NOTATION

NUMERICAL SUBSCRIPT DENOTES POSITION

- A — AREA OF FLOW, SQUARE FEET (ft^2)
- b — WIDTH OF RECTANGULAR CHANNEL, FEET
- D — DIAMETER OF CONDUIT, FEET
- d — DEPTH OF FLOW, FEET
- Δy — CHANGE IN WATER SURFACE ELEVATION, FEET (PLUS WHEN INCREASING UPSTREAM; MINUS WHEN DECREASING UPSTREAM)
- F — NET FORCE ACTING AT JUNCTION = ΣP
- g — ACCELERATION OF GRAVITY (32.2 FEET PER SECOND PER SECOND)
- H — ENERGY HEAD – $d + \frac{V^2}{2g}$
- h_v — $= \frac{V^2}{2g}$
- θ — THE ANGLE OF CONVERGENCE BETWEEN THE ℄ OF THE MAIN LINE AND THE ℄ OF THE LATERAL
- L — LENGTH OF JUNCTION, FEET
- M — MOMENTUM OF A MOVING MASS OF WATER $\left(\frac{QV}{g}\right)$
- n — MANNING'S ROUGHNESS COEFFICIENT
- P — HYDROSTATIC PRESSURE
- P_f — FRICTION LOSS
- P_i — LONGITUDINAL COMPONENT OF INVERT PRESSURE
- P_w — LONGITUDINAL COMPONENT OF WALL PRESSURE
- Q — QUANTITY OF FLOW, CUBIC FEET PER SECOND (cfs)
- R — HYDRAULIC RADIUS – $\frac{A}{w.p.}$
- S — SLOPE, FEET PER FOOT

SUBSCRIPT "c" DENOTES CRITICAL FLOW
SUBSCRIPT "f" DENOTES FRICTION
SUBSCRIPT "i" DENOTES INVERT
SUBSCRIPT "n" DENOTES NORMAL FLOW AT SLOPE OF INVERT
SUBSCRIPT "s" DENOTES SEQUENT OR CONJUGATE DEPTH
SUBSCRIPT "w" DENOTES WALL

- Σ — SUMMATION OF
- T — WIDTH OF WATER SURFACE IN CIRCULAR CONDUIT, FEET
- V — VELOCITY, FEET PER SECOND (fps)
- w.s. — WATER SURFACE
- w.p. — WETTED PERIMETER, FEET
- $\bar{y}$ — DISTANCE FROM WATER SURFACE TO CENTER OF GRAVITY, FEET
- z — CHANGE IN MAIN LINE INVERT ELEVATION ACROSS THE JUNCTION, FEET

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260A

BASIS OF ANALYSIS:

THE NET HYDROSTATIC PRESSURE ACTING AT THE JUNCTION EQUALS THE CHANGE IN MOMENTUM THROUGH THE JUNCTION PLUS FRICTION.

GENERAL FORMULA WITH FRICTION INCLUDED (UNIT WEIGHT OF WATER OMITTED):

(1) $P_2 + M_2 = P_1 + M_1 + M_3 \cos\theta + P_w + P_i - P_f$

$M_2 - M_1 - M_3 \cos\theta + P_f = P_1 + P_w + P_i - P_2$

NET HYDROSTATIC PRESSURE $= \Sigma P = P_1 + P_w + P_i - P_2 = F$

(2) $\Delta y \times$ AVERAGE AREA $= P_1 + P_w + P_i - P_2$

AVERAGE AREA $= \frac{A_1 + 4A_m + A_2}{6}$ OR FOR PRACTICAL USE, $\frac{A_1 + A_2}{2}$

(3) $\Delta y\left(\frac{A_1 + A_2}{2}\right) = M_2 - M_1 - M_3 \cos\theta + P_f = \frac{Q_2V_2 - Q_1V_1 - Q_3V_3\cos\theta}{g} + L\left(\frac{S_1 + S_2}{2}\right)\left(\frac{A_1 + A_2}{2}\right)$

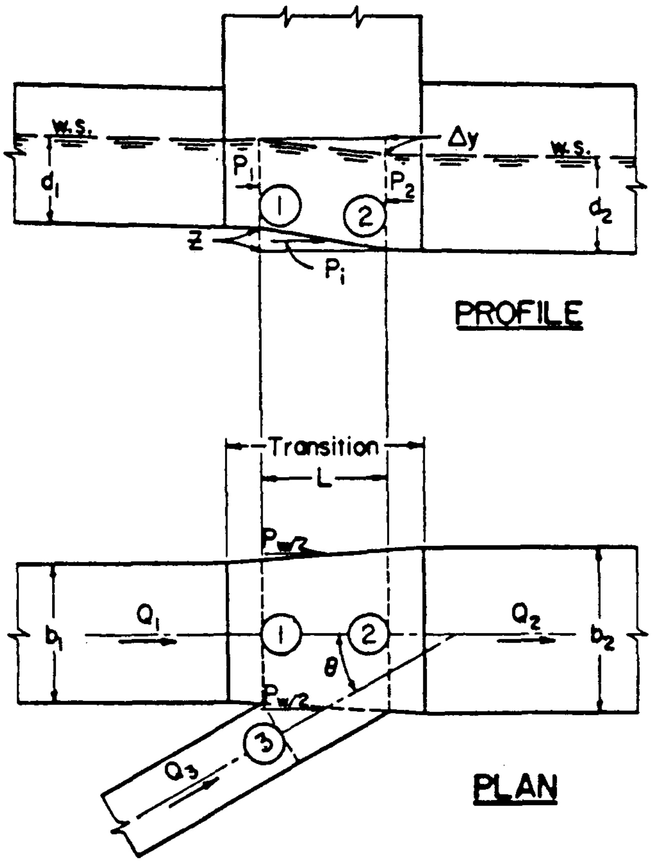
OMITTING FRICTION:

EQUATION (3) IS SHOWN AS:

(4) $\Delta y\left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2V_2 - Q_1V_1 - Q_3V_3\cos\theta}{g}$

(5) $= \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g} - \frac{Q_3^2 \cos\theta}{A_3 g}$

TYPICAL JUNCTION:



NOTE:

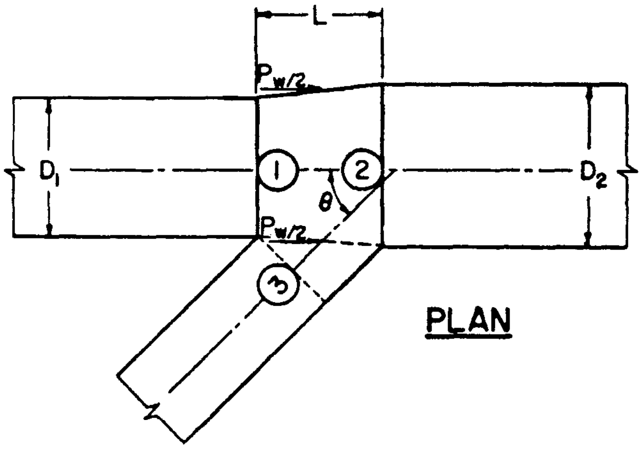
IF THE EXPANSION IS LONGER THAN DIMENSION L, i.e., EXTENDS UPSTREAM AND DOWNSTREAM FROM SECTIONS (1) AND (2), ACTUAL WIDTHS OR DIAMETERS SHALL BE USED AT SECTIONS (1) AND (2) IN CALCULATING THE WATER SURFACE PROFILE. WITH THE ABOVE CONDITION IT WILL BE NECESSARY TO CALCULATE THE CHANGES IN THE WATER SURFACE BETWEEN SECTION (1) AND THE UPSTREAM END OF THE EXPANSION AND BETWEEN THE DOWNSTREAM END OF THE EXPANSION AND SECTION (2). THESE CALCULATIONS ARE ILLUSTRATED IN CASE F., HEREIN. FRICTION AND TRANSITION LOSSES CAN BE IGNORED.

WATER SURFACE ELEVATIONS AT SECTIONS (1) AND (3) ARE IDENTICAL.

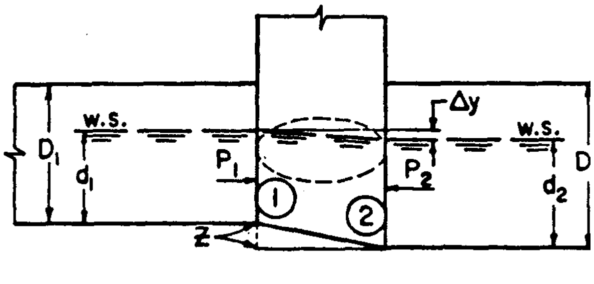
Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260B

DERIVATION OF EQUATION (4)

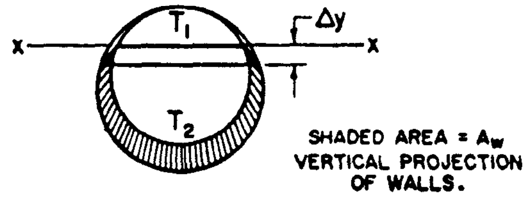
CIRCULAR CONDUIT WITH EXPANSION, FRICTION IGNORED



PLAN



PROFILE



$$P_1 + P_w - P_2 = \frac{Q_2V_2 - Q_1V_1 - Q_3V_3\cos\theta}{g}$$

$P_1 = A_1\bar{y}_1$ $\qquad P_w = A_w\bar{y}_w$

$P_2 = A_2\bar{y}_2$ $\qquad P_T = 0$

$$A_w = A_2 + \left(\frac{T_1 + T_2}{2}\right)(\Delta y) - A_1$$

Σ MOMENTS ABOUT x-x

$$\bar{y}_w = \frac{\left[A_2(\bar{y}_2 + \Delta y) - A_1\bar{y}_1 + \frac{T_1\Delta y^2}{2} + \left(\frac{T_2 - T_1}{2}\right)\frac{\Delta y}{2}\left(\frac{2}{3}\Delta y\right)2\right]}{A_2 + \left(\frac{T_1 + T_2}{2}\right)(\Delta y) - A_1} - \frac{\Delta y}{2}$$

$$\bar{y}_w = \frac{\left[A_2(\bar{y}_2 + \Delta y) - A_1\bar{y}_1 + \frac{\Delta y}{3}\left(\frac{T_1}{2} + T_2\right)\right]}{A_2 + \frac{T_1 + T_2}{2}(\Delta y) - A_1} - \frac{\Delta y}{2}$$

$$P_w = A_w\bar{y}_w = \left[A_2(\bar{y}_2 - \Delta y) - A_1\bar{y}_1 + \frac{\Delta y^2}{3}\left(\frac{T_1}{2} + T_2\right)\right] - \frac{\Delta y}{2}\left[A_2 + \left(\frac{T_1 + T_2}{2}\right)\Delta y - A_1\right]$$

MULTIPLYING OUT AND COLLECTING TERMS

$$P_w = \left[A_2\bar{y}_2 - A_1\bar{y}_1 + \frac{\Delta y}{2}(A_1 + A_2) + \frac{\Delta y^2}{12}(T_2 - T_1)\right]$$

$$F = P_1 + P_w - P_2 = A_1\bar{y}_1 + A_2\bar{y}_2 - A_1\bar{y}_1 + \Delta y\left(\frac{A_1 + A_2}{2}\right) + \Delta y^2\frac{(T_2 - T_1)}{12} - A_2\bar{y}_2$$

$\Delta y^2\frac{(T_2 - T_1)}{12}$ WILL BE SMALL AND CAN BE NEGLECTED.

Formulas Derived By:
DONALD THOMPSON Sept. 7, 19

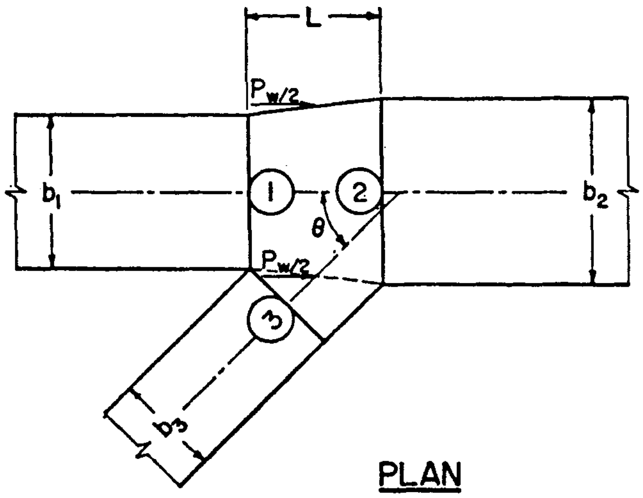
THEN F $= \Delta y\frac{(A_1 + A_2)}{2}$

$\therefore F = \Delta y \times$ AVERAGE AREA $=$ Σ MOMENTUMS AND $\Delta y \times$ AVERAGE AREA $= \frac{Q_2V_2 - Q_1V_1 - Q_3V_3\cos\theta}{g}$ (4)

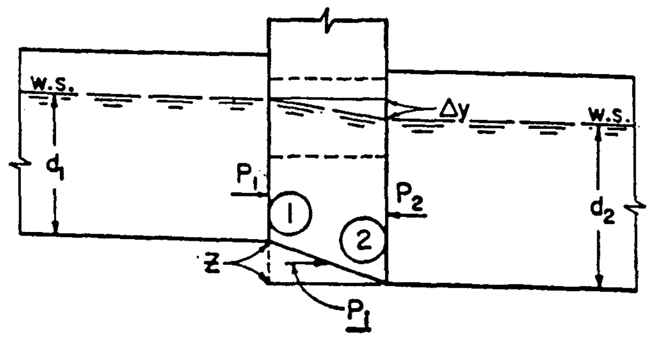
Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260C

DERIVATION OF EQUATION (4)

RECTANGULAR CHANNEL WITH EXPANSION, FRICTION IGNORED



PLAN



PROFILE

$$P_1 + P_w + P_i - P_2 = \frac{Q_2V_2 - Q_1V_1 - Q_3V_3\cos\theta}{g}$$

$$P_1 = \frac{3b_1d_1^2}{6}$$

$$P_w = \frac{(d_1^2 + d_1d_2 + d_2^2)(b_2 - b_1)}{6} = \frac{b_2d_1^2 + b_2d_1d_2 + b_2d_2^2 - b_1d_1^2 - b_1d_1d_2 - b_1d_2^2}{6}$$

$$P_i = \frac{(2b_1d_1 + b_1d_2 + b_2d_1 + 2b_2d_2)Z}{6}$$

$$P_2 = \frac{3b_2d_2^2}{6}$$

$$F = \frac{3b_1d_1^2}{6} + \frac{b_2d_1^2 + b_2d_1d_2 + b_2d_2^2 - b_1d_1^2 - b_1d_1d_2 - b_1d_2^2}{6} + \frac{(2b_1d_1 + b_1d_2 + b_2d_1 + 2b_2d_2)Z}{6} - \frac{3b_2d_2^2}{6}$$

$\Delta y = d_1 - d_2 + Z$ AND AVERAGE AREA $= \dfrac{2b_1d_1 + b_1d_2 + b_2d_1 + 2b_2d_2}{6}$

$$\Delta y \times \text{AVERAGE AREA} = \frac{2b_1d_1^2 - b_1d_1d_2 + b_2d_1^2 + b_2d_1d_2 - b_1d_2^2 - 2b_2d_2^2}{6} + \frac{(2b_1d_1 + b_1d_2 + b_2d_1 + 2b_2d_2)Z}{6}$$

$$F = P_1 + P_w + P_i - P_2$$

BY INSPECTION $\Delta y \times$ AVERAGE AREA $= F = \Sigma$ MOMENTUMS

$$\Delta y \ \text{AVERAGE AREA} = \frac{Q_2V_2 - Q_1V_1 - Q_3V_3\cos\theta}{g} \qquad [\text{EQUATION (4)}]$$

EQUATIONS (3), (4) AND (5) ARE VALID FOR ALL TYPES OF PRISMATOIDAL AND CIRCULAR CHANNELS.

Formulas Derived By:
DONALD THOMPSON March, 1955

GENERAL INSTRUCTIONS

PART FULL FLOW IN PIPES AND FLOW IN OPEN CHANNELS, WITH EXPANSION, FRICTION IGNORED THROUGH THE JUNCTION EXCEPT AS NOTED.

FORMULA:

$$\Sigma P = \Sigma M$$

$$\Delta y\left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2V_2 - Q_1V_1 - Q_3V_3\cos\theta}{g}$$

$$= \frac{Q_2^2}{A_2g} + \frac{Q_1^2}{A_1g} - \frac{Q_3^2\cos\theta}{A_3g}$$

$$\Delta y = Z + d_1 - d_2$$

$$(Z + d_1 - d_2)\left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2^2}{A_2g} - \frac{Q_1^2}{A_1g} - \frac{Q_3^2\cos\theta}{A_3g}$$

CONTROL POINTS:

1. SUBCRITICAL FLOW

   $d_2 = d_{2n}$

2. SUPERCRITICAL FLOW

   WHEN $M_{2c} > M_{1n} + M_3\cos\theta + \Delta y\left(\frac{A_1 + A_{2c}}{2}\right)$, A HYDRAULIC JUMP WILL FORM UPSTREAM OF THE JUNCTION AND

   $d_2 = d_{2c}$

   WHEN $M_{2c} < M_{1n} + M_3\cos\theta + \Delta y\left(\frac{A_1 + A_{2c}}{2}\right)$

   $d_1 = d_{1n}$

IN ALL CASES, COMPUTATIONS SHALL BE MADE TO DETERMINE THE UPSTREAM AND/OR DOWNSTREAM WATER SURFACE PROFILE THROUGH REACHES OF NON-UNIFORM FLOW.

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260E

I. CIRCULAR CONDUITS, WITH EXPANSION

1. SUBCRITICAL FLOW

CASE A.

$Z = 0.50'$, $d_2 = d_{2n}$; DETERMINE d_1

CASE B.

$d_1 = d_{1n}$, $d_2 = d_{2n}$, DETERMINE Z

2. SUPERCRITICAL FLOW

CASE C.

$Z = 0.50'$, $M_{2c} > M_{1n} + M_3 \text{COS}\theta + \Delta y \left(\frac{A_1 + A_2}{2}\right)$

$d_2 = d_{2c}$; DETERMINE d_1 $\left(\frac{d_1}{D_1} \text{ SHOULD NOT BE } > 0.82\right)$

CASE D.

$d_1 = d_{1n}$, $d_2 = d_{2n}$; DETERMINE Z FOR NO CONTROL POINT AT SECTION (2)

$M_{2c} < M_{1n} + M_3 \text{COS}\theta + \Delta y \left(\frac{A_1 + A_2}{2}\right)$

CASE E.

$d_1 = d_{1n}$, $Z = 0.38'$; $M_{2c} < M_{1n} + M_3 \text{COS}\theta + \Delta y \left(\frac{A_1 + A_2}{2}\right)$

NO CONTROL POINT AT SECTION (2)

DETERMINE d_2

II. RECTANGULAR CHANNELS, WITH EXPANSION

1. SUBCRITICAL FLOW

CASE F.

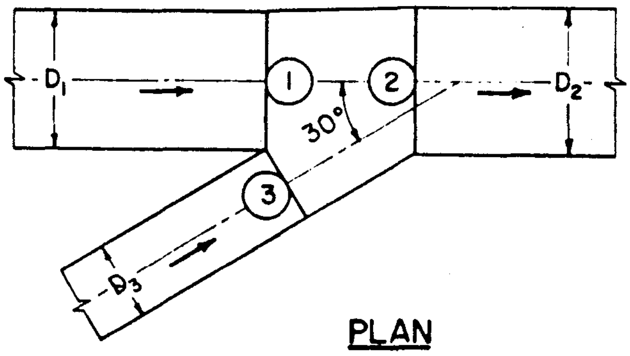
$d_4 = d_{4n}$, $d_5 = d_{5n}$; DETERMINE Z

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260F

I. CIRCULAR CONDUITS, WITH EXPANSION

1. SUBCRITICAL FLOW

CASE A. FRICTION IGNORED



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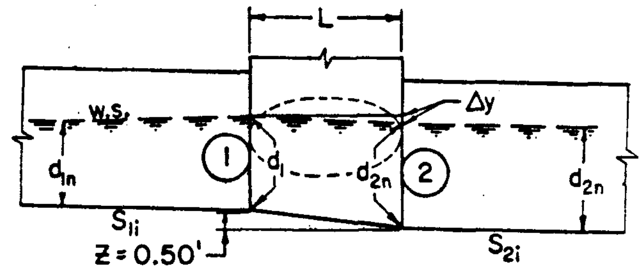


PROFILE

GIVEN:

$Q_1 = 60$ cfs	$Q_2 = 75$ cfs	$Q_3 = 15$ cfs
$D_1 = 4.0'$	$D_2 = 4.25'$	$D_3 = 2.25'$
$S_{1i} = 0.0044$	$S_{2i} = 0.0030$	$S_{3i} = 0.0036$
$d_{1c} = 2.34'$	$d_{2c} = 2.58'$	$d_{3c} = 1.35'$
$d_{1n} = 2.42'$	$d_{2n} = 3.08'$	$d_{3n} = 1.63'$
$A_{1n} = 7.92\ ft^2$	$A_{2n} = 11.00\ ft^2$	$A_{3n} = 3.06\ ft^2$
$V_{1n} = 7.58$ fps	$V_{2n} = 6.82$ fps	$V_{3n} = 4.89$ fps

$\theta = 30°$, $n = 0.014$ AND $L = 4.33'$

DETERMINE d_1: $d_2 = 3.08'$ AND $Z = 0.50'$

FORMULA: $\Sigma P = \Sigma M$

$$(Z + d_1 - d_2)\left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g} - \frac{Q_3^2 \cos\theta}{A_3 g}$$

$$(0.50 + d_1 - 3.08)\left(\frac{A_1 + 11.00}{2}\right) = \frac{75^2}{11.00(32.2)} - \frac{60^2}{A_1(32.2)} - \frac{15^2(0.866)}{3.06(32.2)}$$

$$(d_1 - 2.58)\left(\frac{A_1}{2} + 5.50\right) = 13.92 - \frac{112}{A_1}$$

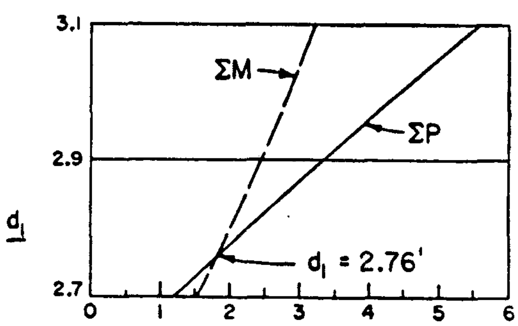
SOLUTION:

$\frac{d_1}{D_1}$	d_1	A_1	ΣP	ΣM
0.675	2.7	9.03	1.20	1.52
0.725	2.9	9.76	3.32	2.44
0.775	3.1	10.45	5.59	3.20

PLOT d_1 VERSUS ΣP AND ΣM

$d_1 = 2.76'$

$\Delta y = Z + d_1 - d_2 = 0.5 + 2.76 - 3.08 = 0.18'$

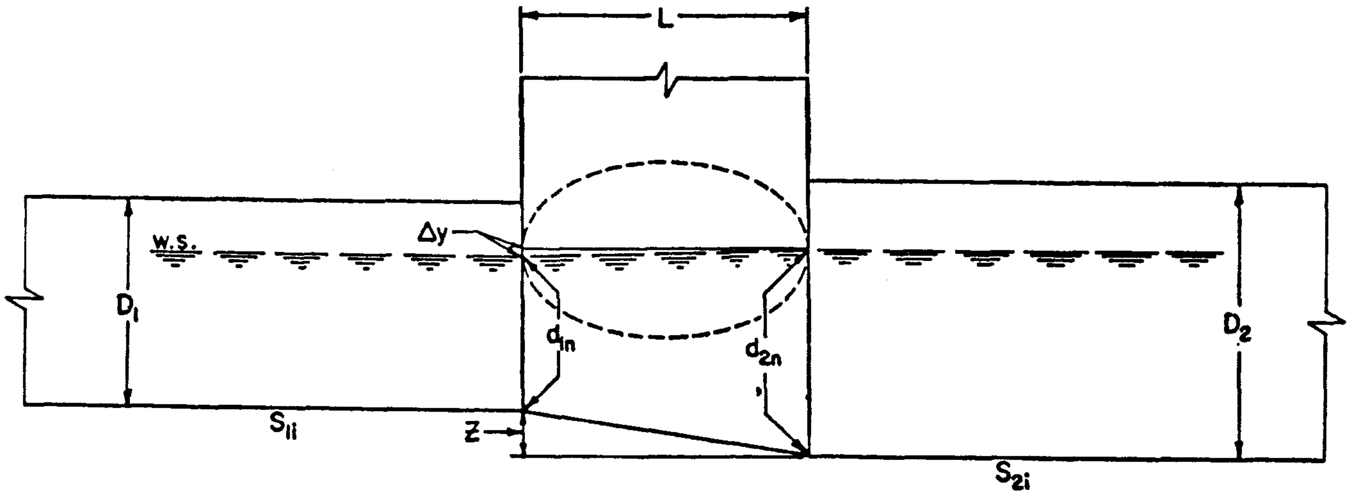


ΣP & ΣM

I. CIRCULAR CONDUITS, WITH EXPANSION

1. SUBCRITICAL FLOW

CASE B. FRICTION INCLUDED



PROFILE

GIVEN:

Q_1 = 3.98 cfs	Q_2 = 5.41 cfs	Q_3 = 1.43 cfs
D_1 = 1.5'	D_2 = 2.0'	D_3 = 1.25'
S_{1i} = 0.0020	S_{2i} = 0.0008	S_{3i} = 0.0028
$\frac{d}{D}$ = 0.75	$\frac{d}{D}$ = 0.75	$\frac{d}{D}$ = 0.49
n = 0.014	n = 0.014	n = 0.015
d_{1c} = 0.76'	d_{2c} = 0.82'	d_{3c} = 0.47'
d_{1n} = 1.13'	d_{2n} = 1.50'	d_{3n} = 0.61'
A_{1n} = 1.42 ft²	A_{2n} = 2.53 ft²	A_{3n} = 0.60 ft²
V_{1n} = 2.78 fps	V_{2n} = 2.14 fps	V_{3n} = 2.38 fps

θ = 30° AND L = 2.07'

DETERMINE Z: d_{1n} = 1.13' AND d_{2n} = 1.50'

FORMULA: $\Sigma P = \Sigma M + P_f$

$$(Z + d_1 - d_2)\left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g} - \frac{Q_3^2 \cos\theta}{A_3 g} + L\left(\frac{S_{1i} + S_{2i}}{2}\right)\left(\frac{A_{1n} + A_{2n}}{2}\right)$$

SOLUTION:

$$(Z + 1.13 - 1.50)\left(\frac{1.42 + 2.53}{2}\right) = \frac{29.27}{81.47} - \frac{15.84}{45.72} - \frac{2.05 \times 0.866}{19.32} + 2.07\left(\frac{.002 + .0008}{2}\right)\left(\frac{1.42 + 2.53}{2}\right)$$

$$Z = 0.333'$$

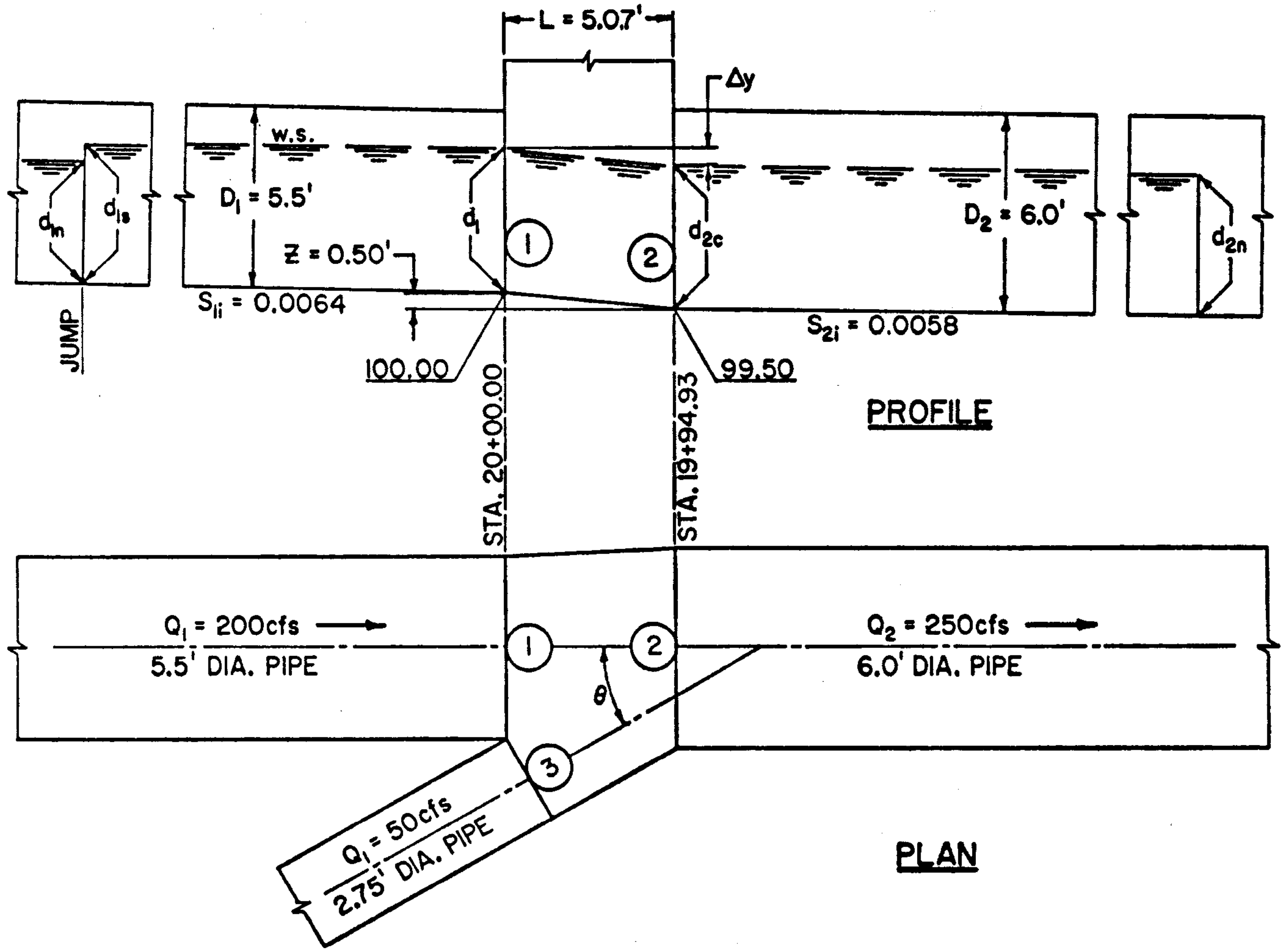
$$\Delta y = Z + d_1 - d_2 = 0.333 + 1.13 - 1.50 = -0.037$$

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260H

I. CIRCULAR CONDUITS, WITH EXPANSION

2. SUPERCRITICAL FLOW

CASE C. FRICTION IGNORED



GIVEN:

Q_1	=	200 cfs	Q_2	=	250 cfs	Q_3	=	50 cfs
D_1	=	5.5'	D_2	=	6.0'	D_3	=	2.75'
S_{1i}	=	0.0064	S_{2i}	=	0.0058	$\frac{d_3}{D_3}$	=	0.66
d_{1n}	=	3.73'	d_{2n}	=	4.19'	d_3	=	1.82'
d_{1c}	=	3.96'	d_{2c}	=	4.33'	d_{3c}	=	2.33'
A_{1n}	=	17.15 ft^2	A_{2n}	=	21.07 ft^2	A_3	=	4.16 ft^2
			A_{2c}	=	21.86 ft^2			
V_{1n}	$\doteq$	11.67 fps	V_{2c}	=	11.44 fps	V_3	=	12.00 fps

θ = 30°, n = 0.014, L = 5.07'

SOLUTION ON FOLLOWING PAGE.

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 2601

POINT OF CONTROL: CASE C - CONTINUED

IF M_{2c} IS GREATER THAN $M_1 + M_3 + (Z + d_{In} - d_{2c})\left(\frac{A_{In} + A_{2c}}{2}\right)$, A POINT OF CONTROL WILL EXIST AT STATION 19 + 94.93 (SECTION ②), $d_2 = d_{2c}$, AND A HYDRAULIC JUMP WILL OCCUR UPSTREAM FROM SECTION ①

$$\frac{Q_2^2}{A_{2c}g} = \frac{250 \times 250}{21.86 \times 32.2} = \underline{88.9}$$

$$\frac{Q_1^2}{A_{In}g} + \frac{Q_3^2 \cos\theta}{A_3 g} + (Z + d_1 - d_{2c})\left(\frac{A_{In} + A_{2c}}{2}\right) = \frac{200 \times 200}{17.15 \times 32.2} + \frac{50 \times 50 \times 0.866}{4.16 \times 32.2} +$$

$$(0.5 + 3.73 - 4.33)\left(\frac{17.15 + 21.86}{2}\right) = 72.43 + 16.16 + (-1.95) = \underline{86.64}$$

88.90 > 86.64 ∴ A JUMP WILL FORM UPSTREAM FROM SECTION ①

DETERMINE d_1: $d_2 = d_{2c}$

FORMULA: $\Sigma P = \Sigma M$

$$(Z + d_1 - d_{2c})\left(\frac{A_1 + A_{2c}}{2}\right) = \frac{Q_2^2}{A_{2c}g} - \frac{Q_1^2}{A_1 g} - \frac{Q_3^2 \cos\theta}{A_3 g}$$

$$(0.50 + d_1 - 4.33)\left(\frac{A_1 + 21.86}{2}\right) = 88.90 - \frac{\overline{200}^2}{A_1(32.2)} - 16.16$$

$$(d_1 - 3.83)\left(\frac{A_1}{2} + 10.93\right) = 72.74 - \frac{1243}{A_1}$$

SOLUTION:

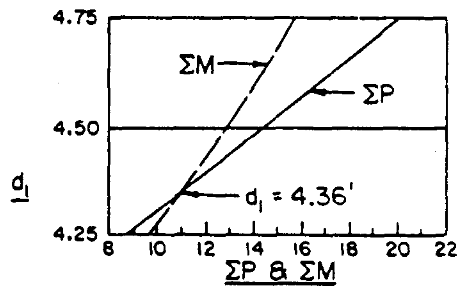
$\frac{d_1}{D_1}$	d_1	A_1	ΣP	ΣM
0.773	4.25	19.7	8.71	9.64
0.818	4.50	20.8	14.3	12.98
0.863	4.75	21.8	20.1	15.72

PLOT d_1 VERSUS ΣP AND ΣM

$d_1 = 4.36'$

$$\frac{d_1}{D_1} = \frac{4.36}{5.50} = 0.795$$

$$\Delta y = Z + d_1 - d_{2c} = 0.5 + 4.36 - 4.33 = 0.53'$$



DETERMINE SEQUENT DEPTH (d_{1s}) AT HYDRAULIC JUMP:

FORMULA: $P_{In} + M_{In} = P_s + M_s$

$$A_{In}\bar{y}_{In} + \frac{Q_1 V_{In}}{g} = A_{1s}\bar{y}_{1s} + \frac{Q_1 V_{1s}}{g}$$

SOLVE BY TRIAL AND ERROR

TRY $d_{1s} = 4.20'$

$$17.15 \times 1.64 + \frac{200 \times 11.67}{32.2} = 100.61 = 19.48 \times 1.89 + \frac{200 \times 10.27}{32.2}$$

$\therefore d_{1s} = 4.20'$

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260J

CASE C - CONTINUED

WATER SURFACE PROFILES

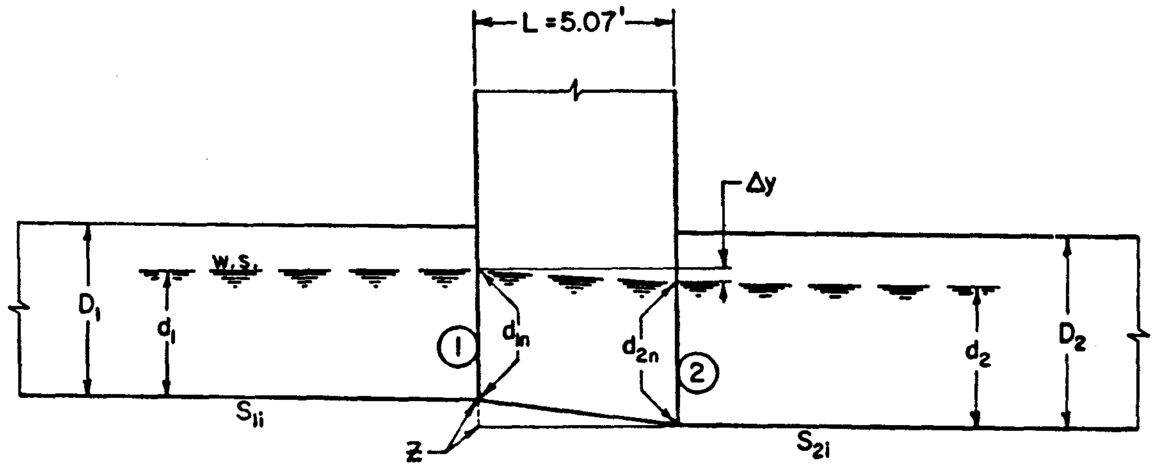
UPSTREAM AND DOWNSTREAM FROM JUNCTION

FIGURES UNDERLINED IN TABLE ARE GIVEN.
V SHOULD VARY BY NOT MORE THAN 5%.

STATION	INVERT ELEV.	d	W. S.	$\frac{d}{D}$	A	V	R	$R^{2/3}$	'C' $\frac{1.486}{n} R^{2/3}$	S_f $\left(\frac{V}{C}\right)^2$	h_v $\frac{V^2}{2g}$	H $d+h_v$	ΔH	Av. S_f	ΔS S_i−Av. S_f	L $\frac{\Delta H}{\Delta S}$
BACKWATER CURVE FROM STATION 20 + 00.0							D=5.5'		Q=200cfs	n=0.014			S_i=0.0064			
20 + 00.0	100.00	4.36	104.36	0.795	20.20	9.90	1.67	1.41	149.6	0.00400	1.52	5.88				
													0.04	0.00459	0.00181	22.1
20 + 22.1	100.14	4.20	104.34	0.764	19.48	10.27	1.66	1.40	148.6	0.00478	1.64	5.84				
JUMP	100.14	3.73	103.87	0.678												
DOWNWATER CURVE FROM STATION 19 + 94.9							D=6.0'		Q=250cfs	n=0.014			S_i=0.0058			
19 + 94.9	99.50	4.33	103.83	0.721	21.80	11.46	1.79	1.47	156.0	0.00543	2.03	6.36				
													0.01	0.00552	0.00028	35.7
19 + 59.2	99.30	4.25	103.55	0.708	21.40	11.68	1.78	1.47	156.0	0.00561	2.12	6.37				
													0.01	0.00570	0.00010	100.0
18 + 59.2	98.72	4.19	102.91	0.698	21.07	11.87	1.78	1.47	156.0	0.00580	2.19	6.38				

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260K

I. CIRCULAR CONDUITS, WITH EXPANSION
2. SUPERCRITICAL FLOW
CASE D. FRICTION INCLUDED



PROFILE

GIVEN:

CONDITIONS ARE IDENTICAL TO THOSE IN CASE C. EXCEPT THAT THE INVERT DROP Z IS UNDETERMINED.

DETERMINE Z:

$$d_2 = d_{2n} = 4.19' \qquad d_1 = d_{1n} = 3.73'$$

FORMULA:

$$M_{2n} = M_{1n} + M_3 \cos\theta + (Z + d_{1n} - d_{2n})\left(\frac{A_{1n} + A_{2n}}{2}\right) - L\left(\frac{S_1 + S_2}{2}\right)\left(\frac{A_1 + A_2}{2}\right)$$

SOLUTION:

$$\frac{250^2}{21.07(32.2)} = \frac{200^2}{17.15(32.2)} + \frac{50^2(0.866)}{4.16(32.2)} + (Z + 3.73 - 4.19)\left(\frac{21.07 + 17.15}{2}\right) - 5.07\left(\frac{0.0064 + 0.0058}{2}\right)\left(\frac{21.07 + 17.15}{2}\right)$$

$$92.12 = 72.43 + 16.16 + (Z - 0.46)\left(\frac{17.15 + 21.07}{2}\right) - 5.07(0.0061)(19.11)$$

$$Z = 0.68'$$

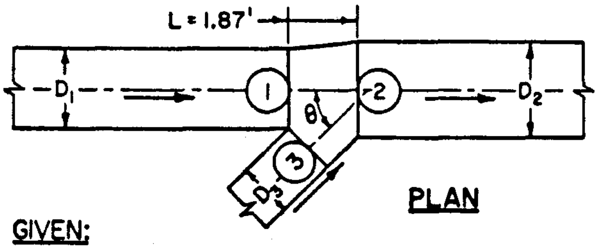
$$\Delta y = Z + d_{1n} - d_{2n} = 0.68 + 3.73 - 4.19 = 0.22'$$

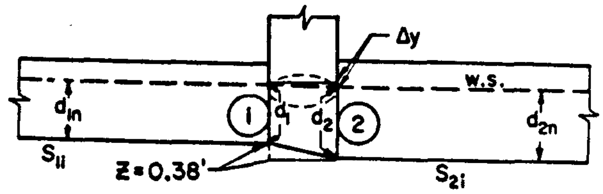
Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260L

I. CIRCULAR CONDUITS, WITH EXPANSION

2. SUPERCRITICAL FLOW

CASE E. FRICTION IGNORED





GIVEN:

$Q_1 = 35.2$ cfs	$Q_2 = 45.7$ cfs	$Q_3 = 10.5$ cfs
$D_1 = 2.25'$	$D_2 = 2.75'$	$D_3 = 1.50'$
$S_{1i} = 0.0180$	$S_{2i} = 0.0104$	$S_{3i} = 0.0140$
$d_{1n} = 1.69'$	$d_{2n} = 2.06'$	$d_{3n} = 1.13'$
$A_{1n} = 3.20\ ft^2$	$A_{2n} = 4.78\ ft^2$	$A_{3n} = 1.42\ ft^2$
	$d_{2c} = 2.20'$	
	$A_{2c} = 5.09\ ft^2$	

$\theta = 45°$, $n = 0.014$ AND $L = 1.87'$

DETERMINE POINT OF CONTROL:

IF M_{2c} IS SMALLER THAN $M_{1n} + M_3\cos\theta + (Z + d_{1n} - d_{2c})\left(\frac{A_{1n} + A_{2c}}{2}\right)$ A POINT OF CONTROL WILL NOT EXIST AT SECTION (2) AND $d_1 = d_{1n}$.

$$\frac{Q_2^2}{A_{2c}g} + \frac{2088}{137} = 12.7$$

$$\frac{Q_1^2}{A_{1n}g} + \frac{Q_3^2\cos\theta}{A_{3n}g} + (Z + d_{1n} - d_{2c})\left(\frac{A_{1n} + A_{2c}}{2}\right) = \frac{1239}{103} + \frac{110 \times 0.707}{45.7} + (0.38 + 1.69 - 2.20)\left(\frac{3.20 + 5.09}{2}\right) = 13.2$$

$12.7 < 13.2$ ∴ NO POINT OF CONTROL AT SECTION (2)

DETERMINE d_2: $d_1 = d_{1n}$

FORMULA: $\Sigma P = \Sigma M$

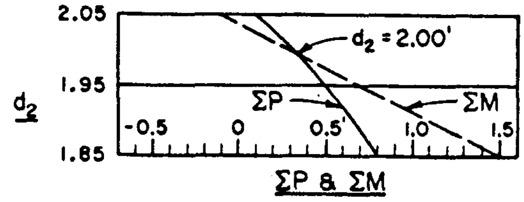
$$(Z + d_{1n} - d_2)\left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g} - \frac{Q_3^2\cos\theta}{A_3 g}$$

$$(0.38 + 1.69 - d_2)\left(1.60 + \frac{A_2}{2}\right) = \frac{45.7^2}{A_2(32.2)} - \frac{35.2^2}{3.20(32.2)} - \frac{10.5^2(0.707)}{1.42(32.2)}$$

$$(2.07 - d_2)\left(1.60 + \frac{A_2}{2}\right) = \frac{64.9}{A_2} - 13.73$$

SOLUTION:

$\frac{d_2}{D_2}$	d_2	A_2	ΣP	ΣM
0.672	1.85	4.25	0.8	1.5
0.709	1.95	4.50	0.5	0.7
0.745	2.05	4.75	0.1	-0.1



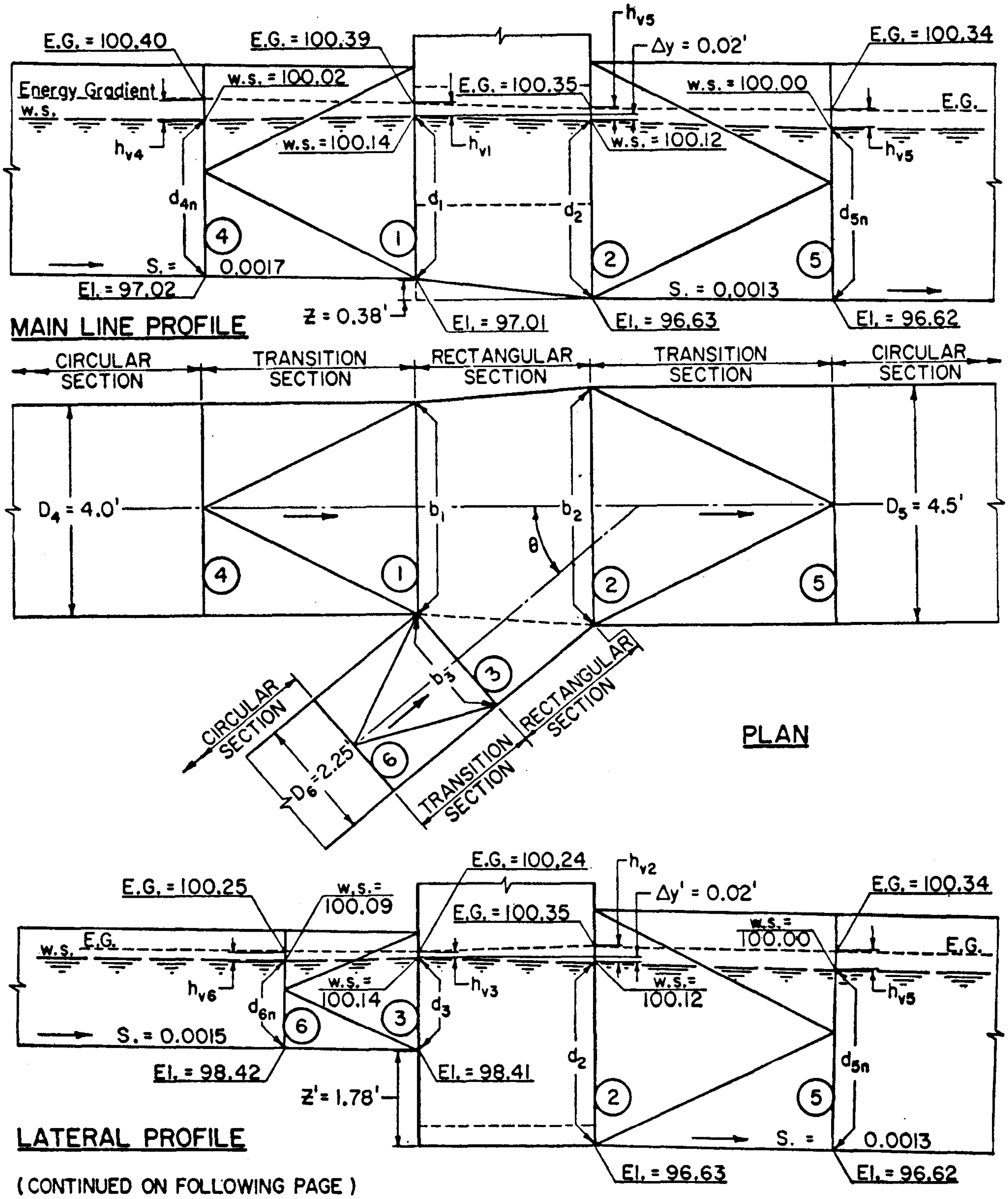
PLOT d_2 VERSUS ΣP AND ΣM $d_2 = 2.00'$ $\Delta y = Z + d_1 - d_2 = 0.38 + 1.69 - 2.00 = 0.07'$

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260M

II. RECTANGULAR CHANNEL, WITH EXPANSION

1. SUBCRITICAL FLOW

CASE F. FRICTION IGNORED



(CONTINUED ON FOLLOWING PAGE)

Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260N

CASE F. CONTINUED

GIVEN:

Q_1 = 50cfs	Q_2 = 60cfs	Q_3 = 10cfs
D_4 = 4.0'	D_5 = 4.5'	D_6 = 2.25'
S_{4i} = 0.0017	S_{5i} = 0.0013	S_{6i} = 0.0015
d_{4c} = 2.12'	d_{5c} = 2.25'	d_{6c} = 1.09'
b_1 = 4.0'	b_2 = 4.50'	b_3 = 2.25'
Transition length = 4.0'	Transition length = 4.50'	Transition length = 2.50'
d_{4n} = 3.00'	d_{5n} = 3.38'	d_{6n} = 1.67'
A_{4n} = 10.10ft²	A_{5n} = 1.28ft²	A_{6n} = 3.17ft²
V_{4n} = 4.94fps	V_{5n} = 4.69fps	V_{6n} = 3.16fps
h_{v4} = 0.38'	h_{v5} = 0.34'	h_{v6} = 0.16'

θ = 40°, n = 0.014 AND L = 3.22'
TRANSITION LOSSES ARE NEGLIGIBLE (LESS THAN 0.01')

FORMULA:

$$H_1 = H_4 = d_{4n} + \frac{V_4^2}{2g} = d_1 + \frac{V_1^2}{2g}, \quad d_{5n} + \frac{V_5^2}{2g} = d_2 + \frac{V_2^2}{2g} = H_5 = H_2$$

$$H_3 : H_{6n} = d_{6n} + \frac{V_c^2}{2g} = d_3 + \frac{V_3^2}{2g}$$

DETERMINE d_1, d_2 AND d_3

H_4 = 3.00 + 0.38 = 3.38'	H_5 = 3.38 + 0.34 = 3.72'	H_6 = 1.67 + 0.16 = 1.83'
Try d_1 = 3.13'	Try d_2 = 3.49'	Try d_3 = 1.73'
A_1 = 12.5ft²	A_2 = 15.7ft²	A_3 = 3.89ft²
V_1 = 4.00fps	V_2 = 3.82fps	V_3 = 2.57fps
h_{v1} = 0.25'	h_{v2} = 0.23'	h_{v3} = 0.10'
H_1 = 3.13 + 0.25 = 3.38'	H_2 = 3.49 + 0.23 = 3.72'	H_3 = 1.73 + 0.10 = 1.83'

DETERMINE Z: d_1 = 3.13', d_2 = 3.49'

FORMULA: $\Sigma P = \Sigma M$

$$(Z + d_1 - d_2)\left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g} - \frac{Q_3^2 \cos\theta}{A_3 g}$$

$$(Z + 3.13 - 3.49)\left(\frac{12.5 + 15.7}{2}\right) = \frac{3600}{15.7 \times 32.2} - \frac{2500}{12.5 \times 32.2} - \frac{100 \times 0.766}{3.89 \times 32.2}$$

$$14.10Z - 5.08 = 7.12 - 6.21 - 0.61$$

$$14.10Z = 5.38$$

$$Z = 0.38'$$

$$\Delta y = 0.38 + 3.13 - 3.49 = 0.02'$$

$$\Delta y = \Delta y' = 0.02'$$

$$Z' = d_2 - d_3 + \Delta y' = 3.49 - 1.73 + 0.02$$

$$Z' = 1.78'$$

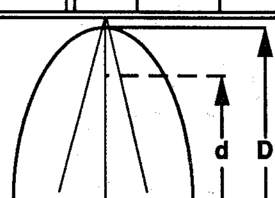
Hydraulic Analysis of Junctions
Open Channel Flow
Figure 260O

$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{R}{D}$	$\frac{R^{2/3}}{D^{2/3}}$	$\frac{AR^{2/3}}{D^{8/3}}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
.01	.0034	.0065	.0299	.0001	.0033	.00003
.02	.0071	.0131	.0547	.0004	.0069	.0001
.03	.0112	.0198	.0734	.0008	.0110	.0002
.04	.0158	.0264	.0887	.0014	.0159	.0003
.05	.0211	.0330	.1030	.0022	.0219	.0005
.06	.0271	.0394	.1158	.0031	.0298	.0008
.07	.0339	.0458	.1280	.0043	.0400	.0011
.08	.0416	.0523	.1399	.0058	.0528	.0015
.09	.0501	.0587	.1508	.0076	.0679	.0020
.10	.0594	.0652	.1618	.0096	.0860	.0026
.105	.0636	.0683	.1671	.0106	.0960	.0029
.11	.0680	.0725	.1740	.0118	.1061	.0032
.12	.0762	.0798	.1857	.0142	.1272	.0040
.13	.0849	.0872	.1968	.0167	.1496	.0048
.14	.0938	.0944	.2072	.0194	.1723	.0057
.15	.1029	.1015	.2171	.0223	.1970	.0066
.16	.1121	.1083	.2266	.0254	.2230	.0077
.17	.1214	.1150	.2360	.0287	.2509	.0089
.18	.1307	.1213	.2447	.0320	.2804	.0102
.19	.1400	.1275	.2528	.0354	.3118	.0115
.20	.1490	.1330	.2599	.0387	.3451	.0130
.21	.1580	.1388	.2674	.0422	.377	.0145
.22	.1670	.1442	.2745	.0458	.410	.0160
.23	.1759	.1493	.2811	.0494	.444	.0177
.24	.1849	.1542	.2875	.0532	.478	.0195
.25	.1937	.1588	.2934	.0568	.513	.0215
.26	.2027	.1634	.2991	.0606	.549	.0235
.27	.2115	.1677	.3042	.0643	.585	.0256
.28	.2203	.1719	.3093	.0681	.623	.0278
.29	.2292	.1761	.3143	.0720	.662	.0300
.30	.2377	.1799	.3189	.0758	.7003	.0323
.31	.2463	.1837	.3234	.0797	.740	.0348
.32	.2551	.1874	.3279	.0836	.780	.0372
.33	.2639	.1911	.3322	.0877	.822	.0399
.34	.2728	.1946	.3361	.0917	.864	.0428

$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{R}{D}$	$\frac{R^{2/3}}{D^{2/3}}$	$\frac{AR^{2/3}}{D^{8/3}}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
.35	.2816	.1981	.3399	.0957	.907	.0455
.36	.2904	.2015	.3437	.0998	.950	.0484
.37	.2990	.2047	.3472	.1038	.995	.0513
.38	.3077	.2077	.3505	.1078	1.040	.0543
.39	.3165	.2107	.3538	.1120	1.086	.0574
.40	.3249	.2134	.3567	.1159	1.1332	.0605
.41	.3335	.2161	.3597	.1200	1.178	.0638
.42	.3421	.2187	.3626	.1240	1.224	.0674
.43	.3506	.2211	.3652	.1280	1.273	.0709
.44	.3591	.2235	.3679	.1321	1.322	.0746
.45	.3675	.2259	.3705	.1362	1.371	.0781
.46	.3760	.2282	.3730	.1402	1.422	.0818
.47	.3845	.2306	.3757	.1445	1.473	.0856
.48	.3928	.2329	.3782	.1486	1.526	.0892
.49	.4011	.2352	.3807	.1527	1.578	.0931
.50	.4093	.2373	.3830	.1568	1.6318	.0971
.51	.4177	.2395	.3855	.1610	1.685	.1012
.52	.4259	.2416	.3878	.1652	1.739	.1052
.53	.4340	.2434	.3897	.1691	1.794	.1094
.54	.4421	.2452	.3917	.1732	1.849	.1136
.55	.4503	.2468	.3935	.1772	1.906	.1180
.56	.4585	.2489	.3958	.1815	1.963	.1226
.57	.4666	.2500	.3970	.1852	2.021	.1272
.58	.4746	.2515	.3985	.1891	2.078	.1321
.59	.4827	.2530	.4000	.1931	2.136	.1371
.60	.4900	.2544	.4014	.1969	2.1947	.1422
.61	.4986	.2557	.4027	.2008	2.253	.1473
.62	.5064	.2569	.4039	.2045	2.312	.1523
.63	.5141	.2582	.4052	.2083	2.371	.1574
.64	.5218	.2593	.4063	.2120	2.432	.1623
.65	.5295	.2605	.4076	.2158	2.495	.1674
.66	.5371	.2616	.4088	.2196	2.558	.1726
.67	.5446	.2627	.4100	.2233	2.620	.1781
.68	.5520	.2637	.4111	.2269	2.685	.1836
.69	.5595	.2647	.4122	.2306	2.748	.1890

$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{R}{D}$	$\frac{R^{2/3}}{D^{2/3}}$	$\frac{AR^{2/3}}{D^{8/3}}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
.70	.5670	.2656	.4132	.2343	2.8163	.1950
.71	.5745	.2665	.4142	.2380	2.886	.2008
.72	.5820	.2673	.4150	.2415	2.954	.2066
.726	.5861	.2678	.4156	.2436	2.9836	.2100
.73	.5891	.2682	.4160	.2451	3.020	.2124
.74	.5962	.2688	.4167	.2484	3.087	.2183
.75	.6033	.2695	.4175	.2518	3.1547	.2242
.76	.6103	.2702	.4182	.2552	3.227	.2304
.77	.6173	.2706	.4186	.2584	3.301	.2365
.78	.6242	.2710	.4190	.2615	3.378	.2428
.79	.6312	.2714	.4194	.2647	3.459	.2491
.80	.6378	.2716	.4196	.2676	3.6409	.2554
.81	.6443	.2718	.4198	.2705	3.631	.2619
.82	.6507	.2719	.4199	.2732	3.722	.2685
.83	.6571	.2720	.4200	.2760	3.814	.2752
.84	.6634	.2718	.4198	.2785	3.908	.2820
.85	.6697	.2715	.4195	.2809	4.0059	.2888
.86	.6756	.2710	.4190	.2831	4.114	.2958
.87	.6814	.2704	.4184	.2851	4.229	.3029
.88	.6870	.2698	.4178	.2870	4.352	.3100
.89	.6925	.2690	.4169	.2887	4.485	.3170
.90	.6977	.2681	.4159	.2902	4.6203	.3239
.91	.7029	.2672	.4149	.2916	4.776	.3312
.92	.7077	.2658	.4134	.2926	4.948	.3383
.93	.7123	.2643	.4117	.2933	5.142	.3455
.94	.7164	.2623	.4095	.2934	5.380	.3526
.95	.7202	.2599	.4069	.2930	5.6523	.3596
.96	.7233	.2565	.4035	.2919		.3666
.97	.7262	.2523	.3993	.2900		.3739
.98	.7287	.2470	.3937	.2869		.3812
.99	.7310	.2403	.3863	.2824		.3886
1.00	.7330	.2316	.3768	.2762		.3961

$$Q = \left(\frac{AR^{2/3}}{AR^{8/3}}\right)(D^{8/3})\left(\frac{1.486}{D}\right)(S^{1/2})$$



SIZE		D^2	$D^{8/3}$	$D^{5/2}$	D^3
Nominal	Actual				
42"	3.6108'	13.0379	30.6861	24.7747	47.0772
45"	3.9575'	15.6618	39.1852	31.1568	61.9816
48"	4.3633'	19.0384	50.8363	39.7684	83.0702
54"	4.6100'	21.2521	58.8666	45.6302	97.9722

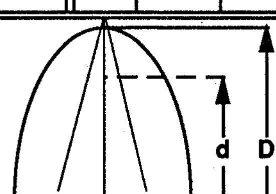
Hydraulic Elements For Partial Flow In
City of Glendale Burns - McDonnell Semi-Elliptical Conduit

$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{R}{D}$	$\frac{R^{2/3}}{D^{2/3}}$	$\frac{AR^{2/3}}{D^{8/3}}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
.01	.005	.007	.035	.0002	.003	.00005
.02	.010	.013	.056	.0006	.008	.00015
.03	.015	.020	.074	.0011	.013	.00029
.04	.021	.026	.088	.0018	.020	.00049
.05	.0282	.0331	.103	.0029	.0292	.00075
.06	.036	.040	.117	.0042	.041	.00110
.07	.045	.046	.128	.0058	.056	.00151
.08	.056	.053	.141	.0079	.075	.00199
.0833	.0605	.0549	.144	.0087	.0810	.00217
.09	.067	.061	.154	.0103	.096	.00259
.10	.0783	.0689	.168	.0132	.1202	.00337
.11	.090	.077	.181	.0163	.147	.00423
.12	.101	.085	.194	.0196	.174	.00527
.13	.112	.093	.206	.0230	.202	.00632
.14	.123	.101	.217	.0267	.232	.00744
.15	.1341	.1082	.227	.0304	.2628	.00869
.16	.145	.115	.237	.0344	.294	.00997
.17	.157	.122	.246	.0386	.328	.0114
.18	.168	.129	.256	.0430	.363	.0130
.19	.179	.136	.264	.0473	.401	.0148
.20	.1808	.1422	.273	.0520	.4419	.0168
.21	.202	.149	.280	.0566	.482	.0187
.22	.214	.155	.288	.0616	.523	.0208
.23	.225	.161	.295	.0664	.566	.0231
.24	.236	.166	.302	.0713	.609	.0254
.25	.2483	.1721	.309	.0769	.6521	.0278
.26	.260	.178	.316	.0822	.698	.0303
.27	.272	.183	.322	.0876	.744	.0331
.28	.283	.188	.328	.0928	.792	.0358
.29	.295	.193	.334	.0985	.841	.0387
.30	.3061	.1984	.340	.1041	.8908	.0416
.31	.318	.203	.346	.1100	.841	.0447
.32	.330	.208	.351	.1158	.993	.0479
.33	.341	.213	.356	.1214	1.047	.0512
.333	.3453	.2145	.358	.1237	1.0651	.0519

$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{R}{D}$	$\frac{R^{2/3}}{D^{2/3}}$	$\frac{AR^{2/3}}{D^{8/3}}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
.34	.353	.218	.362	.1278	1.101	.0547
.35	.3647	.2220	.367	.1337	1.1566	.0584
.36	.376	.226	.371	.1395	1.214	.0620
.37	.388	.231	.376	.1459	1.271	.0659
.38	.400	.235	.380	.1520	1.328	.0698
.39	.411	.239	.385	.1582	1.387	.0739
.40	.4229	.2426	.389	.1645	1.4476	.0781
.41	.434	.246	.393	.1706	1.509	.0824
.42	.446	.250	.397	.1771	1.572	.0868
.43	.457	.254	.401	.1833	1.634	.0913
.44	.469	.257	.405	.1899	1.699	.0958
.45	.4804	.2607	.408	.1961	1.7635	.1007
.46	.492	.264	.411	.2022	1.828	.1054
.47	.503	.267	.415	.2087	1.895	.1104
.48	.515	.270	.418	.2153	1.963	.1155
.49	.526	.273	.421	.2214	2.032	.1207
.50	.5376	.2763	.424	.2281	2.1035	.1261
.51	.549	.279	.427	.2344	2.173	.1317
.52	.560	.282	.430	.2408	2.245	.1373
.53	.571	.285	.433	.2472	2.319	.1429
.54	.582	.287	.435	.2532	2.395	.1487
.55	.5935	.2896	.437	.2598	2.4690	.1544
.56	.604	.292	.440	.2658	2.54	.1605
.57	.615	.294	.442	.2718	2.62	.1667
.58	.626	.296	.445	.2786	2.70	.1728
.59	.637	.299	.447	.2847	2.78	.1790
.60	.6478	.3006	.449	.2907	2.86	.1854
.61	.659	.303	.451	.2972	2.94	.1921
.62	.669	.304	.453	.3031	3.02	.1987
.63	.680	.306	.455	.3094	3.11	.2054
.64	.690	.308	.456	.3146	3.19	.2123
.65	.7002	.3094	.458	.3204	3.2796	.2191
.66	.710	.311	.459	.3259	3.37	.229
.67	.720	.312	.460	.3312	3.46	.233
.68	.730	.314	.461	.3365	3.55	.241

$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{R}{D}$	$\frac{R^{2/3}}{D^{2/3}}$	$\frac{AR^{2/3}}{D^{8/3}}$	$\frac{Q}{D^{5/2}}$	$\frac{P}{D^3}$
.69	.740	.315	.463	.3426	3.64	.248
.70	.7503	.3158	.464	.3479	3.7320	.2554
.71	.760	.317	.465	.3534	3.82	.263
.72	.769	.318	.466	.3584	3.92	.271
.73	.779	.319	.466	.3630	4.02	.278
.74	.788	.319	.467	.3680	4.12	.286
.75	.7975	.3199	.468	.3730	4.2251	.2941
.76	.807	.320	.468	.3777	4.33	.302
.77	.816	.321	.469	.3827	4.43	.310
.78	.824	.321	.469	.3865	4.54	.318
.7833	.8272	.3213	.469	.3880	4.5828	.321
.79	.833	.321	.469	.3907	4.66	.327
.80	.8414	.3214	.469	.3946	4.7713	.3350
.81	.850	.321	.469	.3987	4.89	.344
.82	.858	.321	.469	.4024	5.02	.352
.83	.866	.321	.469	.4062	5.15	.361
.84	.874	.321	.469	.4099	5.28	.369
.85	.8812	.3201	.468	.4125	5.4231	.3781
.86	.888	.319	.467	.4151	5.58	.387
.87	.896	.318	.466	.4177	5.74	.396
.88	.902	.317	.465	.4199	5.91	.405
.89	.909	.316	.464	.4220	6.08	.414
.90	.9159	.3146	.462	.4237	6.2766	.4230
.91	.922	.313	.461	.4249	6.49	.432
.92	.928	.311	.459	.4258	6.73	.441
.93	.933	.309	.457	.4262	7.00	.450
.94	.938	.306	.454	.4261		.459
.95	.9431	.3032	.451	.4255		.4685
.96	.947	.300	.448	.4240		.478
.97	.951	.295	.443	.4213		.488
.98	.954	.289	.437	.4170		.497
.99	.956	.281	.429	.4105		.507
1.00	.9584	.2678	.415	.3982		.5170

$$Q = \left(\frac{AR^{2/3}}{AR^{8/3}}\right)(D^{8/3})\left(\frac{1.486}{D}\right)(S^{1/2})$$



To calculate critical depth, enter table with computed value of $Q/D^{5/2}$ and read corresponding value of d/D

Hydraulic Elements For Partial Flow In
City of Los Angeles STD. Semi-Elliptical Conduit