CULVERT SLIPLINE DESIGN

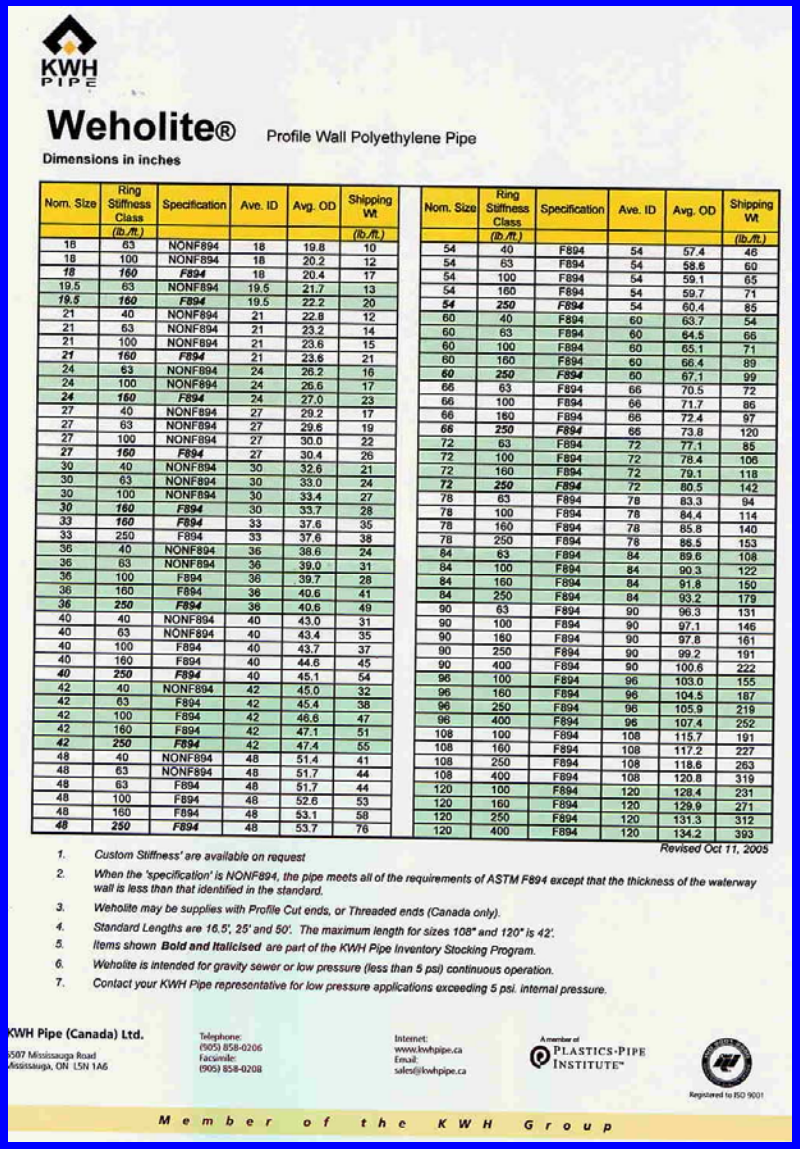
John Owen Hurd, MS, PE

Replace or Slipline?

What Size Slipline Will Fit?

Slipline OD < Min ID Host Pipe - Clearance

Manufacturer's Cut Sheet



KWH PIPE

Weholite® Profile Wall Polyethylene Pipe

Dimensions in inches

Nom. Size	Ring Stiffness Class	Specification	Ave. ID	Avg. OD	Shipping Wt
	(lb./ft.)				(lb./ft.)
18	63	NONF894	18	19.8	10
18	100	NONF894	18	20.2	12
18	***160***	***F894***	18	20.4	17
19.5	63	NONF894	19.5	21.7	13
19.5	***160***	***F894***	19.5	22.2	20
21	40	NONF894	21	22.8	12
21	63	NONF894	21	23.2	14
21	100	NONF894	21	23.6	15
21	***160***	***F894***	21	23.6	21
24	63	NONF894	24	26.2	16
24	100	NONF894	24	26.6	17
24	***160***	***F894***	24	27.0	23
27	40	NONF894	27	29.2	17
27	63	NONF894	27	29.6	19
27	100	NONF894	27	30.0	22
27	***160***	***F894***	27	30.4	26
30	40	NONF894	30	32.6	21
30	63	NONF894	30	33.0	24
30	100	NONF894	30	33.4	27
30	***160***	***F894***	30	33.7	28
33	***160***	***F894***	33	37.6	35
33	250	F894	33	37.6	38
36	40	NONF894	36	38.6	24
36	63	NONF894	36	39.0	31
36	100	F894	36	39.7	28
36	160	F894	36	40.6	41
36	***250***	***F894***	36	40.6	49
40	40	NONF894	40	43.0	31
40	63	NONF894	40	43.4	35
40	100	F894	40	43.7	37
40	160	F894	40	44.6	45
40	***250***	***F894***	40	45.1	54
42	40	NONF894	42	45.0	32
42	63	F894	42	45.4	38
42	100	F894	42	46.6	47
42	160	F894	42	47.1	51
42	***250***	***F894***	42	47.4	55
48	40	NONF894	48	51.4	41
48	63	NONF894	48	51.7	44
48	63	F894	48	51.7	44
48	100	F894	48	52.6	53
48	160	F894	48	53.1	58
48	***250***	***F894***	48	53.7	76

Nom. Size	Ring Stiffness Class	Specification	Ave. ID	Avg. OD	Shipping Wt
	(lb./ft.)				(lb./ft.)
54	40	F894	54	57.4	46
54	63	F894	54	58.6	60
54	100	F894	54	59.1	65
54	160	F894	54	59.7	71
54	***250***	***F894***	54	60.4	85
60	40	F894	60	63.7	54
60	63	F894	60	64.5	66
60	100	F894	60	65.1	71
60	160	F894	60	66.4	89
60	***250***	***F894***	60	67.1	99
66	63	F894	66	70.5	72
66	100	F894	66	71.7	86
66	160	F894	66	72.4	97
66	***250***	***F894***	66	73.8	120
72	63	F894	72	77.1	85
72	100	F894	72	78.4	106
72	160	F894	72	79.1	118
72	***250***	***F894***	72	80.5	142
78	63	F894	78	83.3	94
78	100	F894	78	84.4	114
78	160	F894	78	85.8	140
78	250	F894	78	86.5	153
84	63	F894	84	89.6	108
84	100	F894	84	90.3	122
84	160	F894	84	91.8	150
84	250	F894	84	93.2	179
90	63	F894	90	96.3	131
90	100	F894	90	97.1	146
90	160	F894	90	97.8	161
90	250	F894	90	99.2	191
90	400	F894	90	100.6	222
96	100	F894	96	103.0	155
96	160	F894	96	104.5	187
96	250	F894	96	105.9	219
96	400	F894	96	107.4	252
108	100	F894	108	115.7	191
108	160	F894	108	117.2	227
108	250	F894	108	118.6	263
108	400	F894	108	120.8	319
120	100	F894	120	128.4	231
120	160	F894	120	129.9	271
120	250	F894	120	131.3	312
120	400	F894	120	134.2	393

Revised Oct 11, 2005

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2. *When the 'specification' is NONF894, the pipe meets all of the requirements of ASTM F894 except that the thickness of the waterway wall is less than that identified in the standard.*
3. *Weholite may be supplies with Profile Cut ends, or Threaded ends (Canada only).*
4. *Standard Lengths are 16.5', 25' and 50'. The maximum length for sizes 108" and 120" is 42'.*
5. *Items shown **Bold and Italicised** are part of the KWH Pipe Inventory Stocking Program.*
6. *Weholite is intended for gravity sewer or low pressure (less than 5 psi) continuous operation.*
7. *Contact your KWH Pipe representative for low pressure applications exceeding 5 psi. internal pressure.*

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sales@kwhpipe.ca

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Member of the KWH Group

Measure Twice Cut Once!

Monitor the existing culvert until the liner is installed.

Evaluate Hydraulic Performance

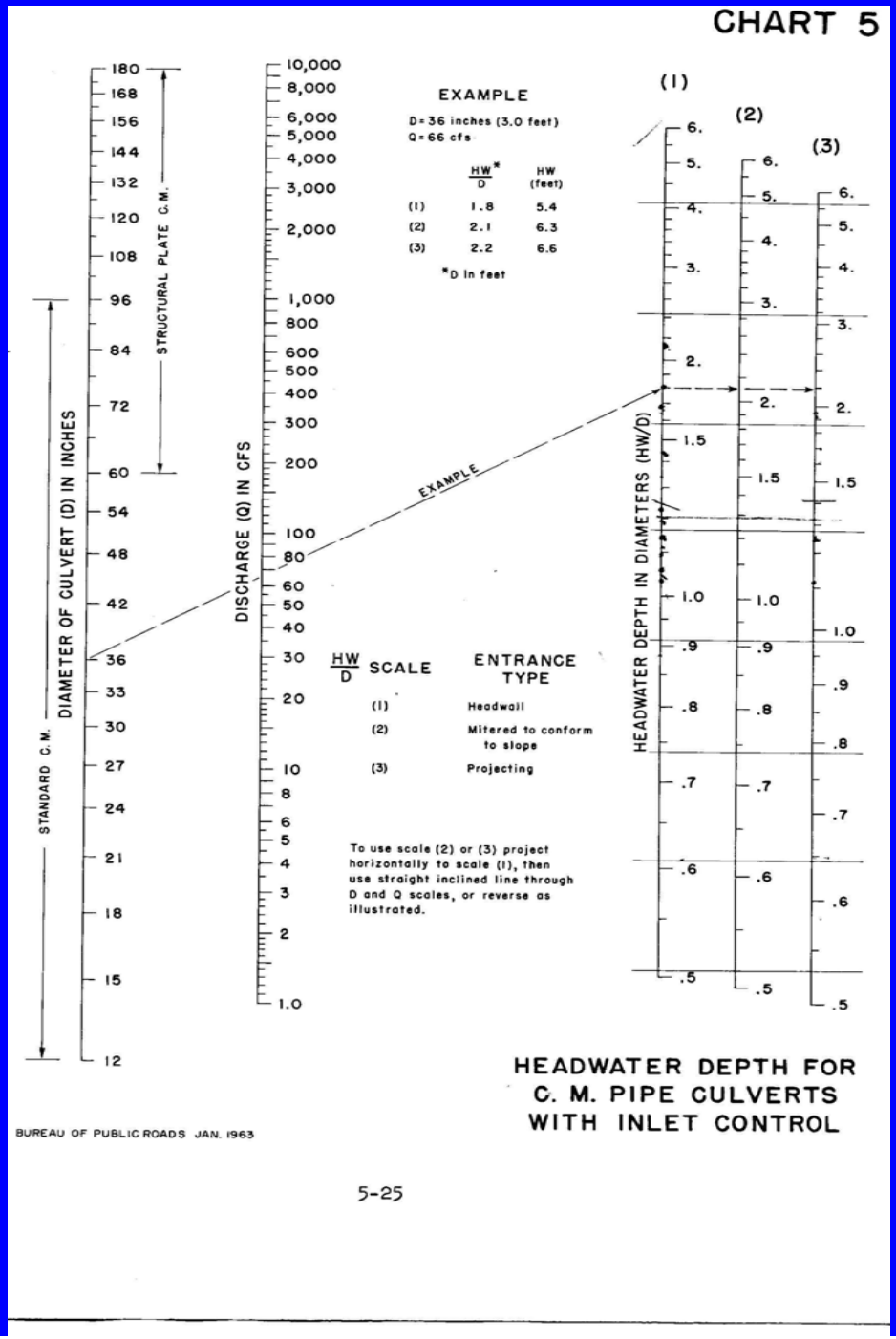
Is an increase in the existing headwater permissible; and if so, how much?

Consider

- What's upstream
  (Design and 100 yr Discharge)
- Arbitrary controls
  (D+2 or D+4, Design Flood)
  (2D, 100 yr Discharge)
- Roadway Clearance
  (2ft below EP)

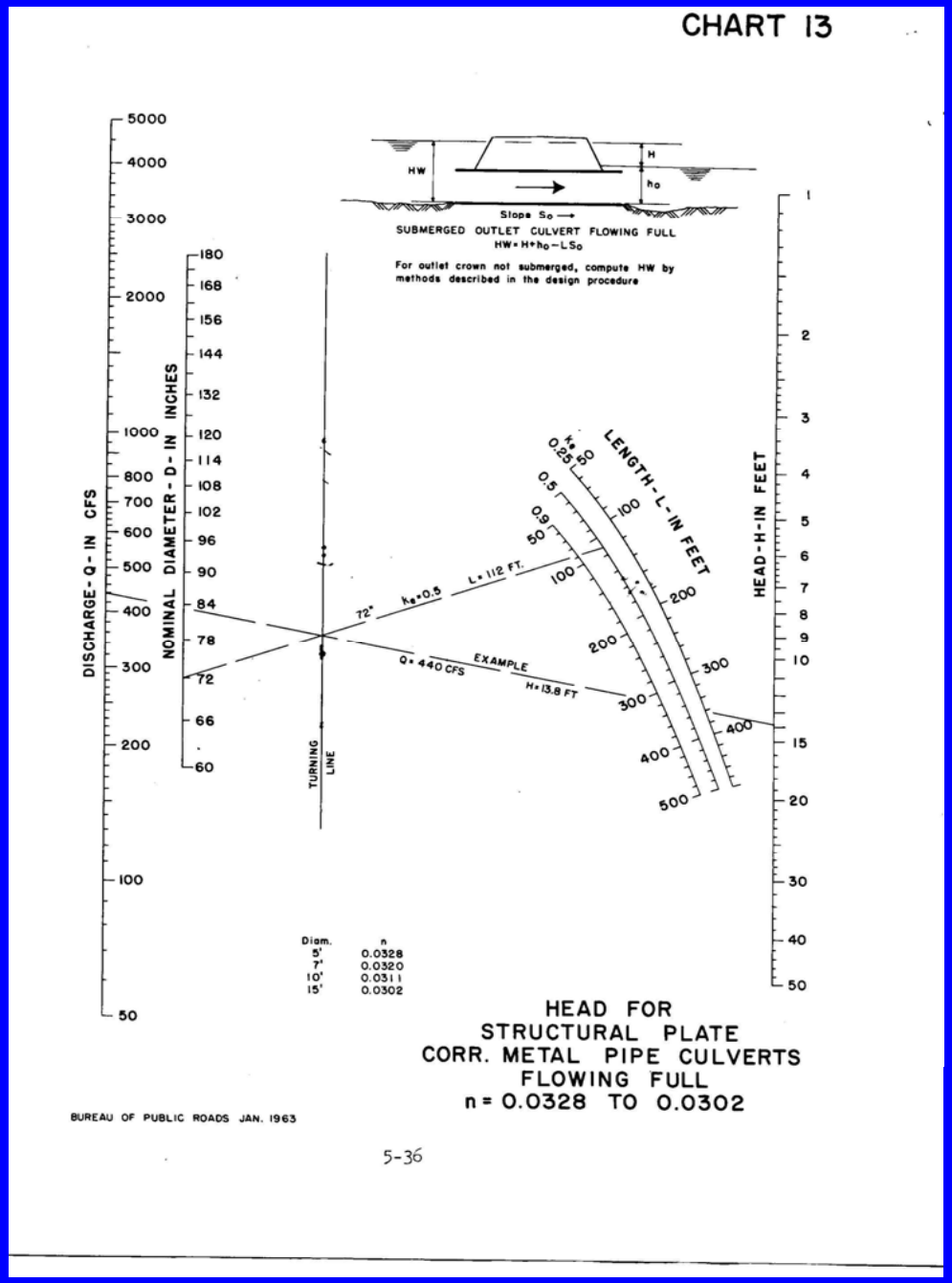
Existing Culvert

- Check inlet control



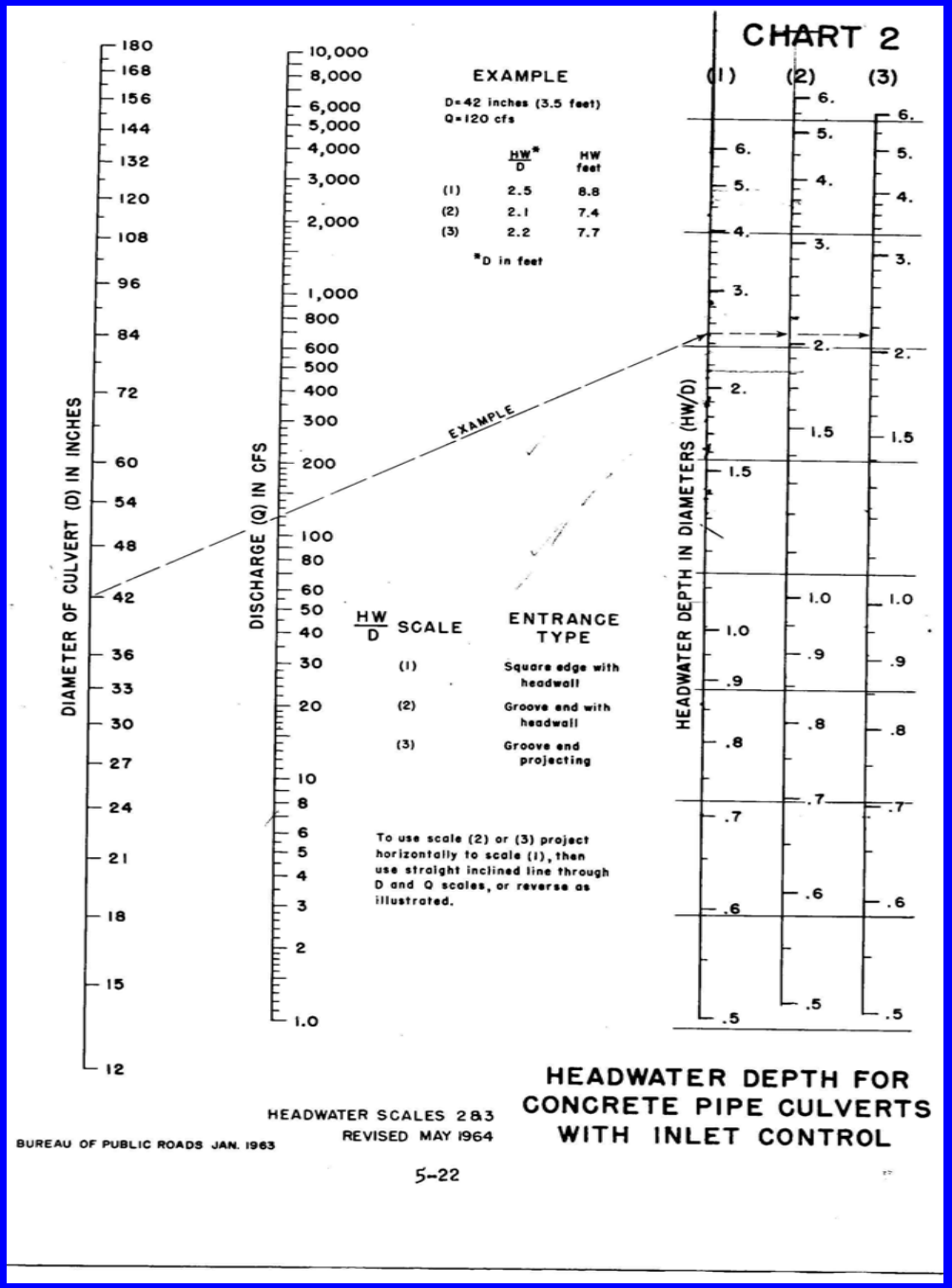
Existing Culvert

- Check Outlet Control



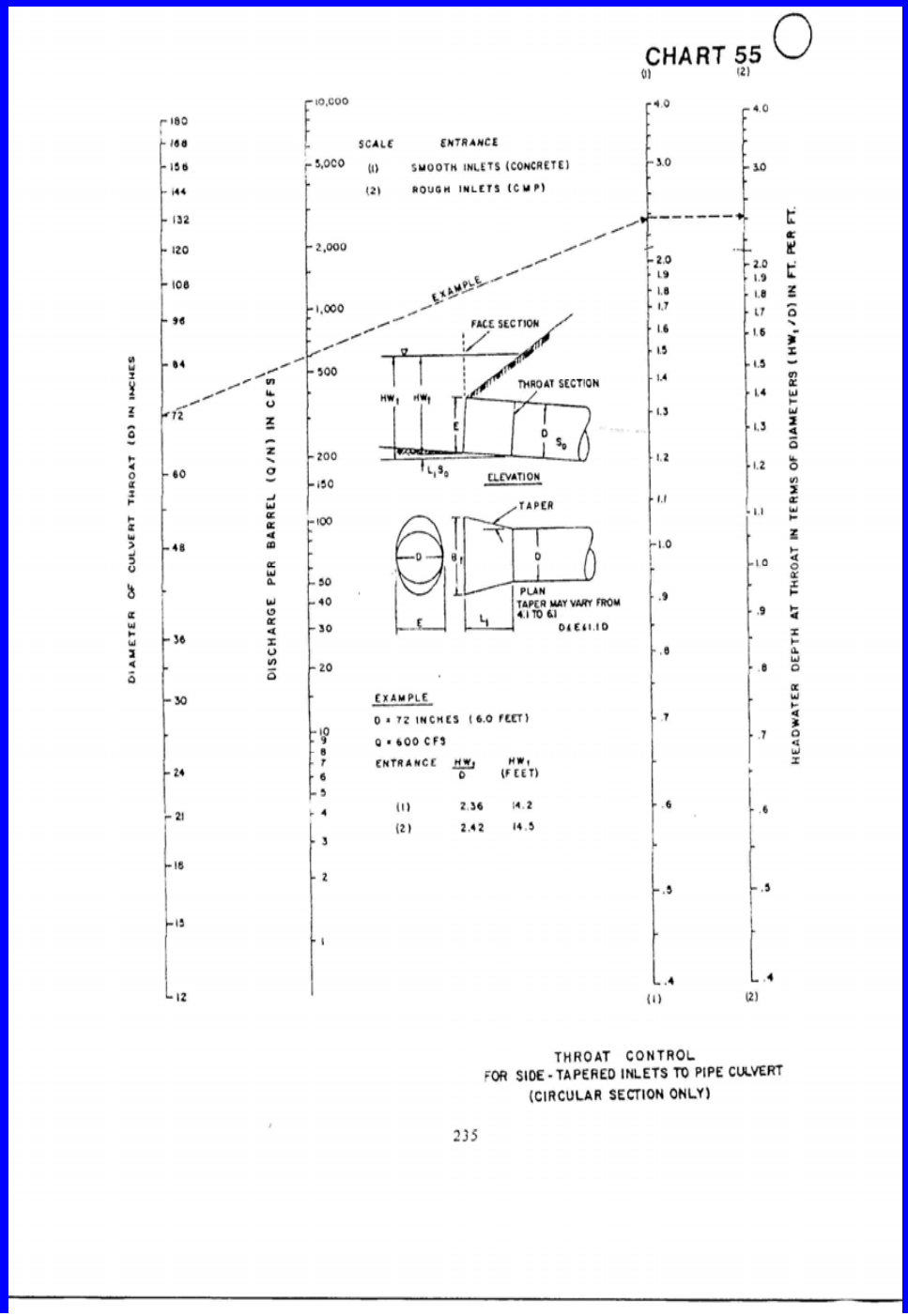
Slipline

- If slipline extends to entrance of existing pipe check inlet control



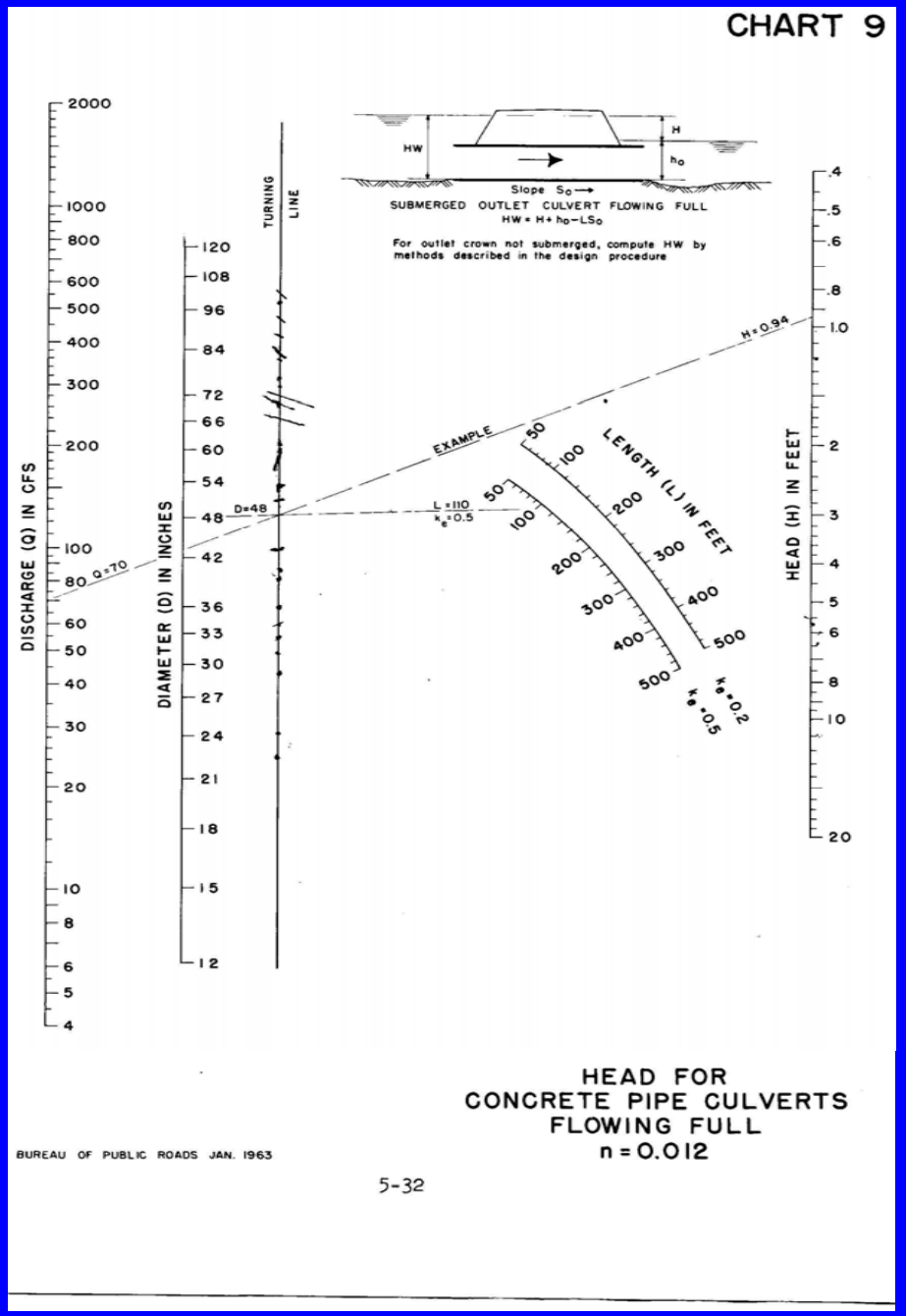
Slipline

- If the slipline is recessed and a 4:1 to 6:1 taper provided check throat control



Slipline

- Check outlet control



If the hydraulic requirements can be met by the sliplined pipe, sliplining is a viable option.

Consider Costs

Costs for Culvert Replacement

- Traffic control
- Excavation and pipe removal
- Pipe and pipe installation
- Backfill and embankment
- Pavement
- Erosion control
- Guardrail
- Anything else?????

Cost of detour to traveling public

$0.48 x detour length (mi.) x ADT
per day

Does not include lost time

Costs for Sliplining

- Traffic control?
- Pipe and pipe installation
- Grouting the voids

Factors Favoring Culvert Replacement

- Lower ADT
- Shallower cover
- Smaller pipe
- Shorter detour routes

Factors Favoring Sliplining

- Higher ADT
- Deeper cover
- Larger pipe
- Longer detour routes

Structural Considerations

Will the slipline pipe need to support the embankment?

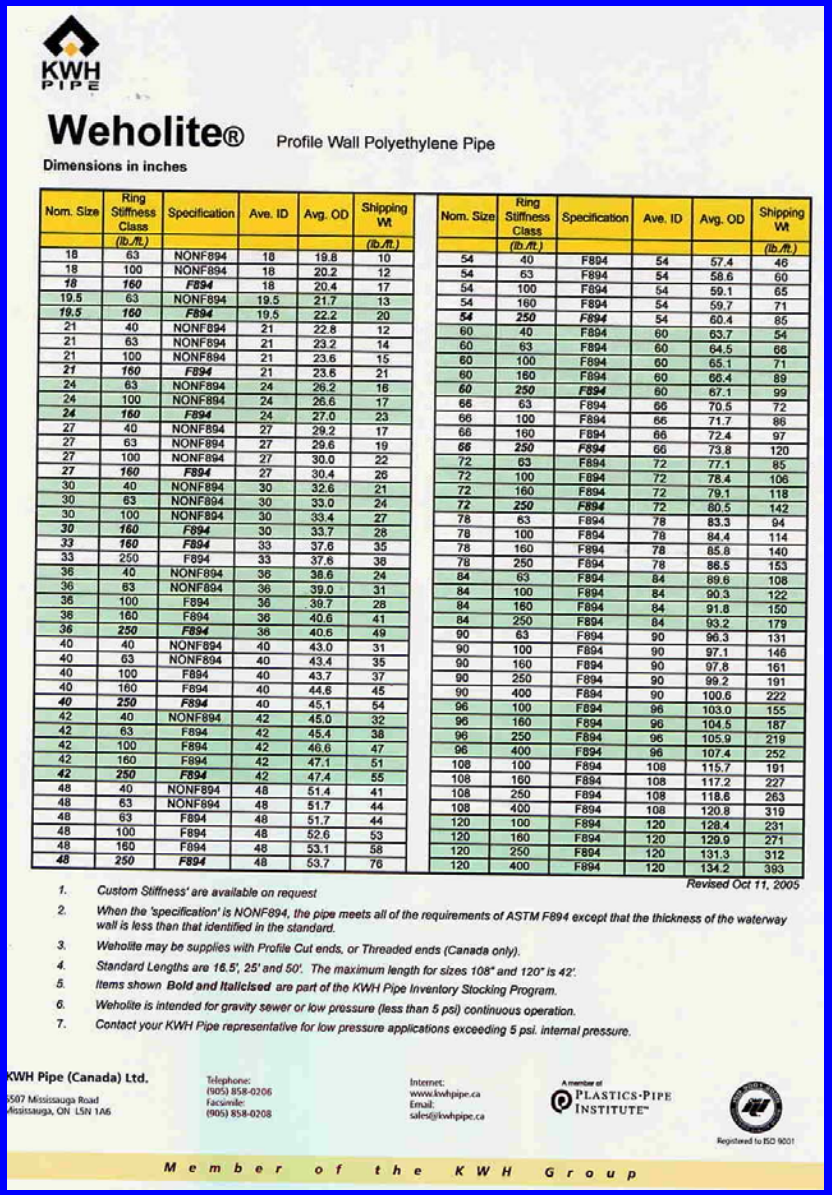
In a large majority of cases when the host pipe can accommodate a hydraulically adequate slipline pipe, no.

Will the slipline pipe need to withstand insertion?

Definitely

Pushing Force
PF=Length x #/ft x FF

Manufacturer's Cut Sheet



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Resistance

Min wall area normal to flow

x

Minimum tensile strength of pipe material

Will the slipline pipe need to withstand grouting?

Definitely

Buckling Resistance

Love's Formula

$$P_{cr} = 3EI/R^3$$

Hydrostatic pressure on unsupported pipe

Weholite External Collapse Resistance (psi)

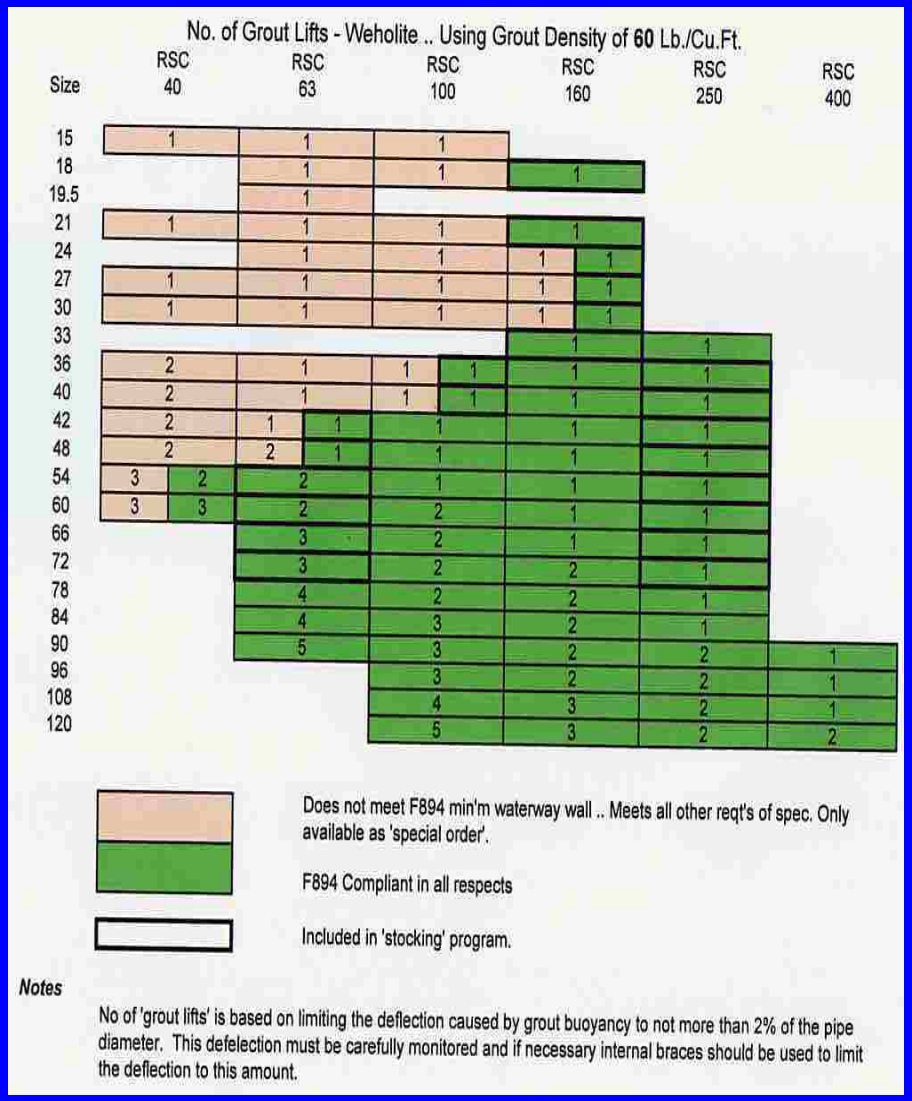
Stiffness (RSC / Kpa)

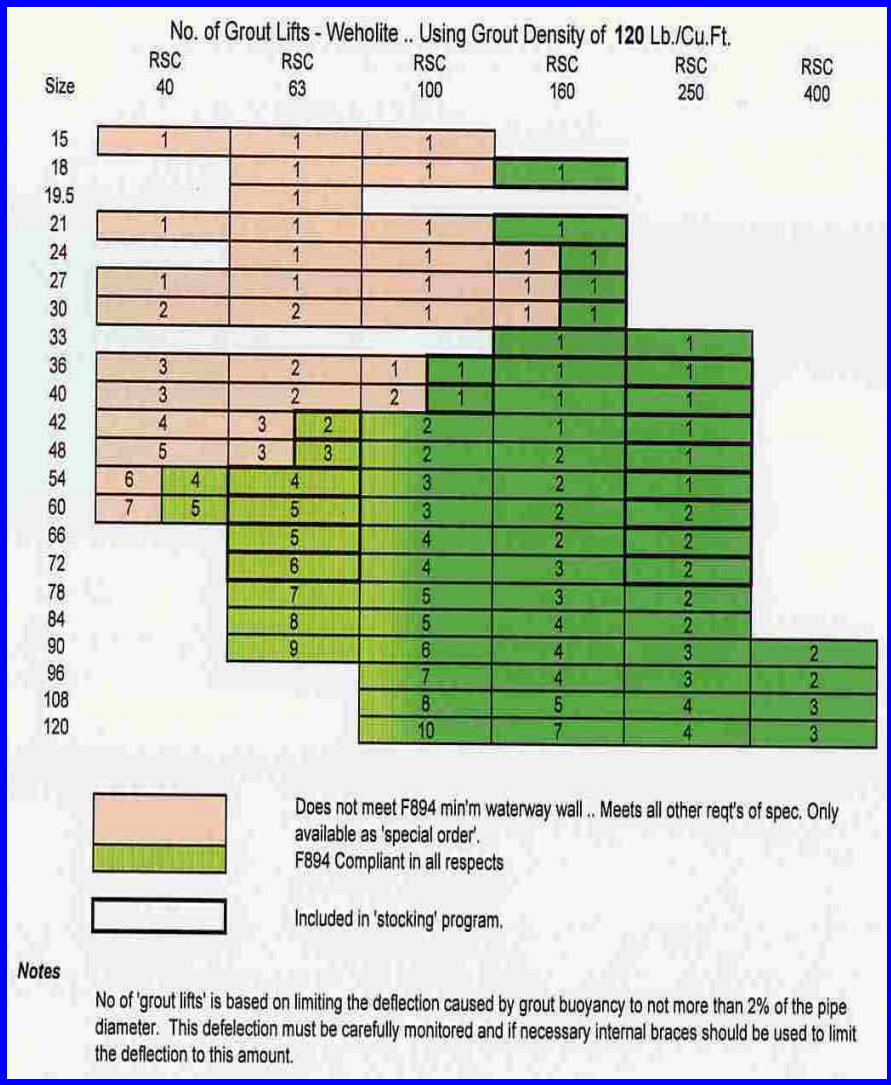
Size	RSC 40	RSC 63	RSC 100	RSC 160	RSC 250	RSC 400
18		3.3	5.3			
21	1.9	3.0	4.6	7.4		
24		2.6	4.1	6.4		
27	1.5	2.3	3.6	5.8		
30	1.3	2.1	3.3	5.3		
36	1.1	1.8	2.8	4.4	6.9	
40	1.0	1.6	2.5	4.0	6.3	
42	1.0	1.5	2.5	4.0	6.3	
48	0.9	1.4	2.2	3.4	5.3	
54	0.8	1.4	2.2	3.4	5.3	
60	0.7	1.1	1.8	2.8	4.3	
66		1.0	1.5	2.6	4.0	
72		0.9	1.5	2.4	3.7	
78		0.9	1.4	2.2	3.4	
84		0.8	1.4	2.2	3.4	
90		0.8	1.2	1.9	3.0	4.8
96			1.2	1.8	2.8	4.5
108			1.0	1.6	2.5	4.0
120			0.9	1.5	2.3	3.7

Notes:

1. *The calculated external collapse resistance values have a 'factor of safety' of 1.5.*
2. *Calculations are based on Love's formula. Based on an assumed grout set up time of 10 hours at 100F, 46,900 psi has been used as the apparent modulus of elasticity.. 2% initial ovality of the pipe was also assumed.*

Limit Deflection ($d=f(Wr^3/EI)$)

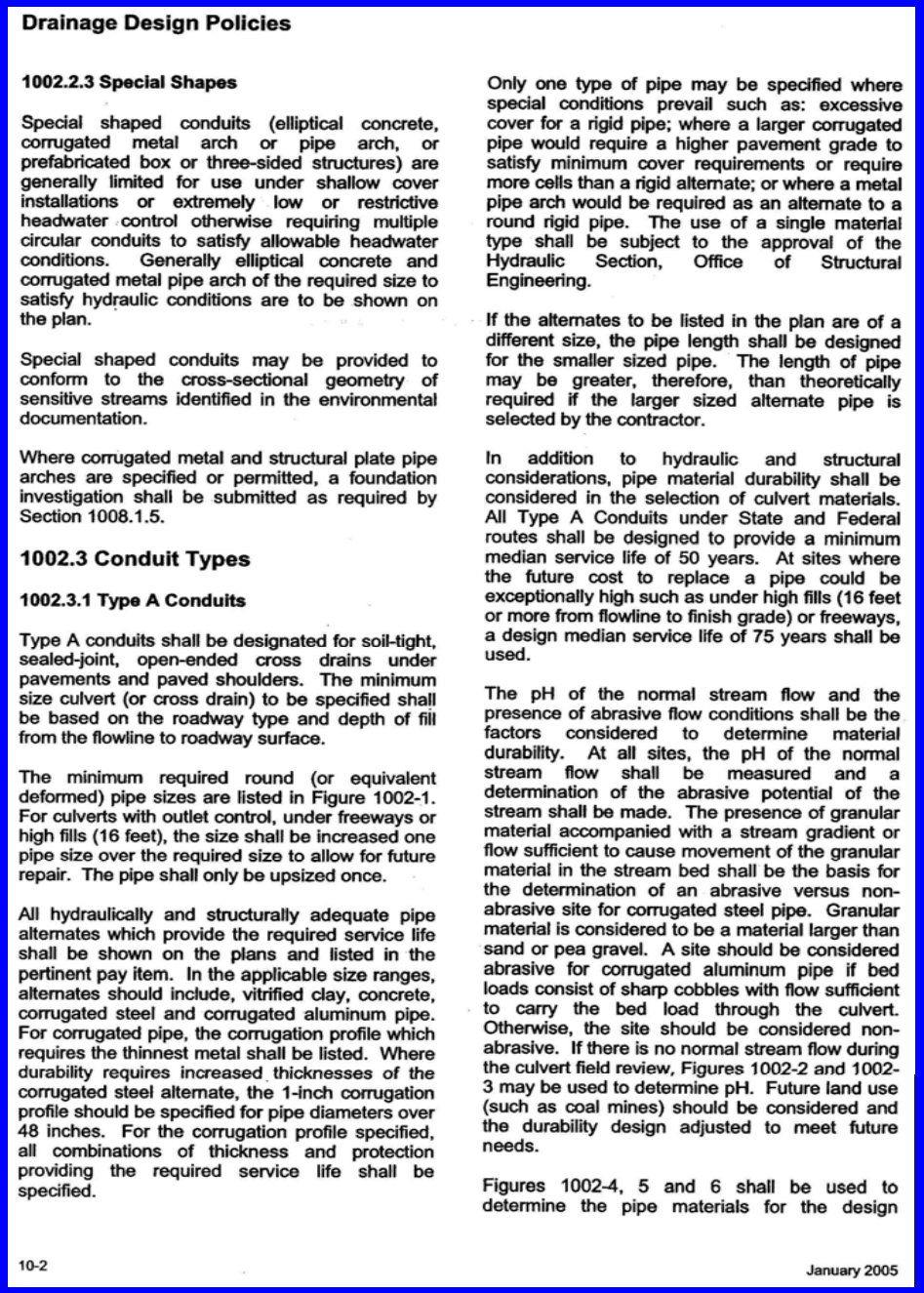




Durability Requirements of the Slipline Pipe

Required Minimum Median Service Life OhioDOT

- 75 years for freeways and other important roadways and high fills (16 ft F/L to finish grade)
- 50 years for other situations



Drainage Design Policies

1002.2.3 Special Shapes

Special shaped conduits (elliptical concrete, corrugated metal arch or pipe arch, or prefabricated box or three-sided structures) are generally limited for use under shallow cover installations or extremely low or restrictive headwater control otherwise requiring multiple circular conduits to satisfy allowable headwater conditions. Generally elliptical concrete and corrugated metal pipe arch of the required size to satisfy hydraulic conditions are to be shown on the plan.

Special shaped conduits may be provided to conform to the cross-sectional geometry of sensitive streams identified in the environmental documentation.

Where corrugated metal and structural plate pipe arches are specified or permitted, a foundation investigation shall be submitted as required by Section 1008.1.5.

1002.3 Conduit Types

1002.3.1 Type A Conduits

Type A conduits shall be designated for soil-tight, sealed-joint, open-ended cross drains under pavements and paved shoulders. The minimum size culvert (or cross drain) to be specified shall be based on the roadway type and depth of fill from the flowline to roadway surface.

The minimum required round (or equivalent deformed) pipe sizes are listed in Figure 1002-1. For culverts with outlet control, under freeways or high fills (16 feet), the size shall be increased one pipe size over the required size to allow for future repair. The pipe shall only be upsized once.

All hydraulically and structurally adequate pipe alternates which provide the required service life shall be shown on the plans and listed in the pertinent pay item. In the applicable size ranges, alternates should include, vitrified clay, concrete, corrugated steel and corrugated aluminum pipe. For corrugated pipe, the corrugation profile which requires the thinnest metal shall be listed. Where durability requires increased thicknesses of the corrugated steel alternate, the 1-inch corrugation profile should be specified for pipe diameters over 48 inches. For the corrugation profile specified, all combinations of thickness and protection providing the required service life shall be specified.

Only one type of pipe may be specified where special conditions prevail such as: excessive cover for a rigid pipe; where a larger corrugated pipe would require a higher pavement grade to satisfy minimum cover requirements or require more cells than a rigid alternate; or where a metal pipe arch would be required as an alternate to a round rigid pipe. The use of a single material type shall be subject to the approval of the Hydraulic Section, Office of Structural Engineering.

If the alternates to be listed in the plan are of a different size, the pipe length shall be designed for the smaller sized pipe. The length of pipe may be greater, therefore, than theoretically required if the larger sized alternate pipe is selected by the contractor.

In addition to hydraulic and structural considerations, pipe material durability shall be considered in the selection of culvert materials. All Type A Conduits under State and Federal routes shall be designed to provide a minimum median service life of 50 years. At sites where the future cost to replace a pipe could be exceptionally high such as under high fills (16 feet or more from flowline to finish grade) or freeways, a design median service life of 75 years shall be used.

The pH of the normal stream flow and the presence of abrasive flow conditions shall be the factors considered to determine material durability. At all sites, the pH of the normal stream flow shall be measured and a determination of the abrasive potential of the stream shall be made. The presence of granular material accompanied with a stream gradient or flow sufficient to cause movement of the granular material in the stream bed shall be the basis for the determination of an abrasive versus non-abrasive site for corrugated steel pipe. Granular material is considered to be a material larger than sand or pea gravel. A site should be considered abrasive for corrugated aluminum pipe if bed loads consist of sharp cobbles with flow sufficient to carry the bed load through the culvert. Otherwise, the site should be considered non-abrasive. If there is no normal stream flow during the culvert field review, Figures 1002-2 and 1002-3 may be used to determine pH. Future land use (such as coal mines) should be considered and the durability design adjusted to meet future needs.

Figures 1002-4, 5 and 6 shall be used to determine the pipe materials for the design

For New Installations

pH	Under 6.5•	6.5	7.0	7.5	8.0	8.5	9.0 and Above	Steel Conduit Size & Type		Protection
Gage Required for 75 year Design Service Life ••							8	707.01 or 707.02		Galvanized
				10	12	14	16	707.01 or 707.02, Aluminum Coated		Aluminized
					10	12	12	≤48"	707.05 or 707.07	Galvanized - Asphalt coated and paved
						10	12	≥54"		
			12	14	16	16	16	≤48"	707.05 or 707.07 Al-Coated	Aluminized - Asphalt coated and paved
				12	12	16	16	≥54"		
			12	14	16	16	16	707.04 (1/2" corr.)		Polymer Coated
								707.04 (1" corr.)		
	10	12	14	16	16	16	16	707.04 (1/2" corr.) paved per 707.07		Polymer coated-Asphalt coated and paved
								707.04 (1" corr.) paved per 707.07		
	16 w/CFP ••	16 w/CFP	16 w/CFP	16 w/CFP	16 w/CFP	16 w/CFP	16 w/CFP	707.02 w/ field paving		Galvanized - Concrete field paved invert
	12 w/CFP ••	12 w/CFP	12 w/CFP	1(or 12 w/CFP)	3(or 12 w/CFP)	8(or 12 w/CFP)	10(or 12 w/CFP)	707.03 (Invert Plates)		Structural Plate

REQUIREMENTS FOR CORRUGATED METAL PIPE THICKNESS AND PROTECTION AT ABRASIVE SITES - 75 YEAR DESIGN SERVICE LIFE

1002-6(75)

REFERENCE SECTION 1002.3.1

REVISED OCTOBER, 2003

For Culvert Replacements

Past performance of the existing culvert material should also be Considered

service life. These tabulations are based on the ODOT Culvert Durability Study and later reports. The equations in the referenced study can be used to determine service lives other than 50 and 75 years.

The following shall govern the determination of the pH factor for the categories listed in Figures 1002-4, 1002-5 and 1002-6.

1. The instrument used to measure the pH shall be capable of determining the pH within an accuracy of 0.1.
2. The firm or agency responsible for the preparation of the plans shall be responsible for obtaining the pH readings.
3. A report shall be submitted, with the Drainage Review plans, listing for all culvert sites: the pH of the stream flow, an evaluation of whether the site is abrasive or non-abrasive, and a statement that the tests were made in dry weather or low flow.

Protection greater than required for existing conditions may be specified for a culvert with potential flow conditions more corrosive than measured, if the district office is of the opinion that future use of the contributing watershed will alter such conditions. A statement of this opinion, including the reasons for the opinion, shall accompany the pH report.

At culvert replacement sites, past performance of existing material should also be considered.

1002.3.2 Type B Conduits

Type B conduit shall be designated for soil-tight, sealed joint sewers under pavements, paved shoulders, and commercial or industrial drives.

In areas with highly erodible soils (e.g., fine sands or silts), premium joints shall be provided.

Additional protection (epoxy coating as per 706.03 for concrete pipe and polymer coating per 707.04 for asphalt paved corrugated steel pipe) shall be provided for storm sewers carrying corrosive flow.

1002.3.3 Type C Conduits

Type C conduit shall be designated for soil-tight, sealed joint sewers not under pavements, paved shoulders, or commercial or industrial drives.

In areas with highly erodible soils (e.g., fine sands or silts), premium joints shall be provided.

Additional protection (epoxy coating as per 706.03 for concrete pipe and polymer coating per 707.04 for asphalt paved corrugated steel pipe) shall be provided for storm sewers carrying corrosive flow.

1002.3.4 Type D Conduits

Type D conduits shall be designated for pipes under driveways and bikeways. The minimum size required is 12 inches. For sizes 24 inches and larger, it will be necessary to submit calculations and specify pipe sizing required to satisfy the hydraulic controls. Such analyses shall be submitted with the Drainage Review plans. The design frequency used to analyze the hydraulic performance of the Type D conduit is the same as that used for the flow capacity of the connected ditch or channel and the headwater for that frequency shall not exceed a point 1 foot below the edge of the pavement. If potential exists for the drive pipe headwater to encroach on the adjacent roadway, the drive pipe shall be sized utilizing a design frequency as per 1004.2.

Generally, the pipe alternates listed in 603.02 of the Construction and Material Specifications are applicable, except that equal size corrugated pipe will provide satisfactory alternates for sizes smaller than 24 inches. If the control is critical, a hydraulic analysis will be required to determine the proper size of pipe alternates.

Drive pipes under commercial or industrial drives shall be designed for material durability as per 1002.3.1. Additional protection for residential and field drives may be specified if conditions warrant.

1002.3.5 Type E Conduits

Type E conduits shall be designated for farm drain headers inside or outside of the right-of-way lines. Headers are ordinarily provided to intercept small, closely spaced lines in a tiled field thereby precluding the need for numerous field tile outlets through the backslope of the highway ditch.

Type E conduits may be used beyond the paved shoulder to eliminate a ditch in front of a yard where such ditch elimination can be justified. When required by hydraulic analysis, all proper sized alternates shall be specified.

Why?

General Notes – Figures 1002-5 and 1002-6

Tables 1002-5(50) & 1002-5(75)

Tables 1002-5(50) and 1002-5(75) are based on equations 6 and 8 from the ODOT Location & Design publication 82-1, "Culvert Durability Study" including:

- A 15-year service life for Bituminous Coating with Invert Paving for culverts 54" and larger.
- A 25-year service life for Bituminous Coating with Invert Paving for culverts 48" and smaller.
- A 35-year service life for Aluminium Coating with pH above 5.0
- A 50-year service life for Polymeric Coating
- All base metal must provide a minimum of 10 years of service life.

Corrugated aluminium alloy pipe (707.21 and 707.22) and aluminium alloy structural plate pipe (707.23) are acceptable with the minimum thickness required to satisfy cover conditions for all non-abrasive sites with a pH between 5.0 and 9.0

A blank space in the table indicates that a gage, which satisfies the design service life, is not available.

Tables 1002-6(50) & 1002-6(75)

Tables 1002-6(50) and 1002-6(75) are based on equations 7 and 9 from the ODOT Location & Design publication 82-1, "Culvert Durability Study" including:

- A 15-year service life for Bituminous Coating with Invert Paving for culverts 54" and larger.
- A 25-year service life for Bituminous Coating with Invert Paving for culverts 48" and smaller.
- A 35-year service life for Aluminium Coating with pH above 5.0.
- A 50-year service life for Polymeric Coating
- All base metal must provide a minimum of 10 years of service life.

Corrugated aluminium alloy pipe (707.21 and 707.22) with Concrete Field Paving and aluminium alloy structural plate pipe (707.23) with Concrete Field Paving are acceptable with the minimum thickness required to satisfy cover conditions for all abrasive sites with a pH between 5.0 and 9.0

A blank space in the table indicates that a gage, which satisfies the design service life, is not available.

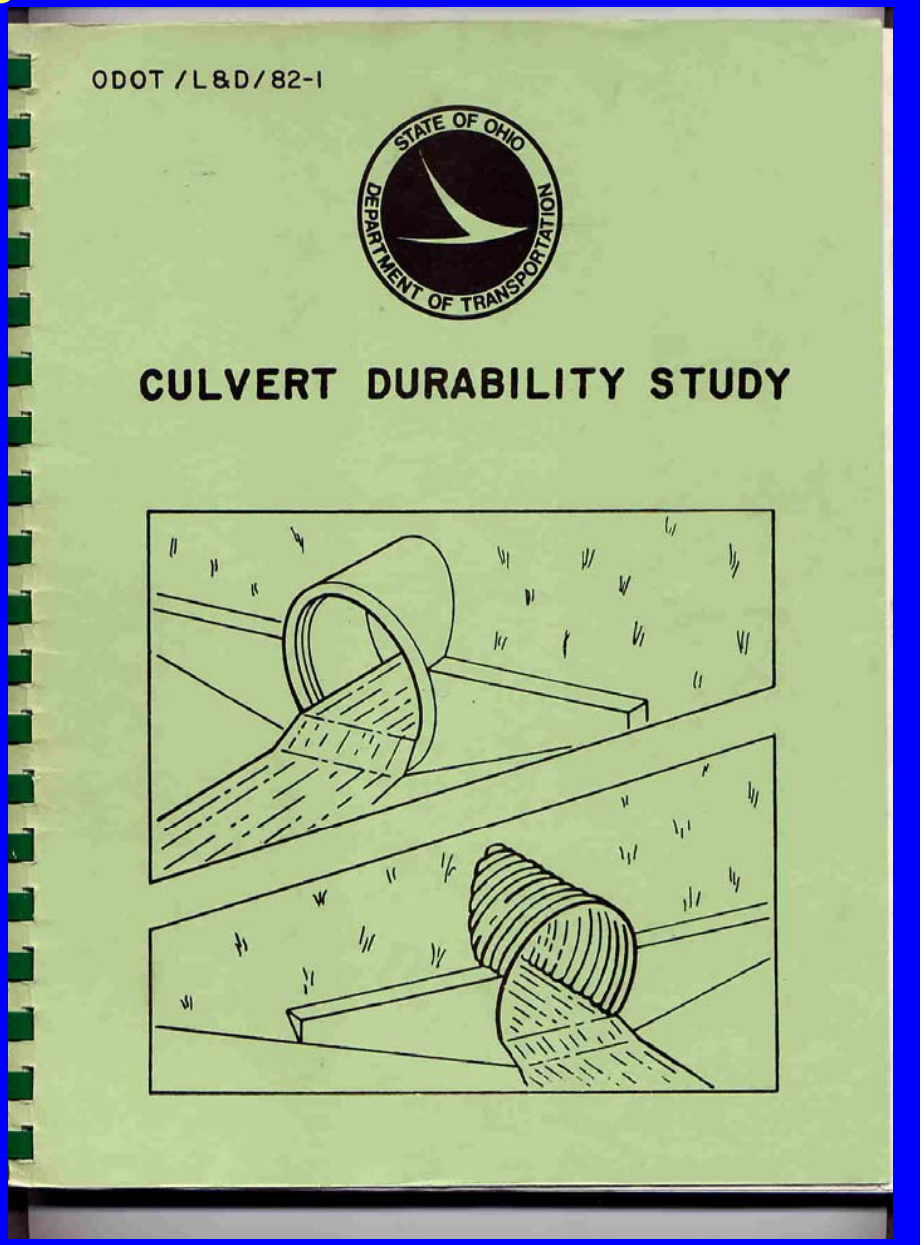
Abbreviations and Symbols

* Concrete field paving shall be epoxy coated per 706.03 for pH < 5.0

** Externally coated per AASHTO M243

w/CFP With concrete field paving of invert

January 2005



Standard Errors of Estimate

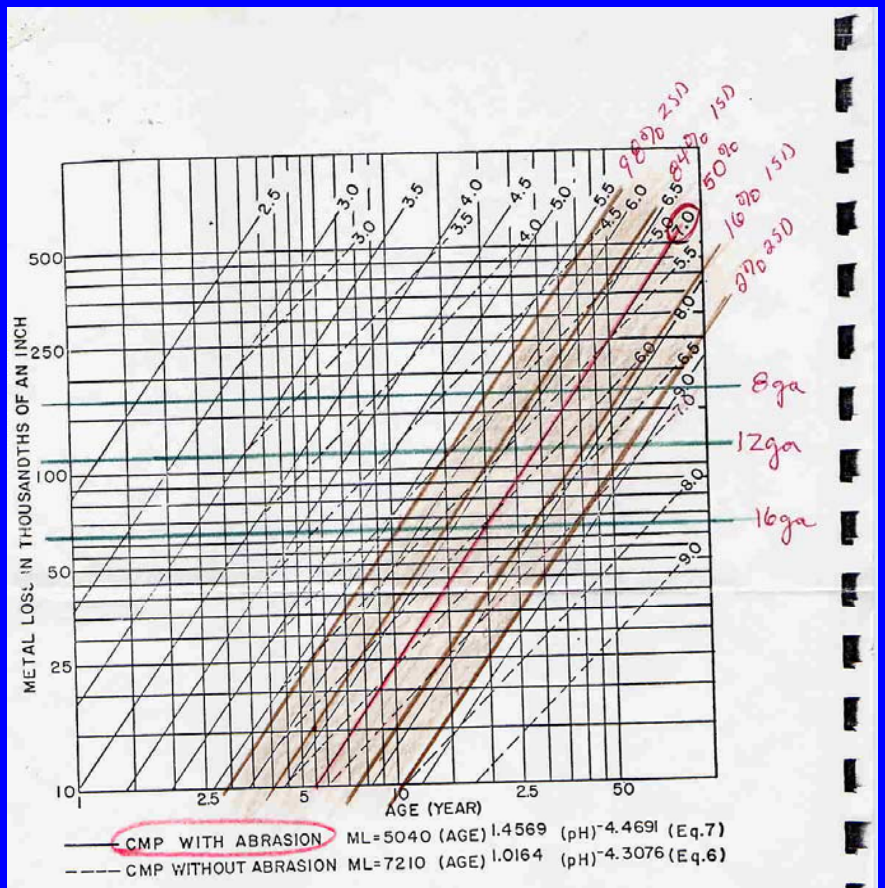


Figure 23. Predicted metal loss for corrugated metal pipe (CMP) culverts.

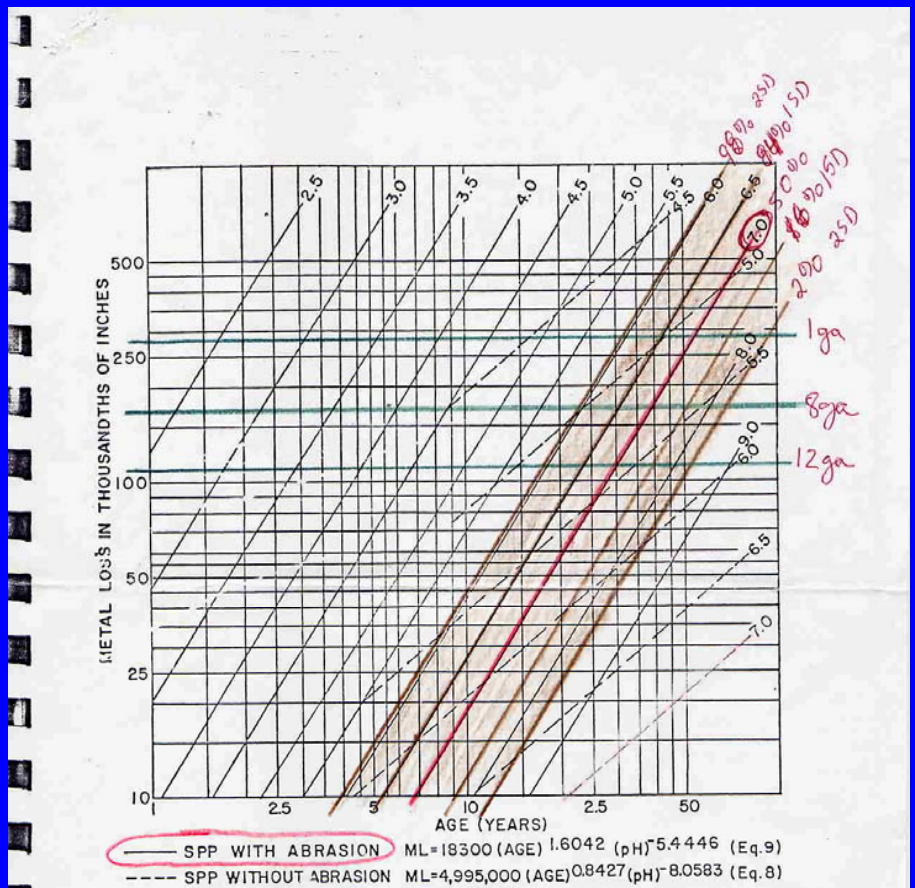


Figure 24. Predicted metal loss for structural plate pipe (SPP) culverts.