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MONTANA DEPARTMENT OF  
TRANSPORTATION

**ROAD DESIGN MANUAL**

**Chapter Seventeen**

***DRAINAGE AND IRRIGATION  
DESIGN***



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## **Chapter Seventeen**

# **DRAINAGE AND IRRIGATION DESIGN**

Chapter Seventeen presents policies and criteria for the design of facilities to accommodate surface water. Included are policies and criteria for the design of:

1. pipe culverts,
2. special drainage facilities,
3. irrigation facilities,
4. storm drains, and
5. underdrains.

The chapter also presents design policies for special-purpose large culverts, and a group of general reference tables. See the *AASHTO Model Drainage Manual* for additional information on highway drainage. The Hydraulics Section has revised and adopted Chapters Seven, Nine, Ten and Thirteen of the *AASHTO Model Drainage Manual*. These chapters are available on MDT's website.

### **17.1 PIPE CULVERTS**

Nearly all drainage and irrigation facilities involve the use of some type of pipe culvert. Pipe culvert design requires a determination of:

1. pipe material,
2. design service life,
3. pipe size,
4. structural requirements,
5. multiple pipe installation requirements,
6. culvert end treatments,
7. culvert inlet and outlet edge protection,
8. culvert lengths, and
9. culvert bedding/foundation.

#### **17.1.1 Pipe Material**

Pipes may be fabricated from concrete, steel, aluminum or plastic material. Material selection will be based on an evaluation of the project location's soil and water conditions. Provisions will be included to permit optional bids for pipes of different materials. The Hydraulics Section will provide information for the different pipe materials including wall thickness, size of corrugations and class of concrete for all

culverts larger than 24" (600 mm) in diameter. The designer will be advised in writing of these decisions. For additional information, see the Department's policy for Optional Material for Culverts.

For reconstruction projects where existing pipes can be used in place and require lengthening, the additional lengths of pipe usually will be constructed of the same material as the existing pipe. These special conditions will be identified in recommendations at the time of the field survey.

### **17.1.2 Design Service Life**

The issue of culvert service life will be addressed during the preliminary field review. The Hydraulics Section will use service life to determine the required wall thickness, type of coating and any special requirements for new pipes. The Hydraulics Section will evaluate the corrosive soil report, as provided by the Materials Bureau, to determine design service life. For specific design criteria, see the "Culvert Service Life Guidelines" as published in the *Hydraulics Manual*. The remaining service life of existing pipes will guide the decision to replace the pipes or use them in place. The culvert service life will comply with the following guidelines:

1. The design service life for new or replacement culverts will be:
  - a. 40 years for approach pipes\*;
  - b. 75 years for mainline pipes;
  - c. 75 years for storm drains; and
  - d. for irrigation pipe, siphons and active streamflow pipes, the life of the pipe is the time it takes for the first perforation to occur. Therefore, the design service life pulled stated in the AISI charts must be doubled (e.g., for design purposes a mainline irrigation crossing effectively needs a 150-year life and a minor irrigation approach pipe needs an effective 80-year life).

\* Approach pipes will not receive any coating unless specifically recommended.

2. The design service life for overlay and minor widening projects will be 20 years for all in-place culverts.
3. The design service life for pipes used in place on reconstruction and major widening projects will be:

- a. 25 years for all in-place pipes except as follows;
- b. 50 years for all pipes where any one of the following applies:
  - fill heights are over 15' (4.5 m);
  - ADT is greater than 5,000;
  - grade raises over 5' (1.5 m);
  - all 4-lane highways; and/or
  - extensions greater than 50% of the in-place length of the culvert.

### **17.1.3 Pipe Size**

The locations and sizes of existing pipe culverts will be documented at the time of the location or pick-up survey. Any problems with existing culvert facilities, such as insufficient capacity, roadway overtopping, erosion, pipe damage, rusting/corrosion, or debris/ice obstruction, should also be noted at the time of survey.

All new mainline drainage culverts must be at least 24" (600 mm) in diameter. All new irrigation pipe culverts and approach culverts must be at least 18" (450 mm) in diameter. Equivalent arch pipes may be used.

The Hydraulics Section will provide recommendations for all irrigation crossings greater than 18" (450 mm) in diameter and drainage crossings requiring pipes greater than 24" (600 mm) in diameter. The road designer will determine the location of all minimum size drainage crossings and will design all inlet, outlet, and roadside ditches for positive drainage.

### **17.1.4 Structural Requirements for Reinforced Concrete Pipe**

Reinforced Concrete Pipes (RCP) are identified by "class" numbers, depending on their respective strength characteristics. Four classes are available — Class 2, 3, 4 and 5. The higher the number, the stronger the pipe. Figure 17.1A identifies permissible fill heights for various classes of pipe and bedding. Concrete Arch Pipes will normally be Class 3, Wall "B". Figure 17.1B provides the equivalent RCP diameters for reinforced concrete pipe arches. Maximum fill height is measured from the top of the pipe to the point of maximum cover including the total surfacing thickness.

US Customary		
CLASS OF PIPE	MAXIMUM FILL HEIGHTS <sup>②,③</sup>	
	INSTALLATION TYPE	
	Trench	Embankment
	P=0.0 <sup>①</sup>	P=0.7
	ft.	ft.
2	14	11
3	20	14
4	28	22
5	42	32
4000D <sup>①</sup>	-	40

Metric		
CLASS OF PIPE	MAXIMUM FILL HEIGHTS <sup>②,③</sup>	
	INSTALLATION TYPE	
	Trench	Embankment
	P=0.0 <sup>①</sup>	P=0.7
	M	m
2	4.3	3.4
3	6.1	4.3
4	8.5	6.7
5	12.8	9.8
4000D <sup>①</sup>	-	12.2

*P = Projection Ratio. A projection ratio of 0.0 is a trench condition and may be achieved by excavation below existing ground or by building embankment and excavating the trench. A projection ratio of 0.7 is for embankment conditions.*

Notes:

- ① *Not to be used without Hydraulic Section's approval. For more information on bedding, see the MDT Detailed Drawings.*
- ② *This fill height table was developed using the indirect design method detailed in the ACPA Concrete Pipe Design Manual. This table applies only to pipes having "B" wall thickness.*
- ③ *Pipes should not extend into the surfacing section. Although not desirable, pipes may extend into the special borrow course. Consult the Hydraulics Section for minimum cover requirements for concrete pipe if cover is less than 1.5 feet (0.5 m).*

## STRUCTURAL REQUIREMENTS FOR RCP

Figure 17.1A

## US Customary

Span (Inch)	Rise (Inch)	Equivalent Diameter (Inch)
18	11	15
22	13 ½	18
26	15 ½	21
28½	18	24
36¼	22 ½	30
43¾	26 ⅝	36
51⅛	31 5/16	42
58½	36	48
65	40	54
73	45	60
88	54	72
102	62	84

## Metric

Span (mm)	Rise (mm)	Equivalent Diameter (mm)
460	280	375
560	345	450
660	395	525
725	460	600
920	570	750
1110	675	900
1300	795	1050
1485	915	1200
1650	1015	1350
1855	1145	1500
2235	1370	1800
2590	1575	2100

*Table values are from AASHTO Materials, Standard Specifications for Transportation Materials, Part 1, M206 & M206M.*

**REINFORCED CONCRETE PIPE ARCHES****Figure 17.1B**

Pipes should not extend into the surfacing section. Although not desirable, pipes may extend into the special borrow course. Consult the Hydraulics Section for minimum cover requirements for concrete pipe if the cover is less than 1.5' (0.5 m).

### **17.1.5 Structural Requirements for Corrugated Steel Pipe**

Metal thickness and soil support are the principal measures of strength in Corrugated Steel Pipe (CSP). The required metal thickness depends on the following factors:

1. height of fill over pipe,
2. dimensions of corrugations,
3. shape of pipe,
4. soil compaction,
5. corner bearing pressure, and
6. soil corrosiveness.

Figure 17.1C illustrates some of the relationships between these factors. The figure shows the minimum and the maximum permissible fill heights for each combination of pipe size and metal thickness. Maximum fill height is measured from the top of the pipe to the point of maximum cover. The depth of surfacing (e.g., bituminous, gravel, concrete) is included in the height of cover. Pipes should be placed at a minimum of 0.3' (0.1 m) to 1.0' (0.3 m) below the bottom of the surfacing section exclusive of special borrow (i.e., surfacing subgrade). Although not desirable, pipes may extend into the special borrow course. See the fill height tables for additional information.

Normally, for steel culvert installations up to 120" (3000 mm) in diameter, CSP will be specified for installation. The fill heights for these culverts must fall within the limits of the fill height tables.

The following corrugation sizes will be specified for steel pipe:

1.  $2\frac{2}{3}$ " x  $\frac{1}{2}$ " (68 mm x 13 mm),
2. 3" x 1" (75 mm x 25 mm), or
3. 5" x 1" (125 mm x 25 mm).

Note the corrugation sizes on the pipe summary.

Most culvert installations will be "round" pipe. Specify pipe arches only where cover is limited or where local conditions make the shape of the pipe arch more effective for carrying the water. Figure 17.1D presents structural requirements for Corrugated Steel Pipe Arch (CSPA) culverts.

## US Customary

2 $\frac{2}{3}$ " x 1 $\frac{1}{2}$ " CORRUGATIONS ①, ② WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
12	18	213	266			
18	18	142	177			
24	18	106	133	186		
30	18	85	106	149		
36	18	71	88	124	159	
42	18	60	76	106	137	167
48	18	53	66	93	119	146
54	18		59	82	106	130
60	18			74	95	117
66	18				87	106
72	18				79	97
78	18					90
84	18					83

## Metric

68 mm x 13 mm CORRUGATIONS ①, ② WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
300	0.5	66.0	82.5			
450	0.5	44.0	55.0			
600	0.5	33.0	41.2	57.8		
750	0.5	26.4	33.0	46.2		
900	0.5	22.0	27.5	38.5	49.5	
1050	0.5	18.9	23.6	33.0	42.5	51.9
1200	0.5	16.5	20.6	28.9	37.2	45.4
1350	0.5		18.3	25.7	33.0	40.4
1500	0.5			23.1	29.7	36.4
1650	0.5			21.0	27.0	33.0
1800	0.5				24.8	30.3
1950	0.5					28.0
2100	0.5					26.0

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

In addition, for all pipes less than 84" (2100 mm), the top of the pipe should be located 0.3' (0.1 m) below the bottom of the surfacing subgrade. For all pipes 84" (2100 mm), and larger, the top of the pipe should be located 1.0' (0.3 m) below the surfacing subgrade.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

② For a given fill height, the wall thicknesses for both the 2 $\frac{2}{3}$ " x 1 $\frac{1}{2}$ " (68 mm x 13 mm) and the 3" x 1" (75mm x 25mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.

**STRUCTURAL REQUIREMENTS FOR CSP**  
**(Welded or Lock-Seam)**  
**Figure 17.1C**

## US Customary

3" x 1" CORRUGATIONS ①, ②						
WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
54	18	54	68	95	122	150
60	18	49	61	85	110	135
66	18	44	55	78	100	122
72	18	40	51	71	92	112
78	18	37	47	66	85	104
84	18		43	61	78	96
90	18		40	57	73	90
96	18			53	69	84
102	18			50	65	79
108	18			47	61	75
114	18				58	71
120	18				55	67

## Metric

75 mm x 25 mm CORRUGATIONS ①, ②						
WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1350	0.5	16.9	21.1	29.5	38.0	46.5
1500	0.5	15.2	19.0	26.6	34.2	41.9
1650	0.5	13.8	17.2	24.2	31.1	38.1
1800	0.5	12.6	15.8	22.2	28.5	34.9
1950	0.5	11.7	14.6	20.5	26.3	32.2
2100	0.5		13.5	19.0	24.4	29.9
2250	0.5		12.6	17.7	22.8	27.9
2400	0.5			16.6	21.4	26.2
2550	0.5			15.6	20.1	24.6
2700	0.5			14.8	19.0	23.3
2850	0.5				18.0	22.0
3000	0.5				17.1	20.9

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

In addition, for all pipes less than 84" (2100 mm), the top of the pipe should be located 0.3' (0.1 m) below the bottom of the surfacing subgrade. For all pipes 84" (2100 mm), and larger, the top of the pipe should be located 1.0' (0.3 m) below the surfacing subgrade.

Notes:

- ① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.
- ② For a given fill height, the wall thicknesses for both the 2<sup>2</sup>/<sub>3</sub>" x 1/2" (68 mm x 13 mm) and 3" x 1" (75 mm x 25 mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.

**STRUCTURAL REQUIREMENTS FOR CSP  
(Welded or Lock-Seam)**

**Figure 17.1C**

## US Customary

5" x 1" CORRUGATIONS ①						
WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
54	18	48	60	84	109	133
60	18	43	54	76	98	120
66	18	39	49	69	89	109
72	18	36	45	63	82	100
78	18	33	42	58	75	92
84	18		39	54	70	85
90	18		36	51	65	80
96	18			47	61	75
102	18			45	57	70
108	18			42	54	66
114	18				51	63
120	18				49	60

## Metric

125 mm x 25 mm CORRUGATIONS ①						
WELDED OR LOCK-SEAM STEEL PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1350	0.5	15.0	18.8	26.3	33.9	41.4
1500	0.5	13.5	16.9	23.7	30.5	37.3
1650	0.5	12.3	15.4	21.5	27.7	33.9
1800	0.5	11.3	14.1	19.7	25.4	31.0
1950	0.5	10.4	13.0	18.2	23.4	28.7
2100	0.5		12.1	16.9	21.8	26.6
2250	0.5		11.3	15.8	20.3	24.8
2400	0.5			14.8	19.0	23.3
2550	0.5			13.9	17.9	21.9
2700	0.5			13.2	16.9	20.7
2850	0.5				16.0	19.6
3000	0.5				15.2	18.6

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

In addition, for all pipes less than 84" (2100 mm), the top of the pipe should be located 0.3' (0.1 m) below the bottom of the surfacing subgrade. For all pipes 84" (2100 mm), and larger, the top of the pipe should be located 1.0' (0.3 m) below the surfacing subgrade.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

**STRUCTURAL REQUIREMENTS FOR CSP  
(Welded or Lock-Seam)  
Figure 17.1C**

## US Customary

2 <sup>2</sup> / <sub>3</sub> " x 1 <sup>1</sup> / <sub>2</sub> " CORRUGATIONS STEEL PIPE ARCH (ALL SEAM FABRICATIONS)						
PIPE DIMENSIONS SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)①				
		MINIMUM METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
21 x 15	24	9				
28 x 20	24	10**				
35 x 24	30	7**				
42 x 29	30	7**				
49 x 33	36		7**			
57 x 38③	24			8**		
64 x 43③	24			9**		
71 x 47③	24				10**	
77 x 52③	24					10**
83 x 57③	24					10**

## Metric

68 mm x 13 mm CORRUGATIONS STEEL PIPE ARCH (ALL SEAM FABRICATIONS)						
PIPE DIMENSIONS SPAN x RISE (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)①				
		MINIMUM METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
530 x 380	0.6	2.9				
710 x 510	0.6	3.2**				
885 x 610	0.7	2.1**			②	
1060 x 740	0.8	2.1**				
1240 x 840	0.9		2.0**			
1440 x 970③	0.6			2.6**		
1620 x 1100③	0.6			2.8**		
1800 x 1200③	0.6				3.0**	
1950 x 1320③	0.6					3.1**
2100 x 1450③	0.6					3.3**

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

In addition, for all pipe 2 2/3" x 1/2" (68mm x 13mm) corrugations, the top of the pipe should be located 0.3' (0.1m) below the surfacing subgrade.

\*\* Based upon a 3 ton (287 kPa) corner bearing pressure. Special foundation investigation required.

① Based upon a 2 ton (192 kPa) corner bearing pressure except as noted. Special foundation investigation required when higher corner bearing pressures need to be developed.

② Thicknesses above heavy line will not be used unless specified by the Hydraulics Section.

③ These sizes should not be used unless site conditions preclude the use of arches with 3" x 1" (75 mm x 25 mm) corrugations.

## STRUCTURAL REQUIREMENTS FOR CSPA

Figure 17.1D

## US Customary

3" x 1" or 5" x 1" CORRUGATIONS STEEL PIPE ARCH (ALL SEAM FABRICATIONS)						
PIPE DIMENSIONS+ SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) ①				
		MINIMUM METAL THICKNESS (in)				
		0.064	0.079	0.109	0.138	0.168
53 x 41	24		8④			
60 x 46	24		9④			
66 x 51	24		9④			
73 x 55	24		11④		②	
81 x 59	24		11④			
87 x 63	24		10④			
95 x 67	24		11④			
103 x 71	24			10		
112 x 75	24			10		
117 x 79	24			10		
128 x 83	24				9	

## Metric

75 mm x 25 mm OR 125 mm x 25 mm CORRUGATIONS STEEL PIPE ARCH (ALL SEAM FABRICATIONS)						
PIPE DIMENSIONS+ SPAN x RISE (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ①				
		MINIMUM METAL THICKNESS (mm)				
		1.63	2.01	2.77	3.51	4.27
1340 x 1050	0.6		2.7④			
1520 x 1170	0.6		2.7④			
1670 x 1300	0.6		2.7④			
1850 x 1400	0.6		3.3④		②	
2050 x 1500	0.6		3.5④			
2200 x 1620	0.6		3.2④			
2400 x 1720	0.6		3.4④			
2600 x 1820	0.6			3.1		
2840 x 1920	0.6			3.2		
2970 x 2020	0.6			3.1		
3240 x 2120	0.6				2.8	

## Notes:

- \* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.  
In addition, for all pipe arches less than 95" x 67" (2400mm x 1720mm), the top of the pipe should be located 0.3' (0.1m) below the surfacing subgrade. For all pipe arches less than 95" x 67" (2400mm x 1720mm), and larger, the top of the pipe should be located 1.0' (0.3m) below the surfacing subgrade.
- + Nominal dimensions per manufacturer/supplier's product information.
- ① Based upon a 2 ton (192 kPa) corner bearing pressure except as noted. Special foundation investigation required when higher corner bearing pressures need to be developed.
- ② Thicknesses above heavy line will not be used unless specified by the Hydraulics Section.
- ④ Specify 0.109" (2.77 mm) thickness for 5" x 1" (125 mm x 25 mm) corrugations.

**STRUCTURAL REQUIREMENTS FOR CSPA**  
**Figure 17.1D**

### **17.1.6 Structural Requirements for Structural Steel Plate Culverts**

Normally, for culvert installations larger than 120" (3000 mm), Structural Steel Plate Pipe (SSPP) culverts will be specified. Figure 17.1E provides SSPP criteria for minimum and maximum fill heights permitted with various combinations of pipe size and metal thickness. The Hydraulics Section must specify adequate metal thickness for each installation. The dimension of SSPP will be called out in feet and inches (meters to three decimal places).

Figure 17.1F presents the structural requirements for Structural Steel Plate Pipe Arch (SSPPA) culverts.

### **17.1.7 Structural Requirements for Corrugated Aluminum Pipe**

When Corrugated Aluminum Pipe (CAP) is specified or permitted as an option, determine the metal thickness requirements from Figure 17.1G for the particular conditions of pipe shape and height of fill.

### **17.1.8 Multiple Pipe Installations**

To provide an adequate waterway, it may be necessary to install two or more adjacent culverts at one location. Identify these installations as a "double" or a "triple" installation at the station representing the center of the installation.

The spacing between outside faces of adjacent pipes normally will be a minimum of 4' (1.2 m) and a maximum of 8' (2.4 m). If flared end terminal sections are used, specify at least 2' (0.6 m) between the outside ends of adjacent terminal sections.

US Customary

6" x 2" CORRUGATIONS STRUCTURAL STEEL PLATE PIPE								
PIPE DIAMETER** (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) ①						
		METAL THICKNESS (in)						
		0.109	0.138	0.168	0.188	0.218	0.249	0.280
60	18	47	68	90	103	124	146	160
72	18	39	57	75	86	103	122	133
84	18	34	49	64	73	88	104	114
96	18	29	43	56	64	77	91	100
108	18	26	38	50	57	69	81	88
120	18	23	34	45	51	62	73	80
132	18	21	31	40	47	56	66	72
144	18	19	28	37	43	51	61	66
156	20	18	26	34	39	47	56	61
168	24	17	24	32	36	44	52	57
180	24	15	23	30	34	41	48	53
192	24		21	28	32	38	45	50
204	28		20	26	30	36	43	47
216	28			25	28	34	40	44
228	32			23	27	32	38	42
240	32				25	31	36	40
252	32					29	34	38

Metric

152 mm x 51 mm CORRUGATIONS STRUCTURAL STEEL PLATE PIPE								
PIPE DIAMETER** (m)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ①						
		METAL THICKNESS (mm)						
		2.82	3.56	4.32	4.79	5.54	6.32	7.11
1.500	0.5	14.6	21.0	27.5	31.5	38.0	44.7	48.8
1.810	0.5	12.1	17.5	22.9	26.3	31.6	37.3	40.7
2.120	0.5	10.4	15.0	19.6	22.5	27.1	32.0	34.9
2.430	0.5	9.1	13.1	17.2	19.7	23.7	28.0	30.5
2.740	0.5	8.1	11.7	15.3	17.5	21.1	24.9	27.1
3.050	0.5	7.3	10.5	13.7	15.8	19.0	22.4	24.4
3.360	0.5	6.6	9.6	12.5	14.3	17.3	20.3	22.2
3.670	0.5	6.1	8.8	11.4	13.1	15.8	18.6	20.3
3.980	0.5	5.6	8.1	10.6	12.1	14.6	17.2	18.8
4.290	0.6	5.2	7.5	9.8	11.3	13.6	16.0	17.4
4.600	0.6	4.9	7.0	9.2	10.5	12.7	14.9	16.3
4.910	0.7		6.6	8.6	9.8	11.9	14.0	15.3
5.220	0.7		6.2	8.1	9.3	11.2	13.2	14.4
5.530	0.7			7.6	8.8	10.5	12.4	13.6
5.840	0.8			7.2	8.3	10.0	11.8	12.8
6.150	0.8				7.9	9.5	11.2	12.2
6.460	0.8					9.0	10.7	11.6

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

In addition, for all pipes less than 84" (2.120 m), the top of the pipe should be located 0.3' (0.1 m) below the surfacing subgrade. For all pipes 84" (2.120 m), and larger, the top of the pipe should be located 1.0' (0.3 m) below the surfacing subgrade.

\*\* Nominal diameters per manufacturers'/suppliers' product information.

Notes:

① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.

**STRUCTURAL REQUIREMENTS FOR SSPP**

**Figure 17.1E**

## US Customary

SSPPA, 6" x 2" CORRUGATIONS 18" CORNER RADIUS <sup>①</sup>					
PIPE DIMENSIONS @ SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) <sup>③</sup>			
		MINIMUM METAL THICKNESS (in)			
		0.109			
6'-1" x 4'-7"	24	16			
6'-4" x 4'-9"	24	15			
7'-0" x 5'-1"	24	14			
7'-3" x 5'-3"	24	13			
7'-8" x 5'-5"	24	13			
8'-2" x 5'-9"	30	12			
8'-10" x 6'-1"	30	11			
9'-9" x 6'-7"	30	10			
10'-8" x 6'-11"	30	9			
10'-11" x 7'-1"	30	9			
11'-10" x 7'-7"	36	7			
12'-8" x 8'-1"	36	6			
12'-10" x 8'-4"	48	6			
13'-5" x 8'-5"	48	5			

## Metric

SSPPA, 152 mm x 51 mm CORRUGATIONS 457-mm CORNER RADIUS <sup>①</sup>					
PIPE DIMENSIONS @ SPAN x RISE (m)	MINIMUM FILL HEIGHT* (,m)	MAXIMUM FILL HEIGHT (m) <sup>③</sup>			
		MINIMUM METAL THICKNESS (mm)			
		2.82			
1.850 x 1.400	0.6	5.0			
1.930 x 1.450	0.6	4.8			
2.130 x 1.550	0.6	4.4			
2.210 x 1.600	0.6	4.2			
2.340 x 1.650	0.6	4.0			
2.490 x 1.750	0.8	3.7			
2.690 x 1.850	0.8	3.5			
2.970 x 2.010	0.8	3.1			
3.250 x 2.110	0.8	2.9			
3.330 x 2.160	1.0	2.8			
3.610 x 2.310	1.0	2.1			
3.860 x 2.460	1.0	1.8			
3.910 x 2.540	1.3	1.8			
4.090 x 2.570	1.3	1.5			

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. For all SSPPA pipes, the top of the pipe should be located 1.0' (0.3 m) below the surfacing subgrade.

## Notes:

- ① These sizes should not be specified unless site conditions preclude the use of CSPA or SSPPA with 31" (787 mm) corner radii.
- ② Intermediate sizes not listed have the same maximum and minimum fill heights and metal thicknesses as the next larger size listed in this table.
- ③ Based upon a 2 ton (192 kPa) corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.

**STRUCTURAL REQUIREMENTS FOR SSPPA****Figure 17.1F**

## US Customary

SSPPA, 6" x 2" CORRUGATIONS 31" CORNER RADIUS						
PIPE DIMENSIONS @ SPAN x RISE (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft) ③				
		MINIMUM METAL THICKNESS (in)				
		0.109	0.138	0.168	0.188	
13'-6" x 9'-6"	30	12				
14'-2" x 9'-10"	30	12				
15'-7" x 10'-6"	30	11				
15'-10" x 10'-8"	30		10			
17'-2" x 11'-4"	30		10			
17'-11" x 11'-8"	30			9		
18'-1" x 11'-10"	30			9		
18'-9" x 12'-2"	36			9		
19'-11" x 12'-10"	36				7	
20'-7" x 13'-2"	36				7	

## Metric

SSPPA, 152 m x 51 mm CORRUGATIONS 787-mm CORNER RADIUS						
PIPE DIMENSIONS @ SPAN x RISE (m)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m) ③				
		MINIMUM METAL THICKNESS (mm)				
		2.82	3.56	4.32	4.79	
4.110 x 2.900	0.8	3.9				
4.320 x 3.000	0.8	3.7				
4.750 x 3.200	0.8	3.4				
4.830 x 3.250	0.8		3.3			
5.230 x 3.450	0.8		3.1			
5.460 x 3.560	0.8			2.9		
5.510 x 3.610	0.8			2.9		
5.720 x 3.710	1.0			2.8		
6.070 x 3.910	1.0				2.6	
6.270 x 4.010	1.0				2.6	

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

For all SSPPA pipes, the top of the pipe should be located 1.0' (0.3 m) below the surfacing subgrade.

## Notes:

- ② Intermediate sizes not listed have the same maximum and minimum fill heights and metal thicknesses as the next larger size listed in this table.
- ③ Based upon a 2 ton (192 kPa) corner bearing pressure. Special foundation investigation required when higher corner bearing pressures need to be developed.

**STRUCTURAL REQUIREMENTS FOR SSPPA****Figure 17.1F**

## US Customary

2 $\frac{2}{3}$ " x 1/2" CORRUGATIONS <sup>①</sup> , <sup>②</sup> , <sup>③</sup>						
LOCK-SEAM ALUMINUM PIPE						
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.060	0.075	0.105	0.135	0.164
12	18	113	142			
18	18	75	94			
24	18	56	71	99		
30	18		56	79		
36	18		47	66	85	
42	18			56	73	
48	18			49	63	78
54	18			43	56	69
60	18				50	62
66	18					56
72	18					45

## Metric

68 mm x 13 mm CORRUGATIONS <sup>①</sup> , <sup>②</sup> , <sup>③</sup>						
LOCK-SEAM ALUMINUM PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.52	1.91	2.67	3.43	4.17
300	0.5	34.4	43.3			
450	0.5	22.9	28.7			
600	0.5	17.1	21.6	30.2		
750	0.5		17.1	24.1		
900	0.5		14.3	20.1	25.9	
1050	0.5			17.1	22.3	
1200	0.5			14.9	19.2	23.8
1350	0.5			13.1	17.1	21.0
1500	0.5				15.2	18.9
1650	0.5					17.1
1800	0.5					13.7

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

For all aluminum pipes, the top of the pipe should be located 0.3' (0.1 m) below the surfacing subgrade.

## Notes:

- ① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.
- ② For a given fill height, the wall thicknesses for both the 2 $\frac{2}{3}$ " x 1/2" (68 mm x 13 mm) and 3" x 1" (75 mm x 25 mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.
- ③ Fill heights taken from manufacturers'/suppliers' product information.

**STRUCTURAL REQUIREMENTS FOR CAP  
(Lock-Seam Aluminum)  
Figure 17.1G**

## US Customary

3" x 1" CORRUGATIONS ①, ②, ③						
LOCK-SEAM ALUMINUM PIPE						
PIPE DIAMETER (in)	MINIMUM FILL HEIGHT* (in)	MAXIMUM FILL HEIGHT (ft)				
		METAL THICKNESS (in)				
		0.060	0.075	0.105	0.135	0.164
30	18	52	65	91		
36	18	43	54	76	98	
42	18	36	46	65	84	
48	18	32	40	57	73	90
54	18	28	35	50	65	80
60	18		32	45	58	72
66	18		28	41	53	65
72	18		26	37	48	59

## Metric

75 mm x 25 mm CORRUGATIONS ①, ②, ③						
LOCK-SEAM ALUMINUM PIPE						
PIPE DIAMETER (mm)	MINIMUM FILL HEIGHT* (m)	MAXIMUM FILL HEIGHT (m)				
		METAL THICKNESS (mm)				
		1.52	1.91	2.67	3.43	4.17
750	0.5	15.8	19.8	27.7		
900	0.5	13.1	16.5	23.2	29.9	
1050	0.5	11.0	14.0	19.8	25.6	
1200	0.5	9.8	12.2	17.4	22.3	27.4
1350	0.5	8.5	10.7	15.2	19.8	24.4
1500	0.5		9.8	13.7	17.7	21.9
1650	0.5		8.5	12.5	16.2	19.8
1800	0.5		7.9	11.3	14.6	18.0

\* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement.

For all aluminum pipes, the top of the pipe should be located 0.3' (0.1 m) below the surfacing subgrade.

## Notes:

- ① Fill heights based on suitable backfill (granular material) and foundation conditions. Consult the Geotechnical Section for special backfill/foundation requirements when wet and/or unsuitable in-place soil conditions exist.
- ② For a given fill height, the wall thicknesses for both the 2<sup>2</sup>/<sub>3</sub>" x 1/2" (68 mm x 13 mm) and 3" x 1" (75 mm x 25 mm) corrugations should be compared, and the corrugations that allow the use of the thinner wall should be used.
- ③ Fill heights taken from manufacturers'/suppliers' product information.

**STRUCTURAL REQUIREMENTS FOR CAP  
(Lock-Seam Aluminum)  
Figure 17.1G**

### **17.1.9 Culvert End Treatments**

Consideration should be given to special treatments required for the ends of culvert installations. Specific detailed drawings and criteria for their application are presented below.

The end treatments discussed in Section 17.1.9 apply to both single and multiple-pipe installations. See the *MDT Detailed Drawings* for the standard end treatments.

#### **17.1.9.1 Reinforced Concrete Pipe**

Where fill slopes are 2:1 or steeper, concrete culverts less than 60" (1500 mm) in diameter will have no special end treatment (square ends) and will extend 2' (0.5 m) beyond the toe of the fill slope. For pipes  $\geq 60$ " (1500 mm), RCP terminal sections will be specified.

Where fill slopes are flatter than 2:1, RCP terminal sections will be specified for all concrete pipe.

#### **17.1.9.2 Corrugated Metal Pipe $\leq 48$ " (1200 mm)**

Where fill slopes are 2:1 or steeper, metal culverts 48" (1200 mm) or less in diameter will have no special end treatment (square ends) and will extend 2' (0.5 m) beyond the toe of the fill slope.

Where fill slopes are flatter than 2:1, the following end treatment sections will be specified:

$\leq 48$ " (1200 mm)	CMP Flared End Terminal Section (FETS)
$\leq 53$ " S x 41" R (1340 mm x 1050 mm)	CMP Arch FETS

#### **17.1.9.3 Corrugated Metal Pipe and Structural Plate Pipe $\geq 54$ " (1350 mm)**

The end treatments for the types and sizes of culverts listed below apply to all fill slopes:

$\geq 54$ " (1350 mm)	Step Bevel for CSP, SSPP and CAP
$\geq 60$ " S x 46" R ( 1520 mm x 1170 mm)	Bevel on CSP Arch

≥ 6'-1" S x 4'-7" R (1.850 m x 1.400 m)

Bevel on SSPP Arch

The bevel is defined as the angle between the invert line and fill slope line.

#### **17.1.9.4 Road Approach Culverts**

Locate the entire road approach culvert including end treatment outside the clear zone where practical. FETS will be provided for all approach culverts located outside the clear zone. Where it is not practical to place approach culverts outside the clear zone, specify the 6:1 Road Approach Culvert End Treatment (RACET).

#### **17.1.10 Roadway Orientation**

The end treatments for all single concrete pipe and corrugated metal pipe installations with diameters less than 54" (1350 mm) will be installed perpendicular to the centerline of the pipe regardless of pipe skew, unless specified otherwise by the Hydraulics Section.

Concrete pipes will not be beveled or skew-beveled.

The following will apply to corrugated metal and structural plate pipe installations 54" (1350 mm) or greater in diameter:

1. Installations Perpendicular to the Roadway Centerline. Pipes will typically be designed and fabricated with the beveled ends perpendicular to the centerline of the pipe. The type of bevel will be identified on the plans (e.g., 2:1 step-bevel, 2:1 bevel, etc.).
2. Skewed Installations. The skew is defined as the angle measured left or right from a line which is perpendicular to the roadway centerline. Note: Skew-bevel or skew step-bevel end sections are cut parallel to the centerline of the roadway. The type of bevel and the amount of skew are to be identified in the Culvert Summary:
  - a. Pipe skews will typically not exceed 35°.
  - b. The pipe end treatment for single pipe installations will be designed as indicated below for the following skews:

0 to 15°	End treatment perpendicular to the centerline of pipe.
----------	--

- |            |   |
|------------|---|
| 16° to 35° | When the fill height is less than 10' (3 m), the end treatment should be skew beveled.  |
| 16° to 35° | When the fill height is greater than 10' (3 m), the end treatment should be perpendicular to the centerline of the pipe and the fill warped to the pipe ends. |
- c. Multiple pipe installations will utilize the same end treatment as single pipe installations except that, for skews from 16° to 35°, the end treatment will be skew beveled regardless of fill height.
  - d. If it is determined necessary to skew-bevel a pipe end, provide concrete edge protection and cutoff walls on both ends.
  - e. If temporary bracing of skew-beveled pipe ends is required, it must be addressed by special provision.
  - f. Consider channel changes to limit pipe skew where appropriate. Environmental concerns need to be considered when using this policy.

#### **17.1.11 Metal Pipe Culvert Extensions**

The following will apply:

1. The Hydraulics Section will evaluate the remaining service life of the pipe to determine if it should be extended or replaced. This determination is generally based on the condition of the in-place culverts.
2. The length of extension includes the new end treatment section, unless the existing section will be removed and relayed. Note this in the culvert summary.
3. The road designer is responsible for determining the length of pipe extensions. The Hydraulics Section may recommend new end treatments on a case-by-case basis.
4. If the existing pipe is a metric size, the diameter will be converted to US Customary units and rounded to the nearest inch (e.g. 600mm = 24"). The pipe extensions will be called out using the available US Customary size for the pipe. When the material or configuration of the existing pipe cannot be matched, a concrete collar will be needed to connect the extension to the existing pipe. Metal bands can be used to connect CSP to SSPP where the connection is beyond the edge of the surfacing section. This will require a special detail.

5. Fill height for pipe extensions will be measured at the point of connection to the existing pipe unless otherwise specified.

### **17.1.12 RCP Culvert Extensions**

The required minimum length of extension for concrete culverts is as follows:

1. Diameter  $\leq$  30" (750 mm): 10' (3 m), including 4' (1.0 m) of new pipe and a 6' (2.0 m) standard terminal section.
2. 30" (750 mm) < Diameter  $\leq$  72" (1800 mm): 12' (3.5m), including 4' (1.0 m) of new pipe and a 8' (2.5 m) standard terminal section.
3. Diameter > 72" (1800 mm): Contact the Hydraulics Section
4. If extension of the barrel is not required, a FETS can be added without any additional length of pipe.
5. Fill height for pipe extensions should be measured at the point of connection to the existing pipe.

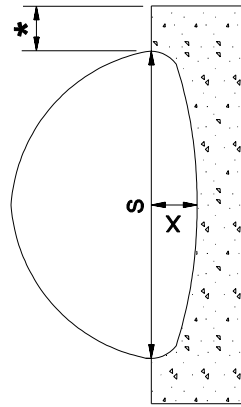
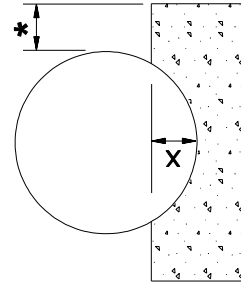
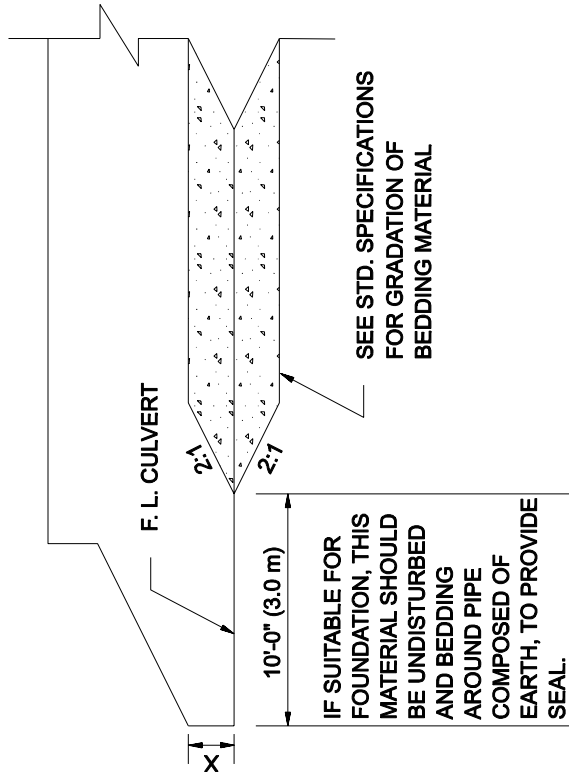
### **17.1.13 Culvert Bedding**

Use the *MDT Detailed Drawings* and Figure 17.1H to specify culvert bedding.

For most ordinary culvert installations less than or equal to 48" (1200 mm) in diameter, it will not be necessary to include bedding quantities in the plans unless specifically recommended by the Hydraulics or Geotechnical Section.

For all culvert installations of 54" (1350 mm) in diameter and larger (and equivalent size arch culverts — 64" x 43" (1620 mm x 1100 mm) for 2 $\frac{2}{3}$ " x 1 $\frac{1}{2}$ " (68 mm x 13 mm) corrugations and 60" x 46" (1520 mm x 1170 mm) for 3" x 1" (75 mm x 25 mm) corrugations), specify bedding materials and quantities in accordance with the *MDT Detailed Drawings*.

When foundation material is specified, it will be placed below the bedding material. Consult the Geotechnical Section for special foundation requirements when unusual subsurface conditions exist.



2'-0" (0.6 m) FOR ALL PIPE SIZES UNLESS OTHERWISE INDICATED

\*2'-0" (0.6 m) MINIMUM FOR ALL PIPES 54" (1350 m) AND GREATER IN DIAMETER UNLESS SPECIFICALLY RECOMMENDED.

NOTE: FOR X DISTANCE, SEE MDT DETAILED DRAWINGS.

**BEDDING MATERIALS**  
**(Culverts with  $D \geq 54"$  (1350 mm))**

Figure 17.1H

#### **17.1.14 Culvert Inlet and Outlet Protection**

The hydraulic characteristics of some drainage channels may require special protection for the roadway embankment at the inlets and outlets of culvert installations. Recommendations for special protection measures will be made at the time of the location survey or during subsequent field investigations. The Hydraulics Section will provide design information for special features.

If skew bevels are used, concrete edge protection is required to strengthen the top arch on the pipe inlet and outlet. Bolting should be similar to that shown in the MDT Detailed Drawings.

For pipes 48" (1200 mm) or less in diameter, it is not necessary to provide for special protection unless the Hydraulics Section provides specific recommendations to do so. For pipes of 54" (1350 mm) diameter and larger, provide the protective measures described in the *MDT Detailed Drawings* for, as applicable:

1. Cutoff walls at both ends,
2. Concrete edge protection at inlet, and/or
3. Culvert riprap at outlet.

Concrete pipe 54" (1350 mm) or larger in diameter that has standard end treatment should be provided with cutoff walls at both ends. However, concrete edge protection and culvert riprap should not be used in conjunction with the standard end treatment for concrete pipe unless specified by the Hydraulics Section.

See the *MDT Detailed Drawings* for estimated quantities for cutoff walls, edge protection and culvert riprap.

#### **17.1.15 Riprap**

The Hydraulics Section will typically design embankment protection, outlet aprons and other permanent erosion control features which require riprap. The road designer will calculate quantities and provide the necessary details. Show the riprap on the plans and cross sections and include the quantities in the appropriate summary.

The layout and quantities of riprap at bridge ends will be provided by the Bridge Bureau. It will be shown on both the plan and profile, and the quantities will be included in the appropriate summary.

With the exception of culvert riprap (i.e., edge protection), geotextile will be provided with all riprap installations unless otherwise specified.



## 17.2 SPECIAL DRAINAGE FACILITIES

### 17.2.1 Embankment Protectors

Generally, install embankment protectors, as shown in the *MDT Detail Drawings*, at the corners of bridges and on high fills to control runoff. Do not install embankment protectors for bridges having rail configurations without curb (e.g., T101 rail). Typical installations for bridges are described in the following:

1. Four-lane divided highway on tangent:
  - a. Embankment protectors at the 4 outside corners.
  - b. Bituminous curb at the 4 inside (median side) corners.
  - c. Median drains with median inlet and cross drain or an outlet between structures with an embankment protector. Ditch blocks should be installed at the median inlet, and bituminous curbs should be designed to intercept drainage and prevent it from eroding the material at the ends of the structure wingwalls.
2. Four-lane divided highway on curve:
  - a. Embankment protectors on the 2 outside corners on low side of curve.
  - b. Bituminous curb at the 2 inside (median side) corners on low side of curve.
  - c. Median drains same as on tangent section.
3. Two-lane or four-lane with narrow median:
  - a. On tangent — embankment protectors at 4 corners.
  - b. On curve — embankment protectors at 2 corners on low side of curve.

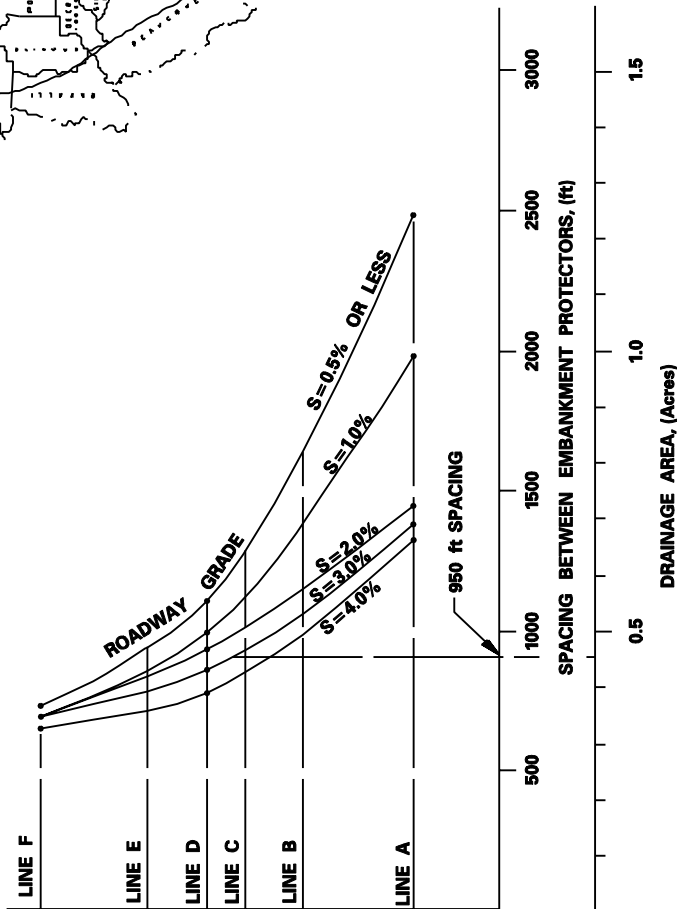
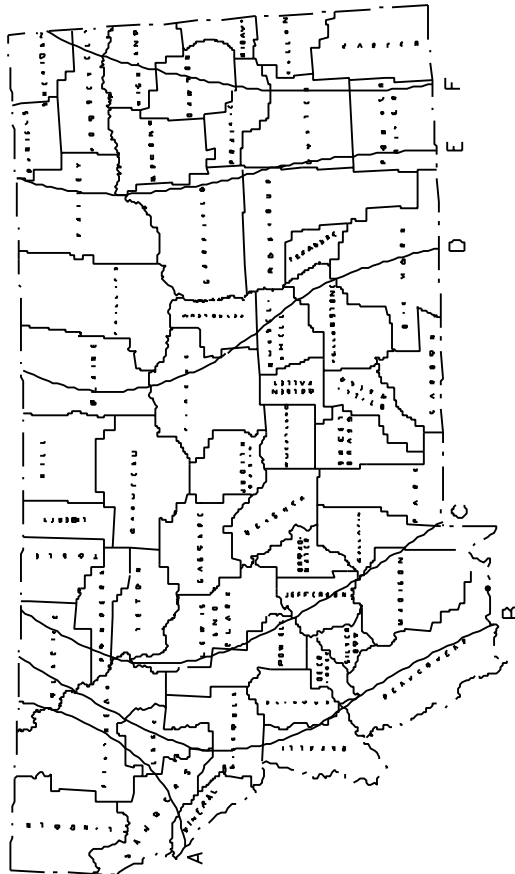
Where drainage flows toward the structure, place embankment protectors as near the structure as practical. On long, continuous sections of high fill, locate embankment protectors at intervals not exceeding the spacing shown on Figure 17.2A. Figure 17.2B prescribes appropriate spacings for median inlets. Embankment protectors must be used in conjunction with bituminous curb.

Please note that Figure 17.2A and Figure 17.2B are used for general guidance only. These figures are not to be substituted for proper engineering analysis to determine specific hydraulic requirements in unusual or site specific applications.

Example

Location: Shelby  
Road Grade: 3.0%

Shelby is located between C & D  
From chart, spacing= 950 ft.  
This spacing will also accommodate 0.47 ac. Check the actual area.  
If it is greater than 0.47 ac, the embankment protector spacing  
should be reduced.



Note:

Bituminous curb must be in place for this spacing criteria to apply. Spacings are for 1/2 roadway width on tangent sections. Where protectors are needed on curve sections, compute area to be drained by protector, and check the area with the area scale. If the computed area is greater than the scale reading, reduce the spacing of the embankment protectors.

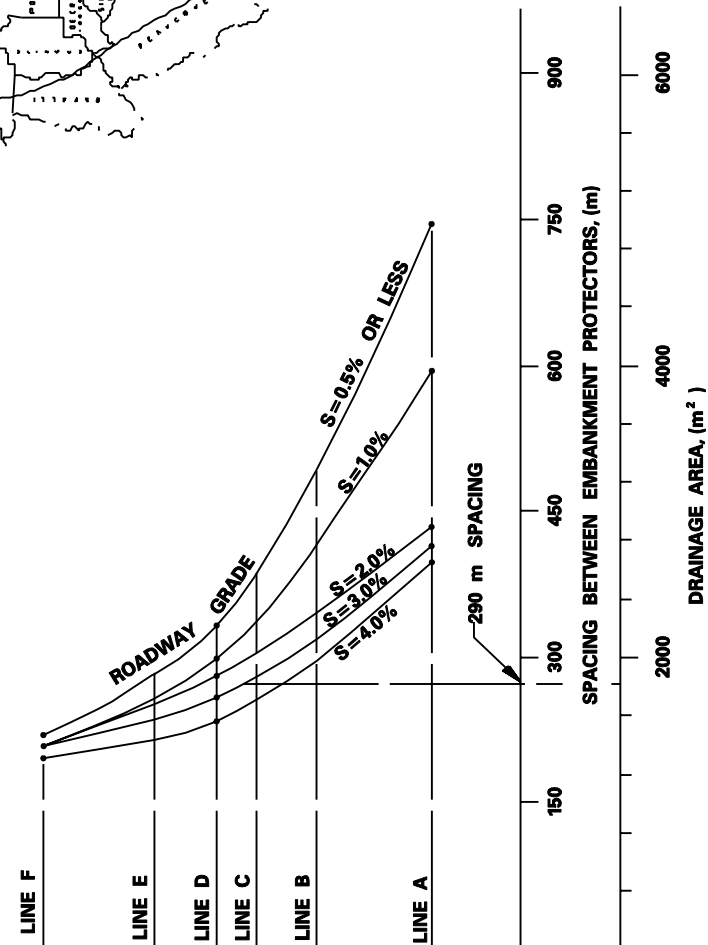
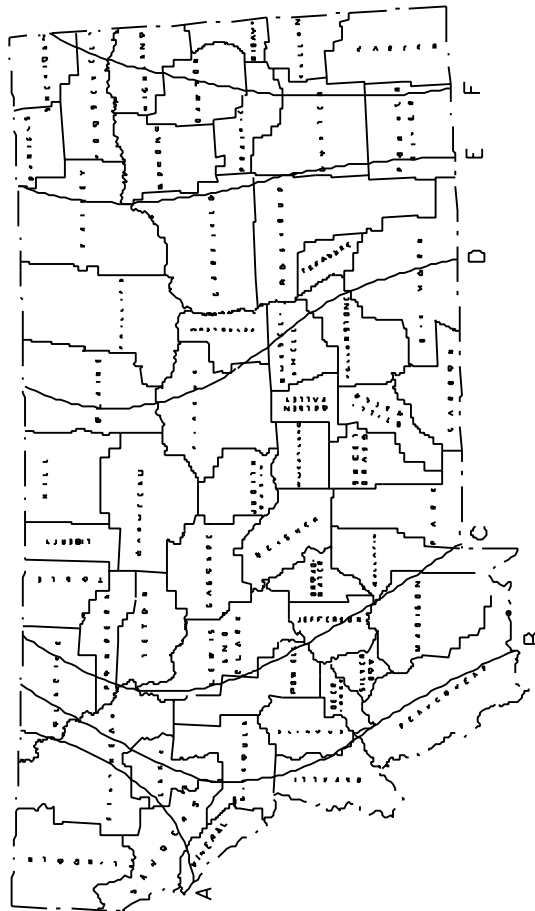
EMBANKMENT PROTECTOR SPACING

Figure 17.2A (US Customary)

**Example**

Location: Shelby  
Road Grade: 3.0%

Shelby is located between C & D  
From chart, spacing= 290 m  
This spacing will also accommodate 1900 m. Check the actual area.  
If it is greater than 1900 m<sup>2</sup>, the embankment protector spacing should be reduced.

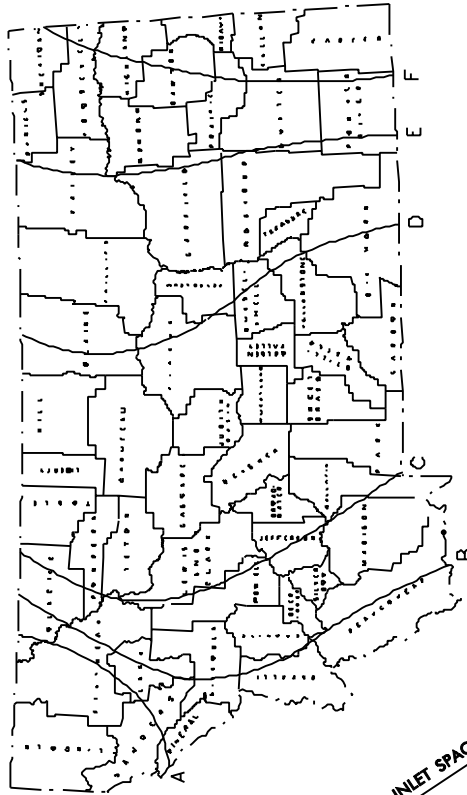


**Note:**

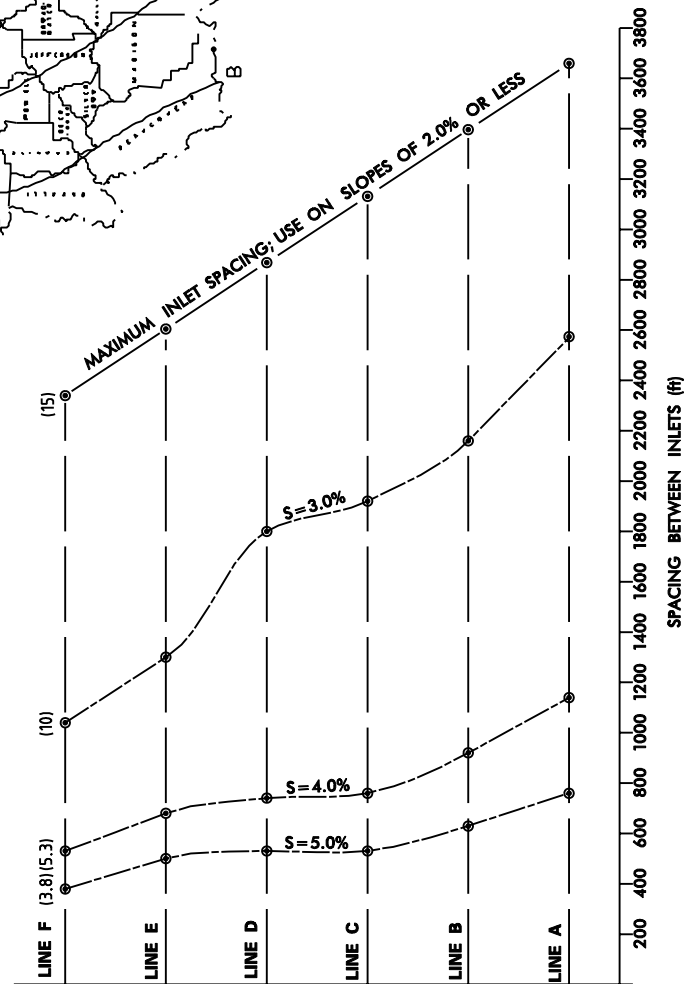
Bituminous curb must be in place for this spacing criteria to apply. Spacings are for 1/2 roadway width on tangent sections. Where protectors are needed on curve sections, compute area to be drained by protector, and check the area with the area scale. If the computed area is greater than the scale reading, reduce the spacing of the embankment protectors.

**EMBANKMENT PROTECTOR SPACING**

**Figure 17.2A (Metric)**

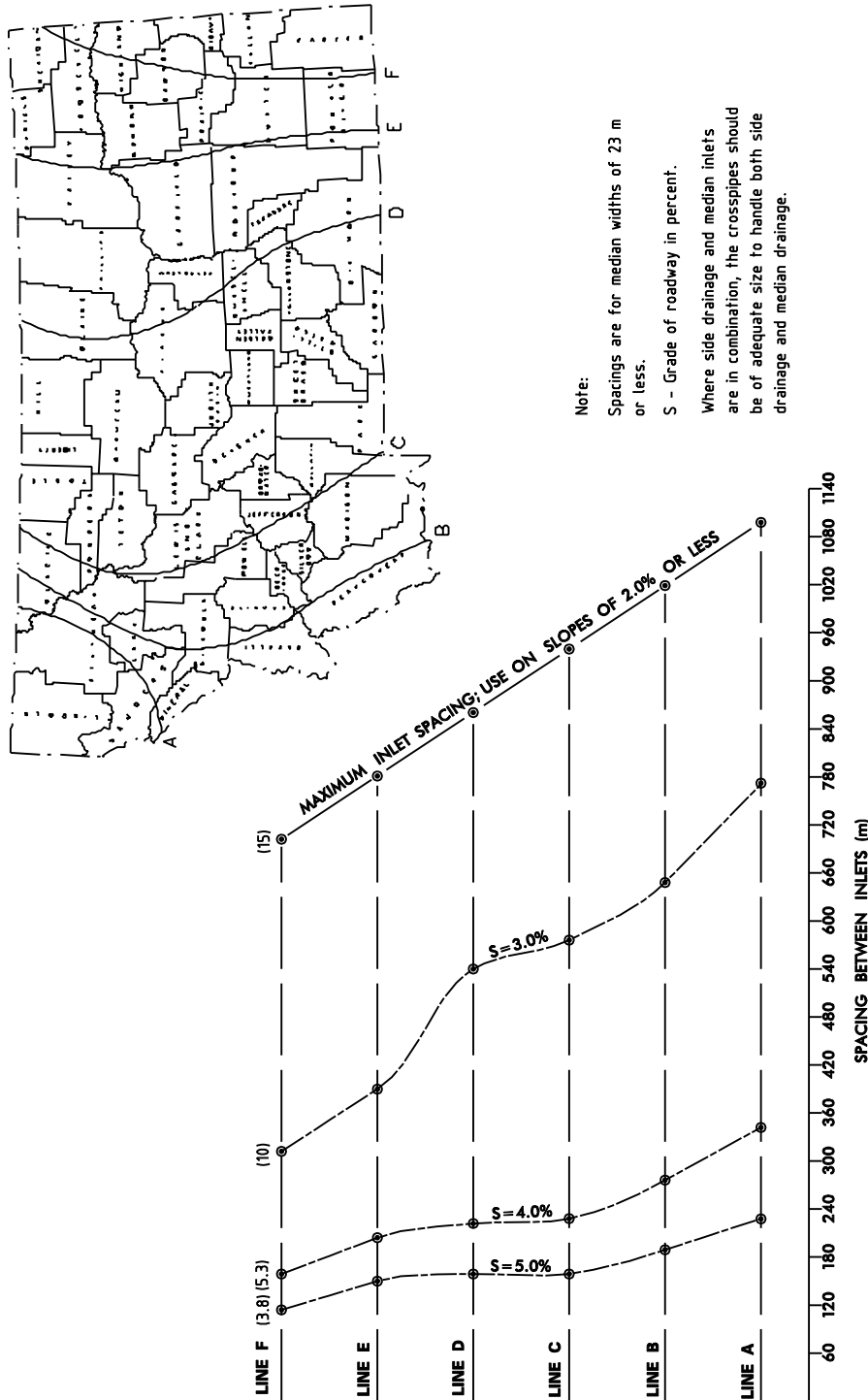


Note:  
 Spacings are for median widths of 75 ft or less.  
 S - Grade of roadway in percent.  
 Where side drainage and median inlets are in combination, the crosspipes should be of adequate size to handle both side drainage and median drainage.



**MEDIAN INLET SPACING**

Figure 17.2B (US Customary)



Note:  
 Spacings are for median widths of 23 m or less.  
 S - Grade of roadway in percent.  
 Where side drainage and median inlets are in combination, the crosspipes should be of adequate size to handle both side drainage and median drainage.

**MEDIAN INLET SPACING**

**Figure 17.2B (Metric)**

**17.2.2 Drainage Chutes**

The Concrete Drainage Chute described in the *MDT Detailed Drawings* may be used for backslope protection where the backslope intercepts a natural drainage coulee. Riprap and grouted riprap drainage chutes may be used in place of concrete.

**17.2.3 Median Inlets**

Three types of median inlets are available. Each type is shown in the *MDT Detailed Drawings*.

The Hydraulics Section will determine the type of inlet to be used. Specify the type clearly on the plans. Tables on the applicable *MDT Detailed Drawings* present estimated quantities of materials, but the bid item will be for the "Median Inlet Cover."

## **17.3 IRRIGATION FACILITIES**

### **17.3.1 Irrigation Pipe**

Irrigation facilities will require water-tight pipe. In the culvert summary and the culvert summary recap, record these pipes separately and identify them as "Irrigation" or "Siphon."

The Hydraulics Section will provide flowline and pipe invert elevations for irrigation installations. This is critical to effective operation. Minor irrigation pipes [18" (450 mm)] can be placed on the plans and cross sections by the designer without a recommendation from the Hydraulics Section. The Hydraulics Section will review these items for accuracy. If there are unusual conditions, coordinate with the Hydraulics Section to prepare clear, specific details on the plans.

Aluminum is not an option for irrigation pipe.

### **17.3.2 Irrigation Siphon Pipe**

Some irrigation pipes will be "siphons," where the pipes are angled down under the roadway ditches with the inlet and outlet elevations higher than the roadway centerline. Siphons will be designed and the Siphon Detail Sheet will be provided by the Hydraulics Section.

### **17.3.3 Division Boxes**

Where existing irrigation ditches are disturbed, it may be necessary to provide new division boxes. The Hydraulics Section will provide the design and details for concrete division boxes. Some types of division boxes are shown in the *MDT Detailed Drawings*.

### **17.3.4 Irrigation Ditch Relocations**

Relocate longitudinal irrigation ditches outside of the right-of-way line. The Hydraulics Section will provide recommendations for ditch linings, if required.

To avoid irrigation ditch maintenance within the highway right-of-way, irrigation culverts of 30" (750 mm) diameter and less should be extended 24" (0.5 m) beyond the R/W line where practical. The R/W fence may be winged into the pipe ends for irrigation pipes larger than 30" (750 mm) diameter to minimize the cost of pipe extension.

**17.3.5 Inlet and Outlet Headwalls**

The Hydraulics Section will provide recommendations and design details for concrete headwalls. Some headwall details are included in the *MDT Detailed Drawings*.

## **17.4 STORM DRAINS**

The detailed design of underground storm drains will be prepared by the Hydraulics Section. The design will include the size, type and location of the trunk line, manholes and drop inlets. The Hydraulics Section will also provide trench and bedding typical sections for the trunk line.

The road designer will be responsible for calculating the quantity of trunk line, trench excavation, bedding and length of lateral lines. Record all quantities for the storm drain facility in the appropriate frames. In addition, check the finished grade elevations at manholes and drop inlets and ensure that adequate cover is provided for the trunk line and laterals.

### **17.4.1 Storm Drain Inlets**

The Hydraulics Section will recommend the types and locations. Details for storm drain inlets are provided in the *MDT Detailed Drawings*.

The road designer should check the inlet locations to determine if they are located at low points of sags. Also check the inlet locations to determine if conflicts exist with curb ramps, in-place utilities, approaches or other features.

### **17.4.2 Manholes**

The size and location of manholes will be specified by the Hydraulics Section. The road designer should check the locations to determine if conflicts exist. Existing manholes can be adjusted up a maximum of 1' (0.3 m) through the use of adjusting rings to match new grades.

Manholes which have been previously adjusted and manholes that require adjustments greater than 1' (0.3 m) will require additional investigation and may result in substantial modification or replacement.

### **17.4.3 Bulb Out**

Where bulb outs are used on urban routes with curb and gutter sections, the road designer should check bulb out locations and gutter grades to determine if the bulb outs will block the gutter flow or interfere with storm drain inlets. The Hydraulics Section will determine if existing storm drain inlets should be relocated or if new inlets or other drainage features are required to maintain roadway drainage.



**17.5 UNDERDRAINS**

Unusual subsurface water conditions frequently are encountered during field locations and soils surveys. Some form of underdrain will be recommended by the Geotechnical Section to alleviate such conditions.

For each underdrain, the details should clearly define the location, the type, the depth of placement and the drain aggregate and geotextile to be installed with the pipe.

The Geotechnical Section should be consulted for all sub-surface recommendations.



## **17.6 SPECIAL-PURPOSE LARGE CULVERTS**

Large culverts frequently may be used for purposes other than to accommodate drainage. They may serve as stockpasses or vehicular underpasses with surfacing. The designer will be advised by the Right-of-Way Bureau when conditions warrant these installations. The following criteria present guidance for special-purpose large culverts.

### **17.6.1 Stockpasses**

A standard metal pipe may be designed to serve as a stockpass by using the treatment shown in the *MDT Detailed Drawings*. It should be specified only when justified by right-of-way negotiations. The primary purpose of this structure is to serve as a stockpass. However, the majority of stockpasses also act as cross drains. Where drainage is not a consideration, the design elevation should be so as to avoid water flow. Adjacent, lower elevation culverts may also be provided for drainage when necessary. The designer should attempt to minimize stockpass length whenever practical.

The length is measured along the invert of the pipe. A right-angle crossing is preferred; however, if a skew is necessary, it should not exceed 15°.

Record stockpass culverts in a separate summary frame. Include associated paving in the additional surfacing frame.

Bedding material is required under the structure as required for CSP drain culverts.

Adhere to the maximum and minimum fill height requirements in the fill height tables.

### **17.6.2 Vehicular Underpasses**

Specify the circular SSPPC vehicular underpass unless directed otherwise by the Hydraulics or Geotechnical Sections. Construction and design personnel should review the installation for special construction requirements when stage construction may be specified.

Record the quantities for vehicular underpasses in a separate summary frame.

Bedding material should be specified for all large culverts.

The *MDT Detailed Drawings* show the backfill retainer and cutoff wall requirements as well as the floor surfacing criteria for the underpass. The concrete collar shown in the *MDT Detailed Drawings* will be provided for vehicular underpasses.

Adhere to the maximum and minimum fill height requirements in the fill height tables.

## 17.7 ROADSIDE DRAINAGE

### 17.7.1 Cut sections.

Roadside ditches generally utilize a 10' (3 m) flat-bottom configuration and the grade of roadside ditches typically matches the profile grade of the roadway. However, more detailed ditch design needs to be considered for the following situations:

1. Ditches on sustained grades may carry relatively high volumes of runoff, which can result in erosion to the ditch as well as the cut-to-fill transition. When sustained grades are encountered the designer needs to consider the use of the following features:
  - a. Installation of cross drains and ditch blocks to allow the runoff to outfall into a natural drainage.
  - b. If no viable outfalls exist within reasonable intervals, the use of check structures to reduce the flow velocities and corresponding erosion potential must be evaluated. The designer should coordinate with the Hydraulics Section to determine spacing and type of check structures. Check structures within the clear zone should have 6:1 or flatter slopes.
  - c. Some type of erosion protection should be considered at the cut-to-fill transitions (riprap chute, ditch block with embankment protector).
2. Extremely flat ditches also need additional design. Separate ditch grades need to be considered for 50' (15 m) on each side of the crest if the grades along the curve are 0.30% or less. Separate ditch grades may also be necessary on the high side of a superelevated section where the profile grade is 0.5% or less.

### 17.7.2 Fill Sections:

Drainage considerations in fill sections generally involve the following features:

1. The location of minimum size (24" or 600 mm) culverts is often overlooked. The road designer should review as-built plans to determine the location of existing culverts. They also need to conduct on-site reviews (A&G, PIH) to determine the location of minor natural drainages. When a project involves modification to the existing vertical alignment, the designer must also review the new profile grade to

ensure that cross drains are provided in low spots where water would otherwise be trapped.

2. Many older sections of roadway were constructed using side borrow which resulted in substantial road-side ditches adjacent to the roadway embankment. New wider templates often fill these ditches leaving no clear drainage path and often pushing runoff onto adjacent landowners.

Designers should review these areas to determine if additional cross drains will alleviate the problem. Construction of a drain ditch at the toe of fill may be needed to convey runoff to a natural drainage.

Drainage in the roadside ditch is sometimes complicated by landowners who use the roadside ditch to carry irrigation wastewater. Although we prefer to have irrigation wastewater ditches, like all irrigation facilities constructed outside of the highway right-of-way, perpetuation of irrigation wastewater in the roadside ditch should be evaluated on a case-by-case basis. Whenever the roadside ditch is used for any irrigation purpose the designer should coordinate with the Hydraulics Section.

**17.8 CULVERT EXCAVATION AND TRENCH EXCAVATION**

Culvert excavation and trench excavation are not measured for payment. The quantities of culvert and trench excavation are shown for informational purposes. The costs of culvert and trench excavation are included in the unit price bid per linear foot (meter) of new culvert. The cost of excavation for culvert removal, culvert bedding and special foundations is included in the unit prices bid for those items. The process for calculating culvert excavation and trench excavation is shown in Section 5.3

