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3.31. Flow in a rectangular open channel is choked when

$$E_1 = E_2 + \Delta z_c$$

$$y_1 + \frac{V_1^2}{2g} = \frac{3}{2}y_c + \Delta z_c$$

$$y_1 + \frac{V_1^2}{2g} = \frac{3}{2}\left(\frac{q^2}{g}\right)^{1/3} + \Delta z_c$$

$$y_1 + \frac{V_1^2}{2g} = \frac{3}{2}\left(\frac{Q^2}{gb^2}\right)^{1/3} + \Delta z_c$$

$$y_1 + \frac{V_1^2}{2g} = \frac{3}{2}\left[\frac{(V_1by_1)^2}{gb^2}\right]^{1/3} + \Delta z_c$$

$$y_1 + \frac{V_1^2}{2g} = \frac{3}{2}\frac{(V_1^{2/3}y_1^{2/3})}{g^{1/3}} + \Delta z_c$$

Dividing by y_1 yields

$$1 + \frac{V_1^2}{2gy_1} = \frac{3}{2} \left(\frac{V_1^2}{gy_1}\right)^{1/3} + \frac{\Delta z_c}{y_1} \tag{1}$$

and defining

$$Fr_1 = \frac{V_1}{\sqrt{gy_1}}$$

then Equation 1 can be written as

$$\frac{\Delta z_c}{y_1} = 1 + \frac{Fr_1^2}{2} - \frac{3}{2}Fr_1^{2/3}$$

From Problem 3.30: b=3 m, Q=4 m $^3/{\rm s}, y_1=1.5$ m, and $\Delta z_c=0.15$ m. Therefore

$$V_1 = \frac{Q}{by_1} = \frac{4}{(3)(1.5)} = 0.889 \text{ m/s}$$

 $\text{Fr}_1 = \frac{V_1}{\sqrt{gy_1}} = \frac{0.889}{\sqrt{(9.81)(1.5)}} = 0.232$

which yields

$$\frac{\Delta z_c}{y_1} = 1 + \frac{\text{Fr}_1^2}{2} - \frac{3}{2} \text{Fr}_1^{2/3}$$

$$\frac{\Delta z_c}{1.5} = 1 + \frac{(0.232)^2}{2} - \frac{3}{2} (0.232)^{2/3}$$

and solving for Δz_c gives

$$\Delta z_c = 0.69 \text{ m}$$