arthur beard engineers, Inc.
4628 N. 17TH ST., STE. H-105, PHOENIX, AZ 85016-4653 - (602) 266-8469

CALCULATIONS FOR

UNION HILLS DRIVE STORM SEWER

43rd AVENUE TO 37th AVENUE

INDEX No: ST-880534

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009

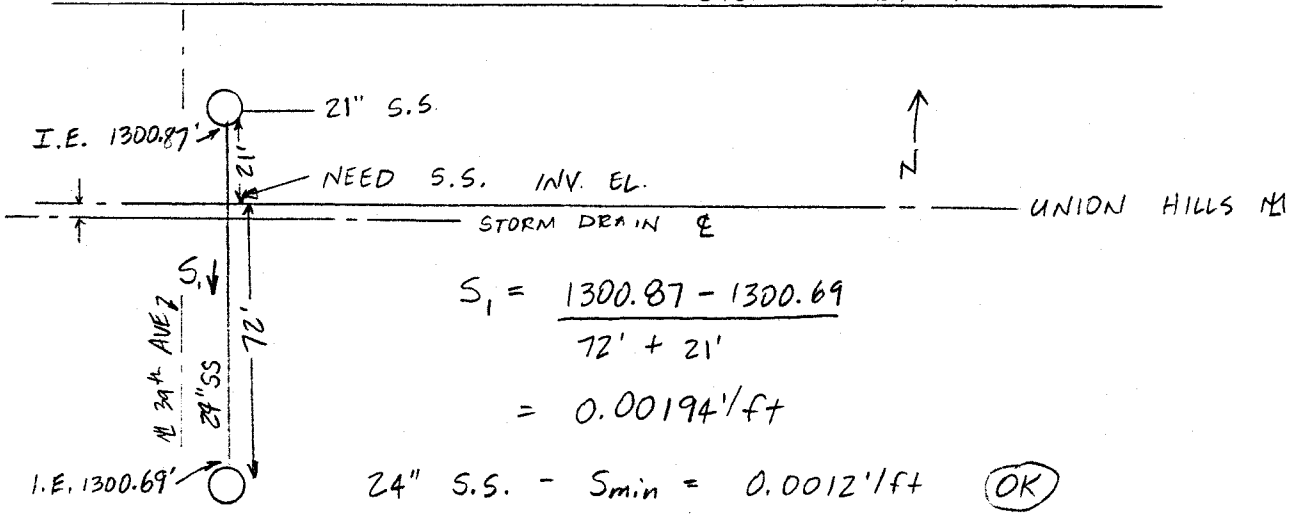
Registered Professional Engineer (Civil)
CERTIFICATE NO.
1458
ARTHUR H.
BEARD, JR.
Date Signed 1-15-90
ARIZONA, U.S.A.

PLAN-PROFILE CALCULATIONS

arthur beard engineers, inc.

PROJECT UNION HILLS DRIVE STORM DRAIN	PROJ. NO. 1248
SUBJECT PLAN/PROFILE SHEET DESIGN CALCS	CLIENT CUP
COMP. BY SC DATE 1/13/89 CKD BY ____ DATE ____	SHEET 1 OF ____

INV. ELEV. OF 24" SANITARY SEWER AT 39th AVE CROSSING UNION HILLS DRIVE STORM DRAIN



$$S_1 = \frac{1300.87 - 1300.69}{72' + 21'}$$

$$= 0.00194'/ft$$

24" S.S. - S_{min} = 0.0012'/ft (OK)

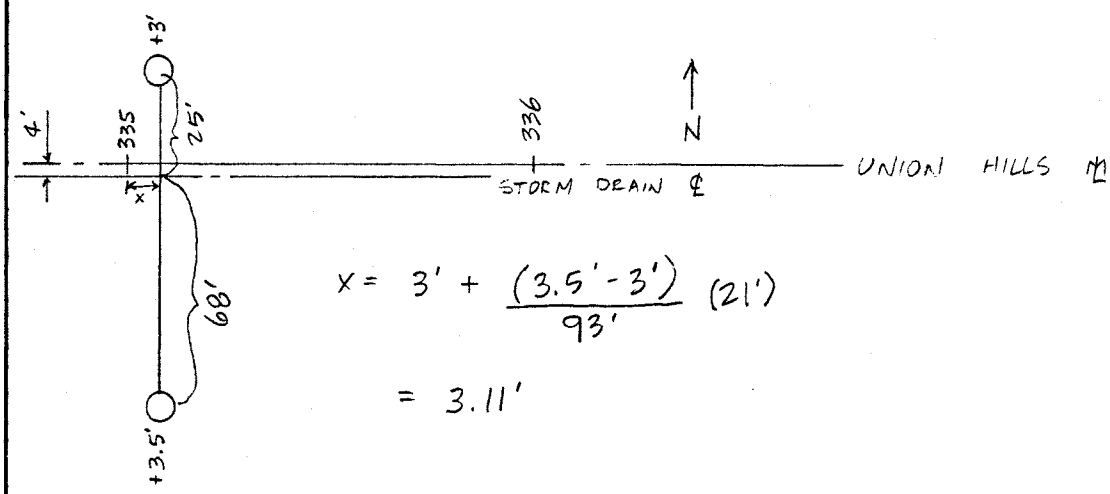
DROP OF 24" SS FROM NORTH MH TO SD ℄ $= (21' + 1')(0.00194'/ft)$

$= 0.043'$

24" SS I.E. @ SD ℄ $= 1300.87' - 0.043'$

$= 1300.83' \pm$

DISTANCE FROM STA 335



$$x = 3' + \frac{(3.5' - 3')}{93'}(21')$$

$$= 3.11'$$

arthur beard engineers, Inc.

PROJECT UNION HILLS STORM DRAIN
SUBJECT PLAN/PROFILE SHEET DESIGN CALCS
PROJ. NO. 1248
CLIENT C.O.P.
COMP. BY SC DATE 1/13/89 CKD BY _____ DATE _____
SHEET 2 OF _____

FIND EQUATION FOR CONVERTING FROM ERIKSON + SALMON STATIONS TO A.B.E. STATIONS ALONG UNION HILLS DRIVE

LOCATION	E + S Sta	A.B.E. Sta
N 37th AVE	6+73.60	348+17.09
END OF A.B.E. SEGMENT	9+60	?

EQUATION — ABE sta = (ABE − E+S) + E+S

= E+S + (348+17.09 − 6+73.60)

$$\boxed{\text{ABE sta} = (\text{E+S}) + (34{,}143.49)}$$

UPSTREAM END OF ABE SEGMENT = (9+60) + 34,143.49

= 351 + 03.49

I.E. sta 351+03.49 = 1306.47'

SLOPE = 0.0010'/ft

ELEVATIONS AT MATCH LINES

START AT DOWNSTREAM END AND WORK UPSTREAM

DESIRED I.E. = STARTING STA + (HOR. DIST) SLOPE

STARTING STA:

I.E. STA 335 = I.E. STA 351+03.49 − (H.D.) SLOPE

= 1306.47 − ((351+03.49) − (335+00))(0.0010'/ft)

= 1304.866

I.E. STA 338 = I.E. Sta 335 + (H.D.)(SLOPE)

= 1304.866 + (300')(0.0010'/ft)

= 1305.166

arthur beard engineers, inc.

PROJECT UNION HILLS STORM DRAIN
SUBJECT PLAN/PROFILE DESIGN CALCS
PROJ. NO. 1248
CLIENT C.O.P.

COMP. BY SC DATE 1/13/89 CKD BY _____ DATE _____ SHEET 3 OF _____

I.E. STA 342 = 1305.166 + (400')(0.001'/ft)

= 1305.566

I.E. STA 346 = 1305.566 + (400')(0.0010'/ft)

= 1305.966

CHECK: I.E. STA 351 + 03.49 = 1305.966 + (503.49)(0.0010'/ft)

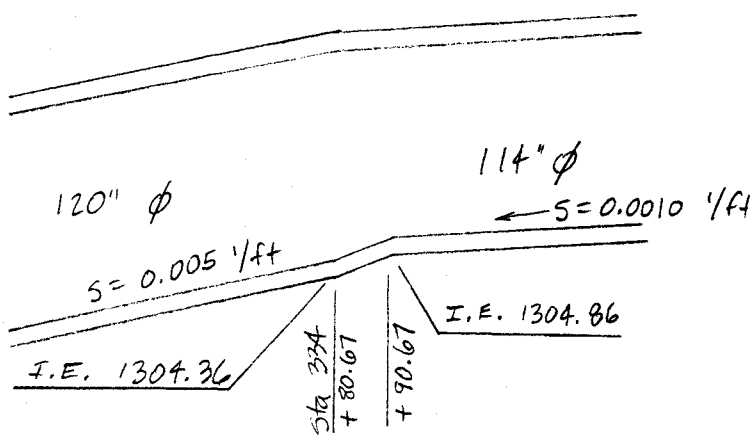
= 1306.47 OK

I.E. STA 334 + 90.67 = I.E. Sta 335 − (9.33')(0.0010'/ft)

= 1304.866 − 0.0093'

= 1304.857

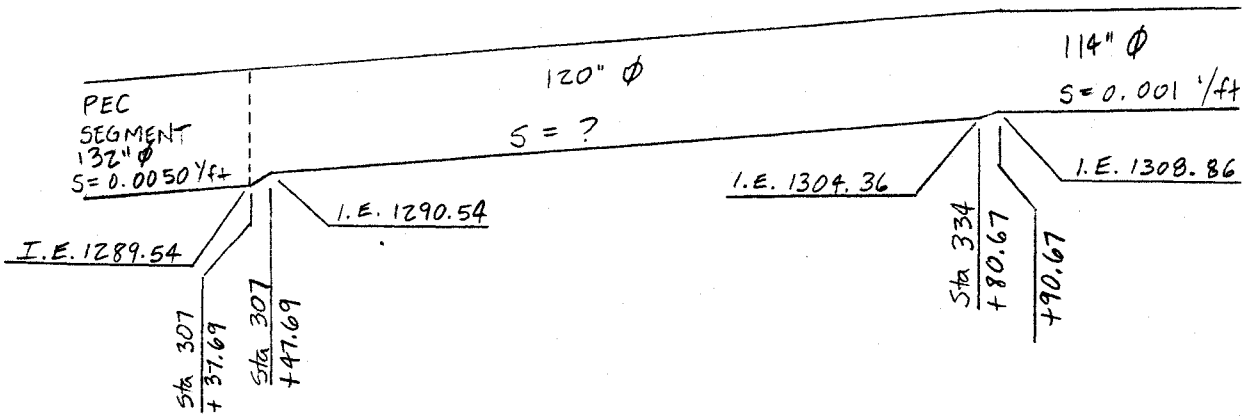
ASSUME 10' LONG TRANSITION @ STA 334 + 90.67 TO ACCOMODATE GRADE BREAK AND PIPE SIZE CHANGE



arthur beard engineers, inc.

PROJECT UNION HILLS STORM DRAIN	PROJ. NO. 1248
SUBJECT PLAN/PROFILE SHEET DESIGN CALCS	CLIENT C.O.P.
COMP. BY SC DATE 1/13/89 CKD BY ____ DATE ____	SHEET 4 OF ____

FIND SLOPE OF 120" PIPE



$$S = \frac{1304.36 - 1290.54}{(334+80.67)-(307+47.69)}$$

$$= 0.00506 \ '/ft$$

FIND INV. ELEVATIONS AT MATCH LINES

I.E. STA 310+00 = I.E. STA 307+47.69 + [(310+00) − (307+47.69)] * 0.00506 '/ft

= 1290.54 + 1.277

= 1291.817

I.E. STA 315 = 1291.817 + (500')(0.00506 '/ft)

= 1294.347

I.E. STA 320 = 1294.347 + (500')(0.00506 '/ft)

= 1294.347 + 2.53'

= 1296.877

I.E. STA 325 = 1296.877 + 2.53'

= 1299.407

arthur beard engineers, inc.

PROJECT UNION HILLS STORM DRAIN
SUBJECT PLAN/PROFILE SHEET DESIGN CALCS
PROJ. NO. 1248
CLIENT C.O.P.

COMP. BY SC DATE 1/13/89 CKD BY _____ DATE _____ SHEET 5 OF _____

I.E. STA 330 = 1299.407 + 2.53

= 1301.937

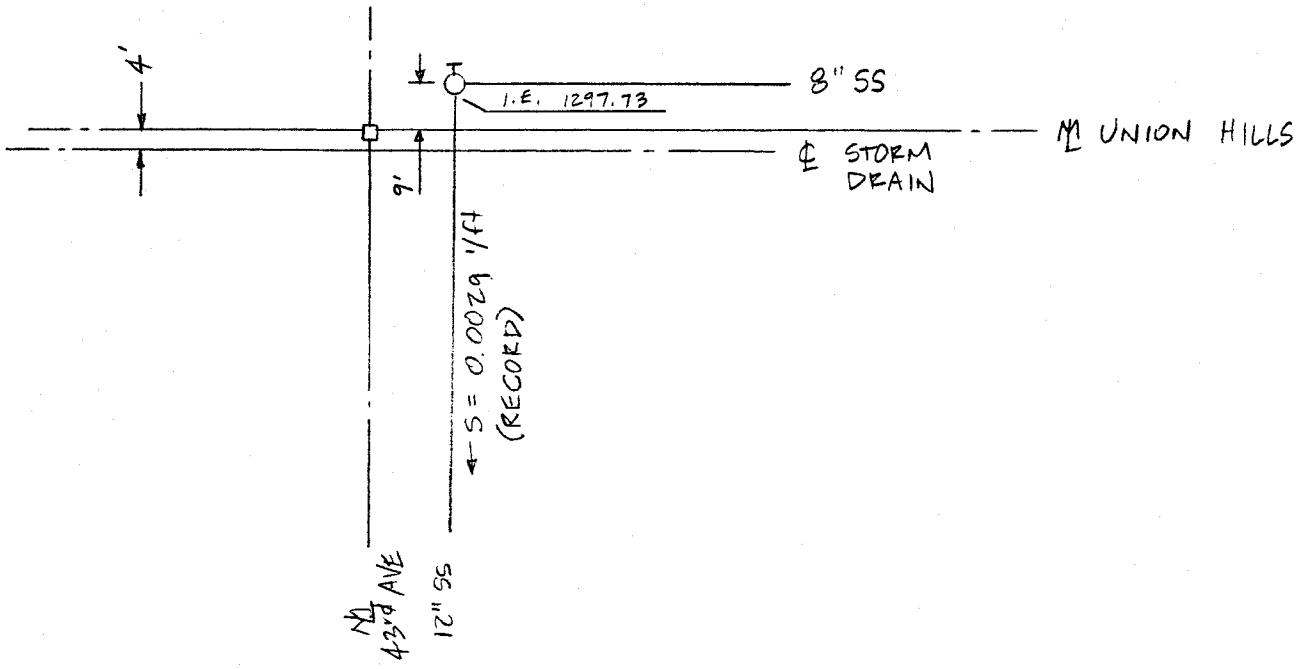
I.E. STA 334 = 1301.937 + (400')(0.00506'/ft)

= 1303.961

CHECK: I.E. STA 334 + 80.67 = 1303.961 + (80.67)(0.00506)

= 1304.369 OK

FIND INV. EL. OF 12" SS CROSSING UNION HILLS DR @ 43rd AVE



I.E. OF S.S. AT S.D. ℄ = 1297.73' − (9' + 4')(0.0029 '/ft)

= 1297.692' ±

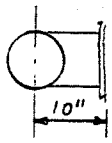
arthur beard engineers, inc.

PROJECT UNION HILLS STORM DRAIN
SUBJECT PLAN / PROFILE SHEET DESIGN CALCS
PROJ. NO. 1248
CLIENT C.O.P.

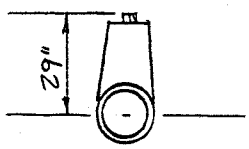
COMP. BY SC DATE 1/13/89 CKD BY _____ DATE _____ SHEET 6 OF _____

WATER LINE DIMENSIONS (FROM CLOW)

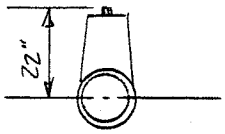
8" x 8" TAPPING SLEEVE:



12" MJ VALVE:



8" MJ VALVE:



STA 309 + 72 8" WV TOP OF NUT EL. = 1309.57

FLOWLINE ELEV. = 1309.57 − (22" + 4") (1'/12")

1307.40 ±

STA 308 + 59 12" WV TOP OF NUT EL. = 1307.76

FLOWLINE EL. = 1307.76 − (29" + 6") (1'/12')

= 1304.84 ±

STA 317 + 87 8" WV TOP OF NUT EL. = 1310.43

FLOWLINE EL. = 1310.43 − (29" + 4") (1'/12")

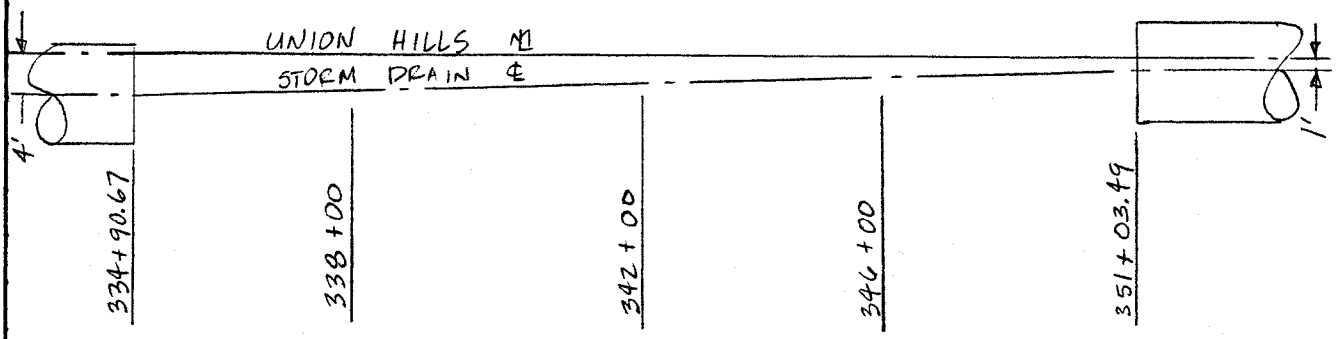
= 1307.68 ±

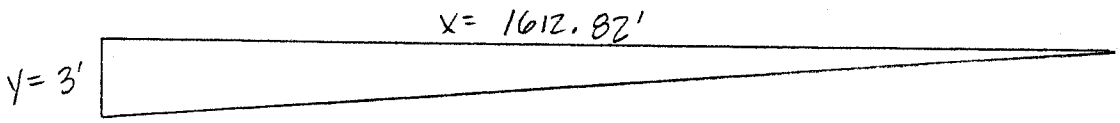
arthur beard engineers, inc.

PROJECT UNION HILLS STORM DRAIN
SUBJECT PLAN/PROFILE SHEET DESIGN CALCS
PROJ. NO. 1248
CLIENT C.O.P.

COMP. BY SC DATE 1/13/89 CKD BY _____ DATE _____ SHEET 7 OF _____

FIND DISTANCES FROM UNION HILLS ℳ OF STORM DRAIN AT MATCH LINES (PLAN)

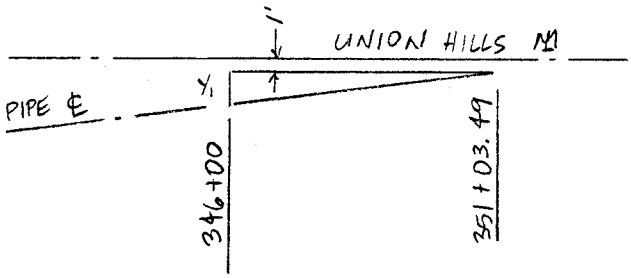




RATIO $Y/X = 3'/1612.82'$

$Y_i = 0.00186\,x$

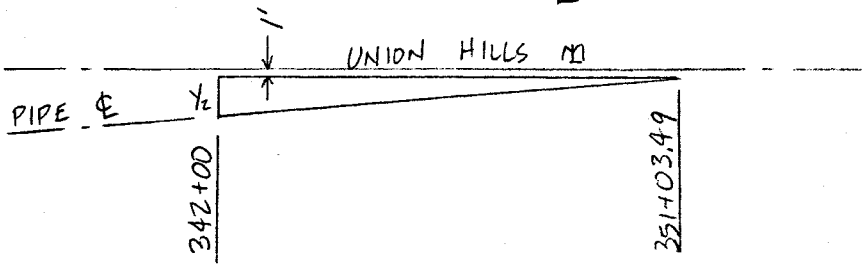
STA 346



$Y_1 = [(351+03.49) - (346+00)](0.00186) + 1'$

$= 1.936'$ SOUTH OF UNION HILLS ℳ

STA 342



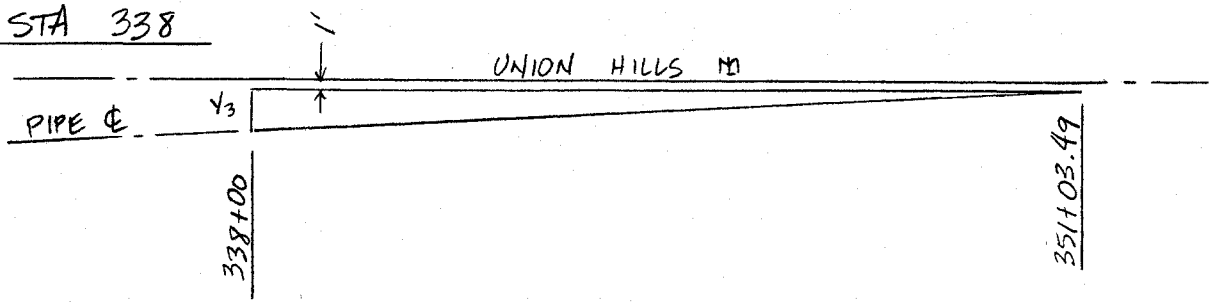
$Y_2 = [(351+03.49) - (342+00)](0.00186) + 1'$

$= 2.680'$ SOUTH OF U.H. ℳ

arthur beard engineers, Inc.

PROJECT UNION HILLS STORM DRAIN	PROJ. NO. 1248
SUBJECT PLAN/PROFILE SHEET DESIGN CALCS	CLIENT C.O.P.
COMP. BY SC DATE 1/13/88 CKD BY ____ DATE ____	SHEET 8 OF ____

STA 338



$$Y_3 = [(351+03.49) - (338+00)](0.00186) + 1'$$

$$= 3.424' \text{ SOUTH OF U.H. } ℳ$$

CATCH BASIN SIZING

arthur beard engineers, Inc.

PROJECT Union Hills Dr. | PROJ. NO. 1248
SUBJECT Type 'N' & 'M' CB depths & pipe sizing | CLIENT COP

COMP. BY JM DATE 6/29/89 CKD BY _____ DATE _____ | SHEET 1 OF 7

Determine Depths of Catch Basins and Size of Connector Pipes (min. size = 15")

37th Ave & Union Hills ; Type 'N' (Triple) inlet

$Q^* = 16.7$ cfs , $L = 20'$

HGL @ Connection of 48" pipe & Trunk = 1318.5'

Need HGL at connection of 'N' CB pipe;

Expansion Loss for 48" pipe

$$h_L = \frac{(V_1 - V_2)^2}{2g} = \frac{(14-6)^2}{64.4} = 1.0'$$

Friction Loss

$$R = \frac{VD}{\nu} = \frac{6(4)}{1.664 \times 10^{-5}} = 1.44 \times 10^6$$

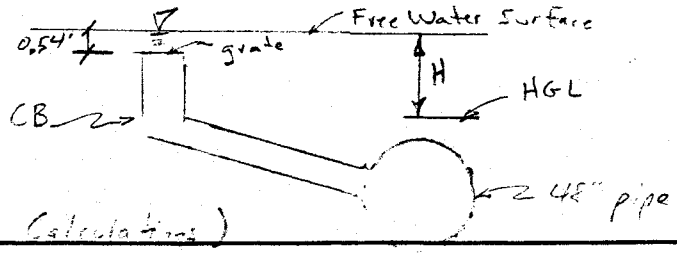
$$\epsilon = \frac{e}{D} = \frac{50 \times 10^{-4}}{4} = 0.0013$$

$$\therefore \quad f = 0.024$$

$$h_f = f \frac{L}{D} \frac{V^2}{2g} = 0.024 \frac{(70)}{4} \frac{(6)^2}{64.4} = 0.24'$$

$$h_{L_T} = 1 + .24 = 1.2'$$

$$HGL = 1318.5 + 1.2 = 1319.7'$$



$H = (1323.7 + .5) - 1319.7$

$H = 4.5'$ available

(* See Flowbase Calculations)

arthur beard engineers, Inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP. BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 2 OF 7

37th AVE & Union Hills CB (cont)

From figure on pg 31 of COP Storm Drain Design Manual;

using, $H = 4.5'$, $Q = 16.7$ cfs, $L = 20'$

$\therefore$ pipe size = 15"

$$V = \frac{Q}{A} = \frac{16.7}{\frac{\pi (15/12)^2}{4}} = 13.6 \text{ fps}$$

Entrance Loss: $\frac{.3V^2}{2g} = \frac{0.3(13.6)^2}{2(32.2)} = 0.86'$

$$H = 4.5 - .86 = 3.64'$$

figure pg 31: $\boxed{D = 18''}$ (Both sides of street)

Catch Basin Depth, V

$$V = \frac{16.7}{\frac{\pi (1.5)^2}{4}} = 9.45 \text{ fps}$$

$$D.CB = 1.17' + 1.5\frac{V_1^2}{2g} + d$$

; where V_1 = velocity in connector pipe
a = area of connector pipe
d = diameter of connector pipe

$$D.CB = 1.17' + 1.5\frac{(9.45)^2}{2(32.2)} + \left(\frac{18}{12}\right) = 4.75, \text{ minimum}$$

$\therefore$ use $\boxed{V = 4.75' \text{ depth}}$ (Both sides of street)

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP. BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 3 OF 7

39th Ave & Union Hills ; Type N (double) inlets both sides

$Q^* = 11.9$ cfs , $L = 28'$

HGL @ connection of 48" pipe & Trunk = 1312.1

HGL @ connection of 'N' Type CB & 48" pipe = ?

Expansion Loss for 48" pipe

$$h_L = \frac{(V_1 - V_2)^2}{2g_c} = \frac{(13-6)^2}{64.4} = \underline{0.76'}$$

Friction Loss in 48" pipe

$$R = \frac{VD}{\nu} = \frac{6(4)}{1.664\times10^{-5}} = 1.44\times10^{6}$$

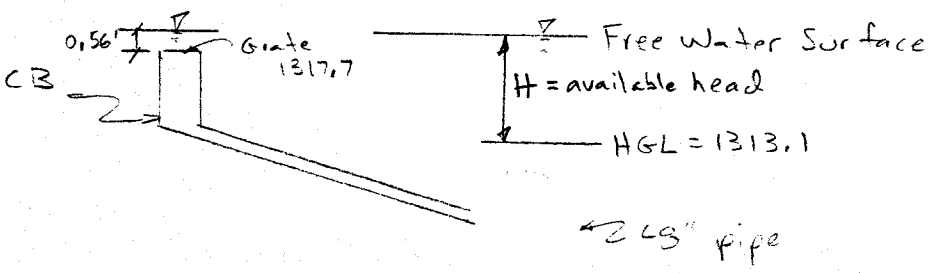
$$\epsilon = \frac{e}{D} = \frac{50\times10^{-4}}{4} = 0.0013$$

$$\therefore f = 0.024$$

$$h_f = f\frac{L}{D}\frac{V^2}{2g} = 0.024\left(\frac{70}{4}\right)\frac{6^2}{64.4} = \underline{0.24'}$$

$$h_{L_T} = 0.76 + 0.24 = \underline{1.0'}$$

$$HGL = 1312.1 + 1.0 = \underline{1313.1'}$$



$$H = (1317.7 + 0.56) - 1313.1 = \underline{5.2'}$$

(* See Flowing Calculations)

arthur beard engineers, Inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP. BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 4 OF 7

39th Ave & Union Hills (cont)

From fig. on pg 31 C.O.P. S.D. Design Manual;

using $H = 5.2'$, $Q = 11.9$ cfs, $L = 28'$

$\therefore$ pipe, $D = \underline{15''}$

$$V = \frac{Q}{A} = \frac{11.9}{\frac{\pi (15/12)^2}{4}} = \underline{9.7 \text{ fps}}$$

Entrance Loss: $\frac{0.3V^2}{2g} = \frac{0.3(9.7)^2}{2(32.2)} = 0.44'$

$$H = 5.2 - .44 = \underline{4.76'}$$

fig. pg. 31 : $\boxed{\underline{D = 15''}}$ (Both sides of street)

Catch Basin Depth, V

$$D.CB = 1.17 + \frac{1.5V^2}{2g} + d$$

$$= 1.17 + \frac{1.5(9.7)^2}{2(32.2)} + \frac{15}{12} = 4.6' \text{ minimum}$$

$\therefore$ Use $\boxed{\underline{V = 4.75' \text{ depth}}}$ both sides

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP. BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 5 OF 7

41st Ave & Union Hills ; Type 'N' (triple) CB, East side
; Type 'M-1', L=17' CB, West side

Type 'N' Triple CB

$Q^* = 12.5 cfs$, $L = 19'$

HGL at Connection of 54" pipe & Trunk = 1305.8'

HGL at Connection of CB's pipe & 54" pipe = ?

Expansion Loss for 48" pipe

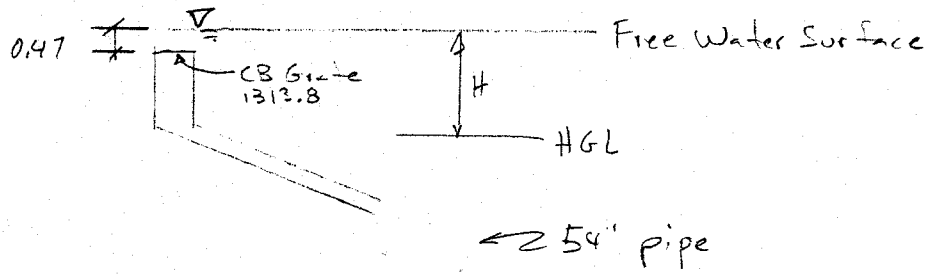
$$h_L = \frac{(14-6)^2}{64.4} = 1.0'$$

Friction Loss for 48" pipe

$$h_f = 0.024\left(\frac{70}{4}\right)\frac{6}{64.4} = 0.24'$$

$$h_{L_T} = 1 + .24 = \underline{1.24'}$$

$$HGL = 1305.8 + 1.24 = \underline{1307.04'}$$



$$H = (1313.8 + 0.47) - 1307.04 = \underline{7.23'}$$

(* See Flowby Calculations)

41st Ave & Union Hills (cont) ; (Type N)

Fig. pg 31 COP S.D. Design Manual;

using; $H = 7.2'$, $L = 19'$; $Q = 12.5 cfs$

$\therefore$ pipe, $D = 15''$

$$V = \frac{Q}{A} = \frac{9}{\pi \frac{(15/12)^2}{4}} = 7.3 \text{ fps}$$

Entrance Loss : $\frac{0.3V^2}{2g} = \frac{0.3(7.3)^2}{64.4} = 0.25'$

$$H = 7.23 - 0.25 = 7'$$

$\therefore$ use; $\boxed{D = 15''}$ (for Type 'N' CB)

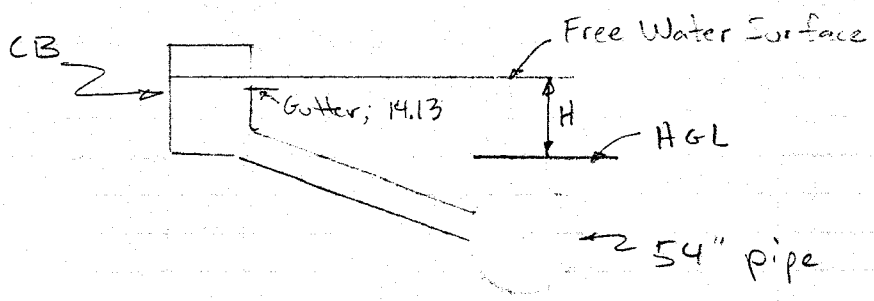
Catch Basin Depth, V

$$D_{CB} = 1.17 + \frac{1.5V^2}{2g} + d = 1.17 + \frac{1.5(7.3)^2}{2(32.2)} + \frac{15}{12} = 3.66'$$

$\therefore$ Use $\boxed{V = 4.0' \text{ depth}}$ ('N' Type CB)

41st Ave & Union Hills (cont)

Type 'M-1', L=17' sump cond. $Q = 15.6$ cfs



$H = (1314.13 + 0.47) - 1307.04 = \underline{7.6'}$

$\therefore$ pipe, $\underline{D = 15''}$ $\quad V = \frac{15.6}{\pi \frac{1.5^2}{4}} =$

Entrance Loss: $\frac{0.3V^2}{2g} = \frac{0.3\left(\frac{15.6}{\pi(15/12)^2/4}\right)^2}{2(32.2)} = 0.75'$

$H = 7.6 - 0.75 = \underline{6.8'}$

$\therefore$ $\boxed{\text{use } D = 15''}$ (for 'M-1' L=17')

Catch Basin Depth, V

$D.CB = 1.17 + \frac{1.5V^2}{2g} + d = 1.17 + \frac{1.5(12.7)^2}{2(32.2)} + \frac{15}{12} = 6.17'$

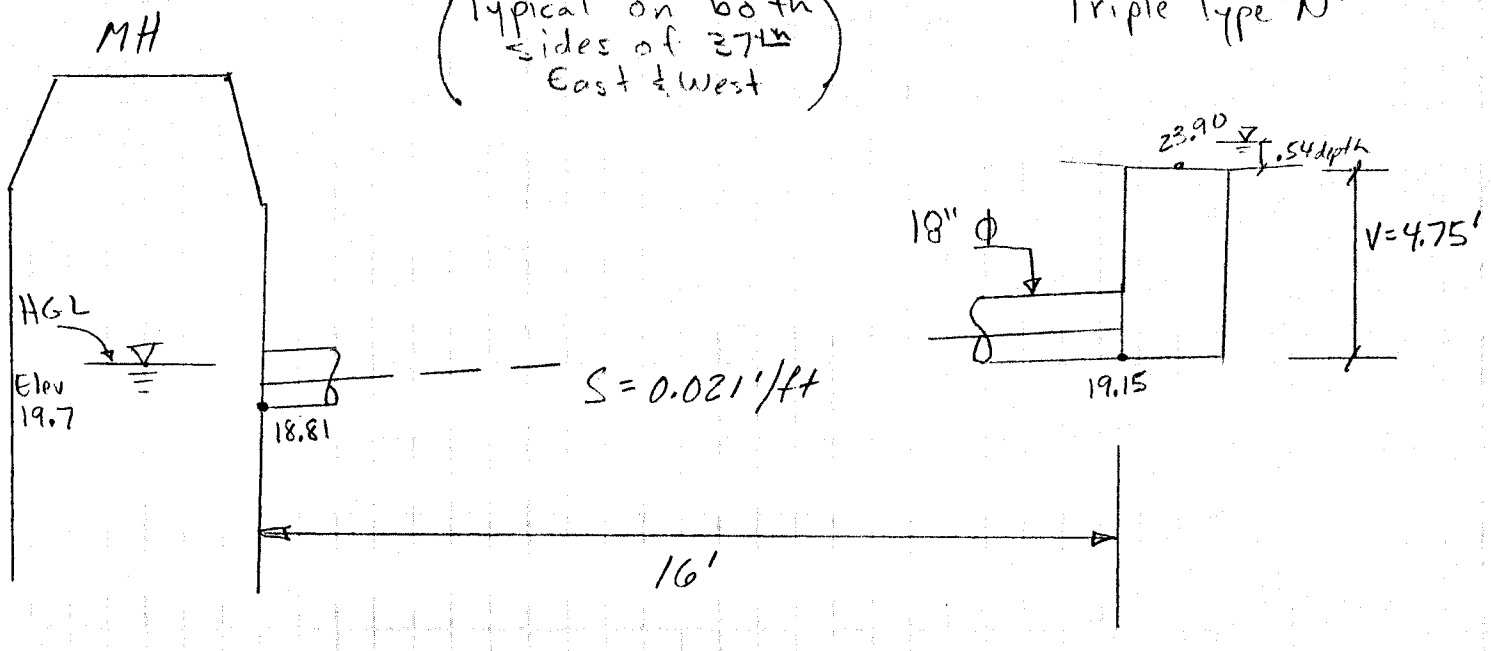
use; $\boxed{V = 6.25' \text{ depth}}$

CONNECTOR PIPE LOCATIONS

37th Ave

(Typical on both sides of 37th East & West)

Triple Type 'N'



Design full flowing @ $Q_{MAX} = 16.7$ cfs

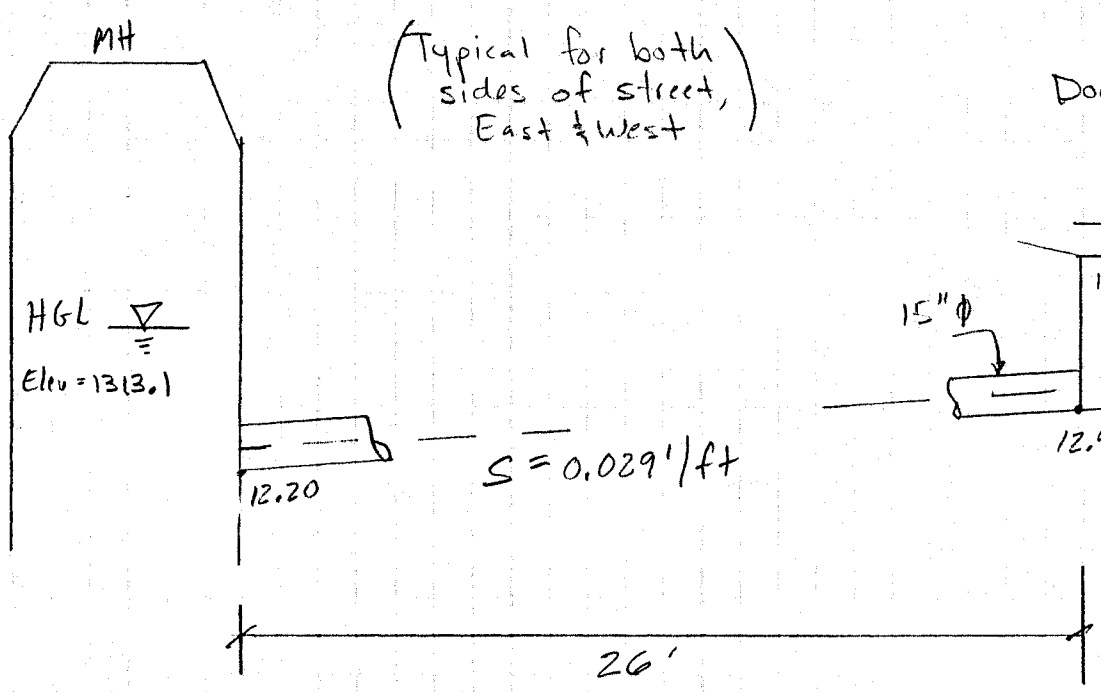
$$S = \left[\frac{Qn}{1.49\,AR^{2/3}}\right]^2 = \left(\frac{16.7 \times 0.012}{1.49\,(1.767)(.375^{2/3})}\right)^2 = 0.021\ '/ft$$

Checking Velocity ; $V = \frac{Q}{A} = \frac{16.7}{1.767} = 9.4$ fps → ok

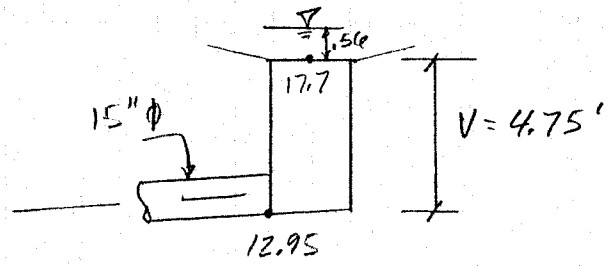
Note: NTS

39th AVE

(Typical for both sides of street, East & West)



Double Type 'N'



Design full flowing, $Q_{MAX} = 11.9$ cfs

$$S = \left[\frac{Qn}{1.49AR^{2/3}}\right]^2 = \left[\frac{11.9(.012)}{1.49(1.227)(.312)^{2/3}}\right]^2 = 0.029'/ft$$

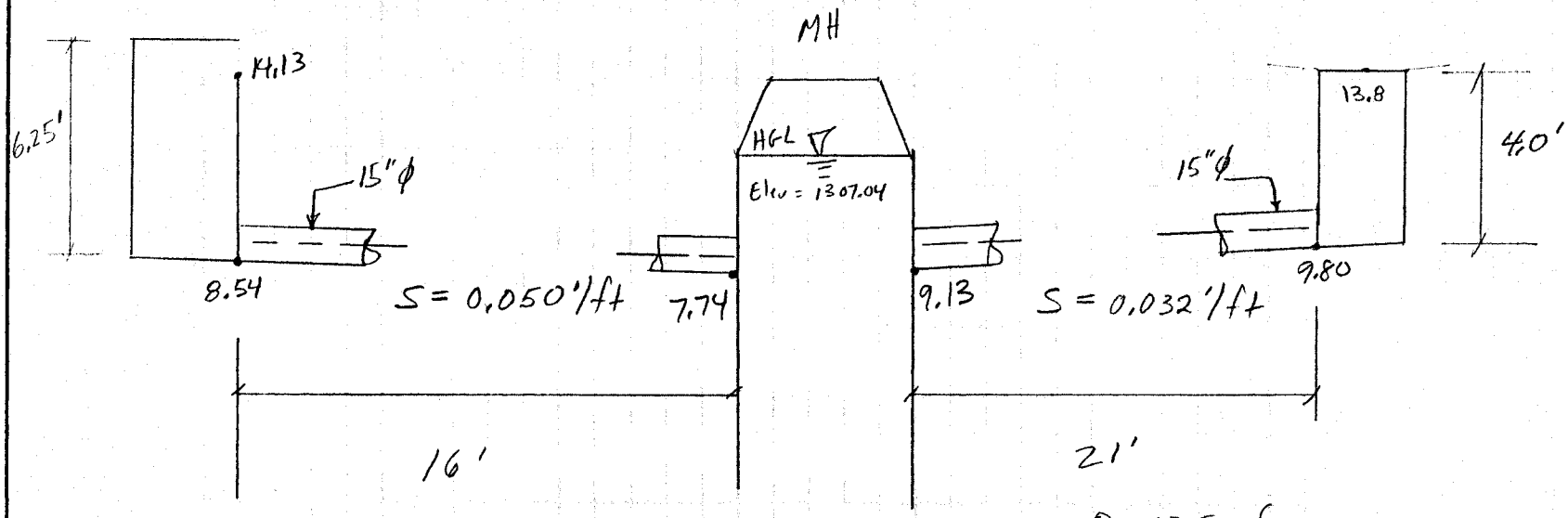
Checking Velocity; $V = \frac{Q}{A} = \frac{11.9}{1.227} = 9.7$ fps → ok

Note: NTS

41st AVE

'M-1' Type Inlet

Triple Type 'N'



Q = 15.6 cfs

$$S = \left(\frac{Qn}{1.49AR^{2/3}}\right)^2 = \left(\frac{15.6(0.012)}{1.49(1.227)(.312)^{2/3}}\right)^2 = 0.050'/ft$$

checking velocity, $V = \frac{Q}{A} = \frac{15.6}{1.227} = 12.7$ fps OK

Q = 12.5 cfs

$$S = \left(\frac{Qn}{1.49AR^{2/3}}\right)^2 = \left(\frac{12.5(0.012)}{1.49(1.227)(.312)^{2/3}}\right)^2 = 0.032'/ft$$

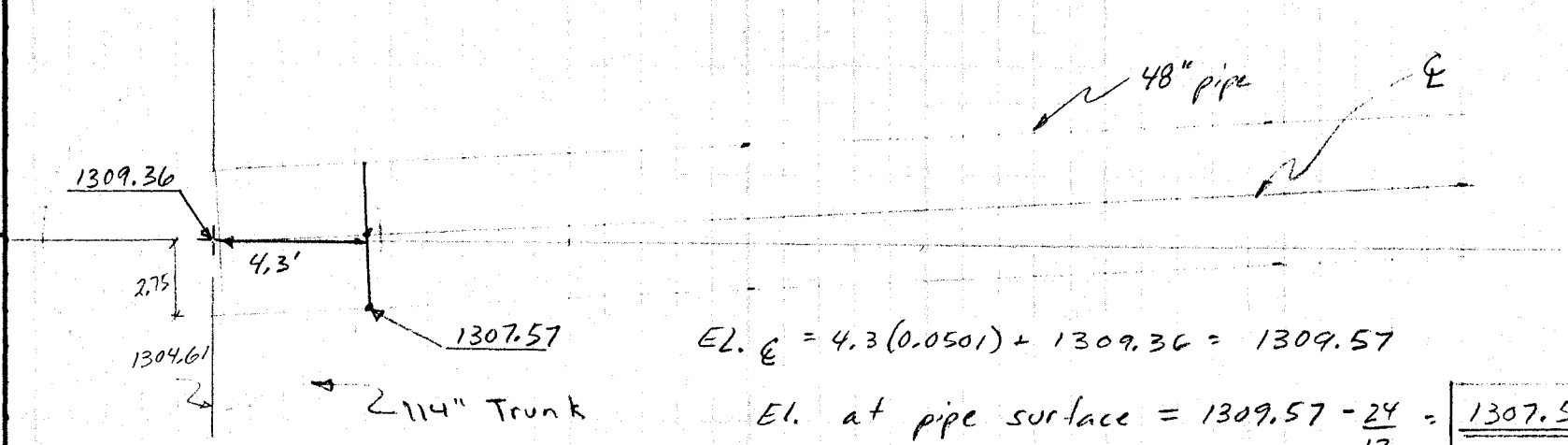
checking velocity, $V = \frac{Q}{A} = \frac{12.5}{1.227} = 10.2$ fps OK

NOTE: NTS

arthur beard engineers, inc. Phoenix - Tucson, Arizona

PROJECT Union Hills Dr.
SUBJECT Pipe connections for - period Inlets
COMP BY JM DATE 8/1/89 CKD BY DATE
PROJ. NO. 1248
CLIENT COP
SHEET 1 OF 2

$$\text{Slope} = \frac{1311.32 - (1304.61 + 2.75)}{79} = 0.0501$$

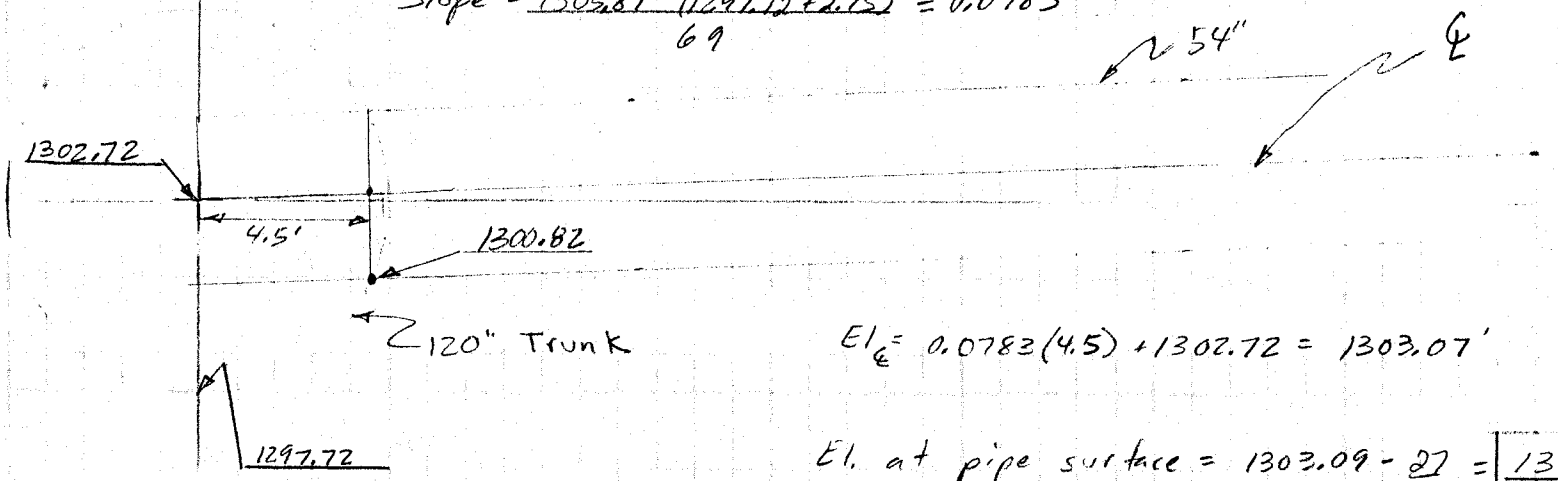


$$\text{El.}_{℄} = 4.3(0.0501) + 1309.36 = 1309.57$$

$$\text{El. at pipe surface} = 1309.57 - \frac{24}{12} = \boxed{1307.57}$$

39th Ave & Union Hills Dr.

$$\text{Slope} = \frac{1305.87 - (1297.72 + 2.75)}{69} = 0.0783$$



$$\text{El}_{℄} = 0.0783(4.5) + 1302.72 = 1303.07'$$

$$\text{El. at pipe surface} = 1303.09 - \frac{27}{12} = \boxed{1300.82}$$

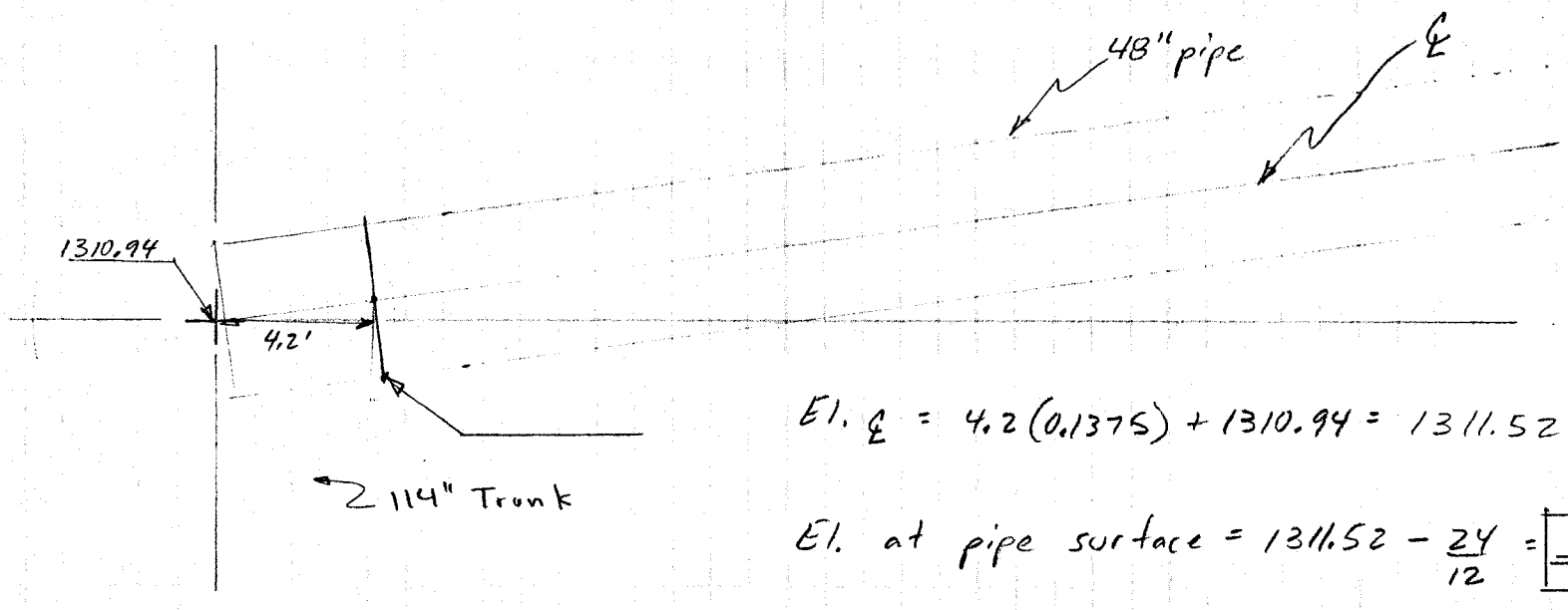
41st Ave & Union Hills Dr.

arthur beard engineers, inc. Phoenix - Tucson, Arizona

PROJECT ____ PROJ. NO. ____
SUBJECT ____ CLIENT ____

COMP BY ____ DATE ____ CKD BY ____ DATE ____ SHEET 2 OF 2

$$\text{Slope} = \frac{1317.88 - (1306.19 + 2.75)}{65} = 0.1375$$



$$\text{El. } ℄ = 4.2(0.1375) + 1310.94 = 1311.52$$

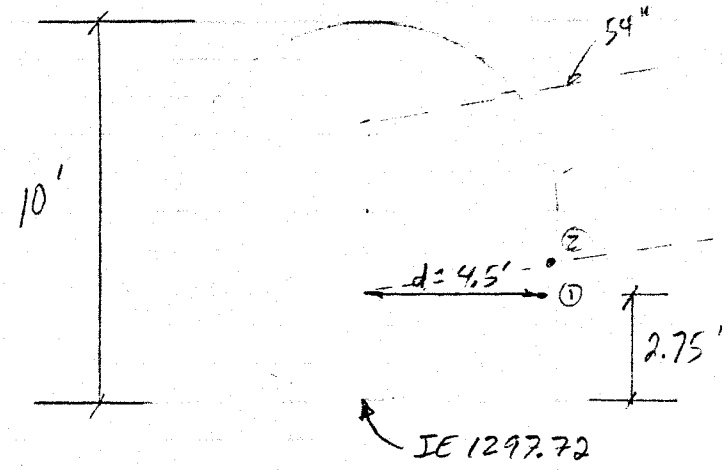
$$\text{El. at pipe surface} = 1311.52 - \frac{24}{12} = \boxed{1309.52}$$

37th Ave & Union Hills Dr.

arthur beard engineers, inc. Phoenix - Tucson, Arizona

PROJECT: UNION HILLS DR. S.D. | PROJ. NO. 1249
SUBJECT: PIPE CONNECTS, MATCHING ℄ | CLIENT: COP

COMP BY: JM DATE: 8/1/89 CKD BY: _____ DATE: _____ | SHEET 1 OF 2



$2\sqrt{120''} = 60''$

$2\sqrt{54''} = 27''$

$33'' = 2.75'$

41st AVE

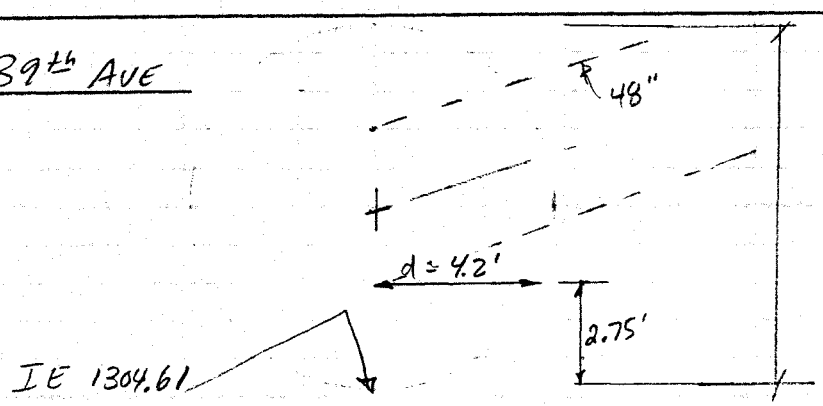
Slope from 10' pipe to special inlet

$$= \frac{1305.87 - (1297.72 + 2.75)}{69'} = 0.0783$$

② Elev. at pipe surface $= 4.5(0.0783) + (1297.72 + 2.75)$

$$= \boxed{1300.82'}$$

39th AVE



$2\sqrt{114} = 57''$

$2\sqrt{48} = 24''$

$33'' = 2.75'$

$$\text{Slope} = \frac{1311.32 - (1304.61 + 2.75)}{79} = 0.0501$$

Elev. at pipe surface $= 4.2(0.0501) + (1304.61 + 2.75)$

$$= \boxed{1307.57'}$$

arthur beard engineers, inc. Phoenix - Tucson, Arizona

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 2 OF 2

37th Ave

$2\sqrt{114} = 57$

$2\sqrt{48} = 24$

$33'' = 2.75'$

$$\text{Slope} = \frac{1317.88 - (1306.19 + 2.75)}{65} = 0.1375$$

$$\text{Elev. at pipe surface} = 4.2(0.1375) + (1306.19 + 2.75)$$

$$= \boxed{1309.52}$$

arthur beard engineers, Inc.

PROJECT 1248 - Union Hills Drive
SUBJECT Connector Pipe for Special Inlets
PROJ. NO. 1248
CLIENT COP

COMP. BY JM DATE 6/9/89 CKD BY _____ DATE _____
SHEET 1 OF 2

41st Ave - 54" connector pipe from special inlet
L=65' Length

Elev = 1314.37

New Special Type I inlet, depth = ? Let = x

Elev. of invert at inlet = 1314.37 - x

Elev. of invert at main connection = 1299.72

$$\text{slope} = \frac{x - 1299.72}{65} = 0.0015$$

slope req'd for 5 fps velocity = 0.0015
(from Storm Drain Design COP pg 25 54" pipe)

$\Rightarrow$ max depth = 1314.37 - [0.0015(65) + 1299.72] = 14.55'

39th Ave - 48" connector pipe from special inlet, L=70

Elev = 1318.32

New special type I inlet depth = ? let = x

Elev. of invert at inlet = 1318.32 - x

Elev. of invert at main connection = 1306.8

$$\text{slope} = \frac{x - 1306.8}{70} = 0.0018$$

slope req'd for 5 fps velocity = 0.0018 → {S.D.D. COP pg 50 48" pipe}

$\Rightarrow$ max depth = 1318.32 - 0.0018(70) - 1306.8

= 11.39'

arthur beard engineers, Inc.

PROJECT
SUBJECT
PROJ. NO.
CLIENT

COMP. BY ____ DATE ____ CKD BY ____ DATE ____ SHEET 2 OF 2

<u>37th Ave</u> 48" connector pipe from special inlet, L = 63'

Elev = 1324.13'

New Special Type I inlet, depth = ? Let = x

Elev. of invert at inlet = 1324.13 −

Elev. of invert at main connection = 1308.00

$$\text{slope} = \frac{x - 1308.00}{63} = 0.0018$$

Slope req'd for 5fps velocity = 0.0018
(S.D.D, COP pg 50, 48" pipe)

$\Rightarrow$ max. depth = 1324.13 − [0.0018(63) + 1308.00]

= 16.0'

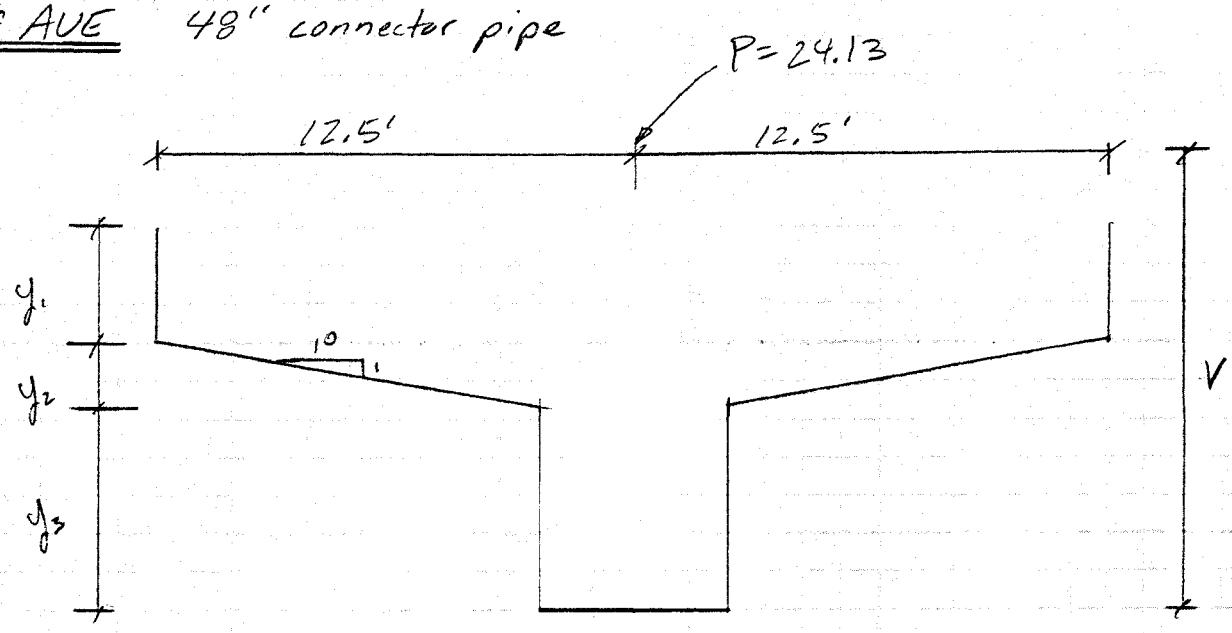
DEPTH CALCULATIONS OF SPECIAL INLETS

arthur beard engineers, inc. Phoenix - Tucson, Arizona

PROJECT: Union Hills Dr
SUBJECT: Depth's of Special Inlets
PROJ. NO. 1248
CLIENT: COP

COMP BY: JM DATE: 7/21/89 CKD BY: _____ DATE: _____ SHEET 1 OF 3

37th AVE 48" connector pipe



$y_1 = 1.0'$

$y_2 = 12.5/10 = 1.25'$

$y_3 = \frac{48}{12} = 4.0'$

$\therefore \quad z = 1.0 + 1.25 + 4 = \boxed{6.25'}$

Minimum Depth: $1.17 + \frac{1.5V_1^2}{2g} + d$ (COP, Design Manual, pg 32)

$V = 1.17 + \frac{1.5\left(12.5/(\pi(4)^2/4)\right)^2}{2(32.2)} + 4 = 5.94' \Rightarrow$ OK

arthur beard engineers, inc. Phoenix - Tucson, Arizona

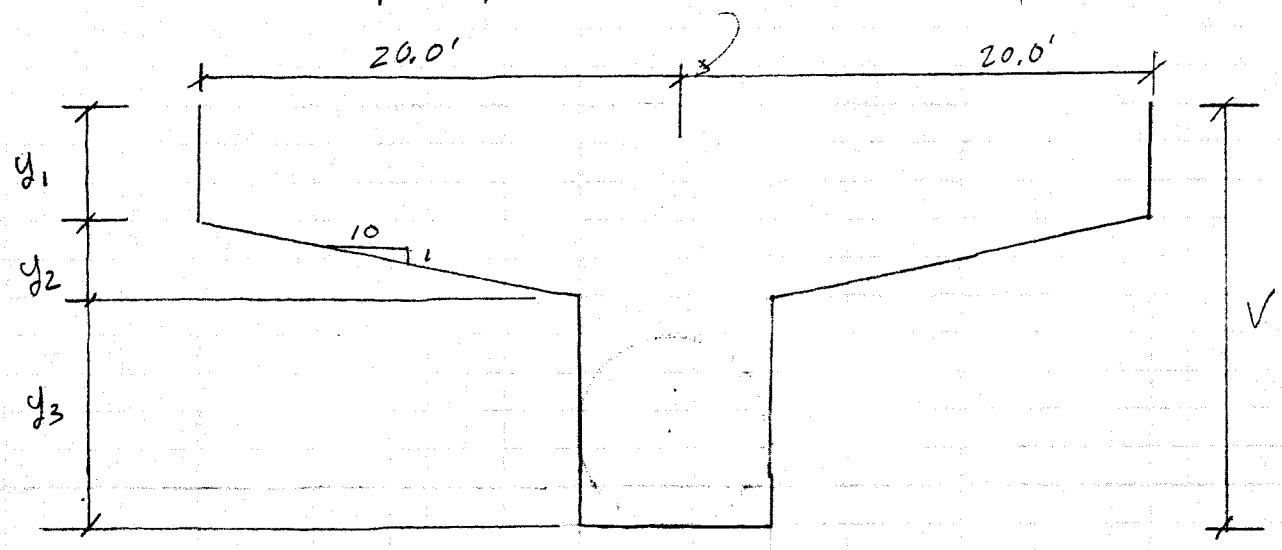
PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 2 OF 3

CATCH BASIN LATERALS

39th Ave 48" connector pipe

Elevation at top of pavement = 1318.32



$y_1 = 1.0'$

$y_2 = 20'/10'/ft = 2.0'$

$y_3 = 4'$

$V = 1 + 2 + 4 = \boxed{7.0'}$

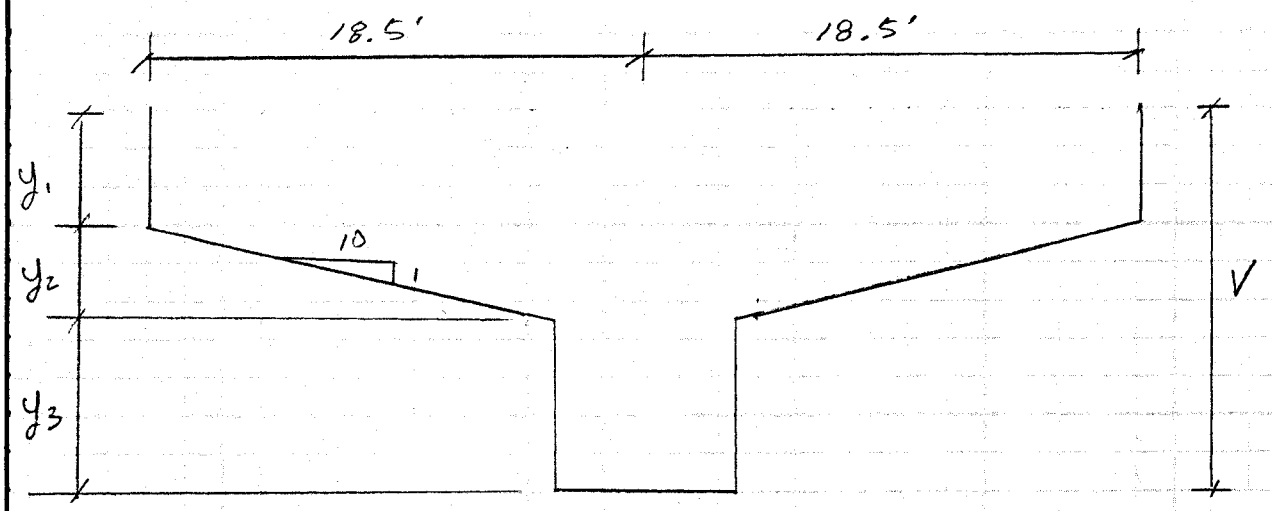
Minimum Depth; $V = 1.17 + \frac{1.5(84/144)^2}{2(32.2)} + 4 = 6.2' \Rightarrow$ OK

arthur beard engineers, inc. Phoenix - Tucson, Arizona

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 3 OF 3

41st Ave 54" connector pipe



$y_1 = 1.0'$

$y_2 = \frac{18.5}{10} = 1.85'$ use $\rightarrow$ 2.0'

$y_3 = \frac{54}{12} = 5.5$

$\therefore \; V = 1.0 + 2.0 + 5.5 = \boxed{8.5'}$

Minimum Depth ; $V = 1.17 + \frac{1.5\left(\frac{70.1}{\pi(4.5)^2/4}\right)^2}{2(32.2)} + 5.5 = 7.1' \Rightarrow$ ok

FLOWBY CALCULATIONS

arthur beard engineers, Inc.

PROJECT Union Hills DR. | PROJ. NO. 1248
SUBJECT Flowby Calculations | CLIENT COP

COMP. BY JM DATE 6/28/89 CKD BY _____ DATE _____ | SHEET 1 OF 4

37th Ave Q = 76 cfs, 10-yr event {From: Erikson & Salmons' Drainage Report ST-85334V1 Drainage Map see attached copy}

Capacities:

I) Special Inlet Type I

Perimeter, $P = 2(25) + 2(3) = 56'$

Depth of flow, $Y = \frac{1.245(Q \cdot n \cdot S_c)^{3/8}}{S^{3/16}}$

where: S = slope, longitudinal of street
S_c = cross slope of street
$n \approx 0.021$, see street capacity calculations, it was adjusted to take into account flow not in street (i.e. no gutter)

$S_c = \frac{25.46 - 25.34}{12.5} = 0.0096$

$\therefore Y = \frac{1.245(76 \times 0.021 \times 0.0096)^{3/8}}{(0.01984)^{3/16}} = 0.54'$

From pg. 30, COP Design Manual for Storm Drains;

Discharge/ft of effective perimeter of grate = 1.4

$\therefore$ Capacity, $Q = (56\,ft)\,1.4\,\frac{cfs}{(ft)}\,(0.5 \text{ clogging})$

$= \underline{\underline{39.2\,cfs}}$

arthur beard engineers, inc.

PROJECT Union Hills Dr. | PROJ. NO. 1248
SUBJECT Flowby Calculations | CLIENT COP

COMP. BY SM DATE 6/28/89 CKD BY _____ DATE _____ | SHEET 2 OF 4

37th AVE (cont.)

II) Triple Type 'N' Catch Basin (Both Sides)

$P = (9.9 + 2)\,2 = 23.8'$ per triple basin

$Y = 0.54'$ (previous pg)

Discharge/ft = 1.4 (previous pg)

$\therefore$ Capacity, $Q = 23.8(1.4)(.5) = \underline{16.7\,cfs}$ (per basin)

2 basins (one each side) $= \underline{33.3\,cfs}$

Total Capacity $= 39.2 + 33.3 = \underline{72.52\,fs}$ ←

Flowby $= 76 - 72.52 = \boxed{3.48\,cfs}$

arthur beard engineers, Inc.

PROJECT Union Hills Dr. | PROJ. NO. 1248
SUBJECT Flowby Calculations | CLIENT COP

COMP. BY JM DATE 6/28/89 CKD BY _____ DATE _____ | SHEET 3 OF 4

39th AVE $Q = 76$ cfs (see pg 1)

I) Special Inlet, Type I $P = 2(40) + 6 = 86'$

$$Y = \frac{1.245(76 \times 0.021 \times 0.0105)^{3/8}}{(0.0194)^{3/16}} = 0.56'$$

$\therefore$ Discharge/ft = 1.4

$\therefore$ Capacity, $Q = 86(1.4)(.5) = 60.2$ cfs

II) Double Type 'N' $P = 17'$ (Both Sides)

Capacity, $Q = 17(1.4)(.5) = 11.9$ cfs

2 basins = 23.8 cfs

Total Capacity = $60.2 + 23.8 = 84$ cfs

$84 > 76 \Rightarrow$ Flowby = 0 cfs

arthur beard engineers, inc.

PROJECT Union Hills Dr. | PROJ. NO. 1248
SUBJECT Flowby Calculations | CLIENT COP

COMP. BY JM DATE 6/28/89 CKD BY _____ DATE _____ | SHEET 4 OF 4

41st AVE $Q = 75$ cfs ← (see pg 1)

I) $P = 2(37) + 2(3) = 80'$

$$Y = \frac{1.245(75 \times 0.017 \times 0.008)^{3/8}}{(0.0182)^{3/16}} = \underline{0.47'}$$

∴ Discharge/ft = 1.05

∴ Capacity, $Q = 80(1.05)(.5) = \underline{42 \text{ cfs}}$

II) M-1, L=17, (Sump condition); (West Side)

From graph pg 40 COP Design Manual for Storm Drains;

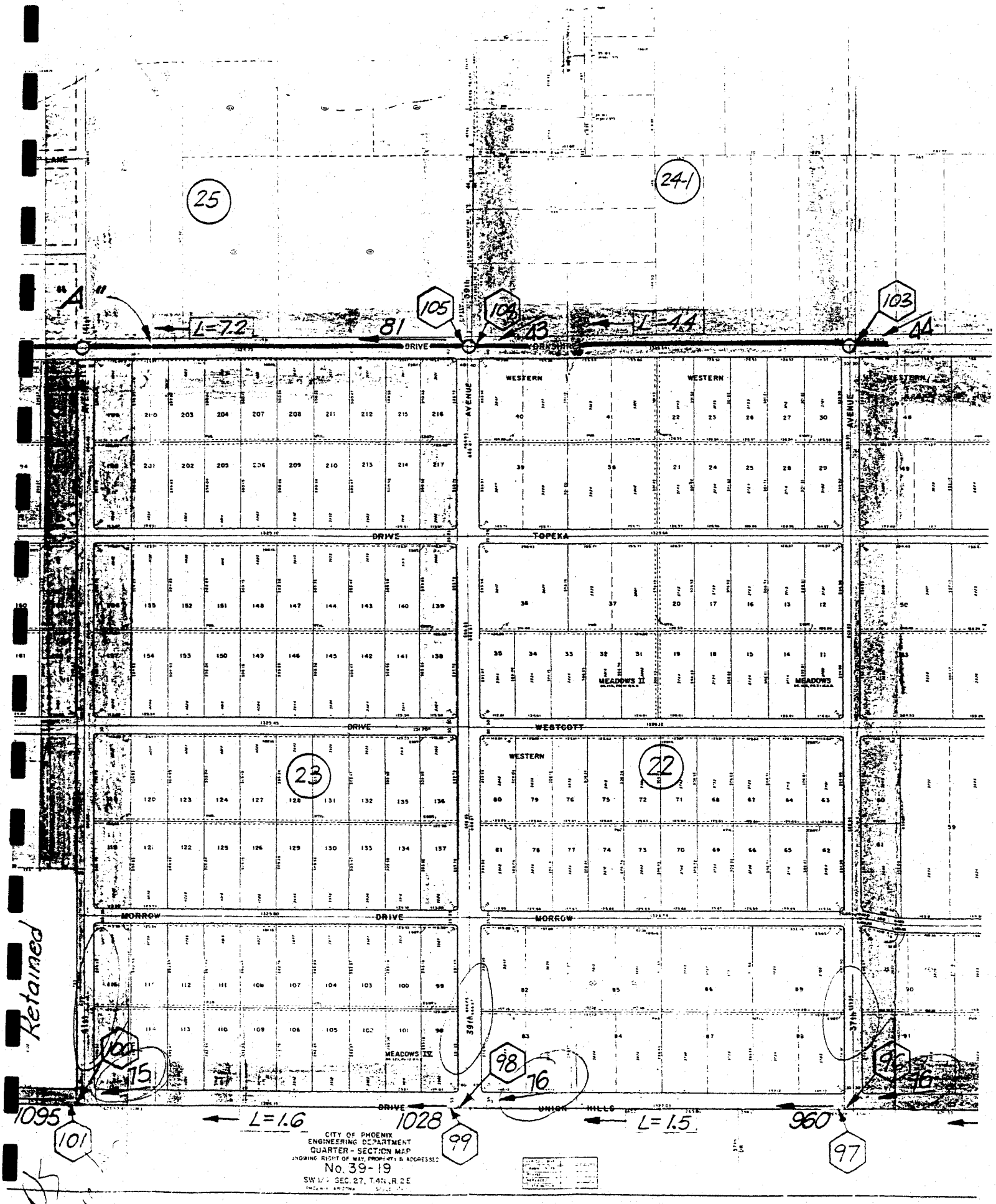
∴ Capacity, $Q = \underline{15.6 \text{ cfs}}$

III) Triple Type 'N' $P = 23.8'$ (East Side)

Capacity, $Q = 1.05(23.8) \cdot .5 = \underline{12.5 \text{ cfs}}$

Total Capacity $= 42 + 15.6 + 12.5 = \underline{70.1 \text{ cfs}}$ ←

Flowby $= 75 - 70.1 = \boxed{4.9 \text{ cfs}}$


25
24-1
A
L=7.2
81
105
104
43
L=4.4
103
44
DRIVE
WESTERN
AVENUE
TOPEKA
WESTCOTT
MEADOWS II
MEADOWS
23
22
MORROW
MEADOWS IV
Retained
100
75
98
76
96
46
1095
101
L=1.6
1028
99
UNION HILLS
L=1.5
960
97
CITY OF PHOENIX
ENGINEERING DEPARTMENT
QUARTER - SECTION MAP
SHOWING RIGHT OF WAY, PROPERTY & ADDRESSES
No. 39-19
SW 1/4 SEC. 27, T4N, R.2E

STREET CAPACITIES

arthur beard engineers, Inc.

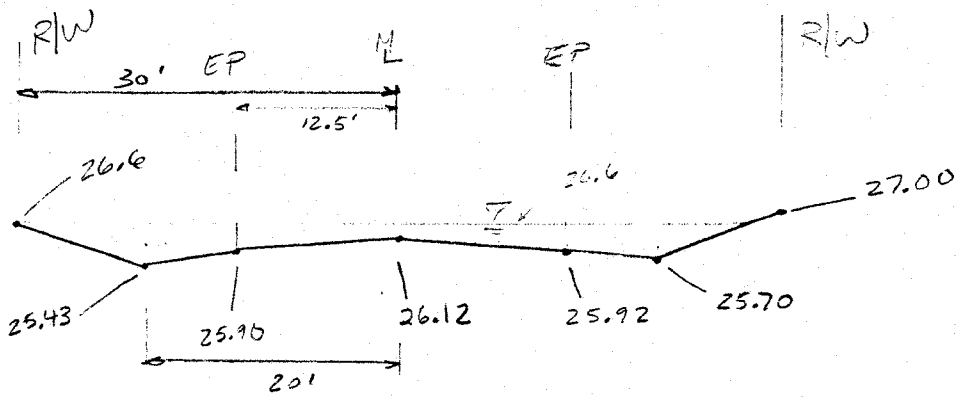
PROJECT Union Hills Dr
SUBJECT Street Capacities

PROJ. NO. 1248
CLIENT COP

COMP. BY JM DATE 6/26/89 CKD BY _____ DATE _____

SHEET 1 OF 6

37th Ave & Union Hills (Sta 12+00 North)



n = 0.015 for asphalt paving
= 0.025 for ditch on side of streets

$$\Sigma A \text{ (for asphalt)} = \left(26.6 - \frac{25.90+26.12}{2}\right)12.5 + \left(26.6 - \frac{26.12+25.92}{2}\right)12.5$$

$$= \underline{14.625 \text{ ft}^2}$$

$$\Sigma A \text{ (for ditch)} = \left(26.6 - \frac{25.43+25.90}{2}\right)7.5 + \frac{1}{2}(10)(26.6-25.43)$$

$$+ \left(26.6 - \frac{25.92+25.70}{2}\right)7.5 + \frac{1}{2}(10)(26.6-25.7)$$

$$= \underline{23.29 \text{ ft}^2}$$

$$\text{Avg. } n, = \frac{0.015(14.625)}{(14.625+23.29)} + \frac{0.025(23.29)}{(14.625+23.29)} = \underline{0.021}$$

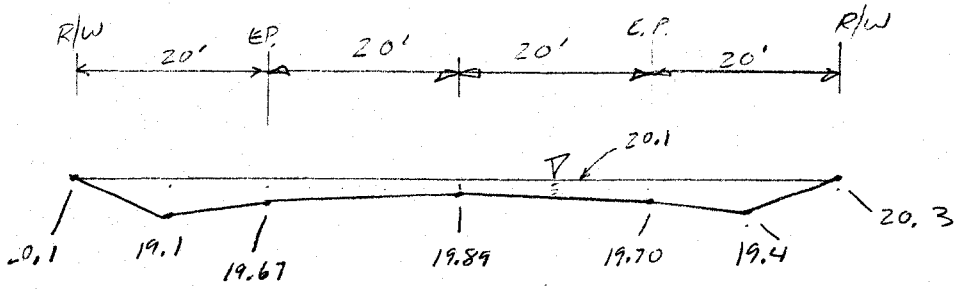
$$V = \frac{1.486}{0.021}\left(\frac{23.29+14.625}{60}\right)^{2/3}(0.008)^{1/2} = \underline{4.66 \text{ fps}}$$

$$Q = VA = 4.66(37.92) = \boxed{176 \text{ cfs}}$$

arthur beard engineers, inc.

PROJECT Union Hills Dr.	PROJ. NO. 1248
SUBJECT Street Capacities	CLIENT COP
COMP. BY JM DATE 6/26/89 CKD BY _____ DATE _____	SHEET 2 OF 6

39th AVE & Union Hills (Sta 11+50)



$$\Sigma A\ (\text{asphalt}) = \left(20.1 - \frac{19.67+19.89}{2}\right)20 + \left(20.1 - \frac{19.89+19.70}{2}\right)20$$

$$= \underline{12.5\ ft^2}$$

$$\Sigma A\ (\text{ditch}) = \left(20.1 - \frac{19.1+19.67}{2}\right)10 + \frac{1}{2}(10)(20.1-19.1)$$

$$+ \left(20.1 - \frac{19.7+19.4}{2}\right)10 + \frac{1}{2}(10)(20.1-19.4)$$

$$= \underline{21.2\ ft^2}$$

$$n = \frac{0.015(12.5)}{33.7} + \frac{0.025(21.2)}{33.7} = 0.021$$

$$V = \frac{1.486}{0.021}\left(\frac{33.7}{80}\right)^{2/3}(0.0053)^{1/2} = \underline{2.85\ fps}$$

$$Q = VA = 2.85(33.7) = \boxed{96\ cfs}$$

arthur beard engineers, Inc.

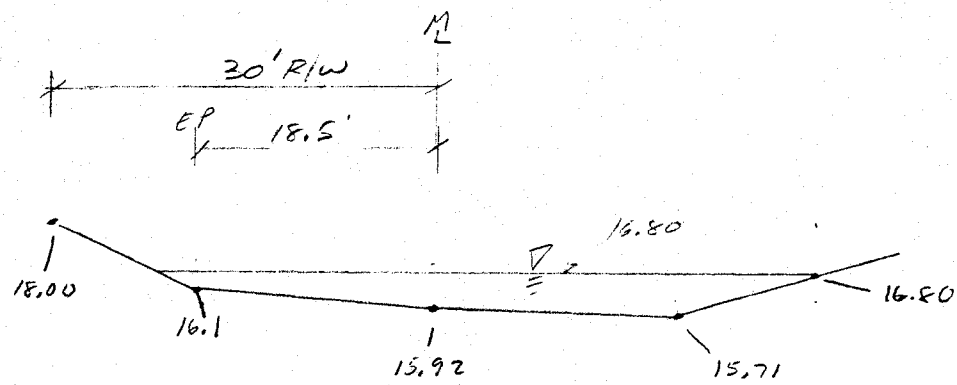
PROJECT Union Hills Dr
SUBJECT Street Capacities

PROJ. NO. 1248
CLIENT COP

COMP. BY JM DATE 6/26/89 CKD BY _____ DATE _____

SHEET 3 OF 6

41st AVE & Union Hills (12+50 North)



$$\Sigma A\,(\text{asphalt}) = \left(16.80 - \frac{16.1+15.92}{2}\right)18.5 + \left(16.8 - \frac{15.92+15.71}{2}\right)18.5$$

$$= \underline{32.8\ ft^2}$$

$$\Sigma A\,(\text{ditch}) = \frac{1}{2}(16.8-15.71)(11.5) + \frac{1}{2}(16.8-16.1)(4.3) = \underline{7.8\ ft^2}$$

$$n = \frac{32.8(0.015)}{40.6} + \frac{7.8(0.025)}{40.6} = 0.017$$

$$V = \frac{1.486}{0.017}\left(\frac{40.6}{52.8}\right)^{2/3}(0.005)^{1/2} = \underline{5.15\ fps}$$

$$Q = VA = 5.15(40.6) = \boxed{209\ cfs}$$

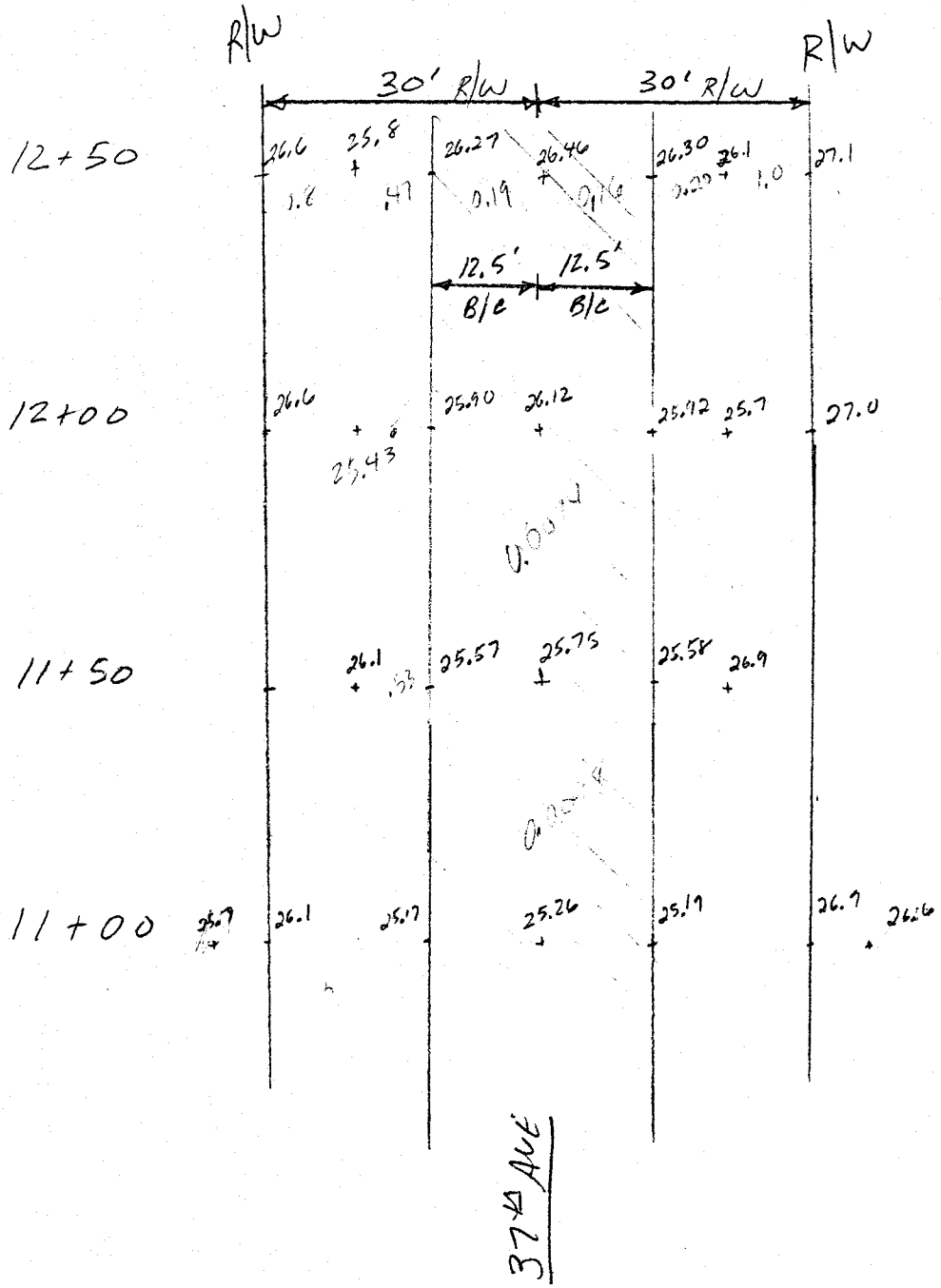
arthur beard engineers, Inc.

PROJECT Union Hills Dr.
SUBJECT Street Capacities

PROJ. NO. 1248
CLIENT COP

COMP. BY JM DATE 6/26/89 CKD BY _____ DATE _____

SHEET 4 OF 6



UNION HILLS DR
(℄ @ 10+00-North)

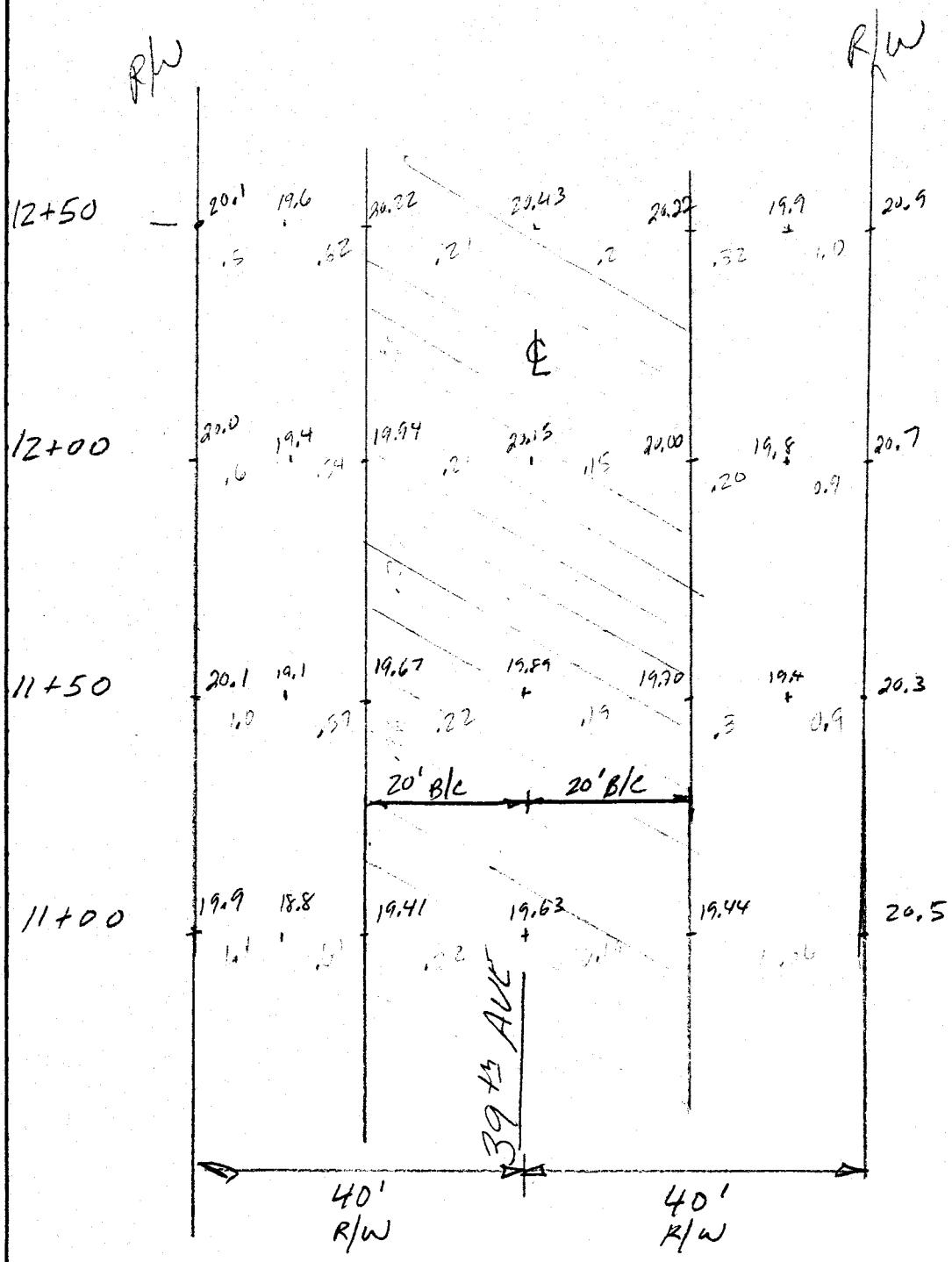
arthur beard engineers, inc.

PROJECT Union Hills Dr.
SUBJECT Street Capacities

PROJ. NO. 1248
CLIENT COP

COMP. BY JP DATE 6/26/89 CKD BY _____ DATE _____

SHEET 5 OF 6



UNION HILLS DR.
(M_L = 10+00)

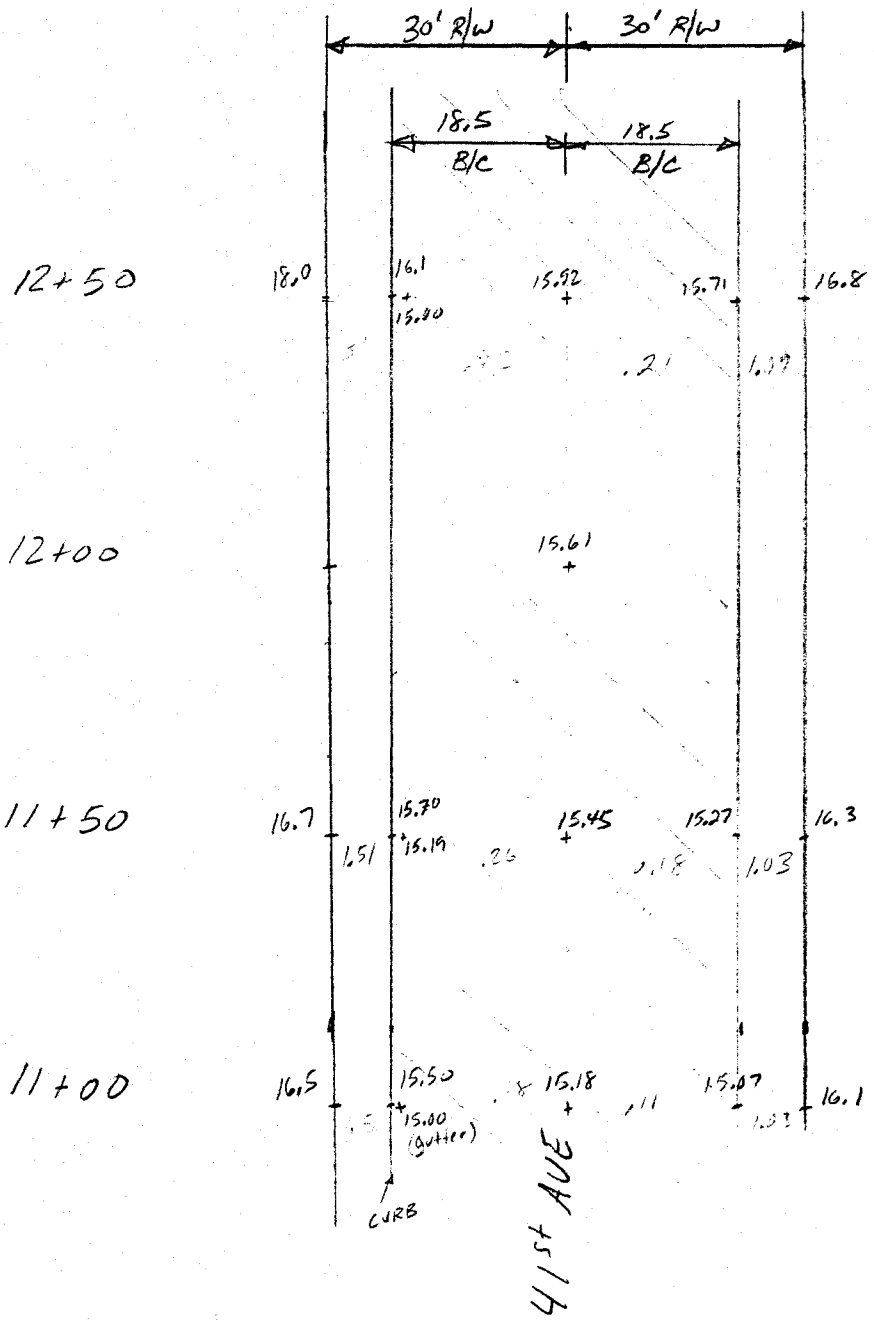
arthur beard engineers, Inc.

PROJECT Union Hills Dr.
SUBJECT Street Capacities

PROJ. NO. 1248
CLIENT COP

COMP. BY [illegible] DATE [illegible] CKD BY _____ DATE _____

SHEET 6 OF 6



HGL & EGL CALCULATIONS

FROM ERICKSON:

SLOPE OF HYDRAULIC GRADE LINE (HGL) $S = \left(\frac{Q}{C_1}\right)^2$

UNION HILLS DRIVE AND 43rd AVENUE

$Q_{10} = 1095$ CFS

<u>11 x 7 CIPP</u> $C_1 = 15,414$

$$S = \left(\frac{Q}{C_1}\right)^2$$

$$= \left(\frac{1095}{15,414}\right)^2$$

$$= 0.00505$$

<u>11 x 8 CIPP</u> $C_1 = 18,605$

$$S = \left(\frac{1095}{18,605}\right)^2$$

$$= 0.00346$$

<u>11 x 9 CIPP</u> $C_1 = 21,911$

$$S = \left(\frac{1095}{21,911}\right)^2$$

$$= 0.00250$$

START HG AT STATION 308+50

H.G. = 1301.87

STA 308+50

HGL = 1301.87 + (HOR. DIST)(HGL SLOPE)

<u>11x7 CIPP</u>

HGL = 1301.87 +

=

11x 8 CIPP

$$HGL = 1301.87 + (1033')(0.00346)$$
$$= 1305.444$$

11x 9 CIPP

$$HGL = 1301.87 + (1033')(0.00250)$$
$$= 1304.452$$

UPSTREAM SIDE OF UNION HILLS DRIVE AND 41st AVE

$Q_{10} = 1028$ CFS

11x 7 CIPP $C_1 = 15,414$

$$S = \left(\frac{Q}{C_1}\right)^2$$
$$= \left(\frac{1028}{15,414}\right)^2$$
$$= 0.00445$$

11x 8 CIPP $C_1 = 18,605$

$$S = \left(\frac{1028}{18,605}\right)^2$$
$$= 0.00305$$

11x9 CIPP $C_1 = 21,911$

$$S = \left(\frac{1028}{21,911}\right)^2$$
$$= 0.00220$$

TRANSITION LOSSES STA

11x7 CIPP

UPSTREAM VELOCITY $V_1 = \frac{Q}{A} = \frac{960 \text{ ft}^3/\text{s}}{75.396 \text{ ft}^2}$

$$= 12.73 \text{ ft/s}$$

DOWNSTREAM VELOCITY $V_2 = \frac{Q}{A} = \frac{1028\ Ft^3/s}{75.396\ Ft^2}$

$= 13.63\ Ft/s$

GO THROUGH AND FIND H.G.L. FOR EACH CIPP SIZE

N x 7 CIPP	H.G.	E.G.
STA 308 + 50 (GIVEN) →	1301.87	

$Q = 1028\ Ft^3/s$

$V = \frac{Q}{A} = \frac{1028\ Ft^3/s}{75.396\ Ft^2}$

$= 13.63\ Ft/s$

$V^2/2g = (13.63)^2/2(32.2) = 2.88$

$EG = 1301.87 + 2.88 \rightarrow 1304.75$

(STA 322 +00) − (STA 308+50) = 1350'

$(1350')(0.00445\ 1/ft) = 6.01'$

	6.01'	6.01
STA 322 + 00 →	1307.88	1310.76

TRANSITION LOSSES STA 322+00

$\Delta y(\bar{A}) = \frac{Q_2 V_2 - Q_1 V_1}{g}$

WRONG - USED WRONG FLOWS

$V_2 = \frac{1028\ Ft^3/s}{75.396\ Ft^2} = 13.63\ Ft/s$

$V_1 = \frac{960\ CFS}{75.396\ Ft^2} = 12.73\ Ft/s$

$\frac{V_1^2}{2g} = \frac{(12.73\ Ft/s)^2}{2(32.2\ Ft/s^2)} = 2.52$

$\Delta y(\bar{A}) = \frac{(1028)(13.63) - (960)(12.73)}{32.2} = 55.62$

$\Delta y = \frac{55.62}{75.396} = 0.74$

	0.74	
STA 322+00 →	1308.62 + 2.52 =	1311.14

H.G. E.G.

STA 334+80

$$S_{HGL} = \left(\frac{Q}{C_1}\right)^2 = \left(\frac{960 \text{ CFS}}{15{,}414}\right)^2 = 0.0039$$

$$[(334+80)-(322+00)](0.0039) \longrightarrow 4.99$$

STA 334+80 $\longrightarrow$ 1313.61 + 2.52 = 1316.13

TRANSITION LOSS sta 334+80

$$\Delta y(\bar{A}) = \frac{Q_2 V_2 - Q_1 V_1}{g}$$

V_2 = 960 CFS/75.396 Ft² = 12.73 Ft/s

CONTINUE WITH 11x7 CIPP

$$V_1 = \frac{891 \text{ CFS}}{75.396 \text{ Ft}^2} = 11.82 \text{ Ft/s}$$

Used wrong flows

$$V_1^2/2g = 2.17$$

$$\Delta y(\bar{A}) = \frac{(960)(12.73)-(891)(11.82)}{32.2} = 52.46$$

$$\Delta y = \frac{52.46}{75.396} = 0.70 \longrightarrow 0.70$$

STA 334+80 $\longrightarrow$ 1314.31 + 2.17 = 1316.48

STA 348+05

$$S_{HGL} = \left(\frac{Q}{C_1}\right)^2 = \left(\frac{891}{15{,}414}\right)^2 = 0.0033$$

$$[(348+05)-(334+80)]\,0.0033 \longrightarrow 4.43 \quad 4.43$$

STA 348+05 $\longrightarrow$ 1318.74 1320.91

TRANSITION LOSS STA 348+05

$$\Delta y(\bar{A}) = \frac{Q_2 V_2 - Q_1 V_1}{g}$$

V_2 = 891 CFS/75.396 Ft² = 11.82 Ft/s

Q/A

H.G. E.G.

$$V_1 = \frac{Q}{A} = \frac{694 \text{ CFS}}{75.396 \text{ Ft}^2} = 9.20 \text{ Ft/s}$$

$$V_1^2/2g = (9.20)^2/64.4 = 1.32$$

$$\Delta y\,(\bar{A}) = \frac{(891)(11.82) - (694)(9.20)}{32.2}$$

$$= 128.78 \text{ Ft}^3$$

$$\Delta y = \frac{128.78 \text{ Ft}^3}{75.396 \text{ Ft}^2}$$

$$= 1.71 \text{ Ft} \longrightarrow 1.71$$

STA 348 + 05 $\longrightarrow$ 1320.45 + 1.32 = 1321.77

Used wrong flows

42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE
NATIONAL

arthur beard engineers, inc. Revised 10/10/89 JM

PROJECT Valley Hills Storm Drain	PROJ. NO. 1248
SUBJECT Hydraulic Line Calculations	CLIENT COP
COMP BY JM DATE 8/30/89 CKD BY _____ DATE _____	SHEET 1 OF 6

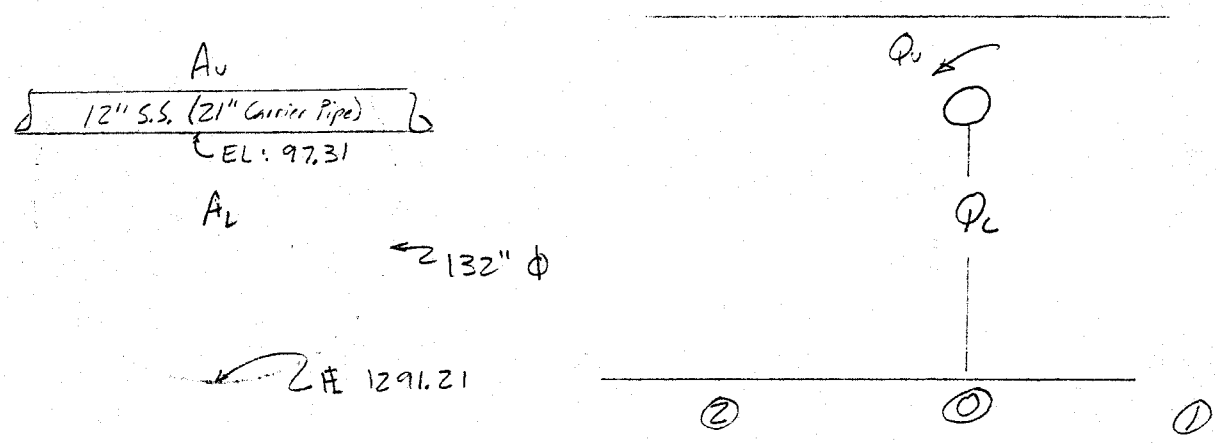
Compute: hydraulic grade line (HGL) & energy grade line (EGL) from Sta 307+37.69 (begin project) to Sta 351+03.54 (end project)

Given: HGL = 1297.94 at Sta 307+37.69 } From "Project Engineering" the
EGL = 1302.14 at Sta 307+37.69 } downstream Engineer

$$S_F = \left(\frac{Q}{C_1}\right)^2$$

where: Q = flow in pipe, cfs
C_1 = conveyance coefficient = $\frac{1.486}{n} A \left(\frac{A}{WP}\right)^{2/3}$

Sta 308+62 (12" Sewer Crossing Loss), w/full pipe



A_L $\frac{d}{D} = \frac{6.1}{11} = 0.55$; $\frac{A}{D^2} = 0.4426$ From pg 467, T-A-10 Concrete Pipe Design Manual, ACPA, '87

$\therefore A_L = .4426(11)^2 = \underline{53.55 \text{ ft}^2}$

A_U $\frac{d}{D} = \frac{3.15}{11} = 0.29$; $\frac{A}{D^2} = 0.1890$

$\therefore A_U = 0.1890(11)^2 = \underline{22.87 \text{ ft}^2}$

Expansion Loss: $V_2 = \frac{1095}{95.033} = 11.52$ fps ; $V_1 = \frac{1095}{53.55+22.87} = 14.33$ fps

$$h_e = \frac{(14.33-11.52)^2}{64.4} = \underline{0.13}$$

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 2 OF 8

Sta 308+62 (cont)

Contraction Loss: $h_c = \frac{0.7(14.33-11.52)^2}{64.4} = 0.09$

$h_L = 0.13 + 0.09 = \underline{0.22'}$

Sta 308+94 (MH Transition 132" to 120")

$S_F = 0.0058$ $H_L = 0.0058(60.31) = \underline{0.35'}$

HGL (downstream of MH) = 1297.94 + 0.22 + 0.35 = $\boxed{1298.51}$

EGL (downstream of MH) = $1298.51 + \frac{14.33^2}{64.4}$ $\boxed{1301.70}$

Transition Loss:

$Q_2 = 1095$ cfs $Q_1 = 1095$ cfs

$d_2 = 10'$ $d_1 = 11'$

$D_2 =$ $D_1 = 8.14'$

$A_2 =$ $A_1 = 75.395$ ft^2

$Z = 1.0$ $V_1 = 14.52$ fps

$$\Sigma P = \Sigma M$$

$$\tfrac{1}{2}(A_1 + A_2)(Z + D_1 - D_2) = \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g}$$

$$\tfrac{1}{2}(75.4 + A_2)(1 + 8.14 - D_2) = \frac{1095^2}{A_2(32.2)} - \frac{1095^2}{75.4(32.2)}$$

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 3 OF 8

Sta 308+94 (cont.)

Let $D_2 = 9.7 \therefore A_2 = 77.85$

$-42.9 \neq -15.54$

Let $D_2 = 9.3 \therefore A_2 = 76.12$

$-12.1 \neq -4.7$

Let $D_2 = 9.2 \therefore A_2 = 75.6$

$-4.5 \neq -1.3$

Let $D_2 = 9.1 \therefore A_2 = 75.04$ ← OK

$V = \frac{1095}{75.04} = 14.6$

$3.0 \simeq 2.4$

Let $D_2 = 9.0 \therefore A_2 = 74.45$

$+10.5 \neq +6.3$

HGL (upstream of MH) = $1291.32 + 9.1 = \boxed{1300.42}$

EGL (upstream of MH) = $1300.42 + \frac{(14.6)^2}{64.4} = \boxed{1303.73}$

Sta 321+69.16 (54" Connector Pipe)

$S_F = \left(\frac{1095}{16540}\right)^2 = 0.00438$

$H_{Lf} = 1275.16(0.00438) = 5.59'$

H_L MH (flow straight through): $H_L = 0.05\left(\frac{14.6^2}{64.4}\right) = 0.17'$

HGL (downstream of 54" pipe) = $1300.42 + 5.59 + 0.17 = \boxed{1306.18'}$

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 4 OF 8

Sta 321+69.16 (cont.)

$$EGL\ (\text{downstream of } 54'' \text{ pipe}) = 1306.18 + \frac{14.6^2}{64.4} = \boxed{1309.49}$$

Transition Loss:

$Q_1 = 1028$ cfs $\qquad Q_2 = 1095$ cfs

$d_1 = 10'$ $\qquad d_2 = 10'$

$D_1 =$ $\qquad D_2 = 8.36'$

$A_1 =$ $\qquad A_2 = 70.43\ ft^2$

$z = 0$

$$\Sigma P = \Sigma M$$

$$\tfrac{1}{2}(A_1 + A_2)(z + D_1 - D_2) = \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g}$$

$$\tfrac{1}{2}(A_1 + 70.43)(D_1 - 8.36) = \frac{1095^2}{70.43(32.2)} - \frac{1028^2}{A_1(32.2)}$$

Let $D_1 = 9.0'$ $\therefore$ $A_1 = 74.45\ ft^2$

$46.36 \neq 87.88$

Let $D_1 = 9.2'$ $\therefore$ $A_1 = 75.60\ ft^2$

$61.33 \neq 94.58$

Let $D_1 = 9.5'$ $\therefore$ $A_1 = 77.07\ ft^2$

$84.08 \neq 102.87$

Let $D_1 = 9.7'$ $\therefore$ $A_1 = 77.85\ ft^2$

$99.35 \doteq 107.13$

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 5 OF 8

Sta 321+69.16 (cont.)

Let $D_1 = 9.8'$ $\therefore$ $A_1 = 78.16\ ft^2$

$106.98 \doteq 108.8$ ← ok

$V = \frac{1028}{78.16} = 13.15\ fps$

Let $D_1 = 9.9'$ $\therefore$ $A_1 = 78.41\ ft^2$

$114.61 \neq 110.15$

HGL (upstream 54" pipe) = 1297.82 + 9.8 = **1307.62**

EGL (upstream 54" pipe) = $1307.62 + \frac{13.15^2}{64.4}$ = **1310.31**

Sta 334+90.67 (Transition MH 120" to 114" & 48" Connector Pipe)

$\frac{d}{D} = \frac{9.8}{10} = 0.98$; $\frac{A}{D^2} = 0.7816$ $\therefore$ $A = 78.16\ ft^2$

$\frac{R}{D} = 0.2735$ $\therefore$ $R = 2.735'$

$C = \frac{1.486}{0.013}(78.16)(2.735)^{2/3} = 17,472$

$S_f = \left(\frac{1028}{17,472}\right)^2 = 0.00346$

$H_L = 0.00346(1321.51) = 4.57'$

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 6 OF 8

Sta 334+91.67 (cont)

HGL (downstream of MH) = 1307.62 + 4.57 = **1312.19**

EGL (downstream of MH):

$$1312.19 + \left(\frac{1022}{78.16}\right)^2 \frac{1}{64.4} = \boxed{1314.88}$$

Transition Loss:

$Q_1 = 960$ cfs $\qquad Q_2 = 1022$ cfs

$d_1 = 9.5'$ $\qquad d_2 = 10'$

$D_1 =$ $\qquad D_2 = 7.67'$

$A_1 =$ $\qquad A_2 = 64.47\ ft^2$

$$\Sigma P = \Sigma M$$

$$\tfrac{1}{2}(A_1 + 64.47)(.5 + D_1 - 7.67) = \frac{1022^2}{64.47(32.2)} - \frac{960^2}{A_1(32.2)}$$

Let $D_1 = 8.5'$, $A_1 = 66.64\ ft^2$

$87.19 \neq 79.57$

Let $D_1 = 8.4'$, $A_1 = 66.06\ ft^2$

$80.28 = 75.80$

Let $D_1 = 8.2'$, $A_1 = 65.06\ ft^2$

$66.71 \doteq 69.15$

arthur beard engineers, Inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 7 OF 8

Sta 334+90.67 (cont.)

Let $D_1 = 8.3'$, $A_1 = 65.66\ ft^2$ ← ok

$73.53 \approx 73.17$

$$V = \frac{960}{65.66} = 14.62\ fps$$

HGL (upstream of MH) = 1304.76 + 8.3 = **1313.06**

EGL (upstream of MH) = $1313.06 + \frac{(14.62)^2}{64.4}$ = **1316.38**

Sta 348+17.09 (48" Connector Pipe)

$$S_F = \left(\frac{960}{14420}\right)^2 = 0.0044$$

$$H_{L_f} = 1326.42\,(0.0044) = 5.84'$$

H_L (MH Flow Straight Through) = $0.05\,\frac{(14.62)^2}{64.4} = 0.16$

HGL (downstream 48" pipe) = 1313.06 + 5.84 + 0.16

= **1319.06**

EGL (downstream 48" pipe)

= $1319.06 + \frac{14.62^2}{64.4}$ = **1322.38**

arthur beard engineers, inc.

PROJECT _____ PROJ. NO. _____
SUBJECT _____ CLIENT _____

COMP BY _____ DATE _____ CKD BY _____ DATE _____ SHEET 8 OF 8

Sta 348+17.09 (cont.)

Transition Loss:

$$\Delta Y(\bar{A}) = \frac{Q_2 V_2 - Q_1 V_1}{g}$$

$$V_2 = \frac{960}{70.882} = 13.54 \text{ fps} \qquad V_1 = \frac{891}{70.882} = 12.57 \text{ fps}$$

$$\Delta Y(\bar{A}) = \frac{960(13.54) - 894(12.57)}{32.2} = 54.68$$

$$\Delta Y = \frac{54.68}{70.882} = 0.77'$$

HGL (upstream of MH) = 1319.06 + 0.77 = **1319.83**

EGL (upstream of MH) = $1319.83 + \frac{(12.57)^2}{64.4}$ = **1322.28**

Sta 351+03.54 (End of Project)

$$S_F = \left(\frac{891}{14{,}420}\right)^2 = 0.0038$$

$$H_L = 286.45(0.0038) = 1.08'$$

HGL = 1319.83 + 1.08 = **1320.91**

EGL = $1320.91 + \frac{(12.57)^2}{64.4}$ = **1323.36**

HYDRAULIC CHECK OF ERICKSON'S CALCULATIONS

HYDRAULICS - CHECK OF ERICKSON'S CRITICAL DEPTH CALCS

1

NOTES

1/10/89

Bernoulli equation

$$\frac{V_1^2}{2g} + D_1 = \frac{V_2^2}{2g} + D_2 + \Delta z + h_e$$

$\frac{Q^2}{g} = \frac{a^3}{T}$ must be satisfied for flow at critical depth

Mean depth $D_m = \frac{a}{T}$

T = channel width @ top

When $D = D_c$ then $H_c = H_m$

H_m = minimum specific energy

Rectangular cross-sections - critical depth D_c is equal to mean depth D_m

critical velocity $V_c = \sqrt{g D_c}$

critical depth $D_c = \frac{V_c^2}{g}$

- bottom width b = Top width T.
- take flow q as discharge per foot of width

total flow $Q = \sqrt{g}\, b\, D_c^{3/2}$

$q \doteq \sqrt{g}\,(2/3)^{3/2} H_m^{3/2}$

$g = 32.16$, so $q = 3.087\, H_m^{3/2}$

flow per ft. width $q = \sqrt{g}\, D_c^{3/2}$

critical depth $D_c = \sqrt[3]{q^2/g}$

min. specific energy $H_m = 3/2\, D_c$

critical depth $D_c = 2/3\, H_m$

Notch for 12" SS

Sta 256+85

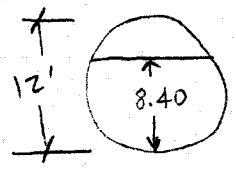
~~11'x11' CIPP~~ 12' ∅ RCP

$A = bd$

$\boxed{d = 8.40'}$

$b = 11'$

$A = bd = (11')(8.40') = 92.40\ ft^2$

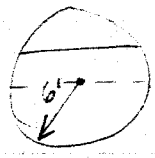


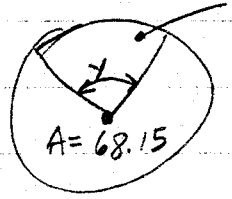
$A = ?$

$d = 2r \quad r = d/2$

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

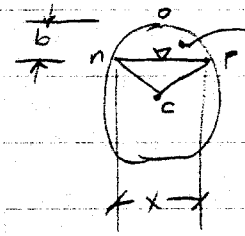
$A = \frac{\pi}{4} d^2 \quad \pi/4 = 0.7854$



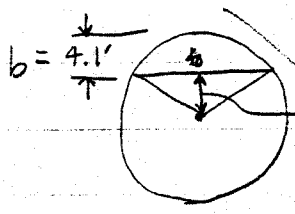


A = Area of circle × $Y/360$

$= \pi(6')^2 \times 143.07/360 = 44.947$

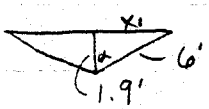


$A = \frac{(\text{Length of arc nop} \times r) - x(r-b)}{2}$



$r = 6'$

$6' - 4.1' = 1.9' = b$



$x_1^2 + 1.9^2 = 6^2$

$x_1^2 + 3.61 = 36$

$x_1^2 = 32.39$

$x_1 = 5.69$

$x = 2(x_1)$

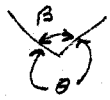
$= 2(5.69')$

$= 11.38'$

ANGLE $\alpha = \tan^{-1}\left(\frac{5.69}{1.9}\right)$

$= \tan^{-1} 2.99$

$= 71.53°$



$\beta = 2\alpha = 2(71.53°) = \underline{143.07°}$

$\theta = 360° - \beta$

$= 360° - 143.07°$

$= 216.93°$

Arc length $= \frac{\pi r A°}{180°} = 0.017453 r A°$

$= 0.017453(6')(143.07°)$

$= 14.98'$

$A_{top\ segment} = \frac{(14.98' \times 6') - (11.38')(6' - 4.1')}{2}$

$= 34.13\ Ft^2$

Area circle $= \pi r^2 = \pi(6')^2 = \cancel{113.0}\ 113.10\ Ft^2$

Area bottom segment $= A_{circle} - A_{top\ segment}$

$= 113.10\ Ft^2 - 34.13\ Ft^2$

$= 78.96\ Ft^2$

$V = Q/A$

$= \frac{1493\ Ft^3/s}{84.528\ Ft^2}$

$= 17.66\ Ft/s$

$V^2/2g = (17.66^2)/2(32.2)$

$= 4.84$

$\cancel{H_c = H_m}$ $\cancel{H_m = D_c + D_m/2}$

$$H_e = D + Q^2/2ga^2 = V$$

$$= 8.40' + (1493 \text{ cfs})^2/2(32.2)(84.528)^2$$

$$= \cancel{8.4032} \quad 13.244$$

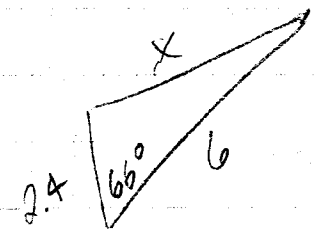
~~1.5767~~
~~1.5566~~
~~1.5356~~
~~1.5164~~

Need to find equations for A and E
A = x-sect area of flow
E = Specific energy (EGL)

FORMULAS

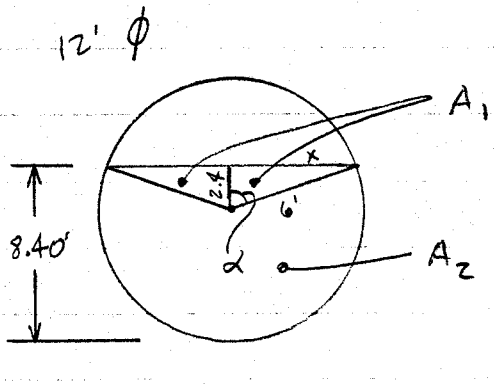
$$V = \frac{Q}{A}$$

$$E = d + \frac{Q^2}{2ga^2}$$



$\sin 66 = x/6$

$x = 6 \sin 66$



$x^2 + 2.4^2 = 6^2$

$x^2 = 6^2 - 2.4^2$

$x^2 = 30.24$

$x = 5.50'$

~~$2x = 11.00'$~~

$A_1 = \frac{1}{2}bh = \frac{1}{2}(5.50')(2.4') = 3.00 \text{ ft}^2$

$2A_1 = 6.00 \text{ ft}^2$

$\alpha = \cos^{-1}(2.4'/6') = \cos^{-1} 0.40 = 66.4218°$

$2\alpha = 132.8436°$

$360° - 132.8436° = 227.1564°$

$$A_2 = A_{circle} \times \frac{227.1564°}{360°}$$

$$= \pi (6')^2 (227.1564° / 360°)$$

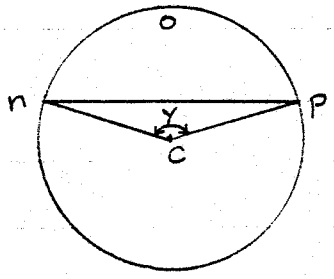
$$= 71.36 \text{ Ft}^2$$

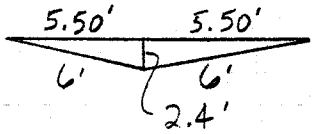
$$A_{total} = A_1 + A_2 = 3 \text{ ft}^2 + 71.36 \text{ ft}^2$$
$$= 74.36 \text{ ft}^2$$

Check area from circular segment formula:

Area of segment nop = Area of sector ncpo − Area of triangle ncp

= (Area of circle × Y/360) − Area triangle ncp





$$\text{Area of sector ncpo} = \frac{Y}{360} \times \text{Area of circle}$$

$Y = 132.8436°$

Area of circle $= \pi r^2 = \pi (6')^2 = \pi (36) = 113.10 \text{ Ft}^2$

$$\text{Area}_{ncpo} = \frac{132.8436°}{360°} (113.10 \text{ ft}^2)$$

$$= 41.74 \text{ Ft}^2$$

Area triangle ncp $= 2(\frac{1}{2} bh) = 2(\frac{1}{2})(5.50)(2.40') =$ ~~6.6 Ft²~~ 13.2 Ft^2

Area top segment $= 41.74 \text{ Ft}^2 - 13.2 \text{ Ft}^2$

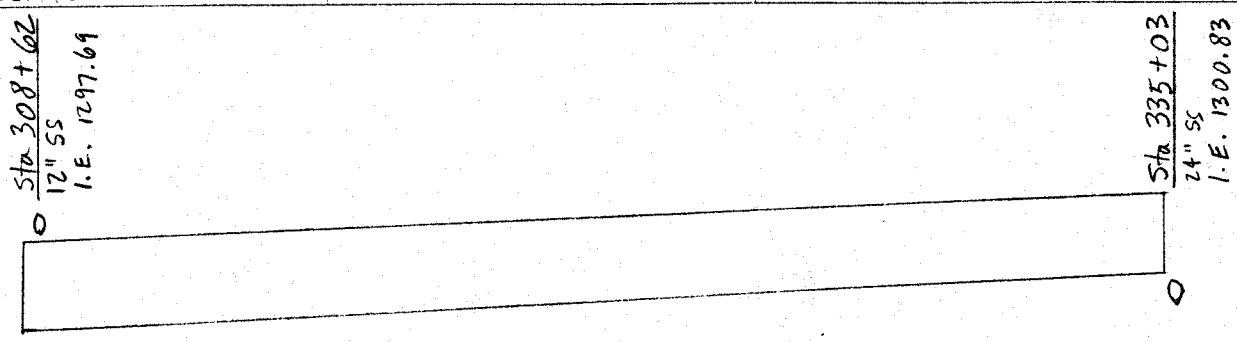
$= 28.54 \text{ Ft}^2$

Area of bottom segment = Area of circle - area of top segment

$= 113.10\ ft^2 - 28.54\ ft^2$

$= 84.56$ vs. 84.528 OK

CONVEYANCE COEFFICIENTS

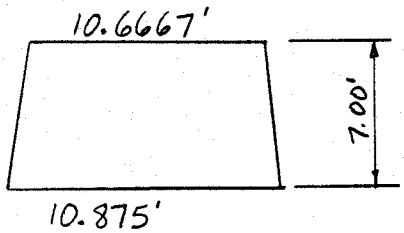


NEED PIPE STATIONS + ELEVATIONS FROM REDLINES

CONVEYANCE COEFFICIENTS

EQUIVALENT 114" Ø PIPE – 11 x 7 CIPP

CONVEYANCE COEFFICIENT $C_1 = \frac{1.486}{n} A \left(\frac{A}{WP}\right)^{2/3}$

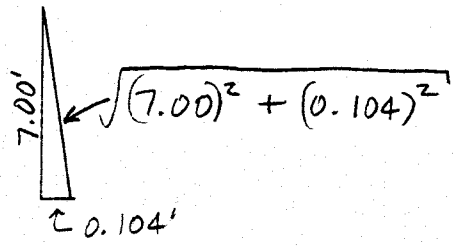


$$A = \frac{(\text{TOP} + \text{BOTTOM})}{2} \times \text{HEIGHT}$$

$$= \frac{10.6667' + 10.875'}{2} (7.00')$$

$$= 75.396 \text{ Ft}^2$$

WETTED PERIMETER WP



$$\sqrt{(7.00)^2 + (0.104)^2} = 7.001 \text{ Ft}$$

WETTED PERIMETER = 7' + 7' + 10.6667' + 10.875'

= 35.542 Ft

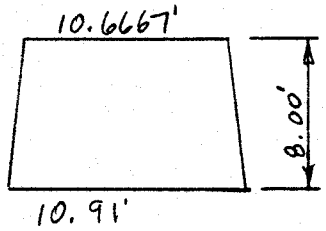
ASSUME n = 0.012

$$C_1 = \frac{1.486}{0.012}(75.396)\left(\frac{75.396}{35.542}\right)^{2/3}$$

= 15,414.3

= 15,414 FOR 11' x 7' CIPP

EQUIVALENT 120" ϕ PIPE - 11 x 8 CIPP



$$A = \frac{10.6667 + 10.91}{2} \times 8.00$$

= 86.307 Ft²

WP = 10.6667' + 10.91' + 8' + 8'

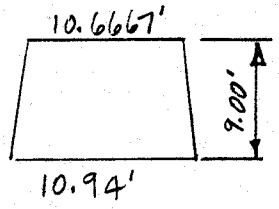
= 37.577 Ft

$$C_1 = \frac{1.486}{0.012}(86.307)\left(\frac{86.307}{37.577'}\right)^{2/3}$$

= 18,605.1

= 18,605 FOR 11' x 8' CIPP

EQUIVALENT 132" Ø PIPE - 11x9 CIPP



$$A = \frac{10.6667' + 10.94'}{2} \times 9.00'$$

$$= 97.230 \ Ft^2$$

$$WP = 10.6667' + 10.94' + 9' + 9'$$

$$= 39.607 \ Ft$$

$$C_1 = \frac{1.486}{0.012}(97.23 \ Ft^2)\left(\frac{97.23 \ Ft^2}{39.607 \ Ft}\right)^{2/3}$$

$$C_1 = 21,910.7$$

$$= \underline{\underline{21,911 \text{ FOR } 11' \times 9' \text{ CIPP}}}$$

NATIONAL 42 381 50 SHEETS 5 SQUARE 42 382 100 SHEETS 5 SQUARE 42 389 200 SHEETS 5 SQUARE

CONVEYANCE COEFFICIENTS

ALTERNATE I - FLOWING FULL

1

$$C = \frac{1.486}{n_{.012}} \times A \times \left(\frac{A}{W.P}\right)^{2/3} =$$

$$S = \left(\frac{Q}{C}\right)^2 \qquad \frac{Q^2}{C^2} \quad Q = C\sqrt{S}$$

A

144" ϕ PIPE

$A = \pi r^2$

$= \pi (144''/2)^2$

$= 16,286.0 \text{ in}^2 \times \left(\frac{1 \text{ Ft}}{12 \text{ in}}\right)^2$

$= 113.10 \text{ Ft}^2$

hyd radius
slipforming
hyd grade line

WP

WP = Circumference

$= \pi d$

$= \pi (144'')(1'/12'')$

$= 37.699 \text{ Ft}$

$= 37.70 \text{ Ft}$

CONVEYANCE COEFFICIENT $C_1 = \frac{1.486}{n} A \left(\frac{A}{WP}\right)^{2/3}$

$$C_1 = \frac{1.486}{0.012}(113.1 \text{ Ft}^2)\left(\frac{113.1 \text{ Ft}^2}{37.7 \text{ Ft}}\right)^{2/3}$$

$= 29,132.7$

$= 29,133$ vs. $29,133$

DIA	A	WP
132" PIPE	95.03 Ft^2	34.56 Ft
120" PIPE	78.54 Ft^2	31.42 Ft
114" PIPE	70.88 Ft^2	29.85 Ft
108" PIPE	63.62 Ft^2	28.27 Ft

132" Ø

$$C_1 = \frac{1.486}{0.012}(95.03\ Ft^2)(95.03/34.56)^{2/3}$$

$$= 123.8\overline{3}\ (\qquad\qquad)$$

$$= 23,097 \quad vs. \quad 23,104$$

120" Ø

$$C = 123.83\ (78.54)(78.54/31.42)^{2/3}$$

$$= 17,914 \quad vs. \quad 17,915$$

114" Ø

$$C = 123.83\ (70.88)(70.88/29.85)^{2/3}$$

$$= 15,622 \quad vs. \quad 15,624$$

108" Ø

$$C = 123.83(63.62)(63.62/28.27)^{2/3}$$

$$= 13,529 \quad vs. \quad 13,526$$

ALTERNATE II - FLOWING FULL

SIZE	AREA	WP		C	CITY OF PHOENIX "C" COP-C
11'x11'	121 Ft²	44 Ft	2.11 607	29,411	28,804
11'x9'	99 Ft²	40	2.42 529	22,431	21,902
11'x8'	88 Ft²	38	2.49 463	19,074	18,611
11'x7'	77 Ft²	36	2.70 416	15,829	15,413

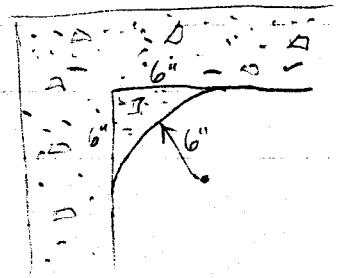
$$C = \frac{1.486}{0.012}(A)\left(\frac{A}{WP}\right)^{2/3}$$

↑ 123.83

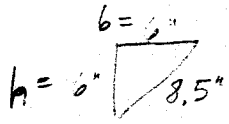
TRY SETTING WATER LEVEL JUST BELOW TOP OF BOX CULVERT:

SIZE	WP	C	COP "C"
11x11	33'	35,629	28,804
11x9	29'	27,795	21,902
11x8	27'	23,955	18,611
11x7	25'	20,185	15,413

TRY INSTALLING 6" FILLET AT 2 TOP CORNERS:



APPROXIMATE WITH TRIANGLE:



2 FILLETS: AREA $= 2(\frac{1}{2} bh)$

$= (6")(6")$

$= 36 in^2 \left(1'/12"\right)^2$

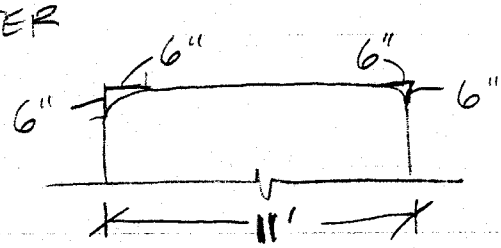
$= 0.25 \ ft^2$

<u>11x8 CULVERT</u>:

X-SECT AREA (W/ FILLETS) $= 88 \ ft^2 - 0.25 \ ft^2$

$= 87.75 \ ft^2$

PERIMETER



FIND CIRCUMFERENCE OF 6" R CIRCLE

$c = \pi d = \pi (12") = 37.699 \ in = 3.14 \ ft$

WETTED $P = 38' - 4(6") + (3.14 \ ft)/2$

$= 37.57 \ ft$

$$C_1 = 123.83 (87.75) \left(\frac{87.75}{37.57}\right)^{2/3}$$

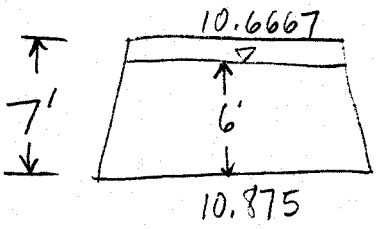
$= 19,129$ vs. $18,611$

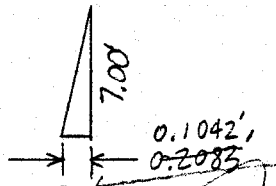
check $^{2/3}$

CRITICAL DEPTH CALCULATIONS

FIND CRITICAL DEPTH: Q = 1095 CFS, 11'x7' BOX CULVERT
ALT. II

10.77 Average width

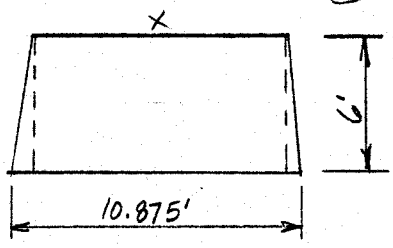




RATIO = $\frac{0.1042 \;\cancel{0.2083}}{7.00}$ = 0.0149 ~~0.0298~~

2 × RATIO = 0.0298 ~~0.059~~

~~TOP LENGTH = BOTTOM LENGTH − (VERTICAL × RATIO)~~



TOP LENGTH x = BOTTOM LENGTH − (Ht × 0.0298)

$x = 10.875 - (6' \times \cancel{0.0595}\ 0.0298)$

$= \cancel{10.875 - 0.357}$

$= \cancel{10.518}\ 10.696$

CHECK: TOP LENGTH = BOTTOM LENGTH − 2(VERTICAL × RATIO)

OK − GIVES SAME RESULT

6' WATER DEPTH: $A = \frac{\text{SUM OF PARALLEL SIDES}}{2} \times \text{HEIGHT}$

$= \frac{\cancel{10.518}\ 10.696 + 10.875}{2} \times 6'$

$= \cancel{64.179}\ 64.714\ Ft^2$

$Q = VA$

$V = Q/A$

$= 1095/\cancel{64.179}\ 64.714$

$= \cancel{17.06}$

$= 16.92$

6.1 Water depth

$$x = 10.875 - (6.1 \times 0.0298)$$
$$= 10.693$$

$$A = \frac{10.693 + 10.875}{2} \times 6.1' = 65.783$$

$$V = \frac{Q}{A} = \frac{1095}{65.783} = \cancel{16.65}\ 16.646$$

6.2' depth

$$x = 10.875 - (6.2 \times 0.0298)$$
$$= 10.690$$

$$A = \frac{10.690 + 10.875}{2} \times 6.2' = 66.852$$

$$V = \frac{Q}{A} = \frac{1095}{66.852} = 16.379$$

6.3' Depth

$$x = 10.875 - (6.3 \times 0.0298)$$
$$= 10.687$$

$$A = \frac{10.687 + 10.875}{2} \times 6.3 = 67.921$$

$$V = \frac{Q}{A} = \frac{1095}{67.921} = 16.122$$

6.5' Depth

$$x = 10.875 - (6.5 \times 0.0298) = 10.681$$

$$A = \frac{10.681 + 10.875}{2}(6.5) = 70.058$$

$$V = \frac{Q}{A} = \frac{1095}{70.058} = 15.630$$

6.7' Depth

$x = (10.875) - (6.7 \times 0.0298)$

$= 10.675$

$A = \frac{10.675 + 10.875}{2} (6.7')$

$= 72.194'$

$V = \frac{Q}{A} = \frac{1095}{72.194} = 15.168$

6.9' DEPTH

$x = (10.875) - (6.9 \times 0.0298)$

$= 10.669$

$A = \frac{10.669 + 10.875}{2} \times 6.9 = 74.328$

$V = \frac{Q}{A} = \frac{1095}{74.328} = 14.732$

6.95' DEPTH

$x = 10.875 - (6.95 \times 0.0298) = 10.6679$

$A = \frac{10.668 + 10.875}{2} \times 6.95 = 74.862$

$V = Q/A = 1095/74.862 = 14.627$

6.92' DEPTH

$x = 10.875 - (6.92 \times 0.0298) = 10.6688$

$A = \frac{10.6688 + 10.875}{2} \times 6.92 = 74.542$

$V = Q/A = 1095/74.542 = 14.690$

6.88' Depth

$x = 10.875 - (6.88 \times 0.0298) = 10.6700$

$A = (10.6700 + 10.875)/2 \times 6.88 = 74.1147$

$V = Q/A = 1095/74.1147 = 14.7744$

6.8' DEPTH

$x = 10.875 - (6.8 \times 0.0298) = 10.6724$

$A = \frac{10.6724 + 10.875}{2} \times 6.8 = 73.261$

$V = Q/A = 1095/73.261 = 14.9466$

6.75' DEPTH

$x = 10.875 - (6.75 \times 0.0298) = 10.6739$

$A = \frac{10.6739 + 10.875}{2} \times 6.75 = 72.7274$

$V = Q/A = 1095/72.7274 = 15.0562$

6.79' Depth

$x = 10.875 - (6.79 \times 0.0298) = 10.6727$

$A = \frac{10.6727 + 10.875}{2} \times 6.79' = 73.1543$

$V = Q/A = 1095/73.1543 = 14.9684$

6.81' Depth

$x = 10.875 - (6.81 \times 0.0298) = 10.6721$

$A = \frac{10.6721 + 10.875}{2} \times 6.81 = 73.3677$

$V = Q/A = 1095/73.3677 = 14.925$

6.85' Depth

$x = 10.875 - (6.85 \times 0.0298) = 10.6709$

$A = \frac{10.6709 + 10.875}{2} \times 6.85 = 73.7946$

$V = Q/A = 1095/73.7946 = 14.8385$

6.83' Depth

$x = 10.875 - (6.83 \times 0.0298) = 10.6715$

$A = (10.6715 + 10.875)/2 \times 6.83 = 73.5812$

$V = Q/A = 1095/73.5812 = 14.8815$

6.84' Depth

$x = 10.875 - (6.84 \times 0.0298) = 10.6712$

$A = \frac{10.6712 + 10.875}{2} \times 6.84 = 73.6879$

$V = \frac{Q}{A} = \frac{1095}{73.6879} = 14.8600$

6.82' Depth

$x = 10.875 - (6.82 \times 0.0298) = 10.6718$

$A = \frac{10.6718 + 10.875}{2} \times 6.82 = 73.4745$

$V = \frac{Q}{A} = \frac{1095}{73.4745} = 14.9031$

CRITICAL DEPTH: Q = 1028 CFS, ALT. II 11×7 BOX CULVERT
SAME CROSS-SECTION DIMENSIONS AS BEFORE.

6.7' Depth

$x = 10.675$ (FROM BEFORE)

$A = 72.1936$

$V = Q/A = 1028/72.1936 = 14.2395$

6.6' Depth

$x = 10.875 - (6.6 \times 0.0298) = 10.6783$

$A = \frac{10.875 + 10.6783}{2} \times 6.6 = 71.1260$

$V = Q/A = 1028/71.1260 = 14.4532$

6.4' depth

$x = 10.875 - (6.4 \times 0.0298) = 10.6843$

$A = (10.6843 + 10.875)/2 \times 6.4' = 68.9897$

$V = Q/A = 1028/68.9897 = 14.9005$

6.45' depth

$x = 10.875 - (6.45 \times 0.0298) = 10.6828$

$A = \frac{10.6828 + 10.875}{2} \times 6.45 = 69.5239$

$V = Q/A = 1028/69.5239$

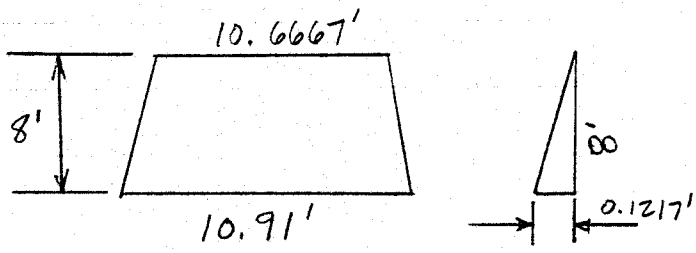
$= 14.7863$

#1248

2/14/89

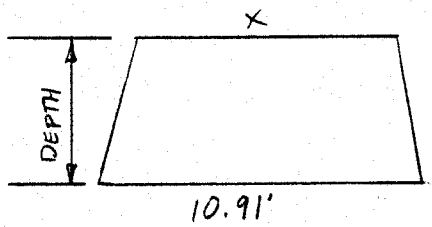
7

FIND EQUATION FOR TOP LENGTH OF 11x8 BOX CULVERT



$$\text{RATIO} = \frac{0.1217'}{8'} = 0.015213$$

$$2 \times \text{RATIO} = 0.030425$$



TOP LENGTH x = BOTTOM LENGTH − (DEPTH × 0.030425)

CHECK: DEPTH = 8'

$$x = 10.91' - (8' \times 0.030425)$$

$$= 10.6666'$$ OKAY

CROSS-SECTIONAL AREA $A = \dfrac{\text{SUM OF PARALLEL SIDES}}{2} \times \text{HEIGHT}$

ARBITRARILY CHOOSE 6' DEPTH TO START CALCS:

TOP LENGTH $x = 10.91' - (6' \times 0.0304) = 10.7276'$

AREA $A = \dfrac{10.7276' + 10.91'}{2} \times 6' = 64.9128 \text{ Ft}^2$

$V = Q/A = 1028/64.9128 = 15.8366$

6.5' DEPTH

$x = 10.91 - (6.5' \times 0.0304) = 10.7124$

$A = \dfrac{10.7124 + 10.91}{2} \times 6.5' = 70.2728$

$V = Q/A = 1028/70.2728 = 14.6287$

1248

7.00' DEPTH

$x = 10.91 - (7.00 \times 0.0304) = 10.6972$

$A = \frac{10.6972' + 10.91'}{2} \times 7.00' = 75.6252$

$V = Q/A = 1028 / 75.6252 = 13.5934$

6.75' DEPTH

$x = 10.91 - (6.75 \times 0.0304) = 10.7048$

$A = \frac{10.7048' + 10.91'}{2} \times 6.75' = 72.9500$

$V = Q/A = 1028/72.9500 = 14.0919$

6.60' Depth

$x = 10.91 - (6.60' \times 0.0304) = 10.7094$

$A = \frac{10.7094 + 10.91}{2} \times 6.60 = 71.3439$

$V = Q/A = 1028/71.3439 = 14.4091$

6.40' Depth

$x = 10.91 - (6.40' \times 0.0304) = 10.7154$

$A = \frac{10.7154 + 10.91}{2} \times 6.40 = 69.2014$

$V = Q/A = 1028/69.2014 = 14.8552$

6.55' Depth

$x = 10.91 - (6.55 \times 0.0304) = 10.7109$

$A = (10.7109 + 10.91)/2 \times 6.55' = 70.8084$

$V = Q/A = 1028/70.8084 = 14.5181$

#1248

6.53' Depth

$x = 10.91 - (6.53 \times 0.0304) = 10.7115$

$A = \frac{10.7115 + 10.91}{2} \times 6.53' = 70.5942$

$V = Q/A = 1028/70.5942 = 14.5621$

6.52' Depth

$x = 10.91 - (6.52 \times 0.0304) = 10.7118$

$A = \frac{10.7118 + 10.91}{2} \times 6.52 = 70.4870$

$V = Q/A = 1028/70.4870 = 14.5842$

6.51' Depth

$x = 10.91 - (6.51 \times 0.0304) = 10.7121$

$A = \frac{10.7121 + 10.91}{2} \times 6.51' = 70.3799$

$V = Q/A = 1028/70.3799 = 14.6064$

6.54 Depth

$x = 10.91 - (6.54 \times 0.0304) = 10.7112$

$A = \frac{10.7112 + 10.91}{2} \times 6.54' = 70.7013$

$V = Q/A = 1028/70.7013 = 14.5400$

1248
2/16/89

CALCS FOR CRITICAL DEPTH : 11 × 8 BOX CULVERT, Q = 1095 CFS

6.50' DEPTH

$x = 10.91 - (6.50 \times 0.0304) = 10.7124$

$A = \frac{10.7124 + 10.91}{2} \times 6.50' = 70.2728$

$V = Q/A = 1095/70.2728 = 15.5821$

7.00' DEPTH

$x = 10.91 - (7.00 \times 0.0304) = 10.6972$

$A = \frac{10.91 + 10.6972}{2} \times 7.00 = 75.6252$

$V = Q/A = 1095/75.6252 = 14.4793$

7.50' Depth

$x = 10.91 - (7.50' \times 0.0304) = 10.6820$

$A = \frac{10.6820 + 10.91}{2} \times 7.50' = 80.9700$

$V = Q/A = 1095/80.9700 = 13.5235$

7.25' DEPTH

$x = 10.91 - (7.25 \times 0.0304) = 10.6896$

$A = \frac{10.6896 + 10.91}{2} \times 7.25 = 78.2986$

$V = Q/A = 1095/78.2986 = 13.9849$

#1248

6.75' DEPTH

$x = 10.91 - (6.75 \times 0.0304) = 10.7048$

$A = \frac{10.7048 + 10.91}{2} \times 6.75' = 72.9500$

$V = Q/A = 1095/72.9500 = 15.0103$

6.60' DEPTH

$x = 10.91 - (6.60 \times 0.0304) = 10.7094$

$A = \frac{10.7094 + 10.91}{2} \times 6.60' = 71.3439$

$V = Q/A = 1095/71.3439 = 15.3482$

6.80' DEPTH

$x = 10.91 - (6.80' \times 0.0304) = 10.7033$

$A = \frac{10.7033 + 10.91}{2} \times 6.80' = 73.4852$

$V = Q/A = 1095/73.4852 = 14.9010$

6.90' DEPTH

$x = 10.91 - (6.90' \times 0.0304) = 10.7002$

$A = \frac{10.7002 + 10.91}{2} \times 6.90' = 74.5553$

$V = Q/A = 1095/74.5553 = 14.6871$

6.85' DEPTH

$x = 10.91 - (6.85' \times 0.0304) = 10.7018$

$A = (10.7018 + 10.91)/2 \times 6.85' = 74.0203$

$V = Q/A = 1095/74.0203 = 14.7932$

6.81' DEPTH

$x = 10.91 - (6.81 \times 0.0304) = 10.7030$

$A = \frac{10.7030' + 10.91}{2} \times 6.81 = 73.5922$

$V = Q/A = 1095/73.5922 = 14.8793$

6.82' DEPTH

$x = 10.91 - (6.82 \times 0.0304) = 10.7027$

$A = \frac{10.7027 + 10.91}{2} \times 6.82 = 73.6993$

$V = Q/A = 1095/73.6993 = 14.8577$

6.83' Depth

$x = 10.91 - (6.83 \times 0.0304) = 10.7024$

$A = \frac{10.7024 + 10.91}{2} \times 6.83 = 73.8062$

$V = Q/A = 1095/73.8062 = 14.8361$

UNION HILLS #1248 2/13/89

FIND CRITICAL DEPTH d_c IN 11x8 BOX CULVERT WITH Q=1028 CFS

d (FT)	A (Ft^2)	V (Ft/s)	$\frac{V^2}{2g}$ (ft)	E (Ft)
6.00	64.9128	15.8366	3.8944	9.8944
6.50	70.2728	14.6287	3.323	9.8230
7.00	75.6252	13.5934	2.8692	9.8692
6.75	72.9500	14.0919	3.0835	9.8335
6.60	71.3439	14.4091	3.2239	9.8239
6.40	69.2014	14.8552	3.4267	9.8267
6.55	70.8084	14.5181	3.2729	9.8229
→ 6.53	70.5942	14.5621	3.2928	9.82278 ←
6.52	70.4870	14.5842	3.3028	9.82280
6.51	70.3799	14.6064	3.3129	9.8229
6.54	70.7013	14.5400	3.2828	9.82281

NATIONAL 42-381 50 SHEETS 5 SQUARE 42-382 100 SHEETS 5 SQUARE 42-389 200 SHEETS 5 SQUARE

FIND CRITICAL DEPTH IN 11 X 7 BOX CULVERT W/ Q = 1028

d (ft)	A (ft²)	V (ft/s)	V²/2g (ft)	E (ft)
6.7	72.1936	14.2395	3.1485	9.8485
6.8	73.2610	14.0320	3.0574	9.8574
6.6	71.1260	14.4532	3.2437	9.8437
6.5	70.0580	14.6736	3.3434	9.8434
6.4	68.9897	14.9008	3.4477	9.8477
6.45	69.5239	14.7863	3.3949	9.8449
6.55	70.5920	14.5626	3.2930	9.842982
6.58	70.9124	14.4968	3.2633	9.8433
6.52	70.2716	14.6290	3.3231	9.8431
6.53	70.3784	14.6068	3.3130	9.843001
→ 6.54	70.4852	14.5846	3.3030	9.842969 ←

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE
NATIONAL

CRITICAL DEPTHS

FIND CRITICAL DEPTH d_c IN 11x7 BOX CULVERT W/Q= 1095

d (Ft)	A (Ft²)	V (Ft/s)	$\frac{V^2}{2g}$ (Ft)	E (Ft)
6.0	64.714	16.921	4.446	10.446
6.1	65.783	16.646	4.302	10.402
6.2	66.852	16.379	4.166	10.366
6.3	67.921	16.122	4.036	10.336
6.5	70.057	15.630	3.794	10.294
6.7	72.194	15.168	3.572	10.2723
6.9	74.328	14.732	3.370	10.2700
6.95	74.867	14.627	3.322	10.2722
6.92	74.542	14.690	3.351	10.2708
6.88	74.115	14.774	3.390	10.2695
6.8	73.261	14.947	3.469	10.2689
6.75	72.727	15.056	3.520	10.2700
6.79	73.154	14.968	3.479	10.2691
6.81	73.3677	14.925	3.459	10.2689
6.85	73.7946	14.838	3.419	10.2690
6.83	73.5812	14.882	3.439	10.268815
6.84	73.6879	14.860	3.429	10.2689
→ 6.82	73.4745	14.903	3.449	10.268812 ←

NATIONAL 42-381 50 SHEETS 5 SQUARE 42-382 100 SHEETS 5 SQUARE 42-389 200 SHEETS 5 SQUARE

UNION HILLS #1248 2/15/89

FIND CRITICAL DEPTH d_c IN 11x8 BOX CULVERT WITH Q = 1095 CFS

d (Ft)	A (Ft²)	V (Ft/s)	$\frac{V^2}{2g}$ (ft)	E (Ft)
6.50	70.2728	15.5821	3.7702	10.2702
7.00	75.6252	14.4793	3.2554	10.2554
7.50	80.9700	13.5235	2.8398	10.3398
7.25	78.2986	13.9849	3.0369	10.2869
6.75	72.9500	15.0103	3.4986	10.2486
6.60	71.3439	15.3482	3.6579	10.2579
6.80	73.4852	14.9010	3.4478	10.24781
6.90	74.5553	14.6871	3.3495	10.2495
6.85	74.0203	14.7932	3.3981	10.2481
→ 6.81	73.5922	14.8793	3.4378	10.24779 ←
6.82	73.6993	14.8577	3.4278	10.24781
6.83	73.8062	14.8361	3.4179	10.24788

12 - DC