notes and open mind.

✓ **The procedure will be graded. Please justify your answers**

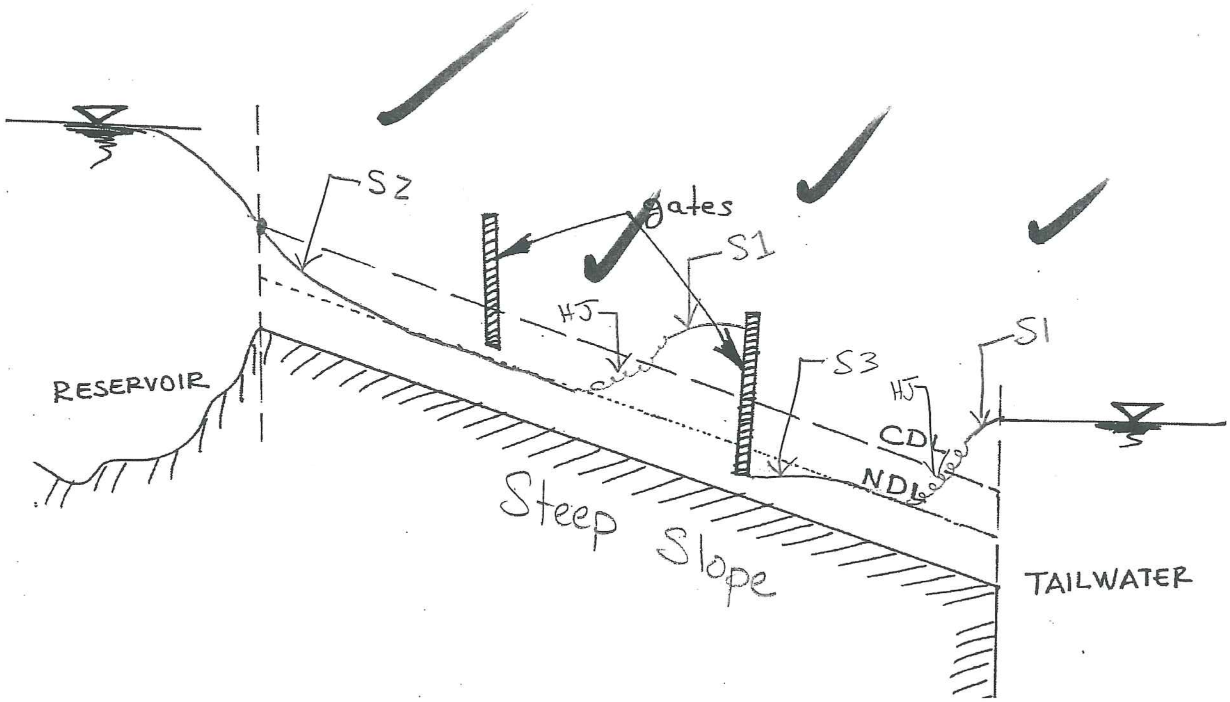
CE 544 - final

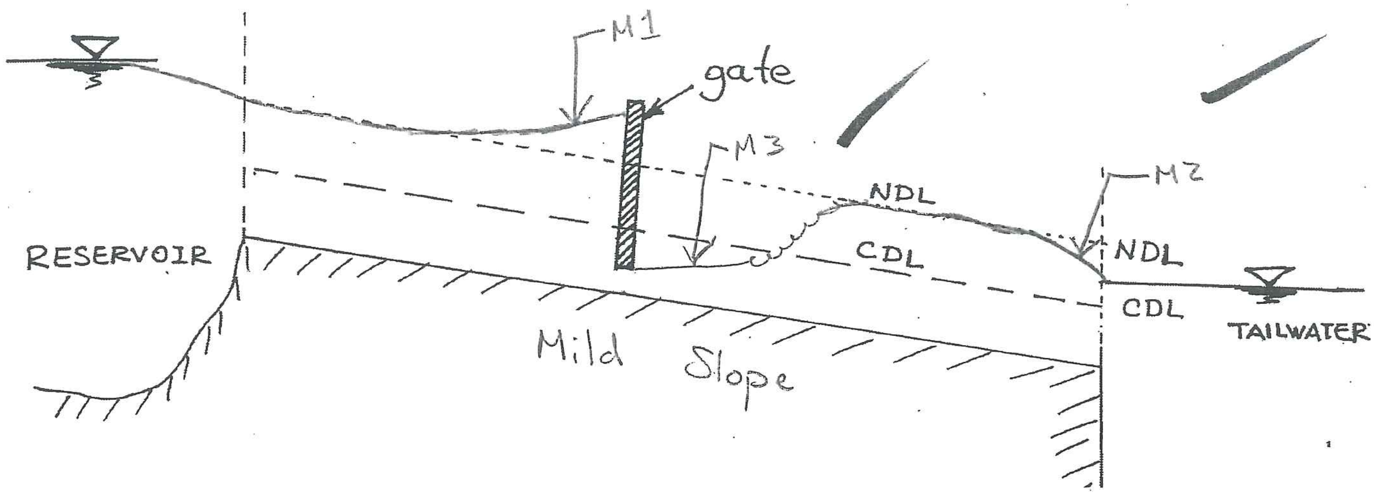
2015

1. (20 points) Sketch and label the types of water surface profiles in the two channels below. **Assume very long (e.g., infinitely long reaches).**

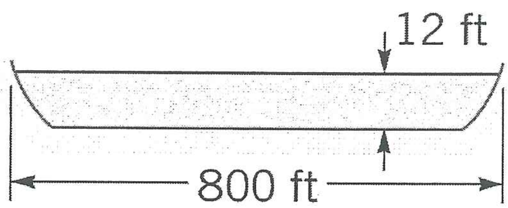
CDL = Critical depth line
NDL = Normal depth line

20/20



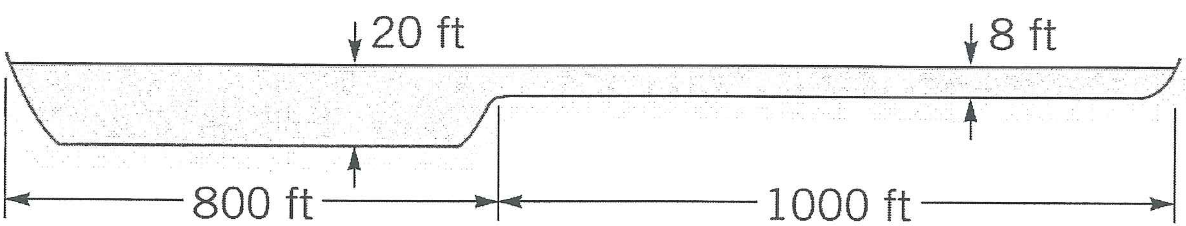

M1
gate
M3
NDL
M2
RESERVOIR
CDL
NDL
CDL
TAILWATER
Mild Slope

2. (20 points) At a given location, under normal conditions a river flows with a Manning coefficient of **0.040**, and a cross section as indicated in Figure (a) [see below]. During flood conditions at this location, the river has a Manning coefficient of **0.060** and a cross section as shown in Figure (b). Determine the ratio of the flowrate during flood conditions to that during normal conditions.



(*a*)

20/20



(*b*)

Non-flood
MC

$n = 0.040$

$A = 800 \times 12 = 9600$

$P = 800 + 2 \times 12 =$

Flood

MC	FP
$n = 0.060$	$n = 0.060$
$A = 800 \times 20$	$A = 8 \times 1000$
$P = 800 + 2 \times 20$	$P = 1000 + 2 \times 8$

$A_T = 24000$

$P_T = 1856$

$$Q_{normal} = \frac{k_n}{n} \times A \times R^{2/3} S_0^{1/2}$$

$$= \frac{1.49}{0.04} \times 9600 \times \left(\frac{9600}{824}\right)^{2/3} \times S_0^{1/2}$$

$$Q_{flood} = \frac{k_n}{n} \times (A_{MC} + A_{FP}) \times \left(\frac{A_{MC} + A_{FP}}{P_{MC} + P_{FP}}\right)^{2/3} \times S_0^{1/2}$$

$$= \frac{1.49}{0.060} \times (24{,}000) \times \left(\frac{24{,}000}{1856}\right)^{2/3} \times S_0^{1/2}$$

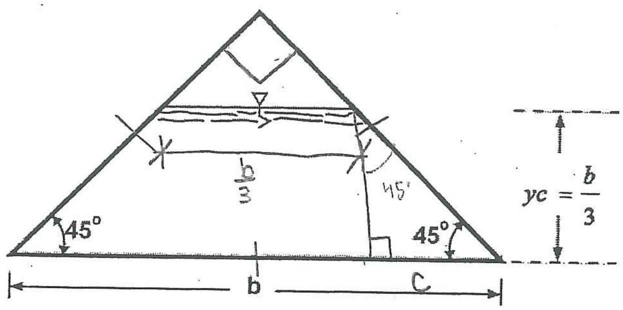
ratio
$$\frac{Q_{flood}}{Q_{normal}} = \frac{\frac{\cancel{1.49}}{0.04} \times 167766.9903 \times \cancel{S_0^{1/2}}}{\frac{\cancel{1.49}}{0.06} \times 132220.897 \times \cancel{S_0^{1/2}}} = \frac{1233409.406}{2203681.567}$$

$= 0.5597$

$\boxed{\text{Qflood is 56\% of Qnormal}}$

3. (10 points) If the critical flow depth (y_c) for the channel below is $y_c = b/3$, determine "b" as a function of the flow discharge (Q).

Find: $b(Q) = KQ^n$ Hint!



$Q = vA$

$\frac{Q}{A} = v$

$y_c = \frac{b}{3}$

$1 = \frac{v}{\sqrt{g\frac{A}{T}}}$

$1 = \frac{v^2}{g\frac{A}{T}} = \frac{Q^2}{A^2} \cdot \frac{T}{gA} = \frac{Q^2 T}{A^3 g}$

$\frac{Q^2}{g} = \frac{A^3}{T}$

$\frac{Q^2}{g} = \frac{\left(\frac{2}{9}b^2\right)^3}{\frac{b}{3}} = \frac{\frac{8}{729}b^6}{\frac{b}{3}} = \frac{24}{729}b^5$

$\left(\frac{729}{24} \cdot \frac{1}{g} \cdot Q^2\right)^{\frac{1}{5}} = b = \boxed{\left(\frac{243}{8g} \cdot Q^2\right)^{\frac{1}{5}} = b}$ ✓

$\tan 45° = \frac{b}{3} \cdot \frac{1}{c}$

$1 = \frac{b}{c} \cdot \frac{1}{3}$

$c = \frac{b}{3}$

$\therefore T = \frac{b}{3}$

$Q = vA$

$= v \cdot \frac{b + \frac{b}{3}}{2} \cdot \frac{b}{3}$

$= v \cdot \frac{\frac{4}{3}b}{\cancel{2}} \cdot \frac{b}{3}$

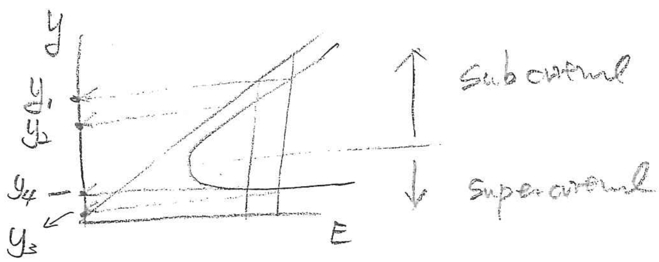
$Q = v \cdot \frac{2}{9}b^2$

$A = \frac{2}{9}b^2$

10/10

4. (10 points) We discussed in class that piers of a bridge may produce contraction of the flow. Assuming that there is no flow choking, will the water stage increase or decrease at the location of the contraction for (a) subcritical flow, (b) supercritical flow? To receive credit, justify briefly your answer for each flow type.

10/10



(a) subcritical case: Bridge cause water surface decrease because reduced energy caused by the bridge makes y reduced as shown above ($y_1 \to y_2$)

(b) Supercritical case: Bridge cause water surface Increase because reduced energy caused by the bridge make y increased as shown aboved figure

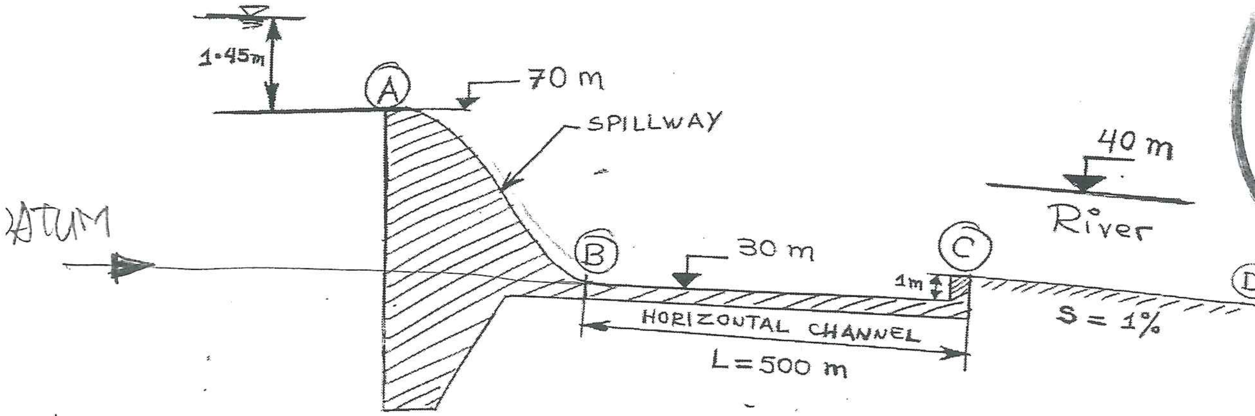
($y_3 \to y_4$)

5. (20 points) A rectangular channel (b = 100 m) has a spillway and the configuration shown below. If the flow discharge is Q = 1000 m³/s, determine if the hydraulic jump will occur upstream or downstream of section B. Justify your answer.

$$q = \frac{Q}{b} = \frac{1000}{100} = 10 \ \frac{m^2}{s}$$

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = 2.17 \ m$$

20/20



Assume HJ happen at (B)

$$Fr = \frac{V}{\sqrt{gD}}$$

From (A) - (B)

$$E_L + E_o = z_b + y_B + \frac{q^2}{2 g y_B^2}$$

$$70 + \frac{2}{3} \times 2.17 = 30 + y_B + \frac{100^2}{2 \times 9.8 \times y_B^2} \Rightarrow y_B = 0.345 \ m$$

$$Fr_A = \frac{V_B}{\sqrt{g y_B}} = \frac{28.985}{\sqrt{9.8 \times 0.345}} = 15.76.$$

$$Q = 1000 = V_B \, y_B \times 100$$

$$\therefore V_B = 28.985 \ m/s$$

HJ equation:

$$\frac{y_2}{y_B} = \frac{1}{2}\left(-1 + \sqrt{1 + 8 Fr_B^2}\right) = 21.79$$

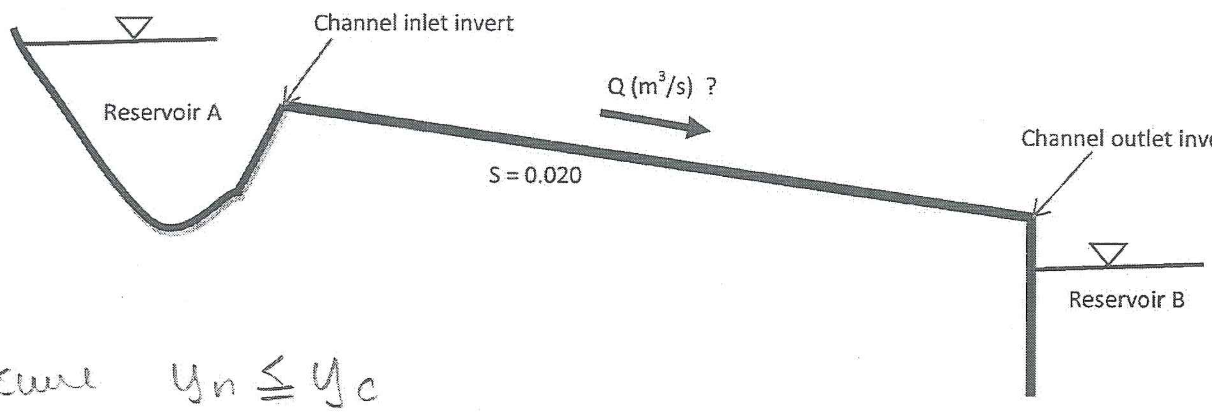
$$\therefore y_2 = 7.51 \ m$$

$y_2 + 30 = 37.51 < TW\,(40m)$ → therefore HJ will occur between (A) & (B), i.e. Before (B).

ele. of Congulagale depth.

6

2. A long rectangular channel connects reservoirs "A" and "B" as sketched below. The channel has a width of 10 m, a longitudinal slope of 0.020 and a Manning's roughness "n" of 0.040. If the upstream reservoir water surface is 4.00m above the channel inlet invert and the downstream reservoir water surface is below the channel outlet invert, determine the flow discharge in the channel in m^3/s. Neglect local head losses.



Assume $y_n \leqq y_c$

Since $Fr = 1$ $\quad V_c = \sqrt{g y_c}$, $\quad V_c^2/2g + y_c = 4$

Solve for $y_c = 2/3 H = 2.667m$

On the other hand, $\quad q = Q^*/b = \sqrt{g y_c^3} = 13.6 m^2/s$

$Q^* = q \times b = 136\ m^3/s = \frac{k}{n} A R_h^{2/3} S^{1/2}$

Solving for y_n,

$$Q^* = \frac{1}{0.040} (y_n b) \left(\frac{y_n b}{y_n + 2b} \right)^{2/3} (0.020)^{1/2} = 136 m^3/s$$

$y_n = 2.667m \quad (= y_c = 2.667m)$

∴ Assumption is correct $y_n \leq y_c$

Note that $y_n = y_c$, which means that the flow in the channel is critical and normal at the same time