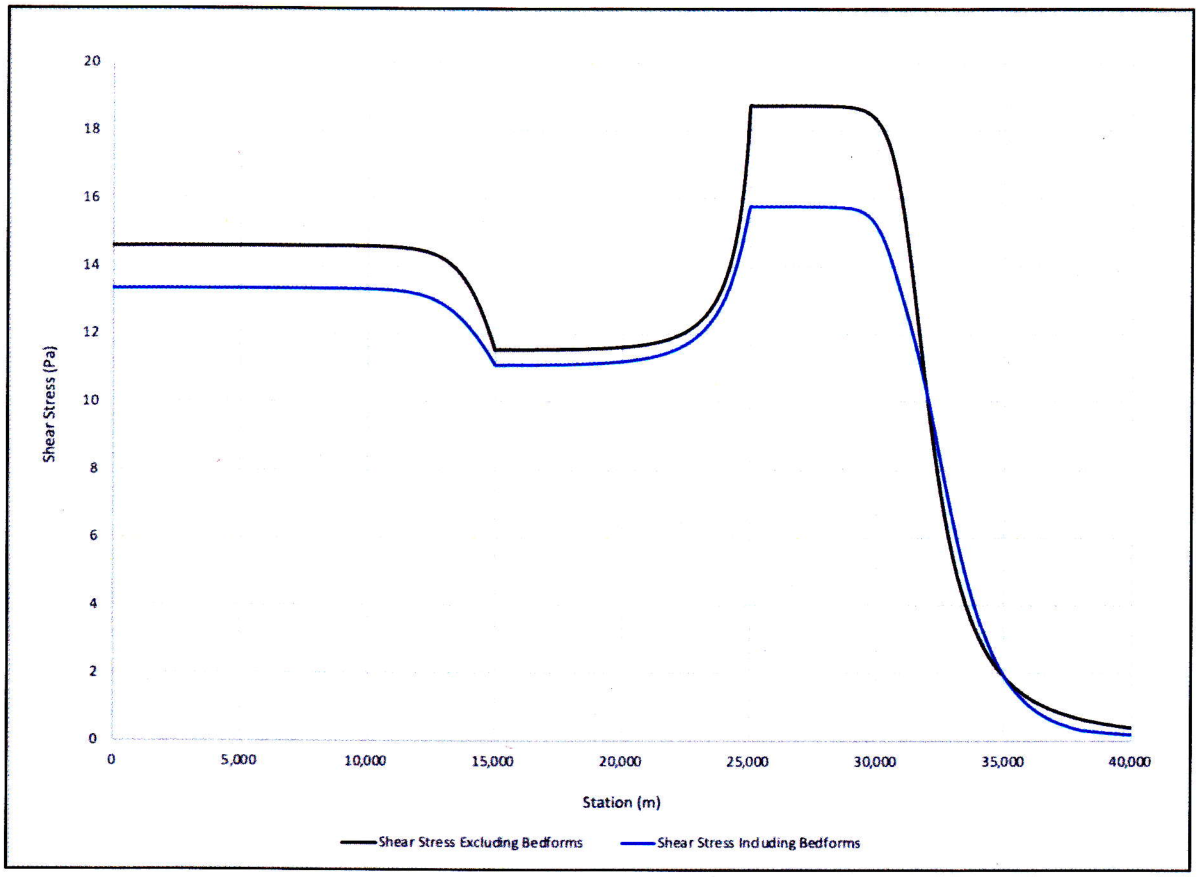


Figure 5: Total Shear Stress

CP2 Problem B

Given: The total shear stress computed in Problem A.

Calculate: bedload in metric tons per meter per day for the entire reach in Problem A using the Einstein bedload formula. Compare results with the sediment discharge by volume in equation 9.4d. Provide a diagram showing the sediment transport distribution over the entire reach from these two equations.

Solution:

Einstein-Brown's equation introduces the idea that grains more in steps proportional to their size. This method using a bed layer thickness twice that of the median particle diameter. The Einstein-Brown bedload sediment transport formula is given by the following:

$$q_{bv*} = \frac{q_{bv}}{\omega_o d_s} = \frac{q_{bv}}{\sqrt{(G-1)gd_s^3}\left\{\sqrt{\frac{2}{3}+\frac{36v^2}{(G-1)gd_s^3}}-\sqrt{\frac{36v^2}{(G-1)gd_s^3}}\right\}} \quad (9.3a)$$

/

$$q_{bv*} = 40\tau_*^3; \text{ when } 0.52 > \tau* > 0.18 \quad (9.4b)$$

$$q_{bv*} = 15\tau_*^{1.5}; \text{ when } \tau* > 0.52 \quad (9.4c)$$

Where $\tau* = \tau_o/(\gamma_s - \gamma)d_s$.

At high shear stress rates, however, as is the case for equation 9.4c, vast amounts of sediment move in suspension and thus the 9.4c approximation is not very accurate. The gradient of the sediment-rating curve is steep such that bedload sediment transport quickly becomes negligible at low discharges. Within the domain shown below, Equation 9.4d, presented by Julien (2002), approximates the unit sediment discharge by volume as follows:

/

$$q_{bv} \simeq 18\sqrt{g d_s^3}\tau_*^2 \quad 0.1 < \tau_* < 1 \quad (9.4d)$$

Figure 6 provides a longitudinal profile of expected sediment transport rates along the reach using both methods. Sediment discharges by volume have been converted to sediment discharges by mass in metric tons per meter per day for the entire reach. It is found that Julien (2002)'s method predicts generally lower sediment transport distribution rates, within an order of magnitude as compared to the Einstein-Brown method. In this problem, the maximum deviation between the two methods is approximately 45%, occurring at the upstream end of reach 1, the reach upstream of the dam.

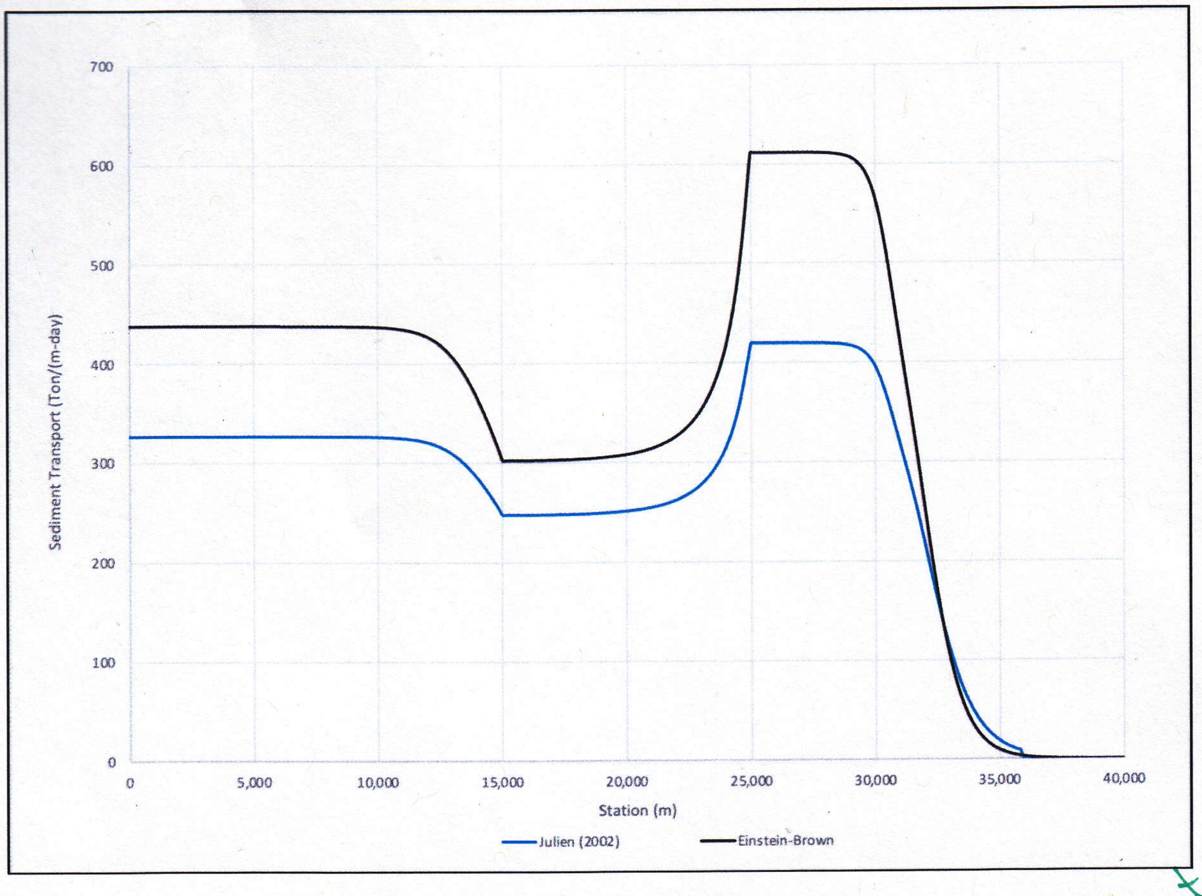


Figure 6: Sediment Transport Distribution

Great.