CE 4353/5360 Open Channel Hydraulic Design

110 total points

HW 7

Problems 1-4. Assume the following channel slopes occur in a prismatic open channel. Note where the water surface begins on the left.

[a] **Label y_c and y_o for each reach (state if y_o is infinite).**

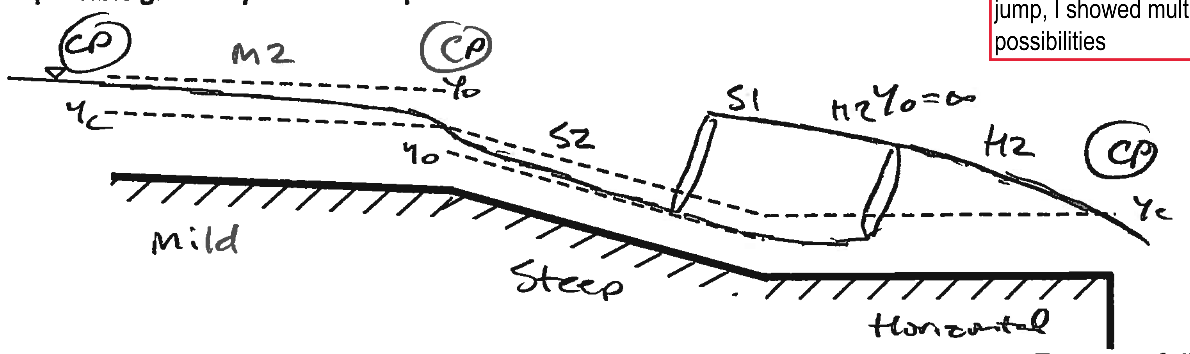
[b] **Label the bed slopes.**

[c] **Label the control points.**

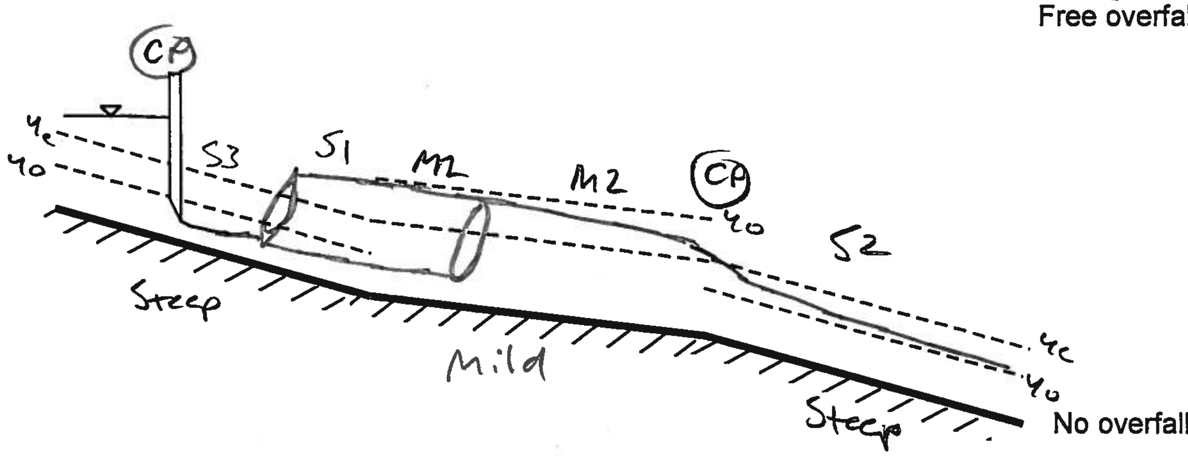
[d] **Draw a possible gradually varied flow profile and label all the curves.**

15 points each
You only need to show 1 jump, I showed multiple possibilities

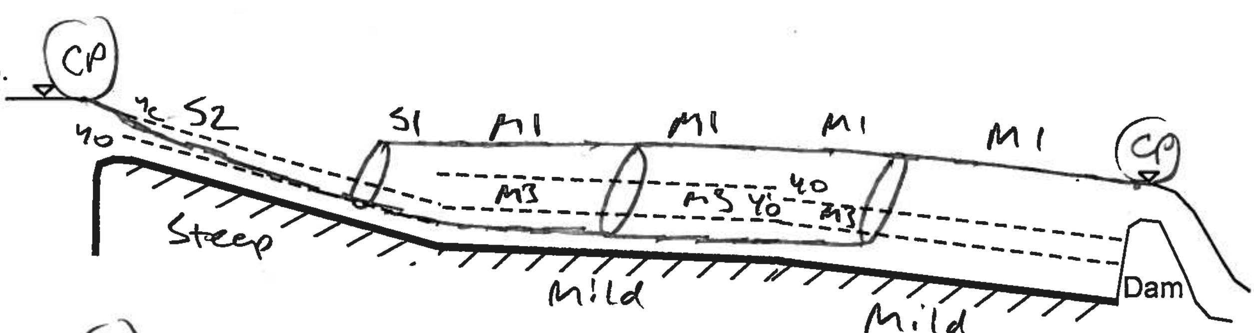
1.



2.



3.



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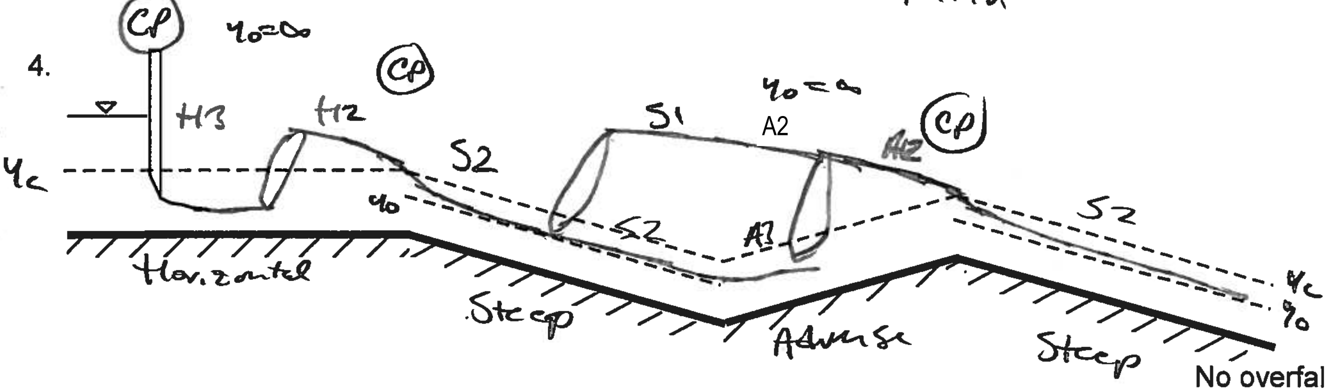

5.2 Given: Reservoir discharges into long trapezoidal channel.
$b = 20$ ft, $m = 3$, $n = 0.025$, $S_0 = 0.001$.
Reservoir water surface 10ft above invert of channel entrance

Find: Q

(1) Assume steep slope.
Find y_c

$$\frac{Q^2 B_c}{g A_c^3} = 1 \implies \frac{Q^2}{g} = \frac{A_c^3}{B_c} \qquad (\alpha = 1)$$

$$H = y_c + \frac{Q^2}{2gA_c^2} = y_c + \frac{A_c^3}{B_c}\frac{1}{2A_c^2}$$

$$H = y_c + \frac{A_c}{2B_c} = y_c + \frac{y_c(b + m y_c)}{2(b + 2m y_c)}$$

20 total

10

$$10\text{ft} = y_c + \frac{y_c(20\text{ft} + 3y_c)}{2(20\text{ft} + 2(3)y_c)}$$

$\boxed{y_c = 7.54\text{ ft}}$ — using Goal Seek in Excel

$A_c = 321\text{ ft}^2$ $\quad B_c = 65.2\text{ ft}$ $\quad P = b + 2y_c(1+m^2)^{1/2} = 20\text{ft} + 2(7.54\text{ft})\sqrt{10}$

$P = 67.7\text{ ft}$

$$R_c = \frac{A_c}{P_c} = 4.75\text{ ft}$$

$$Q = \left[\frac{g A_c^3}{B_c}\right]^{1/2} = \left[\frac{(32.2\text{ft/s}^2)(321\text{ft}^2)^3}{65.2\text{ft}}\right]^{1/2} = 4040\text{ cfs}$$

$$S_c = \left[\frac{Qn}{1.49 A_c R_c^{2/3}}\right]^2 = \left[\frac{4040\text{ cfs}(0.025)}{1.49(321\text{ft}^2)(4.75\text{ft})^{2/3}}\right]^2$$

$\boxed{S_c = 0.0056} > S_0 = 0.001$, so slope is mild

$$H_0 = y_0 + \frac{Q^2}{2gA_0^2} = y_0 + \frac{Q^2}{2g\left[y_0(b + m y_0)\right]^2}$$

10

$$10\text{ft} = y_0 + \frac{Q^2}{2(32.2\text{ft/s}^2)\left[y_0(20\text{ft} + 3y_0)\right]^2} \qquad [1]$$

$$Q = \frac{1.49}{n} A_0 R_0^{2/3} S_0^{1/2} = \frac{1.49}{n} \frac{A_0^{5/3}}{P_0^{2/3}} S_0^{1/2}$$

$$Q = \frac{1.49}{0.025} \frac{\left[y_0(20\text{ft} + 3y_0)\right]^{5/3}}{\left[20\text{ft} + 2y_0(1+3^2)^{1/2}\right]^{2/3}} (0.001)^{1/2} \qquad [2]$$

Using Goal Seek in Excel $\boxed{y_0 = 9.43\text{ ft}}$ $\boxed{Q = 2750\text{ cfs}}$

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33 total

5.5 | **Given:** Rectangular channel $b = 6.1\,m$ $n = 0.014$ $S_0 = 0.001$

$Q = 17\,m^3/sec$

Find: Water surface profiles & hydraulic jump location

$$q = \frac{Q}{b} = \frac{17\,m^3/s}{6.1\,m} = 2.79\,m^2/sec$$

$$\underline{y_c} = \left(\frac{q^2}{g}\right)^{1/3} = \left[\frac{(2.79\,m^2/s)^2}{9.81\,m/s^2}\right]^{1/3} = \underline{0.925\,m}$$

$$Q = \frac{1}{n} A R^{2/3} S_0^{1/2} = \frac{1}{n}\, by \left(\frac{by}{b+2y}\right)^{2/3} S_0^{1/2}$$

$$17\,m^3/sec = \frac{1}{0.014}\,\frac{[(6.1\,m)y_0]^{5/3}}{[6.1\,m + 2y_0]^{2/3}}\,(0.001)^{1/2}$$

$\underline{y_0 = 1.31\,m}$ – Goalseek in Excel

10

Direct Step Method

$A_i = by_i = (6.1\,m)y_i$
$P_i = b + 2y_i = (6.1\,m) + 2y_i$
$R_i = A_i / P_i$
$V_i = \frac{Q}{A_i} = \frac{17\,m^3/sec}{A_i}$

See spreadsheet

$E_i = y_i + \frac{V^2}{2g} = y_i + \frac{V^2}{2(9.81\,m/s^2)}$

$$S_{e_i} = \left[\frac{n V_i}{R_i^{2/3}}\right]^2 = \left[\frac{0.014\, V_i}{R_i^{2/3}}\right]^2$$

$$S_{e\,bar} = \frac{S_{e1} + S_{e2}}{2}$$

$\Delta E = E_2 - E_1$

$$\Delta x = \frac{\Delta E}{S_0 - S_{e\,bar}}$$

For Hydraulic Jump – need Momentum function

$$M = A h_c + \frac{Q^2}{gA} \rightarrow \frac{by^2}{2} + \frac{Q^2}{g\,by} = \frac{(6.1\,m)y^2}{2} + \frac{(17\,m^3/s)^2}{(9.81\,m/s^2)(6.1\,m)y}$$

Intersection $M_u = 8.58\,m^3$ @ $x = 56.5\,m \rightarrow y_u = 0.67\,m$
$M_d = 8.58\,m^3$ @ $x = 56.5\,m \rightarrow \underline{y_d = 1.24\,m}$

$$Fr_1 = \frac{V_1}{(gy_1)^{1/2}} = \frac{(4.16\,m/s)}{[(9.81\,m/s^2)(0.67\,m)]^{1/2}} = 1.62$$

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Check $\frac{y_2}{y_1} = \frac{1}{2}\left[-1+\sqrt{1+8\mathbb{F}_{r_1}^2}\right]$

$= \frac{1}{2}\left[-1+\sqrt{1+8(1.62)^2}\right] = 1.85$

$y_2 = 1.85\, y_1 = 1.85\,(0.67\,m)$

$\boxed{y_2 = 1.24\,m}$ ✓

5.5

Given: Rectangular channel

b = 6.1 m

n = 0.014

S_o = 0.001

y_o (m)	A_o (m^2)	P_o(m)	R_o (m)	Q (m^3/s)
1.31	7.98	8.72	0.92	17.00

y_c (m)

0.93

300 m upstream from overfall

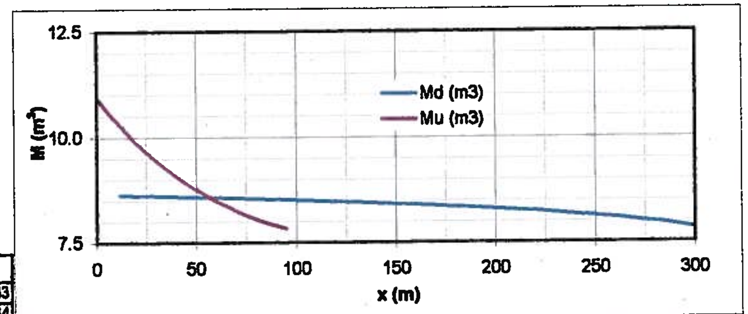
y = 0.47 m

Q = 17 m^3/sec

Find: Water surface profiles and location of hydraulic jump

Direct Step Method

Δy (m) = 0.02 m



Moving upstream from overfall

y (m)	A (m^2)	P (m)	R (m)	V (m/s)	E (m)	S_e	S_{ebar}	ΔE (m)	Δx (m)	$\sum$x (m)	M_d (m^3)
0.93	5.67	7.98	0.71	3.00	1.38769	0.002765				300.00	7.83
0.95	5.80	8.00	0.72	2.93	1.38862	0.002593	0.002679	0.00093	-0.55	299.45	7.84
0.97	5.92	8.04	0.74	2.87	1.39072	0.002435	0.002514	0.00210	-1.39	298.06	7.85
0.99	6.04	8.08	0.75	2.82	1.39390	0.002290	0.002362	0.00317	-2.33	295.73	7.87
1.01	6.16	8.12	0.76	2.76	1.39806	0.002156	0.002223	0.00416	-3.40	292.33	7.89
1.03	6.28	8.16	0.77	2.71	1.40313	0.002033	0.002095	0.00508	-4.64	287.69	7.92
1.05	6.41	8.20	0.78	2.65	1.40905	0.001919	0.001976	0.00592	-6.06	281.63	7.96
1.07	6.53	8.24	0.79	2.60	1.41576	0.001814	0.001867	0.00670	-7.73	273.89	8.01
1.09	6.65	8.28	0.80	2.56	1.42319	0.001717	0.001765	0.00743	-9.70	264.19	8.05
1.11	6.77	8.32	0.81	2.51	1.43129	0.001626	0.001671	0.00810	-12.07	252.12	8.11
1.13	6.89	8.36	0.82	2.47	1.44001	0.001542	0.001584	0.00873	-14.94	237.18	8.17
1.15	7.02	8.40	0.84	2.42	1.44933	0.001464	0.001503	0.00931	-18.52	218.66	8.23
1.17	7.14	8.44	0.85	2.38	1.45918	0.001391	0.001427	0.00985	-23.07	195.59	8.30
1.19	7.26	8.48	0.86	2.34	1.46954	0.001323	0.001357	0.01036	-29.05	166.54	8.38
1.21	7.38	8.52	0.87	2.30	1.48038	0.001259	0.001291	0.01084	-37.26	129.27	8.46
1.23	7.50	8.56	0.88	2.27	1.49165	0.001200	0.001229	0.01128	-49.20	80.08	8.54
1.25	7.63	8.60	0.89	2.23	1.50335	0.001144	0.001172	0.01169	-68.12	11.95	8.63
1.27	7.75	8.64	0.90	2.19	1.51543	0.001092	0.001118	0.01208	-102.66	-90.71	8.72
1.29	7.87	8.68	0.91	2.16	1.52788	0.001043	0.001067	0.01245	-185.54	-276.26	8.82
1.31	7.99	8.72	0.92	2.13	1.54067	0.000997	0.001020	0.01279	-653.34	-929.60	8.92

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Moving downstream from sluice gate

y (m)	A (m^2)	P (m)	R (m)	V (m/s)	E (m)	S_e	S_{ebar}	ΔE (m)	Δx (m)	$\sum$x (m)	M_u (m^3)
0.47	2.87	7.04	0.41	5.93	2.26202	0.022829				0.00	10.95
0.49	2.99	7.08	0.42	5.69	2.13872	0.020019	0.021424	-0.12330	6.04	6.04	10.59
0.51	3.11	7.12	0.44	5.48	2.03194	0.017652	0.018836	-0.10678	5.99	12.02	10.26
0.53	3.23	7.16	0.45	5.26	1.93925	0.015644	0.016648	-0.09270	5.92	17.95	9.97
0.55	3.36	7.20	0.47	5.07	1.85862	0.013930	0.014787	-0.08063	5.85	23.80	9.70
0.57	3.48	7.24	0.48	4.89	1.78840	0.012458	0.013194	-0.07022	5.76	29.55	9.46
0.59	3.60	7.28	0.49	4.72	1.72720	0.011187	0.011823	-0.06120	5.66	35.21	9.25
0.61	3.72	7.32	0.51	4.57	1.67385	0.010084	0.010636	-0.05335	5.54	40.75	9.05
0.63	3.84	7.36	0.52	4.42	1.62737	0.009122	0.009603	-0.04647	5.40	46.15	8.88
0.65	3.97	7.40	0.54	4.29	1.58694	0.008279	0.008701	-0.04043	5.25	51.40	8.72
0.67	4.09	7.44	0.55	4.16	1.55184	0.007538	0.007908	-0.03510	5.08	56.48	8.58
0.69	4.21	7.48	0.56	4.04	1.52146	0.006883	0.007210	-0.03038	4.89	61.37	8.45
0.71	4.33	7.52	0.58	3.93	1.49528	0.006302	0.006592	-0.02618	4.68	66.05	8.34
0.73	4.45	7.56	0.59	3.82	1.47284	0.005785	0.006044	-0.02244	4.45	70.50	8.24
0.75	4.58	7.60	0.60	3.72	1.45375	0.005324	0.005555	-0.01909	4.19	74.69	8.15
0.77	4.70	7.64	0.61	3.62	1.43766	0.004911	0.005118	-0.01608	3.91	78.60	8.08
0.79	4.82	7.68	0.63	3.53	1.42429	0.004541	0.004726	-0.01338	3.59	82.19	8.02
0.81	4.94	7.72	0.64	3.44	1.41335	0.004207	0.004374	-0.01094	3.24	85.43	7.96
0.83	5.06	7.76	0.65	3.36	1.40462	0.003905	0.004056	-0.00873	2.86	88.29	7.92
0.85	5.19	7.80	0.66	3.28	1.39790	0.003632	0.003768	-0.00672	2.43	90.72	7.89
0.87	5.31	7.84	0.68	3.20	1.39300	0.003384	0.003508	-0.00490	1.95	92.67	7.86
0.89	5.43	7.88	0.69	3.13	1.38976	0.003158	0.003271	-0.00324	1.43	94.10	7.84
0.91	5.55	7.92	0.70	3.06	1.38803	0.002953	0.003056	-0.00173	0.84	94.94	7.83
0.93	5.67	7.96	0.71	3.00	1.38769	0.002765	0.002859	-0.00034	0.18	95.12	7.83
0.95	5.80	8.00	0.72	2.93	1.38862	0.002593	0.002679	0.00093	-0.55	94.56	7.84

Δx (m) changes sign, because passed critical depth

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5.5

Moving downstream from sluice gate

∑x (m)	y (m)
0.00	0.47
6.04	0.49
12.02	0.51
17.95	0.53
23.80	0.55
29.55	0.57
35.21	0.59
40.75	0.61
46.15	0.63
51.40	0.65
56.48	0.67
35.25	0.59
38.04	0.60
40.79	0.61
43.51	0.62
46.20	0.63
48.84	0.64
51.45	0.65
54.02	0.66
56.54	0.67
56.55	1.24
80.08	1.23
129.27	1.21
166.54	1.19
195.59	1.17
218.66	1.15
237.18	1.13
252.12	1.11
264.19	1.09
273.89	1.07
281.63	1.05
287.69	1.03
292.33	1.01
295.73	0.99
298.06	0.97
299.45	0.95
300.00	0.93