Introduction to 1D HEC-RAS Modeling

Governing Equations

1D hydraulic models compute cross-sectional average water surface elevation (WSE) and velocity at discrete cross-sections by solving a full version of 1D Saint-Venant equations using implicit finite difference method.

Continuity Equation

$$\frac{\partial A}{\partial t} + \frac{\partial \phi Q}{\partial x_c} + \frac{\partial (1-\phi) Q}{\partial x_f} = 0$$

Momentum Equation

Convective acceleration

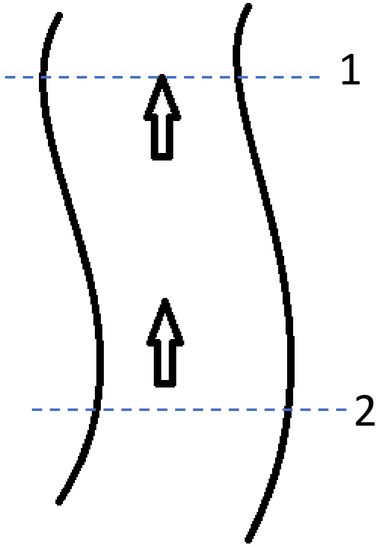
$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x_c}\left(\frac{\partial \phi^2 Q^2}{A_c}\right) + \frac{\partial}{\partial x_f}\left(\frac{(1-\phi)^2 Q^2}{A_f}\right) + gA_c\left(\frac{\partial z}{\partial x_c} + S_c\right)$$
$$+ gA_f\left(\frac{\partial z}{\partial x_f} + S_f\right) = 0$$

Local acceleration

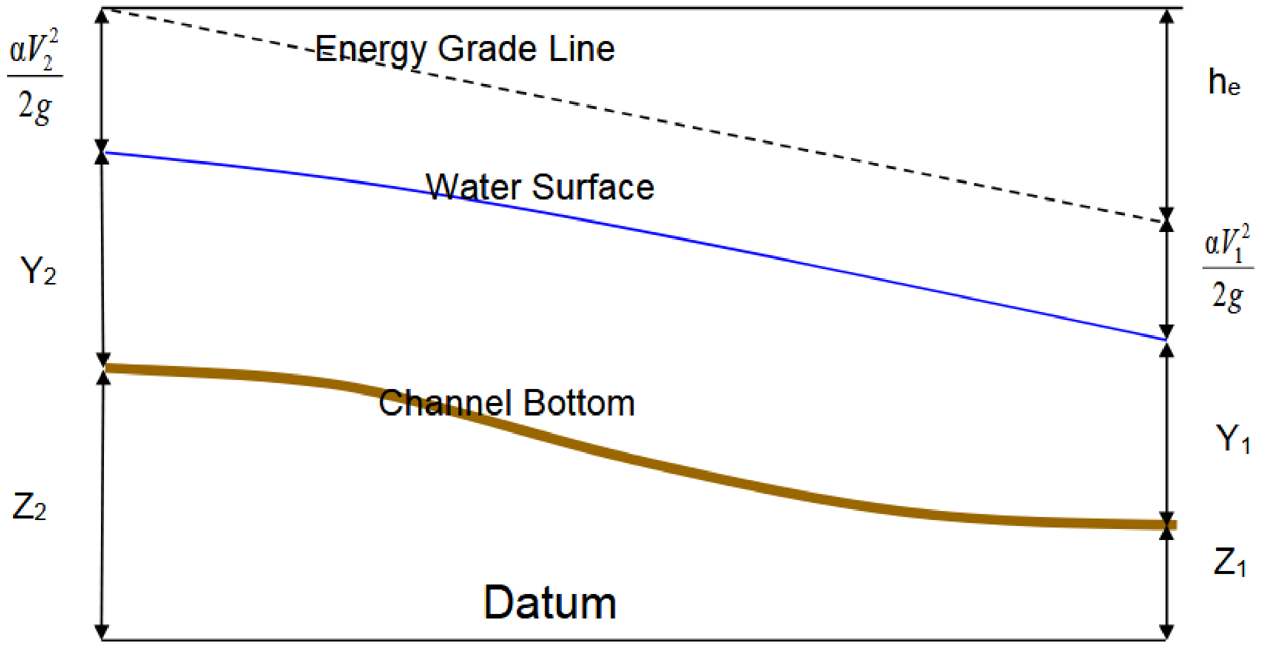
Pressure and energy

A: cross-sectional area, **Q**: Discharge, **S**: frictional slope, **z**: water depth, **x**: distance along the flow, **ϕ**: fraction to determine channel versus floodplain discharge, **t**: time

1D Profile Calculations



Plan View



Longitudinal/profile view

$$Z_2 + Y_2 + \frac{a_2 V_2^2}{2g} = Z_1 + Y_1 + \frac{a_1 V_1^2}{2g} + h_e$$

$$h_e = L\bar{S}_f + C\left|\frac{a_2 V_2^2}{2g} - \frac{a_1 V_1^2}{2g}\right|$$

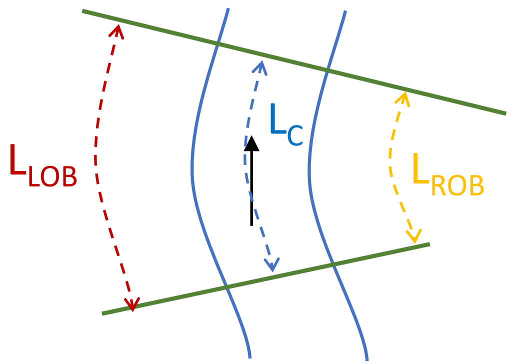
h_e: head loss, **V**: velocity, **g**: gravitational acceleration, **L**: reach length, **a**: velocity coefficient

Loss in Energy head

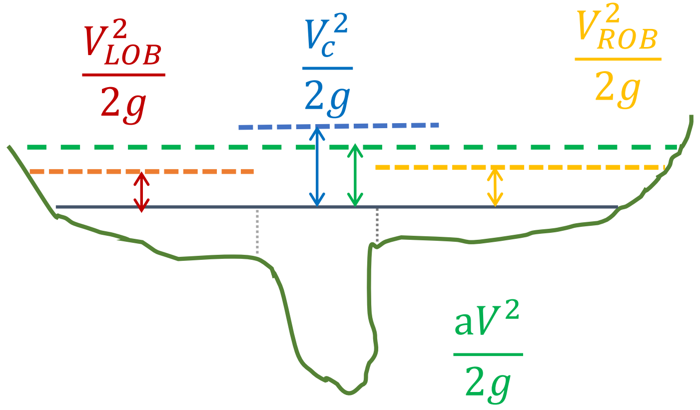
$$h_e = L\bar{S}_f + C\left|\frac{a_2V_2^2}{2g} - \frac{a_1V_1^2}{2g}\right|$$

$$L = \frac{L_{lob}\overline{Q}_{lob} + L_{ch}\overline{Q}_{ch} + L_{rob}\overline{Q}_{rob}}{\overline{Q}_{lob} + \overline{Q}_{ch} + \overline{Q}_{rob}}$$

C: contraction/expansion coefficient. Contraction occurs when downstream velocity head is higher and vice versa.



Plan View



Cross-sectional View

Flow conveyance and Frictional Slope

$$Q = K S_f^{1/2}$$

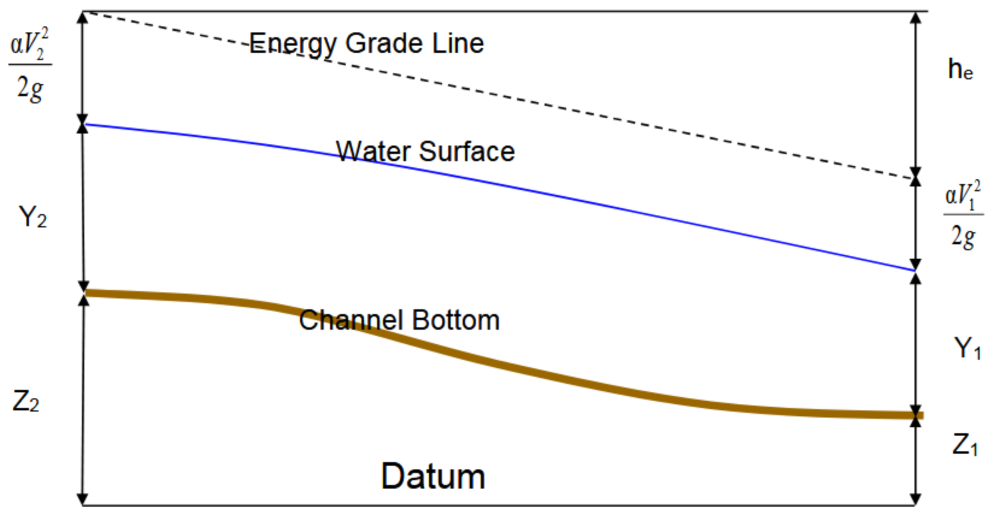
$$S_f = \left(\frac{Q}{K} \right)^2$$

$$K = \frac{1.486}{n} A R^{2/3}$$

$$\bar{S}_f = \left(\frac{Q_1 + Q_2}{K_1 + K_2} \right)^2$$

Computation of flow conveyance (K) and frictional slope (S_f) is based on Manning's n values. Thus Manning's n or roughness coefficient plays a critical role in hydraulic modeling.

Putting it all together



$$Z_2 + Y_2 + \frac{a_2 V_2^2}{2g} = Z_1 + Y_1 + \frac{a_1 V_1^2}{2g} + h_e$$

$$h_e = L\bar{S}_f + C\left|\frac{a_2 V_2^2}{2g} - \frac{a_1 V_1^2}{2g}\right|$$

- Y1 is given. Assume Y2
- Based on Y1 and Y2, compute conveyance (K) and friction slope (Sf), and then get he.
- Use he to compute Y2.
- If the error between computed Y2 and assumed Y2 is greater than a specified tolerance (e.g., 0.01 ft), iterate Y2 until the error is within tolerance.
- If the difference between computed Y2 and assume Y2 is within the specified tolerance, Y2 becomes Y1 and the computations move upstream.

HEC-RAS 1D Geometry