MAJOR TRUNK STORM SEWER
9TH STREET
FROM
BELL ROAD TO UNION HILLS DRIVE
INDEX NO. ST-887299

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DRAINAGE REPORT

PREPARED FOR
THE CITY OF PHOENIX, ARIZONA

PREPARED BY
EVANS, KUHN & ASSOCIATES, INC.
727 EAST BETHANY HOME ROAD
SUITE D-225
PHOENIX, ARIZONA 85014

EKA# 3097
MAY 3, 1993

Registered Professional Engineer (Civil)
CERTIFICATE NO.
13483
BRUCE J.
FRIEDHOFF
5/3/93
Date Signed
ARIZONA, U.S.A.

EVANS, KUHN & ASSOCIATES, INC.

EVANS, KUHN & ASSOCIATES, INC.

GEORGE L. EVANS, P.E.
JOHN D. KUHN, JR., P.E.

CONSULTING ENGINEERS
727 East Bethany Home Road, Suite D-225
Phoenix, Arizona 85014
(602) 241-0782
FAX NUMBER (602) 248-9158

RECEIVED
CITY OF PHOENIX
STREET TRANSPORTATION
DCM DIVISION
MAY 19 11 58 AM '93

May 19, 1993

Mr. Ralph Goodall
City of Phoenix, Street Transportation Department
Design & Construction Management Division
1034 East Madison Street
Phoenix, Arizona 85034-2292

Re: Major Trunk Storm Sewer
9th Street from Bell Road to Union Hills
Index No. ST-887299
Drainage Report Addendum No. 1
EKA# 3097

Dear Mr. Goodall:

Enclosed herewith for your use are revised CMP structural design calculations. Adding a second iteration using the thickness required for a 75-year first perforation results in the following acceptable design specifications:

Diameter	Corrugation	Thickness
114"	3" X 1"	0.109"
102"	3" X 1"	0.109"
90"	3" X 1"	0.109"
78"	3" X 1"	0.109"
66"	2 2/3" X 1/2"	0.109"

If you have any question please call.

Very truly yours,

EVANS, KUHN & ASSOCIATES, INC.

Bruce J. Friedhoff, P.E.
Project Manager

Enclosures
3097PC1.305/ADMIN1/dma

Rudy: 5-20

Please securely attach this to the FINAL DRAIN. REPORT for 9 ST- B to UH.

RLG

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		1	
LOCATION:		STA 13+50	
d = Pipe diameter	=	102	in
h = Height of cover	=	9	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1260 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	20.58	ft
W = Width of Plane	=	21.42	ft
Pavg = Average Pressure Acting on Plane = P * IF / (W * L)	=	109	psf
LL = Live load	=	109	psf

Compute the design load,

pv = Design pressure = DL + LL = 1369 psf

Structure design,

s = Span = d/12	=	8.5	ft
c = Ring compression = pv * s/2	=	5818	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1275	2333	2.494	0.168	0.020	0.212
2x1/2	0.170	600	10534	0.552	0.052	0.018	0.226
2-2/3x1/2	0.172	593	10784	0.540	0.052	0.018	0.231
3 x 1	0.344	297	25291	0.230	0.034	0.051	0.081
5 x 1	0.368	277	25385	0.229	0.064	0.106	0.039
6 x 2	0.688	148	25385	0.229	0.109	0.725	0.006

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 7.8

R = Soil resistivity = 3350 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 82 years

af = Adjustment factor required = y / y1 = 1.83

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1275	2333	2.494	0.109	0.010	0.404
2x1/2	0.170	600	10534	0.552	0.109	0.042	0.098
2-2/3x1/2	0.172	593	10784	0.540	0.109	0.041	0.101
3 x 1	0.344	297	25291	0.230	0.109	0.185	0.022
5 x 1	0.368	277	25385	0.229	0.109	0.188	0.022
6 x 2	0.688	148	25385	0.229	0.109	0.725	0.006

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

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Re: Handbook of Steel Drainage and Highway Construction Products,
American and Steel Institute, 1983, Chapter 3, Pages 99-124.

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Site conditions,

PIPE RECORD NUMBER:		2	
LOCATION:		STA 18+50	
d = Pipe diameter	=	102	in
h = Height of cover	=	9	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1260 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from
Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	20.58	ft
W = Width of Plane	=	21.42	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	109	psf
LL = Live load	=	109	psf

Compute the design load,

pv = Design pressure = DL + LL = 1369 psf

Structure design,

s = Span = d/12	=	8.5	ft
c = Ring compression = pv * s/2	=	5818	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1275	2333	2.494	0.168	0.020	0.212
2x1/2	0.170	600	10534	0.552	0.052	0.018	0.226
2-2/3x1/2	0.172	593	10784	0.540	0.052	0.018	0.231
3 x 1	0.344	297	25291	0.230	0.034	0.051	0.081
5 x 1	0.368	277	25385	0.229	0.064	0.106	0.039
6 x 2	0.688	148	25385	0.229	0.109	0.725	0.006

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 7.8

R = Soil resistivity = 3350 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 82 years

af = Adjustment factor required = y / y1 = 1.83

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1275	2333	2.494	0.109	0.010	0.404
2x1/2	0.170	600	10534	0.552	0.109	0.042	0.098
2-2/3x1/2	0.172	593	10784	0.540	0.109	0.041	0.101
3 x 1	0.344	297	25291	0.230	0.109	0.185	0.022
5 x 1	0.368	277	25385	0.229	0.109	0.188	0.022
6 x 2	0.688	148	25385	0.229	0.109	0.725	0.006

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		3	
LOCATION:		STA 23+45	
d = Pipe diameter	=	102	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	8.5	ft
c = Ring compression = pv * s/2	=	6344	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1275	2333	2.720	0.168	0.020	0.212
2x1/2	0.170	600	10534	0.602	0.052	0.018	0.226
2-2/3x1/2	0.172	593	10784	0.588	0.052	0.018	0.231
3 x 1	0.344	297	25291	0.251	0.034	0.051	0.081
5 x 1	0.368	277	25385	0.250	0.064	0.106	0.039
6 x 2	0.688	148	25385	0.250	0.109	0.725	0.006

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 9.2

R = Soil resistivity = 3930 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 88 years

af = Adjustment factor required = y / y1 = 1.71

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1275	2333	2.720	0.109	0.010	0.404
2x1/2	0.170	600	10534	0.602	0.109	0.042	0.098
2-2/3x1/2	0.172	593	10784	0.588	0.109	0.041	0.101
3 x 1	0.344	297	25291	0.251	0.109	0.185	0.022
5 x 1	0.368	277	25385	0.250	0.109	0.188	0.022
6 x 2	0.688	148	25385	0.250	0.109	0.725	0.006

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street — EK3097
Corrugated Metal Pipe — 05/18/93
Structural Design — BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		4	
LOCATION:		STA 28+45.71, 33.2	
d = Pipe diameter	=	66	in
h = Height of cover	=	11.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1610	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.95	ft
W = Width of Plane	=	25.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	75	psf
LL = Live load	=	75	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1685	psf

Structure design,

s = Span = d/12	=	5.5	ft
c = Ring compression = pv * s/2	=	4633	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2
ff = Flexibility factor = d^2/E/I*12	< .0433 for factory made pipe.		
	< .0200 for field assembled pip		

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	825	5572	0.831	0.079	0.007	0.256
2x1/2	0.170	388	21378	0.217	0.034	0.002	0.968
2-2/3x1/2	0.172	384	21595	0.215	0.034	0.011	0.156
3 x 1	0.344	192	25385	0.182	0.034	0.051	0.034
5 x 1	0.368	179	25385	0.182	0.064	0.106	0.016
6 x 2	0.688	96	25385	0.182	0.109	0.725	0.002

t = Minimum thickness for strength = 0.034 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 9.2

R = Soil resistivity = 3930 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 88 years

af = Adjustment factor required = y / y1 = 1.71

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	825	5572	0.831	0.109	0.010	0.169
2x1/2	0.170	388	21378	0.217	0.109	0.042	0.041
2-2/3x1/2	0.172	384	21595	0.215	0.109	0.041	0.042
3 x 1	0.344	192	25385	0.182	0.109	0.185	0.009
5 x 1	0.368	179	25385	0.182	0.109	0.188	0.009
6 x 2	0.688	96	25385	0.182	0.109	0.725	0.002

Use for Design: Corrugation = 2x1/2 in

Thickness = 0.109 in

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		5	
LOCATION:		STA 31+00	
d = Pipe diameter	=	114	in
h = Height of cover	=	7.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1050	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	17.95	ft
W = Width of Plane	=	18.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	142	psf
LL = Live load	=	142	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1192	psf

Structure design,

s = Span = d/12	=	9.5	ft
c = Ring compression = pv * s/2	=	5663	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1425	1868	3.032	0.168	0.020	0.265
2x1/2	0.170	671	8433	0.672	0.064	0.023	0.223
2-2/3x1/2	0.172	663	8633	0.656	0.064	0.023	0.229
3 x 1	0.344	331	23926	0.237	0.034	0.051	0.101
5 x 1	0.368	310	24780	0.229	0.064	0.106	0.049
6 x 2	0.688	166	25385	0.223	0.109	0.725	0.007

t = Minimum thickness for strength = 0.109 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 9.3

R = Soil resistivity = 2440 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 72 years

af = Adjustment factor required = y / y1 = 2.08

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1425	1868	3.032	0.109	0.010	0.505
2x1/2	0.170	671	8433	0.672	0.109	0.042	0.122
2-2/3x1/2	0.172	663	8633	0.656	0.109	0.041	0.126
3 x 1	0.344	331	23926	0.237	0.109	0.185	0.028
5 x 1	0.368	310	24780	0.229	0.109	0.188	0.028
6 x 2	0.688	166	25385	0.223	0.109	0.725	0.007

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		6	
LOCATION:		STA 37+50	
d = Pipe diameter	=	114	in
h = Height of cover	=	10.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1470	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	23.20	ft
W = Width of Plane	=	24.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	86	psf
LL = Live load	=	86	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1556	psf

Structure design,

s = Span = d/12	=	9.5	ft
c = Ring compression = pv * s/2	=	7391	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1425	1868	3.958	0.168	0.020	0.265
2x1/2	0.170	671	8433	0.876	0.079	0.029	0.176
2-2/3x1/2	0.172	663	8633	0.856	0.079	0.029	0.181
3 x 1	0.344	331	23926	0.309	0.034	0.051	0.101
5 x 1	0.368	310	24780	0.298	0.064	0.106	0.049
6 x 2	0.688	166	25385	0.291	0.109	0.725	0.007

t = Minimum thickness for strength = 0.109 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y =	Years for first perforation =	= 75	
y =	Years for average life = 2 * Y	= 150	
pH =	pH of soil environment	= 9.3	
R =	Soil resistivity	= 2440	ohm-cm
y1 =	Years for average life for t=.052 in.		
	= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3		
	= 2.94 * R^.41, pH>7.3	= 72	years
af =	Adjustment factor required = y / y1	= 2.08	
	Adjustment Factor Used :	2.2	
	Corresponding t:	0.109	in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1425	1868	3.958	0.109	0.010	0.505
2x1/2	0.170	671	8433	0.876	0.109	0.042	0.122
2-2/3x1/2	0.172	663	8633	0.856	0.109	0.041	0.126
3 x 1	0.344	331	23926	0.309	0.109	0.185	0.028
5 x 1	0.368	310	24780	0.298	0.109	0.188	0.028
6 x 2	0.688	166	25385	0.291	0.109	0.725	0.007

Use for Design: Corrugation = 3 x 1 in
Thickness = 0.109 in

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		7	
LOCATION:		STA 37+50	
d = Pipe diameter	=	90	in
h = Height of cover	=	10.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1470	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	23.20	ft
W = Width of Plane	=	24.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	86	psf
LL = Live load	=	86	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1556	psf

Structure design,

s = Span = d/12	=	7.5	ft
c = Ring compression = pv * s/2	=	5835	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1125	2996	1.947	0.168	0.020	0.165
2x1/2	0.170	529	13531	0.431	0.040	0.014	0.236
2-2/3x1/2	0.172	523	13851	0.421	0.040	0.013	0.240
3 x 1	0.344	262	25385	0.230	0.034	0.051	0.063
5 x 1	0.368	245	25385	0.230	0.064	0.106	0.031
6 x 2	0.688	131	25385	0.230	0.109	0.725	0.004

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 9.3

R = Soil resistivity = 2440 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 72 years

af = Adjustment factor required = y / y1 = 2.08

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1125	2996	1.947	0.109	0.010	0.315
2x1/2	0.170	529	13531	0.431	0.109	0.042	0.076
2-2/3x1/2	0.172	523	13851	0.421	0.109	0.041	0.079
3 x 1	0.344	262	25385	0.230	0.109	0.185	0.017
5 x 1	0.368	245	25385	0.230	0.109	0.188	0.017
6 x 2	0.688	131	25385	0.230	0.109	0.725	0.004

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		8	
LOCATION:		STA 40+00	
d = Pipe diameter	=	90	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	7.5	ft
c = Ring compression = pv * s/2	=	5598	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1125	2996	1.868	0.168	0.020	0.165
2x1/2	0.170	529	13531	0.414	0.040	0.014	0.236
2-2/3x1/2	0.172	523	13851	0.404	0.040	0.013	0.240
3 x 1	0.344	262	25385	0.221	0.034	0.051	0.063
5 x 1	0.368	245	25385	0.221	0.064	0.106	0.031
6 x 2	0.688	131	25385	0.221	0.109	0.725	0.004

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 8.9

R = Soil resistivity = 2200 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 69 years

af = Adjustment factor required = y / y1 = 2.17

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1125	2996	1.868	0.109	0.010	0.315
2x1/2	0.170	529	13531	0.414	0.109	0.042	0.076
2-2/3x1/2	0.172	523	13851	0.404	0.109	0.041	0.079
3 x 1	0.344	262	25385	0.221	0.109	0.185	0.017
5 x 1	0.368	245	25385	0.221	0.109	0.188	0.017
6 x 2	0.688	131	25385	0.221	0.109	0.725	0.004

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		9	
LOCATION:		STA 45+00	
d = Pipe diameter	=	90	in
h = Height of cover	=	9.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1330 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	21.45	ft
W = Width of Plane	=	22.29	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	100	psf
LL = Live load	=	100	psf

Compute the design load,

pv = Design pressure = DL + LL = 1430 psf

Structure design,

s = Span = d/12	=	7.5	ft
c = Ring compression = pv * s/2	=	5364	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1125	2996	1.790	0.168	0.020	0.165
2x1/2	0.170	529	13531	0.396	0.034	0.002	1.800
2-2/3x1/2	0.172	523	13851	0.387	0.034	0.011	0.289
3 x 1	0.344	262	25385	0.211	0.034	0.051	0.063
5 x 1	0.368	245	25385	0.211	0.064	0.106	0.031
6 x 2	0.688	131	25385	0.211	0.109	0.725	0.004

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 8.9

R = Soil resistivity = 2200 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 69 years

af = Adjustment factor required = y / y1 = 2.17

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1125	2996	1.790	0.109	0.010	0.315
2x1/2	0.170	529	13531	0.396	0.109	0.042	0.076
2-2/3x1/2	0.172	523	13851	0.387	0.109	0.041	0.079
3 x 1	0.344	262	25385	0.211	0.109	0.185	0.017
5 x 1	0.368	245	25385	0.211	0.109	0.188	0.017
6 x 2	0.688	131	25385	0.211	0.109	0.725	0.004

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		10	
LOCATION:		STA 56+00	
d = Pipe diameter	=	78	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	6.5	ft
c = Ring compression = pv * s/2	=	4852	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	975	3989	1.216	0.109	0.010	0.236
2x1/2	0.170	459	17652	0.275	0.034	0.002	1.352
2-2/3x1/2	0.172	453	17956	0.270	0.034	0.011	0.217
3 x 1	0.344	227	25385	0.191	0.034	0.051	0.047
5 x 1	0.368	212	25385	0.191	0.064	0.106	0.023
6 x 2	0.688	113	25385	0.191	0.109	0.725	0.003

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 8.9

R = Soil resistivity = 2200 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 69 years

af = Adjustment factor required = y / y1 = 2.17

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	975	3989	1.216	0.109	0.010	0.236
2x1/2	0.170	459	17652	0.275	0.109	0.042	0.057
2-2/3x1/2	0.172	453	17956	0.270	0.109	0.041	0.059
3 x 1	0.344	227	25385	0.191	0.109	0.185	0.013
5 x 1	0.368	212	25385	0.191	0.109	0.188	0.013
6 x 2	0.688	113	25385	0.191	0.109	0.725	0.003

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
05/18/93
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		11	
LOCATION:		STA 59+61.60	
d = Pipe diameter	=	78	in
h = Height of cover	=	11.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1610 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.95	ft
W = Width of Plane	=	25.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	75	psf
LL = Live load	=	75	psf

Compute the design load,

pv = Design pressure = DL + LL = 1685 psf

Structure design,

s = Span = d/12	=	6.5	ft
c = Ring compression = pv * s/2	=	5475	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	975	3989	1.372	0.138	0.014	0.168
2x1/2	0.170	459	17652	0.310	0.034	0.002	1.352
2-2/3x1/2	0.172	453	17956	0.305	0.034	0.011	0.217
3 x 1	0.344	227	25385	0.216	0.034	0.051	0.047
5 x 1	0.368	212	25385	0.216	0.064	0.106	0.023
6 x 2	0.688	113	25385	0.216	0.109	0.725	0.003

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y =	Years for first perforation =	= 75	
y =	Years for average life = 2 * Y	= 150	
pH =	pH of soil environment	= 8	
R =	Soil resistivity	= 3670	ohm-cm
y1 =	Years for average life for t=.052 in.		
	= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3		
	= 2.94 * R^.41, pH>7.3	= 85	years
af =	Adjustment factor required = y / y1	= 1.76	
	Adjustment Factor Used :	2.2	
	Corresponding t:	0.109	in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	975	3989	1.372	0.109	0.010	0.236
2x1/2	0.170	459	17652	0.310	0.109	0.042	0.057
2-2/3x1/2	0.172	453	17956	0.305	0.109	0.041	0.059
3 x 1	0.344	227	25385	0.216	0.109	0.185	0.013
5 x 1	0.368	212	25385	0.216	0.109	0.188	0.013
6 x 2	0.688	113	25385	0.216	0.109	0.725	0.003

Use for Design: Corrugation = 3 x 1 in
Thickness = 0.109 in

9th Street EK3097
Corrugated Metal Pipe 05/18/93
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		12	
LOCATION:		CL STA 59+76.47	
d = Pipe diameter	=	78	in
h = Height of cover	=	12.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1750 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	26.70	ft
W = Width of Plane	=	27.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	65	psf
LL = Live load	=	65	psf

Compute the design load,

pv = Design pressure = DL + LL = 1815 psf

Structure design,

s = Span = d/12	=	6.5	ft
c = Ring compression = pv * s/2	=	5900	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	975	3989	1.479	0.138	0.014	0.168
2x1/2	0.170	459	17652	0.334	0.034	0.002	1.352
2-2/3x1/2	0.172	453	17956	0.329	0.034	0.011	0.217
3 x 1	0.344	227	25385	0.232	0.034	0.051	0.047
5 x 1	0.368	212	25385	0.232	0.064	0.106	0.023
6 x 2	0.688	113	25385	0.232	0.109	0.725	0.003

t = Minimum thickness for strength = 0.064 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 8

R = Soil resistivity = 3670 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 85 years

af = Adjustment factor required = y / y1 = 1.76

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	975	3989	1.479	0.109	0.010	0.236
2x1/2	0.170	459	17652	0.334	0.109	0.042	0.057
2-2/3x1/2	0.172	453	17956	0.329	0.109	0.041	0.059
3 x 1	0.344	227	25385	0.232	0.109	0.185	0.013
5 x 1	0.368	212	25385	0.232	0.109	0.188	0.013
6 x 2	0.688	113	25385	0.232	0.109	0.725	0.003

Use for Design: Corrugation = 3 x 1 in

Thickness = 0.109 in

9th Street — EK3097
Corrugated Metal Pipe — 05/18/93
Structural Design — BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		13	
LOCATION:		CL STA 23+45, STUB	
d = Pipe diameter	=	66	in
h = Height of cover	=	11.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1610	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.95	ft
W = Width of Plane	=	25.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	75	psf
LL = Live load	=	75	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1685	psf

Structure design,

s = Span = d/12	=	5.5	ft
c = Ring compression = pv * s/2	=	4633	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pip

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	825	5572	0.831	0.079	0.007	0.256
2x1/2	0.170	388	21378	0.217	0.034	0.002	0.968
2-2/3x1/2	0.172	384	21595	0.215	0.034	0.011	0.156
3 x 1	0.344	192	25385	0.182	0.034	0.051	0.034
5 x 1	0.368	179	25385	0.182	0.064	0.106	0.016
6 x 2	0.688	96	25385	0.182	0.109	0.725	0.002

t = Minimum thickness for strength = 0.034 in

Select thickness for a 75-year first perforation or 1/2 average life,

Y = Years for first perforation = = 75

y = Years for average life = 2 * Y = 150

pH = pH of soil environment = 9.2

R = Soil resistivity = 3930 ohm-cm

y1 = Years for average life for t=.052 in.

= 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3

= 2.94 * R^.41, pH>7.3 = 88 years

af = Adjustment factor required = y / y1 = 1.71

Adjustment Factor Used : 2.2

Corresponding t: 0.109 in.

Select Corrugation for Minimum Thickness of 0.109 in.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	825	5572	0.831	0.109	0.010	0.169
2x1/2	0.170	388	21378	0.217	0.109	0.042	0.041
2-2/3x1/2	0.172	384	21595	0.215	0.109	0.041	0.042
3 x 1	0.344	192	25385	0.182	0.109	0.185	0.009
5 x 1	0.368	179	25385	0.182	0.109	0.188	0.009
6 x 2	0.688	96	25385	0.182	0.109	0.725	0.002

Use for Design: Corrugation = 2x1/2 in

Thickness = 0.109 in

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A. List of Research Documents

B. Drainage Calculations

1. Hydraulic Grade Line Profile Calculations
2. Inlet Calculations
3. Slotted Drain Collector Pipe Capacity Calculations
4. Connector Pipe Calculations
5. Main Line D-Load Calculations
6. Connector Pipe D-Load Calculations
7. Main Line CMP Calculations
8. Connector Pipe CMP Calculations
9. Slotted Drain Pipe CMP Calculations

Registered Professional Engineer (Civil)
CERTIFICATE NO.
13483
BRUCE J.
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Date Signed 5/3/93
ARIZONA, U.S.A.

I. Introduction

City of Phoenix project St-887299 is a major trunk storm drain in 9th Street between Bell Road and Union Hills Drive. The storm drain and catch basin system have been designed to intercept the two year storm. The drain has also been designed to provide the outfall system for two detention basins; Basin No. 2 (ST-896803), located at 9th Street and Union Hills Drive, and Basin No. 5 (ST-896837), located at 9th Street and Campo Bello Drive. For the 100 year storm, the outflow from Basin 5 will be 295 cfs and the outflow from Basin No. 2 will be 336 cfs. This storm drain will connect to what will be an existing drain in Bell Road (P-860981).

II. Main Trunk Sewer HGL

Two separate segments were used to compute the HGL profile for 9th Street. The first segment extends from the beginning project Station 12+55 (just north of Bell Road) to Detention Basin No. 5. A fixed invert of 1365.60 and HGL elevation of 1381.83 at Station 12+55 were taken from MCHD Project No. 68553 and C.O.P. No. P-860981 by John Carollo Engineers, February, 1990. An invert elevation of 1372.00 was provided for Detention Basin No. 5 by Project Engineering consultants, Ltd. It was necessary to lower this elevation 1' from 1372.00 to 1371.00 in order to accommodate a 24" water line north of the basin which could not be relocated.

The second segment extends from Basin No. 5 to Basin No. 2. The segment was designed with a starting invert elevation at Basin 5 of 1371.00 (lowered from 1372.00 as mentioned previously) and an ending invert elevation of 1389.00 at Basin No. 2 provided by HDR Engineering, Inc. A High Water Level of 1386.00 at Detention Basin No. 5 taken from the Preliminary System Layout by NBS/Lowry Engineering was also used as a basis of design. The critical section of this design is the segment from Detention Basin No. 5 to Station 31+00 where the HGL is less than two feet below the finished grade. Subsequent contact with Project Engineering Consultants, Ltd. indicated that the Highwater Level for Basin No. 5 had been raised from 1386.00 to 1388.00. This increase would raise the HGL by two feet throughout this segment and cause the HGL to be above ground in the critical section mentioned previously. Therefore, the system was designed using 1386.00 as the HWL for Detention Basin No. 5.

III. Inlets

Location and sizing of inlets is based on the City of Phoenix Storm Drain Manual. The drainage area for the project was delineated and broken into 12 sub areas, each contributing to an inlet. Two M-1-P-1569 (L=10') inlets have been placed near the intersection of 9th Street and Grovers Avenue. All remaining inlets consist of 40' slotted drains connected to modified Type N Catch Basins located in the inverted crown of the street.

IV. Connector Pipes

Calculations followed the City of Phoenix procedure for connector pipe design. It was determined that 15" reinforced concrete connector pipes would be adequate for 8 of the inlets while the other four would require 18" pipes.

V. D-Loads

Calculations were performed following the new City of Phoenix guidelines which assume a positive projection condition. This procedure was based on information from the Concrete Pipe Handbook and Concrete Pipe Design Manual as included in the list of reference documents. Values for Ku, Weight of soil, Coefficient of Friction, settlement ratio, projection ratio and factor of safety supplied by the City were used. The D-Loads calculated using this positive projection condition assumption were then compared to D-Loads calculated assuming trench conditions at the transition width. In all cases, the trench condition produced the higher D-Load which was included in the alternate pipe chart. Calculations were performed for both the main line and the connector pipes.

VI. Corrugated Metal Pipe

Calculations for the minimum gage of corregated metal pipe to be used were performed using the new City of Phoenix guidelines based on information contained in the Handbook of Steel Drainage and Highway Construction Products, as included in the list of reference documents. Minimum thicknesses for strength and for a 75-year first perforation were computed separately and then compared. The thicker of the two was then used to specify the minimum gage required. Calculations were performed for the main line, connector pipes and slotted drain pipes.

APPENDIX A

9th Street Major Trunk Sewer
List of Reference Documents

1. City of Phoenix Engineering Department Administrative Procedures No. 13 and No. 55.

2. Preliminary System Layout of North Central Master Storm Drainage by NBS/Lowry Engineering, 9/13/89.

3. Soils Report by Thomas - Hartig and Associates.

4. City of Phoenix Storm Drain Manual, 1987 Revised Edition.

5. Evans, Kuhn & Associates, Inc., Field Notes.

6. Concrete Pipe Handbook, American Concrete Pipe Association, 1988.

7. Concrete Pipe Design Manual, American Concrete Pipe Association, 1987.

8. Handbook ot Steel Drainage and Highway Construction Products, American Iron and Steel Institute, 1983 Third Edition.

9. Project Engineering Consultants, LTD. - Information pertaining to Detention Basin No. 5.

10. HDR Engineering, Inc. - Information Pertaining to Detention Basin No. 2.

11. City of Phoenix Official 1/4 Section Maps - 37-29, 38-29.

12. City of Phoenix Official Contour Maps - 37-29, 38-29.

13. Southwest Gas Distribution - 37-29, 38-29.

14. Underground Electric Distribution - 37-29, 38-29.

15. Mountain Bell - Buried Facility maps - 37-29, 38-29.

16. City of Phoenix Water 1/4 Section Maps - 37-29, 38-29.

17. City of Phoenix Sewer 1/4 Section Maps - 37'29, 38-29.

18. City of Phoenix Right-Of-Way maps - 37-29, 38-29.

19. Handbook ot Hydraulics, Horace King and Ernest Brater, McGraw Hill, 1963, Fifth Edition, pp. 6-14.

APPENDIX B

9th Street Major Storm Trunk Sewer — EK3097
Bell Road to Basin No. 5 — 7/2/91
ST-887299 — BJF
Table No. 1. Site Data

Point No.	Station	Length (Ft)	Pipe Diameter (In)	Type of Pipe	Pipe Thickness (In)	Flow (Cfs)	Pipe N-Value	Ke	Finished Grade (Elev)	Pipe Slope (Ft/Ft)
Starting EGL =			1382.36							
Starting HGL =			1381.83							
Starting Invert Elev. =			1365.50							
1	12 + 55.00								1382.70	
		5.00	96	rcp	9.50	295	0.013			0.00160
2	12 + 60.00								1382.70	
		90.00	96	rcp	9.50	295	0.013			0.00160
3	13 + 50.00								1383.00	
		500.00	96	rcp	9.50	295	0.013			0.00160
4	18 + 50.00								1384.00	
		290.00	96	rcp	9.50	295	0.013			0.00160
5	21 + 40.00								1384.70	
		205.00	96	rcp	9.50	295	0.013			0.00160
6	23 + 45.00								1385.30	
		255.00	60	rcp	6.50	79	0.013			0.00080
7	26 + 00.00								1386.30	
		253.54	60	rcp	6.50	79	0.013			0.00080
8	28 + 53.54								1387.40	
		85.60	60	rcp	6.50	79	0.013			0.00409
9	29 + 39.14							0.50	1387.50	

Ke = Entrance + Exit Loss Coeficients

$Q = \frac{1.486}{n} A R^{2/3} S_f^{1/2}$

$\frac{Q \times n}{1.486 \times A \times R^{2/3}} = (S_f)^{1/2} = S_f$

$A = 50.27\ ft^2$

$R = D/4 = \frac{(96/12)}{4} = 2\ ft$

$S_f = .001$

$h_f = S_f \times L$

$= .001 \times 5$

$= .0052$

9th Street Major Storm Trunk Sewer — EK3097
Bell Road to Basin No. 5 — 7/2/91
ST-887299 — BJF

Table No. 2. Hydraulic Profile Design Calculation

Point No.	v (Fps)	hv (Ft)	he (Ft)	s (Ft/Ft)	hl (Ft)	H (Ft)	EGL (Elev)	EGL (Elev)	HGL (Elev)	HGL (Elev)
1							1382.36	1382.36	1381.83	1381.83
	5.87	0.53		0.00105	0.01	0.01				
2							1382.37	1382.37	1381.83	1381.83
	5.87	0.53		0.00105	0.09	0.09				
3							1382.46	1382.46	1381.92	1381.92
	5.87	0.53		0.00105	0.52	0.52				
4							1382.98	1382.98	1382.45	1382.45
	5.87	0.53		0.00105	0.30	0.30				
5							1383.29	1383.29	1382.75	1382.75
	5.87	0.53		0.00105	0.21	0.21				
6							1383.50	1383.50	1382.97	1383.25
	4.02	0.25		0.00092	0.23	0.23				
7							1383.73	1383.73	1383.48	1383.48
	4.02	0.25		0.00092	0.23	0.23				
8							1383.97	1383.97	1383.72	1383.72
	4.02	0.25		0.00092	0.08	0.08				
9							1384.05	1384.05	1383.80	1384.05

Friction Slope, $Sf = 4.66 * n^2 * Q \div ((d/1)^{(16/3)})$
Velocity, $v = Q / (\pi(d/12)^2/4)$
Velocity Head, $hv = v^2 \div 2g$
Pipe Loss, $hl = Sf * l$

$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$

$\frac{Q \times n}{1.486 \times A \times R^{2/3}} = S^{1/2}$

$Q = VA \therefore V = \frac{295}{50.27} = 5.87$ fps

9th Street Major Storm Trunk Sewer — EK3097
Bell Road to Basin No. 5 — 7/2/91
ST-887299 — BJF

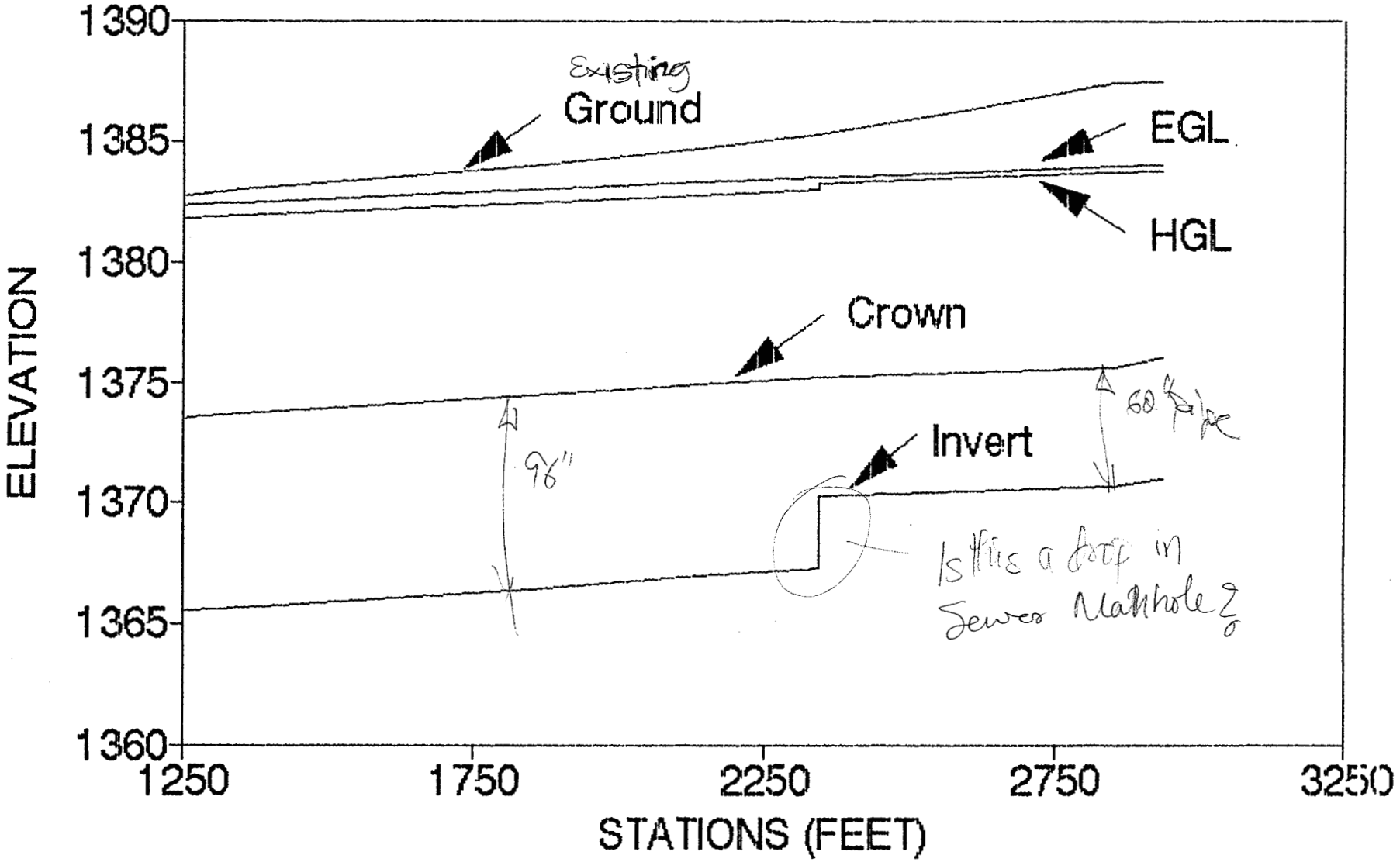
Table No. 3. Pipe Design Data.

Point No.	Pipe Slope (Ft/Ft)	Crown (Elev)	Outlet Invert (Elev)	Inlet Invert (Elev)	Top of Pipe (Elev)	Pipe Cover (Ft)	FG-HGL (Ft)	HGL-Crown (Ft)
1		1373.50			1374.29	8.41	0.87	8.33
	0.00160		1365.50	1365.51				
2		1373.51			1374.30	8.40	0.87	8.32
	0.00160		1365.51	1365.65				
3		1373.65			1374.44	8.56	1.08	8.27
	0.00160		1365.65	1366.45				
4		1374.45			1375.24	8.76	1.55	8.00
	0.00160		1366.45	1366.92				
5		1374.92			1375.71	8.99	1.95	7.83
	0.00160		1366.92	1367.24				
6		1375.24			1375.79	9.51	2.33	8.00
	0.00080		1370.24	1370.45				
7		1375.45			1375.99	10.31	2.82	8.04
	0.00080		1370.45	1370.65				
8		1375.65			1376.19	11.21	3.68	8.07
	0.00409		1370.65	1371.00				
9		1376.00			1376.00	11.50	3.70	8.05

(1) Starting invert elevation = 1365.50 taken from City of Phoenix Project P-860981

HYDRAULIC PROFILE

BELL ROAD TO BASIN NO. 5



9th Street Major Storm Trunk Sewer
Basin No. 5 to Basin No. 2
ST-887299
Table No. 1. Site Data

EK3097
7/17/91
BJF

Point No.	Station	Length (Ft)	Pipe Diameter (In)	Type of Pipe	Pipe Thickness (In)	Flow (Cfs)	Pipe N-Value	Ke	Finished Grade (Elev)	Pipe Slope (Ft/Ft)
Starting EGL =			1386.00							
Starting HGL =			1386.00							
Starting Invert Elev. =			1371.00							
1	28 + 69.86							1.00	1387.80	
		85.60	108	rcp	10.00	636	0.013			0.00100
2	29 + 55.46								1387.80	
		89.44	108	rcp	10.00	636	0.013			0.00100
3	30 + 44.90								1388.20	
		55.10	108	rcp	10.00	636	0.013			0.00100
4	31 + 00.00								1388.50	
		521.00	108	rcp	10.00	636	0.013			0.00100
5	36 + 21.00								1391.20	
		44.00	108	rcp	10.00	636	0.013			0.00100
6	36 + 65.00								1391.50	
		35.00	108	rcp	10.00	636	0.013			0.00100
7	37 + 00.00								1391.69	
		50.00	108	rcp	10.00	636	0.013			0.00100
8	37 + 50.00								1391.90	
		250.00	84	rcp	8.75	456	0.013			0.00600
9	40 + 00.00								1393.00	
		300.00	84	rcp	8.75	456	0.013			0.00600
10	43 + 00.00								1394.70	
		200.00	84	rcp	8.75	456	0.013			0.00600
11	45 + 00.00								1395.54	
		200.00	84	rcp	8.75	456	0.013			0.00600
12	47 + 00.00								1396.38	
		300.00	84	rcp	8.75	456	0.013			0.00600
13	50 + 00.00								1397.86	
		10.00	72	rcp	7.75	336	0.013			0.00390
14	50 + 10.00								1397.87	
		360.00	72	rcp	7.75	336	0.013			0.00390
15	53 + 70.00								1399.90	
		230.00	72	rcp	7.75	336	0.013			0.00390
16	56 + 00.00								1400.98	
		200.00	72	rcp	7.75	336	0.013			0.00390
17	58 + 00.00								1402.66	
		161.60	72	rcp	7.75	336	0.013			0.00390
18	59 + 61.60							1.00	1403.93	
		37.22	72	rcp	7.75	336	0.013			0.02610
19	59 + 98.82								1406.00	
		72.78	72	rcp	7.75	336	0.013			0.02610
20	60 + 71.60							0.50	1406.00	

Ke = Entrance + Exit Loss Coefficients

9th Street Major Storm Trunk Sewer — EK3097
Basin No. 5 to Basin No. 2 — 7/17/91
ST-88/299 — BJF
Table No. 2. Hydraulic Profile Design Calculation

Point No.	v (Fps)	hv (Ft)	he (Ft)	s (Ft/Ft)	hl (Ft)	H (Ft)	EGL (Elev)	EGL (Elev)	HGL (Elev)	HGL (Elev)
1			1.55				1386.00	1387.55	1386.00	1386.00
	10.00	1.55		0.00259	0.22	0.22				
2							1387.77	1387.77	1386.22	1386.22
	10.00	1.55		0.00259	0.23	0.23				
3							1388.01	1388.01	1386.45	1386.45
	10.00	1.55		0.00259	0.14	0.14				
4							1388.15	1388.15	1386.60	1386.60
	10.00	1.55		0.00259	1.35	1.35				
5							1389.50	1389.50	1387.95	1387.95
	10.00	1.55		0.00259	0.11	0.11				
6							1389.61	1389.61	1388.06	1388.06
	10.00	1.55		0.00259	0.09	0.09				
7							1389.70	1389.70	1388.15	1388.15
	10.00	1.55		0.00259	0.13	0.13				
8							1389.83	1389.83	1388.28	1387.65
	11.85	2.18		0.00509	1.27	1.27				
9							1391.11	1391.11	1388.93	1388.93
	11.85	2.18		0.00509	1.53	1.53				
10							1392.64	1392.64	1390.46	1390.46
	11.85	2.18		0.00509	1.02	1.02				
11							1393.65	1393.65	1391.47	1391.47
	11.85	2.18		0.00509	1.02	1.02				
12							1394.67	1394.67	1392.49	1392.49
	11.85	2.18		0.00509	1.53	1.53				
13							1396.20	1396.20	1394.02	1394.01
	11.88	2.19		0.00629	0.06	0.06				
14							1396.26	1396.26	1394.07	1394.07
	11.88	2.19		0.00629	2.27	2.27				
15							1398.53	1398.53	1396.34	1396.34
	11.88	2.19		0.00629	1.45	1.45				
16							1399.98	1399.98	1397.78	1397.78
	11.88	2.19		0.00629	1.26	1.26				
17							1401.24	1401.24	1399.04	1399.04
	11.88	2.19		0.00629	1.02	3.21				
18			2.19				1402.25	1404.45	1400.06	1402.25
	11.88	2.19		0.00629	0.23	0.23				
19							1404.68	1404.68	1402.49	1402.49
	11.88	2.19		0.00629	0.46	0.46				
20							1405.14	1405.14	1402.94	1405.14

Friction Slope, $Sf = 4.66 * n^2 * Q \div ((d/1)^{(16/3)})$
Velocity, $v = Q / (\pi(d/12)^2/4)$
Velocity Head, $hv = v^2 \div 2g$
Pipe Loss, $hl = Sf * l$

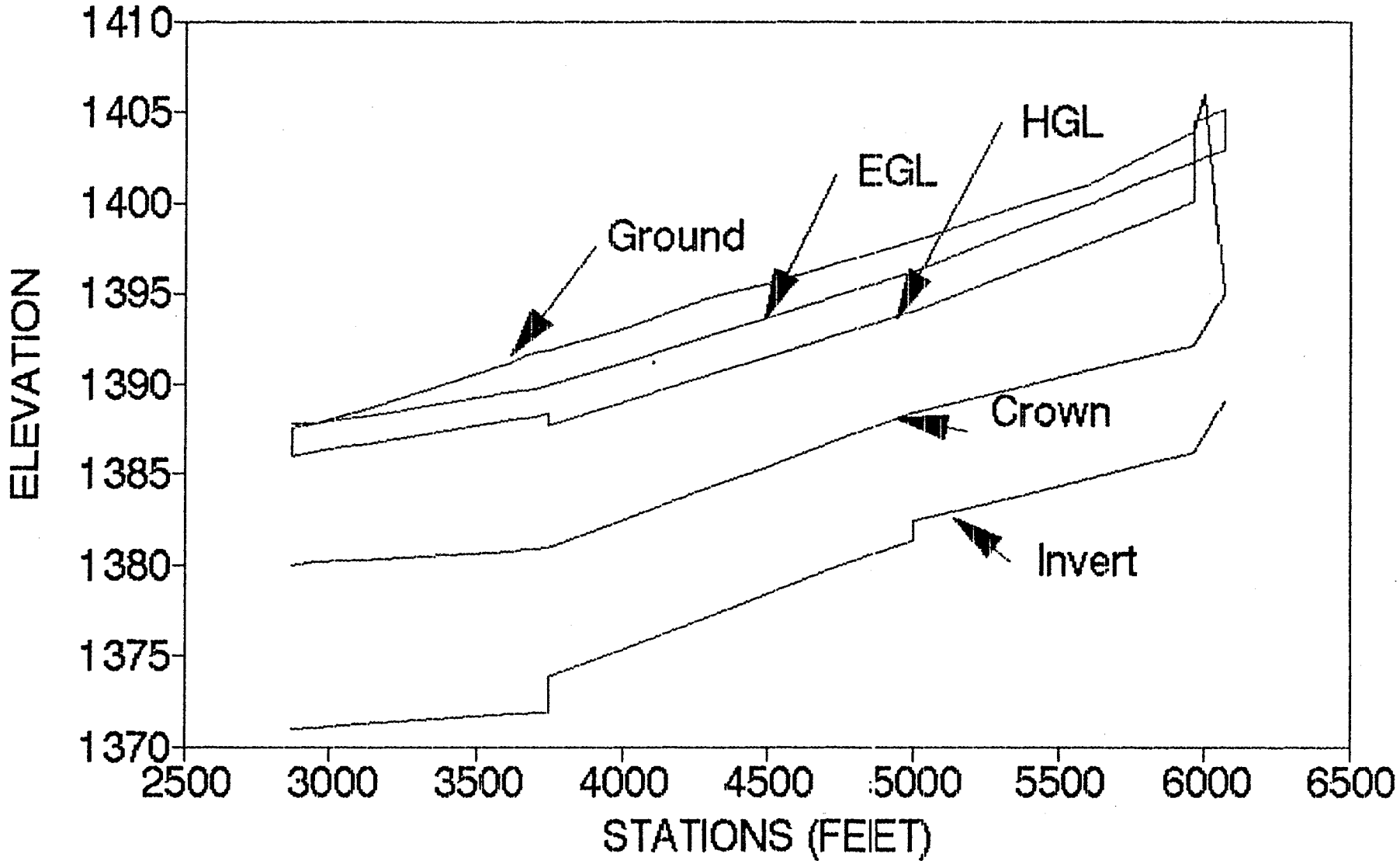
9th Street Major Storm Trunk Sewer — EK3097
Basin No. 5 to Basin No. 2 — 7/17/91
ST-88/299 — BJF
Table No. 3. Pipe Design Data.

Point No.	Pipe Slope (Ft/Ft)	Crown (Elev)	Outlet Invert (Elev)	Inlet Invert (Elev)	Top of Pipe (Elev)	Pipe Cover (Ft)	FG-HGL (Ft)	HGL-Crown (Ft)
1		1380.00			1380.83	6.97	1.80	6.00
	0.00100		1371.00	1371.09				
2		1380.09			1380.92	6.88	1.58	6.14
	0.00100		1371.09	1371.18				
3		1380.18			1381.01	7.19	1.75	6.28
	0.00100		1371.18	1371.23				
4		1380.23			1381.06	7.44	1.90	6.37
	0.00100		1371.23	1371.75				
5		1380.75			1381.58	9.62	3.25	7.20
	0.00100		1371.75	1371.80				
6		1380.80			1381.63	9.87	3.44	7.27
	0.00100		1371.80	1371.83				
7		1380.83			1381.66	10.03	3.54	7.32
	0.00100		1371.83	1371.88				
8		1380.88			1381.61	10.29	3.62	6.77
	0.00600		1373.88	1375.38				
9		1382.38			1383.11	9.89	4.07	6.55
	0.00600		1375.38	1377.18				
10		1384.18			1384.91	9.79	4.24	6.28
	0.00600		1377.18	1378.38				
11		1385.38			1386.11	9.43	4.07	6.09
	0.00600		1378.38	1379.58				
12		1386.58			1387.31	9.07	3.89	5.91
	0.00600		1379.58	1381.38				
13		1388.38			1389.03	8.83	3.84	5.63
	0.00390		1382.38	1382.42				
14		1388.42			1389.06	8.81	3.80	5.65
	0.00390		1382.42	1383.82				
15		1389.82			1390.47	9.43	3.56	6.51
	0.00390		1383.82	1384.72				
16		1390.72			1391.37	9.61	3.20	7.06
	0.00390		1384.72	1385.50				
17		1391.50			1392.15	10.51	3.62	7.54
	0.00390		1385.50	1386.13				
18		1392.13			1392.78	11.15	3.87	10.12
	0.02610		1386.13	1387.10				
19		1393.10			1393.75	12.25	3.51	9.38
	0.02610		1387.10	1389.00				
20		1395.00			1395.65	10.35	3.06	10.14

(1) Starting invert elevation = 1372.00 taken from Detention Basin No. 5, City of Phoenix No. ST-896837

HYDRAULIC PROFILE

BASIN NO.5 TO BASIN NO.2



Summary Table No. 1: Drainage Area Data

Point No.	Subarea No.	Zoning Factor	Area (Ac.)	Ai (Ac.)
1	1	1	.57	0.57
			Total	0.57
2	1	.6	10.02	6.01
			Total	6.01
3	1	.6	10	6.00
			Total	6.00
4	1	.6	10.91	6.55
			Total	6.55
5	1	.6	10.05	6.03
			Total	6.03
6	1	.25	6.59	1.65
			Total	1.65
7	1	.25	8.520001	2.13
			Total	2.13
8	1	.7	.87	0.61
			Total	0.61
9	1	.7	1.04	0.73
			Total	0.73
10	1	.65	.64	0.42
			Total	0.42
11	1	.65	3.7	2.41
			Total	2.41
12	1	.75	2.09	1.57
			Total	1.57

Summary Table No.2. Time of Concentration and Runoff Data

Point No.	Avg. S (Ft/Ft)	Max. Dist. (Feet)	Tc (Min.)	Inlet I (In/Hr)	Q (c.f.s.)
1	0.0104	450	2.5	2.40	1.13
2	0.0073	1500	9.5	2.40	11.90
3	0.0072	1500	9.6	2.40	11.88
4	0.0064	1500	10.0	2.40	12.96
5	0.0062	1550	10.5	2.37	11.76
6	0.0053	1450	10.4	2.37	3.22
7	0.0066	3760	24.8	1.53	2.54
8	0.0038	1300	10.5	2.36	1.18
9	0.0050	800	5.8	2.40	1.44
10	0.0042	400	3.1	2.40	0.82
11	0.0064	800	5.3	2.40	4.76
12	0.0021	900	9.1	2.40	3.10

Summary Table No. 3. Upstream Gutter Flow Data

Point No.	Slope (Ft/Ft)	Sx (Ft/Ft)	Flow-By (c.f.s.)	Total Q (c.f.s.)	Depth (Feet)	Spread (Feet)	Velocity (f.p.s.)
1	0.0080	0.0303	0.00	1.13	0.14	9.13	1.79
2	0.0055	0.0313	0.00	11.90	0.36	23.25	2.82
3	0.0055	0.0256	0.45	12.33	0.34	26.66	2.71
4	0.0040	0.0200	1.23	14.19	0.35	34.87	2.33
5	0.0055	0.0222	2.41	14.16	0.34	30.69	2.71
6	0.0049	0.0196	2.47	5.69	0.24	24.12	2.00
7	0.0173	0.0269	0.00	2.54	0.20	7.48	3.37
8	0.0140	0.0146	0.00	1.18	0.13	8.57	2.21
9	0.0064	0.0213	1.25	2.69	0.18	16.46	1.87
10	0.0042	0.0263	0.00	0.82	0.13	9.99	1.26
11	0.0026	0.0294	0.00	4.76	0.29	19.65	1.68
12	0.0015	0.0303	0.00	3.10	0.28	18.24	1.23

Summary Table No. 4. Inlet and Flow-By Data

Point No.	Sump (Feet)	Inlet Type	Capacity (c.f.s.)	Flow-By (c.f.s.)	To Inlet No.
1	0.00	SLOTTED DRAIN	1.13	0.00	2
2	0.00	SLOTTED DRAIN	11.45	0.45	3
3	0.00	SLOTTED DRAIN	11.10	1.23	4
4	0.00	SLOTTED DRAIN	11.78	2.41	5
5	0.00	SLOTTED DRAIN	11.69	2.47	6
6	0.00	SLOTTED DRAIN	5.47	0.23	9
7	0.00	'M'-P-1569'L=10	1.75	0.80	9
8	0.00	'M'-P-1569'L=10	0.96	0.23	9
9	0.00	SLOTTED DRAIN	2.69	0.00	10
10	0.00	SLOTTED DRAIN	0.82	0.00	11
11	0.00	SLOTTED DRAIN	4.76	0.00	12
12	0.00	SLOTTED DRAIN	3.10	0.00	0

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	1.13 c.f.s.
Approach Depth	=	0.14 feet
Approach Spread	=	9.13 feet
La = Length for Total Capture	=	16.76 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	%100.00 %
Q = Capacity	=	1.13 c.f.s.
Qg = Flow-by To Grate		
= Qa - Q	=	0.00 c.f.s.

Grate not required

Total Inlet Capacity:

Curb Opening Capacity	=	1.13 c.f.s.
Grated Inlet Capacity	=	0.00 c.f.s.
Total Inlet Capacity	=	1.13 c.f.s.

Flow-By To Point No. 2 :

Approach Flow To Inlet	=	1.13 c.f.s.
Total Capacity Of Inlet	=	1.13 c.f.s.
Flow-By	=	0.00 c.f.s.

Point number: 2
Location: STA. 53+70

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-3	10.02	.6	6.01
			Total	6.01

Approach Flow to Point No. 2 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0073 Ft./Ft.
Avg. Velocity	=	2.63 f.p.s.
Stream Length	=	1500 feet
Time Of Concentration	=	9.51 min.
Intensity	=	2.40 In./Hr.
Impervious Area	=	6.01 acres
Flow From Drainage Area		= 11.90 c.f.s.
Flow-by From Upstream Inlets		= 0.00 c.f.s.
Approach Flow		= 11.90 c.f.s.

Approach Depth & Spread To Point No.: 2

V-Ditch

Approach Flow	=	11.90 c.f.s.
Ditch Slope	=	0.00550 Ft./Ft.
Side Slope(Z:1)	=	32.000
Approach Depth	=	0.36 feet
Spread	=	23.25 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	11.90 c.f.s.
Approach Depth	=	0.36 feet
Approach Spread	=	23.25 feet
La = Length for Total Capture	=	39.89 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	94.78 %
Q = Capacity	=	11.28 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	0.62 c.f.s.

Grated Inlet Capacity:

V-Ditch		
Qg = Approach Flow	=	0.62 c.f.s.
Approach Depth	=	0.12 feet
T = Approach Spread	=	7.68 feet
Eo = 1-(1-(Wg/T)^2.67	=	0.55
Cg = Clogging Factor	=	0.50
Q = Capacity = Qg x Cg x Eo	=	0.17 c.f.s.

Total Inlet Capacity:

Curb Opening Capacity	=	11.28 c.f.s.
Grated Inlet Capacity	=	0.17 c.f.s.
Total Inlet Capacity	=	11.45 c.f.s.

Flow-By To Point No. 3 :

Approach Flow To Inlet	=	11.90 c.f.s.
Total Capacity Of Inlet	=	11.45 c.f.s.
Flow-By	=	0.45 c.f.s.

Point number: 3
Location: STA. 50+10

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-3	10	.6	6.00
			Total	6.00

Approach Flow to Point No. 3 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0072 Ft./Ft.
Avg. Velocity	=	2.61 f.p.s.
Stream Length	=	1500 feet
Time Of Concentration	=	9.56 min.
Intensity	=	2.40 In./Hr.
Impervious Area	=	6.00 acres
Flow From Drainage Area		= 11.88 c.f.s.
Flow-by From Upstream Inlets		= 0.45 c.f.s.
Approach Flow		= 12.33 c.f.s.

Approach Depth & Spread To Point No.: 3

V-Ditch

Approach Flow	=	12.33 c.f.s.
Ditch Slope	=	0.00550 Ft./Ft.
Side Slope(Z:1)	=	39.000
Approach Depth	=	0.34 feet
Spread	=	26.66 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	12.33 c.f.s.
Approach Depth	=	0.34 feet
Approach Spread	=	26.66 feet
La = Length for Total Capture	=	47.12 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	87.71 %
Q = Capacity	=	10.81 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	1.52 c.f.s.

Grated Inlet Capacity:

V-Ditch

Qg = Approach Flow	=	1.52 c.f.s.
Approach Depth	=	0.16 feet
T = Approach Spread	=	12.14 feet
Eo = 1-(1-(Wg/T)^2.67	=	0.38
Cg = Clogging Factor	=	0.50
Q = Capacity = Qg x Cg x Eo	=	0.29 c.f.s.

Total Inlet Capacity:

Curb Opening Capacity	=	10.81 c.f.s.
Grated Inlet Capacity	=	0.29 c.f.s.
Total Inlet Capacity	=	11.10 c.f.s.

Flow-By To Point No. 4 :

Approach Flow To Inlet	=	12.33 c.f.s.
Total Capacity Of Inlet	=	11.10 c.f.s.
Flow-By	=	1.23 c.f.s.

Point number: 4
Location: STA. 47+00

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-3	10.91	.6	6.55
			Total	6.55

Approach Flow to Point No. 4 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0064 Ft./Ft.
Avg. Velocity	=	2.50 f.p.s.
Stream Length	=	1500 feet
Time Of Concentration	=	9.99 min.
Intensity	=	2.40 In./Hr.
Impervious Area	=	6.55 acres
Flow From Drainage Area		= 12.96 c.f.s.
Flow-by From Upstream Inlets		= 1.23 c.f.s.
Approach Flow		= 14.19 c.f.s.

Approach Depth & Spread To Point No.: 4

V-Ditch

Approach Flow	=	14.19 c.f.s.
Ditch Slope	=	0.00398 Ft./Ft.
Side Slope(Z:1)	=	50.000
Approach Depth	=	0.35 feet
Spread	=	34.87 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	14.19 c.f.s.
Approach Depth	=	0.35 feet
Approach Spread	=	34.87 feet
La = Length for Total Capture	=	54.83 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	80.51 %
Q = Capacity	=	11.42 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	2.76 c.f.s.

Grated Inlet Capacity:

V-Ditch		
Qg = Approach Flow	=	2.76 c.f.s.
Approach Depth	=	0.19 feet
T = Approach Spread	=	18.88 feet
Eo = 1-(1-(Wg/T)^2.67	=	0.26
Cg = Clogging Factor	=	0.50
Q = Capacity = Qg x Cg x Eo	=	0.36 c.f.s.

Total Inlet Capacity:

Curb Opening Capacity	=	11.42 c.f.s.
Grated Inlet Capacity	=	0.36 c.f.s.
Total Inlet Capacity	=	11.78 c.f.s.

Flow-By To Point No. 5 :

Approach Flow To Inlet	=	14.19 c.f.s.
Total Capacity Of Inlet	=	11.78 c.f.s.
Flow-By	=	2.41 c.f.s.

Point number: 5
Location: STA. 43+00

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-3	10.05	.6	6.03
			Total	6.03

Approach Flow to Point No. 5 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0062 Ft./Ft.
Avg. Velocity	=	2.47 f.p.s.
Stream Length	=	1550 feet
Time Of Concentration	=	10.45 min.
Intensity	=	2.37 In./Hr.
Impervious Area	=	6.03 acres
Flow From Drainage Area		= 11.76 c.f.s.
Flow-by From Upstream Inlets		= 2.41 c.f.s.
Approach Flow		= 14.16 c.f.s.

Approach Depth & Spread To Point No.: 5

V-Ditch

Approach Flow	=	14.16 c.f.s.
Ditch Slope	=	0.00552 Ft./Ft.
Side Slope(Z:1)	=	45.000
Approach Depth	=	0.34 feet
Spread	=	30.69 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	14.16 c.f.s.
Approach Depth	=	0.34 feet
Approach Spread	=	30.69 feet
La = Length for Total Capture	=	55.85 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	79.63 %
Q = Capacity	=	11.28 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	2.89 c.f.s.

Grated Inlet Capacity:

V-Ditch		
Qg = Approach Flow	=	2.89 c.f.s.
Approach Depth	=	0.19 feet
T = Approach Spread	=	16.90 feet
Eo = 1-(1-(Wg/T)^2.67	=	0.29
Cg = Clogging Factor	=	0.50
Q = Capacity = Qg x Cg x Eo	=	0.41 c.f.s.

Total Inlet Capacity:

Curb Opening Capacity	=	11.28 c.f.s.
Grated Inlet Capacity	=	0.41 c.f.s.
Total Inlet Capacity	=	11.69 c.f.s.

Flow-By To Point No. 6 :

Approach Flow To Inlet	=	14.16 c.f.s.
Total Capacity Of Inlet	=	11.69 c.f.s.
Flow-By	=	2.47 c.f.s.

Point number: 6
Location: STA. 37+00

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R1-8	6.59	.25	1.65
			Total	1.65

Approach Flow to Point No. 6 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0053 Ft./Ft.
Avg. Velocity	=	2.33 f.p.s.
Stream Length	=	1450 feet
Time Of Concentration	=	10.37 min.
Intensity	=	2.37 In./Hr.
Impervious Area	=	1.65 acres
Flow From Drainage Area	=	3.22 c.f.s.
Flow-by From Upstream Inlets	=	2.47 c.f.s.
Approach Flow	=	5.69 c.f.s.

Approach Depth & Spread To Point No.: 6

V-Ditch

Approach Flow	=	5.69 c.f.s.
Ditch Slope	=	0.00489 Ft./Ft.
Side Slope(Z:1)	=	51.000
Approach Depth	=	0.24 feet
Spread	=	24.12 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	5.69 c.f.s.
Approach Depth	=	0.24 feet
Approach Spread	=	24.12 feet
La = Length for Total Capture	=	40.14 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	94.54 %
Q = Capacity	=	5.38 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	0.31 c.f.s.

Grated Inlet Capacity:

V-Ditch		
Qg = Approach Flow	=	0.31 c.f.s.
Approach Depth	=	0.08 feet
T = Approach Spread	=	8.11 feet
Eo = 1-(1-(Wg/T)^2.67	=	0.53
Cg = Clogging Factor	=	0.50
Q = Capacity = Qg x Cg x Eo	=	0.08 c.f.s.

Total Inlet Capacity:

Curb Opening Capacity	=	5.38 c.f.s.
Grated Inlet Capacity	=	0.08 c.f.s.
Total Inlet Capacity	=	5.47 c.f.s.

Flow-By To Point No. 9 :

Approach Flow To Inlet	=	5.69 c.f.s.
Total Capacity Of Inlet	=	5.47 c.f.s.
Flow-By	=	0.23 c.f.s.

Point number: 7
Location: STA. 36+65 45'RT

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R1-8	8.520001	.25	2.13
			Total	2.13

Approach Flow to Point No. 7 :

Avg. Q = 3 c.f.s.
Avg. Slope = .0066 Ft./Ft.
Avg. Velocity = 2.53 f.p.s.
Stream Length = 3760 feet
Time Of Concentration = 24.77 min.
Intensity = 1.53 In./Hr.
Impervious Area = 2.13 acres
Flow From Drainage Area = 2.54 c.f.s.
Flow-by From Upstream Inlets = 0.00 c.f.s.

Approach Flow = 2.54 c.f.s.

Approach Depth & Spread To Point No.: 7

Curb & Gutter
Approach Flow = 2.54 c.f.s.
Gutter Slope = 0.01730 Ft./Ft.
Cross Slope = 0.027 Ft./Ft.
Approach Depth = 0.20 feet
Spread = 7.48 feet

Type Of Inlet: 'M'-P-1569'L=10
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	2.54 c.f.s.
Approach Depth	=	0.20 feet
Approach Spread	=	7.48 feet
La = Length for Total Capture	=	18.87 feet
Lu = Upstream Opening	=	13.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	10.40 feet
Q/Qa = Inlet Efficiency	=	68.71 %
Q = Capacity	=	1.75 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	0.80 c.f.s.

Grated Inlet Capacity:

Curb & Gutter		
Qg = Approach Flow	=	0.80 c.f.s.
Approach Depth	=	0.13 feet
T = Approach Spread	=	4.84 feet
Eo = 1-(1-(Wg/T)^2.67	=	0.00
Cg = Clogging Factor	=	1.00
Q = Capacity = Qg x Cg x Eo	=	0.00 c.f.s.

Total Inlet Capacity:

Curb Opening Capacity	=	1.75 c.f.s.
Grated Inlet Capacity	=	0.00 c.f.s.
Total Inlet Capacity	=	1.75 c.f.s.

Flow-By To Point No. 9 :

Approach Flow To Inlet	=	2.54 c.f.s.
Total Capacity Of Inlet	=	1.75 c.f.s.
Flow-By	=	0.80 c.f.s.

Point number: 8
Location: STA. 36+21 45'RT

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-4A	.87	.7	0.61
			Total	0.61

Approach Flow to Point No. 8 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0038 Ft./Ft.
Avg. Velocity	=	2.06 f.p.s.
Stream Length	=	1300 feet
Time Of Concentration	=	10.53 min.
Intensity	=	2.36 In./Hr.
Impervious Area	=	0.61 acres
Flow From Drainage Area	=	1.18 c.f.s.
Flow-by From Upstream Inlets	=	0.00 c.f.s.
Approach Flow	=	1.18 c.f.s.

Approach Depth & Spread To Point No.: 8

Curb & Gutter

Approach Flow	=	1.18 c.f.s.
Gutter Slope	=	0.01400 Ft./Ft.
Cross Slope	=	0.015 Ft./Ft.
Approach Depth	=	0.13 feet
Spread	=	8.57 feet

Type Of Inlet: 'M'-P-1569'L=10
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	1.18 c.f.s.
Approach Depth	=	0.13 feet
Approach Spread	=	8.57 feet
La = Length for Total Capture	=	14.25 feet
Lu = Upstream Opening	=	13.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	10.40 feet
Q/Qa = Inlet Efficiency	=	80.81 %
Q = Capacity	=	0.96 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	0.23 c.f.s.

Grated Inlet Capacity:

Curb & Gutter		
Qg = Approach Flow	=	0.23 c.f.s.
Approach Depth	=	0.07 feet
T = Approach Spread	=	4.61 feet
Eo = 1-(1-(Wg/T)^2.67	=	0.00
Cg = Clogging Factor	=	1.00
Q = Capacity = Qg x Cg x Eo	=	0.00 c.f.s.

Total Inlet Capacity:

Curb Opening Capacity	=	0.96 c.f.s.
Grated Inlet Capacity	=	0.00 c.f.s.
Total Inlet Capacity	=	0.96 c.f.s.

Flow-By To Point No. 9 :

Approach Flow To Inlet	=	1.18 c.f.s.
Total Capacity Of Inlet	=	0.96 c.f.s.
Flow-By	=	0.23 c.f.s.

Point number: 9
Location: 30+50

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-4A	1.04	.7	0.73
			Total	0.73

Approach Flow to Point No. 9 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.005 Ft./Ft.
Avg. Velocity	=	2.28 f.p.s.
Stream Length	=	800 feet
Time Of Concentration	=	5.85 min.
Intensity	=	2.40 In./Hr.
Impervious Area	=	0.73 acres
Flow From Drainage Area	=	1.44 c.f.s.
Flow-by From Upstream Inlets	=	1.25 c.f.s.
Approach Flow	=	2.69 c.f.s.

Approach Depth & Spread To Point No.: 9

V-Ditch

Approach Flow	=	2.69 c.f.s.
Ditch Slope	=	0.00640 Ft./Ft.
Side Slope(Z:1)	=	47.000
Approach Depth	=	0.18 feet
Spread	=	16.46 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	2.69 c.f.s.
Approach Depth	=	0.18 feet
Approach Spread	=	16.46 feet
La = Length for Total Capture	=	29.73 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	%100.00 %
Q = Capacity	=	2.69 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	0.00 c.f.s.

Grate not required

Total Inlet Capacity:

Curb Opening Capacity	=	2.69 c.f.s.
Grated Inlet Capacity	=	0.00 c.f.s.
Total Inlet Capacity	=	2.69 c.f.s.

Flow-By To Point No. 10 :

Approach Flow To Inlet	=	2.69 c.f.s.
Total Capacity Of Inlet	=	2.69 c.f.s.
Flow-By	=	0.00 c.f.s.

Point number: 10
Location: STA. 26+00

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-4	.64	.65	0.42
			Total	0.42

Approach Flow to Point No. 10 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0042 Ft./Ft.
Avg. Velocity	=	2.14 f.p.s.
Stream Length	=	400 feet
Time Of Concentration	=	3.12 min.
Intensity	=	2.40 In./Hr.
Impervious Area	=	0.42 acres
Flow From Drainage Area	=	0.82 c.f.s.
Flow-by From Upstream Inlets	=	0.00 c.f.s.
Approach Flow	=	0.82 c.f.s.

Approach Depth & Spread To Point No.: 10

V-Ditch

Approach Flow	=	0.82 c.f.s.
Ditch Slope	=	0.00423 Ft./Ft.
Side Slope(Z:1)	=	38.000
Approach Depth	=	0.13 feet
Spread	=	9.99 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	0.82 c.f.s.
Approach Depth	=	0.13 feet
Approach Spread	=	9.99 feet
La = Length for Total Capture	=	13.43 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	%100.00 %
Q = Capacity	=	0.82 c.f.s.
Qg = Flow-by To Grate		
= Qa - Q	=	0.00 c.f.s.
Grate not required		

Total Inlet Capacity:

Curb Opening Capacity	=	0.82 c.f.s.
Grated Inlet Capacity	=	0.00 c.f.s.
Total Inlet Capacity	=	0.82 c.f.s.

Flow-By To Point No. 11 :

Approach Flow To Inlet	=	0.82 c.f.s.
Total Capacity Of Inlet	=	0.82 c.f.s.
Flow-By	=	0.00 c.f.s.

Point number: 11
Location: STA. 21+40

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	R-4	3.7	.65	2.41
			Total	2.41

Approach Flow to Point No. 11 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0064 Ft./Ft.
Avg. Velocity	=	2.50 f.p.s.
Stream Length	=	800 feet
Time Of Concentration	=	5.33 min.
Intensity	=	2.40 In./Hr.
Impervious Area	=	2.41 acres
Flow From Drainage Area	=	4.76 c.f.s.
Flow-by From Upstream Inlets	=	0.00 c.f.s.
Approach Flow	=	4.76 c.f.s.

Approach Depth & Spread To Point No.: 11

V-Ditch

Approach Flow	=	4.76 c.f.s.
Ditch Slope	=	0.00264 Ft./Ft.
Side Slope(Z:1)	=	34.000
Approach Depth	=	0.29 feet
Spread	=	19.65 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	4.76 c.f.s.
Approach Depth	=	0.29 feet
Approach Spread	=	19.65 feet
La = Length for Total Capture	=	22.59 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	%100.00 %
Q = Capacity	=	4.76 c.f.s.
Qg = Flow-by To Grate		
= Qa - Q	=	0.00 c.f.s.
Grate not required		

Total Inlet Capacity:

Curb Opening Capacity	=	4.76 c.f.s.
Grated Inlet Capacity	=	0.00 c.f.s.
Total Inlet Capacity	=	4.76 c.f.s.

Flow-By To Point No. 12 :

Approach Flow To Inlet	=	4.76 c.f.s.
Total Capacity Of Inlet	=	4.76 c.f.s.
Flow-By	=	0.00 c.f.s.

Point number: 12
Location: STA. 12+60

Drainage Area

Subarea No.	Zoning Type	Area (Ac.)	Zoning Factor	Ai (Ac.)
1	IND. PARK	2.09	.75	1.57
			Total	1.57

Approach Flow to Point No. 12 :

Avg. Q	=	3 c.f.s.
Avg. Slope	=	.0021 Ft./Ft.
Avg. Velocity	=	1.65 f.p.s.
Stream Length	=	900 feet
Time Of Concentration	=	9.11 min.
Intensity	=	2.40 In./Hr.
Impervious Area	=	1.57 acres
Flow From Drainage Area	=	3.10 c.f.s.
Flow-by From Upstream Inlets	=	0.00 c.f.s.
Approach Flow	=	3.10 c.f.s.

Approach Depth & Spread To Point No.: 12

V-Ditch

Approach Flow	=	3.10 c.f.s.
Ditch Slope	=	0.00151 Ft./Ft.
Side Slope(Z:1)	=	33.000
Approach Depth	=	0.28 feet
Spread	=	18.24 feet

Type Of Inlet: SLOTTED DRAIN
Inlet Condition: On-grade
Flow Condition: Weir flow

Curb Opening Capacity:

Qa = Approach Flow	=	3.10 c.f.s.
Approach Depth	=	0.28 feet
Approach Spread	=	18.24 feet
La = Length for Total Capture	=	15.51 feet
Lu = Upstream Opening	=	40.00 feet
Cc = Clogging Factor	=	0.80
L = Cc x Lu	=	32.00 feet
Q/Qa = Inlet Efficiency	=	%100.00 %
Q = Capacity	=	3.10 c.f.s.
Qg = Flow-by To Grate = Qa - Q	=	0.00 c.f.s.

Grate not required

Total Inlet Capacity:

Curb Opening Capacity	=	3.10 c.f.s.
Grated Inlet Capacity	=	0.00 c.f.s.
Total Inlet Capacity	=	3.10 c.f.s.

Flow-By To Point No. 0 :

Approach Flow To Inlet	=	3.10 c.f.s.
Total Capacity Of Inlet	=	3.10 c.f.s.
Flow-By	=	0.00 c.f.s.

9TH STREET MAJOR TRUNK STORM DRAIN
ST-887299
SLOTTED DRAIN COLLECTOR PIPE CAPACITIES
USING THE MANNING FORMULA

EKA3097
7-18-91
KM

$$d_{req} = \left(\frac{2.159\ Qn}{S^{1/2}}\right)^{3/8}$$

Pt. No.	1	2	3	4	5	6
Station	58+00	53+70	50+10	47+00	43+00	37+00
Q (cfs)=	1.13	11.45	11.10	11.78	11.69	5.47
n=	0.024	0.024	0.024	0.024	0.024	0.024
s (ft/ft)=	0.00802	0.0055	0.0055	0.00398	0.00552	0.00489
d req. (in)=	10.23	26.17	25.87	28.11	26.36	20.28
use d (in)=	12	30	30	30	30	21

Pt. No.	7	8	9	10	11	12
Station	*	*	30+50	26+00	21+40	12+60
Q (cfs)=			2.69	0.82	4.76	3.10
n=			0.024	0.024	0.024	0.024
s (ft/ft)=			0.0064	0.00423	0.00264	0.00151
d req. (in)=			14.78	10.23	21.61	20.43
use d (in)=			15	12	24	21

* Point Nos. 7 & 8 are curb inlets without slotted drain

9TH STREET EKA#3097
CONNECTOR PIPE CALCS 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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PIPE RECORD NO. 1

Location:	STA 58+00	
Pipe material:	RCP	
Mannings N-Value, n =	0.013	
Pipe diameter (D) =	15	In
Pipe Length (l) =	11	Ft
Pipe Angle at Inlet (O) =	90.00	Deg
Grate Elevation (G) =	1402.65	Ft
Outlet Invert Elevation (ELo) =	1390.13	Ft
Inlet Invert Elevation (ELi) =	1399.65	Ft
Curb Face Opening (cf) =	0	In
Design Flow (Q) =	1.13	cfs
Tailwater Elevation (Tw) =	1399.04	Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.25 Ft	
Deflection Angle, Θ =	90.00	Deg
Inlet Diameter, di = d / sin Θ =	1.25	Ft
Velocity, v = Q / (π(d/12)²/4) =	0.92	Fps
Velocity Head, hv = v²÷2g =	0.01 Ft	
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) =	0.00031	Ft/Ft
Entrance Loss Coeficient, Ke =	0.50	
Exit Loss Coeficient, Ko =	1	
Pipe Loss, hp = Sf * l =	0.00	Ft
Entrance Loss, he = Ke * hv =	0.01	Ft
Exit Loss, ho = Ko * hv =	0.01	Ft
Total Friction Loss, H = hp + he + ho =	0.02	Ft
Headwater Elevation, Hwo = Tw + H =	1399.06	Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	1.13 cfs
x = Q / d^2.5 =	0.6468
Hw/d =	0.46 Ft/Ft
Hwi = Hw * d + ELi =	1400.22 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1400.22 Ft

Freeboard, FB = G - cf÷12 - HW =	2.43 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	1.27 Ft		
Drop Inlet Depth, V = G - ELi =	3.00 Ft	≥	1.27 Ft

9TH STREET
CONNECTOR PIPE CALCS
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN.
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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7/19/91
BJF/KM

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PIPE RECORD NO. 2

Location:	STA 53+70
Pipe material:	RCP
Mannings N-Value, n =	0.013
Pipe diameter (D) =	18 In
Pipe Length (l) =	9 Ft
Pipe Angle at Inlet (O) =	90.00 Deg
Grate Elevation (G) =	1399.79 Ft
Outlet Invert Elevation (ELo) =	1388.34 Ft
Inlet Invert Elevation (ELi) =	1396.29 Ft
Curb Face Opening (cf) =	0 In
Design Flow (Q) =	11.45 cfs
Tailwater Elevation (Tw) =	1396.34 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.50 Ft
Deflection Angle, Θ =	90.00 Deg
Inlet Diameter, di = d / sin Θ =	1.50 Ft
Velocity, v = Q / (π(d/12)²/4) =	6.48 Fps
Velocity Head, hv = v²÷2g =	0.64 Ft
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) =	0.01188 Ft/Ft
Entrance Loss Coeficient, Ke =	0.50
Exit Loss Coeficient, Ko =	1
Pipe Loss, hp = Sf * l =	0.11 Ft
Entrance Loss, he = Ke * hv =	0.32 Ft
Exit Loss, ho = Ko * hv =	0.64 Ft
Total Friction Loss, H = hp + he + ho =	1.07 Ft
Headwater Elevation, Hwo = Tw + H =	1397.41 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	11.45 cfs
x = Q / d^2.5 =	4.1551
Hw/d =	1.77 Ft/Ft
Hwi = Hw * d + ELi =	1398.95 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1398.95 Ft

Freeboard, FB = G - cf÷12 - HW =	0.84 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	2.47 Ft		
Drop Inlet Depth, V = G - ELi =	3.50 Ft	≥	2.47 Ft

9TH STREET
CONNECTOR PIPE CALCS
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN.
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

EKA#3097
7/19/91
BJF/KM

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PIPE RECORD NO. 3

Location:	STA 50+10
Pipe material:	RCP
Mannings N-Value, n =	0.013
Pipe diameter (D) =	18 In
Pipe Length (l) =	9 Ft
Pipe Angle at Inlet (O) =	90.00 Deg
Grate Elevation (G) =	1397.81 Ft
Outlet Invert Elevation (ELo) =	1386.94 Ft
Inlet Invert Elevation (ELi) =	1394.31 Ft
Curb Face Opening (cf) =	0 In
Design Flow (Q) =	11.10 cfs
Tailwater Elevation (Tw) =	1394.07 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.50 Ft
Deflection Angle, Θ =	90.00 Deg
Inlet Diameter, di = d / sin Θ =	1.50 Ft
Velocity, v = Q / (π(d/12)²/4) =	6.28 Fps
Velocity Head, hv = v²÷2g =	0.61 Ft
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) =	0.01116 Ft/Ft
Entrance Loss Coeficient, Ke =	0.50
Exit Loss Coeficient, Ko =	1
Pipe Loss, hp = Sf * l =	0.10 Ft
Entrance Loss, he = Ke * hv =	0.30 Ft
Exit Loss, ho = Ko * hv =	0.61 Ft
Total Friction Loss, H = hp + he + ho =	1.01 Ft
Headwater Elevation, Hwo = Tw + H =	1395.08 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	11.10 cfs
x = Q / d^2.5 =	4.0280
Hw/d =	1.71 Ft/Ft
Hwi = Hw * d + ELi =	1396.87 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1396.87 Ft

Freeboard, FB = G - cf÷12 - HW =	0.94 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	2.41 Ft		
Drop Inlet Depth, V = G - ELi =	3.50 Ft	≥	2.41 Ft

9TH STREET
CONNECTOR PIPE CALCS
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN.
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

EKA#3097
7/19/91
BJF/KM

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PIPE RECORD NO. 4

Location:	STA 47+00	
Pipe material:	RCP	
Mannings N-Value, n =	0.013	
Pipe diameter (D) =	18	In
Pipe Length (l) =	9	Ft
Pipe Angle at Inlet (O) =	90.00	Deg
Grate Elevation (G) =	1396.41	Ft
Outlet Invert Elevation (ELo) =	1384.97	Ft
Inlet Invert Elevation (ELi) =	1392.91	Ft
Curb Face Opening (cf) =	0	In
Design Flow (Q) =	11.78	cfs
Tailwater Elevation (Tw) =	1392.49	Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.50 Ft	
Deflection Angle, Θ =	90.00	Deg
Inlet Diameter, di = d / sin Θ =	1.50	Ft
Velocity, v = Q / (π(d/12)²/4) =	6.67	Fps
Velocity Head, hv = v²÷2g =	0.68 Ft	
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) =	0.01257	Ft/Ft
Entrance Loss Coeficient, Ke =	0.50	
Exit Loss Coeficient, Ko =	1	
Pipe Loss, hp = Sf * l =	0.11	Ft
Entrance Loss, he = Ke * hv =	0.34	Ft
Exit Loss, ho = Ko * hv =	0.68	Ft
Total Friction Loss, H = hp + he + ho =	1.14	Ft
Headwater Elevation, Hwo = Tw + H =	1393.63	Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	11.78	cfs
x = Q / d^2.5 =	4.2748	
Hw/d =	1.84	Ft/Ft
Hwi = Hw * d + ELi =	1395.67	Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1395.67 Ft

Freeboard, FB = G - cf÷12 - HW =	0.74 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	2.52 Ft		
Drop Inlet Depth, V = G - ELi =	3.50 Ft	≥	2.52 Ft

9TH STREET — EKA#3097
CONNECTOR PIPE CALCS — 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. — BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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PIPE RECORD NO. 5

Location:	STA 43+00	
Pipe material:	RCP	
Mannings N-Value, n =	0.013	
Pipe diameter (D) =	18	In
Pipe Length (l) =	10	Ft
Pipe Angle at Inlet (O) =	90.00	Deg
Grate Elevation (G) =	1394.57	Ft
Outlet Invert Elevation (ELo) =	1382.57	Ft
Inlet Invert Elevation (ELi) =	1391.07	Ft
Curb Face Opening (cf) =	0	In
Design Flow (Q) =	11.69	cfs
Tailwater Elevation (Tw) =	1390.46	Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.50 Ft	
Deflection Angle, Θ =	90.00	Deg
Inlet Diameter, di = d / sin Θ =	1.50	Ft
Velocity, v = Q / (π(d/12)^2/4) =	6.62	Fps
Velocity Head, hv = $v^2 \div 2g$ =	0.67 Ft	
Friction Slope, Sf = 4.66 * n^2 * Q^2 ÷ (d^(16/3)) =	0.01238	Ft/Ft
Entrance Loss Coeficient, Ke =	0.50	
Exit Loss Coeficient, Ko =	1	
Pipe Loss, hp = Sf * l =	0.12	Ft
Entrance Loss, he = Ke * hv =	0.34	Ft
Exit Loss, ho = Ko * hv =	0.67	Ft
Total Friction Loss, H = hp + he + ho =	1.13	Ft
Headwater Elevation, Hwo = Tw + H =	1391.59	Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	11.69 cfs	
x = Q / d^2.5 =	4.2422	
Hw/d =	1.82 Ft/Ft	
Hwi = Hw * d + ELi =	1393.80 Ft	

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1393.80 Ft

Freeboard, FB = G - cf÷12 - HW =	0.77 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	2.51 Ft		
Drop Inlet Depth, V = G - ELi =	3.50 Ft	≥	2.51 Ft

9TH STREET
CONNECTOR PIPE CALCS
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN.
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

EKA#3097
7/19/91
BJF/KM

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PIPE RECORD NO.	6
Location:	STA 37+00
Pipe material:	RCP
Mannings N-Value, n =	0.013
Pipe diameter (D) =	15 In
Pipe Length (l) =	11 Ft
Pipe Angle at Inlet (O) =	90.00 Deg
Grate Elevation (G) =	1391.62 Ft
Outlet Invert Elevation (ELo) =	1379.04 Ft
Inlet Invert Elevation (ELi) =	1388.62 Ft
Curb Face Opening (cf) =	0 In
Design Flow (Q) =	5.47 cfs
Tailwater Elevation (Tw) =	1388.15 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.25 Ft
Deflection Angle, Θ =	90.00 Deg
Inlet Diameter, di = d / sin Θ =	1.25 Ft
Velocity, v = Q / (π(d/12)²/4) =	4.46 Fps
Velocity Head, hv = v²÷2g =	0.31 Ft
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) =	0.00717 Ft/Ft
Entrance Loss Coeficient, Ke =	0.50
Exit Loss Coeficient, Ko =	1
Pipe Loss, hp = Sf * l =	0.08 Ft
Entrance Loss, he = Ke * hv =	0.15 Ft
Exit Loss, ho = Ko * hv =	0.31 Ft
Total Friction Loss, H = hp + he + ho =	0.54 Ft
Headwater Elevation, Hwo = Tw + H =	1388.69 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	5.47 cfs
x = Q / d^2.5 =	3.1312
Hw/d =	1.30 Ft/Ft
Hwi = Hw * d + ELi =	1390.25 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1390.25 Ft

Freeboard, FB = G - cf÷12 - HW =	1.37 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	1.71 Ft		
Drop Inlet Depth, V = G - ELi =	3.00 Ft	≥	1.71 Ft

9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCS — 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. — BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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PIPE RECORD NO.	7
Location:	STA 36+65 45'RT
Pipe material:	RCP
Mannings N-Value, n =	0.013
Pipe diameter (D) =	15 In
Pipe Length (l) =	45 Ft
Pipe Slope at Inlet (s) =	0.26270 Ft/Ft
Top of Curb Elevation (tc) =	1392.15 Ft
Outlet Invert Elevation (ELo) =	1376.81 Ft
Inlet Invert Elevation (ELi) =	1388.15 Ft
Curb Face Opening (cf) =	8 In
Design Flow (Q) =	1.75 cfs
Tailwater Elevation (Tw) =	1388.06 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.25 Ft
Deflection Angle, Θ = arctan (s) =	14.72 Deg
Inlet Diameter, di = d / cos Θ =	1.29 Ft
Velocity, v = Q / (π(d/12)^2/4) =	1.43 Fps
Velocity Head, hv = $v^2 \div 2g$ =	0.03 Ft
Friction Slope, Sf = 4.66 * n^2 * Q^2 ÷ (d^(16/3)) =	0.00073 Ft/Ft
Entrance Loss Coeficient, Ke =	0.50
Exit Loss Coeficient, Ko =	1
Pipe Loss, hp = Sf * l =	0.03 Ft
Entrance Loss, he = Ke * hv =	0.02 Ft
Exit Loss, ho = Ko * hv =	0.03 Ft
Total Friction Loss, H = hp + he + ho =	0.08 Ft
Headwater Elevation, Hwo = Tw + H =	1388.14 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	1.75 cfs
x = Q / d^2.5 =	1.0018
Hw/d =	0.60 Ft/Ft
Hwi = Hw * d + ELi =	1388.90 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1388.90 Ft

Freeboard, FB = tc - cf÷12 - HW =	2.58 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	2.01 Ft		
Drop Inlet Depth, V = tc - ELi =	4.00 Ft	≥	2.01 Ft

9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCS — 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. — BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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PIPE RECORD NO.	8
Location:	STA 36+21 45'RT
Pipe material:	RCP
Mannings N-Value, n =	0.013
Pipe diameter (D) =	15 In
Pipe Length (l) =	45 Ft
Pipe Slope at Inlet (s) =	0.26830 Ft/Ft
Top of Curb Elevation (tc) =	1392.38 Ft
Outlet Invert Elevation (ELo) =	1376.80 Ft
Inlet Invert Elevation (ELi) =	1388.38 Ft
Curb Face Opening (cf) =	8 In
Design Flow (Q) =	0.96 cfs
Tailwater Elevation (Tw) =	1387.95 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.25 Ft
Deflection Angle, Θ = arctan (s) =	15.02 Deg
Inlet Diameter, di = d / cos Θ =	1.29 Ft
Velocity, v = Q / (π(d/12)^2/4) =	0.78 Fps
Velocity Head, hv = $v^2 \div 2g$ =	0.01 Ft
Friction Slope, Sf = 4.66 * n^2 * Q^2 ÷ (d^(16/3)) =	0.00022 Ft/Ft
Entrance Loss Coeficient, Ke =	0.50
Exit Loss Coeficient, Ko =	1
Pipe Loss, hp = Sf * l =	0.01 Ft
Entrance Loss, he = Ke * hv =	0.00 Ft
Exit Loss, ho = Ko * hv =	0.01 Ft
Total Friction Loss, H = hp + he + ho =	0.02 Ft
Headwater Elevation, Hwo = Tw + H =	1387.97 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	0.96 cfs
x = Q / d^2.5 =	0.5495
Hw/d =	0.41 Ft/Ft
Hwi = Hw * d + ELi =	1388.89 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1388.89 Ft

Freeboard, FB = tc - cf÷12 - HW =	2.82 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	1.97 Ft		
Drop Inlet Depth, V = tc - ELi =	4.00 Ft	≥	1.97 Ft

9TH STREET EKA#3097
CONNECTOR PIPE CALCS 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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PIPE RECORD NO. 9
Location: STA 30+50
Pipe material: RCP
Mannings N-Value, n = 0.013
Pipe diameter (D) = 15 In
Pipe Length (l) = 9 Ft
Pipe Angle at Inlet (O) = 90.00 Deg
Grate Elevation (G) = 1388.14 Ft
Outlet Invert Elevation (ELo) = 1378.40 Ft
Inlet Invert Elevation (ELi) = 1385.14 Ft
Curb Face Opening (cf) = 0 In
Design Flow (Q) = 2.69 cfs
Tailwater Elevation (Tw) = 1386.46 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d = 1.25 Ft
Deflection Angle, Θ = 90.00 Deg
Inlet Diameter, di = d / sin Θ = 1.25 Ft
Velocity, v = Q / (π(d/12)²/4) = 2.19 Fps
Velocity Head, hv = v²÷2g = 0.07 Ft
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) = 0.00173 Ft/Ft
Entrance Loss Coeficient, Ke = 0.50
Exit Loss Coeficient, Ko = 1
Pipe Loss, hp = Sf * l = 0.02 Ft
Entrance Loss, he = Ke * hv = 0.04 Ft
Exit Loss, ho = Ko * hv = 0.07 Ft

Total Friction Loss, H = hp + he + ho = 0.13 Ft
Headwater Elevation, Hwo = Tw + H = 1386.59 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall
Q = 2.69 cfs
x = Q / d^2.5 = 1.5398
Hw/d = 0.78 Ft/Ft
Hwi = Hw * d + ELi = 1386.12 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1386.59 Ft
Freeboard, FB = G - cf÷12 - HW = 1.55 Ft ≥ 0.50 Ft
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Minimum Allowable Drop Inlet Depth,
V' = cf÷12 + 1.5 * hv + di = 1.36 Ft
Drop Inlet Depth, V = G - ELi = 3.00 Ft ≥ 1.36 Ft
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9TH STREET EKA#3097
CONNECTOR PIPE CALCS 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

PIPE RECORD NO. 10
Location: STA 26+00
Pipe material: RCP
Mannings N-Value, n = 0.013
Pipe diameter (D) = 15 In
Pipe Length (l) = 10 Ft
Pipe Angle at Inlet (O) = 90.00 Deg
Grate Elevation (G) = 1386.24 Ft
Outlet Invert Elevation (ELo) = 1374.22 Ft
Inlet Invert Elevation (ELi) = 1383.24 Ft
Curb Face Opening (cf) = 0 In
Design Flow (Q) = 0.82 cfs
Tailwater Elevation (Tw) = 1383.48 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d = 1.25 Ft
Deflection Angle, Θ = 90.00 Deg
Inlet Diameter, di = d / sin Θ = 1.25 Ft
Velocity, v = Q / (π(d/12)^2/4) = 0.67 Fps
Velocity Head, hv = $v^2 \div 2g$ = 0.01 Ft
Friction Slope, Sf = 4.66 * n^2 * Q^2 ÷ (d^(16/3)) = 0.00016 Ft/Ft
Entrance Loss Coeficient, Ke = 0.50
Exit Loss Coeficient, Ko = 1
Pipe Loss, hp = Sf * l = 0.00 Ft
Entrance Loss, he = Ke * hv = 0.00 Ft
Exit Loss, ho = Ko * hv = 0.01 Ft

Total Friction Loss, H = hp + he + ho = 0.01 Ft
Headwater Elevation, Hwo = Tw + H = 1383.49 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall
Q = 0.82 cfs
x = Q / d^2.5 = 0.4694
Hw/d = 0.37 Ft/Ft
Hwi = Hw * d + ELi = 1383.70 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1383.70 Ft
Freeboard, FB = G - cf÷12 - HW = 2.54 Ft ≥ 0.50 Ft

Minimum Allowable Drop Inlet Depth,
V' = cf÷12 + 1.5 * hv + di = 1.26 Ft
Drop Inlet Depth, V = G - ELi = 3.00 Ft ≥ 1.26 Ft

9TH STREET EKA#3097
CONNECTOR PIPE CALCS 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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PIPE RECORD NO. 11
Location: STA 21+40
Pipe material: RCP
Mannings N-Value, n = 0.013
Pipe diameter (D) = 15 In
Pipe Length (l) = 9 Ft
Pipe Angle at Inlet (O) = 90.00 Deg
Grate Elevation (G) = 1384.62 Ft
Outlet Invert Elevation (ELo) = 1373.27 Ft
Inlet Invert Elevation (ELi) = 1381.62 Ft
Curb Face Opening (cf) = 0 In
Design Flow (Q) = 4.76 cfs
Tailwater Elevation (Tw) = 1382.75 Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d = 1.25 Ft
Deflection Angle, Θ = 90.00 Deg
Inlet Diameter, di = d / sin Θ = 1.25 Ft
Velocity, v = Q / (π(d/12)²/4) = 3.88 Fps
Velocity Head, hv = v²÷2g = 0.23 Ft
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) = 0.00543 Ft/Ft
Entrance Loss Coeficient, Ke = 0.50
Exit Loss Coeficient, Ko = 1
Pipe Loss, hp = Sf * l = 0.05 Ft
Entrance Loss, he = Ke * hv = 0.12 Ft
Exit Loss, ho = Ko * hv = 0.23 Ft

Total Friction Loss, H = hp + he + ho = 0.40 Ft
Headwater Elevation, Hwo = Tw + H = 1383.15 Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall
Q = 4.76 cfs
x = Q / d^2.5 = 2.7248
Hw/d = 1.15 Ft/Ft
Hwi = Hw * d + ELi = 1383.06 Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1383.15 Ft
Freeboard, FB = G - cf÷12 - HW = 1.47 Ft ≥ 0.50 Ft ✓

Minimum Allowable Drop Inlet Depth,
V' = cf÷12 + 1.5 * hv + di = 1.60 Ft
Drop Inlet Depth, V = G - ELi = 3.00 Ft ≥ 1.60 Ft ✓

9TH STREET — EKA#3097
CONNECTOR PIPE CALCS — 7/19/91
CITY OF PHOENIX PROCEDURE FOR CONNECTOR PIPE DESIGN. — BJF/KM
RE: Storm Drain Design Manual, City of Phoenix, 1987, Pages 18, 31-34.

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PIPE RECORD NO. 12

Location:	STA 12+60	
Pipe material:	RCP	
Mannings N-Value, n =	0.013	
Pipe diameter (D) =	15	In
Pipe Length (l) =	13	Ft
Pipe Angle at Inlet (O) =	90.00	Deg
Grate Elevation (G) =	1382.75	Ft
Outlet Invert Elevation (ELo) =	1370.45	Ft
Inlet Invert Elevation (ELi) =	1379.75	Ft
Curb Face Opening (cf) =	0	In
Design Flow (Q) =	3.10	cfs
Tailwater Elevation (Tw) =	1381.83	Ft

ASSUMING OUTLET CONTROL AND PIPE FLOWING FULL CALCULATE THE FOLLOWING:

Pipe Diameter, d =	1.25 Ft	
Deflection Angle, Θ =	90.00	Deg
Inlet Diameter, di = d / sin Θ =	1.25	Ft
Velocity, v = Q / (π(d/12)²/4) =	2.53	Fps
Velocity Head, hv = v²÷2g =	0.10 Ft	
Friction Slope, Sf = 4.66 * n² * Q² ÷ (d^(16/3)) =	0.00230	Ft/Ft
Entrance Loss Coeficient, Ke =	0.50	
Exit Loss Coeficient, Ko =	1	
Pipe Loss, hp = Sf * l =	0.03	Ft
Entrance Loss, he = Ke * hv =	0.05	Ft
Exit Loss, ho = Ko * hv =	0.10	Ft
Total Friction Loss, H = hp + he + ho =	0.18	Ft
Headwater Elevation, Hwo = Tw + H =	1382.01	Ft

ASSUMING INLET CONTROL, CALCULATE THE FOLLOWING (RE: BUREAU OF PUBLIC ROADS, 1964.):

Square Edged Headwall

Q =	3.10	cfs
x = Q / d^2.5 =	1.7745	
Hw/d =	0.86	Ft/Ft
Hwi = Hw * d + ELi =	1380.82	Ft

CALCULATE FREEBOARD AND DEPTH OF BASIN:

Controlling Headwater Condition (Max. of Hwo or Hwi),
HW = 1382.01 Ft

Freeboard, FB = G - cf÷12 - HW =	0.74 Ft	≥	0.50 Ft
Minimum Allowable Drop Inlet Depth, V' = cf÷12 + 1.5 * hv + di =	1.40 Ft		
Drop Inlet Depth, V = G - ELi =	3.00 Ft	≥	1.40 Ft

9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/19/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

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INPUT DATA:

PIPE RECORD NO.	1
Location:	STA 13+50
Pipe material:	rcp
Internal Pipe diameter (D):	96 In
Wall thickness:	9.5 In
Outside Diameter (d):	9.58 Ft
Height of Cover (H):	9 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.	
P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	20.58 Ft
W = Width of plane =	21.42 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	109 Psf
s = Effective width =	9.58 Ft
Wt = Active weight on pipe = Pavg * L * s =	21,490 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	33.16 Ft
LL = Wt / Le =	648 Lbs/Lf

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1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):	
Mimimum Trench Width =	11.58 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	0.94
Cc = Load coeficient, positive projection =	1.48
Try Transition Width (tw) =	16.71 Ft
j = 2*ku'*H/tw =	0.21
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	16.71 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.49
DL = Cd * w * b^2 =	19,021 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	19,669 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,300 Lbs/Lf/Dia.Ft.

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2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		0.94
Cc = Load coeficient, positive projection =		1.48
DL = Cc * w * d^2 =		19,021 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		19,669 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.31	
LF =	2.82	
D-Load = TL / LF* SF / (D/12) =	900 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,300 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/19/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

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INPUT DATA:

PIPE RECORD NO.	2
Location:	STA 18+50
Pipe material:	rcp
Internal Pipe diameter (D):	96 In
Wall thickness:	9.5 In
Outside Diameter (d):	9.58 Ft
Height of Cover (H):	9 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	20.58 Ft
W = Width of plane =	21.42 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	109 Psf
s = Effective width =	9.58 Ft
Wt = Active weight on pipe = Pavg * L * s =	21,490 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	33.16 Ft
LL = Wt / Le =	648 Lbs/Lf

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1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	11.58 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	0.94
Cc = Load coeficient, positive projection =	1.48
Try Transition Width (tw) =	16.71 Ft
j = 2*ku'*H/tw =	0.21
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	16.71 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.49
DL = Cd * w * b^2 =	19,021 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	19,669 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,300 Lbs/Lf/Dia.Ft.

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2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		0.94
Cc = Load coeficient, positive projection =		1.48
DL = Cc * w * d^2 =		19,021 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		19,669 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.31	
LF =	2.82	
D-Load = TL / LF* SF / (D/12) =	900 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,300 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER
MAIN LINE PIPE CALCULATIONS
LOADING ON RIGID CONCRETE PIPES.
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

EK3097
7/22/91
BJF/KM

INPUT DATA:

PIPE RECORD NO.	3
Location:	STA 23+45
Pipe material:	rcp
Internal Pipe diameter (D):	96 In
Wall thickness:	9.5 In
Outside Diameter (d):	9.58 Ft
Height of Cover (H):	10 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.	
P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	22.33 Ft
W = Width of plane =	23.17 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	93 Psf
s = Effective width =	9.58 Ft
Wt = Active weight on pipe = Pavg * L * s =	19,895 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	34.91 Ft
LL = Wt / Le =	570 Lbs/Lf

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):	
Mimimum Trench Width =	11.58 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	1.04
Cc = Load coeficient, positive projection =	1.64
Try Transition Width (tw) =	16.88 Ft
j = 2*ku'*H/tw =	0.23
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	16.88 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.53
DL = Cd * w * b^2 =	21,134 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	21,704 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,450 Lbs/Lf/Dia.Ft.

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.04
Cc = Load coeficient, positive projection =		1.64
DL = Cc * w * d^2 =		21,134 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		21,704 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.30	
LF =	2.78	
D-Load = TL / LF* SF / (D/12) =	1,000 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,450 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

INPUT DATA:

PIPE RECORD NO.	4
Location:	CL STA 28+45.71, 33.29'RT
Pipe material:	rcp
Internal Pipe diameter (D):	60 In
Wall thickness:	6.5 In
Outside Diameter (d):	6.08 Ft
Height of Cover (H):	11.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	24.95 Ft
W = Width of plane =	25.79 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	75 Psf
s = Effective width =	6.08 Ft
Wt = Active weight on pipe = Pavg * L * s =	11,379 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	32.94 Ft
LL = Wt / Le =	345 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	8.08 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	1.89
Cc = Load coeficient, positive projection =	2.98
Try Transition Width (tw) =	11.54 Ft
j = 2*ku'*H/tw =	0.38
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	11.54 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.83
DL = Cd * w * b^2 =	15,428 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	15,773 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,700 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.89
Cc = Load coeficient, positive projection =		2.98
DL = Cc * w * d^2 =		15,428 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		15,773 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.26	
LF =	2.64	
D-Load = TL / LF* SF / (D/12) =	1,200 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,700 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

INPUT DATA:

PIPE RECORD NO.	5
Location:	STA 31+00
Pipe material:	rcp
Internal Pipe diameter (D):	108 In
Wall thickness:	9.5 In
Outside Diameter (d):	10.58 Ft
Height of Cover (H):	7.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	17.95 Ft
W = Width of plane =	18.79 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	142 Psf
s = Effective width =	10.58 Ft
Wt = Active weight on pipe = Pavg * L * s =	26,975 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	31.85 Ft
LL = Wt / Le =	847 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	12.58 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	0.71
Cc = Load coeficient, positive projection =	1.12
Try Transition Width (tw) =	18.04 Ft
j = 2*ku'*H/tw =	0.16
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	18.04 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.38
DL = Cd * w * b^2 =	17,504 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	18,351 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,100 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		0.71
Cc = Load coeficient, positive projection =		1.12
DL = Cc * w * d^2 =		17,504 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		18,351 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.35	
LF =	2.95	
D-Load = TL / LF* SF / (D/12) =		700 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,100 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

INPUT DATA:

PIPE RECORD NO.	6
Location:	STA 37+50
Pipe material:	rcp
Internal Pipe diameter (D):	108 In
Wall thickness:	10.5 In
Outside Diameter (d):	10.75 Ft
Height of Cover (H):	10.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	23.20 Ft
W = Width of plane =	24.04 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	86 Psf
s = Effective width =	10.75 Ft
Wt = Active weight on pipe = Pavg * L * s =	21,453 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	37.31 Ft
LL = Wt / Le =	575 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	12.75 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	0.98
Cc = Load coeficient, positive projection =	1.54
Try Transition Width (tw) =	18.82 Ft
j = 2*ku'*H/tw =	0.21
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	18.82 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.50
DL = Cd * w * b^2 =	24,892 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	25,467 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,500 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	0.98
Cq = Load coeficient, positive projection =	1.54
DL = Cc * w * d^2 =	24,892 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	25,467 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.31
LF =		2.80
D-Load = TL / LF* SF / (D/12) =		1,050 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,500 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

==========

INPUT DATA:

PIPE RECORD NO.	7
Location:	STA 37+50
Pipe material:	rcp
Internal Pipe diameter (D):	84 In
Wall thickness:	8.5 In
Outside Diameter (d):	8.42 Ft
Height of Cover (H):	10.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	23.20 Ft
W = Width of plane =	24.04 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	86 Psf
s = Effective width =	8.42 Ft
Wt = Active weight on pipe = Pavg * L * s =	16,803 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	34.25 Ft
LL = Wt / Le =	491 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	10.42 Ft

Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,

rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	1.25
Cc = Load coeficient, positive projection =	1.97
Try Transition Width (tw) =	15.11 Ft
j = 2*ku'*H/tw =	0.27
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	15.11 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.61
DL = Cd * w * b^2 =	19,489 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	19,980 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,550 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.25
Cc = Load coeficient, positive projection =		1.97
DL = Cc * w * d^2 =		19,489 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =		19,980 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.29
LF =		2.73
D-Load = TL / LF* SF / (D/12) =		1,050 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,550 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

==========

INPUT DATA:

PIPE RECORD NO.	8	
Location:	STA 40+00	
Pipe material:	rcp	
Internal Pipe diameter (D):	84	In
Wall thickness:	8.5	In
Outside Diameter (d):	8.42	Ft
Height of Cover (H):	10	Ft
Coefficient of Friction (u) :	0.6	
Ku:	0.1924	
K :	0.32	
Settlement Ratio (rsd):	0.7	
Projection Ratio (p) =	1	
Soil density (w):	140	Pcf
Trench Bedding Factor (Bf):	1.9	
Load Factor Parameters: N:	0.707	
x:	0.638	
Safety Factor (SF):	1	

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000	Lbs
IF = Impact factor =	1	
L = Length of plane =	22.33	Ft
W = Width of plane =	23.17	Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	93	Psf
s = Effective width =	8.42	Ft
Wt = Active weight on pipe = Pavg * L * s =	17,486	Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	33.38	Ft
LL = Wt / Le =	524	Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	10.42	Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,		
rsd * p = Settlement * Projection ratio =	0.7	
H/d = Height of cover / diameter =	1.19	
Cc = Load coeficient, positive projection =	1.87	
Try Transition Width (tw) =	15.03	Ft
j = 2*ku'*H/tw =	0.26	
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00	
Design Width (b) =	15.03	Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.59	
DL = Cd * w * b^2 =	18,561	Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =	19,085	Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):		
Safety Factor (SF) =	1	
Bedding Factor (BF) =	1.9	
D-LOAD = TL / BF * SF / (D/12) =	1,450	Lbs/Lf/Dia.Ft.

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2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.19
Cc = Load coeficient, positive projection =		1.87
DL = Cc * w * d^2 =		18,561 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		19,085 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.29	
LF =	2.74	
D-Load = TL / LF* SF / (D/12) =	1,000 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,450 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

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INPUT DATA:

PIPE RECORD NO.	9	
Location:	STA 45+00	
Pipe material:	rcp	
Internal Pipe diameter (D):	84	In
Wall thickness:	8.5	In
Outside Diameter (d):	8.42	Ft
Height of Cover (H):	9.5	Ft
Coefficient of Friction (u) :	0.6	
Ku:	0.1924	
K :	0.32	
Settlement Ratio (rsd):	0.7	
Projection Ratio (p) =	1	
Soil density (w):	140	Pcf
Trench Bedding Factor (Bf):	1.9	
Load Factor Parameters: N:	0.707	
x:	0.638	
Safety Factor (SF):	1	

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000	Lbs
IF = Impact factor =	1	
L = Length of plane =	21.45	Ft
W = Width of plane =	22.29	Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	100	Psf
s = Effective width =	8.42	Ft
Wt = Active weight on pipe = Pavg * L * s =	18,065	Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	32.5	Ft
LL = Wt / Le =	556	Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	10.42	Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,		
rsd * p = Settlement * Projection ratio =	0.7	
H/d = Height of cover / diameter =	1.13	
Cc = Load coeficient, positive projection =	1.78	
Try Transition Width (tw) =	14.95	Ft
j = 2*ku'*H/tw =	0.24	
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00	
Design Width (b) =	14.95	Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.56	
DL = Cd * w * b^2 =	17,633	Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =	18,189	Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):		
Safety Factor (SF) =	1	
Bedding Factor (BF) =	1.9	
D-LOAD = TL / BF * SF / (D/12) =	1,400	Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.13
Cc = Load coeficient, positive projection =		1.78
DL = Cc * w * d^2 =		17,633 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		18,189 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.29	
LF =	2.75	
D-Load = TL / LF* SF / (D/12) =	950	Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,400 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER
MAIN LINE PIPE CALCULATIONS
LOADING ON RIGID CONCRETE PIPES.
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

EK3097
7/22/91
BJF/KM

INPUT DATA:

PIPE RECORD NO.	10
Location:	STA 56+00
Pipe material:	rcp
Internal Pipe diameter (D):	72 In
Wall thickness:	7.5 In
Outside Diameter (d):	7.25 Ft
Height of Cover (H):	10 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	22.33 Ft
W = Width of plane =	23.17 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	93 Psf
s = Effective width =	7.25 Ft
Wt = Active weight on pipe = Pavg * L * s =	15,056 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	31.85 Ft
LL = Wt / Le =	473 Lbs/Lf

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	9.25 Ft

Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,

rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	1.38
Cc = Load coeficient, positive projection =	2.17
Try Transition Width (tw) =	13.17 Ft
j = 2*ku'*H/tw =	0.29
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	13.17 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.66
DL = Cd * w * b^2 =	15,988 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	16,461 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,450 Lbs/Lf/Dia.Ft.

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	1.38	
Cc = Load coeficient, positive projection =	2.17	
DL = Cc * w * d^2 =	15,988	Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	16,461	Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707	
	x =	0.638	
	q = pK/Cc(H/d+p/2) =	0.28	
LF =		2.70	
D-Load = TL / LF* SF / (D/12) =		1,050	Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,450 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
MAIN LINE PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

INPUT DATA:

PIPE RECORD NO.	11
Location:	STA 59+61.60
Pipe material:	rcp
Internal Pipe diameter (D):	72 In
Wall thickness:	7.5 In
Outside Diameter (d):	7.25 Ft
Height of Cover (H):	11.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	24.95 Ft
W = Width of plane =	25.79 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	75 Psf
s = Effective width =	7.25 Ft
Wt = Active weight on pipe = Pavg * L * s =	13,569 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	34.47 Ft
LL = Wt / Le =	394 Lbs/Lf

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	9.25 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	1.59
Cc = Load coeficient, positive projection =	2.50
Try Transition Width (tw) =	13.41 Ft
j = 2*ku'*H/tw =	0.33
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	13.41 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.73
DL = Cd * w * b^2 =	18,387 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	18,781 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,650 Lbs/Lf/Dia.Ft.

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.59
Cc = Load coeficient, positive projection =		2.50
DL = Cc * w * d^2 =		18,387 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		18,781 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.27	
LF =	2.67	
D-Load = TL / LF* SF / (D/12) =	1,200 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,650 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER
MAIN LINE PIPE CALCULATIONS
LOADING ON RIGID CONCRETE PIPES.
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

EK3097
7/22/91
BJF/KM

==========

INPUT DATA:

PIPE RECORD NO.	12
Location:	CL STA 59+76.74, 33'RT
Pipe material:	rcp
Internal Pipe diameter (D):	72 In
Wall thickness:	7.5 In
Outside Diameter (d):	7.25 Ft
Height of Cover (H):	12.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	26.70 Ft
W = Width of plane =	27.54 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	65 Psf
s = Effective width =	7.25 Ft
Wt = Active weight on pipe = Pavg * L * s =	12,585 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	36.22 Ft
LL = Wt / Le =	347 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	9.25 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	1.72
Cc = Load coeficient, positive projection =	2.72
Try Transition Width (tw) =	13.56 Ft
j = 2*ku'*H/tw =	0.35
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	-0.00
Design Width (b) =	13.56 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.78
DL = Cd * w * b^2 =	19,985 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	20,332 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,800 Lbs/Lf/Dia.Ft.

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2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.72
Cc = Load coeficient, positive projection =		2.72
DL = Cc * w * d^2 =		19,985 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		20,332 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.26	
LF =	2.65	
D-Load = TL / LF* SF / (D/12) =	1,300 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,800 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER
MAIN LINE PIPE CALCULATIONS
LOADING ON RIGID CONCRETE PIPES.
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

EK3097
7/22/91
BJF/KM

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INPUT DATA:

PIPE RECORD NO.	13
Location:	CL STA 23+45, STUBOUT
Pipe material:	rcp
Internal Pipe diameter (D):	60 In
Wall thickness:	6.5 In
Outside Diameter (d):	6.08 Ft
Height of Cover (H):	11.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	24.95 Ft
W = Width of plane =	25.79 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	75 Psf
s = Effective width =	6.08 Ft
Wt = Active weight on pipe = Pavg * L * s =	11,379 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	32.94 Ft
LL = Wt / Le =	345 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	8.08 Ft

Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,

rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	1.89
Cc = Load coeficient, positive projection =	2.98
Try Transition Width (tw) =	11.54 Ft
j = 2*ku'*H/tw =	0.38
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	11.54 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	0.83
DL = Cd * w * b^2 =	15,428 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	15,773 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,700 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		1.89
Cc = Load coeficient, positive projection =		2.98
DL = Cc * w * d^2 =		15,428 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		15,773 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.26	
LF =	2.64	
D-Load = TL / LF* SF / (D/12) =	1,200 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,700 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

INPUT DATA:

PIPE RECORD NO.	1	
Location:	STA 58+00	
Pipe material:	rcp	
Internal Pipe diameter (D):	15	In
Wall thickness:	3.5	In
Outside Diameter (d):	1.83	Ft
Height of Cover (H):	11.5	Ft
Coefficient of Friction (u) :	0.6	
Ku:	0.1924	
K :	0.32	
Settlement Ratio (rsd):	0.7	
Projection Ratio (p) =	1	
Soil density (w):	140	Pcf
Trench Bedding Factor (Bf):	1.9	
Load Factor Parameters: N:	0.707	
x:	0.638	
Safety Factor (SF):	1	

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000	Lbs
IF = Impact factor =	1	
L = Length of plane =	24.95	Ft
W = Width of plane =	25.79	Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	75	Psf
s = Effective width =	1.83	Ft
Wt = Active weight on pipe = Pavg * L * s =	3,425	Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	27.36	Ft
LL = Wt / Le =	125	Lbs/Lf

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17	Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,		
rsd * p = Settlement * Projection ratio =	0.7	
H/d = Height of cover / diameter =	6.27	
Cc = Load coeficient, positive projection =	9.88	
Try Transition Width (tw) =	4.53	Ft
j = 2*ku'*H/tw =	0.98	
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00	
Design Width (b) =	4.53	Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.62	
DL = Cd * w * b^2 =	4,649	Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =	4,774	Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):		
Safety Factor (SF) =	1	
Bedding Factor (BF) =	1.9	
D-LOAD = TL / BF * SF / (D/12) =	2,050	Lbs/Lf/Dia.Ft.

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		6.27
Cc = Load coeficient, positive projection =		9.88
DL = Cc * w * d^2 =		4,649 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =		4,774 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.22
LF =		2.52
D-Load = TL / LF* SF / (D/12) =		1,550 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 2,050 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

==========

INPUT DATA:

PIPE RECORD NO.	2
Location:	STA 53+70
Pipe material:	rcp
Internal Pipe diameter (D):	18 In
Wall thickness:	3.75 In
Outside Diameter (d):	2.13 Ft
Height of Cover (H):	10.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	23.20 Ft
W = Width of plane =	24.04 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	86 Psf
s = Effective width =	2.13 Ft
Wt = Active weight on pipe = Pavg * L * s =	4,251 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	25.99 Ft
LL = Wt / Le =	164 Lbs/Lf

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1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.46 Ft

Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,

rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	4.94
Cc = Load coeficient, positive projection =	7.78
Try Transition Width (tw) =	4.91 Ft
j = 2*ku'*H/tw =	0.82
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.91 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.46
DL = Cd * w * b^2 =	4,921 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	5,085 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,800 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		4.94
Cc = Load coeficient, positive projection =		7.78
DL = Cc * w * d^2 =		4,921 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		5,085 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.22	
LF =	2.54	
D-Load = TL / LF* SF / (D/12) =	1,350 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,800 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

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INPUT DATA:

PIPE RECORD NO.	3
Location:	STA 50+10
Pipe material:	rcp
Internal Pipe diameter (D):	18 In
Wall thickness:	3.75 In
Outside Diameter (d):	2.13 Ft
Height of Cover (H):	10 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	22.33 Ft
W = Width of plane =	23.17 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	93 Psf
s = Effective width =	2.13 Ft
Wt = Active weight on pipe = Pavg * L * s =	4,423 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	25.12 Ft
LL = Wt / Le =	176 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.46 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	4.71
Cc = Load coeficient, positive projection =	7.41
Try Transition Width (tw) =	4.85 Ft
j = 2*ku'*H/tw =	0.79
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.85 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.42
DL = Cd * w * b^2 =	4,686 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	4,862 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,750 Lbs/Lf/Dia.Ft.

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2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	4.71
Cc = Load coeficient, positive projection =	7.41
DL = Cc * w * d^2 =	4,686 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	4,862 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)	
Safety Factor (SF) = 1	
Load Factor (LF): (pg 4-63 - 4-64)	
LF = 1.431/(N-xq)	
Where: N =	0.707
x =	0.638
q = pK/Cc(H/d+p/2) =	0.23
LF =	2.54
D-Load = TL / LF* SF / (D/12) =	1,300 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,750 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

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INPUT DATA:

PIPE RECORD NO.	4
Location:	STA 47+00
Pipe material:	rcp
Internal Pipe diameter (D):	18 In
Wall thickness:	3.75 In
Outside Diameter (d):	2.13 Ft
Height of Cover (H):	10.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	23.20 Ft
W = Width of plane =	24.04 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	86 Psf
s = Effective width =	2.13 Ft
Wt = Active weight on pipe = Pavg * L * s =	4,251 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	25.99 Ft
LL = Wt / Le =	164 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.46 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	4.94
Cc = Load coeficient, positive projection =	7.78
Try Transition Width (tw) =	4.91 Ft
j = 2*ku'*H/tw =	0.82
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.91 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.46
DL = Cd * w * b^2 =	4,921 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	5,085 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,800 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	4.94
Cc = Load coeficient, positive projection =	7.78
DL = Cc * w * d^2 =	4,921 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	5,085 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.22
LF =		2.54
D-Load = TL / LF* SF / (D/12) =		1,350 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,800 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

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INPUT DATA:

PIPE RECORD NO.	5
Location:	STA 43+00
Pipe material:	rcp
Internal Pipe diameter (D):	18 In
Wall thickness:	3.75 In
Outside Diameter (d):	2.13 Ft
Height of Cover (H):	11 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	24.08 Ft
W = Width of plane =	24.92 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	80 Psf
s = Effective width =	2.13 Ft
Wt = Active weight on pipe = Pavg * L * s =	4,103 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	26.87 Ft
LL = Wt / Le =	153 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.46 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	5.18
Cc = Load coeficient, positive projection =	8.15
Try Transition Width (tw) =	4.97 Ft
j = 2*ku'*H/tw =	0.85
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.97 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.49
DL = Cd * w * b^2 =	5,155 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	5,308 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,900 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		5.18
Cc = Load coeficient, positive projection =		8.15
DL = Cc * w * d^2 =		5,155 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		5,308 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.22	
LF =	2.53	
D-Load = TL / LF* SF / (D/12) =	1,400 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,900 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

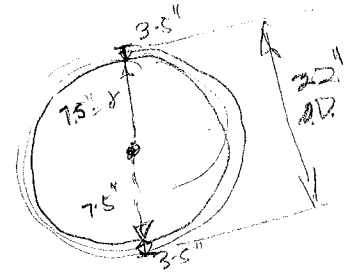
==========

INPUT DATA:

PIPE RECORD NO.	6
Location:	STA 37+00
Pipe material:	rcp
Internal Pipe diameter (D):	15 In
Wall thickness:	3.5 In
Outside Diameter (d):	1.83 Ft
Height of Cover (H):	12.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

7.5" + 3.5" = 11" x 2 = 22"/12 = 1.834

OUTSIDE DIAMETER



LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	26.70 Ft ①
W = Width of plane =	27.54 Ft
Pavg = Average pressure acting on plane = P * IF / (W * L) =	65 Psf ②
s = Effective width =	1.83 Ft ③
Wt = Active weight on pipe = Pavg * L * s = ①*②*③ →	3,177 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	29.11 Ft
LL = Wt / Le =	109 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	6.82
Cc = Load coeficient, positive projection =	10.74
Try Transition Width (tw) =	4.64 Ft
j = 2*ku'*H/tw =	1.04
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.64 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.68
DL = Cd * w * b^2 =	5,054 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	5,163 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	2,200 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	6.82
Cc = Load coeficient, positive projection =	10.74
DL = Cc * w * d^2 =	5,054 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	5,163 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.22
LF =		2.52
D-Load = TL / LF* SF / (D/12) =		1,650 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 2,200 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER
CONNECTOR PIPE CALCULATIONS
LOADING ON RIGID CONCRETE PIPES.
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

EK3097
7/22/91
BJF/KM

INPUT DATA:

PIPE RECORD NO.	7
Location:	STA 36+65, 45'RT
Pipe material:	rcp
Internal Pipe diameter (D):	15 In
Wall thickness:	3.5 In
Outside Diameter (d):	1.83 Ft
Height of Cover (H):	14.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	30.20 Ft
W = Width of plane =	31.04 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	51 Psf
s = Effective width =	1.83 Ft
Wt = Active weight on pipe = Pavg * L * s =	2,819 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	32.61 Ft
LL = Wt / Le =	86 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17 Ft

Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,

rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	7.91
Cc = Load coeficient, positive projection =	12.46
Try Transition Width (tw) =	4.86 Ft
j = 2*ku'*H/tw =	1.15
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.86 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.77
DL = Cd * w * b^2 =	5,862 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	5,948 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	2,550 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	7.91
Cc = Load coeficient, positive projection =	12.46
DL = Cc * w * d^2 =	5,862 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	5,948 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.22
LF =		2.52
D-Load = TL / LF* SF / (D/12) =		1,900 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 2,550 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER
CONNECTOR PIPE CALCULATIONS
LOADING ON RIGID CONCRETE PIPES.
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

EK3097
7/22/91
BJF/KM

==========

INPUT DATA:

PIPE RECORD NO.	8	
Location:	STA 36+21, 45'RT	
Pipe material:	rcp	
Internal Pipe diameter (D):	15	In
Wall thickness:	3.5	In
Outside Diameter (d):	1.83	Ft
Height of Cover (H):	14.5	Ft
Coefficient of Friction (u) :	0.6	
Ku:	0.1924	
K :	0.32	
Settlement Ratio (rsd):	0.7	
Projection Ratio (p) =	1	
Soil density (w):	140	Pcf
Trench Bedding Factor (Bf):	1.9	
Load Factor Parameters: N:	0.707	
x:	0.638	
Safety Factor (SF):	1	

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000	Lbs
IF = Impact factor =	1	
L = Length of plane =	30.20	Ft
W = Width of plane =	31.04	Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	51	Psf
s = Effective width =	1.83	Ft
Wt = Active weight on pipe = Pavg * L * s =	2,819	Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	32.61	Ft
LL = Wt / Le =	86	Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17	Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,		
rsd * p = Settlement * Projection ratio =	0.7	
H/d = Height of cover / diameter =	7.91	
Cc = Load coeficient, positive projection =	12.46	
Try Transition Width (tw) =	4.86	Ft
j = 2*ku'*H/tw =	1.15	
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00	
Design Width (b) =	4.86	Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.77	
DL = Cd * w * b^2 =	5,862	Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	5,948	Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1	
Bedding Factor (BF) =	1.9	
D-LOAD = TL / BF * SF / (D/12) =	2,550	Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	7.91
Cc = Load coeficient, positive projection =	12.46
DL = Cc * w * d^2 =	5,862 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	5,948 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)	
Safety Factor (SF) =	1
Load Factor (LF): (pg 4-63 - 4-64)	
LF = 1.431/(N-xq)	
Where: N =	0.707
x =	0.638
q = pK/Cc(H/d+p/2) =	0.22
LF =	2.52
D-Load = TL / LF* SF / (D/12) =	1,900 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 2,550 Lbs/Lf/Dia.Ft.

==========

9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

==========

INPUT DATA:

PIPE RECORD NO.	9
Location:	STA 30+50
Pipe material:	rcp
Internal Pipe diameter (D):	15 In
Wall thickness:	3.5 In
Outside Diameter (d):	1.83 Ft
Height of Cover (H):	9.5 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

for $H \geq 4.1$

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	21.45 Ft
W = Width of plane =	22.29 Ft
Eq. 4.43 Pavg = Average pressure acting on plane = P * IF / (W * L) =	100 Psf
s = Effective width =	1.83 Ft
Wt = Active weight on pipe = Pavg * L * s =	3,926 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	23.86 Ft
LL = Wt / Le =	165 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17 Ft

Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,

rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	5.18
Cc = Load coeficient, positive projection =	8.16
Try Transition Width (tw) =	4.29 Ft
j = 2*ku'*H/tw =	0.85
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.29 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.49
DL = Cd * w * b^2 =	3,841 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	4,006 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,700 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =	5.18
Cc = Load coeficient, positive projection =	8.16
DL = Cc * w * d^2 =	3,841 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	4,006 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) = 1

Load Factor (LF): (pg 4-63 - 4-64)

LF = 1.431/(N-xq)

Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.22
LF =		2.53
D-Load = TL / LF* SF / (D/12) =		1,300 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,700 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

==========

INPUT DATA:

PIPE RECORD NO.	10
Location:	STA 26+00
Pipe material:	rcp
Internal Pipe diameter (D):	15 In
Wall thickness:	3.5 In
Outside Diameter (d):	1.83 Ft
Height of Cover (H):	11 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	24.08 Ft
W = Width of plane =	24.92 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	80 Psf
s = Effective width =	1.83 Ft
Wt = Active weight on pipe = Pavg * L * s =	3,525 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	26.49 Ft
LL = Wt / Le =	133 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	6.00
Cc = Load coeficient, positive projection =	9.45
Try Transition Width (tw) =	4.47 Ft
j = 2*ku'*H/tw =	0.95
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.47 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.59
DL = Cd * w * b^2 =	4,447 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	4,580 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,950 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		6.00
Cc = Load coeficient, positive projection =		9.45
DL = Cc * w * d^2 =		4,447 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		4,580 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.22	
LF =	2.53	
D-Load = TL / LF* SF / (D/12) =	1,500 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,950 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

==========

INPUT DATA:

PIPE RECORD NO.	11
Location:	STA 21+40
Pipe material:	rcp
Internal Pipe diameter (D):	15 In
Wall thickness:	3.5 In
Outside Diameter (d):	1.83 Ft
Height of Cover (H):	10 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	22.33 Ft
W = Width of plane =	23.17 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	93 Psf
s = Effective width =	1.83 Ft
Wt = Active weight on pipe = Pavg * L * s =	3,800 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	24.74 Ft
LL = Wt / Le =	154 Lbs/Lf

---

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17 Ft

Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,

rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	5.45
Cc = Load coeficient, positive projection =	8.59
Try Transition Width (tw) =	4.35 Ft
j = 2*ku'*H/tw =	0.88
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.35 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.53
DL = Cd * w * b^2 =	4,043 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =	4,197 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):

Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,800 Lbs/Lf/Dia.Ft.

---

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		5.45
Cc = Load coeficient, positive projection =		8.59
DL = Cc * w * d^2 =		4,043 Lbs/Lf

TOTAL LOAD (TL):

TL = LL + DL =		4,197 Lbs/Lf

MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)

Safety Factor (SF) =		1
Load Factor (LF):	(pg 4-63 - 4-64)	
LF = 1.431/(N-xq)		
Where:	N =	0.707
	x =	0.638
	q = pK/Cc(H/d+p/2) =	0.22
LF =		2.53
D-Load = TL / LF* SF / (D/12) =		1,350 Lbs/Lf/Dia.Ft.

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,800 Lbs/Lf/Dia.Ft.

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9TH STREET MAJOR TRUNK STORM SEWER — EK3097
CONNECTOR PIPE CALCULATIONS — 7/22/91
LOADING ON RIGID CONCRETE PIPES. — BJF/KM
RE: Concrete Pipe Handbook, ACPA, 1988, Chapter 4.

INPUT DATA:

PIPE RECORD NO.	12
Location:	STA 12+60
Pipe material:	rcp
Internal Pipe diameter (D):	15 In
Wall thickness:	3.5 In
Outside Diameter (d):	1.83 Ft
Height of Cover (H):	11 Ft
Coefficient of Friction (u) :	0.6
Ku:	0.1924
K :	0.32
Settlement Ratio (rsd):	0.7
Projection Ratio (p) =	1
Soil density (w):	140 Pcf
Trench Bedding Factor (Bf):	1.9
Load Factor Parameters: N:	0.707
x:	0.638
Safety Factor (SF):	1

LIVE LOAD ON EFFECTIVE PLANE AT TOP OF PIPE (LL)(Pg. 4-38 - 4-43):

Critical HS-20 loading configuration.

P = Point load =	48,000 Lbs
IF = Impact factor =	1
L = Length of plane =	24.08 Ft
W = Width of plane =	24.92 Ft
Pavg = Average pressure acting on plane = P * IF / W / L =	80 Psf
s = Effective width =	1.83 Ft
Wt = Active weight on pipe = Pavg * L * s =	3,525 Lbs
Le = Effective supporting length of pipe = L + 1.75 * (.75 * d) =	26.49 Ft
LL = Wt / Le =	133 Lbs/Lf

1. TRENCH CONDITIONS:

DEAD LOAD (DL) (Pg. 4-4):

Mimimum Trench Width =	3.17 Ft
Compute the transition width for trench loading = positive projecting loading using Fig. 4.11, page 4-17,	
rsd * p = Settlement * Projection ratio =	0.7
H/d = Height of cover / diameter =	6.00
Cc = Load coeficient, positive projection =	9.45
Try Transition Width (tw) =	4.47 Ft
j = 2*ku'*H/tw =	0.95
err = (1-exp(-j))*tw^2/(2*ku)-Cc*d^2 =	0.00
Design Width (b) =	4.47 Ft
Cd = (1-exp(-2*ku'*H/b))/(2*ku') =	1.59
DL = Cd * w * b^2 =	4,447 Lbs/Lf
TOTAL LOAD (TL):	
TL = LL + DL =	4,580 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68):	
Safety Factor (SF) =	1
Bedding Factor (BF) =	1.9
D-LOAD = TL / BF * SF / (D/12) =	1,950 Lbs/Lf/Dia.Ft.

2. POSITIVE PROJECTION CONDITIONS (4-12, 4-17):

DEAD LOAD (DL):

H/d =		6.00
Cc = Load coeficient, positive projection =		9.45
DL = Cc * w * d^2 =		4,447 Lbs/Lf
TOTAL LOAD (TL):		
TL = LL + DL =		4,580 Lbs/Lf
MINIMUM REQUIRED PIPE STRENGTH (4-67 - 4-68)		
Safety Factor (SF) =	1	
Load Factor (LF): (pg 4-63 - 4-64)		
LF = 1.431/(N-xq)		
Where: N =	0.707	
x =	0.638	
q = pK/Cc(H/d+p/2) =	0.22	
LF =	2.53	
D-Load = TL / LF* SF / (D/12) =	1,500 Lbs/Lf/Dia.Ft.	

For design use the greater of D-Loads for trench and positive projecting conditions,

D-Load = 1,950 Lbs/Lf/Dia.Ft.

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9th Street EK3097
Corrugated Metal Pipe 7/18/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		1	
LOCATION:		STA 13+50	
d = Pipe diameter	=	102	in
h = Height of cover	=	9	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1260 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	20.58	ft
W = Width of Plane	=	21.42	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	109	psf
LL = Live load	=	109	psf

Compute the design load,

pv = Design pressure = DL + LL = 1369 psf

Structure design,

s = Span = d/12	=	8.5	ft
c = Ring compression = pv * s/2	=	5818	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	1275	2333	2.494	0.168	0.020	0.212	Too High
2x1/2	0.170	600	10534	0.552	0.052	0.018	0.226	
2-2/3x1/2	0.172	593	10784	0.540	0.052	0.018	0.231	
3 x 1	0.344	297	25291	0.230	0.034	0.051	0.081	
5 x 1	0.368	277	25385	0.229	0.064	0.106	0.039 ✓	
6 x 2	0.688	148	25385	0.229	0.109	0.725	0.006 ✓	

```
    t = Minimum thickness for strength                  =     0.064        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       7.8
    R = Soil resistivity                                =      3350    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        82     years
   af = Adjustment factor required = y / y1             =      1.83
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109         in.
```

t_{min} for Strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

5" x 1" Corrugation

9th Street EK3097
Corrugated Metal Pipe 7/18/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		2	
LOCATION:		STA 18+50	
d = Pipe diameter	=	102	in
h = Height of cover	=	9	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1260 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	20.58	ft
W = Width of Plane	=	21.42	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	109	psf
LL = Live load	=	109	psf

Compute the design load,

pv = Design pressure = DL + LL = 1369 psf

Structure design,

s = Span = d/12	=	8.5	ft
c = Ring compression = pv * s/2	=	5818	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	1275	2333	2.494	0.168	0.020	0.212	Too High
2x1/2	0.170	600	10534	0.552	0.052	0.018	0.226	
2-2/3x1/2	0.172	593	10784	0.540	0.052	0.018	0.231	
3 x 1	0.344	297	25291	0.230	0.034	0.051	0.081	
5 x 1	0.368	277	25385	0.229	0.064	0.106	0.039 ✓	
6 x 2	0.688	148	25385	0.229	0.109	0.725	0.006 ✓	

```
    t = Minimum thickness for strength                  =     0.064        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       7.8
    R = Soil resistivity                                =      3350    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        82     years
   af = Adjustment factor required = y / y1             =      1.83
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for Strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

5" x 1" Corrugation

9th Street EK3097
Corrugated Metal Pipe 7/18/91
Structural Design BJF/KM

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Re: Handbook of Steel Drainage and Highway Construction Products,
American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		3	
LOCATION:		STA 23+45	
d = Pipe diameter	=	102	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from
Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	8.5	ft
c = Ring compression = pv * s/2	=	6344	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	1275	2333	2.720	0.168	0.020	0.212	Too High
2x1/2	0.170	600	10534	0.602	0.052	0.018	0.226	
2-2/3x1/2	0.172	593	10784	0.588	0.052	0.018	0.231	
3 x 1	0.344	297	25291	0.251	0.034	0.051	0.081	
5 x 1	0.368	277	25385	0.250	0.064	0.106	0.039 ✓	
6 x 2	0.688	148	25385	0.250	0.109	0.725	0.006 ✓	

t	= Minimum thickness for strength	=	0.064	in

Select thickness for a 75-year first perforation or 1/2 average life,

Y	= Years for first perforation =	=	75	
y	= Years for average life = 2 * Y	=	150	
pH	= pH of soil environment	=	9.2	
R	= Soil resistivity	=	3930	ohm-cm
y1	= Years for average life for t=.052 in.			
	= 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3			
	= 2.94 * R^.41, pH>7.3	=	88	years
af	= Adjustment factor required = y / y1	=	1.71	
	Adjustment Factor Used :		2.2	
	Corresponding t:		0.109	in.

t_{min} for Strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

5" x 1" Corrugation

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/18/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		4	
LOCATION:		STA 28+45.71, 33.29' RT	
d = Pipe diameter	=	66	in
h = Height of cover	=	11.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1610 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.95	ft
W = Width of Plane	=	25.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	75	psf
LL = Live load	=	75	psf

Compute the design load,

pv = Design pressure = DL + LL = 1685 psf

Structure design,

s = Span = d/12	=	5.5	ft
c = Ring compression = pv * s/2	=	4633	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	825	5572	0.831	0.079	0.007	0.256
2x1/2	0.170	388	21378	0.217	0.034	0.002	0.968
2-2/3x1/2	0.172	384	21595	0.215	0.034	0.011	0.156
3 x 1	0.344	192	25385	0.182	0.034	0.051	0.034 ✓
5 x 1	0.368	179	25385	0.182	0.064	0.106	0.016 ✓
6 x 2	0.688	96	25385	0.182	0.109	0.725	0.002 ✓

Too High

mc-4

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       9.2
    R = Soil resistivity                                =      3930    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        88     years
   af = Adjustment factor required = y / y1             =      1.71
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

3" x 1" Corrugation

9th Street — EK3097
Corrugated Metal Pipe — 7/18/91
Structural Design — BJF/KM

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Re: Handbook of Steel Drainage and Highway Construction Products,
American and Steel Institute, 1983, Chapter 3, Pages 99-124.

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Site conditions,

PIPE RECORD NUMBER:		5	
LOCATION:		STA 31+00	
d = Pipe diameter	=	114	in
h = Height of cover	=	7.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1050 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from
Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	17.95	ft
W = Width of Plane	=	18.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	142	psf
LL = Live load	=	142	psf

Compute the design load,

pv = Design pressure = DL + LL = 1192 psf

Structure design,

s = Span = d/12	=	9.5	ft
c = Ring compression = pv * s/2	=	5663	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	1425	1868	3.032	0.168	0.020	0.265	Too High
2x1/2	0.170	671	8433	0.672	0.064	0.023	0.223	
2-2/3x1/2	0.172	663	8633	0.656	0.064	0.023	0.229	
3 x 1	0.344	331	23926	0.237	0.034	0.051	0.101	
5 x 1	0.368	310	24780	0.229	0.064	0.106	0.049	
6 x 2	0.688	166	25385	0.223	0.109	0.725	0.007 ✓	

t	= Minimum thickness for strength	=	0.109	in

Select thickness for a 75-year first perforation or 1/2 average life,

Y	= Years for first perforation =	=	75	
y	= Years for average life = 2 * Y	=	150	
pH	= pH of soil environment	=	9.3	
R	= Soil resistivity	=	2440	ohm-cm
y1	= Years for average life for t=.052 in.			
	= 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3			
	= 2.94 * R^.41, pH>7.3	=	72	years
af	= Adjustment factor required = y / y1	=	2.08	
	Adjustment Factor Used :		2.2	
	Corresponding t:		0.109	in.

t_{min} for strength = 0.109 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

6" x 2" Corrugation

9th Street EK3097
Corrugated Metal Pipe 7/18/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		6	
LOCATION:		STA 37+50	
d = Pipe diameter	=	114	in
h = Height of cover	=	10.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1470 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	23.20	ft
W = Width of Plane	=	24.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	86	psf
LL = Live load	=	86	psf

Compute the design load,

pv = Design pressure = DL + LL = 1556 psf

Structure design,

s = Span = d/12	=	9.5	ft
c = Ring compression = pv * s/2	=	7391	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1425	1868	3.958	0.168	0.020	0.265
2x1/2	0.170	671	8433	0.876	0.079	0.029	0.176
2-2/3x1/2	0.172	663	8633	0.856	0.079	0.029	0.181
3 x 1	0.344	331	23926	0.309	0.034	0.051	0.101
5 x 1	0.368	310	24780	0.298	0.064	0.106	0.049
6 x 2	0.688	166	25385	0.291	0.109	0.725	0.007 ✓

Too High

```
    t = Minimum thickness for strength                  =     0.109        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       9.3
    R = Soil resistivity                                =      2440    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH>7.3                            =        72     years
   af = Adjustment factor required = y / y1             =      2.08
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109        in.
```

t_{min} for strength = 0.109 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

6" x 2" Corrugation

9th Street — EK3097
Corrugated Metal Pipe — 7/18/91
Structural Design — BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		7	
LOCATION:		STA 37+50	
d = Pipe diameter	=	90	in
h = Height of cover	=	10.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1470 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	23.20	ft
W = Width of Plane	=	24.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	86	psf
LL = Live load	=	86	psf

Compute the design load,

pv = Design pressure = DL + LL = 1556 psf

Structure design,

s = Span = d/12	=	7.5	ft
c = Ring compression = pv * s/2	=	5835	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	1125	2996	1.947	0.168	0.020	0.165
2x1/2	0.170	529	13531	0.431	0.040	0.014	0.236
2-2/3x1/2	0.172	523	13851	0.421	0.040	0.013	0.240
3 x 1	0.344	262	25385	0.230	0.034	0.051	0.063
5 x 1	0.368	245	25385	0.230	0.064	0.106	0.031 ✓
6 x 2	0.688	131	25385	0.230	0.109	0.725	0.004 ✓

Too High

```
    t = Minimum thickness for strength                  =     0.064          in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       9.3
    R = Soil resistivity                                =      2440     ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                            =        72      years
   af = Adjustment factor required = y / y1             =      2.08
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109           in.
```

t_{min} for Strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

5" x 1" Corrugation

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/18/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		8	
LOCATION:		STA 40+00	
d = Pipe diameter	=	90	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	7.5	ft
c = Ring compression = pv * s/2	=	5598	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	1125	2996	1.868	0.168	0.020	0.165	Too High
2x1/2	0.170	529	13531	0.414	0.040	0.014	0.236	
2-2/3x1/2	0.172	523	13851	0.404	0.040	0.013	0.240	
3 x 1	0.344	262	25385	0.221	0.034	0.051	0.063	
5 x 1	0.368	245	25385	0.221	0.064	0.106	0.031 ✓	
6 x 2	0.688	131	25385	0.221	0.109	0.725	0.004 ✓	

```
    t = Minimum thickness for strength                  =     0.064        in
    (
Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       8.9
    R = Soil resistivity                                =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        69     years
   af = Adjustment factor required = y / y1             =      2.17
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109         in.
```

t_{min} for Strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage
5" x 1" Corrugations

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/18/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		9	
LOCATION:		STA 45+00	
d = Pipe diameter	=	90	in
h = Height of cover	=	9.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1330 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	21.45	ft
W = Width of Plane	=	22.29	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	100	psf
LL = Live load	=	100	psf

Compute the design load,

pv = Design pressure = DL + LL = 1430 psf

Structure design,

s = Span = d/12	=	7.5	ft
c = Ring compression = pv * s/2	=	5364	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	1125	2996	1.790	0.168	0.020	0.165	
2x1/2	0.170	529	13531	0.396	0.034	0.002	1.800	Too High
2-2/3x1/2	0.172	523	13851	0.387	0.034	0.011	0.289	
3 x 1	0.344	262	25385	0.211	0.034	0.051	0.063	
5 x 1	0.368	245	25385	0.211	0.064	0.106	0.031 ✓	
6 x 2	0.688	131	25385	0.211	0.109	0.725	0.004 ✓	

```
     t = Minimum thickness for strength                =     0.064 ✓      in
Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                 =        75
     y = Years for average life = 2 * Y                =       150
    pH = pH of soil environment                        =       8.9
     R = Soil resistivity                              =      2200    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                          =        69     years
    af = Adjustment factor required = y / y1           =      2.17
         Adjustment Factor Used :                            2.2 ✓
         Corresponding t:                                  0.109 ✓      in.
```

t_{min} for Strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

5" x 1" Corrugations

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/18/91
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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		10	
LOCATION:		STA 56+00	
d = Pipe diameter	=	78	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from
. Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	6.5	ft
c = Ring compression = pv * s/2	=	4852	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	975	3989	1.216	0.109	0.010	0.236	Too High
2x1/2	0.170	459	17652	0.275	0.034	0.002	1.352	
2-2/3x1/2	0.172	453	17956	0.270	0.034	0.011	0.217	
3 x 1	0.344	227	25385	0.191	0.034	0.051	0.047	
5 x 1	0.368	212	25385	0.191	0.064	0.106	0.023 ✓	
6 x 2	0.688	113	25385	0.191	0.109	0.725	0.003 ✓	

```
    t = Minimum thickness for strength                  =     0.064 ✓     in
Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       8.9
    R = Soil resistivity                                =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        69     years
   af = Adjustment factor required = y / y1             =      2.17
        Adjustment Factor Used :                              2.2 ✓
        Corresponding t:                                    0.109 ✓     in.
```

t_{min} for strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage
5" x 1" Corrugations

9th Street
Corrugated Metal Pipe
Structural Design

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7/18/91
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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		11	
LOCATION:		STA 59+61.60	
d = Pipe diameter	=	78	in
h = Height of cover	=	11.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1610 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.95	ft
W = Width of Plane	=	25.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	75	psf
LL = Live load	=	75	psf

Compute the design load,

pv = Design pressure = DL + LL = 1685 psf

Structure design,

s = Span = d/12	=	6.5	ft
c = Ring compression = pv * s/2	=	5475	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	975	3989	1.372	0.138	0.014	0.168	Too High
2x1/2	0.170	459	17652	0.310	0.034	0.002	1.352	
2-2/3x1/2	0.172	453	17956	0.305	0.034	0.011	0.217	
3 x 1	0.344	227	25385	0.216	0.034	0.051	0.047	
5 x 1	0.368	212	25385	0.216	0.064	0.106	0.023 ✓	
6 x 2	0.688	113	25385	0.216	0.109	0.725	0.003 ✓	

```
    t = Minimum thickness for strength                  =     0.064 ✓      in
Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =         8
    R = Soil resistivity                                =      3670    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        85     years
   af = Adjustment factor required = y / y1             =      1.76
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109 ✓      in.
```

t_{min} for strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage
5" x 1" Corrugation

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/18/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		12	
LOCATION:		CL STA 59+76.47	
d = Pipe diameter	=	78	in
h = Height of cover	=	12.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1750	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	26.70	ft
W = Width of Plane	=	27.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	65	psf
LL = Live load	=	65	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1815	psf

Structure design,

s = Span = d/12	=	6.5	ft
c = Ring compression = pv * s/2	=	5900	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	975	3989	1.479	0.138	0.014	0.168
2x1/2	0.170	459	17652	0.334	0.034	0.002	1.352
2-2/3x1/2	0.172	453	17956	0.329	0.034	0.011	0.217
3 x 1	0.344	227	25385	0.232	0.034	0.051	0.047
5 x 1	0.368	212	25385	0.232	0.064	0.106	0.023 ✓
6 x 2	0.688	113	25385	0.232	0.109	0.725	0.003 ✓

Too High

```
    t = Minimum thickness for strength                  =     0.064        in
    t
Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =         8
    R = Soil resistivity                                =      3670    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        85     years
   af = Adjustment factor required = y / y1             =      1.76
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.064 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for Design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

5" x 1" Corrugation

9th Street EK3097
Corrugated Metal Pipe 7/22/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		13	
LOCATION:		CL STA 23+45, STUBOUT	
d = Pipe diameter	=	66	in
h = Height of cover	=	11.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1610 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	49000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.95	ft
W = Width of Plane	=	25.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	75	psf
LL = Live load	=	75	psf

Compute the design load,

pv = Design pressure = DL + LL = 1685 psf

Structure design,

s = Span = d/12	=	5.5	ft
c = Ring compression = pv * s/2	=	4633	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	825	5572	0.831	0.079	0.007	0.256
2x1/2	0.170	388	21378	0.217	0.034	0.002	0.968
2-2/3x1/2	0.172	384	21595	0.215	0.034	0.011	0.156
3 x 1	0.344	192	25385	0.182	0.034	0.051	0.034 ✓
5 x 1	0.368	179	25385	0.182	0.064	0.106	0.016 ✓
6 x 2	0.688	96	25385	0.182	0.109	0.725	0.002 ✓

Too High

```
    t = Minimum thickness for strength                  =    0.034 ✓      in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =       75
    y = Years for average life = 2 * Y                  =      150
   pH = pH of soil environment                          =      9.2
    R = Soil resistivity                                =     3930    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =       88     years
   af = Adjustment factor required = y / y1             =     1.71
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109 ✓      in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

3" x 1" Corrugation

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		1	
LOCATION:		STA 58+00	
d = Pipe diameter	=	15	in
h = Height of cover	=	11.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1610	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.95	ft
W = Width of Plane	=	25.79	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	75	psf
LL = Live load	=	75	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1685	psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1053	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	188	25385	0.041	0.034	0.002	0.036	
2x1/2	0.170	88	25385	0.041	0.034	0.002	0.050	
2-2/3x1/2	0.172	87	25385	0.041	0.034	0.011	0.008	OK
3 x 1	0.344	44	25385	0.041	0.034	0.051	0.002	✓
5 x 1	0.368	41	25385	0.041	0.064	0.106	0.001	
6 x 2	0.688	22	25385	0.041	0.109	0.725	0.000	

```
  t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =       75
  y = Years for average life = 2 * Y                  =      150
 pH = pH of soil environment                          =        8
  R = Soil resistivity                                =     3670    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =       85     years
 af = Adjustment factor required = y / y1             =     1.76
      Adjustment Factor Used :                              2.2
      Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3" x 1/2" Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		2	
LOCATION:		STA 53+70	
d = Pipe diameter	=	18	in
h = Height of cover	=	10.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1470	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	23.20	ft
W = Width of Plane	=	24.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	86	psf
LL = Live load	=	86	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1556	psf

Structure design,

s = Span = d/12	=	1.5	ft
c = Ring compression = pv * s/2	=	1167	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	225	25385	0.046	0.034	0.002	0.052
2x1/2	0.170	106	25385	0.046	0.034	0.002	0.072
2-2/3x1/2	0.172	105	25385	0.046	0.034	0.011	0.012 ✓
3 x 1	0.344	52	25385	0.046	0.034	0.051	0.003
5 x 1	0.368	49	25385	0.046	0.064	0.106	0.001
6 x 2	0.688	26	25385	0.046	0.109	0.725	0.000

```
    t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =       75
    y = Years for average life = 2 * Y                  =      150
   pH = pH of soil environment                          =        8
    R = Soil resistivity                                =     3670    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =       85     years
   af = Adjustment factor required = y / y1             =     1.76
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for Strength = 0.034"

t_{min} for Corrosion = 0.109 in

∴ t_{min} for design = 0.109 in ⟹ 12 gage

∴ Use 12 gage

2 3/5" × 1/2" Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		3	
LOCATION:		STA 50+10	
d = Pipe diameter	=	18	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1400	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1493	psf

Structure design,

s = Span = d/12	=	1.5	ft
c = Ring compression = pv * s/2	=	1120	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	225	25385	0.044	0.034	0.002	0.052
2x1/2	0.170	106	25385	0.044	0.034	0.002	0.072
2-2/3x1/2	0.172	105	25385	0.044	0.034	0.011	0.012
3 x 1	0.344	52	25385	0.044	0.034	0.051	0.003
5 x 1	0.368	49	25385	0.044	0.064	0.106	0.001
6 x 2	0.688	26	25385	0.044	0.109	0.725	0.000

```
    t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =       75
    y = Years for average life = 2 * Y                  =      150
   pH = pH of soil environment                          =      8.9
    R = Soil resistivity                                =     2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =       69     years
   af = Adjustment factor required = y / y1             =     2.17
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		4	
LOCATION:		STA 47+00	
d = Pipe diameter	=	18	in
h = Height of cover	=	10.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1470 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	23.20	ft
W = Width of Plane	=	24.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	86	psf
LL = Live load	=	86	psf

Compute the design load,

pv = Design pressure = DL + LL = 1556 psf

Structure design,

s = Span = d/12	=	1.5	ft
c = Ring compression = pv * s/2	=	1167	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	225	25385	0.046	0.034	0.002	0.052
2x1/2	0.170	106	25385	0.046	0.034	0.002	0.072
2-2/3x1/2	0.172	105	25385	0.046	0.034	0.011	0.012 ✓ OK
3 x 1	0.344	52	25385	0.046	0.034	0.051	0.003
5 x 1	0.368	49	25385	0.046	0.064	0.106	0.001
6 x 2	0.688	26	25385	0.046	0.109	0.725	0.000

```
    t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =       75
    y = Years for average life = 2 * Y                  =      150
   pH = pH of soil environment                          =      8.9
    R = Soil resistivity                                =     2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =       69     years
   af = Adjustment factor required =.y / y1             =     2.17
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3" x 1/2" Corrugations OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		5	
LOCATION:		STA 43+00	
d = Pipe diameter	=	15	in
h = Height of cover	=	11	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1540 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.08	ft
W = Width of Plane	=	24.92	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	80	psf
LL = Live load	=	80	psf

Compute the design load,

pv = Design pressure = DL + LL = 1620 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1012	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.040	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.040	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.040	0.034	0.011	0.008 ✓ OK
3 x 1	0.344	44	25385	0.040	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.040	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.040	0.109	0.725	0.000

```
    t = Minimum thickness for strength                =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                 =       75
    y = Years for average life = 2 * Y                =      150
   pH = pH of soil environment                        =      8.9
    R = Soil resistivity                              =     2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                          =       69     years
   af = Adjustment factor required = y / y1           =     2.17
        Adjustment Factor Used :                            2.2
        Corresponding t:                                  0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3" x 1/2" Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		6	
LOCATION:		STA 37+00	
d = Pipe diameter	=	15	in
h = Height of cover	=	12.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1750 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	26.70	ft
W = Width of Plane	=	27.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	65	psf
LL = Live load	=	65	psf

Compute the design load,

pv = Design pressure = DL + LL = 1815 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1135	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.045	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.045	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.045	0.034	0.011	0.008 ✓ ok
3 x 1	0.344	44	25385	0.045	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.045	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.045	0.109	0.725	0.000

```
  t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =       75
  y = Years for average life = 2 * Y                  =      150
 pH = pH of soil environment                          =      9.3
  R = Soil resistivity                                =     2440    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =       72     years
 af = Adjustment factor required = y / y1             =     2.08
      Adjustment Factor Used :                              2.2
      Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ use 12 gage

$2\frac{2}{3}'' \times \frac{1}{2}''$ Corrugation OK

9th Street EK3097
Corrugated Metal Pipe 7/22/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		7	
LOCATION:		STA 36+65, 45'RT	
d = Pipe diameter	=	15	in
h = Height of cover	=	14.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 2030 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	30.20	ft
W = Width of Plane	=	31.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	51	psf
LL = Live load	=	51	psf

Compute the design load,

pv = Design pressure = DL + LL = 2081 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1301	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.051	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.051	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.051	0.034	0.011	0.008 ✓ ok
3 x 1	0.344	44	25385	0.051	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.051	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.051	0.109	0.725	0.000

```
     t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                   =       75
     y = Years for average life = 2 * Y                  =      150
    pH = pH of soil environment                          =      9.3
     R = Soil resistivity                                =     2440    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                            =       72     years
    af = Adjustment factor required = y / y1             =     2.08
         Adjustment Factor Used :                              2.2
         Corresponding t:                                    0.109        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3" x 1/2" Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		8	
LOCATION:		STA 36+21, 45'RT	
d = Pipe diameter	=	15	in
h = Height of cover	=	14.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 2030 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	30.20	ft
W = Width of Plane	=	31.04	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	51	psf
LL = Live load	=	51	psf

Compute the design load,

pv = Design pressure = DL + LL = 2081 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1301	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.051	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.051	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.051	0.034	0.011	0.008
3 x 1	0.344	44	25385	0.051	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.051	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.051	0.109	0.725	0.000

```
  t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =        75
  y = Years for average life = 2 * Y                  =       150
 pH = pH of soil environment                          =       9.3
  R = Soil resistivity                                =      2440    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =        72     years
 af = Adjustment factor required = y / y1             =      2.08
      Adjustment Factor Used :                              2.2
      Corresponding t:                                    0.109        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in. $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

$2\frac{2}{3}'' \times \frac{1}{2}''$ Corrugations OK

```
  t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =        75
  y = Years for average life = 2 * Y                  =       150
 pH = pH of soil environment                          =       9.3
  R = Soil resistivity                                =      2440    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =        72     years
 af = Adjustment factor required = y / y1             =      2.08
      Adjustment Factor Used :                              2.2
      Corresponding t:                                    0.109        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in. $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

$2\frac{2}{3}'' \times \frac{1}{2}''$ Corrugations OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		9	
LOCATION:		STA 30+50	
d = Pipe diameter	=	15	in
h = Height of cover	=	9.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1330 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	21.45	ft
W = Width of Plane	=	22.29	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	100	psf
LL = Live load	=	100	psf

Compute the design load,

pv = Design pressure = DL + LL = 1430 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	894	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.035	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.035	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.035	0.034	0.011	0.008 ✓
3 x 1	0.344	44	25385	0.035	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.035	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.035	0.109	0.725	0.000

```
  t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =       75
  y = Years for average life = 2 * Y                  =      150
 pH = pH of soil environment                          =      9.3
  R = Soil resistivity                                =     2440    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =       72     years
 af = Adjustment factor required = y / y1             =     2.08
      Adjustment Factor Used :                              2.2
      Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

$2\frac{2}{3}'' \times \frac{1}{2}''$ Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		10	
LOCATION:		STA 26+00	
d = Pipe diameter	=	15	in
h = Height of cover	=	11	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1540	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.08	ft
W = Width of Plane	=	24.92	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	80	psf
LL = Live load	=	80	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1620	psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1012	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.040	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.040	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.040	0.034	0.011	0.008 ✓ OK
3 x 1	0.344	44	25385	0.040	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.040	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.040	0.109	0.725	0.000

```
  t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =       75
  y = Years for average life = 2 * Y                  =      150
 pH = pH of soil environment                          =      9.2
  R = Soil resistivity                                =     3930    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =       88     years
 af = Adjustment factor required = y / y1             =     1.71
      Adjustment Factor Used :                          2.2
      Corresponding t:                                 0.109         in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3 in x 1/2 in Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		11	
LOCATION:		STA 21+40	
d = Pipe diameter	=	15	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	933	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.037	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.037	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.037	0.034	0.011	0.008 ✓ ok
3 x 1	0.344	44	25385	0.037	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.037	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.037	0.109	0.725	0.000

```
     t = Minimum thickness for strength                  =     0.034 ✓      in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                   =        75
     y = Years for average life = 2 * Y                  =       150
    pH = pH of soil environment                          =       9.2
     R = Soil resistivity                                =      3930    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                            =        88     years
    af = Adjustment factor required = y / y1             =      1.71
         Adjustment Factor Used :                              2.2
         Corresponding t:                                    0.109 ✓      in.
```

t_{min} for strength = 0.034 in

t_{min} for corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3" × 1/2" Corrugations ok

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		12	
LOCATION:		STA 12+60	
d = Pipe diameter	=	15	in
h = Height of cover	=	11	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1540 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.08	ft
W = Width of Plane	=	24.92	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	80	psf
LL = Live load	=	80	psf

Compute the design load,

pv = Design pressure = DL + LL = 1620 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1012	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.040	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.040	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.040	0.034	0.011	0.008 ✓ OK
3 x 1	0.344	44	25385	0.040	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.040	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.040	0.109	0.725	0.000

```
    t = Minimum thickness for strength                  =    0.034 ✓      in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =       75
    y = Years for average life = 2 * Y                  =      150
   pH = pH of soil environment                          =      7.8
    R = Soil resistivity                                =     3350   ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =       82    years
   af = Adjustment factor required = y / y1             =     1.83
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109 ✓      in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2⅔" x ½" Corrugation OK

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

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Site conditions,

PIPE RECORD NUMBER:		1	
LOCATION:		STA 58+01.5 - STA 58+41.5	
d = Pipe diameter	=	12	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	1	ft
c = Ring compression = pv * s/2	=	2432	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	150	25385	0.096	0.034	0.002	0.023 ✓
2x1/2	0.170	71	25385	0.096	0.034	0.002	0.032 ✓
2-2/3x1/2	0.172	70	25385	0.096	0.034	0.011	0.005 ✓
3 x 1	0.344	35	25385	0.096	0.034	0.051	0.001 ✓
5 x 1	0.368	33	25385	0.096	0.064	0.106	0.001 ✓
6 x 2	0.688	17	25385	0.096	0.109	0.725	0.000 ✓

ALL OK

```
    t = Minimum thickness for strength                =     0.034 ✓        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                 =        75
    y = Years for average life = 2 * Y                =       150
   pH = pH of soil environment                        =       9.3
    R = Soil resistivity                              =      2440    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                          =        72     years
   af = Adjustment factor required = y / y1           =      2.08
        Adjustment Factor Used :                            2.2 ✓
        Corresponding t:                                  0.109 ✓        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable perforations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		10	
LOCATION:		STA 26+01.5 - STA 26+41.5	
d = Pipe diameter	=	12	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	1	ft
c = Ring compression = pv * s/2	=	2432	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	150	25385	0.096	0.034	0.002	0.023	ALL
2x1/2	0.170	71	25385	0.096	0.034	0.002	0.032	
2-2/3x1/2	0.172	70	25385	0.096	0.034	0.011	0.005	OK
3 x 1	0.344	35	25385	0.096	0.034	0.051	0.001	
5 x 1	0.368	33	25385	0.096	0.064	0.106	0.001	
6 x 2	0.688	17	25385	0.096	0.109	0.725	0.000	

```
     t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                   =        75
     y = Years for average life = 2 * Y                  =       150
    pH = pH of soil environment                          =       9.2
     R = Soil resistivity                                =      3930    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                            =        88     years
    af = Adjustment factor required = y / y1             =      1.71
         Adjustment Factor Used :                              2.2
         Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		11	
LOCATION:		STA 21+41.5 - STA 21+81.5	
d = Pipe diameter	=	24	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2	ft
c = Ring compression = pv * s/2	=	4863	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	300	25162	0.193	0.034	0.002	0.092	Too High
2x1/2	0.170	141	25385	0.192	0.034	0.002	0.128	
2-2/3x1/2	0.172	140	25385	0.192	0.034	0.011	0.021	OK
3 x 1	0.344	70	25385	0.192	0.034	0.051	0.004	
5 x 1	0.368	65	25385	0.192	0.064	0.106	0.002	
6 x 2	0.688	35	25385	0.192	0.109	0.725	0.000	

1(c)

```
     t = Minimum thickness for strength                    =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                     =        75
     y = Years for average life = 2 * Y                    =       150
    pH = pH of soil environment                            =       9.2
     R = Soil resistivity                                  =      3930    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                              =        88     years
    af = Adjustment factor required = y / y1               =      1.71
       Adjustment Factor Used :                                    2.2
       Corresponding t:                                          0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable corrugations

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/8/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		12	
LOCATION:		STA 12+61.5 - STA 13+01.5	
d = Pipe diameter	=	21	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	1.75	ft
c = Ring compression = pv * s/2	=	4256	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	263	25385	0.168	0.034	0.002	0.071	Too High
2x1/2	0.170	124	25385	0.168	0.034	0.002	0.098	
2-2/3x1/2	0.172	122	25385	0.168	0.034	0.011	0.016	
3 x 1	0.344	61	25385	0.168	0.034	0.051	0.003	OK
5 x 1	0.368	57	25385	0.168	0.064	0.106	0.002	
6 x 2	0.688	31	25385	0.168	0.109	0.725	0.000	

```
     t = Minimum thickness for strength                =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                 =        75
     y = Years for average life = 2 * Y                =       150
    pH = pH of soil environment                        =       7.8
     R = Soil resistivity                              =      3350    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                          =        82     years
    af = Adjustment factor required = y / y1           =      1.83
         Adjustment Factor Used :                            2.2
         Corresponding t:                                  0.109        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable corrugation

t

```
    t = Minimum thickness for strength                  =     0.034 ✓        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =         8
    R = Soil resistivity                                =      3670    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                            =        85     years
   af = Adjustment factor required = y / y1             =      1.76
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109 ✓        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/8/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		2	
LOCATION:		STA 53+71.5 - STA 54+11.5	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	✓
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	✓ OK
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	✓
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	✓

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =         8
    R = Soil resistivity                                =      3670    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        85     years
   af = Adjustment factor required = y / y1             =      1.76
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109         in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable corrugations

9th Street
Corrugated Metal Pipe
Structural Design

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7/8/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		3	
LOCATION:		STA 50+11.5 - STA 50+51.5	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	OK
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       8.9
    R = Soil resistivity                                =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        69     years
   af = Adjustment factor required = y / y1             =      2.17
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street
Corrugated Metal Pipe
Structural Design

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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		4	
LOCATION:		STA 47+01.5 - STA 47+41.6	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	OK
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	

t

```
    t = Minimum thickness for strength              =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =               =        75
    y = Years for average life = 2 * Y              =       150
   pH = pH of soil environment                      =       8.9
    R = Soil resistivity                            =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                        =        69     years
   af = Adjustment factor required = y / y1         =      2.17
        Adjustment Factor Used :                          2.2
        Corresponding t:                             0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in. $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		5	
LOCATION:		STA 43+01.5 - STA 43+41.5	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 70 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL = 4863 psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	OK
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       8.9
    R = Soil resistivity                                =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                            =        69     years
   af = Adjustment factor required = y / y1             =      2.17
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		6	
LOCATION:		STA 37+01.5 - 37+41.5	
d = Pipe diameter	=	21	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 70 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL = 4863 psf

Structure design,

s = Span = d/12	=	1.75	ft
c = Ring compression = pv * s/2	=	4256	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	263	25385	0.168	0.034	0.002	0.071	Too High
2x1/2	0.170	124	25385	0.168	0.034	0.002	0.098	
2-2/3x1/2	0.172	122	25385	0.168	0.034	0.011	0.016	OK
3 x 1	0.344	61	25385	0.168	0.034	0.051	0.003	
5 x 1	0.368	57	25385	0.168	0.064	0.106	0.002	
6 x 2	0.688	31	25385	0.168	0.109	0.725	0.000	

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       9.3
    R = Soil resistivity                                =      2440    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        72     years
   af = Adjustment factor required = y / y1             =      2.08
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street — EK3097
Corrugated Metal Pipe — 7/8/91
Structural Design — BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		9	
LOCATION:		STA 30+51.5 - STA 30+91.5	
d = Pipe diameter	=	15	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	3040	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	188	25385	0.120	0.034	0.002	0.036	→ OK
2x1/2	0.170	88	25385	0.120	0.034	0.002	0.050	→ Too High
2-2/3x1/2	0.172	87	25385	0.120	0.034	0.011	0.008	OK
3 x 1	0.344	44	25385	0.120	0.034	0.051	0.002	OK
5 x 1	0.368	41	25385	0.120	0.064	0.106	0.001	OK
6 x 2	0.688	22	25385	0.120	0.109	0.725	0.000	OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		9	
LOCATION:		STA 30+50	
d = Pipe diameter	=	15	in
h = Height of cover	=	9.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1330 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	21.45	ft
W = Width of Plane	=	22.29	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	100	psf
LL = Live load	=	100	psf

Compute the design load,

pv = Design pressure = DL + LL = 1430 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	894	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.035	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.035	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.035	0.034	0.011	0.008 ✓
3 x 1	0.344	44	25385	0.035	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.035	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.035	0.109	0.725	0.000

```
  t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =       75
  y = Years for average life = 2 * Y                  =      150
 pH = pH of soil environment                          =      9.3
  R = Soil resistivity                                =     2440    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =       72     years
 af = Adjustment factor required = y / y1             =     2.08
      Adjustment Factor Used :                              2.2
      Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

$2\frac{2}{3}'' \times \frac{1}{2}''$ Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		10	
LOCATION:		STA 26+00	
d = Pipe diameter	=	15	in
h = Height of cover	=	11	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	1540	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.08	ft
W = Width of Plane	=	24.92	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	80	psf
LL = Live load	=	80	psf

Compute the design load,

pv = Design pressure = DL + LL	=	1620	psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1012	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.040	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.040	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.040	0.034	0.011	0.008 ✓ OK
3 x 1	0.344	44	25385	0.040	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.040	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.040	0.109	0.725	0.000

```
  t = Minimum thickness for strength                  =    0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
  Y = Years for first perforation =                   =       75
  y = Years for average life = 2 * Y                  =      150
 pH = pH of soil environment                          =      9.2
  R = Soil resistivity                                =     3930    ohm-cm
 y1 = Years for average life for t=.052 in.
    = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
    = 2.94 * R^.41, pH>7.3                            =       88     years
 af = Adjustment factor required = y / y1             =     1.71
      Adjustment Factor Used :                          2.2
      Corresponding t:                                 0.109         in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3 in x 1/2 in Corrugation OK

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		11	
LOCATION:		STA 21+40	
d = Pipe diameter	=	15	in
h = Height of cover	=	10	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1400 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	22.33	ft
W = Width of Plane	=	23.17	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	93	psf
LL = Live load	=	93	psf

Compute the design load,

pv = Design pressure = DL + LL = 1493 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	933	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.037	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.037	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.037	0.034	0.011	0.008 ✓ ok
3 x 1	0.344	44	25385	0.037	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.037	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.037	0.109	0.725	0.000

```
     t = Minimum thickness for strength                  =     0.034 ✓      in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                   =        75
     y = Years for average life = 2 * Y                  =       150
    pH = pH of soil environment                          =       9.2
     R = Soil resistivity                                =      3930    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                            =        88     years
    af = Adjustment factor required = y / y1             =      1.71
         Adjustment Factor Used :                              2.2
         Corresponding t:                                    0.109 ✓      in.
```

t_{min} for strength = 0.034 in

t_{min} for corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2 2/3" × 1/2" Corrugations ok

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/22/91
BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		12	
LOCATION:		STA 12+60	
d = Pipe diameter	=	15	in
h = Height of cover	=	11	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w = 1540 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	48000	Lbs
IF = Impact Factor	=	1	
L = Length of Plane	=	24.08	ft
W = Width of Plane	=	24.92	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	80	psf
LL = Live load	=	80	psf

Compute the design load,

pv = Design pressure = DL + LL = 1620 psf

Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	1012	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 < .0433 for factory made pipe.
< .0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	188	25385	0.040	0.034	0.002	0.036
2x1/2	0.170	88	25385	0.040	0.034	0.002	0.050
2-2/3x1/2	0.172	87	25385	0.040	0.034	0.011	0.008 ✓ OK
3 x 1	0.344	44	25385	0.040	0.034	0.051	0.002
5 x 1	0.368	41	25385	0.040	0.064	0.106	0.001
6 x 2	0.688	22	25385	0.040	0.109	0.725	0.000

```
    t = Minimum thickness for strength                  =    0.034 ✓      in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =       75
    y = Years for average life = 2 * Y                  =      150
   pH = pH of soil environment                          =      7.8
    R = Soil resistivity                                =     3350   ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =       82    years
   af = Adjustment factor required = y / y1             =     1.83
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109 ✓      in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

2⅔" x ½" Corrugation OK

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

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Site conditions,

PIPE RECORD NUMBER:		1	
LOCATION:		STA 58+01.5 - STA 58+41.5	
d = Pipe diameter	=	12	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	1	ft
c = Ring compression = pv * s/2	=	2432	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff
1-1/2x1/4	0.080	150	25385	0.096	0.034	0.002	0.023 ✓
2x1/2	0.170	71	25385	0.096	0.034	0.002	0.032 ✓
2-2/3x1/2	0.172	70	25385	0.096	0.034	0.011	0.005 ✓
3 x 1	0.344	35	25385	0.096	0.034	0.051	0.001 ✓
5 x 1	0.368	33	25385	0.096	0.064	0.106	0.001 ✓
6 x 2	0.688	17	25385	0.096	0.109	0.725	0.000 ✓

ALL OK

```
    t = Minimum thickness for strength                =     0.034 ✓        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                 =        75
    y = Years for average life = 2 * Y                =       150
   pH = pH of soil environment                        =       9.3
    R = Soil resistivity                              =      2440    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                          =        72     years
   af = Adjustment factor required = y / y1           =      2.08
        Adjustment Factor Used :                            2.2 ✓
        Corresponding t:                                  0.109 ✓        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable perforations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		10	
LOCATION:		STA 26+01.5 - STA 26+41.5	
d = Pipe diameter	=	12	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	1	ft
c = Ring compression = pv * s/2	=	2432	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	150	25385	0.096	0.034	0.002	0.023	ALL
2x1/2	0.170	71	25385	0.096	0.034	0.002	0.032	
2-2/3x1/2	0.172	70	25385	0.096	0.034	0.011	0.005	OK
3 x 1	0.344	35	25385	0.096	0.034	0.051	0.001	
5 x 1	0.368	33	25385	0.096	0.064	0.106	0.001	
6 x 2	0.688	17	25385	0.096	0.109	0.725	0.000	

```
     t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                   =        75
     y = Years for average life = 2 * Y                  =       150
    pH = pH of soil environment                          =       9.2
     R = Soil resistivity                                =      3930    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                            =        88     years
    af = Adjustment factor required = y / y1             =      1.71
         Adjustment Factor Used :                              2.2
         Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		11	
LOCATION:		STA 21+41.5 - STA 21+81.5	
d = Pipe diameter	=	24	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.2	
R = Soil resistivity	=	3930	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2	ft
c = Ring compression = pv * s/2	=	4863	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	300	25162	0.193	0.034	0.002	0.092	Too High
2x1/2	0.170	141	25385	0.192	0.034	0.002	0.128	
2-2/3x1/2	0.172	140	25385	0.192	0.034	0.011	0.021	OK
3 x 1	0.344	70	25385	0.192	0.034	0.051	0.004	
5 x 1	0.368	65	25385	0.192	0.064	0.106	0.002	
6 x 2	0.688	35	25385	0.192	0.109	0.725	0.000	

1(c)

```
     t = Minimum thickness for strength                    =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                     =        75
     y = Years for average life = 2 * Y                    =       150
    pH = pH of soil environment                            =       9.2
     R = Soil resistivity                                  =      3930    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                              =        88     years
    af = Adjustment factor required = y / y1               =      1.71
       Adjustment Factor Used :                                    2.2
       Corresponding t:                                          0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable corrugations

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/8/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		12	
LOCATION:		STA 12+61.5 - STA 13+01.5	
d = Pipe diameter	=	21	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	7.8	
R = Soil resistivity	=	3350	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	1.75	ft
c = Ring compression = pv * s/2	=	4256	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	263	25385	0.168	0.034	0.002	0.071	Too High
2x1/2	0.170	124	25385	0.168	0.034	0.002	0.098	
2-2/3x1/2	0.172	122	25385	0.168	0.034	0.011	0.016	
3 x 1	0.344	61	25385	0.168	0.034	0.051	0.003	OK
5 x 1	0.368	57	25385	0.168	0.064	0.106	0.002	
6 x 2	0.688	31	25385	0.168	0.109	0.725	0.000	

```
     t = Minimum thickness for strength                =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
     Y = Years for first perforation =                 =        75
     y = Years for average life = 2 * Y                =       150
    pH = pH of soil environment                        =       7.8
     R = Soil resistivity                              =      3350    ohm-cm
    y1 = Years for average life for t=.052 in.
       = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
       = 2.94 * R^.41, pH>7.3                          =        82     years
    af = Adjustment factor required = y / y1           =      1.83
         Adjustment Factor Used :                            2.2
         Corresponding t:                                  0.109        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable corrugation

t

```
    t = Minimum thickness for strength                  =     0.034 ✓        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =         8
    R = Soil resistivity                                =      3670    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                            =        85     years
   af = Adjustment factor required = y / y1             =      1.76
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109 ✓        in.
```

t_{min} for Strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

9th Street
Corrugated Metal Pipe
Structural Design

EK3097
7/8/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		2	
LOCATION:		STA 53+71.5 - STA 54+11.5	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.0	
R = Soil resistivity	=	3670	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	✓
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	✓ OK
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	✓
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	✓

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =         8
    R = Soil resistivity                                =      3670    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        85     years
   af = Adjustment factor required = y / y1             =      1.76
        Adjustment Factor Used :                          2.2
        Corresponding t:                                 0.109         in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable corrugations

9th Street
Corrugated Metal Pipe
Structural Design

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7/8/91
BJF/KM

==========

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		3	
LOCATION:		STA 50+11.5 - STA 50+51.5	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	OK
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	

t

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       8.9
    R = Soil resistivity                                =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                            =        69     years
   af = Adjustment factor required = y / y1             =      2.17
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

∴ t_{min} for design = 0.109 in ⇒ 12 gage

∴ Use 12 gage

See previous page for acceptable Corrugations

9th Street
Corrugated Metal Pipe
Structural Design

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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		4	
LOCATION:		STA 47+01.5 - STA 47+41.6	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	OK
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	

t

```
    t = Minimum thickness for strength              =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =               =        75
    y = Years for average life = 2 * Y              =       150
   pH = pH of soil environment                      =       8.9
    R = Soil resistivity                            =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                        =        69     years
   af = Adjustment factor required = y / y1         =      2.17
        Adjustment Factor Used :                          2.2
        Corresponding t:                             0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in. $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		5	
LOCATION:		STA 43+01.5 - STA 43+41.5	
d = Pipe diameter	=	30	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	8.9	
R = Soil resistivity	=	2200	ohm-cm

Compute dead load,

DL = Dead load = h * w = 70 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL = 4863 psf

Structure design,

s = Span = d/12	=	2.5	ft
c = Ring compression = pv * s/2	=	6079	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	375	22007	0.276	0.034	0.002	0.144	Too High
2x1/2	0.170	176	25385	0.239	0.034	0.002	0.200	
2-2/3x1/2	0.172	174	25385	0.239	0.034	0.011	0.032	OK
3 x 1	0.344	87	25385	0.239	0.034	0.051	0.007	
5 x 1	0.368	82	25385	0.239	0.064	0.106	0.003	
6 x 2	0.688	44	25385	0.239	0.109	0.725	0.000	

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       8.9
    R = Soil resistivity                                =      2200    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH (= 7.3
      = 2.94 * R^.41, pH)7.3                            =        69     years
   af = Adjustment factor required = y / y1             =      2.17
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Longrightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street EK3097
Corrugated Metal Pipe 7/8/91
Structural Design BJF/KM

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Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

==========

Site conditions,

PIPE RECORD NUMBER:		6	
LOCATION:		STA 37+01.5 - 37+41.5	
d = Pipe diameter	=	21	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w = 70 psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL = 4863 psf

Structure design,

s = Span = d/12	=	1.75	ft
c = Ring compression = pv * s/2	=	4256	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	263	25385	0.168	0.034	0.002	0.071	Too High
2x1/2	0.170	124	25385	0.168	0.034	0.002	0.098	
2-2/3x1/2	0.172	122	25385	0.168	0.034	0.011	0.016	OK
3 x 1	0.344	61	25385	0.168	0.034	0.051	0.003	
5 x 1	0.368	57	25385	0.168	0.064	0.106	0.002	
6 x 2	0.688	31	25385	0.168	0.109	0.725	0.000	

```
    t = Minimum thickness for strength                  =     0.034        in

Select thickness for a 75-year first perforation or 1/2 average life,
    Y = Years for first perforation =                   =        75
    y = Years for average life = 2 * Y                  =       150
   pH = pH of soil environment                          =       9.3
    R = Soil resistivity                                =      2440    ohm-cm
   y1 = Years for average life for t=.052 in.
      = 27.58*(log(R)-log(2160-2490*log(pH))) for pH <= 7.3
      = 2.94 * R^.41, pH>7.3                            =        72     years
   af = Adjustment factor required = y / y1             =      2.08
        Adjustment Factor Used :                              2.2
        Corresponding t:                                    0.109        in.
```

t_{min} for strength = 0.034 in

t_{min} for Corrosion = 0.109 in

$\therefore$ t_{min} for design = 0.109 in $\Rightarrow$ 12 gage

$\therefore$ Use 12 gage

See previous page for acceptable Corrugations

9th Street — EK3097
Corrugated Metal Pipe — 7/8/91
Structural Design — BJF/KM

Re: Handbook of Steel Drainage and Highway Construction Products, American and Steel Institute, 1983, Chapter 3, Pages 99-124.

Site conditions,

PIPE RECORD NUMBER:		9	
LOCATION:		STA 30+51.5 - STA 30+91.5	
d = Pipe diameter	=	15	in
h = Height of cover	=	0.5	ft
w = Weight of soil	=	140	pcf
bsd = Backfill soil density (AASHTO specified)	=	95	%
pH = pH of soil environment	=	9.3	
R = Soil resistivity	=	2440	ohm-cm

Compute dead load,

DL = Dead load = h * w	=	70	psf

Compute live load,

Live load on effective plane at top of pipe (LL) from Concrete Pipe Handbook, acpa, 1988, pg 4-38 - 4-33:

Critical HS-20 loading configuration:

P = Point Load	=	16000	Lbs
IF = Impact Factor	=	1.3	
L = Length of Plane	=	1.70	ft
W = Width of Plane	=	2.54	ft
Pavg = Average Pressure Acting on Plane = P * IF / W / L	=	4793	psf
LL = Live load	=	4793	psf

Compute the design load,

pv = Design pressure = DL + LL	=	4863	psf

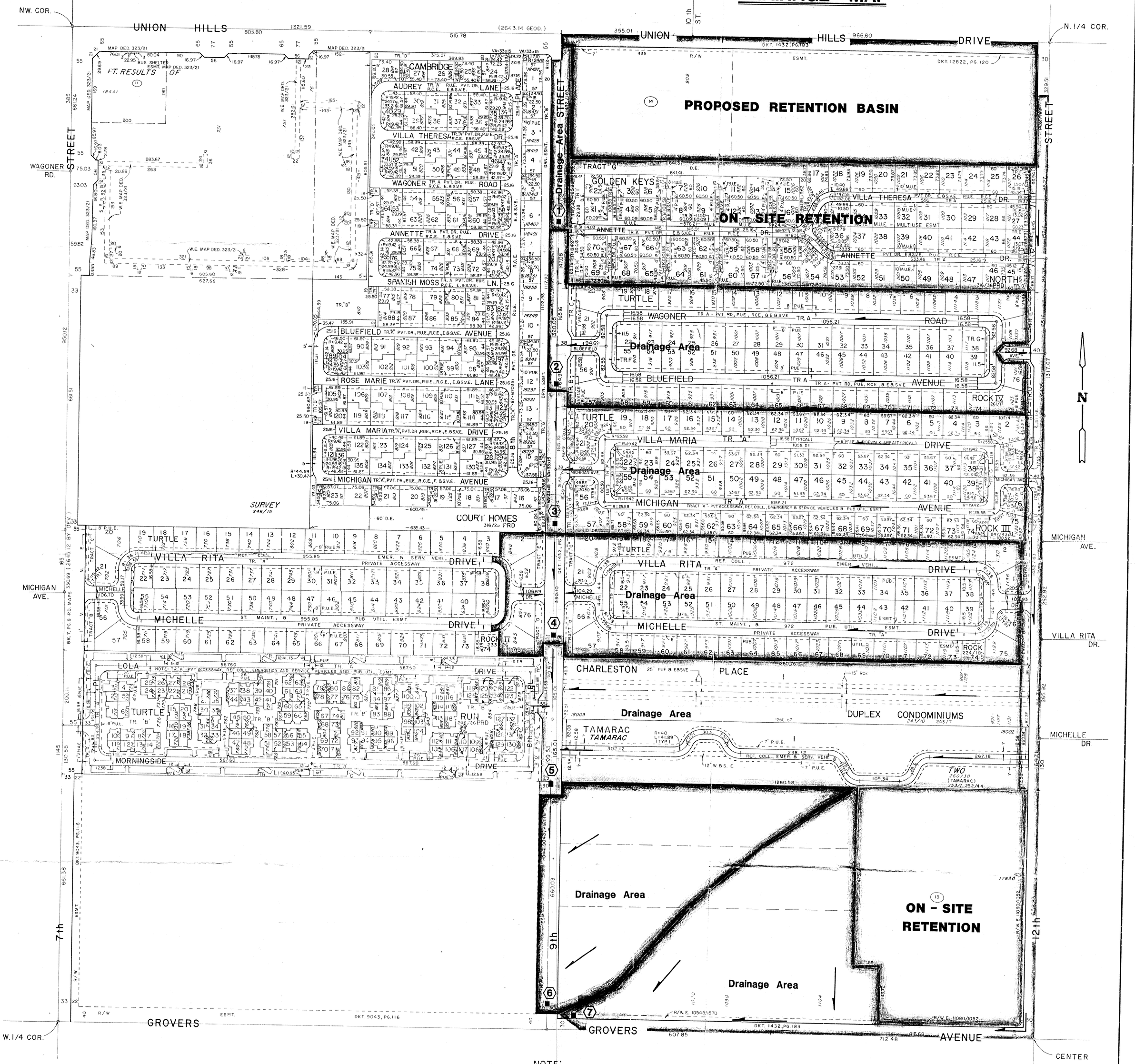
Structure design,

s = Span = d/12	=	1.25	ft
c = Ring compression = pv * s/2	=	3040	ppf
k = Load factor	=	0.65	
r = Radius of gyration from Table 1-4, page 42			in
fc = Allowable wall stress from Figure 3-6, page 105			psi
a = Wall section area = c/fc			in^2/ft
t = Thickness from Table 3-2, page 107			in
I = Moment of inertia from Table 3-2, page 107			in^4/ft
E = Modulus of elasicity		3E+07	lb/in^2

ff = Flexibility factor = d^2/E/I*12 (.0433 for factory made pipe.
(.0200 for field assembled pipe.

Corrugation (in)	r (in)	d/r	fc (psi)	a (in^2/ft)	t (in)	I (in^4/ft)	ff	
1-1/2x1/4	0.080	188	25385	0.120	0.034	0.002	0.036	→ OK
2x1/2	0.170	88	25385	0.120	0.034	0.002	0.050	→ Too High
2-2/3x1/2	0.172	87	25385	0.120	0.034	0.011	0.008	OK
3 x 1	0.344	44	25385	0.120	0.034	0.051	0.002	OK
5 x 1	0.368	41	25385	0.120	0.064	0.106	0.001	OK
6 x 2	0.688	22	25385	0.120	0.109	0.725	0.000	OK

DRAINAGE MAP



NOTE:

THIS MAP SHOULD BE USED FOR INFORMATION PURPOSES ONLY. QUARTER-SECTION LINE DISTANCES HAVE NOT BEEN DETERMINED. DO NOT SCALE.

1/4 SEC. MAP	
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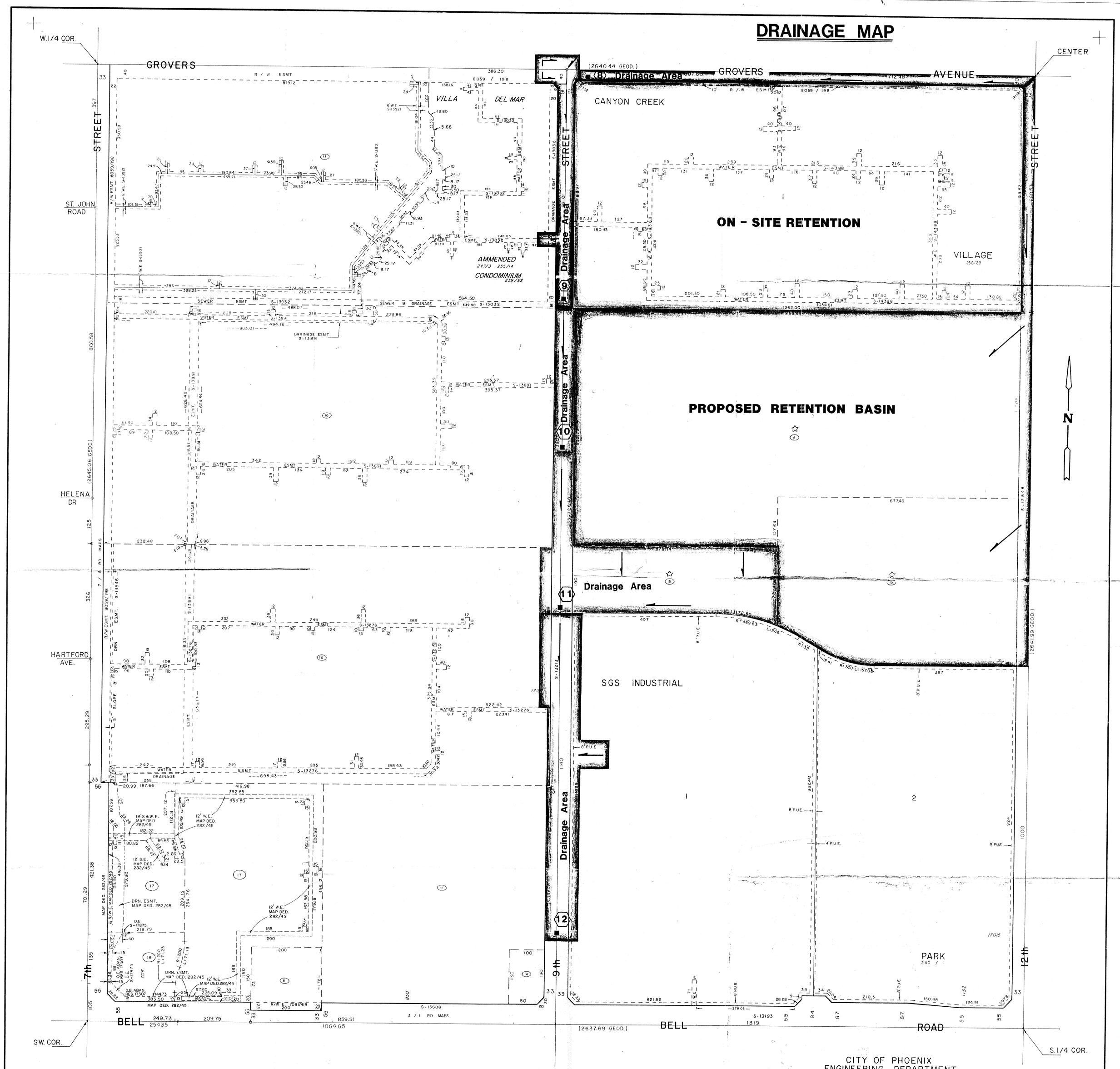
CITY OF PHOENIX
ENGINEERING DEPARTMENT
QUARTER - SECTION MAP
SHOWING RIGHT OF WAY, PROPERTY & ADDRESSES

No. 38-29

NW. 1/4 SEC. 33, T.4N., R.3E.

PHOENIX, ARIZONA SCALE: 1" = 100'

DRAINAGE MAP



☆ UNAPPROVED PROPERTY DIVISION

1/4 SEC MAP	
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CITY OF PHOENIX
ENGINEERING DEPARTMENT
QUARTER-SECTION MAP
SHOWING RIGHT OF WAY, PROPERTY & ADDRESSES

No. 37-29

SW.1/4 SEC. 33, T.4N., R.3E.
PHOENIX, ARIZONA SCALE: 1" = 100'