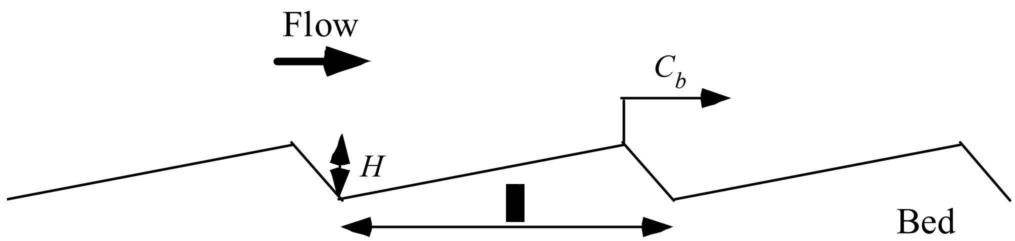
Sample problems #2

1.



The longitudinal profile of dunes formed in a unidirectional turbulent flow often resembles a row of triangles of essentially uniform heights H and lengths l. Once the dunes have reached their equilibrium state they migrate in the direction of flow at a nearly constant speed C_b and practically without a change in form.

In a recent paper experimental observation of dune migration speed C_b and height H were used to determine the sediment transport rate q_s (volume of sediment transported per unit time per unit width perpendicular to the transport direction) from the formula

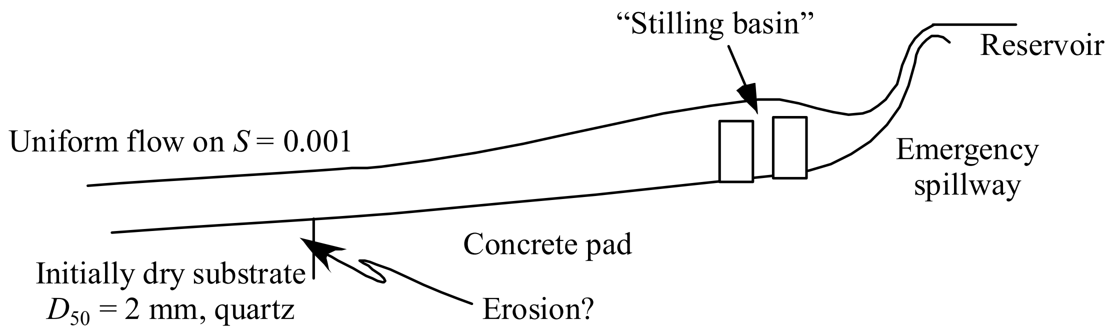
$$q_s = \frac{1}{2}(1 - n_p)HC_b$$

where n_p is the porosity of the bed material. No reference to the origin of the above formula was given.

a) Given the observational 'facts' stated above, deduce the variation of transport rate along the upstream slope of the dunes.

b) Discuss briefly the physical reasoning and assumptions behind the transport formula cited above. That is, what are the implicit assumptions in the model? Are they valid in most flows?

2. A common habitat restoration strategy in dammed watersheds is to release large pulses of (clean) water to simulate a flood. Oftentimes, the emergency spillway was not designed for these events. At the dam below, the Corps of Engineers has told you that the integrity of the spillway will be comprised if more than 2 m of substrate is eroded at the downstream of the spillway. Meanwhile, USGS stream ecologists have recommended a 2-day release that is H = 1 m deep in the 50 m wide spillway section below.



a) How long can you release water before you erode too much material? Defend any assumptions or choices of equations.
b) Approximate how much sediment of similar grain size you have to add (i.e., at what rate) to the stilling basin to ensure that no erosion occurs. You will have to make assumptions, so please document these.
c) Considering a dump truck of sand (~ 20 m^3) costs about $1500, does it make sense to have the Corps reconstruct the spillway at a cost of $1M?

3. You are examining an outcrop of what has been interpreted to be a channelized debris-flow deposit. Like most debris flows, the deposit of interest is inversely graded. That is, it is coarser at the top of the deposit than it is at the bottom. However, you are savvy enough to realize that this could be a result of armoring of the top of the deposit by subsequent clear-water flow. The deposit in outcrop, which is overlain by sand, has the following grain-size distribution:

Top of the deposit:

Size range (mm)	D_i	F_i (% at top of the deposit)	f_i (% in middle)
100-200	144	6	0
75-100	88	17	5
50-75	62	25	17
38-50	44	14	12
25-38	31	12	18
20-25	22	7	9
10-20	13	8	15
5-10	6.8	7	13
2.5-5	3.4	4	11

Use the analysis of Parker and Klingeman (1982) (or alternatively: Parker, 1990) to ascertain whether it is possible that the coarsening observed could be a result of subsequent armoring. Defend your results.

You may find it useful to return to Parker and Klingeman (1982) or Parker (1990) for help solving the problem. However, all you'll need from these works is:

$$G(\phi)=\begin{cases} 5474\left(1-\dfrac{0.853}{\phi}\right)^{4.5} & \phi>1.59 \\ \exp\left[14.2(\phi-1)-9.28(\phi-1)^2\right] & 1\le\phi\le 1.59 \\ \phi^{14.2} & \phi<1 \end{cases}$$

where $\phi=\tau^*/\tau^*_r$; $W^*=W^*_r\, G(\phi_{50})$; $W^*_r=0.002$ when $\tau^*_{r50}=0.0876$.

$$g_s\left(\frac{D_i}{D_{50}}\right)=\left(\frac{D_i}{D_{50}}\right)^{-0.09} \qquad \text{where} \qquad g_s\left(\frac{D_i}{D_{50}}\right)=\frac{1}{\phi_{50}}G^{-1}\left[\frac{f_i}{F_i}G(\phi_{50})\right]$$

and F_i and f_i are the fractions of sediment at the top of the deposit and the middle of the deposit, respectively. This is the last expression is the formula for inversion of grain sizes I mention in the notes.