Date: 11-5-17

Data:

Rectangular flume

$n = 0.012$

$b = 1.5\,m$

$Q = 1.7\,m^3/s$

$S_o = 0.0006$

At certain Section $y = 0.9\,m$

Is the distance upstream or downstream - ?

Distance in one reach to section where $y = 0.75m$ = ?

Sol:

$$q = \frac{Q}{b} = \frac{1.7}{1.5} = 1.13\,m^2/s$$

$y_1 = 0.9\,m$

$$V_1 = \frac{q}{y_1} = \frac{1.13}{0.9} = 1.26\,m/s$$

$$E = y_1 + \frac{V_1^2}{2g}$$

$$= 0.9 + \frac{1.26^2}{2\times 9.81} = 0.98\,m$$

$$R_1 = \frac{A_1}{P_1}$$

$$\Rightarrow A_1 = 1.5 \times 0.9 = 1.35\,m^2$$

$$= \frac{1.35}{3.3}$$

$$\Rightarrow P_1 = 1.5 + 2\times 0.9 = 3.3\,m$$

$R_1 = 0.409\,m$

$y_2 = 0.75$

$$V_2 = \frac{q}{y_2} = \frac{1.13}{0.75} = 1.51\,m/s$$

$$E_2 = y_2 + \frac{V_2^2}{2g}$$

$$= 0.75 + \frac{1.51^2}{2\times 9.81} = 0.87m$$

$$R_2 = \frac{A_2}{P_2}$$

$$\Rightarrow A_2 = 0.75 \times 1.5 = 1.125\,m^2$$

$$= \frac{1.125}{3}$$

$$\Rightarrow P_2 = 1.5 + 2\times 0.75 = 3\,m$$

$R_2 = 0.375\,m$

$$V_m = \frac{V_1 + V_2}{2} = 1.385\,m/s$$

$$R_m = \frac{R_1 + R_2}{2} = 0.392\,m$$

$$S = \frac{V_m^2 n^2}{R_m^{4/3}} = \frac{1.385^2 \times 0.012^2}{0.392^{4/3}} = 0.000963$$

$$L = \frac{E_1 - E_2}{S - S_o} = \frac{0.98 - 0.87}{0.000963 - 0.0006} = 303\,m \text{ (+ve i.e D/s)}$$

+ve answer means assumed directions are correct

$y = 0.9$ at U/s

$y = 0.75$ at D/s

Prob 11.60

Data:

$y = 1.2m$ to $y = 0.9m$

$L = 300m$ D/s

$S_o = ?$ (Using one Reach)

Sketch flume, energy grade line and water surface

$n = 0.012$

$b = 1.5m$

$Q = 1.7 m^3/s$

Sol:

$$q = \frac{Q}{b} = \frac{1.7}{1.5} = 1.13 m^2/s$$

$y_1 = 1.2m$

$$V_1 = \frac{q}{y_1} = \frac{1.13}{1.2} = 0.94 m/s$$

$$E_1 = y_1 + \frac{V_1^2}{2g}$$

$$= 1.2 + \frac{0.94^2}{2 \times 9.81} = 1.25 m$$

$$R_1 = \frac{A_1}{P_1}$$

$$\Rightarrow A_1 = 1.2 \times 1.5 = 1.8 m^2$$

$$\Rightarrow P_1 = 1.5 + 2 \times 1.2 = 3.9 m$$

$$= \frac{1.8}{3.9}$$

$R_1 = 0.462m$

$y_2 = 0.9 m$

$$V_2 = \frac{q}{y_2} = \frac{1.13}{0.9} = 1.26 m/s$$

$$E_2 = y_2 + \frac{V_2^2}{2g}$$

$$= 0.9 + \frac{1.26^2}{2 \times 9.81} = 0.98 m$$

$$R_2 = \frac{A_2}{P_2}$$

$$\Rightarrow A_2 = 0.9 \times 1.5 = 1.35 m^2$$

$$\Rightarrow P_2 = 1.5 + 2 \times 0.9 = 3.3 m$$

$$= \frac{1.35}{3.3}$$

$R_2 = 0.409 m$

$$\Rightarrow V_m = \frac{V_1 + V_2}{2} = 1.1 m/s$$

$$\Rightarrow R_m = \frac{R_1 + R_2}{2} = \frac{0.462 + 0.409}{2} = 0.436 m$$

$$\Rightarrow S = \frac{V_m^2 n^2}{R_m^{4/3}} = 0.000527$$

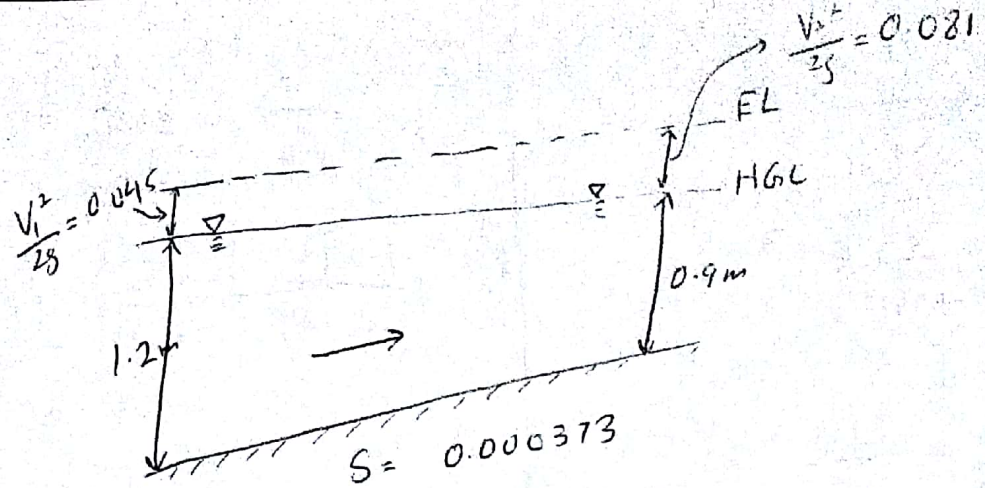
As $L = \frac{E_1 - E_2}{S - S_o}$

$$300 = \frac{1.25 - 0.98}{0.000527 - S_o}$$

$S_o = -3.73 \times 10^{-4}$

$S_o = -0.000373$ (Adverse slope)

Sketch



Prob 11.61

Data:

$S_o = 0.01$ $\quad L = 15m$ (D/S)

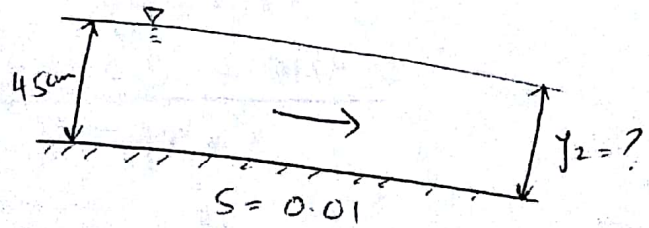
$Q = 1.7 m^3/s$ $\quad y_1 = 45cm$

$b = 1.5m$ $\quad y_2 = ?$ Find the depth D/S

$n = 0.012$ $\quad$ Use one reach only

Flow critical or sub critical = ?

Sketch



$$q = \frac{Q}{b} = \frac{1.7}{1.5} = 1.13 m^2/s$$

$y_1 = 45cm = 0.45m$

$$V_1 = \frac{q}{y_1} = \frac{1.13}{0.45} = 2.51 m/s$$

$$E_1 = y_1 + \frac{V_1^2}{2g}$$

$$= 0.45 + \frac{2.51^2}{2 \times 9.81} = 0.77m$$

$$R_1 = \frac{A_1}{P_1}$$

$$= \frac{0.675}{2.4} = 0.281m$$

$\Rightarrow A_1 = 0.45 \times 1.5 = 0.675 m^2$

$P_1 = 1.5 + 2 \times 0.45$

$= 2.4m$

$y_2 = ?$

$$V_2 = \frac{q}{y_2} = \frac{1.13}{y_2}$$

$$E_2 = y_2 + \frac{V_2^2}{2g}$$

$$= y_2 + \frac{1.13^2}{y_2^2 2 \times 9.81}$$

$$E_2 = y_2 + \frac{0.065}{y_2^2}$$

$$R_2 = \frac{A_2}{P_2} \Rightarrow A_2 = 1.5 \times y_2$$

$$\Rightarrow P_2 = 1.5 + 2y_2$$

$$R_2 = \frac{1.5y_2}{1.5 + 2y_2}$$

As $$V_m = \frac{V_1 + V_2}{2} = \frac{2.51 + \frac{1.13}{y_2}}{2}$$

$$= \frac{2.51y_2 + 1.13}{2y_2}$$

$$R_m = \frac{R_1 + R_2}{2} = \frac{0.281 + \frac{1.5y_2}{1.5 + 2y_2}}{2}$$

$$= \frac{0.4215 + 0.562y_2 + 1.5y_2}{2(1.5 + 2y_2)}$$

$$= \frac{0.4215 + 2.062y_2}{3 + 4y_2}$$

As $$L = \frac{E_1 - E_2}{S - S_0}$$

$$15 = \frac{0.77 - \left(y_2 + \frac{0.065}{y_2^2}\right)}{S - 0.01}$$

$$S = \frac{V_m^2 n^2}{R_m^{4/3}}$$

$$= \frac{\left(\frac{2.51y_2 + 1.13}{2y_2}\right)^2 (0.012)^2}{\left(\frac{0.4215 + 2.062y_2}{3 + 4y_2}\right)^{4/3}}$$

$$\boxed{y_2 = 0.383\ m}$$

$$F_{N_1} = \frac{V_1}{\sqrt{g y_1}}$$

$$= \frac{2.51}{\sqrt{9.81 \times 0.45}}$$

$$= 1.19$$

$$F_{N_2} = \frac{V_2}{\sqrt{g y_2}}$$

$$= \frac{2.95}{\sqrt{9.81 \times 0.383}} = 1.52$$

$$\therefore V_2 = \frac{1.13}{y_2} = \frac{1.13}{0.383}$$

$$= 2.95 \text{ m/s}$$

$$(F_N)_m = \frac{F_{N_1} + F_{N_2}}{2}$$

$$= 1.355 > 1$$

Hence super critical flow

Prob 11.62

When $L = 150$ m

$$y_2 = 2.094 \text{ m}$$

Prob 11.63

Data:

$b = 25\,cm$

Reach length $= 9\,m$

$z_1 - z_2 = 2.7\,mm$

$Q = 4.3\,L/s$

$y_1 = 11.02\,cm$

$y_2 = 11.17\,cm$

$n = ?$ (using only one reach)

Formulas

$$V_m = \frac{1}{n} R_m^{2/3} S_o^{1/2}$$

$$L = \frac{E_1 - E_2}{S - S_o}$$

Sol:

$$S_o = \frac{z_1 - z_2}{L} = \frac{2.7 \times 10^{-3}}{9} = 0.0003$$

$$q = \frac{Q}{b} = \frac{4.3 \times 10^{-3}}{25 \times 10^{-2}} = 0.0172\,m^2/s$$

$y_1 = 11.02^{cm} = 0.1102\,m$

$$V_1 = \frac{q}{y_1} = \frac{0.0172}{0.1102} = 0.156\,m/s$$

$$E = y_1 + \frac{V_1^2}{2g} = 0.1114\,m$$

$$R_1 = \frac{A_1}{P_1} \Rightarrow A_1 = 0.1102 \times 0.25 = 0.0276\,m^2$$

$$\Rightarrow P_1 = 0.25 + 2 \times 0.1102 = 0.4704\,m$$

$$R_1 = \frac{0.0276}{0.4704}$$

$R_1 = 0.0587\,m$

$y_2 = 11.17^{cm} = 0.1117\,m$

$$V_2 = \frac{q}{y_2} = \frac{0.0172}{0.1117} = 0.154\,m/s$$

$$E = y_2 + \frac{V_2^2}{2g} = 0.113\,m$$

$$R_2 = \frac{A_2}{P_2} \Rightarrow A_2 = 0.1117 \times 0.25 = 0.0279\,m^2$$

$$\Rightarrow P_2 = 0.25 + 2 \times 0.1117 = 0.4734\,m$$

$$= \frac{0.0279}{0.4734}$$

$R_2 = 0.0589\,m$

$$\Rightarrow V_m = \frac{V_1 + V_2}{2} = 0.155\,m/s$$

$$\Rightarrow R_m = \frac{R_1 + R_2}{2} = 0.0588\,m$$

$$L = \frac{E_1 - E_2}{S - S_0}$$

$$9 = \frac{0.1114 - 0.113}{S - 0.0003}$$

$$S = 1.2222 \times 10^{-4} = 0.000122$$

Now

$$V_m = \frac{1}{n} R_m^{2/3} S^{\frac{1}{2}}$$

$$n = \frac{1}{0.155} (0.0588)^{2/3} (0.000122)^{1/2}$$

$$n = 0.0108$$

$$\boxed{n \simeq 0.011}$$

Prob 11.64

Data:

$b = 3m$

$n = 0.012$

$S_0 = 20 \text{ cm/km} = \frac{0.2}{1000} = 0.0002$

y at fall $= 0.55m = y_b$

$\therefore y_b = 0.72 y_c$

a) Rate of flow = ?

b) Distance U/S from fall where $y = 1.2m$ = ?

$L_c = 4y_c$ U/s from fall

Reaches with and depths $= 0.82 \text{ m}$

$= 0.9 \text{ m}$

$= 1 \text{ m}$

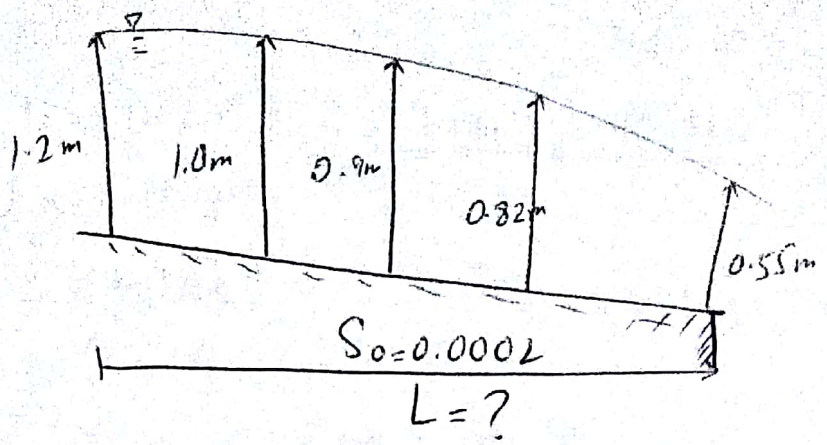
$= 1.2 \text{ m}$

Sol:

$$y_c = \frac{y_b}{0.72} = \frac{0.55}{0.72} = 0.76 \text{ m}$$

and $q = \sqrt{g y_c^3} = \sqrt{9.81 \times 0.76^3} = 2.075 \text{ m}^2/\text{s}$

Sketch



y (m)	V (m/s)	E (m)	A (m^2)	P (m)	R (m)	V_m (m/s)	R_m (m)	S	L (m)	ΣL (m)
0.55	3.77	1.27	1.65	4.1	0.40	–	–	–	–	–
0.82	2.53	1.15	2.46	4.64	0.53	3.15	0.47	3.91×10^{-3}	32.35	
0.9	2.31	1.17	2.7	4.8	0.56	2.42	0.55	1.87×10^{-3}	-11.98	
1	2.075	1.22	3	5	0.6	2.19	0.58	1.43×10^{-3}	-40.65	
1.2	1.73	1.35	3.6	5.4	0.67	1.90	0.64	9.43×10^{-4}	-174.97	

$$V = \frac{q}{y} = \frac{2.075}{y}$$

$$L = \frac{E_1 - E_2}{S - S_o} = \frac{F_1 - F_2}{S - 0.0002}$$

$$E = y + \frac{V_1^2}{2g}$$

$$A = y \times b = 3y$$

$$P = 3 + 2y$$

$$R = \frac{A}{P}$$

$$V_m = \frac{V_1 + V_2}{2}$$

$$R_m = \frac{R_1 + R_2}{2}$$

$$S = \frac{V_m^2 n^2}{R_m^{4/3}} \Rightarrow n = 0.012$$

Prob 11.65

$n = 0.035$

$S_0 = 2\,m/km = \frac{2}{1000} = 0.002$

$Q = 10\,m^3/s$ per m of width i.e $q = 10\,m^2/s$

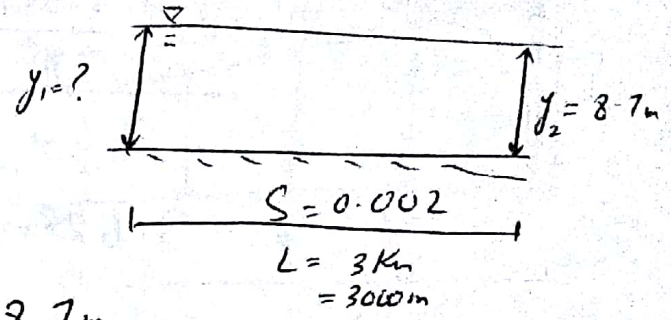
$y_1 = ?$ Find depth U/S

$L = 3\,Km$, depth $y_2 = 8.7m$

a) Compute using single reach

b) Compare results by using 3 reaches.

Sol:



$y_1 = ?$

$V_1 = \frac{q}{y_1} = \frac{10}{y_1}$

$E_1 = y_1 + \frac{V_1^2}{2g}$

$= y_1 + \frac{10^2}{y_1^2 \times 2 \times 9.81}$

$= y_1 + \frac{5.097}{y_1^2}$

For wide Rectangular channels

$R_1 \simeq y_1$

$R_1 = y_1$

$y_2 = 8.7m$

$V_2 = \frac{q}{y_2} = \frac{10}{8.7} = 1.15\,m/s$

$E_2 = y_2 + \frac{V_2^2}{2g}$

$= 8.7 + \frac{1.15^2}{2 \times 9.81} = 8.77m$

For wide Rectangular Channel

$R_2 \simeq y_2$

$R_2 = 8.7m$

$V_m = \frac{V_1 + V_2}{2} = \frac{\frac{10}{y_1} + 1.15}{2} = \frac{10 + 1.15y_1}{2y_1}$

$R_m = \frac{R_1 + R_2}{2} = \frac{y_1 + 8.7}{2}$

$$S = \frac{V_m^2 n^2}{R_m^{4/3}}$$

$$S = \frac{\left(\frac{10 + 1.15y_1}{2y_1}\right)^2 (0.035)^2}{\left(\frac{y_1 + 8.7}{2}\right)^{4/3}}$$

As

$$L = \frac{E_1 - E_2}{S - S_0}$$

$$3000 = \frac{y_1 + \frac{5.097}{y_1^2} - 8.77}{S - 0.002}$$

$$y_1 = 3.625\,m$$

Prob 11.60

Data:

Rectangular stream

$S_o = 0.0002$

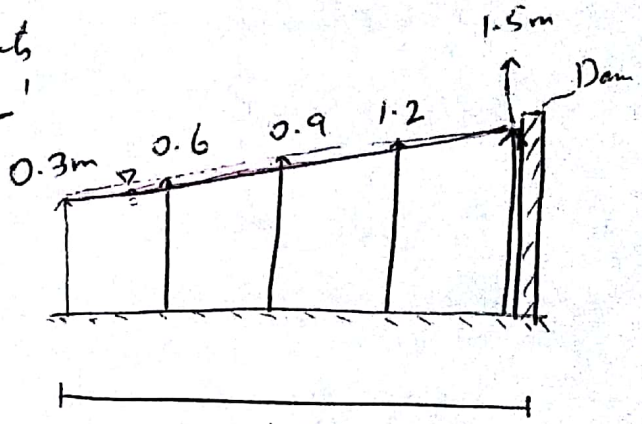
$b = 50\ m$

$C = 43.2\ m^{1/2}/s$

a) $y = ?$ for U.F

$q = 8.25\ m^3/s$ per m of stream

b) Use reaches with 30 cm depth increments to reach 30 cm depth. and find 'L'



Sol: $V = \frac{q}{y}$ $S = \frac{V_m^2 n^2}{C^2 R_m^{4/3}}$

y	V	E	A	P	R	V_m	R_m	S	L	ΣL
m	m/s	m	m^2	m	m	m/s	m		m	m
1.5	5.5	3.042	75	53	1.415	–	–	–	–	–
1.2	6.875	3.609	60	52.4	1.145	6.188	1.28	0.016030	-35.82	-35.82
0.9	9.167	5.183	45	51.8	0.869	8.021	1.007	0.034234	-46.25	-82.07
0.6	13.75	10.236	30	51.2	0.586	11.459	0.7728	0.096648	-52.39	-134.46
0.3	27.5	38.845	15	50.6	0.296	20.625	0.441	0.516871	-55.37	-189.83

a) $V = C\sqrt{RS}$

$V = \frac{q}{y}$

$R = \frac{A}{P} = \frac{50y}{50+2y}$

$\frac{8.25}{y} = 43.2\sqrt{\frac{50y}{50+2y}(0.0002)}$

S = slope of E.L

But here for U.F

$S = S_o$

$y = 6.099\ m$

Prob 70

Data:

Classify Water Surface Profile of Prob 11.59

First check which type of slope it is.

For this we have to find y_c and y_o

Sol:

Data: $n = 0.012$, $b = 1.5m$

$q = 1.13 m^2/s$

$S_o = 0.0006$

$S = 0.000963$

$$\Rightarrow \quad y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}$$

$$= \left(\frac{1.13^2}{9.81}\right)^{\frac{1}{3}}$$

$$y_c = 0.507 m$$

$y_o > y_c$

$$\Rightarrow \quad V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$\frac{q}{y_o} = \frac{1}{n}\left(\frac{b y_o}{b + 2y_o}\right)^{2/3} S_o^{1/2}$$

$y = 0.9 - 0.75$

$$y_o = 0.980 m$$

Mild slope

Also $S_c = 3.5225 \times 10^{-3}$

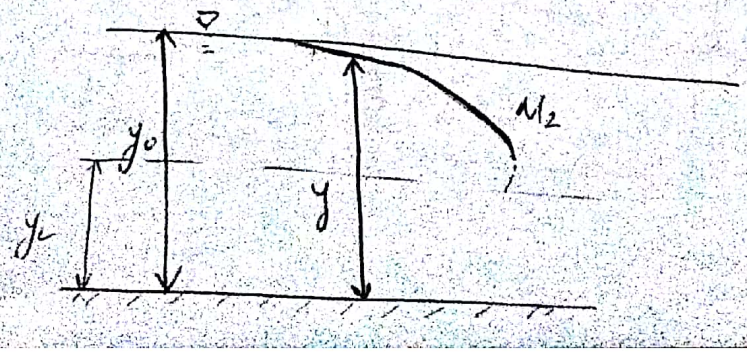
$S_c = 0.0035225$

$S_o < S_c$

$$\Rightarrow \quad As \quad \frac{dy}{dx} = S_o\left[\frac{1 - \left(\frac{y_o}{y}\right)^{10/3}}{1 - \left(\frac{y_c}{y}\right)^3}\right]$$

Condition $\Rightarrow y_o > y > y_c$

$$\frac{dy}{dx} = \frac{-}{+} = -ve$$



Problem 11

Repeat Pro 11.70 when $S_o = -0.0004$

Data Now from previous data

$S = 0.000963$

$y = 0.9 - 0.75$

$\Sigma = 1.13$

$y_c = 0.507\ m$

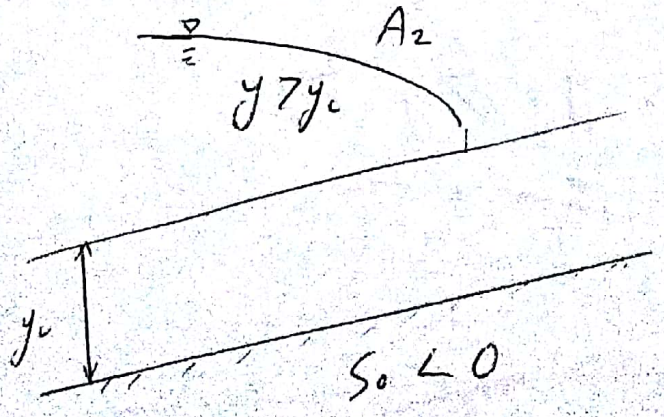
Since S_o is adverse slope

Hence y_o is ∞

$y_o > y > y_c$ (from data)

$$\frac{dy}{dx} = S_o \left[\frac{1 - \left(\frac{y_o}{y}\right)^{10/3}}{1 - \left(\frac{y_c}{y}\right)^3} \right]$$

$$\frac{dy}{dx} = \frac{-ve}{+ve} = -ve$$



Prob 11.72

Data:

$b = 4.5\ m$

Bottom slope is constant

$Q = 40\ m^3/s$

depth by Manning's eq, $y_0 = 1.8\ m$

At certain section, $y = 84\ cm = 0.84\ m$

Will the depth increase, decrease or remain same as one proceeds d/s from this section?

Sketch the physical condition also.

Sol:

$$q = \frac{Q}{B} = \frac{40}{4.5} = 8.89\ m^2/s$$

$$y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}} = \left(\frac{8.89^2}{9.81}\right)^{\frac{1}{3}} = 2\ m$$

Now $y_0 = 1.8\ m$

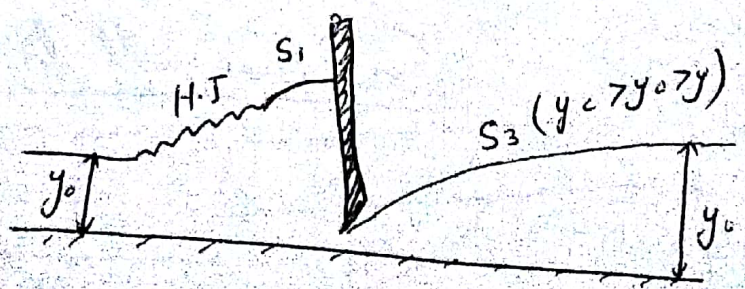
$y = 0.84\ m$

$y_c = 2\ m$

$y_c > y_0 > y$

Conclusion $y_0 < y_c$ Hence, steep slope

(Depth of flow will increase as one proceeds d/s



Prob 11.73

Data: Classify water surface profile in Prob 11.61

$n = 0.012$ $b = 1.5m$

$S_0 = 0.01$

$q = 1.13 m^2/s$

$y = 0.45$ to $0.383 m$

Sol:

$$\Rightarrow y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}$$

$$= \left(\frac{1.13^2}{9.81}\right)^{\frac{1}{3}} = 0.507 m$$

$$\Rightarrow V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$\frac{q}{y_0} = \frac{1}{n}\left(\frac{by_0}{b+2y_0}\right)^{2/3} S_0^{1/2}$$

$$\frac{1.13}{y_0} = \frac{1}{0.012}\left(\frac{1.5y_0}{1.5+2y_0}\right)^{2/3}(0.01)^{1/2}$$

$$y_0 = 0.352 \ m$$

$\Rightarrow$ Now $y_0 = 0.352 m$

$y_c = 0.507 m$

$y = 0.45 \rightarrow 0.383 m$

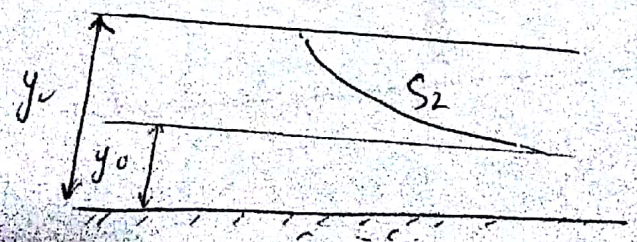
$y_c > y > y_0$

Also $y_0 < y_c$

Hence steep slope

$$\frac{dy}{dx} = \frac{+ve}{-ve} = -ve$$

S_2 curve will be formed



Prob 11.74

Repeat 11.73 by data of 11.63 by changing $n = 0.012$

Data:

$n = 0.012$

$b = 0.25\ m$

$Q = 0.0172\ m^2/s$

$y = 0.1102 \rightarrow 0.1117\ m$

$S_0 = 0.0003$

Sol:

$$\Rightarrow y_c = \left(\frac{Q^2}{g}\right)^{\frac{1}{3}} = \left(\frac{0.0172^2}{9.81}\right)^{\frac{1}{3}} = 0.0311\ m$$

$\Rightarrow y_0 = ?$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$\frac{Q}{y_0} = \frac{1}{n}\left(\frac{b y_0}{b + 2y_0}\right)^{2/3} S_0^{1/2}$$

$$\frac{0.0172}{y_0} = \frac{1}{0.012}\left(\frac{0.25 \times y_0}{0.25 + 2y_0}\right)^{2/3} (0.0003)^{1/2}$$

$$y_0 = 0.0865\ m$$

$\Rightarrow$ Now $y_0 = 0.0865\ m$

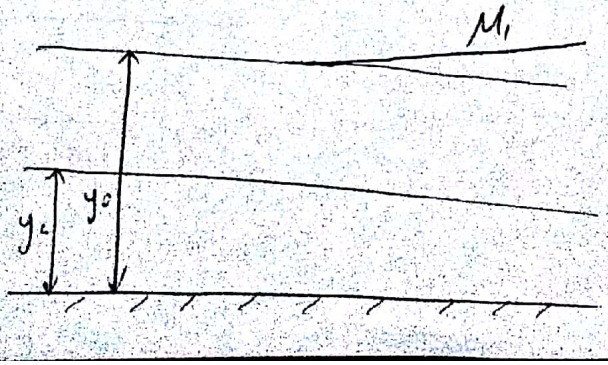
$y = 0.1102 \rightarrow 0.1117\ m$

$y_c = 0.0311\ m$

Condition $y > y_0 > y_c$ (M_1

Also $y > y_c$ ($M.S$)

$$\frac{dy}{dx} = \frac{+}{+} = +$$



Imb 11.75

Data:

Trapezoidal Canal

$n = 0.03$

bottom width = 4.5m

Side slopes = 1:1

$S_0 = 0.0003$

$Q = 23 m^3/s$

$y_c = 1.22 m$

$y_0 = 3.24 m$

Length of M_2 = ? i.e L = ?

Extending from free overfall to y =

Use Reaches

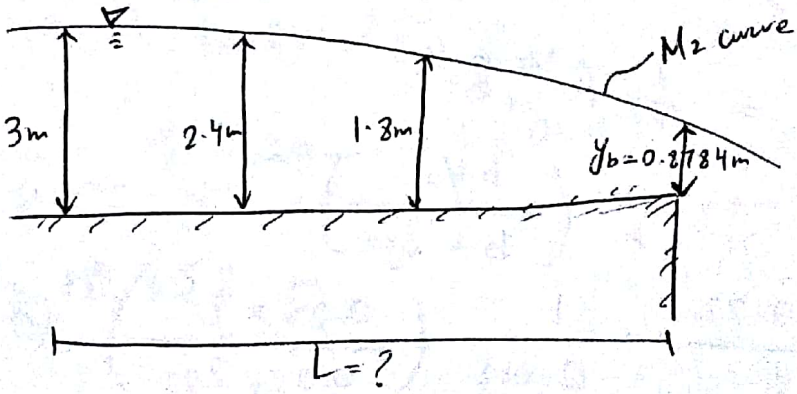
$y = 1.8$ m

$y = 2.4$ m

$y = 3$ m

Sol: Also $y_0 > y > y_c$ Hence M_2 curve will be formed.

Sketch



$\Rightarrow y_b = 0.72 y_c$

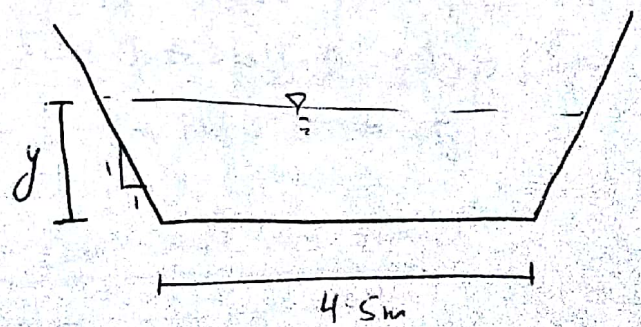
$= 0.72 \times 1.22$

$\boxed{y_b = 0.8784 \text{ m}}$

$\Rightarrow A = 4.5y + 2y^2$

$\Rightarrow P = 4.5 + 2\sqrt{2}\, y$

$\Rightarrow T = 4.5 + 2y$



$H = \sqrt{(1y)^2 + (1y)^2} = \sqrt{2y^2} = \sqrt{2}\, y$

y (m)	V m/s	E m	A m^2	P m	R m	V_m m/s	R_m m	S	L m	ΣL m
0.8784	4.80	2.05	5.5	6.98	0.79	—	—	—	—	—
1.8	2.34	2.08	14.58	9.59	1.52	3.57	1.155	9.465×10^{-3}	-3.27	-3.27
2.4	1.76	2.56	22.32	11.29	1.98	2.05	1.75	1.793×10^{-3}	-321.5	-324.77
3	1.41	3.10	31.5	13	2.42	1.585	2.2	7.90×10^{-4}	-1102.01	-1426.78

$$V = \frac{Q}{y} \qquad S = \frac{V_m^2 n^2}{R_m^{4/3}}$$

$$Q = \sqrt{g y_c^3}$$

$$= \sqrt{9.81 \times 1.22^3}$$

$$= 4.22 \ m^2/s$$

$$L = \frac{E_1 - E_2}{S - S_0}$$