SHEET NUMBER
JOB NAME: HYDRAULICS
RE: RESERVOIR / PIPING
DATE 3/15/06

5.1 MILE @ +280 Ft TO +100 Ft ELEVATION, NEW, SMOOTH, CAST IRON, $f_{DARCY} = 0.021$
Q = 1 MGD

SMALLEST PIPE: $h_L = f\frac{L}{D}\frac{V^2}{2g} = f\frac{L}{D}\left(\frac{Q^2}{2g(\frac{\pi}{4}D^2)}\right) \Rightarrow D^5 = \frac{8fLQ^2}{h_L g \pi^2}$

$D^5 = 8(0.021)\,5.1(5280)\text{Ft}\left(1\times10^6 \frac{G}{D}\right)\left(\frac{1\text{Ft}^3}{7.48\text{GAL}}\right)\left(\frac{1}{3600(24)}\frac{\text{SEC}}{D}\right) / [(280-100)32.2\,\pi^2]$

$D^5 = 0.191\,\text{Ft}^5 \therefore D = 0.717'$ OR 8.6"

AVAILABLE D = 10" (8.6")

FRICTION FACTOR MOODY DIAGRAM ϵ/D VS $Re \rightarrow f$

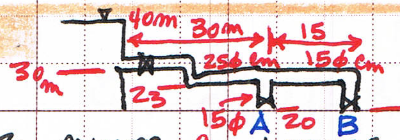
$Re = \frac{VD}{\nu} = \frac{Q}{A}\frac{D}{\nu} = \frac{1.55\text{CFS (SAME AS 1MGD)}}{\frac{\pi}{4}\left(\frac{10}{12}\right)^2 (1.2\times10^{-5}\text{Ft}^2/\text{S})} = 2.0\times10^5$

$\epsilon/D = (\epsilon \text{ C.I. SMOOTH} = 0.0102)/10 = 0.001$ & $Re = 2.0\times10^5 \rightarrow f = 0.021$
$\therefore$ O.K.

MANNING n 1st LOOK UP and CALCULATE

$h_f = f\frac{L}{D}\frac{V^2}{2g} = \left(\frac{n^2 2g}{1.49^2}\frac{4^{4/3}}{D^{4/3}}\right)\frac{L}{D}\frac{V^2}{2g} \rightarrow n^2 = \frac{fD^{1/3}}{184} = \frac{0.021\left(\frac{10}{12}\right)^{1/3}}{184} = 0.000107$

n = 0.010 TABLE



PIPE 25 cm φ, 30m 2 ELBOWS, VALVE
PIPE 15 cm φ, 15m 1 ELBOW

f = 0.02, MINOR LOSSES ARE NEGLECTED. TOTAL Q? A & B OPEN

EQUATION 1: $\cancel{40} - f\frac{L_{25}V_{25}^2}{D_{25}(2g)} - f\frac{L_A V_A^2}{D_{15}(2g)} = \frac{V_A^2}{2g} + \cancel{20}$

2: $\cancel{40} - f\frac{L_{25}V_{25}^2}{D_{25}(2g)} - f\frac{L_B V_B^2}{D_{15}(2g)} = \frac{V_B^2}{2g} + \cancel{20}$

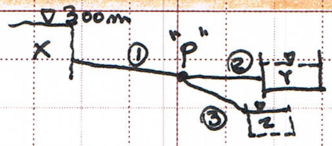
$A_{15}(V_A + V_B) = A_{25}V_{25}$

$V_B = 8.96$ m/s

$-\frac{fL_A V_A^2}{D_{15}(\cancel{2g})} + \frac{fL_B V_B^2}{D_{15}(\cancel{2g})} = \frac{1}{\cancel{2g}}(V_A^2 - V_B^2) = \left\{\frac{V_A^2 - V_B^2}{f} = L_B V_B^2 - L_A V_A^2\right\}$

$V_{25} = 0.887 V_B = 7.95$ m/s

$Q = A_{25}V_{25} = \frac{\pi}{4}(0.25)^2 7.95 = 0.39\,\text{m}^3/\text{s}$



① 3000m, 60 cm φ, LINE X; ② 1500m, 45 cm, $Q_Y = 0.6\,\text{m}^3/\text{s}$, LINE Y
③ LINE Z, D = 45 φ cm, L = 1200m
Y @ 150m

ENERGY GRADE LINE & HYDRAULIC G.L.

ENERGY GRADE LINE = HYDRAULIC GRADE LINE + h_v

$= (h_p + h_z) + h_v$

h_v = ENERGY GRADE LINE – HYDRAULIC GRADE LINE

= EGL – HGL

a. — HGL $\leq$ EGL

b. — EGL = ALWAYS HORIZONTAL

c. — @ $V=0$ (FREE SURFACE), $h_v = 0 = EGL - HGL$; $EGL = HGL$

d. — EGL = RESERVOIR WATER SURFACE

e. — $V_1 = V_2$, FLOW VELOCITY = CONSTANT (AREA NOT CHANGE)

f. — HGL IS PARALLEL TO EGL, REGARDLESS OF PIPE ORIENTATION

g. — FLOW AREA DECREASE HGL DECREASE

h. — FLOW AREA INCREASE HGL INCREASE

j — @ FREE JET (HOSE STREAM): HGL IS SAME AS ELEVATION of STREAM (PARABOLIC TRAJECTORY)

k — FRICTION REDUCES h_p (THUS HGL)

SHEET NUMBER 1
JOB NAME: OPEN CHANNEL
RE:
DATE 8/01/03

INTRODUCTION:

1. OPEN CHANNEL EXPOSED TO ATMOSPHERE (i.e. CULVERT, FLUMES, PIPES (GRAVITY)

2. REACH: STRAIGHT SECTION UNIFORM SHAPE, DEPTH, SLOPE, FLOW QUALITY

3. ERODIBLE VS NON-ERODIBLE

TYPES OF FLOWS:

1. TURBULENT
2. LAMINAR
3. STEADY flow $\neq f(time)$
4. UNIFORM FLOW: XSECTION IS CONSTANT
5. NON- ~~STEADY~~ UNIFORM CAN OCCUR ON STEPS, CHANNELS, ETC.
6. CATEGORIES

SUBCRITICAL	CRITICAL flow	SUPERCRITICAL f.
(TRANQUIL FLOW)		(RAPID, SHOOTING)
UNIFORM FLOW (STEADY flow)		UNIFORM f.
NORMAL FLOW		NORMAL f.
NON UNIFORM FLOW (VARIED FLOW)		NON UNIFORM
accelerating flow		accelerating
decellerating flow		decelerating

MINIMUM VELOCITIES
2-3 Ft/Sec ave.
2.5 Ft/Sec LIMITS PLANT GROWTH

SHEET NUMBER 21
JOB NAME: OPEN CHANNEL
RE:
DATE 8/1/03

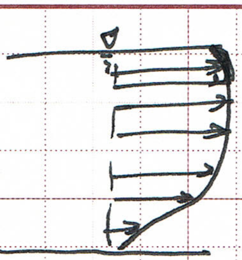
DETAILS
ENGINEERING & CONSULTING

VELOCITY DISTRIBUTION:

flow → $Q = A V$

A → XS UNIFORM AREA

V → V = mean velocity



STREAM GAUGING
AVE. VELOCITY DES.

HYDRAULIC RADIUS

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

P → WETTED PERIMETER

FOR VERY WIDE CHANNELS R_h = dEPTH

HYDRAULIC DEPTH: $D_h = \frac{A}{W}$ W → WIDTH

Table 19.2 TABLES

X SECTION FACTOR: $AR^{2/3}$ R = hydraulic Radius (general UNIFORM Flow)

COMPARE WITH DEPTH of IRREGULAR XSection

X SECTION FACTOR: $A\sqrt{D_h}$ CRITICAL FLOW ONLY

SLOPE: ENERGY LINE: h
Δh

CRITICAL SLOPE → CRITICAL DEPTH
NORMAL SLOPE → NORMAL DEPTH

$A_1V_1 = A_2V_2$ INCOMPRESSIBLE / CONTINUITY

CHEZY EQN $V = C\sqrt{RS}$ → SLOPE

VELOCITY ← V

↳ HYDRAULIC RADIUS

↳ Coef

$$C = \sqrt{\frac{8g}{f}}$$ $f = F$(Re, MOODY DIAGRAM)

IF CHANNEL IS LARGE, → fully TURBULENT

ROUGHNESS of RIVER ←

C = F (ROUGHNESS of SURFACE)
& GEOMETRY

$$= \left(\frac{1.00}{n}\right) R^{1/6} (SI) \Rightarrow \left(\frac{1.49}{n}\right) R^{1/6} \text{ U.S.}$$

n: Manning's n ROUGHNESS Coef.

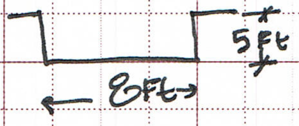
$$V = C\sqrt{RS} = \sqrt{\frac{8g}{f}}\sqrt{RS}$$

$$= \left(\frac{1.00}{n}\right) R^{1/6}\sqrt{RS} = \left(\frac{\overset{1.49}{1.00}}{n}\right) R^{2/3}\sqrt{S}$$

$$Q = AV = \left(\left(\frac{1.00}{n}\right) R^{2/3}\sqrt{S}\right)A = K\sqrt{S}$$

$$K = \left(\frac{1.00}{n}\right) AR^{2/3}$$

EXAMPLE



CONCRETE
S = 0.002
Q = ?

$$Q = VA = K\sqrt{S} = CA\sqrt{RS} = \left(\frac{\overset{\text{"}1.49\text{"}}{1.00}}{n}\right) R^{1/6} A\sqrt{RS}$$

$$R = \frac{A}{P} = \frac{(8)(5)}{5+8+5} = 2.22 \text{ ft}$$

$$C = \left(\frac{1.49}{n}\right) R^{1/6} = \frac{1.49}{n=0.012}(2.22)^{1/6} = 141.8$$ APP. 19A

$$Q = VA = C\sqrt{RS}\,A$$

$$= (141.8)\sqrt{(2.22)(0.002)}\,A$$

$$= 377.9 \text{ ft}^3$$

- n varies with depth
  APPENDIX 19.C VARYING & CONSTANT n
-

EXAMPLE:

$Q = 2.5\ ft^3/s$ n varies w/depth

$\Phi = 20''$ FLOW: UNIFORM & STEADY

$n = 0.015$

$S = 0.001$

$V \overset{?}{=}$ & depth ?

$R_{HYDRAULIC}$ RADIUS $\longrightarrow V_{FULL} = \left(\frac{1.49}{n}\right) R^{2/3} \sqrt{S} \longrightarrow Q_{FULL} = V_{FULL}\, A$

$\frac{V}{V_{FULL}} \longleftarrow$ FIND $\frac{d}{D} \longleftarrow$ (USE CHART) $\longleftarrow \frac{Q_{ACTUAL}}{Q_{FULL}} \longleftarrow$

$\hookrightarrow V = \otimes\, V_{FULL}$ OR $d = D \otimes$

$R = \frac{D}{4} = \frac{20in/12}{4} = 0.417\ ft$ $= \frac{0.5m}{4} = 0.125m$

$V_{FULL} = \left(\frac{1.49}{n \to 0.015}\right)(0.417)\sqrt{0.001} = 1.75 ft/s$ $= \left(\frac{1.0}{0.015}\right)(0.125)^{2/3}\sqrt{0.001}$

$Q_{FULL} = AV_{FULL} = 1.75\left(\frac{20}{12}\right)^2 \frac{\pi}{4} = 3.83$ $= \left(0.53\frac{m}{s}\right)\left(\frac{\pi}{4}\right)(0.5)^2 = 0.1 m^3/s$

$\frac{Q}{Q_{FULL}} = \frac{2.5}{3.83} = 0.65$ $= \frac{0.07}{0.10} = 0.70$

$\frac{d}{D}$; V/V_{FULL}

HAZEN-WILLIAMS VELOCITY

$V = 0.85\ C R^{0.63} S_0^{0.54}$ SI

$1.318\ C R^{0.63} S_0^{0.54}$ US

C = f (Roughness) (Not fluid Characteristics)

dn : NORMAL DEPTH : NEITHER INCREASES OR DECREASE

IF WIDTH IS VERY LARGE XS IS RECTANGULAR & MANNING EQN CAN BE USED.

$(R \approx d_n)$

$$d_n = \left(\frac{nQ}{w\sqrt{S}} \right)^{3/5} \quad (w \gg d_n) \quad \text{SI}$$

0.788 (U.S.)

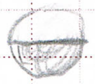
RECTANGULAR

IF CIRCULAR CHANNEL IS FULL

$$D = d_n = 1.548 \left(\frac{nQ}{\sqrt{S}} \right)^{3/8} \text{(full)}$$

1.335 U.S.

$$D = 2d_n = 2.008 \left(\frac{nQ}{\sqrt{S}} \right)^{3/8}$$ HALF full



$$D = 2d_n = 1.731 \left(\frac{nQ}{\sqrt{S}} \right)^{3/8}$$ HALF / FULL

RECTANGULAR CHANNELS

$W \approx d_n$

$$R = \frac{W d_n}{W + d_n}$$

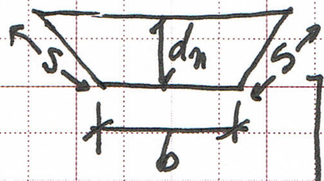
$$A = W d_n$$

$$Q = \left(\frac{1.00}{n}\right) W d_n \left(\frac{W d_n}{W + 2 d_n}\right)^{2/3} \sqrt{S}$$

1.49 U.S.

RECTANGULAR

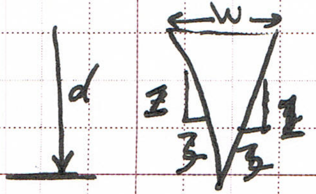
$$R = \frac{d_n (b + W)}{2(b + 2S)}$$



TRAPEZOID

$$A = \frac{d_n (W + b)}{2}$$

$$R = \frac{Z d_n}{2\sqrt{1 + Z^2}}$$



TRIANGULAR

$$A = Z d_n^2$$

ENERGY & FRICTION RELATIONSHIPS

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_f$$

↳ FRICTION head

$$d = \frac{P}{\rho g}$$

FOR UNIFORM FLOW $V_1 = V_2$; $d_1 = d_2$ @ BOTTOM OF CHANNEL

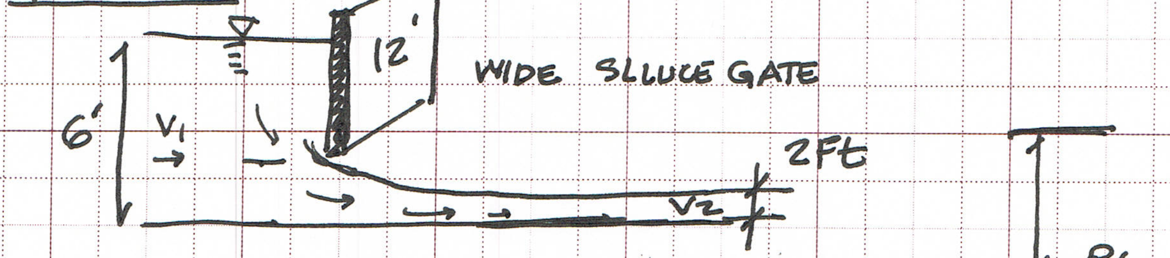
$$h_f = Z_1 - Z_2$$

SLOPE of Channel $S_0 = \frac{Z_1 - Z_2}{L}$

$$h_f = L S = \frac{L n^2 V^2}{R^{4/3}}$$

2.208 U.S

EXAMPLE



FLOW UNIFORM & STEADY

$$d_1 + \frac{V_1^2}{2g} = d_2 + \frac{V_2^2}{2g}$$

$$A_1 V_1 = A_2 V_2$$

$A_1 = (6)(12)\ ft^2$
$A_2 = (2)(12)\ ft^2$
$d_1 = 6'$
$d_2 = 2'$

$$6 + \frac{V_1^2}{2g} = 2 + \frac{V_2^2}{2g} \rightarrow \overset{4}{8}(2g) + V_1^2 = V_2^2 = \left(\frac{V_1}{3}\right)^2 = \frac{9V_1^2}{\text{[illegible]}}$$

$$(6)12V_1 = (2)(12)V_2 \rightarrow V_2 = \frac{3V_1}{3}$$

$$8g = 8V_1^2$$

$$\underline{V_1 = \sqrt{g}}$$

EXAMPLE

NORMAL FLOW

$S = 0.002$ $V = 9.447$ Ft/s

$n = 0.012$ $R = 2.22$ Ft

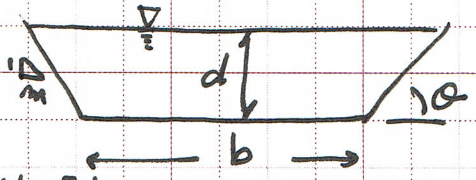
ENERGY LOSS PER 1000 Ft

$$h_f = LS = (1000\text{ Ft})(0.002) = 2\text{ Ft}$$

$$h_f = \frac{L n^2 V^2}{2.208 R^{4/3}} = \frac{(1000)(0.012)^2(9.447)^2}{2.208(2.22)^{4/3}} = 2\text{ft}$$

SIZING TRAPEZOIDAL & RECTANGULAR CHANNELS

$$Q = \frac{K' b^{8/3}}{n}\sqrt{S_0}$$



$$K' = \left(\frac{(1+m(d/b))^{5/3}}{(1+2(\frac{d}{b})\sqrt{1+m^2})^{2/3}}\right)\left(\frac{d}{b}\right)^{5/3}$$

$$K' = \left(1.49 \qquad\qquad \right)^{5/3}$$

CONDITION:

a) USE MANNING w/XS AREA TO REACH FLOW

b) IF UNKNOWN, TRIAL & ERROR ONLY

$m = \cot\theta$

K = CONVEYANCE

CALC. & PLOT K vs delth

GRAPH $^{0.05}d/b < 0.5$ To define K'

IF d/b is very Small $\left(\frac{d}{b} < 0.02\right)$ TRAPEZOID IS RECTANGULAR

$A = bd$

MOST EFFICIENT CROSS SECTION

MAXIMIZE: FLOW WITH $f(n, S, Q) \rightarrow$ also R_h
MINIMIZE: WETTED PERIMETER

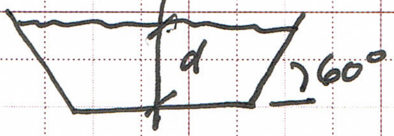
∴ SEMICIRCLE IS HIGHEST (OR SMALLEST PERIMETER)
BUT IS MOST EXPENSIVE TO FORM

RECTANGULAR & TRAPEZOIDS LESS COST

MOST EFFICIENT RECTANGLE: $d = \frac{w}{2} = \frac{WIDTH}{2} = DEPTH$

$$\left.\begin{array}{l} A = dw = \frac{w^2}{2} = 2d^2 \\ P = d + w + d = 4w = 2d \end{array}\right\} R = \frac{w}{4} = \frac{d}{2}$$

MOST EFFICIENT TRAPEZOID: $d = 2R_h$; $\theta = 60°$



$$\left.\begin{array}{l} d = 2R_h \\ b = \frac{2d}{\sqrt{3}} \end{array}\right\} \begin{array}{l} A = 2d/\sqrt{3} \\ P = 3b = 2\sqrt{3}d \ ; \ R = \frac{d}{2} \end{array}$$

EXAMPLE:
MASONARY
$Q = 500\ ft^3/s$
$S = 0.0001$
$n = 0.017$
FIND MOST EFF. DIMEN

RECTANGULAR DIMENSION

$$Q = \left(\frac{1.49}{n}\right) AR^{2/3} S = 500 = \left(\frac{1.49}{0.017}\right) AR^{2/3} \sqrt{0.0001}$$

$$AR^{2/3} = (dw)\left(\frac{A}{P}\right)^{2/3} = dw\left(\frac{dw}{w+2d}\right) = \frac{w^2}{2}\left(\frac{w}{4}\right)^{2/3}$$

If $d = W/2$ For efficient

$$500 = 0.01739W^{8/3} \rightarrow W = 19.82\ ft$$

$$d = W/2 = 9.91\ ft$$

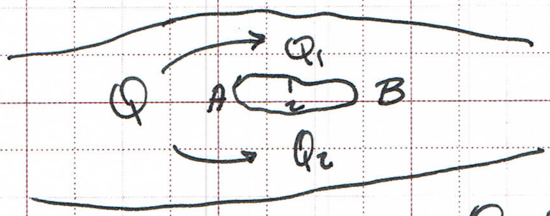
ANALYSIS OF NATURAL WATERCOURSES

NO UNIFORM FLOW

FRICTION LOSS $\alpha(n)^2$

COMPOSITE ROUGHNESS Coefficient $n_c = \left(\frac{\Sigma P_i (n_i)^{3/2}}{\Sigma P_i}\right)^{2/3}$

i: INDIVIDUAL area Perimeter & Roughness



$Q = Q_1 + Q_2$

S_1 & $S_2 \Rightarrow S_1 = \frac{Z_A - Z_B}{L_1}$ $S_2 = \frac{Z_A - Z_B}{L_2}$

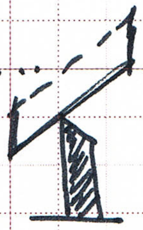
$$Q = 1.49\left[\left(\frac{A_1}{n_1}\right) R_1^{2/3} + \left(\frac{A_2}{n_2}\right)^{\cancel{2/3}} R_2^{2/3}\right]\sqrt{S}$$

$\uparrow$ U.S.

14. FLOW MEASUREMENTS WITH WEIRS

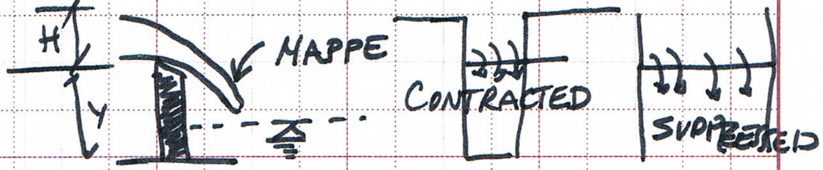
OBSTRUCTION SUCH AS SPILLWAYS, DAM, ...

SHARP CRESTED WEIRS (RECTANGULAR



SOMETIMES TRIANGLE, OR TRAPEZOID

STAFF GAUGE



$$Q\ (\text{RECTANGULAR}) = \frac{2}{3} b\sqrt{2g}\left(\left(H+\frac{V_1^2}{2g}\right)^{3/2} - \left(\frac{V_1^2}{2g}\right)\right)$$

$$= \frac{2}{3} b\sqrt{2g}\, H^{3/2}$$

$$= \frac{2}{3} C_1 b\sqrt{2g}\, H^{3/2}$$ w. FRANCISE Eqn

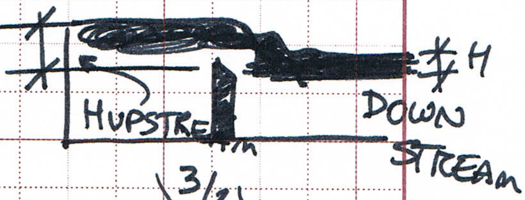
C_1 FRANCISE OR Rehbock

$$C_1 \approx 0.602 + 0.083\left(\frac{H}{Y}\right) \quad \Big| \quad \frac{H}{Y} < 0.2 \qquad C_1 = 0.61 \to 0.62$$

$$\boxed{\begin{aligned} Q_1 &\approx 1.84\, bh^{3/2} && \text{S.I.} \\ &\approx 3.33\, bh^{3/2} && \text{U.S.} \end{aligned}}$$

$$b_{effective} = b_{actual} - 0.1\overset{\#\text{OF CONTRACTIONS}}{N}H$$

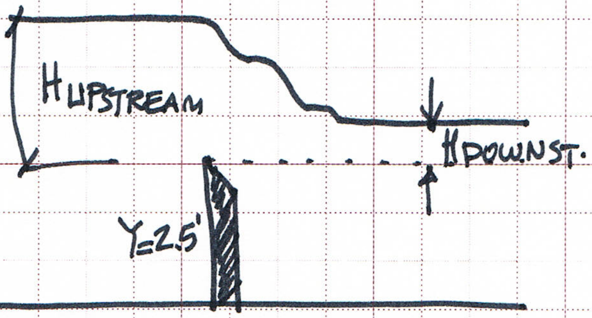
SUBMERGED RECTANGULAR WEIR



$$Q_{SUBMERGED} = Q_{\substack{FREE\\flow}}\left(1 - \left(\frac{H_{DOWNSTREAM}}{H_{UPSTREAM}}\right)^{3/2}\right)$$

EXAMPLE

$H = 4''/12'' = 0.333'$



$$b_{EFFECTIVE} = b_{actual} - 0.1\,N\,H$$

$$= 4\text{ Ft} - 0.1\,(2\text{ CONTRACTIONS})\left(\frac{4}{12}\right)$$

$$= 3.93'$$

$$C_1(\text{Rehbock Ceof}) = \left(0.6035 + 0.0813\overset{(H/Y)}{\left(\frac{4/12}{2.5}\right)} + \left(\frac{0.000295}{2.5}\right)\right)\left(1 + \frac{0.00361}{4/12}\right)^{3/2}$$

$$= 0.624$$

$$Q = \frac{2}{3}\,C_1\,b\sqrt{2g}\,H^{3/2}$$

$$= \frac{2}{3}(0.624)(3.93)\sqrt{2g}\left(\frac{4}{12}\right)^{3/2} = 2.52\ \text{ft}^3/\text{sec}$$

$$V = \frac{Q}{A} = \frac{2.52\ \text{Ft}^3/\text{Sec}}{(4\text{Ft})(2.5 + 0.333)} = 0.222\ \text{ft}/\text{Sec}$$

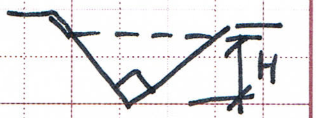
TRIANGULAR WEIRS

$$Q = C_2\left(\frac{8}{15}\right)\tan\left(\frac{\theta}{2}\right)\sqrt{2g}\,H^{5/2}$$

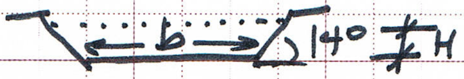
$$\left.\begin{aligned} Q &= 1.4\,H^{2.5} \\ &= 2.5\,H^{2.5} \end{aligned}\right]\ 90^\circ \text{ WEIR}$$

SI

US



TRAPEZOIDAL WEIRS



CIPOLETTI WEIR

$$Q = \frac{2}{3}\,C_d\,b\sqrt{2g}\;H^{3/2}$$

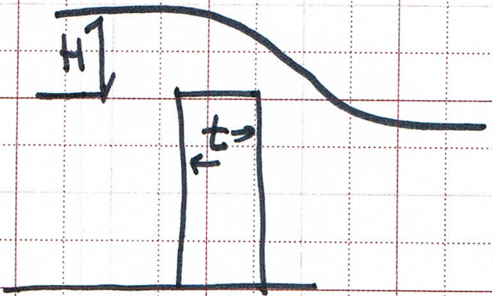
Ave $C_d = 0.63$

$$\left.\begin{aligned} &= 1.86\,b\,H^{3/2} \\ &= 3.367\,b\,H^{3/2} \end{aligned}\right]\begin{aligned} &\text{S.I.} \\ &\text{U.S.} \end{aligned}$$

BROAD CRESTED WEIR

DEFINITION

$t \geq \frac{H}{2}$



$$Q = \frac{2}{3}\,C_1\,b\sqrt{2g}\;H^{3/2}$$

$C_1 = 0.50 \rightarrow 0.57$

$$Q = C_{HORTON}\,b\left(H + \frac{V^2}{2g}\right)^{3/2}$$ IF V = SMALL

$\simeq C_s\,b\,H^{3/2} \longrightarrow$ C_s USED IN SPILLWAY NEXT PAGE

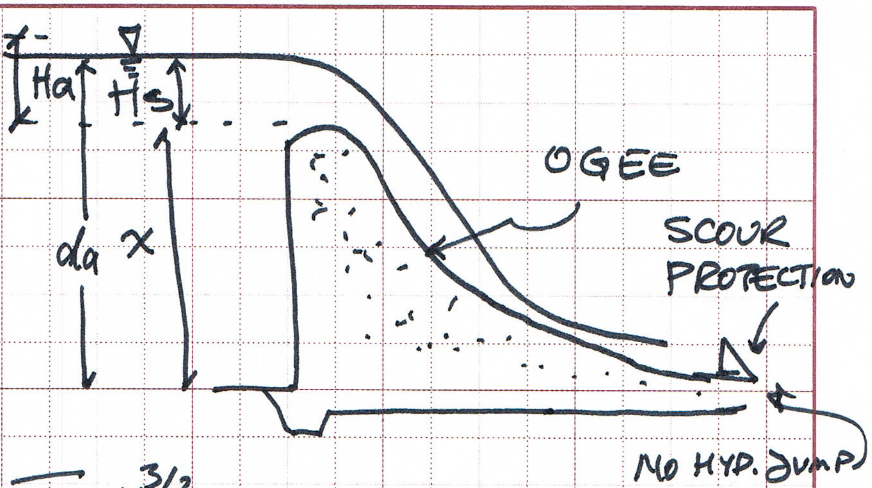
C_s (BROAD CRESTED) $2.63 \rightarrow 3.33\ ft^{0.5}/s$

3.33 1st INITIAL

h_v

SPILL WAY

$$h_v = \frac{Va^2}{2g}$$



$$Q = \frac{2}{3} C_1 b \sqrt{2g}\ H^{3/2} \qquad C_1 = 0.6 \rightarrow 0.75$$

$$Q = C_{HORTON}\ b \left(H + \frac{V^2}{2g}\right)^{3/2}$$

$$= C_s\, b H^{3/2}$$

S FOR SPILLWAY

$C_s = 3.3 \rightarrow 3.97\ ft^{0.5}/s$ FOR OGEE

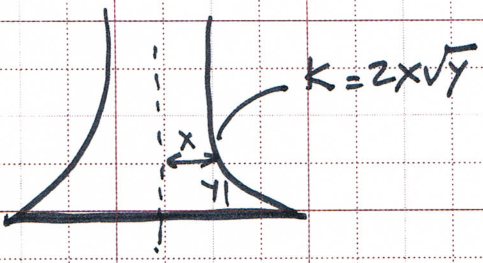
USE 3.97 $ft^{0.5}/sec$ 1st TRIAL

" C_1 & C_s ARE DIFFERENT FACTOR OF 5 "

PROPORTIONAL WEIR

$$Q = C_d K \left(\frac{\pi}{2}\right) \sqrt{2g}\ H$$

$$K = 2x\sqrt{Y}$$



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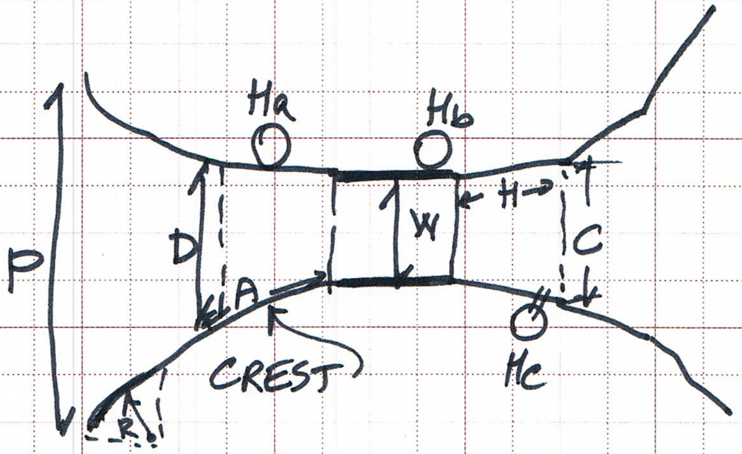
SHEET NUMBER
JOB NAME:
RE:
DATE

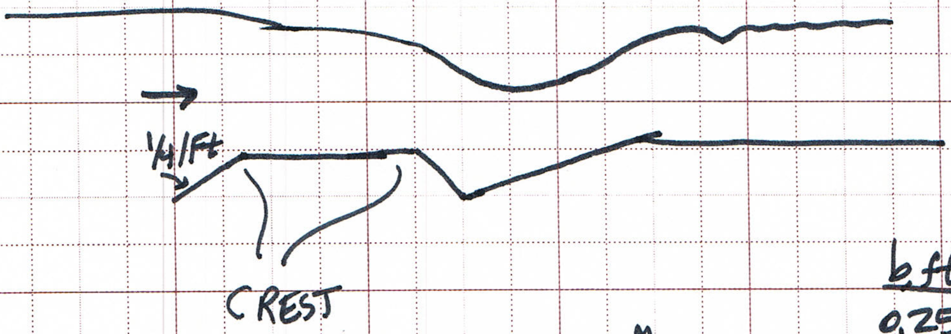
DETAILS

ENGINEERING & CONSULTING

P.292

PARSHAL FLUME



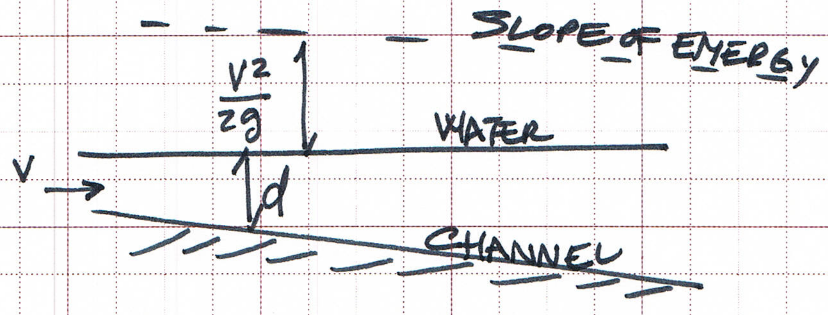


$\frac{H_b}{H_a}$ UP TO 0.7

$$Q = K b H_a^n$$
$$n = 1.522 b^{0.026}$$

b ft	K
0.25	3.97
↓	↓
4.0	4.00

UNIFORM & NON-UNIFORM STEADY FLOW



SPECIFIC ENERGY /FORCE

$$\frac{P}{\rho g} + \frac{V^2}{2g} + Z \qquad Z=0 \qquad P/\gamma = d$$

$$d + \frac{V^2}{2g} = E \text{ SP.EN.} \qquad V = Q/A$$

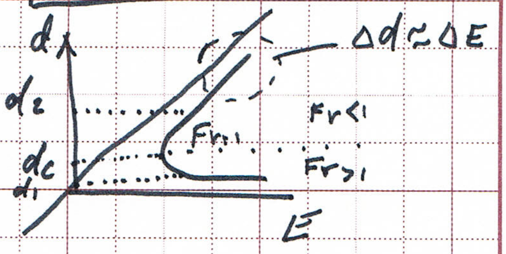
$$E = d + \frac{Q^2}{2gA^2} \quad (\text{if } A = dw)$$

$$= d + Q^2/2g(wd)^2$$

$$\boxed{E = d + \frac{Q^2}{2g(wd)^2}}$$

$$F_{\rho g} = \frac{Q^2}{gA} + \bar{d}A$$

$$F_\gamma = \frac{Q^2}{gA} + \bar{d}A$$



CHANNEL TRANSITION

$$\Delta E = \Delta Z$$

$$E_2 - E_1 = Z_2 - Z_1$$

CRITICAL DEPTH & ENERGY ▭ RECTANG.

$$dc^3 = \frac{Q}{gw^2}$$ RECTANGULAR @ MIN. ENERGY

$$dc = \frac{2}{3} Ec$$

$$Q = dc\, w\, Vc$$

$$Vc = \sqrt{g dc}$$ CRITICAL VELOCITY
@ LOW AMPLITUDE SURFACE WAVE
SURGE WAVE, STANDING WAVES

FOR NON RECTANGULAR

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

FROUD NUMBER

$d < dc;\ V > Vc$ ← | FR > 1 SUP.

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

$D_h = d$ RECTANGULAR | FR = 0 CR.

$d > dc;\ V < Vc$ | FR < 1 SUB

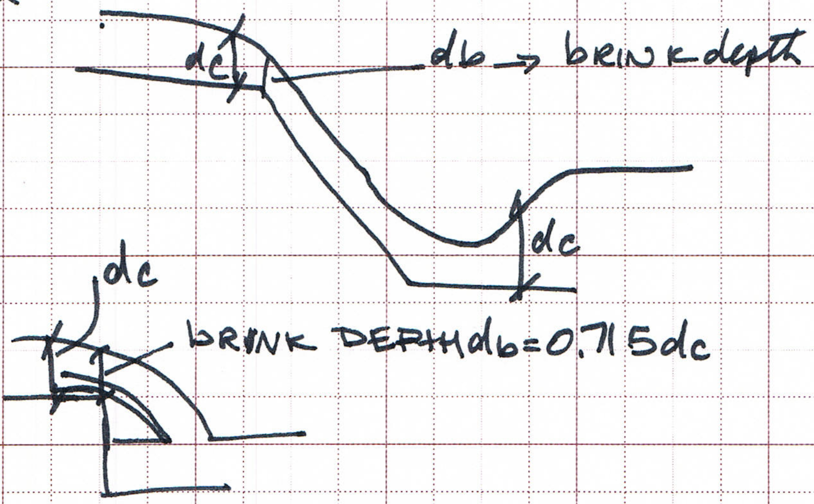
$$FR = \frac{Q/b}{\sqrt{gd^3}}$$ RECTANGULAR

$$= \frac{Q/b_{ave}}{\sqrt{g\left(A/b_{ave}\right)^3}}$$ NON-RECTANGULAR

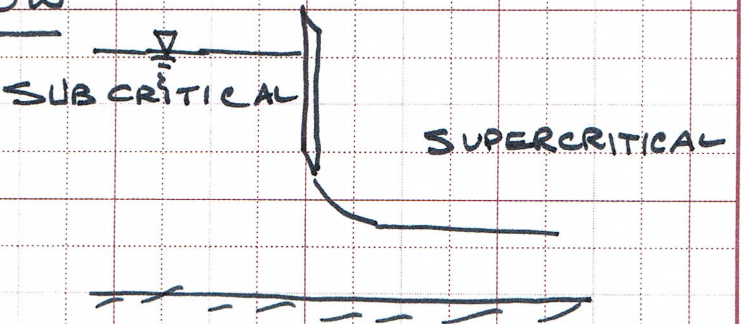
$\frac{d(d)}{dx}(1-Fr^2)+\frac{dz}{dx}=\phi$ if $FR=1$ $\frac{dz}{dx}=\phi$ HORIZ.

$\frac{dz}{dx} > 1$ UPWARD STEP

$\frac{dd}{dx} < 0$ DROP IN DEPTH



CONTROLS ON FLOW

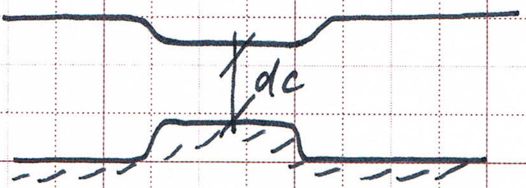


CHOKED FLOW

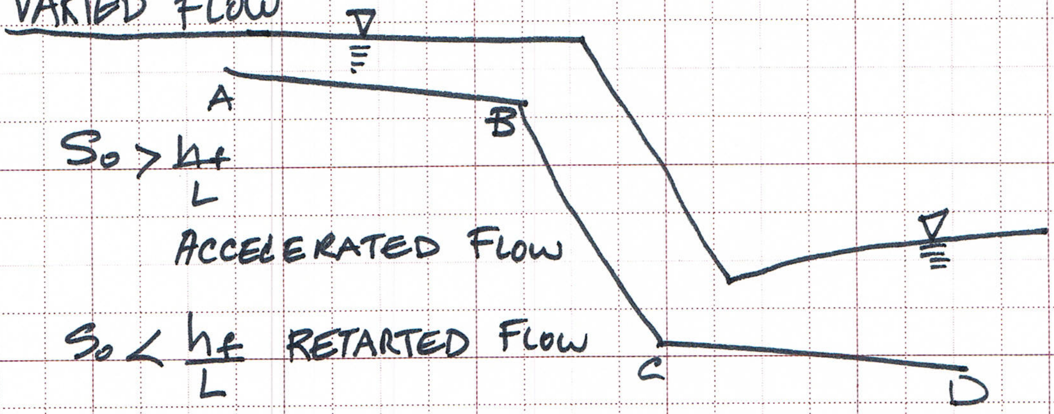
$\Delta Z = \Delta E = E_1 - E_c$

RECT. $\Delta Z = E_1 - \left(d_c + \frac{V_c^2}{2g}\right)$

$= E_1 - \frac{3}{2} d_c$



VARIED FLOW



$S_o > \frac{h_f}{L}$

ACCELERATED FLOW

$S_o < \frac{h_f}{L}$ RETARTED FLOW

$$S_{ave} = \left(\frac{n V_{ave}}{R_{ave}^{2/3}}\right)^{2/3}$$

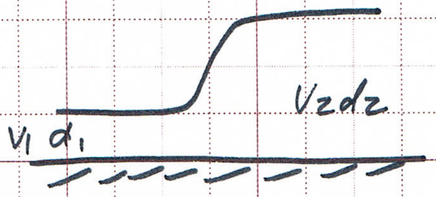
1.49 U.S.

$$V_{ave} = \frac{1}{2}(V_1 + V_2)$$

$$L = \frac{E_1 - E_2}{S - S_o} = \frac{\left(d_1 + \frac{V_1^2}{2g}\right) - \left(d_2 + \frac{V_2^2}{2g}\right)}{S - S_o}$$

S_o = Channel SLOPE

HYDRAULIC JUMP



CONJUGATE DEPTH

RECTAN.

$$d_1 = -\frac{1}{2}d_2 + \sqrt{\frac{2V_2^2 d_2}{g} + \frac{d_2^2}{4}}$$

$$d_2 = -\frac{1}{2}d_1 + \sqrt{\frac{2V_1^2 d_1}{g} + \frac{d_1^2}{4}}$$

$$\frac{d_2}{d_1} = \frac{1}{2}\left(\sqrt{1 + 8(Fr)^2} - 1\right)$$

$$V_1^2 = \left(\frac{g d_2}{2d_1}\right)(d_1 + d_2)$$

ΔE | ENERGY LOSS THRU HYDRAULIC JUMP | $\cong \frac{(d_2 - d_1)^3}{4 d_1 d_2}$

HAZEN WILLIAMS EQN $h_f = \frac{f}{2D} L \frac{V^2}{g}$

$$h_f = 3.022\, V^{1.85} L \big/ C^{1.85} D^{1.17}$$

$$= \frac{10.44\, L\, \dot{Q}_{GPM}^{1.85}}{C^{1.85} d_{inch}^{4.87}} \rightarrow \dot{V}$$

EXAMPLE:

$\nu = 1.41 \times 10^{-5}$ ft²/sec

water 50°F, St. PIPE, Q=300 GPM
L=1000 ft, D=4"
Darcy h_f=?

DARCY)

$$V = \frac{Q}{A} \rightarrow Re \rightarrow \epsilon/D \rightarrow (P.17\text{-}6)\ f \rightarrow E_f = h_f \frac{g}{g_c} = \frac{fLV^2}{2Dg_c}$$

$$V = \frac{300\,GPM}{\pi\left(4/(12)2\right)^2} = \frac{\overset{GPM}{300}\left(0.00228\ ft^3/s\right)/GPM}{0.0884} = 7.56\ Ft/s$$

$$Re = \frac{DV}{\nu} = \frac{(\overset{4/12}{0.3355})(7.56)\ ft\ ft/s}{1.41 \times 10^{-5}\ ft^2/s} = 1.8 \times 10^5$$

$$\frac{\epsilon}{D} = \frac{0.0002}{0.3355} = 0.0006$$

0.0002 → Steel

1.8×10^5, 0.0006 → $f = 0.0195$

$$E_f = h_f\,(g/g_c) = \frac{0.0195\,(1000\,ft)\,(7.56\ ft/sec)^2}{(2)\,(4/12\ ft)\,(32.2\ lb_m\text{-}ft/lb_f\text{-}sec^2)} = 51.6\ \frac{ft\text{-}lb_f}{lb_m}$$

HAZEN WILLIAMS) C=100

$$h_f = 3.022\,(7.56)^{1.85}\,(1000)^{ft} \big/ 100^{1.85} \left(\overset{0.3355}{\cancel{4.026}}\right)^{4.87} = 90.3\ ft$$

Nominal exact

$$= \frac{10.44\,(1000)\,(300)^{1.85}}{100^{1.85}\,(4.026)^{4.87}} = 90.3$$

SHEET NUMBER
JOB NAME: HYDRAULICS
RE: OPEN CHANNEL FLOW - CIRCULAR
DATE 10/1/05

DETAILS ENGINEERING & CONSULTING

4Ft ϕ, CONCRETE, $S=0.02$, $d=1.5$Ft, $n_{Full}=0.013$; n varies WITH DEPTH

VELOCITY FLOWING FULL $V=\frac{1.49}{n}(R_H)^{2/3}\sqrt{S}=\frac{1.49}{0.013}\left(\frac{4}{4}\right)^{2/3}\sqrt{0.02}=$ 16.21Ft/s

$Q=VA$ $=16.21\left(\frac{\pi}{4}\right)d^2$ $=203.7$ Ft³/s

USE APP.19.C $d/D=0.75$ $V/V_{FULL}=0.68$ n varies

$V@_{d/D=0.75}=V_{FULL}(0.68)=0.68(16.21)$ $=11$ ft/s

WHAT IS MAXIMUM VELOCITY POSSIBLE? APP. 19. C $V/_{FULL}=1.04$ @ $d/D\cong0.9$

$V=1.04(V_{FULL})=1.04(16.21)$ $=16.86$ Ft/s

WHAT IS MAXIMUM CAPACITY ? APP. 19.C $Q/Q_{FULL}\sim1.02$ $d/D=0.96$

$Q=1.02\,Q_{FULL}=1.02(203.7)$ $=207.8$ Ft³/s

SEWER, 1% GRADE, $n=0.013$, $Q_{MAX}=3.5$Ft³/s

WHAT PIPE SIZE, D=? $D=1.33\left(nQ/\sqrt{S}\right)^{3/8}=1.33\left(\frac{0.013(3.5)}{\sqrt{0.01}}\right)^{3/8}=0.99$Ft ~ 12in

IF DIAMETER=12in, Q? $Q=(1.49/n)AR^{2/3}\sqrt{S}=\frac{1.49}{0.013}\left(\frac{\pi}{4}(1)^2\right)\left(\frac{1}{4}\right)^{2/3}\sqrt{0.01}=3.57$Ft³/s

WHAT IS THE FULL VELOCITY? V $V=Q/A=3.57/\frac{\pi}{4}(1)^2=$ 4.55Ft/s

WHAT IS DEPTH, $Q=0.7$Ft³/s; APP. C $Q/Q_{FULL}=\frac{0.7}{3.57}=0.2$ w/ n varies $\frac{d}{D}=0.35$

$d=(0.35)D=0.35(12)=4.2$in $d=4.2$in

MINIMUM VELOCITY FOR SELF CLEANING = 2→2.5 Ft/s

$Q=10$Ft³/s @ $d/D=0.70$, $n=0.013$, VERIFY IF $V=3$Ft/s (FULL FLOW - min=2.5Ft/s)

APPENDIX C $d/D=0.70$; $Q/Q_{FULL}=0.85$ $Q_{DESIGN}=(10_{FULL})(0.85)=11.8$ CFS
FULL (PEAK

WITH V=2.5Ft/s

TRY 27" ϕ, S=0.002 WITH $Q=\frac{1.49}{n}AR^{2/3}\sqrt{S}=\frac{1.49}{0.013}\left(\frac{27^2}{144}\frac{\pi}{4}\right)(V_h)^{2/3}\sqrt{0.002}=13.5$Ft³/s; V=3.5Ft/s

TRY 30" ϕ, S=0.0018 17Ft³/s; V=3.5Ft/s

27" ϕ IS BETTER

VERIFY WITH APP. C IF $V=2.5\text{Ft/s}/V_{FULL}=$ USE AS DESIGN COMPONENT

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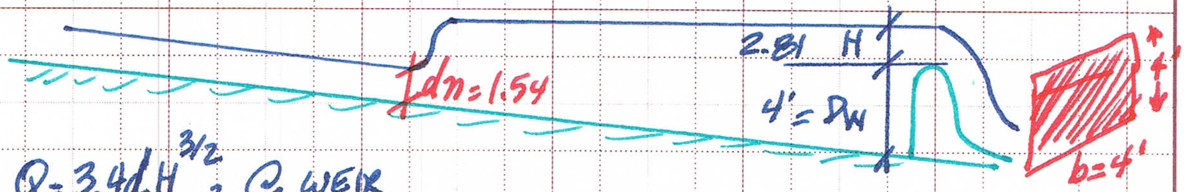
SHEET NUMBER 1
JOB NAME: SURVEY
RE:
DATE 3/30/05

DETAILS
ENGINEERING & CONSULTING

RECTANGULAR CHANNEL $Q = 64$ CFS, $b = 4'$, $n = 0.013$, $S_0 = 0.1$. A WEIR EXTENDS ACROSS THE CHANNEL (HEIGHT = 4 Ft). $Q = 3.4\, b\, H^{3/2}$; b = WIDTH, H = HT.

FIND: DEPTH OF UPSTREAM FROM WEIR; d (NORMAL Depth), dc (CRITICAL), d (DOWNSTREAM) FROM Jump, Length of the channel From the DEPTH IN DOWNSTREAM OF JUMP.



$Q = 3.4 d H^{3/2}$ @ WEIR

$Q^2/(3.4)^2 = d^2 H^3$

$$H = \left(\left(\frac{Q}{3.4d}\right)^2\right)^{1/3} = \left(\left(\frac{64\,CFS}{3.4\,(4)}\right)^2\right)^{1/3} = 2.81\ Ft$$

DEPTH UPSTREAM = 4 + 2.81 = 6.81 Ft ← d_n

SECTIONAL FACTOR: $AR^{2/3} = Qn/(1.49\sqrt{S})$ = "FOR NORMAL DEPTH" $= \frac{64(0.013)}{1.49\sqrt{0.1}} = \underline{5.58}$

$\frac{AR^{2/3}}{b^{8/3}} = \frac{5.58}{40.3} = 0.138$ FROM CHART → $\frac{d}{b} = 0.385$

NORMAL DEPTH $= d_n = (b)(0.385) = 1.54$ d_n

CRITICAL DEPTH: $d_c = (q^2/g)^{1/3} = \left(\left(\frac{Q}{b}\right)^2 1/g\right)^{1/3} = \left(\frac{(64/4)^2}{32.2}\right)^{1/3} = 2.04\ Ft$ $\underline{d_c}$

FROUD NUMBER: $Fr = \frac{Q}{bd\sqrt{gd}} = \frac{64}{4(1.54)} \frac{1}{\sqrt{32.2(1.54)}} = 1.475$ ← FR

$$\frac{d_2}{d_1} = \frac{1}{2}\left(\left(1+8F_R^2\right)^{1/2}-1\right) = \frac{1}{2}\left(\left(1+8(1.475)^2\right)^{1/2}-1\right) = \frac{1}{2}\left[4.29-1\right] = 1.65$$

CONJUGATE DEPTH OR THE DEPTH IMMEDIATELY DOWNSTREAM OF THE JUMP $d_2 = d_n\left(\frac{d_2}{d_n}\right) = d_1\left(\frac{d_2}{d_1}\right) = 1.54\,(1.65) = \underline{\underline{2.53\ Ft}}$

$$d_2 = d_1\left(\frac{d_2}{d_1}\right) = d_n\left(\frac{d_2}{d_n}\right) = d_n\left[\sqrt{1+8Fr^2}-1\right] = d_n\left[\sqrt{1+8\left(\frac{Q}{bd\sqrt{gd}}\right)}-1\right]$$

SHEET NUMBER 1
JOB NAME: HYDRAULICS
RE:
DATE 3/30/05

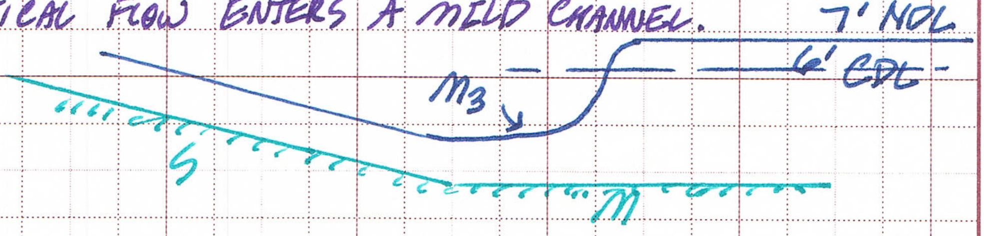
RECTANGULAR CHANNEL ($n = 0.014$, 12 Ft WIDE, $Q = 1000$ CFS, S=CONST.)
DEPTH = 7 Ft. CERTAIN SECTION IS WITH 3 Ft DEPTH.
WHAT HAPPENS AFTER THIS DEPTH TRANSITION

$Q = 1000$ CFS, $q = \frac{1000}{W} = \frac{1000}{12} = 83.33$ CFS/Ft, $d = 7$ Ft,

$d_c = \sqrt[3]{q^2/g} = \left(\frac{83.33}{32.2}\right)^{1/3}$ CRITICAL DEPTH $d_c = 6$ Ft $= [q^2/g)^{1/3}$

IF $d_{normal} > d_c$ SLOPE OF CHANNEL IS MILD.

@ REDUCED $d = 3$ Ft SECTION: $d_n(7) > d_c(6) > d(3)$ REDUCED
TYPE M3 PROFILE & DEPTH WILL INCREASE
DOWNSTREAM OF "A". THIS TYPE OF PROFILE: WHEN
SUPER CRITICAL FLOW ENTERS A MILD CHANNEL.



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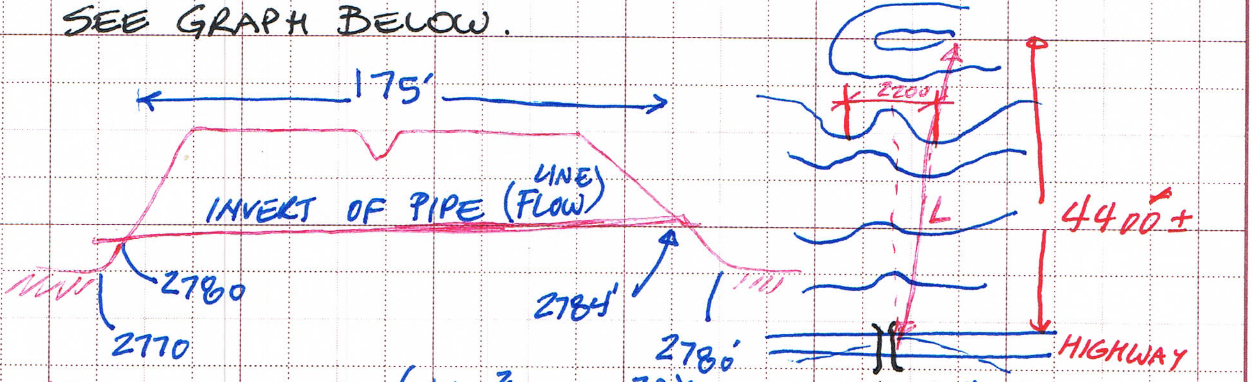
SHEET NUMBER
JOB NAME: HYDRAULICS
RE: CULVERT
DATE 9/15/05

DETAILS

BASED ON AREA (CONCRETE PIPE IS USED) TO DRAIN SITE
STORM = 1/2" PER HOUR FOR FIRST 30 MINUTES
2" PER HOUR FOR NEXT 30 min, 1" PER HOUR FOR NEXT
30 MINUTES. SURFACE ~~D~~ type = DECOMPOSED GRANITE
& FLOW VELOCITY = 3 Ft/S
DEFINE PEAK DISCHARGE & CONCRETE PIPE, FREE OUTLET,
& PIPE ENTRY ELEVATION IS TOP OF PIPE ELEVATION
SEE GRAPH BELOW.



LONGEST PATH OF FLOW = $(4400^2 + 1100^2)^{1/2} = 4580'$ ← PIPE "L"

TIME COLLECTION = t_c = AREA/VELOCITY = 4580 Ft/3 Ft/s = <u>25.5 min</u>

SINCE COLLECTION OF WATER WILL REACH IN 25.5 MINUTES,
2"/HR WILL BE USED FOR DESIGN.
C = 0.5 FOR AREA

$Q = CIA = 0.5\,(2")\left(\frac{2200(4400)}{43560}\right) = 222$ CFS
222 acre-in/HR

USE MANNING FOR PIPE $Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$

$S = \frac{4}{175} = 0.0228$

$S^{1/2} = 0.151$

$A = \pi \frac{d^2}{4}$

$R = \frac{\pi d^2}{4} \frac{1}{\pi d} = \frac{D}{4}$

$n = 0.015$ CONCRETE

$Q = 222\text{ CFS} = \frac{1.49}{0.015} \frac{\pi D^2}{4} \left(\frac{D}{4}\right)^{2/3} 0.051$

$d = 4.25' = 51" \doteq 48"$ TO 54" NOMINAL

$n=0.012$, 2Ft WIDE RECTANGULAR, $Q=3Ft^3/s$, $S=1\%$ depth=?

$R=\frac{2d}{2+2d}=d/(1+d)$; $A=2d$; $Q=3Ft^3/s=\frac{1.49}{0.012}(2d)\left(\frac{d}{1+d}\right)^{2/3}\sqrt{0.01}\Rightarrow$ $d=0.314$ Ft

CONCRETE, $S=0.08$, $Q=17m^3/s$ OPTIMUM CHANNEL DIMENSION? $n_{CONC.}=0.011$

$d=W/2$ OPTIMUM; $Q=\frac{1.49}{0.011}(A)(R_h)^{2/3}\sqrt{S}=\frac{1.49}{0.011}(Wd)\left(\frac{Wd}{W+2d}\right)^{2/3}\sqrt{S}=\frac{1.49}{0.011}\left(\frac{W^2}{2}\right)\left(\frac{W^2/2}{2W}\right)^{2/3}\sqrt{0.08}$
$=17m^3/s$

$W=1.57m$; $d=0.79m$

CONCRETE, $A=30ft^2$, $\frac{1}{2}$ FULL, $W=5Ft$, $S=0.0002$ Q=? $\underset{1/2\,FULL}{A}=15$; $W=5$; $b=3$
$R=11$

$Q=\frac{1.49}{n}A R_h^{2/3}\sqrt{S}=\frac{1.49}{0.013}(15)\left(\frac{15}{PERIM.}\right)^{2/3}(0.0002)^{1/2}=120CFS$

SLOPE OF 5.7Ft ELEVATION CHANGE IN 2670Ft OF RUN, Q=39CFS
$d=W/2$, CONCRETE

$39=Q=\frac{1.49}{n}\left(AR_h^{2/3}\sqrt{S}\right)=\frac{1.49}{0.013}\left(Wd\left(\frac{Wd}{W+2d}\right)^{2/3}\sqrt{5.7/2670}\right)=\frac{1.49}{0.013}\sqrt{0.0021}\left(\frac{W^2/2}{2W}\right)^{2/3}\left(\frac{W^2}{2}\right)$

$W=3.9Ft$; $d=1.9Ft$
VELOCITY $=39/((3.9)(1.9))=5.3FPS$

FIND EQUIV. PIPE 1/2 FULL GALVANIZED
$n=0.024$ GALVANIZED

$A=\frac{1}{2}(\pi D^2/4)=0.0125\pi D^2$; $P=\frac{1}{2}\pi D$; $R=0.25D$ (TABLE); $S=0.0021$;

$Q=\frac{1.49}{0.024}(0.0125\pi D^2)(0.25D)^{2/3}(0.0021)^{1/2}=39$ $D=5.4Ft=64in\left\{\begin{matrix}60''\\72''\end{matrix}\right.$

$W=5'$, $d=8in=\frac{8}{12}ft$, CONCRETE $n=0.013$; $S=0.002$ Q=?

$Q=1.49\,d^{5/3}W\sqrt{S}/n=1.49(8/12)^{5/3}\,5\sqrt{0.002}/0.013=$ $13Ft^3/s$

W=15Ft; Ht OF BARRIER CAN CHANGE. d=8Ft, V=3Ft/s; HOW FAR CAN YOU CHANGE BARRIER BEFORE DEPTH CHANGE UPSTREAM OF BARRIER

??

$Q=Vd_1W=3Ft/s(8Ft)(15Ft)=360Ft^3/s$

$d_1+\frac{Q^2}{2gW^2d_1^2}=d_c+\frac{Q^2}{2gW^2d_c^2}+y_c=8+\frac{360}{2(32.2)(15)^2(8)^2}=8.14Ft=2.62+\frac{360^2}{2(32.2)(15)^2(2.62)^2}+y_c$

$d_c=\left(\frac{Q^2}{gW^2}\right)^{1/3}=\left(\frac{360^2}{32.2(15)^2}\right)^{1/3}=2.62Ft\Rightarrow$

?

$Y_c=4.2Ft$

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SHEET NUMBER 1/
JOB NAME: HYDRAULICS
RE: OPEN CHANNEL
DATE 3/30/05

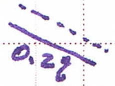
DETAILS

ENGINEERING & CONSULTING

OPEN CHANNEL W=5 Ft, d= 8 in RECTANGULAR CONCRETE LINED WITH 0.2% SLOPE. WHAT IS THE CHANNEL FLOW RATE?

IF $S = \% / 100\%$, $n = 0.013$ CONCRETE, $w = 5$ ft. $d = 8/12$ ft

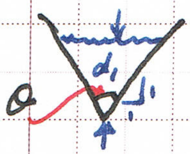
$$Q = 1.49 d_n^{5/3} w \sqrt{S} / n = 1.49 \left(8/12\right)^{5/3} 5 \sqrt{0.2/100} / 0.013 \text{ CONC.}$$
$$= 13 \text{ ft}^3/\text{s}$$



$= 13 \frac{\text{ft}^3}{\text{s}}$

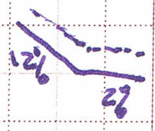
CONCRETE LINED OPEN CHANNEL (TRIANGULAR XS, 1-TO-1 SIDES) WITH 12% SLOPE TRANSITIONS TO 2% SLOPE. IF Q = 0.85 m/s; & UPSTREAM DEPTH IS 0.10 m. WHAT IS DEPTH WITH 2% SLOPE?

R HYDRAULIC RADIUS $\nabla = \frac{d_1 \cos\theta}{2} = \frac{0.1\text{m} \cos 45^\circ}{2}$
$= 0.035$ m



CONCRETE LINING, $n = 0.013$

$$V_1 = R_1^{2/3} \sqrt{S_1} / n = (0.035)^{2/3} \sqrt{0.12} / (0.013)$$
$$= 2.85 \text{ m/s}$$



CONJUGATE DEPTH OF ABRUPT CHANGE

$$d_2 = -0.5 d_1 + \sqrt{2 V_1^2 \frac{d_1}{g} + \frac{d_1^2}{4}} = -0.5(0.1) + \left[2(2.85)^2 \frac{0.1}{9.81} + \frac{(0.1)^2}{4}\right]^{1/2}$$

$= 0.36$m

$d_2 = 0.36$m

SHEET NUMBER 1/
JOB NAME: HYDRAULICS
RE:
DATE 3/30/05

SQUARE BAFFLE OUTLET TO DISSIPATE ENERGY @ BOTTOM OF RECTANGULAR CHUTE (3 Ft BASE). HEAD = 42 Ft, flow = 200 Ft³/s = Q). WHAT IS MINIMUM WIDTH OF BAFFLED OUTLET BASIN? FROUD # & BASIN WIDTH TO CHANNEL OUTLET DEPTH RATIO

$W_c = 3$ ft, $Q = 200$ ft³/s
$h = 42$ Ft

$$W_b / D_c = 0.875\,F_r + 2.7$$

VELOCITY @ BASE OF CHUTE, $V = \sqrt{2gh} = \left(2(32.2)42\right)^{1/2} = 52$ Ft/s

CHUTE AREA, $A_c = Q/V = 200\,\text{Ft}^3/\text{s} \,/\, 52\,\text{Ft/s} = 3.8\,\text{ft}^2$

CHUTE FLOW DEPTH, $D_c = \dfrac{A_c}{W_c} = \dfrac{3.8\,\text{ft}^2}{3\,\text{ft}} = 1.267$ Ft $= 1.267$ Ft

FROUD NUMBER $F_r = V/\sqrt{gD_c} = 52/\left(32.2(1.267)\right)^{1/2} = = 8.14$

USE EQN: FROUD #, BASIN WIDTH TO CHANNEL OUTLET DEPTH RATIO:

$$\frac{W_b}{D_c} = 0.875\,F_r + 2.7 = 0.875(8.14) + 2.7$$

$$W_b = D_c\left(8.75(8.14) + 2.7\right) = 1.267\left(8.75(8.14) + 2.7\right) = \underline{\underline{12.44\ \text{ft}}}$$

REVISIONS
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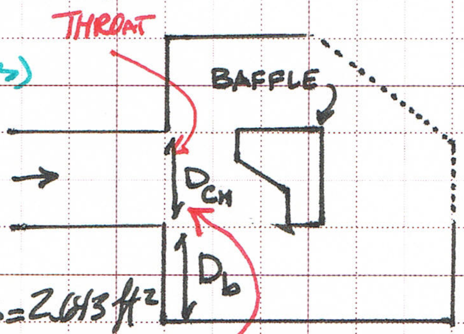
SHEET NUMBER 1
JOB NAME: HYDRAULICS
RE:
DATE 3/30/05

DETAILS
ENGINEERING & CONSULTING

BAFFLED OUTLET, ENERGY DISSIPATOR @ DISCHARGE TO A BASIN FROM SQUARE CHANNEL FLOWING FULL. $Q_{CHANNEL} = 120\ Ft^3/s$, $h = 32 Ft$ (HEAD). WHAT IS MINIMUM REQUIRED DEPTH OF THE BAFFLED OUTLET, IF ITS WIDTH IS 6 Ft? $h = 32\ ft$, $Q = 120\ Ft^3/s$

VELOCITY @ THROAT = $V = \sqrt{2gh} = (2(32.2)32)^{1/2} = 45.4\ ft/s$

(BASED ON "DESIGN OF SMALL CANAL STRUCTURES, DENVER, Co, US DEPT. INTERIORS)



$V_{OUTLET} = 50\ Ft/s$ MAX.

$\therefore V = 45.4 < 50\ Ft/s \therefore$ OK.

BASED ON KNOWN Q & V

$A_{CHANNEL} = 120\ Ft^3/s \big/ 45.4\ ft/s = 2.643\ ft^2$

$D_{CH} = \sqrt{A_{CHANNEL}}$ SQUARE $= \sqrt{2.643} = \underline{1.626\ Ft}$ $\quad D_{CH} = 1.626\ Ft$

USE FROUD # TO CORRELATE: CHANNEL DEPTH TO BASIN DEPTH

$Fr = V \big/ \sqrt{gD_{CH}} = 45.4\ Ft \big/ (32.2(1.626))^{1/2} = 6.274$ $\quad Fr = 6.274$

$Q = Fr\ w\ D_b \sqrt{gD_b} \rightarrow D_b^{2/3} = Q \big/ (F_r W \sqrt{g})$

$D_b = \left(\frac{Q}{F_r W \sqrt{g}}\right)^{2/3} = \left[120\ ft^3/s \big/ ((6.274)(6Ft)(32.2)^{1/2})\right] = 0.68\ Ft$

$\underline{\underline{D_b = 0.68 Ft}}$

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SHEET NUMBER 1
JOB NAME: HYDRAULICS
RE:
DATE 3/30/05

DETAILS

ENGINEERING & CONSULTING

FOLLOWING IS RESULT OF SEWER INFLOW & INFILTRATION EVALUATION WHICH SECTION OF CITY SEWER SHOULD RECIEVE FIRST PRIORITY REHABILITATION

SECTION	TOTAL INFIL. TO SECTION m^3/d	PIPE DIAM (mm)	PIPE LENGTH (Km)
1	2315	100	15.4
		200	6.8
		300	8.2
2	958	100	9.2
		200	7.1
		300	4.4
3	3996	100	14.9
		200	9.1
		300	9.5
4	1867	100	21.3
		200	11.0
		300	4.7

SHEET NUMBER
JOB NAME: HYDRAULICS
RE: HYDRAULIC JUMP
DATE 10/1/05

HYDRAULIC JUMP WATER LEVELS ARE 0.2Ft & 6Ft. VELOCITY BEFORE=54.7Ft/s
WHAT IS ENERGY LOSS?

$$\Delta E = \left(d_1 + \frac{v_1^2}{2g}\right) - \left(d_2 + \frac{V_2^2}{2g}\right) \qquad V_1 A_1 = V_2 A_2 \Rightarrow 2W\left(54.7\right) = 6W\, V_2 \Rightarrow V_2 = 1.82 \text{ Ft/s}$$

$$= 2 + \frac{(54.7)^2}{64.4} - \left(6 + \frac{1.82^2}{64.4}\right) = 40.61 \text{ Ft-lbf/lbm}$$

W=6Ft, UPSTREAM $d_1 = 1.2$Ft, $d_2 = 3.8$Ft

FLOW QUANTITY = $Q = VA = (1.2\text{Ft})(6\text{Ft})\left(\left(\frac{g d_2}{2 d_1}\right)(d_1 + d_2)^{1/2}\right) = 7.2\text{Ft}^2\left(\frac{32.2(3.8)}{2(1.2)} \cdot (1.2+3.8)\right)^{1/2}$

$= 115 \text{ Ft}^3/\text{s}$

VELOCITY DOWNSTREAM $= Q/A = V_2 = 115/(3.8)(6) = 5.04$ Ft/s

ENERGY LOSS $= \Delta E$

$$= \left(d_1 + \frac{V_1^2}{2g}\right) - \left(d_2 + \frac{V_2^2}{2g}\right) = (1.2 - 3.8) + \frac{15.97^2 - 5.04^2}{64.4} = 0.97 \frac{\text{Ft-lbf}}{\text{lbm}}$$

SPILLWAY W=2.5m, WATER d @TOE= 0.15m, 2.93 m³/s, WHAT IS ENERGY LOSS?

$V_1 = \frac{Q}{d_1 W} = 2.93/(0.15)(2.5) = 7.8$ m/s $\qquad V_1 \rightarrow d_2 \rightarrow V_2 \rightarrow \Delta H$

$$d_2 = -0.5 d_1 + \sqrt{2V_1^2 d_1/g + 0.25 d_1^2} = -0.5 d_1 + \sqrt{2V_1^2 d_1 + 0.25 d_1^2} = -0.5(0.15) + \left(\frac{2(7.8)(0.15)}{9.81} + 0.251(0.15)^2\right)^{1/2}$$

$= 1.29$m

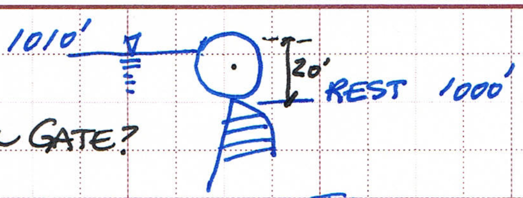
$V_2 = Q/d_2 W = 2.93/(1.29(2.5)) = 0.91$ m/s

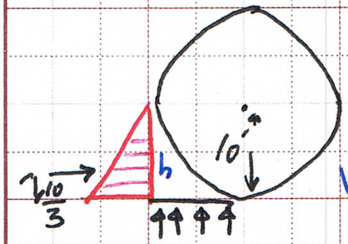
$$\Delta H = d_1 + \frac{V_1^2}{2g} - d_2 - \frac{V_2^2}{2g} = 0.15 - 1.29 + \frac{7.8^2 - 0.91^2}{2(9.81)} = 1.92\text{m}$$

- CAP all med. gases in clg
- All (E) Components on walls Med. gas verify w/ H. Mayo fac.

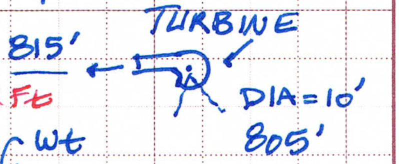
SHEET NUMBER
JOB NAME: HYDRAULICS
RE:
DATE 10/1/05

EXISTING DAM AS SHOWN
SPILL WAY CREST @ 1000'
WHAT ARE FORCES ON CYLINDERICAL GATE?





$H = \text{HORIZONTAL FORCE} = (\gamma h)\left(\frac{h}{2}\right) =$
$= \gamma \frac{10^2}{2} = 50\gamma = 3120$ lbf/Ft PER Ft



$V = \text{VERTICAL FORCE} = \text{UPWARD} = F_v - \overset{Wt}{W}$

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SHEET NUMBER
JOB NAME: HYDRAULICS
RE:
DATE 9/15/05

DETAILS

ENGINEERING & CONSULTING

6' I.D. STORM DRAIN, S^{LOPE}= 0.0020, RECENT MEASUREMENT= 85cfs, n= 0.015. ACTUAL DEPTHS OF FLOW a) 4.75', b) 4.3'; c) 3.5'
DETERMINE DISTANCE BETWEEN a, b, & c.

SHEET NUMBER 1
JOB NAME: SURVEY
RE:
DATE 3/30/05

RECTANGULAR CHANNEL @ TOP OF HILL ($S = 0.04$ Ft/Ft, $L = 2000$ Ft); $Q = 200$CFS THEN SLOPE CHANGED ($S = 0.0024$, $L = 2000$ Ft). WIDTH = 5 Ft, $n = 0.013$,

a. SHOW HYDRAULIC JUMP, b. STATE OF FLOW @ GRADE, c. ELEVATION OF JUMP

---

a. $Q = 200$ CFS, $n = 0.013$, $q = Q/b = \frac{200}{5} = 40$ CFS/Ft ; $d_c = \sqrt[3]{q^2/g} = \left(\frac{40^2}{32.2}\right)^{1/3} = 3.68$ Ft

$S = 0.04$

$S = 0.04$; $AR^{2/3} = \frac{nQ}{1.49\sqrt{3}} = \frac{0.013(200)}{1.49(0.2)} = 8.72$; $\frac{AR^{2/3}}{b^{8/3}} = \frac{8.72}{5^{8/3}} = 0.12$

$\frac{d}{b} = 0.345$; $d_n = 0.345(b) = 0.345(5) = 1.73$ Ft

$d_n < d_c$

∴ SUPERCRITICAL $1.73 < 3.68$

FOR $S = 0.0024$

$\frac{AR^{2/3}}{b^{8/3}} = \frac{nQ}{1.49\sqrt{S}} \; \frac{1}{5^{8/3}} = \frac{0.013(200)}{1.49\sqrt{0.049}} \; \frac{1}{5^{8/3}} = \frac{35.6}{73.1} = 0.49$

FROM FIG. $d/b = 1.0$ $d_n = b\left(\frac{d}{b}\right) = 5.0$ Ft

$d_n > d_c$ SUBCRITICAL

HYDRAULIC JUMP UPSTREAM STEEP SLOPE IS SUPERCRITICAL
DOWNSTREAM SLOPE IS MILD FLOW IS SUBCRITICAL

FLOW DOWNSTREAM OF JUMP

$$\frac{d_1}{d_2} = \frac{1}{2}\left[\left(1+8FR_2^2\right)^{1/2} - 1\right] =$$

$$= \frac{1}{2}\left[\left(1+8(0.62)^2\right)^{1/2} - 1\right] = 0.51$$

$$FR_2 = \frac{Q/bd_n}{\sqrt{g d_n}} = \frac{200/5(d_n)}{\sqrt{g d_n}} = \frac{40/5}{\sqrt{32.2(5)}} = 0.62$$

$d_1 = d_2\left(\frac{d_1}{d_2}\right) = 5(0.51) = 2.55$ Ft $> d_n = 1.73$ Ft dump DOWNSTREAM OF BREAK

$$\Delta X = \frac{E_2 - E_1}{S_0 - S_f} = \left[d_2 + \frac{(Q/b)^2}{2g d_2^2}\right] - \left[d_1 + \frac{(Q/b)^2}{2g d_1^2}\right] \Big/ (S_0 - S_f)$$

$$= \left[\left(2.55 + \frac{(200/5)^2}{2(32.2)(2.55)^2}\right)(= 6.3)\left(1.73 + \frac{(40)^2}{2(32.2)\,1.73^2}\right)\right] \Big/ S_0 - S_f$$

$S_0 = 180$

$$S_0 = \left(\frac{Qn}{1.49}\right)^2 \left(\frac{1}{AR^{2/3}}\right)$$

$$= \frac{(6.3 - 10)}{2.55_2 \quad (0}$$