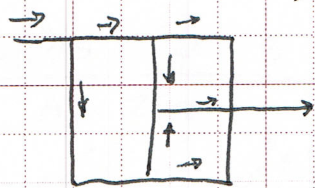
P.17-23

31. PIPE NETWORK, MULTI-LOOP, HARDY CROSS



$\Sigma Q_{in} = \Sigma Q_{out}$

ΣH_L (ANY CLOSED LOOP) $= 0$

friction Loss in a Run is $h_f = K'Q^n$ | $n = 2$ DARCY; $n = 1.85$ H.W.

D, L = ft ; Q = ft³/sec

$K' = 0.02517 \dfrac{fL}{D^5}$ DARCY

$K' = 4.727 \dfrac{L}{D^{4.8655} C^{1.85}}$ H.W.

OTHER UNITS AVAILABLE

$Q = Q_{assumed} + \delta_{CORRECTION}$

$\delta = - \dfrac{\Sigma h_f}{n \Sigma h_f / Q_a}$. Same for all Pipes in one Loop

Hardy Cross

1) $n = 2$ (DARCY); 1.85 H.W.
2) POSITIVE = CLOCKWISE
3) Label All branches in Network
4) Separate All LOOPS that each Branch is in the Loop
5) CALC. K' for each Branch
6) ASSUME REASONABLE Q & DIRECTION FOR EACH BRANCH
7) CAL. δ FOR EACH LOOP
8) APPLY δ To each BRANCH
9) Repeat 7 → 8, 9

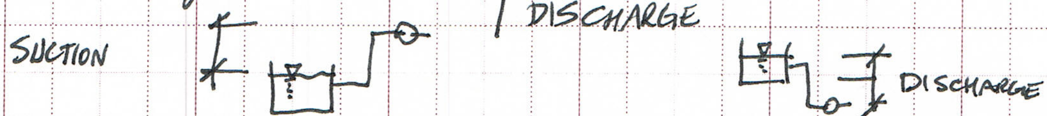
P.18-6 HYDRAULIC MACHINES

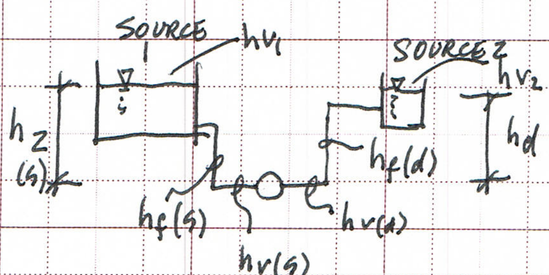
$$h = \frac{P}{\gamma} = \frac{P}{\rho g}(SI) = \frac{P}{\rho}\left(\frac{g_c}{g}\right) US.$$

$$h_f = \frac{fLV^2}{2Dg} \quad \text{friction head}$$

$$h_v = \frac{V^2}{2g} \quad \text{dynamic head}$$

$h_z =$ static | SUCTION / DISCHARGE head





TOTAL STATIC @ PUMP INLET. $h_t(s) = h_p(s) + h_v(s)$ (PRESSURE, VELOCITY)

$h_t(s) = h_p(1) + h_z(s) + h_v(1) - h_f(s)$ (VELOCITY @ 1, FRICTION)

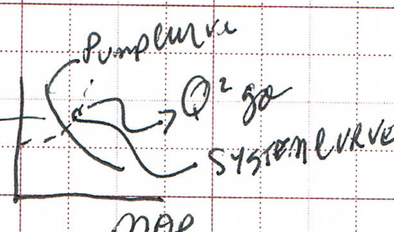
$$-h_z + h_d + h_{PUMP} = h_{f_s} + h_{f_d}$$

$$h_{PUMP} = \pm(h_d - h_z) + h_{f_s} + h_{f_d} \rightarrow \frac{Q^2}{A^2} \frac{fDV^2}{2Dg} = \frac{Q^2}{A^2}\frac{fDV^2}{2g}$$

$$z_1 + h_{pump} = z_2 + f_1\frac{L_1}{D_1}\frac{V_1^2}{2g} + f_2\frac{L_2}{D_2}\frac{V_2^2}{2g}$$

$$h = a + bQ^2$$

Solve pump PROBLEM & Graph



AFFINITY LAWS

P.18-18

a)

$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1}$$

$$\frac{h_2}{h_1} = \left(\frac{n_2}{n_1}\right)^2 = \left(\frac{Q_2}{Q_1}\right)^2$$

POWER $$\frac{P_2}{P_1} = \left(\frac{n_2}{n_1}\right)^3 = \left(\frac{Q_2}{Q_1}\right)^3$$

IMPELLER DIAM. = CONS.
SPEED IS VARIED

b) SPEED CONSTANT / IMPELLER IS VARIED

$$\frac{Q_2}{Q_1} = \frac{D_2}{D_1}$$

$$\frac{h_2}{h_1} = \left(\frac{D_2}{D_1}\right)^2$$

$$\frac{P_2}{P_1} = \left(\frac{D_2}{D_1}\right)^3$$

PUMP SIMILARITIES: (DYNAMICALLY SIMILAR)

$$\frac{n_1 D_1}{\sqrt{h_1}} = \frac{n_2 D_2}{\sqrt{h_2}} \qquad \frac{Q_1}{D_1^2\sqrt{n_1}} = \frac{Q_2}{D_2^2\sqrt{n_2}}$$

$$\frac{P_1}{\rho_1 D_1^2 h_1^{1.5}} = \frac{P_2}{\rho_2 D_2^2 h_2^{1.5}} ; \quad \frac{Q_1}{n_1 D_1^3} = \frac{Q_2}{n_2 D_2^3} ; \quad \frac{P_1}{\rho_1 n_1^3 D_1^5} = \frac{P_2}{\rho_2 n_2^3 D_2^5} ; \quad \frac{n_1\sqrt{Q_1}}{(h_1)^{0.75}} = \frac{n_2\sqrt{Q_2}}{(h_2)^{0.75}}$$

ASSUME: TURBULENT Region

Same Pump Eff.

Same % of WIDE OPEN flow

510-1

1)

$$Q = VA = 1.318\,C\,A\,R^{0.63}\,S^{0.54}$$

C = 100 OR lookup

$\frac{1}{4}\pi D^2 = 0.2083$

$\frac{D}{2} = 0.2083$ ... ≈ 0.101

$$S^{0.54} = 0.03738\,Q$$

$$S = 0.002273\,Q^{1.8159}$$

NO

R: HYDRAULIC RADIUS

$R = \frac{\pi D^2}{4} \Big/ \pi D$ (perim)

AREA $= \frac{D}{4}$

$$h_f = L * S = (3000)\,S$$

$$TDH\ (\text{TOTAL DYNAMIC Head}) = \Delta H + h_f + \frac{V^2}{2g}$$

$$= 560 - 530 + (3000)(0.002273)\,Q^{1.8159} + \frac{V^2}{2g}$$

$$V = Q/A$$

$$TDH = f(Q, Q^2)$$

3) IF PIPE → 8" % @ New Point of OPERATION

$$Q = VA = 1.318\,C\,A\,R^{0.63}\,S^{0.54}$$

$V = Q/A$

$\frac{1}{4}\pi D^2$ — $(8/12)$ $= 0.349\ ft^2$

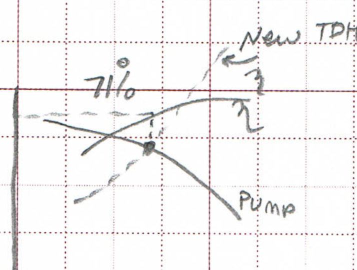
100

$\frac{D}{4} =$

$S = f(Q)$

$$S^{0.54} = \frac{Q}{1.318\,C\,A\,R^{0.63}} = 0.06721\,Q$$

TDH vs Q
X PUMP & SYSTEM
UP TO η CURVE



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REVISIONS

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

DETAILS — ENGINEERING & CONSULTING

AN AVERAGE ANNUAL DISCHARGE RECORD FOR A RIVER COVERS A PERIOD OF 83YR. THE AVERAGE FLOW DURING THE ENTIRE PERIOD OF RECORD WAS 1947 ft^3/SEC WITH A STD DEVIATION OF 613 Ft^3/Sec. WHAT IS THE AVERAGE FLOW WILL PRODUCE THE 50-YEAR FLOOD?

USE GUMBEL DISTRIBUTION COEFFICIENT (GDC) CHARTS

K_{50}	GDC FOR 50 YR RECORD & 50 YR FLOOD	= 2.89
K_{83}	" " 83 " " & 50 " "	= ?
K_{100}	" " 100 " " & 50 " "	= 2.77
n	YEARS OF RECORD	= 83

USE INTERPOLATION $K_{83} = K_{50} + \frac{(K_{100} - K_{50})(n-50)}{}$

$$= 2.89 + \frac{2.77-2.89}{100-50} (100-50) \quad (83-50) =$$

$$K_{83} = 2.89 + (2.77-2.89)(8-50) / (100-50) = 2.81$$

Q_P = FLOW RATE FOR THE PERIOD OF INTEREST $= Q_m + K_{83}\sigma$
(Q_m = AVERAGE FLOW RATE ; σ = STD DEV.) $= 1947 + (2.81)(613)$
$= 3670$ Ft^3/Sec

CANNOT DO & USE:

- SIMPLE RATIO $\frac{QP}{50} = \frac{1947}{83}$ $\quad Q_P = 1173$ (1200) No use of σ
- INCORRECT READING OF GUMBEL CHARTS.
  RETURN PERIOD VS. RECORD OF LENGTH

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REVISIONS

SHEET NUMBER 1
JOB NAME: WATER TREATMENT
RE:
DATE 1/30/05

DETAILS | ENGINEERING & CONSULTING

250 mL WATER SAMPLE WITH AN INITIAL pH OF 9.7 IS TITRATED WITH 0.03 M H_2SO_4. A pH OF 8.3 IS REACHED AFTER 6 mL OF ACID ARE ADDED & a pH OF 4.5 IS REACHED AFTER 12 mL OF ACID ARE ADDED. WHICH ALKALINITY SPECIE DOMINATES & WHAT IS ITS CONCENTRATION?

FIRST FIND OUT, HOW DOES INITIAL pH INFLUENCE DISTRIBUTION OF ALKALINITY SPECIES? pH OF 9.7, DOMINATE ALKALINITY = CARBONATE

FOR HYDROXIDE ALKALINITY pH = 9.7; pH + pOH = 14; pOH = 14 - 9.7 = 4.3

$[OH^-]$ = HYDROXIDE CONCENTRATION mol/L

pOH = - LOG $[OH^-]$ $[OH^-] = (10^{-4.3})$ mol/L

(EW) CALCIUM CARBONATE EQUIV. Wt 50,000 mg/eq

$(OH^-)_{alk}$ HYDROXIDE ALKALINITY mg/L as $CaCO_3$

|V| VALENCE eq/mol

$$OH^-_{alk} = [OH^-]|V|EW = 10^{-4.3}\,\frac{mol}{L}\left(\frac{1\,eq}{mol}\right)\left(\frac{50000\,mg\,CaCO_3}{eq}\right)$$

$= 2.5\,mg/L$ as $CaCO_3$

SPILLWAY 2.5m WIDE & HYDRAULIC JUMP OCCURS AT TOE. WATER DEPTH OF 0.15m & $Q = 2.93\,m^3/s$. WHAT IS TOTAL HEAD DISSIPATED.

V_1, Q, d_1, W_1 — BEFORE HYDRAULIC JUMP

V_2, Q, d_2, W — AFTER HYDRAULIC JUMP

$$V_1 = Q/d_1 W = 2.93\,m^3/s / ((0.15\,m)\,2.5\,m) = 7.8\,m/s$$

CONJUGATE DEPTH: $d_2 = -0.5 d_1 + \sqrt{\frac{2V_1^2 d_1}{g} + 0.25\,d_1^2}$

$$= -0.5(0.15) + \left[2(7.8)^2\frac{0.15}{9.8} + 0.25(0.15)^2\right]^{1/2}$$

$$= 1.29\,m$$

$$V_2 = Q/d_2 W = 2.93\,m^3/s / [1.29\,(2.5)\,m^2] =$$

$d_2 = 1.29\,m$

$V_2 = 0.91\,m/s$

$$H_1 + \frac{V_1^2}{2g} + d_1 = H_2 + \frac{V_2^2}{2g} + d_2$$

$$\Delta H = H_2 - H_1 = \frac{V_1^2}{2g} + d_1 - d_2 - \frac{V_2^2}{2g} = d_1 - d_2 + \frac{1}{2g}(V_1^2 - V_2^2)$$

$$= (0.15 - 1.29) + \frac{1}{(9.81)}\left(\frac{7.8^2 - 0.91^2}{2}\right) = 1.92\,m$$

HEAD ENERGY

1

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REVISIONS

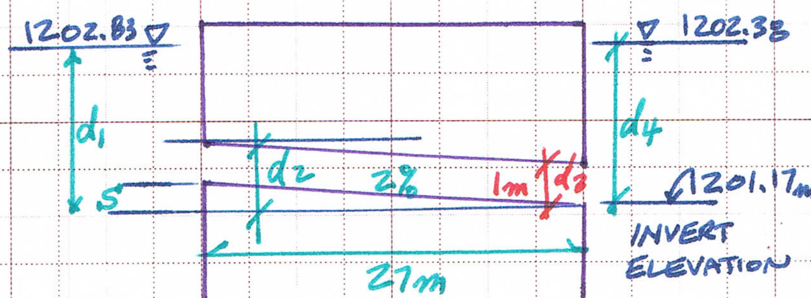
SHEET NUMBER 1
JOB NAME: OPEN CHANNEL
RE: CULVERT
DATE 3/30/05

DETAILS

ENGINEERING & CONSULTING

CULVERT (1m HIGH, 27 m LONG, 2% SLOPE, 1202.83 m UPSTEAM SURFACE ELEVATION, & 1202.38m DOWNSTREAM SURFACE ELEVATION) INVERT ELEVATION OF THE CULVERT OUTLET IS 1201.17 m.
WHAT IS THE CULVERT FLOW CLASSIFICATION?

SLOPE OF CULVER, 2%



$S = \overset{L}{(27)}\overset{S}{(0.02)} = 0.54m$

$d_1 = 1202.83 - 1201.17 = 1.66m$

$d_2 = S + \text{diameter} = S + d_3 = 1.0 + 0.54 = 1.54m$

$d_4 = 1202.38 - 1201.17 = 1.21m > d_3 = 1.0m$ by 0.21m SUBMERGED

SUBMERGED INLET & OUTLET IS TYPE 4

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REVISIONS

SHEET NUMBER 11
JOB NAME: HYDRAULICS
RE:
DATE 3/30/05

DETAILS

ENGINEERING & CONSULTING

RECTANGULAR CHANNEL WITH 8m BASE, 1.5m WATER DEPTH, VELOCITY = 2.5 m/s TRANSITIONS TO A CIRCULAR CULVERT 50 m UNDER A HIGHWAY. CONCRETE BASE & SLOPE OF 0.002 m/m USED. WHAT IS THE REQUIRED CULVERT CONCRETE STANDARD PIPE WITH HALF FULL? USE MULTIPLES OF 9' OR 8' PIPES.

FOR ½ FULL $\theta = \pi = 180°$ $R_{\text{HYDRAULIC RADIUS}} = 0.25\left(1 - \frac{\sin\theta}{\theta}\right)D$

$= 0.25\left(1 - \frac{\sin\pi}{\pi}\right)D = 0.25D$

DEPTH IN CULVERT $= d_2 = D/2 \rightarrow D = 2d_2$

V_2 CONCRETE PIPE (MANNING) $= R^{2/3}\sqrt{S}/n = R^{2/3}\sqrt{0.002}/0.013$

$= (0.5d_2)^{2/3}\sqrt{0.002}/0.013$

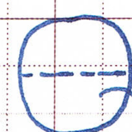
$= 2.167\, d_2^{2/3}$ m/s

$R = 0.25D = (0.25)2d_2 = 0.5d_2$

Channel $V_1A_1 = V_2A_2$ Culvert

$V_1A_1 = (d\,W)V_1 = (1.5)8(2.5) = 30\,m^3/s = A_2V_2$

$= V_2\frac{\pi D^2}{8} = V_2\frac{\pi}{8}4d_2^2$



A_2
$\frac{\pi D^2}{8}$

$= V_2\frac{\pi}{2}d_2^2$

$= (2.167\,d_2^{2/3})\frac{\pi}{2}d_2^2$

$30\,m^3/s = Q = 3.4\,d_2^{8/3}\,m^3/s \rightarrow d_2 = 2.26\,m$

$D = 4.5\,m$

$= 15\,Ft$

TRY 3 PIPES: $\left(\frac{\pi D^2}{4}\right)/3 = \frac{\pi\, 15^2}{4}/3$ OR $= \frac{\pi D^2}{4}/3 = \frac{\pi(4.5)^2}{4}/3 = 5.3\,m^2$

$D_{\text{PER PIPE}} = \sqrt{\frac{4A}{\pi}} = \left[4(5.3)/\pi\right]^{1/2} = 2.6\,m = 8.5\,Ft$

NOMINAL PIPES ≈ 9Ft

TYPICAL OF 3.

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REVISIONS

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

DETAILS ENGINEERING & CONSULTING

A 3IN SCH. 40 PIPE WITH 90° ELBOWS IS POSITIONED NO DIAMETER CHANGE OCCURS & ALL PIPING IS IN ONE X,Z PLANE. FLOW IS 0.55 Ft³/S @ 50 Psig. WHAT RESULTANT FORCE BY WATER IS EXERTED ON EACH ELBOW.?

$$F_R = \sqrt{F_x^2 + F_y^2} = \left[\left[\left(PA(\cos\theta - 1)\right) + \frac{\dot{m}V}{g_c}(\cos\theta - 1)\right]^2 + \left[\left(PA + \frac{\dot{m}V}{g_c}\right)\sin\theta\right]^2\right]^{1/2}$$

$$= \left\{\left[PA(\cos\theta - 1) + \frac{\dot{m}V}{g_c}(\cos\theta - 1)\right]^2 + \frac{\dot{m}V}{g_c}(\cos\theta - 1)\right]^2 + \left(\left(PA + \frac{\dot{m}V}{g_c}\right)\sin\theta\right)^2\right]^{1/2}$$

$$A = \frac{\pi D^2}{4} = \pi \frac{3^2}{(4)144} = 0.049$$

$$V = \frac{Q}{A} = \frac{0.55}{0.049} = 11.2 \text{ ft/s}$$

$$\left[(50 \text{ Psi})\, 144 \frac{in^2}{ft^2}(0.049 ft^2)(\cos 90° - 1) + \frac{34.3 \text{ lbm}}{32.2 \frac{lb_m ft^2}{lb_f Sec}}(\cos 90° - 1)\right]^2$$

$$50 Psi\ 144 \frac{in^2}{ft^2}\ 0.049 ft^2 \sin 90 + \frac{(34.3)\frac{lbm}{s}\ 11.2 ft/s \sin 90°}{32.2 \frac{lb_m ft^2}{lb_f \text{-} s}}$$

$F_x = -381$ lbf $F_y = 381$ lbf

$$F_R = \left[(381)^2 + (-381)^2\right] = 539 \text{ lb}_f$$

5.9.1 Example Problem No. 1:

Refer to Figure 5-8-3(a), Page 5-28. $L_1 = 1000$ ft, $D_1 = 2$ ft, $e_1 = 0.005$ ft, $L_2 = 800$ ft, $D_2 = 3$ ft, $e_2 = 0.001$ ft, $\nu = 0.00001\ \text{ft}^2/\text{sec}$ and H = 20 ft. What is the discharge Q through the system? ($K_e = 0.5$, entrance, $K_o = 1.0$) outlet

Solution:

1. From the energy equation from A to B (including all losses)

$$H + 0 + 0 = K_{e_1}\frac{V_1^2}{2g} + f_1\frac{L_1}{D_1}\frac{V_1^2}{2g} + \frac{(V_1 - V_2)^2}{2g} + f_2\frac{L_2}{D_2}\frac{V_2^2}{2g} + K_{e_2}\frac{V_2^2}{2g}$$

($h_{f_{in}}$, $h_{f_{pipe_1}}$, sudden expansion, $h_{f_{pipe_2}}$, $h_{f_{out}}$)

2. From the continuity equation

$$V_1 D_1^2 = V_2 D_2^2$$

$$V_2 = \frac{V_1 D_1^2}{D_2^2}$$

3. $$H = \frac{V_1^2}{2g}\left\{K_e + \frac{f_1 L_1}{D_1} + \left[1 - \left(\frac{D_1}{D_2}\right)^2\right]^2 + \frac{f_2 L_2}{D_2}\left(\frac{D_1}{D_2}\right)^4 + \left(\frac{D_1}{D_2}\right)^4\right\}$$

$$20 = \frac{V_1^2}{2g}\left\{0.5 + f_1\left(\frac{1000}{2}\right) + \left[1 - \left(\frac{2}{3}\right)^2\right]^2 + f_2\left(\frac{800}{3}\right)\left(\frac{2}{3}\right)^4 + \left(\frac{2}{3}\right)^4\right\}$$

After simplifying,

$$20 = \frac{V_1^2}{2g}(1.01 + 500 f_1 + 52.6 f_2)$$

4. The friction factors f_1 and f_2

$$\frac{e_1}{D} = 0.0025 \qquad \frac{e_2}{D} = 0.00033$$

From the Moody diagram, complete turbulence range choose P. 5-4

$$f_1 = 0.025 \qquad f_2 = 0.015$$

DETAILS ENGINEERING & CONSULTING

A FARM MAINTAINS 500ha IN CURRENT PRODUCTION YEAR. SOD REQUIRES 260cm OF WATER ANNUALLY, THIS IS APPLIED BY IRRIGATION @2cm/hr THREE TIMES WEEKLY. LOT IS SUBDIVIDED EQUALLY. WHAT IS THE MAXIMUM SUBDIVIDED PLOT SIZE IF IRRIGATION AT SOD FARM IS TO OCCUR 12 h/d & 7d/WK?

1. AQUIFERS

= SURFACE WATER = UNDERGROUND WATER = SATURATED GEOLOGICAL FORMATION

VADOSE ZONE (ABOVE) — PORES: EMPTY OR SATURATED

__ATMOSPHERIC PRESSURE____ WATER TABLE

PHREATIC ZONE (BELOW) — PORES = SATURATED

RISE & FALL OF WATER TABLE = CHANGES IN VOLUME
(known as free Aquifer
or UNCONFINED AQUIFER)

GRAVITY WELL = WATER LEVEL IN THE WELL CORRESPOND
TO WATER TABLE
"UNCONFINED WELL"

CONFINED AQUIFER = BOUNDED ON ALL EXTENDS
(MAY BE UNDER PRESSURE)

ONCE DRILLED, WATER IN THE WELL WILL RISE
TO A HEIGHT CORRESPONDING TO THE
HYROSTATIC PRESSURE

PIEZOMETRIC HEIGHT OF RISE IS: $H = \frac{P}{\rho g} = \frac{P}{\gamma} = \frac{P}{\rho} \times \frac{g_c}{g}$

ARTESIAN WELL: IF CONFIENED PRESSURE IS HIGH
ENOUGH, WATER WILL BE EXPELLED
FROM SURFACE

2. AQUIFER CHARACTERISTICS

SOIL MOISTURE CONTENT, W; TENSIOMETER, POROSITY, VOID RATIO, EFFECTIVE POROSITY, HYDRAULIC GRADIENT

W, SOIL MOISTURE CONTENT (WATER CONTENT):

CHANGE IN MASS OF DRY SOIL & WET SOIL

CHANGE IN MASS AFTER OVEN DRYING OF SOIL

$$w = \frac{m_{water}}{m_{soil}}$$ CAN BE DETERMINED BY TENSIOMETER

TENSIOMETER: MEASURES VAPOR PRESSURE OF MOISTURE IN THE SOIL

$$w = \frac{m_w}{m_s} = \frac{m_t - m_s}{m_s}$$ t TOTAL

POROSITY, n = PERCENTAGE OF VOID VOLUME TO TOTAL VOLUME

$$= \frac{V_v}{V_t} = \frac{V_t - V_s}{V_t} = \frac{V_t - V_s}{V_v + V_s}$$ also known as "θ"

WATER CONTENT = $\frac{\text{WEIGHT OF WATER}}{\text{WEIGHT OF SOIL}}$

VOID RATIO, e = $e = \frac{V_v}{V_s} = \frac{V_t - V_s}{V_s}$

VOID RATIO & POROSITY = $e = \frac{n}{1-n}$

EFFECTIVE POROSITY, n_e = 95 TO 98% OF TOTAL POROSITY

PORES ARE PLUGGED OR DEAD END

HYDRAULIC GRADIENT, i = $\frac{\text{CHANGE IN HYDRAULIC HEAD}}{\text{PARTICULAR DISTANCE}} = \frac{\Delta H}{L}$

HYDRAULIC HEAD: MEASURED PIEZOMETRIC HEAD AT OBSERVATION WELLS

3. PERMEABILITY
OF LIQUID AFFECTED BY FLUID & MEDIUM
MEDIUM = INDEPENDENT OF FLUID PROPERTIES

INTRINSIC PERMEABILITY (SPECIFIC PERMEABILITY), k, = EFFECT OF MEDIUM

DARCY = UNIT of k, Length Squared $= 0.987 \times 10^{-8}\ cm^2$

Coefficient of PERMEABILITY = HYDRAULIC CONDUCTIVITY,
= PERMEABILITY, K
= DETERMINED BY TESTS
$= \frac{k\gamma}{\mu} = \frac{k\gamma}{\mu}$ length/sec / TIME

IN U.S. = MEINZER UNITS $= \frac{\text{GALLONS}}{\text{DAY}\ ft^2}$; Now $\frac{Ft}{DAY}$ $\left(\frac{m}{DAY}\right)$

$K = CD^2_{MEAN}$
WHERE D^2 = Square OF MEAN PARTICLE DIAMETER
C = PROPORTIONALITY CONSTANT

HAZEN'S EMPIRICAL FORMULA = APPROXIMATE COEF. OF PERM. FOR CLEAN, UNIFORM SANDS.

$$K_{cm/s} \approx (D_{10,mm})^2 \quad [0.1mm \leq D_{10,mm} \leq 3.0mm]$$

TESTS FOR K: (a) CONSTANT HEAD PERM. TEST (SAND)
(b) FALLING-HEAD PERM. TEST (FINE SAND & SILTS)
(c) CONSOLIDATION TEST (CLAY)
(d) FIELD TEST OF WELL (IN SITU GRAVEL & SANDS

GRAVEL $k = 10^3 - 10^5$ → SANDSTONE 10 → CLAY 10^{-3} DARCY'S
$10^4 - 10^6$ → 10^2 → 10^{-2} gal/Day ft^2

4. DARCY'S LAW

= MOVEMENT OF GROUND WATER THRU AN Aquifer, $Re<1$

$$Q = -K\,i\,A_{gross} = -V_e A_{gross}$$

q = SPECIFIC DISCHARGE = $\frac{Q}{A_{gross}} = Ki = V_e$

= EFFECTIVE VELOCITY = V_e

= ONLY $Re<1$ (WHEN $Re = 2$, SIGNIFICANT CHANGES)

$$Re = \frac{\rho q D_{mean}}{\mu} = \frac{q D_{mean}}{\nu}$$

ρ	DENSITY	lbm/ft^3	Kg/m^3
μ	ABS. VISCOSITY	$lb_f\text{-}Sec/ft^2$	Pa.S
γ	SP. WEIGHT	lb_f/ft^3	
K	HYDRAULIC CONDUCTIVITY	$ft^3/DAY\,ft^2$	$m^3/DAY\,m^2$
q	SPECIFIC DISCHARGE	ft/s	m/s
Q	FLOW QUANTITY	ft^3/s	m^3/s
i	HYDRAULIC GRADIENT	ft/ft	m/m
A	AREA	ft^2	m^2

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REVISIONS

SHEET NUMBER 51
JOB NAME: GROUND WATER
RE: 21
DATE 7/8/03

DETAILS — ENGINEERING & CONSULTING

5. TRANSMISSIVITY
= CEOFFICIENT OF TRANSMISSIVITY
= INDEX FOR RATE OF GROUNDWATER MOVEMENT

Y = SATURATED aquifer THICKNESS
(ΔELEVATION: IMPERMEABLE BOTTOM – WATER TABLE)

b = WIDTH

$$T = KY \rightarrow K = \frac{T}{Y}$$

$$A_{gross} = Yb \rightarrow Y = \frac{A_{GROSS}}{b}$$

$$\Rightarrow K = \frac{Tb}{A_{GROSS}}$$

$$Q = -KiA_{GROSS} = -Tbi \frac{A_{GROSS}}{A_{GROSS}}$$

$$= |-Tbi| = Tbi$$

$$T = KY$$

26.14 FLOW NETS

GROUNDWATER MOVES FROM HYDRAULIC (HIGH) HEAD TO LOWER HEAD. RESULTING PATH OF FLOW IS CALLED "FLOW NET"

IDEAL CASE OF "GROUNDWATER SEEPAGE": STEADY, 2D, INCOMPRESSIBLE, HOMOGENEOUS MEDIUM, VISCOSITY IS CONSTANT

STREAMLINES (FLOW LINES) PATH OF SEEPAGE
EQUIPOTENTIAL LINES (CONTOURS) LINE OF CONSTANT H. HD
HYDRAULIC HEAD

FLOW NETS RULES

21.1 : STREAMLINES ENTER & LEAVE PREVIOUS SURFACES PERPENDICULAR TO THOSE SURFACES

21.2 : STREAMLINES APPROACH LINE OF SEEPAGE ASYMPTOTICALLY

21.3 : STREAMLINES ARE PARALLE TO BUT CANNOT TOUCH IMPERVIOUS SURFACE

21.4 STREAMLINE IS IN DIRECTION FLOW

21.5 STEAMLINES ~ ARE PALL

21-6 12. UNSTEADY flow

- NON-EQUILIBRIUM
- THEIS EQUATION $S_{r,t} = \left(\frac{Q}{4\pi K Y}\right) W(u)$ → WELL FUNCTION DIMENSIONLESS

$$= \left(\frac{Q}{4\pi T}\right) W(u)$$

$$W(u) = -0.577216 - \ln u + u - \frac{u^2}{(2)(2!)} + \left(\frac{u^3}{(3)(3!)}\right) - \frac{u^4}{(4)(4!)} + \dots$$

$$u = \frac{r^2 S}{4Tt}$$

$$S_1 - S_2 = y_2 - y_1 = \frac{Q}{4\pi K Y}\left(W(u_1) - W(u_2)\right)$$

IF $u < 0.01$ use Jacobs

if $u < 0.01$

Jacobs eqn $S_{r,t} = \frac{Q}{4\pi T} \ln\left(\frac{2.25 T t}{r^2 S}\right)$

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REVISIONS

SHEET NUMBER 1
JOB NAME: HYDROLOGY
RE: HYDROGRAPH
DATE

DETAILS — ENGINEERING & CONSULTING

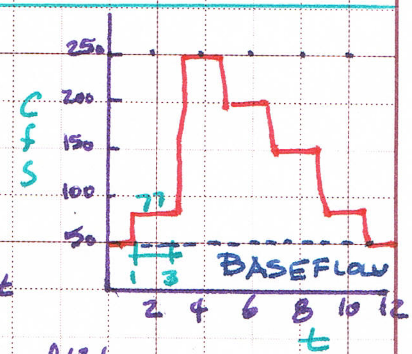
FOR a 3mi SQ. DRAINAGE BASIN @ 2-HR RAINFALL DURATION OF 0.75 IN/HR UNIFORMLY OVER BASIN PRODUCES

T-HRS	0	2	4	6	8	10	12
RUNOFF, CFS	50	77	250	200	150	70	50

FIND: 2-HR & 4HR HYDROGRAPH; TOTAL RUNOFF FROM a 1.5 in/HR (4HR DURATION)
TOTAL RUNOFF 2.5in/HR, 1.2in/HR INFILTRATION 2 HR DURATION

TOTAL CFS (– BASEFLOW)

	0	2	4	6	8	10	12
	50	77	250	200	150	70	50
SUBTRACT 50	0	27	200	150	100	20	0



Σ of (0+27+200+150+100+20) * 2HR * 3600 s/HR * 12 in/ft

Σ CFS RUNOFF / (3 mi SQ * 640 acre/mi² * 43560 ft²/acre)

P = Σ RUNOFF / AREA = 0.51 in

0	2	4	6	8	10	12
0	27/0.51	200/0.51	150/0.51	100/0.51	20/0.51	0
0	53	392	294	196	39	0

UNIT HYDROGRAPH

FOR 2-HR CONVERSION TO 4-HR

1st 2HR	0	53	392	294	196	39	0	0
		0	53	392	294	196	39	
SUM 4HR	0	53	445	686	490	235	39	0
4-HR (SUM/2)		26.5	222.5	343	245	117.5	19.5	4HR UHG.

INFILTRATION: RATE OF RAINFALL – RATE OF ACTUAL MEASURED RUNOFF
2HR * 0.75 in/HR = 1.5 in in 2-HR – (NET RAINFALL = 0.51) ≈ 1.0 OR 0.9 cfs

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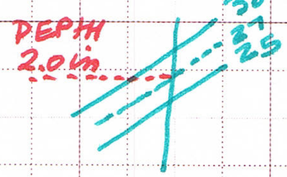
REVISIONS

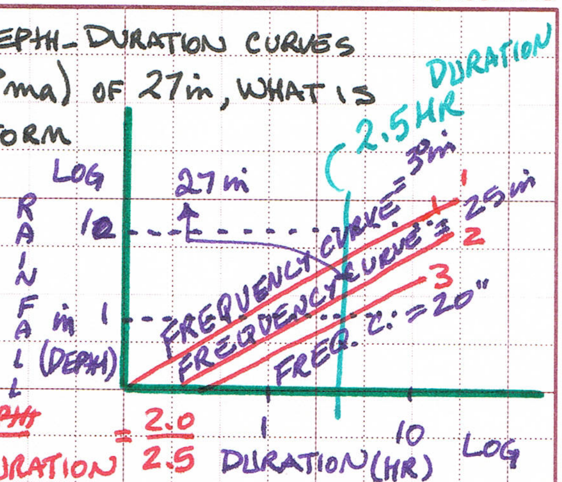
SHEET NUMBER: 1/
JOB NAME: HYDROLOGY
RE: PROBABILITY
DATE: 3/30/05

DETAILS | ENGINEERING & CONSULTING

25YR RETURN PERIOD RAINFALL FREQUENCY-DEPTH-DURATION CURVES FOR a mean ANNUAL PRECIPITATION (Pma) OF 27in, WHAT IS RAINFALL INTENSITY FOR a 2.5 hr STORM

d = RAINFALL DEPTH, in
t = STORM DURATION, hr





i (RAINFALL INTENSITY) in/HR = $\frac{d}{t}$ = $\frac{\text{RAINFALL DEPTH}}{2.5\text{ HR DURATION}}$ = $\frac{2.0}{2.5}$

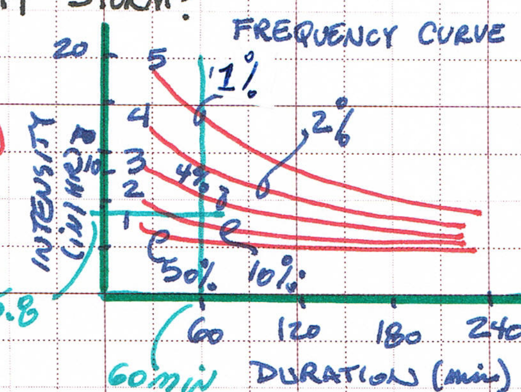
i = (2.0 / 2.5) RAINFALL DEPTH / STORM DURATION = 0.80 in/HR

FREQUENCY-INTENSITY-DURATION CURVES SHOWN WHAT IS FREQUENCY OF 60min DURATION AND 5.8 in/HR INTENSITY STORM?

DURATION 60MIN
INTENSITY (IN/HR) = 5.8

CROSS SECTION OF 60min & I = 5.8 (IN/HR) GIVES CURVE #4 OR 2%

2% means 2 TIMES EVERY YEAR OR ONE IN 50 YRS



FACILITY WILL ACCEPT 1% RISK OF FLOODING DURING 50YR. WHAT IS ANNUAL PROBABILITY THAT FLOODING WILL OCCUR DURING LIFE OF 50 YRS.

n PERIOD OF INTEREST = 50YR = 50YR
P_F ANNUAL PROBABILITY OF FLOOD EVENT = $1-(1)(1-R)^{1/n}$
R ACCEPTABLE RISK OF FLOOD EVENT = 1% = 0.01 OR 1/100

$$P_F = 1-(1)(1-R)^{1/n} = 1-(1)(1-0.01)^{1/50}$$
$$= 0.00020 \text{ OR } 0.02\%$$

44
67
4A

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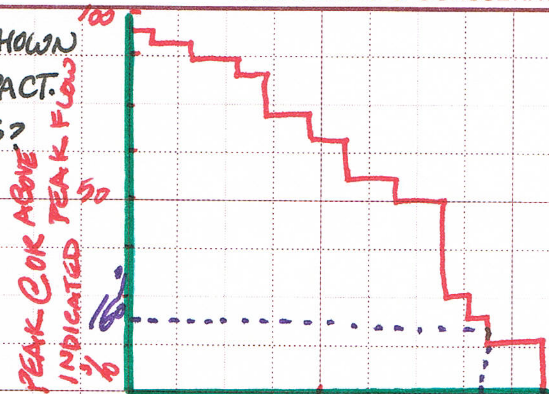
REVISIONS

SHEET NUMBER 4
JOB NAME: HYDROLOGY
RE: PROBABILITY
DATE 3/30/05

DETAILS

ENGINEERING & CONSULTING

HISTOGRAPH W/ 112 EVENTS OVER 94 YEARS SHOWN IF LARGEST 18 EVENT CAUSED ECONOMIC IMPACT. WHAT IS MINIMUM PEAK FLOW OF FLOODS?



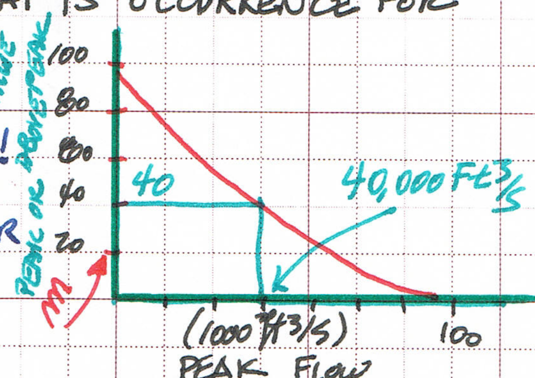
I FLOOD CREATING ECONOMIC IMPACT %
n_e NUMBER OF EVENTS
n_f NUMBER OF FLOODS

$I = \frac{n_f}{n_e}(100\%) = \frac{\text{\# OF FLOODS}}{\text{\# OF EVENTS}} 100 = \frac{18}{112} * 100 = 16\%$

OF PEAK FLOODS IN % @ 16% GIVES ≈ 1900 m³/s PEAK FLOW

HISTOGRAPH OF PEAK FLOW FOR 112 YEARS. WHAT IS OCCURRENCE FOR EVENT FLOW OF 40,000 Ft3/S

t_P = RECURRENCE INTERVAL $= \frac{N+1}{m} = \frac{112+1}{40} = 2.8\text{YR}$
N = PERIOD OF RECORD (112 YR)
m = NO. OF EVENTS OF INTEREST THAT EXCEED THE PEAK FLOW



ANNUAL 97 YR FLOOD DATA: $\text{Log}\,\bar{X}$ (AVE. MEAN FLOOD FLOWS, Ft³/s) = 3.571; SUM OF $[\text{LOG}\,X(\text{EACH EVENT}) - \text{LOG}\,\bar{X}]^2$; SUM OF $[\text{LOG}\,X(\text{EACH EVENT}) - \text{LOG}\,\bar{X}]^3$

WHAT IS MAGNITUDE OF 25 YEAR FLOOD?

USE "LOG PEARSON TYPE III" DISTRIBUTION TO FIND FLOOD MAGNITUDE

N = # OF YEARS RECORD; X = FLOOD MAGNITUDE, Ft³/s, σ = STD DEVIATION

$\sigma = \sqrt{\frac{\Sigma(X-\bar{X})^2}{N-1}} = \left[\frac{3.894}{97-1}\right]^{1/2} = 0.20$; g Skew Coef $= \frac{N\Sigma(\text{Log}\,X - \text{Log}\,\bar{X})^3}{(N-1)(N-2)\sigma^3} = \frac{97(0.181)}{(96)(95)(0.2)^3} = 0.24$ (97-1, 97-2)

K: Log Pearson TYPE III DIST. Coef. w/ 25 YR & g = 0.24 → K = 1.833 LOOK UP

$\text{Log}\,X = \log\bar{X} + K\sigma = 3.571 + 1.833(0.2) = 8662$ Ft³/s (8700 Ft³/s)

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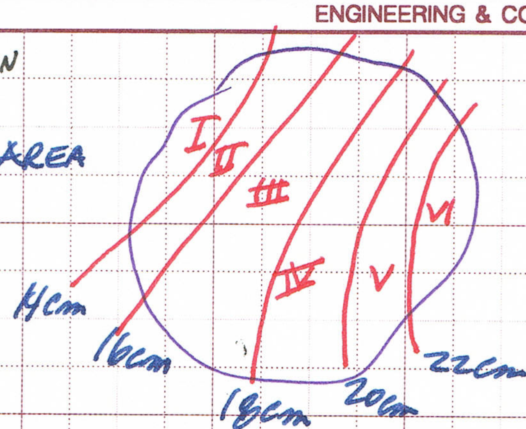
REVISIONS

SHEET NUMBER 4
JOB NAME: HYDROLOGY
RE:
DATE 3/30/05

DETAILS | ENGINEERING & CONSULTING

AN ISOHETAL MAP WITH AREA'S SHOWN
WHAT IS AVERAGE PERCIPITATION ?



AREA	ISOHYET Cm	CLOSED AREA Km²
I	>22	84
II	20	252
III	18	578
IV	16	892
V	14	1136
VI	<14	1294

BASED ON DATA

AREA	ENCLOSED ISOHYET	AREA Km²	NET AREA	AVERAGE PERCIPITATION	PERCIPITATION VOLUME
I	>22cm	84	84	* 23	= 1932 Cm Km²
II	20	252	) = 252 − 84 = 168	* 21	3528
III	18	578	) 578 − 252 = 326	* 19	6194
IV	16	892	− 578 = 314	* 17	5338
V	14	1136	− 892 = 244	* 15	3660
VI	<14	1294	− 1136 = 158	* 13	2054
	A	B	C	D	E

$C = B - B_{i-1}$ $D = A + 1$ $E = D * C$

DETAILS

ENGINEERING & CONSULTING

GIVEN RAINFALL FREQUENCY-DEPTH-DURATION CURVE, STEEL FORMULA K = 80 IN-MIN/HR & 25 MIN. (b). WHAT IS TIME OF CONCENTRATION FOR 2 HR 50 YR STORM

STEEL FORMULA $i = \frac{K}{t_c + b}$

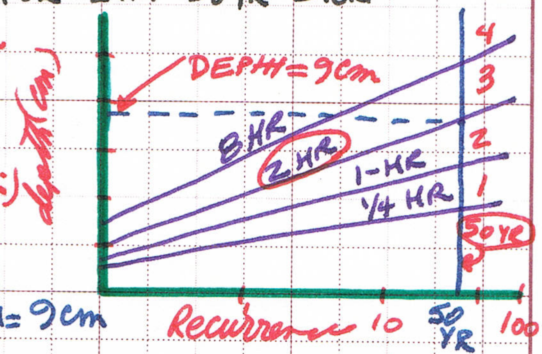
K: 180 in-min/HR

i: INTENSITY

RAINFALL Depth cm / DURATION hr

b: 25 min

t_c: TIME OF CONCENT. (min)



BASED ON 50YR RECURRENCE &
CURVE 3 DURATION 2 HR (Tc) } DEPTH = 9cm

$i = \frac{d}{t} = \frac{\text{9 cm Depth}}{\text{2 HR DURATION}} = 4.5 \text{ cm/HR} = \frac{180 \text{ in-min/HR}}{t_c + 25} \Rightarrow 1.8 \text{ in/HR}$

$\hookrightarrow \frac{4.5}{2.54} = 1.8 \frac{in}{HR}$

$t_c = 75 \text{ min}$

K = UNIT = in - min/HR

"i" MUST BE CONVERTED

WITH 3200 POPULATION, WHAT IS MAXIMUM DAILY DEMAND DURING SUMMER INCLUDING FIRE DEMAND?

$$Q = Q_m P f_s f_p + Q_f = Q_m P f_s f_p + 1020\sqrt{P}\,(1 - 0.01\sqrt{P})$$

- Q_m: 75 TO 130 INCREASED TO 160–165. TAKE 165 G/PERSON.DAY
- P: POPULATION
- f_s (SEASONAL) SUMMER ADDS 20–30% (OR 1.25) 25%
- f_p: DAILY "PEAK" CORRECTION 50–100% OR (1.75) 75%
- Q_f OR 500 GPM min

$$Q = \left(Q_m = 165\,\frac{G}{\text{PERS-DAY}}\right)(1.25)(1.75)(3200) * \left(\frac{(1\text{-DAY})}{(1440\text{ min})}\right) + 1020\sqrt{3200}\left(1 - 0.01\sqrt{3200}\right)$$

$$= \frac{165(1.25)(1.75)3200}{1440} + 1792 = 2594\text{ GPM}$$

($1792 > 500$ ∴ OK)

BASED ON GIVEN DATA WHAT IS PROJECTED APPROXIMATE AVERAGE WATER DEMAND IN 2002?

	YEAR	POPULATION	ΔPOPULATION PER 10 YRS	PER CAPITAL WATER USE (G/DAY)
	1920	20,800		83
1	1930	23,400	2600	89
2	1940	25,100	1700	94
3	1950	27,900	2800	97
4	1960	29,800	1900	137
5	1970	32,600	2800	159
6	1980	35,200	2600	148
7	1990	37,700	2500	144
8	2000	40,100	2400	142

TOTAL CHANGE 19,300

n: # of Decades
ΔP: POPULATION CHANGE FOR EACH DECADE
ΔP_m: AVERAGE POPULATION CHANGE

$$\Delta P_m = \frac{\Sigma \Delta P}{n} = \frac{19{,}300}{8} = 2413\ \frac{\text{PEOPLE}}{\text{DECADE}}$$

P_f (FUTURE POPULATION, 2020) = (POPULATION @ 2000) 40,100 + 2 (DECADES) (2413 PERSON/DECADE)

$40100 + 2(2413) = 44{,}926$ PEOPLE

ASSUME 140 GALLONS/DAY FOR NEXT 2 DECADE

$$Q_f = (140)\text{ GPD} * 44{,}926\text{ PEOPLE} = 6.3 \times 10^6\text{ GAL/DAY}$$

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REVISIONS

SHEET NUMBER 11
JOB NAME: HYDRAULICS
RE: WATER DEMAND
DATE 3/30/05

DETAILS | ENGINEERING & CONSULTING

AVERAGE WATER USE SHOWN. WATER IS PUMPED TO RESERVOIR AT CONSTANT RATE = AVE. DAILY DEMAND. DURING WHAT PERIOD OF DAY WILL THE NET WATER FLOW be INTO RESERVOIR?

TIME	AVE. DEMAND GPM	≤10,342
0-0200	6900	IN FILL
0200-0400	6500	IN "
0400-0600	8100	IN "
0600-0800	12100	OUT
0800-1000	14300	OUT
1000-1200	15,600	OUT
1200-1400	13800	OUT
1400-1600	12500	OUT
1600-1800	9900	FILL IN
1800-2000	8900	FILL IN
2000-2200	8300	FILL IN
2200-2400	7200	FILL IN

$\Sigma q_m = 124,100$

$Q_m = \Sigma q_m / n = 124,100\text{ GPM} / 12 = 10,342$ GPM PUMP RATE

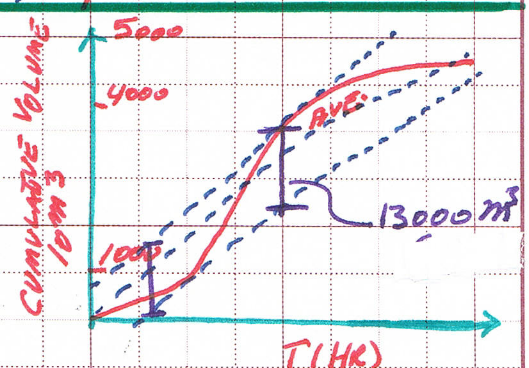
IF $Q_m >$ DEMAND FLOW IN (FILLING) RESERVOIR.

FROM 0600 TO 0800: FLOW 8100 → 12100 INTERPOLATE

$0600 + (8{:}00 - 6{:}00)\dfrac{10,324 - 8100}{12,100 - 8,100} = 0600 + 1.11\text{hr} = 0707 = 7{:}10\text{ a.m.}$

$1800 - (1600 - 1800)\dfrac{10,324 - 9900}{12,500 - 9900} = 1800 - 0.33\text{Hr} = 1740\ (5{:}40\text{PM})$

MASS DIAGRAM: FOR A MUNICIPAL WATER TANK. WHAT IS MINIMUM REQUIRED CAPACITY OF STORAGE TANK?

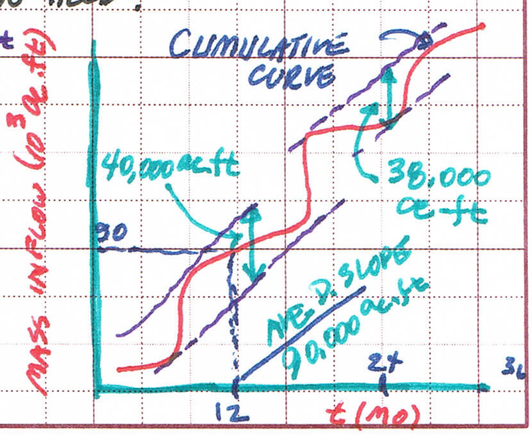


- DRAW AVE LINE. FROM 0 TO MAX. @ 24 HRS
- DRAW PARALLEL TO TANGENT (LOW & HIGH)
- VERTICAL DIFFERENCE IS MIN TANK REQ.

13,000 m^3

RESERVOIR (IRRIGATION WATER): REQUIRED MIN. ANNUAL YIELD = 90,000 acre.ft. INPUT TO RESERVOIR: SEVERAL SMALL STREAMS. MASS INFLOW FOR 3 YR SHOWN. WHAT RESERVOIR CAPACITY REQUIRED TO MEET MIN YIELD?

- ONCE CUMULATIVE RESERVOIR REACHES TO 90,000 ac.ft is @ 12 MONTHS.
- PARALLEL TO CURVE GIVE MIN & MAX POINT



VOLUME OF CAPACITY: SLOPE LOWER OR HIGHER
Δ IN PARALLEL WORK 40,000 ac.ft

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REVISIONS

SHEET NUMBER
JOB NAME:
RE: DEMAND
DATE 5/15/05

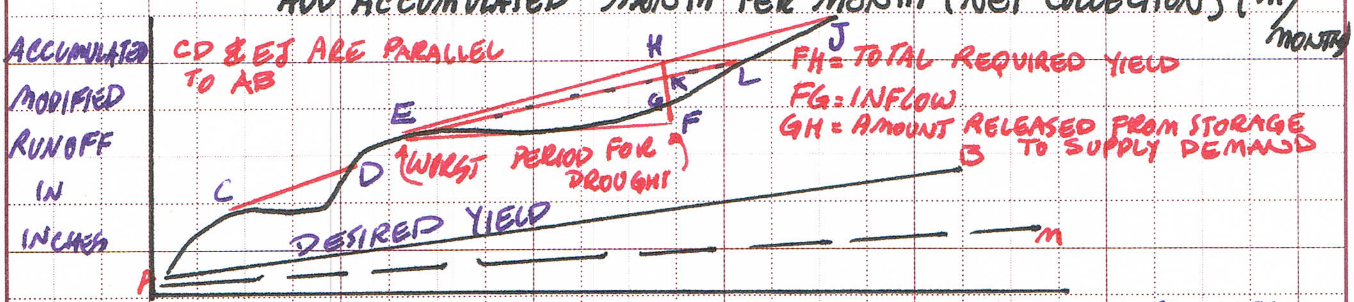
DETAILS | ENGINEERING & CONSULTING

CALCULATE POWER FOR WATER SUPPLY & REQUIRED STORAGE.

METHODS FOR SAFE YIELD OF WATERSHED FROM STORAGE:

(a) MASS CURVE OF MODIFIED RUNOFF

- USE RECORD (MONTHLY) FROM STREAM GAGING STATION
- IDENTIFY DROUGHT PERIODS
- IF IN CFS CONVERT TO DEPTH OF STREAM
- ACCOUNT FOR EVAPORATION LOSS
- ACCOUNT FOR CUSTOMER/OWNER USE (PERIODIC)
- ACCOUNT FOR FULL STORAGE/WASTE ON SPILLWAY
- ADD ACCUMULATED MONTH PER MONTH (NET COLLECTION) (in/month)



IF "AB" IS DESIRED YIELD & EJ (PARALLEL) STORAGE IS NOT ECONOMICAL "EKL" OR "GK" STORAGE MAY BE SUITABLE. THEN EKL PARALLEL BECOMES "Am" NEW YIELD DESIRED.

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SHEET NUMBER
JOB NAME: ENVIRONMENTAL
RE: DEMAND
DATE 6/1/05

DETAILS | ENGINEERING & CONSULTING

40,000 PERSON COMMUNITY

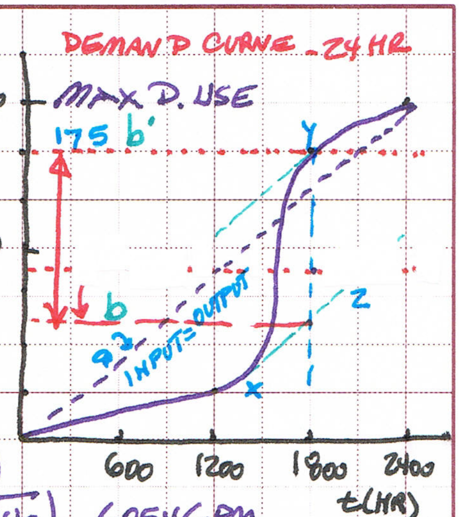
MAX. DAILY CONSUMPTION = 200 * 40,000 = 8 MG

1ST PARALLEL TO MAX. TANGENT Y, DROP VERT. RUN

2ND " " MIN TANGENT X

b_b' LIMITS OF RESERVOIR CAPACITY

175_90 = 85 GPCD * 40000 = 3.4 MG



FOR FIRE FLOW NEEDED Q, $Q = 1020\sqrt{P}(1 - 0.01\sqrt{P})$

$= 1020(\sqrt{40})(1 - 0.01\sqrt{40}) = 6054$ GPM

RECOMMEND 10_HRS FOR TOWNS > 2500 POPULATION

(6045) 60 (10) = 3.63 MG

GENERAL DMND + NFF = 3.63 + 3.4 = 7.03 MG

NORMAL PUMP WORKS FOR 8 MGD / 24 HRS. = 0.33 MG/HR. IF 16-HR PUMP RATE IS 8MGD/16 = 0.5 MG/HR.

THE 7.03 MG * 24 HRS REQUIRED / 16 MG OPERATION = 10.55 MG/HR / 16 HRS

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SHEET NUMBER
JOB NAME: ENVIRONMENTAL
RE: DEMAND
DATE 6/1/30

DETAILS

ENGINEERING & CONSULTING

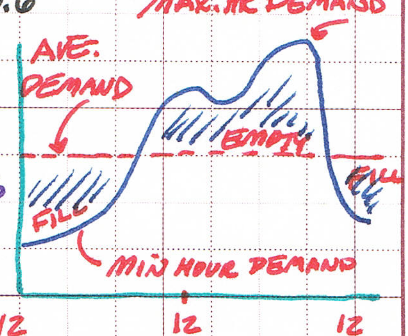
PRESSURE REQUIRED: 20 TO 40 Psi MINIMUM WITH TRUCK PUMPER
40 TO 75 Psi DIRECTLY FROM HYDRANTS
60 TO 80 Psi STATIC PRESSURE
100 Psi OR LARGER, STORAGE @ ELEVATIONS

REQUIRED FLOW $Q_{DESIGN} = Q_{HOURLY}$ (MAXIMUM)
$= Q_{DAILY} + Q_{FIRE}$
(MAX. PAST 3 YRS, DAILY FLOW)

$Q_{FIRE} = f$(AREA, CONSTRUCTION, HEIGHT, LOCAL CODES, FIRE HAZARD)

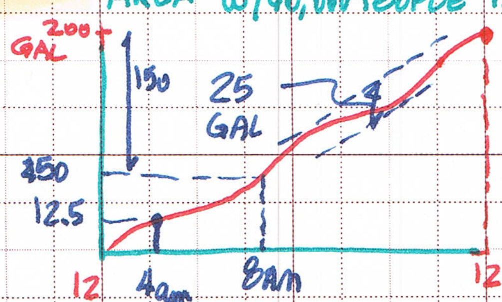
$Q^{FIRE} = 18\,C\,A^{0.5}$ C: 1.5 COMBUSTIBLE MAT'L
0.6

ADD 10% FOR LOSSES



STORAGE: ≈ 30% OF TOTAL DAILY USE
FIRE FLOW STORAGE 1 → 6 HRS

AREA W/40,000 PEOPLE IN 20 YRS



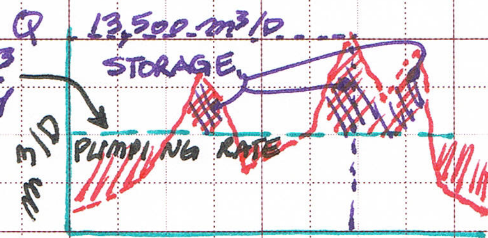
PER CAPITA PER DAY = 200 GAL.

25 GAL * 40,000 = 1×10^6 GAL STORAGE
TANGENT TO LINES

WHILE PUMP IS ON 4:00am to 8:00am. & STORE FOR OTHER TIME. STORES NEEDED
(12.5 + 150) 40,000 = 6.5×10^6 GAL STORAGE

24 HR DISTRIBUTION. PUMP @ 3.6 m^3/min CONTINUOUS. ADD STORAGE.
WHAT IS MAX. PUMPING IF NO STORAGE? STORAGE W/24HR @ 3.6 m^3/min ?

- MAX. Q REQUIRED 13,500 m^3/D
- $@\ 3.6\ m^3/min * 24\ HRS * 60\ \frac{min}{HR} = 5184\ \frac{m^3}{DAY}$
- STORAGE: AREA ABOVE AVE. PUMP CURVE.



$$30\ \text{SQUARE}\left(1\text{-HR} * 1000\ \frac{m^3}{DAY}\right)\frac{1\ DAY}{24\ HR} = 1{,}250\ m^3$$

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SHEET NUMBER
JOB NAME: ENVIRONMENTAL
RE: STORAGE
DATE 5-15-05

DETAILS

ENGINEERING & CONSULTING

STORAGE

RESERVOIR OR WATER TANK/TOWERS TO ACCOUNT FOR DAILY/SEASONAL WATER DEMAND AS WELL AS DEMAND FOR FIRE FIGHTING

STORAGE ALLOWS DESIGN CAPACITY TO BE LESS THAN PEAK WATER DEMAND

- COPPER SULFATE IS USED IN SHALLOW PORTIONS OF RESERVOIRS FOR ALGAE

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

DETAILS — ENGINEERING & CONSULTING

346 SINGLE FAMILY HOMES (1/8 ac each). EQUALLY DIVIDED ONE & TWO STORY WOOD FRAME, 1400 Ft² & 2300 Ft², RESPECTIVELY. AVERAGE NO. OF PERSONS IS 4 PER FAMILY. MOST NEARLY WHAT DESIGN FLOW SHOULD THE WATER LINE SERVICING THE DEVELOPMENT?

$Q_d = Q_{FA}$ (FIRE DEMAND) $+ Q_p$ (PEAK DAILY DOMESTIC)

(1) IF DISTANCE BETWEEN HOUSES 30' → 100'
Q_{fd} (BASED ON DISTANCE TABLE) = 750 GPM

(2) BASED ON WORST CASE 2 STORY UNIT
A AREA Ft²
F DWELLING FACTOR 1.5 WOOD FRAME

$Q_{FA} = 18F\sqrt{A} = 18(1.5)\sqrt{2300} = 1295$ GPM

NEAREST TO 250 GPM ≅ 1250 GPM

(3) BASED ON POPULATION

$Q_{FP} = 1020\sqrt{\frac{P}{1000}}\left(1 - 0.01\sqrt{\frac{P}{1000}}\right)$

$= 1020\sqrt{1.384}\left(1 - 0.01\sqrt{1.384}\right)$

= 1186 GPM

1250 > 1186 > 750 ∴ 1250 GPM

Pq

$(346 \text{ HOUSE})\left(\frac{4 \text{ PEOPLE}}{\text{HOUSE}}\right) = 1384$ PEOPLE

$\left(\frac{165 \text{ GAL}}{\text{PERSON-DAY}}\right)\left(\frac{1\text{-DAY}}{1440 \text{ min}}\right) = q$

$Q_a = (1384 \text{ PEOPLE})\left(\frac{165 \text{ GAL}}{\text{PERSON-DAY}}\right)\left(\frac{1 \text{ DAY}}{1440 \text{ min}}\right)$

= 159 GAL/min

$Q_p = (159 \text{ GPM})\,m = 159(1.5) = 238$ GPM

m: PEAK DAILY FLOW MULTIPLIER = 1.5

$Q_d = Q_{FA} + Q_p$

= 1250 + 238

= 1488 GPM

≅ 1500 GPM

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REVISIONS

DATE: SHEET:
PROJECT:
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RE:

DETAILS CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN ENGINEERING & CONSULTING

PIPE MATERIALS

SMOOTHNESS ←
CORROSION ←
COST ←

→ WATER DISTRIBUTION
→ WASTE WATER
→ AIR CONDITIONING (REF.)
→ PRESSURE
→ EXTERNAL LOAD

MATERIAL	DESCRIPTION
• DUCTILE CAST IRON	STRONG, COSTLY, HEAVY, IMPERVIOUS, SCOUR RESISTANCE
• GRAY CAST IRON	SAME AS DUCTILE CAST IRON
• ASBESTOS CEMENT	LIGHT WEIGHT, CORROSION RESISTANCE, NO ELECTROLYSIS, WEAK STRUCTURALLY
• CONCRETE	WATER TIGHT, DURABLE, SMOOTH INTERIOR, LOW MAINTENANCE
• VITRIFIED CLAY	CORROSION RESISTANCE, SCOUR, EROSION, RESISTANCE
• STEEL	DUCTILE, HIGH STRENGTH, SMOOTH INTERIOR, SUBJECT TO CORROSION, RESISTANCE TO SHOCK
• PLASTIC	PVC & ABS; CHEMICALLY INERT, CORROSON RESTACE LOW COST
• COPPER & BRASS	WATER, CONDENSATE, ...

HYDRAULIC SHOCK SIMPLIFIED EQUATION PRESSURE INCREASE →

P (PSI) = 0.070 L (Ft PIPERUN) VELOCITY FPS / t VALVE CLOSURE TIME (S)

= 0.070LV/t

AIR CHAMBERS: SHOCK ABSORBERS, A PIECE OF SAME DIAMETER PIPE (12" TO 24") CAN BE USED AS WELL. OVER YEARS AIR CHAMBERS SHOWN FAILURE & USELESS. THEY MUST BE CORRECTLY SIZED (VOLUME OF AIR), SIZE AIR CHAMBERS, PERIOD OF PRESSURE, ... REQUIRED FOR SIZING.
INERT GAS/AIR CHAMBER WITHIN MEMBRANES WORK & ONCE SEALED AIR PRESSURE IS STABLE & DO NOT LEAK. EFFECTIVE OPERATION.

SWING VALVE IN DISCHARGE SIDE OF PUMPS: DURING PUMP SHUT DOWN, WATER REVERSAL CAUSE SLAM OF GATE CAUSING SHOCK WAVES.

SPRING VALVE TO BE USED & DESIGNED TO CLOSE EXACT MOMENT WATER FLOW CLOSES
NO CHANGE IN FLUID VELOCITY, THEREFORE:
NO HYDRAULIC SHOCK WAVE.

REVISIONS

DATE: SHEET:
PROJECT:
SUBJECT:
RE:

PIPE DAMAGES

OTHER THAN HYDRAULIC SHOCK,
EROSION, NOISE, & CAVITATION ARE OTHER ISSUES.

CAVITATION: SPONTANEOUS VAPORIZATION OF FLUID IS BASED ON WHEN PRESSURE OF FLUID IS THE LESS THAN VAPOR PRESSURE OF THAT FLUID (WITHIN THERMODYNAMICS of FLUID). POCKETS OF VAPOR CREATED IS CALLED CAVITY. THIS CAN OCCUR WITHIN PUMPS OR SOMETIMES UPSTREAM OF SUCTION SIDE OF PUMP, AS VAPOR CAVITY APPROACHES IMPELLER, NOISE, VIBRATION, IMPELLER PITTING, & STRUCTURAL DAMAGE OCCUR.
WITHIN PIPES, WHEN DIRECTION OF FLOW CHANGES SHARPLY & VELOCITY IS HIGH, CAVITATION OCCURS. SHORT RADUIS PIPES @ HIGH VELOCITY, CAUSES MAJOR CHANGE IN PRESSURE WITHIN FLUID, THUS CAUSING CAVITY. BUBBLES COLLAPSE DOWNSTREAM WITHIN PIPES.

NOISE: PART of HYDRAULIC SHOCK, CAVITATION CAN BE REDUCED BY LOWRING VELOCITY WITHIN PIPES

EROSION: PIPES DEPENDING ON MATERIAL, FLUID, SOLID CONTENT, TEMPERATURE, VELOCITY HAVE DIFFERENT EROSION ISSUES. PIPE ELBOWS, CONNECTIONS, SURFACE ROUGHNESS, CALCIUM BUILDUPS, ARE ALL FACTORS OF ABRASION PROCESS & EROSION. 5FPS & 8FPS ARE NOW LIMITS of HOT & COLD PIPE WATER VELOCITIES BY CODE.

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HYDROMETER

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REVISIONS

DATE: SHEET:
PROJECT: CPD
SUBJECT: PROJECT TASKS
RE:

DETAILS CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN ENGINEERING & CONSULTING

PROJECT INITIAL TASKS

SCOPE, BUDGET, CODES ← "SBCUSWG" → UTILITIES, SEWER, WATER, GAS

1. **SCOPE OF WORK:**
VARIES FOR ALL PROJECTS & "SCOPE CREEP" MAY BECOME MAJOR CONCERNS THROUGHOUT WORK

a. IDENTIFY & TRANSCRIBE CLEAR/STEPWISE SCOPE OF WORK & VERIFY WITH ALL FOR ITS ACCURACIES.
b. LIST & IDENTIFY ALL PLAYERS IN PROJECT
c. NOTIFY PARTIES (P.M., ETC.) ALL WORK BEYOND SCOPE OF WORK

2. **CONSTRUCTION BUDGET**
IDENTIFY THE TYPE OF BUILDING & PROVIDE $/SQFT OR COMPLETE CONSTRUCTION COST. ESTIMATING BOOKS MUST BE CURRENT & MATCH LOCALITIES (R.S. MEANS, ETC) BUDGET CONTROLS DESIGN

3. **A.H.J. (AUTHORITIES HAVING JURISDICTIONS), CODES, LAWS GUIDELINES.**
FULL IDENTIFICATION OF ALL APPLICABLE LAWS IS CRITICAL. INDIVIDUALS ADMINISTERING ARE IMPORTANT: PLAN CHECKERS, INSPECTORS (PLUMBING, MECHANICAL, FIRE, HEALTH, WATER, SEWER, INSURANCE CO.; BUILDING, ...) THERE ARE MANY NATIONAL CODES: IPC, UPC, ADA, OSHA, IBC, AND MANY LOCAL CODES & AMENDMENTS.

4. **UTILITIES:** INVESTIGATE LOCAL CONDITIONS, CREATE UTILITY SITE PLANS WATER, SANITARY, STORM, GAS, ELECTRIC, TOPOGRAPHY (CONTOUR LINES), RIGHT-A-WAY'S (EASEMENTS), HARDSCAPE VS LANDSCAPES, CAPACITIES, SIZES, PRESSURES, MATERIALS. THIS MUST BE COORDINATED WITH CIVIL ENGINEER (IF AVAILABLE), ELECTRICAL & ALL UTILITY COMPANIES, PUBLIC WORKS, OR ANY OTHER AGENCIES. BACKFLOW DEVICES MAY APPLY.

5. **SEWER:** ALL OF #4 CONDITIONS APPLY. POINT OF CONNECTION, ELEVATION, SLOPES, LATERALS, MANHOLES, (INVERT, & TOP OF ELEVATIONS), LOADING CAPACITIES, POSSIBLE SURCHARGE ISSUES. THE LATERAL CONNECTIONS TO BUILDINGS,

6. **WATER:** ALL OF #4 CONDITIONS APPLY. METER, VALVES, BACK FLOW DEVICES, PRESSURES CAPACITIES FOR FIRE, DOMESTIC USE,

7. **GAS:** ALL OF #4 CONDITIONS APPLY. METE, VALVE, PRESSURE, BTU CONTENT, P_{gas}, MATERIAL, ...

4"Ø O.K.

CLEANOUTS: CLEANOUTS PIPES MATCH PIPE SIZE UP TO 4"Ø (6", 8", ...)

a. ANY change in DIRECTIONS > 45°
b. INSIDE/OUTSIDE BUILDING @ POINT of EXIT (WYE BRANCH or House TRAP)
c. 50 FT or MAX. DISTANCE 4" OR LESS, 100 FT FOR LARGER > 4"Ø
   > 10"Ø REQUIRES MANHOLE @ every DIRECTION CHANGE OR 150 FT.
d. BASE of ALL STACKS.
   PROPER ACCESS (18-24" CLEAR), FOR ROTO RODDERS, FIXTURE REMOVAL AS ACCESS TO CLEANOUT IS ACCEPTABLE.

WASTE:

INDIRECT WASTE: INDIRECT CONNECTION TO SANITARY
TRAPPED, VENTED. & DISCHARGE OUTLET SHOULD BE 1.5 TIMES INDIRECT PIPE SIZE ABOVE FLOOD LEVEL. CLEAN OUTS MANDATORY SINCE MANY BLOCKAGE BECAUSE of LOW VELOCITY & LOW FLOW.
INDIRECT WASTES: SINKS, LAVATORIES, CONDENSATE DRAINS.
EXTREME PNEUMATIC EFFECTS DUE TO LOW RATE of FLOW
SPECIAL WASTES
- TANK OVERFLOW, TANK EMPTYING line, Relieve VALVE DISCHARGE SHOULD BE INDIRECT WASTE DUE TO OVER PRESSURIZATION
- DISCHARGES WITH AIR BREAK (F.S., ROOF DRAIN, ..)
- SAME FOR COOLING JACKETS, DRIP ~~TANK~~ PANS, STEAM EXPANSION BOILER OVERFLOWS, ...

RATE of FLOW IN FIXTURES

RATE of FLOW = RATE of DRAINAGE

h = mean vertical height

$$\dot{V} = q = 13.17\, d^2 h^{1/2}$$

gpm, in, ft

IN BRANCHES

- BRANCHES = Σ FLOW FIXTURES TO BRANCH
- UNIFORM FLOW
- BRANCH EXTENDED > 5' DEV. LENGTH
- HYDROSTATIC PRESSURE = SURCHARGING
- IN SHORT RUNS, DUE to HIGH VELOCITY SURCHARGE OCCURS
- BRANCH, q or $\dot{V}$ < STACK $\dot{V}, q$ or House $q, \dot{V}$
- q INTO STACK CANNOT DISTURB STACK
- OR Back PRESSURE INTO BRANCH
- STACK FLOW MAX = $\Sigma\, q_{STACK} + q_{BRANCH}$

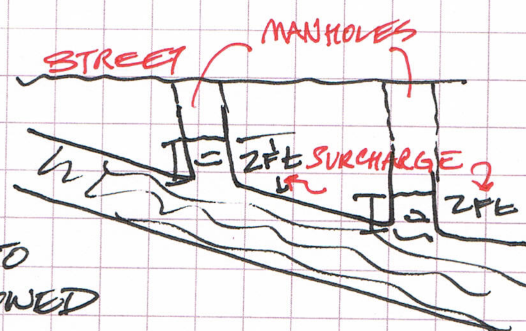
REVISIONS

DATE: SHEET:
PROJECT: DRAINAGE SYSTEMS
SUBJECT:
RE:

SCOURING: TO INSURE SAND, GRIT, PEBBLES, & OTHER SOLIDS ARE IN SUSPENSION, THE FLUID FLOW MUST BE AT MINIMUM TERMINAL VELOCITY. THIS WILL INSURE NO WASTE DEPOSITION & BLOCKAGE. 2FPS IS MINIMUM & 4FPS MINIMUM FOR GREASY CONTENT FLUID FOR 2" & 1 1/2" PIPE WITH FULL OR 1/2 FULL FLOW FLOW VELOCITIES IN DRAINAGE PIPING ARE 1.98 & 1.85 FPS (LESS THAN 2FPS). MINIMIZE LENGTHS OF 1 1/2" & 2" PIPE.

SURCHARGING

TO ACCOMODATE OVERFLOW OR CERTAIN PEAK LOADS, OR WHEN SEWER & STORM DRAINAGE ARE COMBINED, SURCHARGING IS POSSIBLE EVENT & MUST BE ACCOUNTED FOR.
VERTICAL DISTANCE WITHIN MANHOLE IS MEASURE OF SURCHARGING.
THIS MEASURE IS THE LEVEL ABOVE GRAVITY "FULL FLOW" CONDITIONS.
OPTIONS: SMALLER PIPE USED FOR NORMAL CONDITIONS & LESS SLOPE TO MEET TOPOGRAPHY. SURCHARGE IS ALLOWED OVER CAPACITY FOR ABNORMAL CONDITIONS.



SEWER SHAPES.

VARIABLE PIPE SHAPES WILL ALLOW HIGHER TERMINAL VELOCITY IN LOW FLOW CONDITIONS & @ HIGHER FLOW RATES, THE VELOCITY COULD REMAIN THE SAME $V = Q/A$ AS Q↑ INCREASE, A↑ INCREASES HYDRAULIC RADIUS INCREASES

SANITARY SEWER: PUBLIC (WHEN AVAILABLE) & PRIVATE. IN ALL CASES FULLY CONTAINED & NEVER @ HUMAN REACH. NEVER MIX WITH STORM WATER UNLESS FULLY TREATED

COMBINED SEWER & STORM SYSTEM: NOW EXTREMELY RARE, ALL COMBINED NOW MUST BE TREATED BEFORE REUSE OR DISCHARGE. STORM SOMETIMES USED AS OVERLOAD INTO SEWER SYSTEMS.

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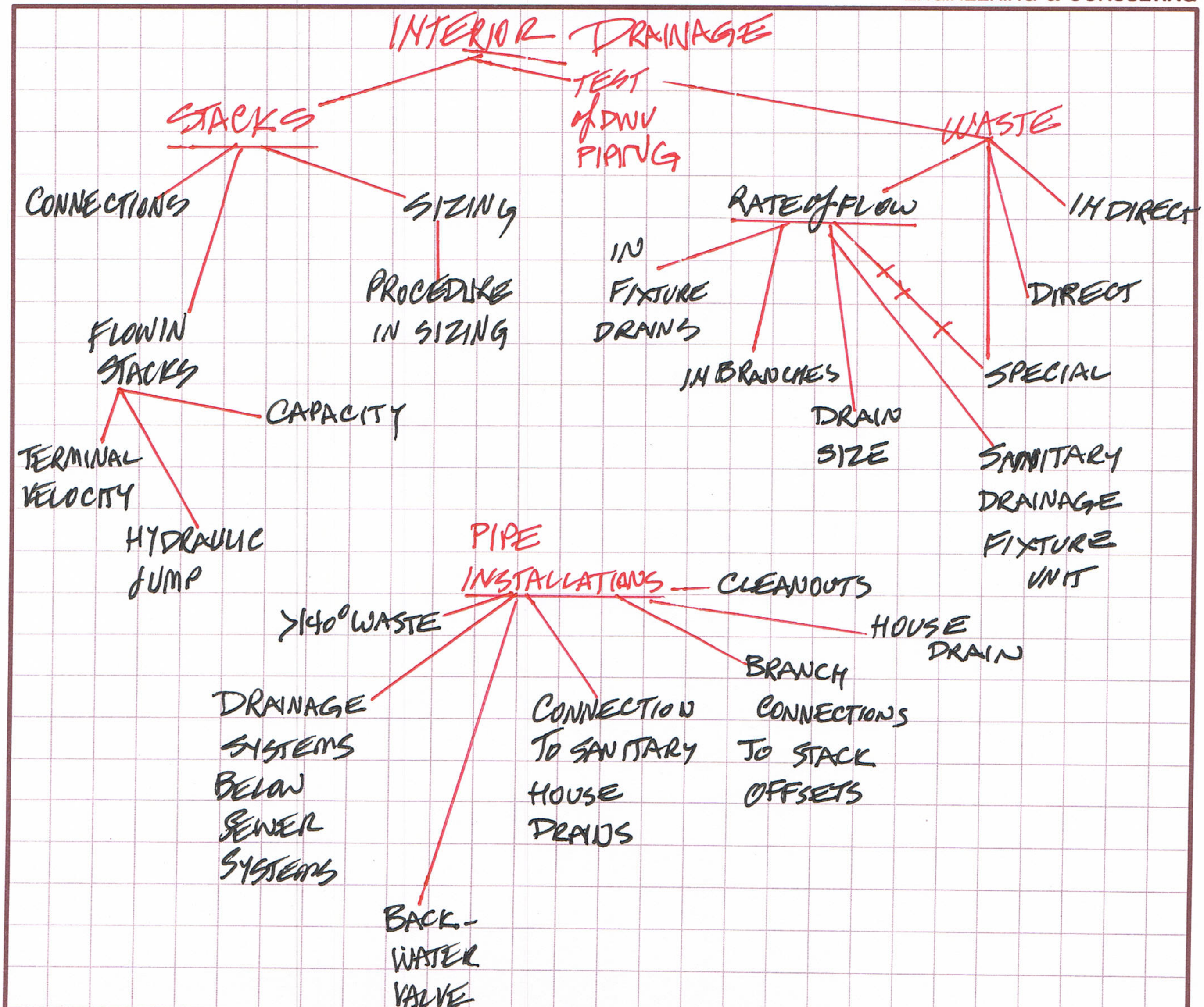
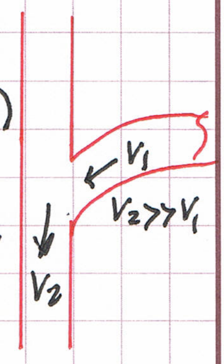


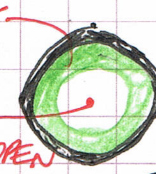
STACKS VERTICAL SEWER PIPING
COLLECTS HORIZONTAL BRANCHES

"SOIL" STACK: FECAL MATER (WATER CLOSET) & URINALS
"WASTE" STACK: SHOWER, SINKS, LAVATORIES
CONNECTIONS: HORIZONTAL TO VERTICAL (SAINTARY TEE)
VERY HIGH VELOCITIES CREATE SELF SIPHONIC OF TRAPS.
TEE-WYE = "SAME" AS: "COMBINATION WYE" & "ONE EIGHTH WYE"
SANTARY TEE: ONLY IN VERTICAL POSITION
TEE WYE : IN ANY POSITION



FLOW IN STACKS. FEARS ARE: HIGH VELOCITY CAUSING UNWANTED IMPACT FLOW, SLUG OR FULL FLOW CAUSING SIPHONAGE & SUCTION OF WATER IN TRAPS, CREATION OF PRESSURE FLUCTUATIONS DUE TO PLUG FLOW (MAX ± 1" H_2O)

SHEET of WATER
1/4 TO 1/3 of PIPE AREA
CORE 3/4 or 2/3 OPEN



TERMINAL VELOCITY
GRAVITATIONAL FLOW WILL REACH EQUILIBRIUM WITH WALL FRICTIONAL FORCES (ASSUMING NO ADDITIONAL FLOW IS ADDED), @ THIS STAGE VELOCITY REMAINS RELATIVELY CONSTANT OR "ULTIMATE" VELOCITY OR TERMINAL VELOCITY. WHICH IS ACHIEVED @ "TERMINAL LENGTH" $V_T \approx 10 \rightarrow 15$ FPS WITHIN $L_T \approx 10 \rightarrow 15$ FT
THEREFORE V_T IS IRRESPECTIVE of L_T
& WITHIN 3 STORY SAME BEHAVIOR AS 50 STORY

$V_T \text{(TERMINAL)} = 3\left(\frac{\dot{V}}{d}\right)^{2/5}$

$L_T \text{(TERMINAL)} = 0.052\, V_T^2$

$\dot{V} = q$ = FLOW RATE
$d = D$ = STACK DIAMETER

CAPACITY of STACKS
PLUG/SLUG FLOW DOES NOT OCCUR TILL $A_F = \left(\frac{1}{4} \text{ to } \frac{1}{3} \text{ of } A_{TOTAL}\right)$

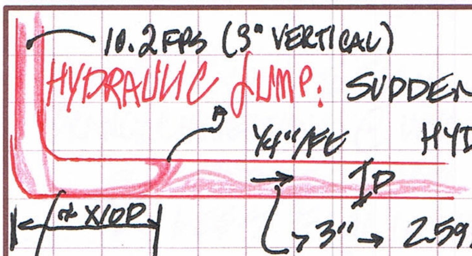
$q_{max} = \dot{V}_{max} = 27.8\, r^{5/3} d^{8/3}$

$r = \frac{\text{AREA OF FLOW}}{\text{AREA of PIPE}}$

MAXIMUM CAPACITY of STACKS (GPM)

PIPE	(r 1/4) q	r 7/24	(r 1/3)
2	18.5	23.5	—
3	54	70	85
4	112	145	180
6	330	435	530
8	710	920	1145
10	1300	1650	2065

UPPER LIMIT DIAPHAGMING



HYDRAULIC JUMP: SUDDEN TRANSITION OF VERTICAL TO HORIZONTAL MAY CAUSE HYDRAULIC JUMP

CRITICAL VELOCITY
"d" DEPTH REDUCES THEN INCREASES TO SUDDEN RISE IN DEPTH = HYDRAULIC JUMP

ANY OFFSETS ~~45~~ DEGREES CREATES HYDRAULIC JUMP

DISTANCE of OCCURANCE of HYDRAULIC JUMP = f(ENTRANCE VELOCITY, DEPTH of HORIZONTAL WATER, PIPE ROUGHNESS, PIPE DIAMETER, SLOPE)

JUMP REDUCES WHEN PIPE DIAMETER, SLOPE, & PIPE ROUGH. INCREASE

SURGING DIES WITH PIPE ROUGHNESS

HIGH TEMPERATURE WASTE: HIGH TEMPERATURE CAUSES PIPE EXPANSION, EXCESSIVE CONTRACTION & EXPANSION WILL DAMAGE PIPES. BOILERS, RESTAURANT DRAINS MUST BE COOLED BELOW 140°F BEFORE DISCHARGING. THIS CAN BE DONE AS ENERGY CONSERVATION TECHNIQUE AS WELL.

DRAINAGE BELOW SEWERLINES: VERIFY ALL OPTIONS BEFORE DESIGNING UNDER SUCH CONDITIONS. EJECTOR/PUMPS ARE REQUIRED (TIGHT & VENTED) CONDITIONS.

BACKWATER VALVE. SEWER BACKWATER VALVES OCCUR WHEN STREET SEWER SYSTEM IS CLOGGED & BUILDING IS FLOODED WITH PUBLIC SEWAGE. ONE BACKWATER VALVE TO SERVE UNITS LOWER THAN SEWER PIPE IS REQUIRED. OTHER FLOORS NOT EFFECTED WILL BE SEGREGATED WITH INDEPENDENT MAIN SEWER CONNECTIONS.

REVISIONS

DATE: SHEET:
PROJECT:
SUBJECT:
RE:

DOMESTIC WATER

SUBJECT IS USED IN PLUMBING, MECHANICAL, CIVIL, & CHEMICAL ENGINEERING. RE > 4000 - TURBULENT, & 2000 < Re < 4000 LAMINAR FLOW OCCURS WHEN MEASURING OR CALCULATING $Re = \frac{DV\rho}{\mu} = \frac{DV}{\nu}$

TURBULENT FLOW OCCURS 1/2", 1", 2" PIPES
V > 0.676, 0.338, 0.169 FPS @ 50°F
V > 0.247, 0.124, 0.0617 FPS @ 140°F

WATER HAMMER: A SYMPTOM OF HYDRAULIC SHOCK

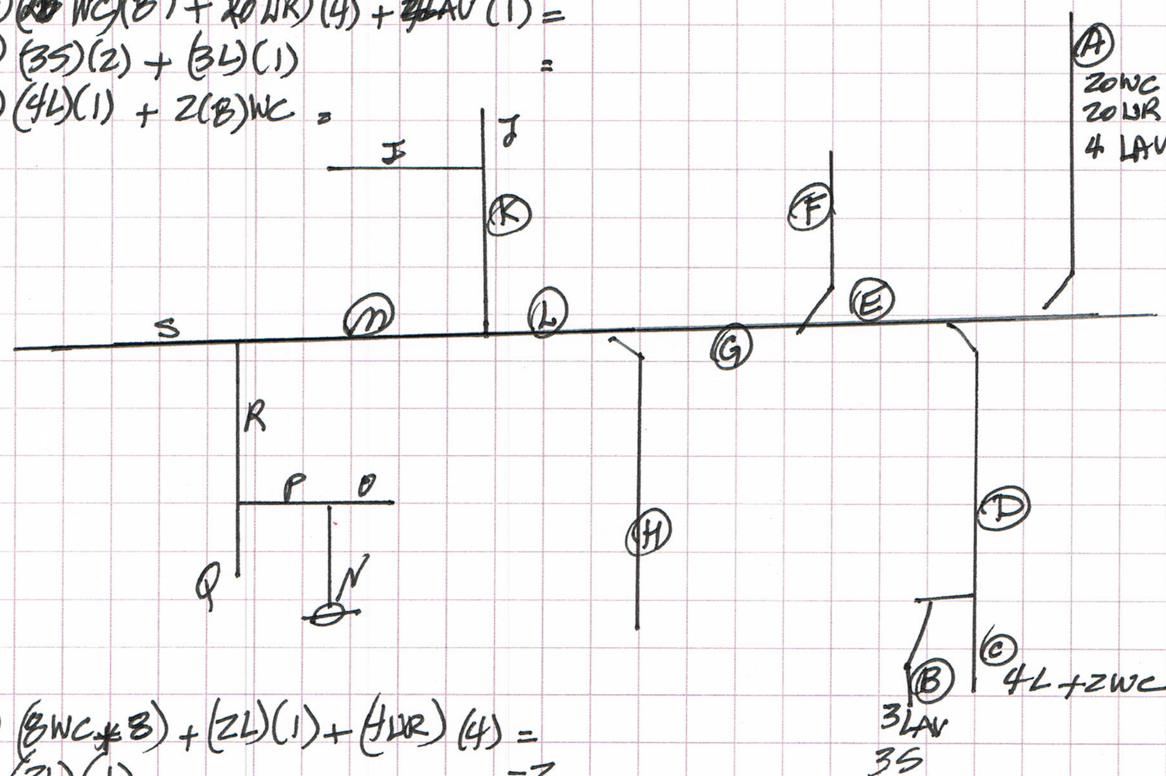
HYDRAULIC SHOCK: SUDDEN & RAPID CHANGE IN VELOCITY
CAUSES: QUICK CLOSING VALVE

HOUSE DRAINAGE

(A) (~~20~~ WC)(8) + (~~20~~ UR)(4) + ~~4~~ LAV (1) =

(B) (3S)(2) + (3L)(1) =

(C) (4L)(1) + 2(8)WC =



(F) (8WC×8) + (2L)(1) + (4UR)(4) =

(H) (2L)(1) =2

(N) CLEAN OUT

(O) (3BT)(2) + (3SH)(2) + (2WC)(8) =

(J) (2BT)(3) + (2L)(2) =

(I) (3WC)(8) + (2SK)(2) =

(Q) 8(3WC) + (2SK)2 + (2L)(2) =

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DATE: ________ SHEET: ________
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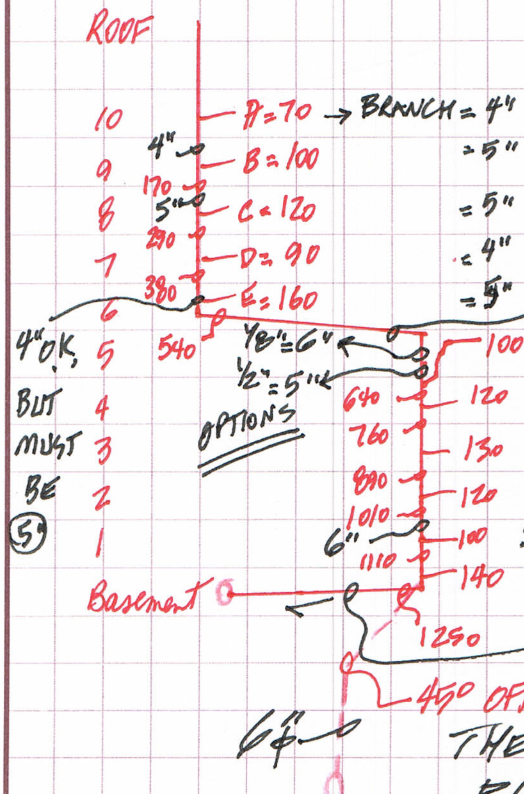
SUBJECT: ________
RE: ________

DETAILS — CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN — ENGINEERING & CONSULTING

STACK SIZING



1/8" = 700, 6"
1/4" = 840, 6"
1/2" = 1000, 6"

5", 1/8" = 390
5", 1/4" = 480
5", 1/2" = 575

6" Cannot work

OPTIONS: 8" minimum Regardless of slope

45° OFFSET ASSUMES STILL VERTICAL
THEREFORE No change in VERT. to HORIZ. PIPE 6"Φ OK.

HOUSE DRAIN SIZING

1/2 CAPACITY to 3/4 MAX. (TO PREVENT FLUCTUATIONS)

1/4"/Ft FOR <3"Φ, & 1/8" >3"Φ O.K. 1/16"/Ft for 6"Φ< O.K.

	1/16"/Ft	1/8"/Ft	1/4"	1/2"
2"Φ	1.02	1.44	2.03	2.88
3	1.24	1.76	2.49	3.53
4	1.44	2.03	2.88	4.07
5	1.61	2.28	3.53	4.56
6	1.76	2.49	4.07	5.0
8	2.03	2.88	4.23	5.75
10	2.28	3.23	4.56	6.44

SUMP PUMP @ 200GPM =
2 × 200 = 400 F.U.

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DETAILS — CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN — ENGINEERING & CONSULTING

FIXTURES

F. DRAIN SIZE
BASED ON MIN TRAP SIZE

SANITARY FIXTURE UNIT (FU) (P.)
ROY HUNTER BMS (1940)
- UNITS ASSIGNED TO DIFFERENT FIXTURES (1923)
- BASED ON PROBABILITY of USE BASE on CUMULATIVE F.U.'S (NOT GPM)

1 F.U. = 7.5 GAL/FT3 FACTOR
= TOTAL GPM of FIXTURE / 7.5 GAL/FT3
= FLOW RATE

- PRIMARY REASON TO CUMULATIVE LOADING IN FU'S

STACK SIZING IN FU

$q = 27.8\,r^{5/3}\,d^{8/3}$

MAX. FU FOR STACKS ($r = 7/24$)

⌀	FU (3 STORIES OR LESS)	> 3 STORIES	TOTAL DISCHARGE 1 BRANCH
2"	10	24	6
2½	20	42	9
3	30*	60*	16+
4	240	500	90
5	540	1100	200
6	960	1900	350
8	2200	3600	600
10	3800	5600	1000
12	6000	8400	1500

* NOT MORE THAN 6 W.C.
\+ NOT MORE THAN 2 W.C.

$$\left[r = A_w / A_T = 7/24 \right]$$

$$q = \dot{V} = 27.8\,r^{5/3}\,d^{8/3} = 27.8\,(7/24)^{5/3}\,(4)^{8/3} = 145\,GPM$$

MAX. LOADING = 145 GPM, $r = 7/24$, > 3 STORIES, 4", 500 FU

MAX FU SANITARY BRANCHES

⌀	F.U.
1½"	3
2	6
2½"	12
3"	20 * < 2 W.C. MAX.
4"	160
5"	360
6"	620
8"	1400

2 F.U. = 1 GPM

MAX. F.U. SANITARY BUILDING & RUNOUTS FROM STACKS

PIPE ⌀	⅛"	¼	½"	
2	—	21	26	26
2½	—	24	31	31
3	20	27	36	36
4	180	216	250	250
5	390	480	575	575
6	700	840	1000	1000
8	1600	1920	2300	2300
10	2500	3500	4200	4200
12	4600	5600	6700	6700
15	8300	10,000	12000	12000

(SLOPE in/ft)

Acknowledgments

The American Society of Plumbing Engineers gratefully acknowledges the contribution of Alfred Steele, P.E., CIPE, the author of the first Certified in Plumbing Design Examination Review Manual. Mr. Steele's original work forms the backbone upon which the ASPE CPD Review Manual Committee developed this revised manual.

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Program Development

The Certified in Plumbing Design (CPD) program is an international certification program for engineers and designers of plumbing systems. Completion of the CPD program and examination confers upon the successful candidate the designation Certified in Plumbing Design, or CPD. The certification program provides the profession, the plumbing industry, and the general public with a single, comprehensive qualification of professional competence for engineers and designers of plumbing systems. The CPD is the only international credential program in the plumbing engineering field. It sets the standards for leadership within the industry and provides formal recognition of outstanding professionals with advanced skills in the design and specification of plumbing systems.

PROGRAM OBJECTIVES

The CPD program was established with five primary objectives:

1. Provide a standard of professional competence for the practice of plumbing engineering.
2. Identify and recognize those individuals who successfully complete the certification examination, thereby demonstrating their acquired knowledge and abilities in the field of plumbing engineering.
3. Encourage plumbing engineers to participate in a continuing program of professional development.
4. Provide a standard for educational programs in plumbing engineering and encourage implementation of such programs.
5. Enhance the status of plumbing engineering as a unique discipline and profession by demonstrating that a realistic standard of professional competence can be clearly defined.

WHO IS ELIGIBLE?

To be eligible to take the CPD examination, a candidate must possess a minimum of four (4) years of practical experience in a position of responsibility for the design of plumbing systems and possess a baccalaureate degree in a field related to engineering. In lieu of an accredited degree, a candidate may substitute up to an additional four (4) years of practical experience in the design of plumbing systems [for a total of eight (8) years] or be granted a credit of one–half year of practical experience for each one (1) full year of education in an accredited curriculum related to plumbing engineering.

THE CPD EXAMINATION

The Certified in Plumbing Design Examination is offered annually in electronic digital form only, available at more than 200 testing sites around the country. The test specifications for the examination were developed by ASPE's Certification Committee with the help of an independent testing and certification service organization, using information derived from a job analysis. The test specifications and content reflect the knowledge, skills, and problem-solving experience essential to performing the job of a plumbing engineer.

Test Content

The Certified in Plumbing Design Examination consists of 100 multiple-choice questions. The questions in the CPD examination are linked to five broad task statements that describe the job dimensions of a plumbing engineer. These task statements are:

Task 1 and Task 2: Gathering Information and Administration — The plumbing engineer identifies the scope of work, existing physical conditions, and project team contacts; determines applicable requirements of authorities having jurisdiction, utility availability, and budgetary constraints; prepares and monitors work plans and schedules; and coordinates work with other members of the professional design team (e.g., HVAC, electrical, etc.).

Task 3: Design — The plumbing engineer identifies the required systems; establishes the design criteria for each system; designs each system; and coordinates the systems with all other building elements.

Task 4: Specifications — The plumbing engineer determines the format and coordinates it with the design; describes the systems to be used; and coordinates plumbing specifications with all other specifications.

Task 5: Construction Services — The plumbing engineer reviews submittals for compliance with contract documents; reviews the installation for compliance with contract documents; and witnesses system test(s).

To receive more information on the CPD exam, visit ASPE.org.