10.3 *Figure P10.3 shows a cross section of a canal that is to carry 2000 cfs. The canal is lined with concrete, for which n is 0.014. (a) What is the slope of this canal, and what is the drop in elevation per mile? (b) If the flow in the canal were to decrease to 1000 cfs, all other data, including the slope and n, being the same, what would be the depth of the water?*

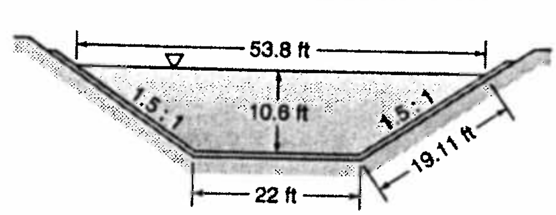


Figure P10.3

BG

(a) $A = [(53.8 + 22)/2]10.6 = 37.9(10.6) = 402\ \text{ft}^2$

$V = Q/A = 2000/402 = 4.98$ fps

$P = 22 + 2(19.11) = 60.2$ ft; $R_h = A/P = 402/60.2 = 6.67$ ft

Manning → Eq. 10.7*b*: $4.98 = (1.486/0.014)(6.67)^{2/3}S_0^{1/2}$; $S_0^{1/2} = 0.013\,24$

$S_0 = 0.000\,1752$ ◀ or 0.925 ft per mile ◀

Note: A very small drop per mile will produce a substantial velocity.

Manning → (b) Eq. 10.8*a*: $1000 = (1.486/0.014)AR_h^{2/3}(0.000\,1752)^{1/2} = 1.405AR_h^{2/3}$

i.e. $712 = AR_h^{2/3} = A(A^{2/3}/P^{2/3}) = A^{5/3}/P^{2/3}$

where $A = 22y + 1.5y^2$ and $P = 22 + 2y(19.11/10.6) = 22 + 3.61y$

$\therefore\ (22y + 1.5y^2)^{5/3} = 712(22 + 3.61y)^{2/3}$.

Solve by trial or by equation solver per Sample Prob. 10.1 to obtain $y = 7.36$ ft ◀

10.16 *The amount of water to be carried by a canal excavated in smooth earth (n = 0.030) is 370 cfs. It has side slopes of 2:1 (see Fig. P10.16), and a bed slope of 2.5 ft/mile. (a) If the depth of water y is to be 5 ft, what must be the bottom width b? (b) How does this compare with the depth and bottom width for the most efficient trapezoidal section for the given conditions?*

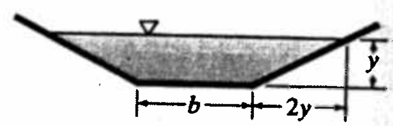


Figure P10.16

BG

(a) $A = 5(b + 10)$; $P = b + 2(5^2 + 10^2)^{1/2} = b + 22.36$

$R_h = A/P = 5(b + 10)/(b + 22.36)$; $S_0 = 2.5/5280 = 0.000473$

Manning → Eq. 10.8*a*: $370 = \dfrac{1.486}{0.03}\dfrac{[5(b + 10)]^{5/3}}{(b + 22.36)^{2/3}}\sqrt{0.000\,473}$

After several trials, ~~or by equation solver per Sample Prob. 10.1d~~, we find $b = 19.63$ ft. ◀

For this *b*: $R_h = 3.53\ \text{ft} \neq y/2 = 2.5$ ft.

(b) Given Q, n, m, and S_0: ~~This is Case 2, Sec. 10.6:~~

$$y_{opt} = 2^{1/4}\left[\frac{370(0.030)}{1.486(2\sqrt{5} - 2)\sqrt{2.5/5280}}\right]^{3/8} = 7.56\ \text{ft}$$ ◀ $b_{opt} = 2(\sqrt{5}-2)7.56 = 3.57$ ft ◀

For this *b*: $A = 141.4\ \text{ft}^2$, $P = 37.4$ ft, and $R_h = 3.78\ \text{ft} = y/2$.

Optimum y for given Q, m, n, and S_o, for trapezoidal cross-section.

10.36 *A flow of 2.0 m^3/s is carried in a rectangular channel 1.8 m wide at a depth of 1.0 m. Will critical depth occur at a section where (a) a frictionless hump 180 mm high is installed across the bed, (b) a frictionless sidewall constriction (with no hump) reduces the channel width to 1.4 m, and (c) the hump and the sidewall constriction are installed together? Show calculations.*

SI

Given: $Q = 2.0$ m^3/s, channel $b = 1.8$ m, $y_0 = 1.0$ m

(a) With hump 0.18 m high: $q = Q/b = 2.0/1.8 = 1.111$ m^3/s per m

For frictionless hump, $\Delta E = -\Delta z$ ✓

Def'n of E — Eq. 10.17: $E_0 = 1.0 + [1/(2 \times 9.81)](1.111/1.0)^2 = 1.063$ m

$y_c = (q^2/g)^{1/3}$ — Eq. 10.23: $y_c = (1.111^2/9.81)^{1/3} = 0.501$ m

$E_{min} = 1.5 y_c$ — Eq. 10.25: $E_{min} = 1.5(0.501) = 0.752$ m; Sec. 10.13: $\Delta z_{crit} = E_0 - E_{min} = 0.311$ m

$\therefore$ $\Delta z = 0.18$ m $< \Delta z_{crit}$, so y_c does not occur at the hump. ◀

Alternative solution (a):

$E_h = E_0 - \Delta z = 1.063 - 0.180 = 0.883$ m

$E_h > E_{min} = 0.752$, so y_c does not occur at the hump. ◀

(b) With constricted $b = 1.4$ m, and no hump: $q = 2.0/1.4 = 1.429$ m^3/s per m

Eq. 10.23: $y_c = (1.429^2/9.81)^{1/3} = 0.593$ m; Eq. 10.25: $E_{min} = 1.5(0.593) = 0.889$ m

$\therefore$ $E_{min} < E_0 = 1.063$, so y_c does not occur at constriction. ◀

(c) With both 0.18-m hump and constricted $b = 1.4$ m:

From part (b): $q_{constriction} = 1.429$ m^3/s per m, $y_c = 0.593$ m, $E_{min} = 0.889$ m

$\Delta z_{crit} = E_0 - E_{min} = 1.063 - 0.889 = 0.1741$ m

So hump height $= 0.18$ m $> \Delta z_{crit}$, so y_c does occur at hump + constriction ◀

Also therefore, the flow must back up, and so increase the y and E just upstream of the hump.

Alternative solution (c):

$E_h = E_0 - \Delta z = 0.883$; $E_{min} = 0.889$ m

$E_h < E_{min}$ is impossible, so y_c does occur and flow must back up, etc. ◀

10.42 *Water flows uniformly in a 2.0-m-wide rectangular channel at a rate of 1.6 m³/s and a depth of 0.75 m (Fig. P10.41). What is the change in water-surface elevation at a section contracted to a 1.4 m width with an 80-mm depression in the bottom?*

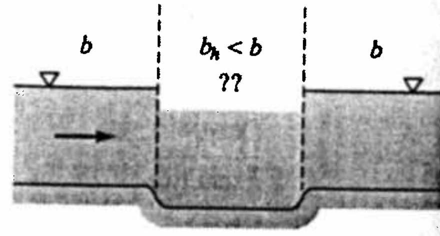


Figure P10.41

SI

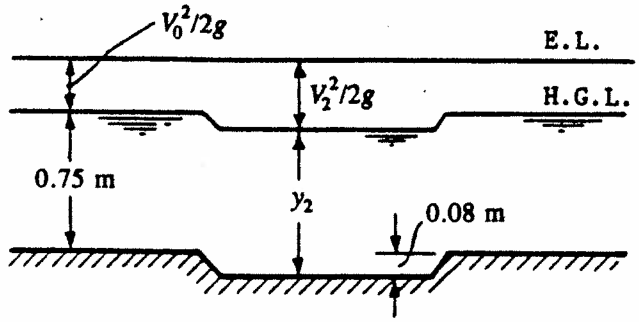
$y_c = (q^2/g)^{1/3}$

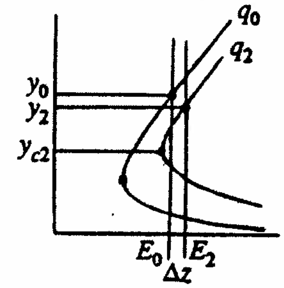
$V = Q/A$

$q_2 = Q/b = 1.6/1.4 = 1.143$ m³/s per m

Eq. 10.23: $y_{c2} = (1.143^2/9.81)^{1/3} = 0.511$ m

$V_0 = 1.6/(2.0 \times 0.75) = 1.067$ m/s, $V_2 = 1.6/(1.4y_2) = 1.143/y_2$





Sec. 10.13 and Eq. 10.17: $E_0 = E_2 - \Delta z$, $\therefore\ 0.75 + V_0^2/2g = y_2 + V_2^2/2g - 0.08$

$\therefore\ 0.75 + 1.067^2/(2 \times 9.81) = 0.808 \text{ m} = y_2 + (1.143/y_2)^2/(2 \times 9.81) - 0.080$

By trial or by polynomial or equation solver, $y_2 = 0.7780$ m (subcritical) or 0.353 m (supercritical).

y_2 cannot be less than $y_{c2} = 0.511$ m, therefore $y_2 = 0.778$ m.

Water-surface change $= y_0 - (y_2 - \Delta z) = 0.750 - (0.7780 - 0.080) = 0.0520$ m drop ◄

10.15.4 *A test on a rectangular glass flume 250 mm wide yielded the following data on a reach of 9-m length: with still water, $z_1 - z_2 = 2.7$ mm; with a measured flow of 4.3 L/s, $y_1 = 110.2$ mm, $y_2 = 111.7$ mm. Find the value of Manning's roughness coefficient n using only one reach.*

SI

$S_0 = 0.0027/9 = 0.0003$; $B_0 = 0.25$ m

$A_1 = 0.0276$ m²; $P_1 = 0.470$ m; $R_1 = A_1/P_1 = 0.0586$ m; $V_1 = Q/A_1 = 0.1561$ m/s;

$V_1^2/2g = 0.001\,242$ m; $A_2 = 0.0279$ m²; $P_2 = 0.473$ m; $R_2 = 0.0590$ m;

$V_2 = Q/A_2 = 0.1540$ m/s; $V_2^2/2g = 0.001\,209$;

$\therefore\ \bar{R} = 0.0588$; $\bar{V} = 0.1550$ m/s

S is h_L/L

Determine average R_h and V in reach

Eq. 10.37: $0.1102 + 0.001\,242 = 0.1117 + 0.001\,209 + (S - 0.0003)9$; $S = 0.000\,1370$

With these values of S, $\bar{R}$, and $\bar{V}$ in Eq. 10.38*b*: $n = 0.011\,41$ ◄

Manning

10.66 *In a rectangular channel 10 ft wide with a flow of 200 cfs the depth is 1 ft. If a hydraulic jump is produced, (a) what will be the depth immediately after it? (b) What will be the loss of energy?*

BG

$$y_2 = \frac{y_1}{2}\left(-1+\sqrt{1+\frac{8q^2}{gy_1^3}}\right)$$

(*a*) Given: $Q = 200$ cfs, $b = 10$ ft, $y_1 = 1.00$ ft; $\therefore$ $q = 200/10 = 20$ cfs/ft

Eq. 10.46*a*: $y_2 = (1.00/2)(-1 + [1 + (8 \times 20^2)/(32.2 \times 1.00^3)]^{1/2}) = 4.51$ ft ◄

(*b*) $V_1 = 20/1.00 = 20.0$ fps, $V_1^2/2g = 20^2/(2 \times 32.2) = 6.21$ ft;

$V_2 = 20/4.51 = 4.44$ fps, $V_2^2/2g = 0.305$ ft

Eq. 10.47: $h_L = E_1 - E_2 = (1.00 + 6.21) - (4.51 + 0.305) = 2.40$ ft·lb/lb ◄

(*b*) Alt: Eq. 10.48: $h_L = (4.51 - 1.00)^3/[4(1.00)4.51] = 2.40$ ft·lb/lb (or ft) ◄

10.18.3 *The hydraulic jump may be used as a crude flowmeter. Suppose that in a horizontal rectangular channel 6 ft wide the observed depths before and after a hydraulic jump are 0.80 and 3.60 ft, respectively. Find the rate of flow and the head loss.*

BG

From Eq. 10.45: $q = \sqrt{32.2(0.80)3.60(0.80+3.60)/2} = 14.28$ cfs/ft; $Q = bq = 6(14.28) = 85.7$ cfs ◄

(An alternative, but less convenient, solution for Q uses Eq. 10.42.)

$V_1 = 14.28/0.80 = 17.85$ fps, $V_1^2/2g = 4.95$ ft; $V_2 = 14.28/3.60 = 3.97$ fps, $V_2^2/2g = 0.244$ ft

$h_L = E_1 - E_2 = (0.80 + 4.95) - (3.60 + 0.244) = 1.906$ ft ◄

$$\frac{q^2}{g} = y_1 y_2 \frac{y_1+y_2}{2}$$