Volume I Figures

1st DRAFT

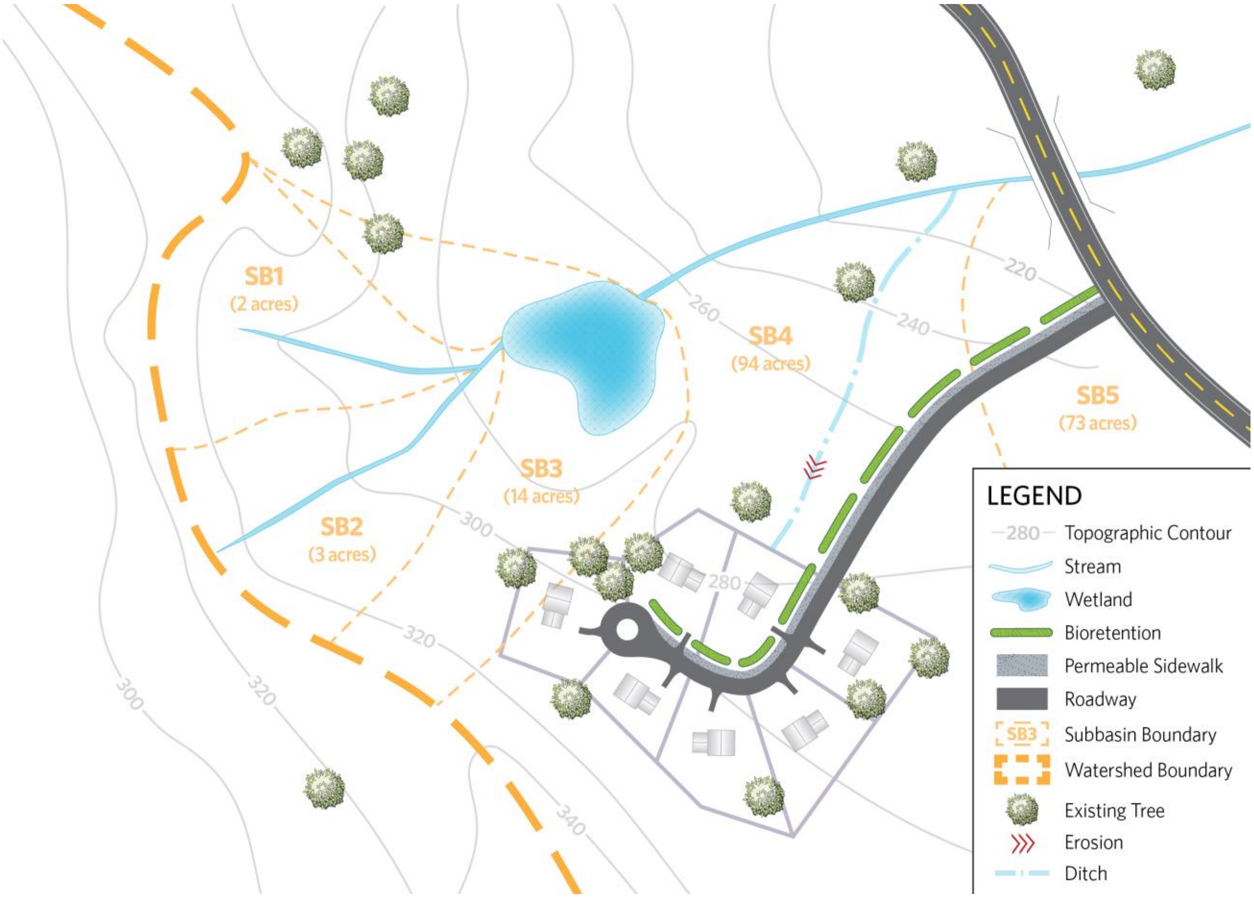


Figure 2.1
Example Map Documenting Existing Hydrologic Features

March 2020

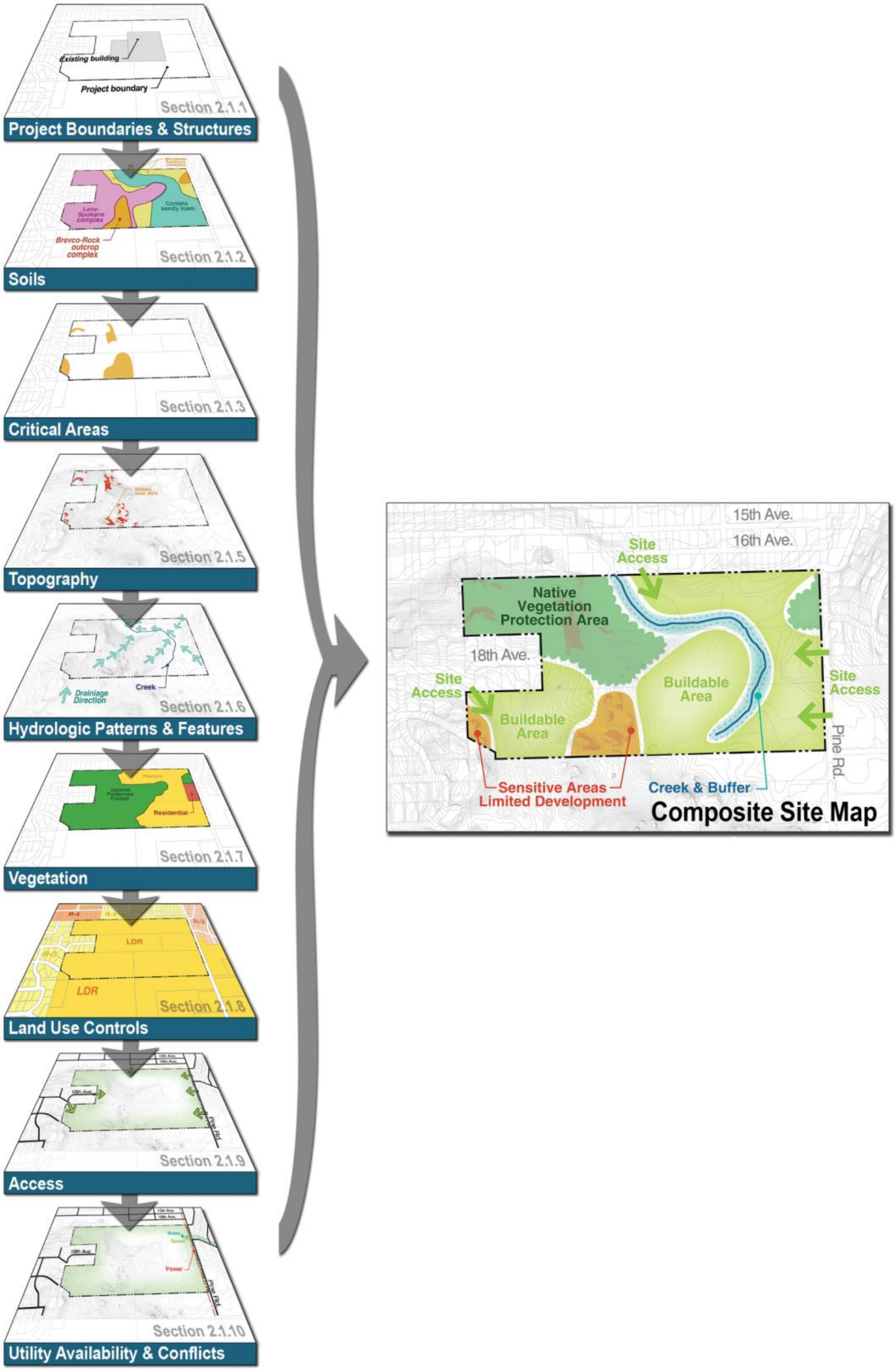
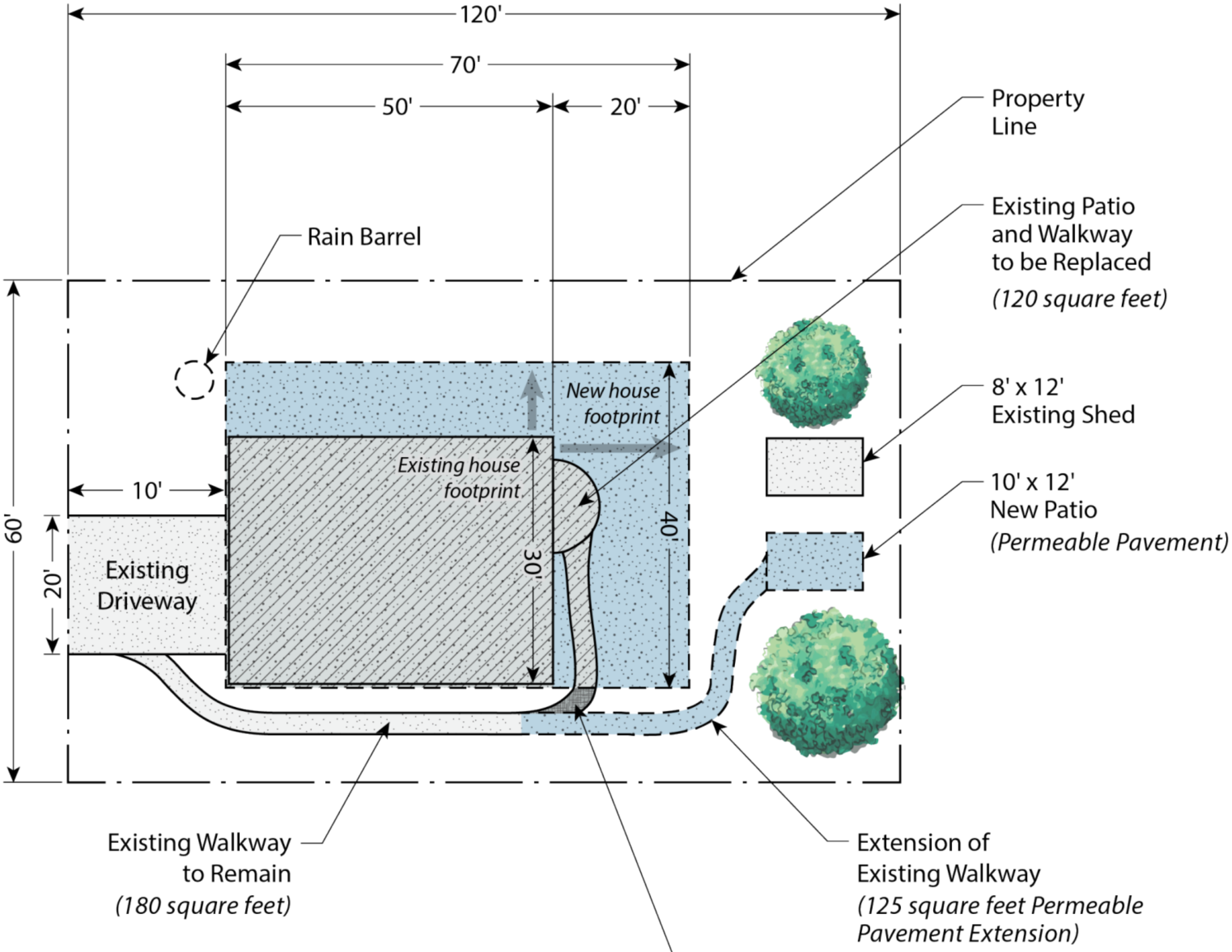


Figure 2.2
Example Composite Site Map

March 2020



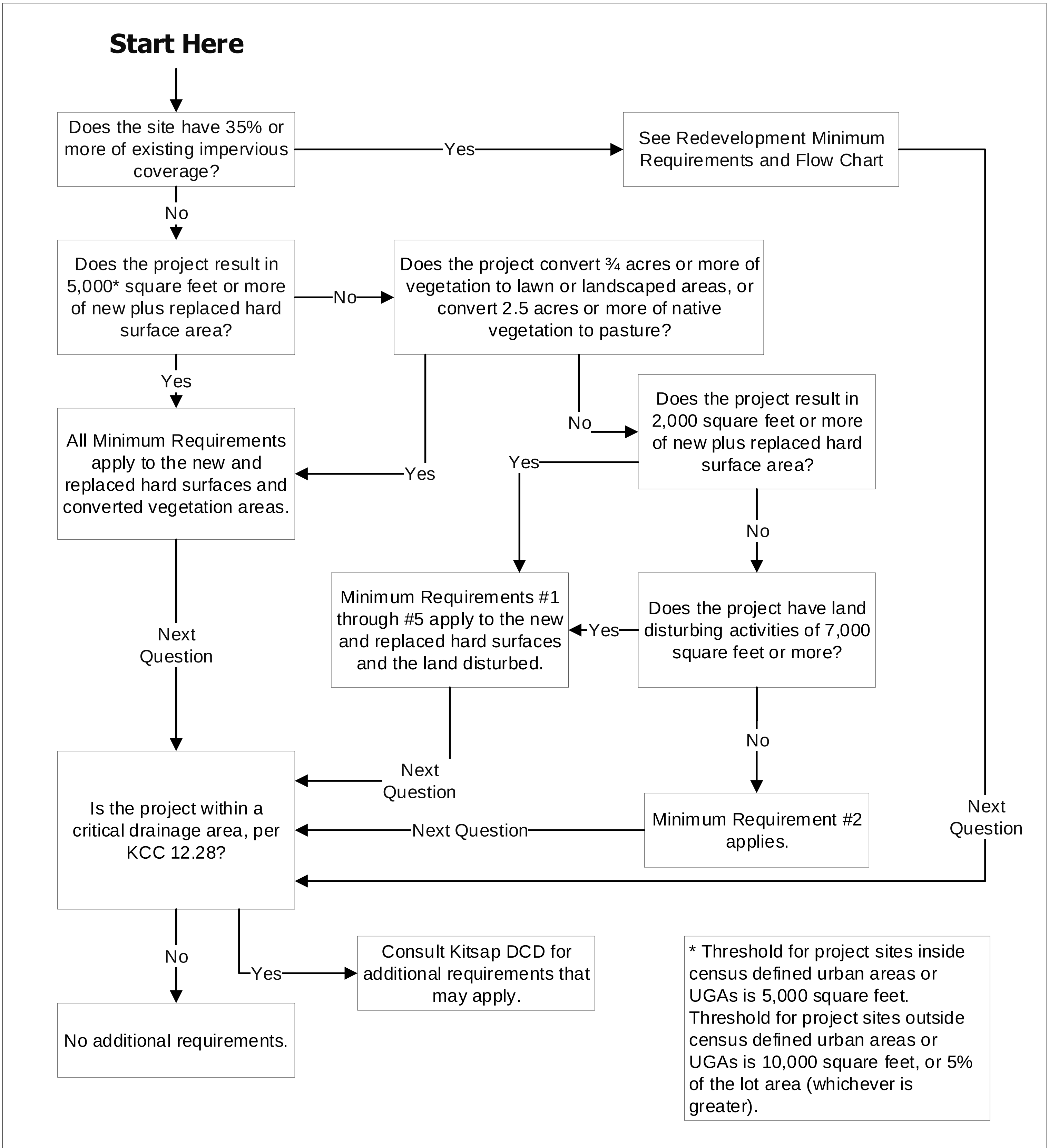
LEGEND

- Property Line
- Existing Hard Surface *(476 square feet)*
- New Hard Surface *(1,425 square feet)*
- Replaced Hard Surface *(1,620 square feet)*
- Removed Hard Surface *(30 square feet)*
- Maple Tree

KITSAP COUNTY 18 57 WASHINGTON

Figure 3.1
Example Determination of New and Replaced Hard Surfaces

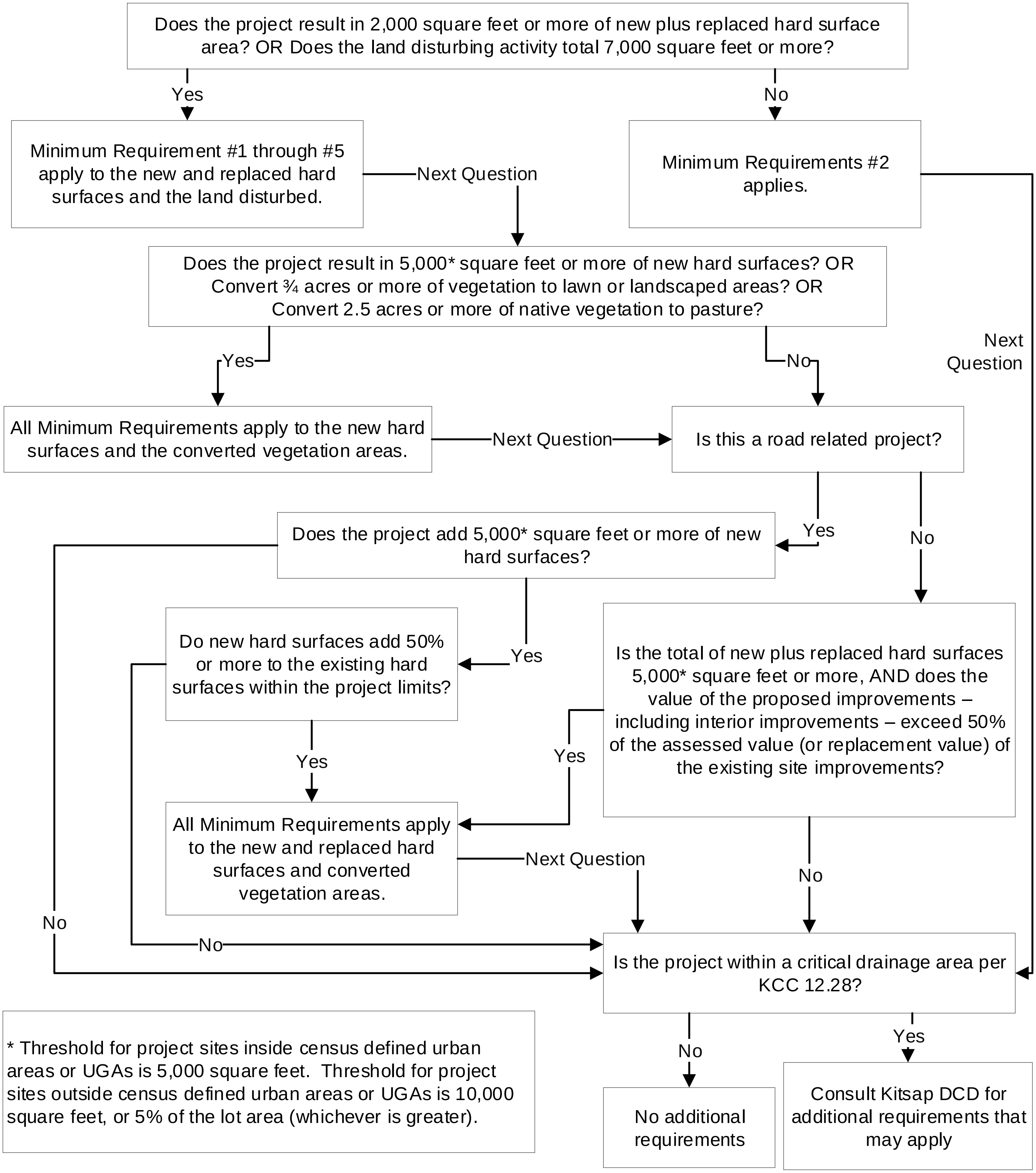
March 2020



KITSAP COUNTY 1857 WASHINGTON

Figure 4.1
Flow Chart for Determining Minimum Requirements for New Development Projects

March 2020



* Threshold for project sites inside census defined urban areas or UGAs is 5,000 square feet. Threshold for project sites outside census defined urban areas or UGAs is 10,000 square feet, or 5% of the lot area (whichever is greater).

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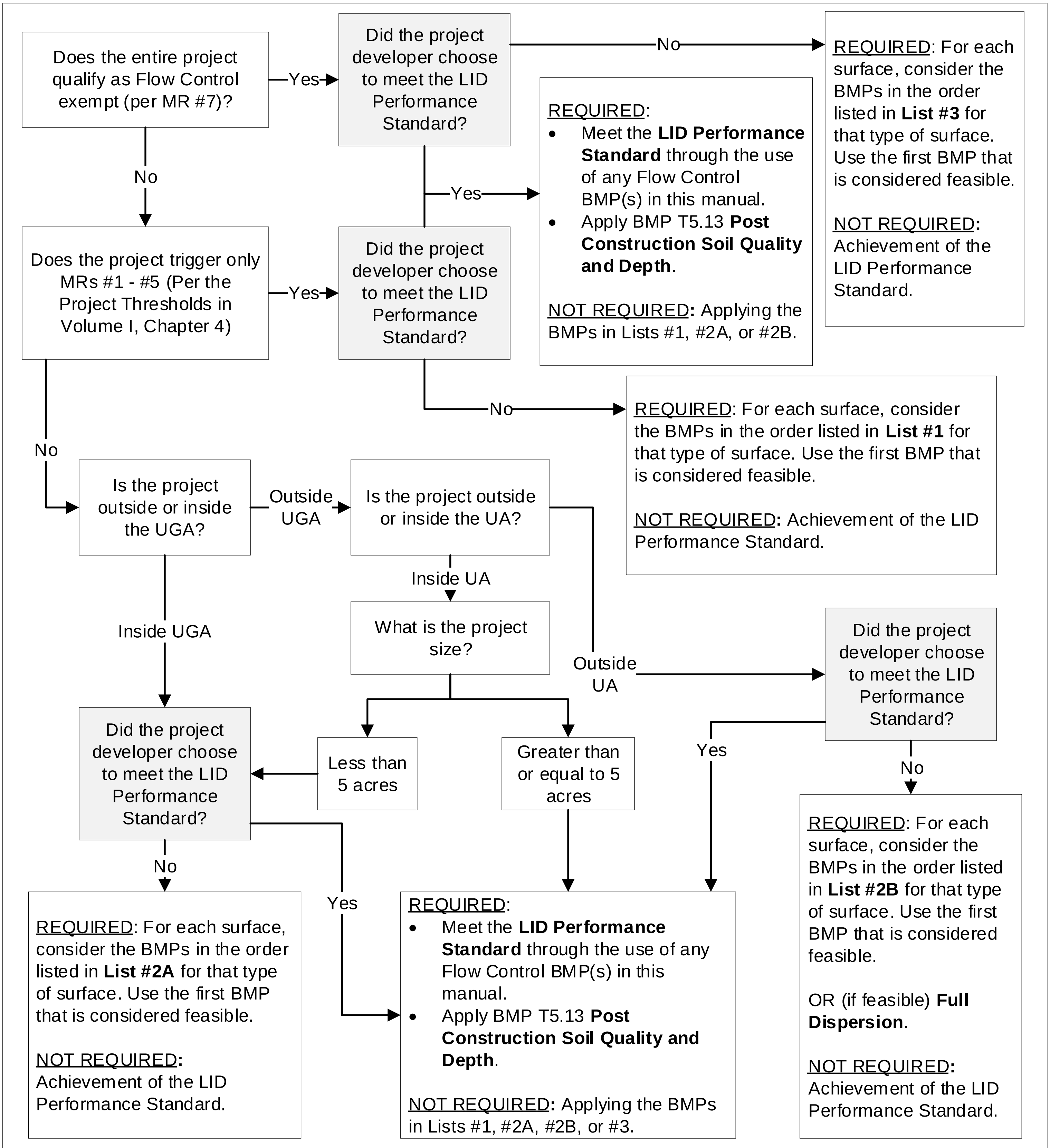
Figure 4.2
Flow Chart for Determining Minimum Requirements for Redevelopment Projects

March 2020



KITSAP COUNTY 1857 WASHINGTON

Figure 4.3
Flow Chart for Determining MR #5 Requirements

March 2020

Volume I Photos

Volume I, Section 2.3 Photo

Bioretention BMP in a cul-de-sac of a LID residential neighborhood in construction in western WA. The bioretention manages stormwater runoff from the roadway and contributing roof and driveway areas. Numerous large existing trees were retained, adding valuable stormwater and community benefits.

Volume I, Section 4.2.2, Element 6 Photo

Example of shallow gradient slope with berm installed at downgradient edge to minimize silt-laden runoff onto the sidewalk.

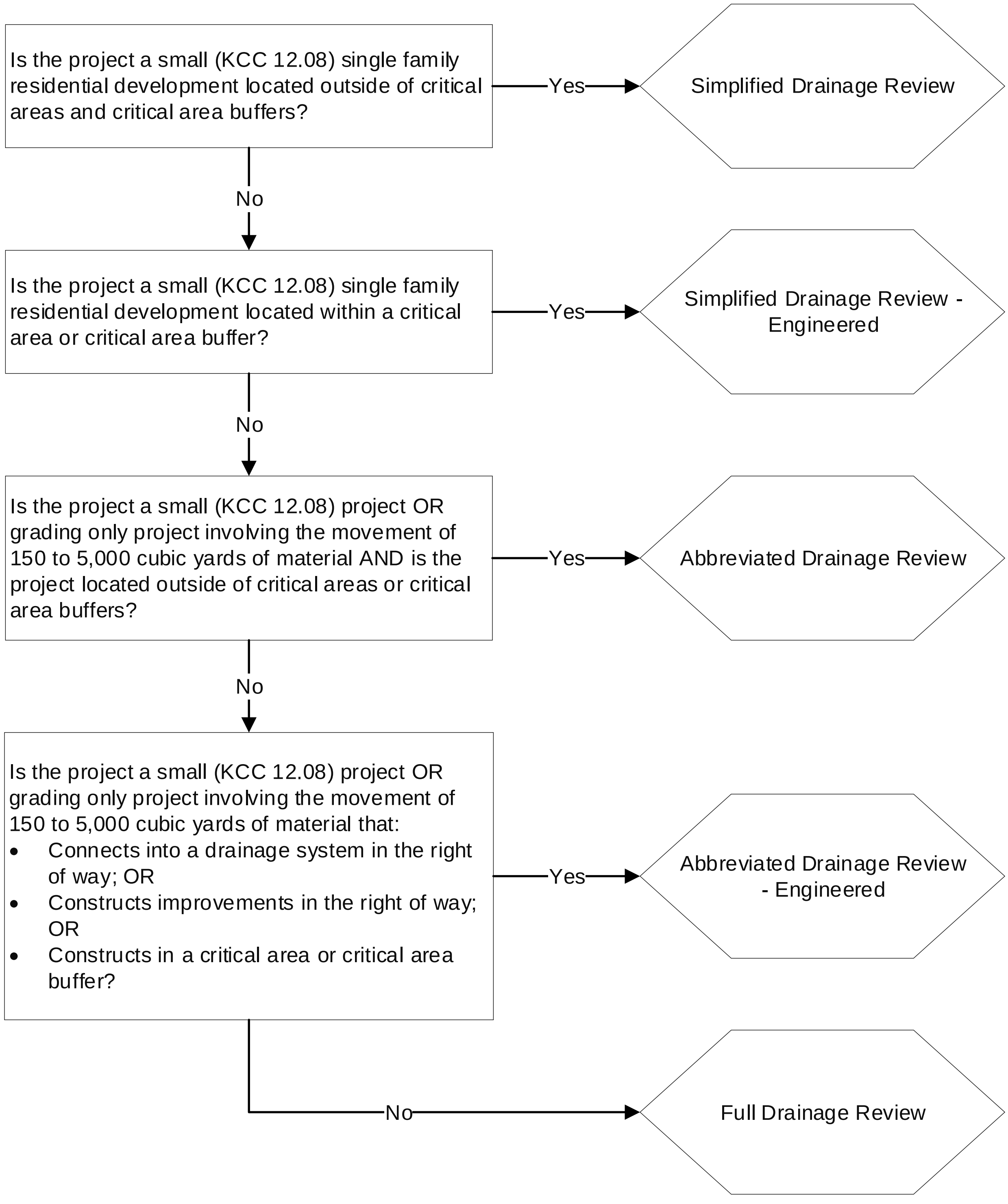
Volume I, Section 4.2.2, Element 9 Photo

Temporary sand bags divert construction site stormwater runoff to inlet protected with a catch basin filter sock.

Volume I, Section 4.2.2, Element 13 Photo

Sand bags prevent silt-laden flow from entering the bioretention BMP. Green construction fencing prevents compaction due to foot traffic.

Volume II Figures



KITSAP COUNTY 18 57 WASHINGTON

Figure 1.1
Flow Chart for Determining Type of Drainage Review

March 2020

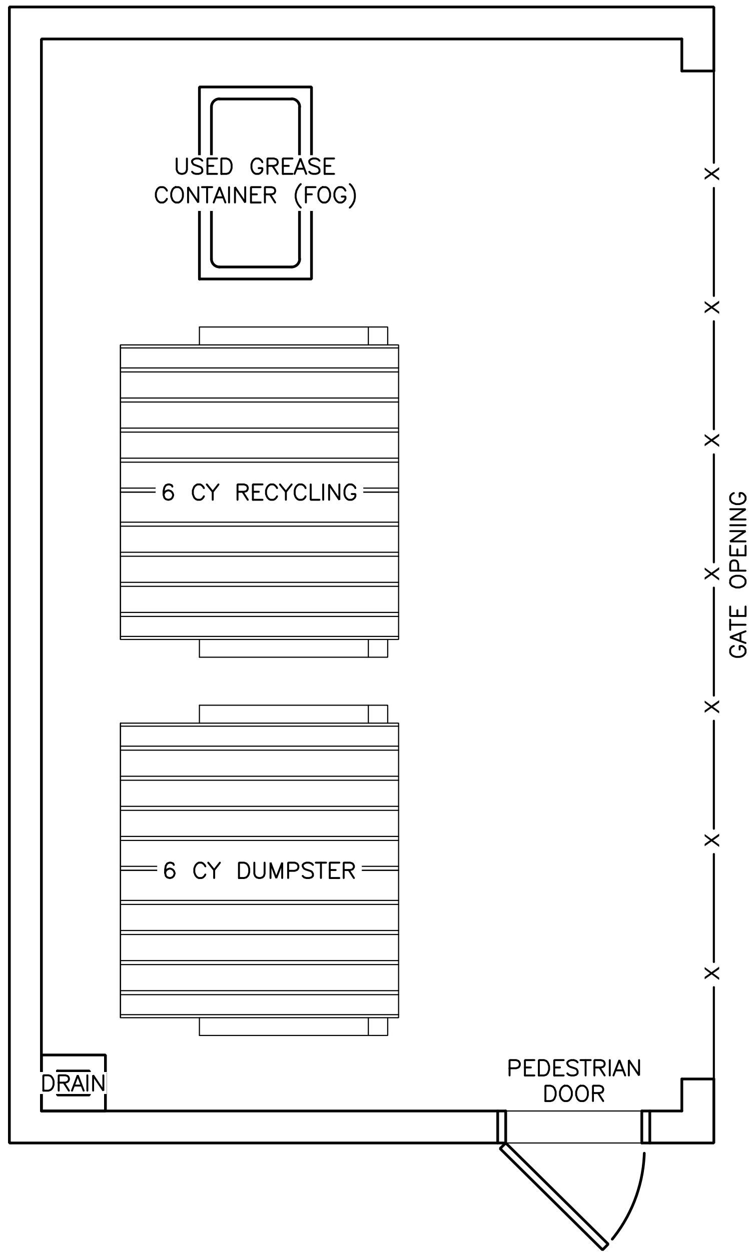


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Figure 3.1
Example of a covered, bermed
and plumbed area - plan view

March 2020

\\herrera.local\hecnet\seattle\proj\Y2019\19-07028-000\CAD\Dwg\FIG 3.dwg

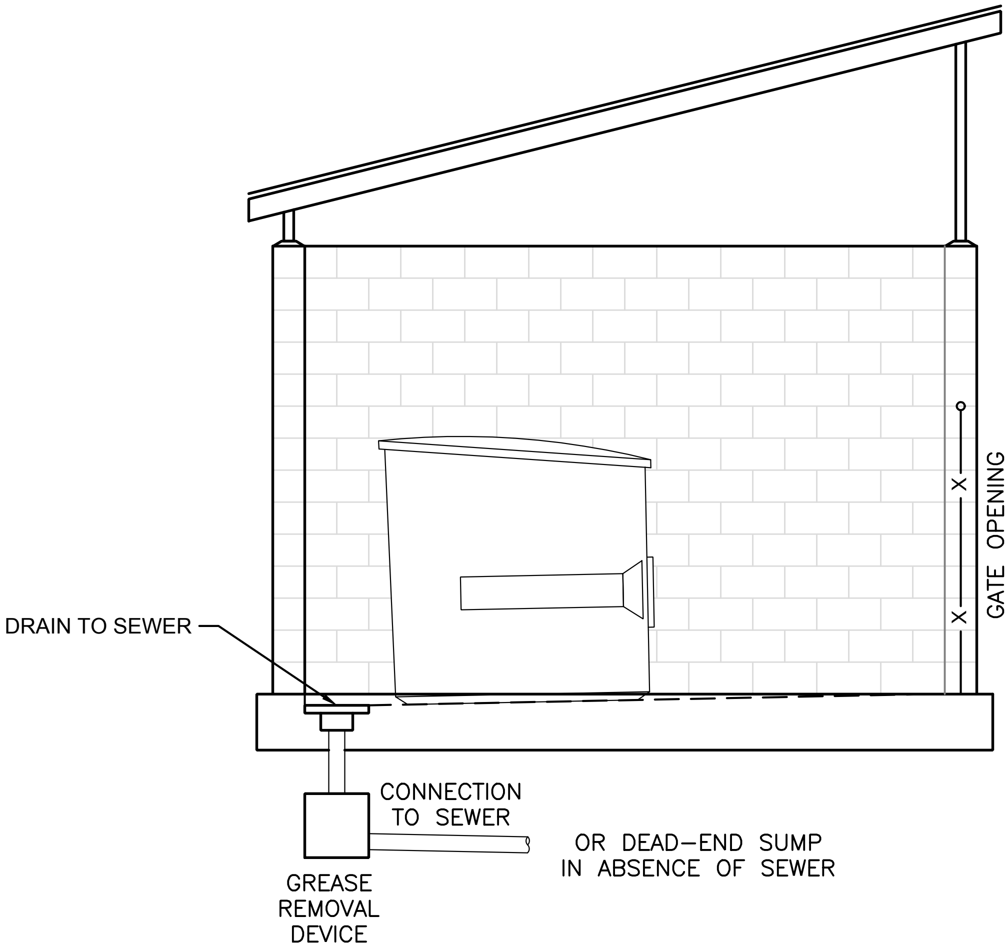

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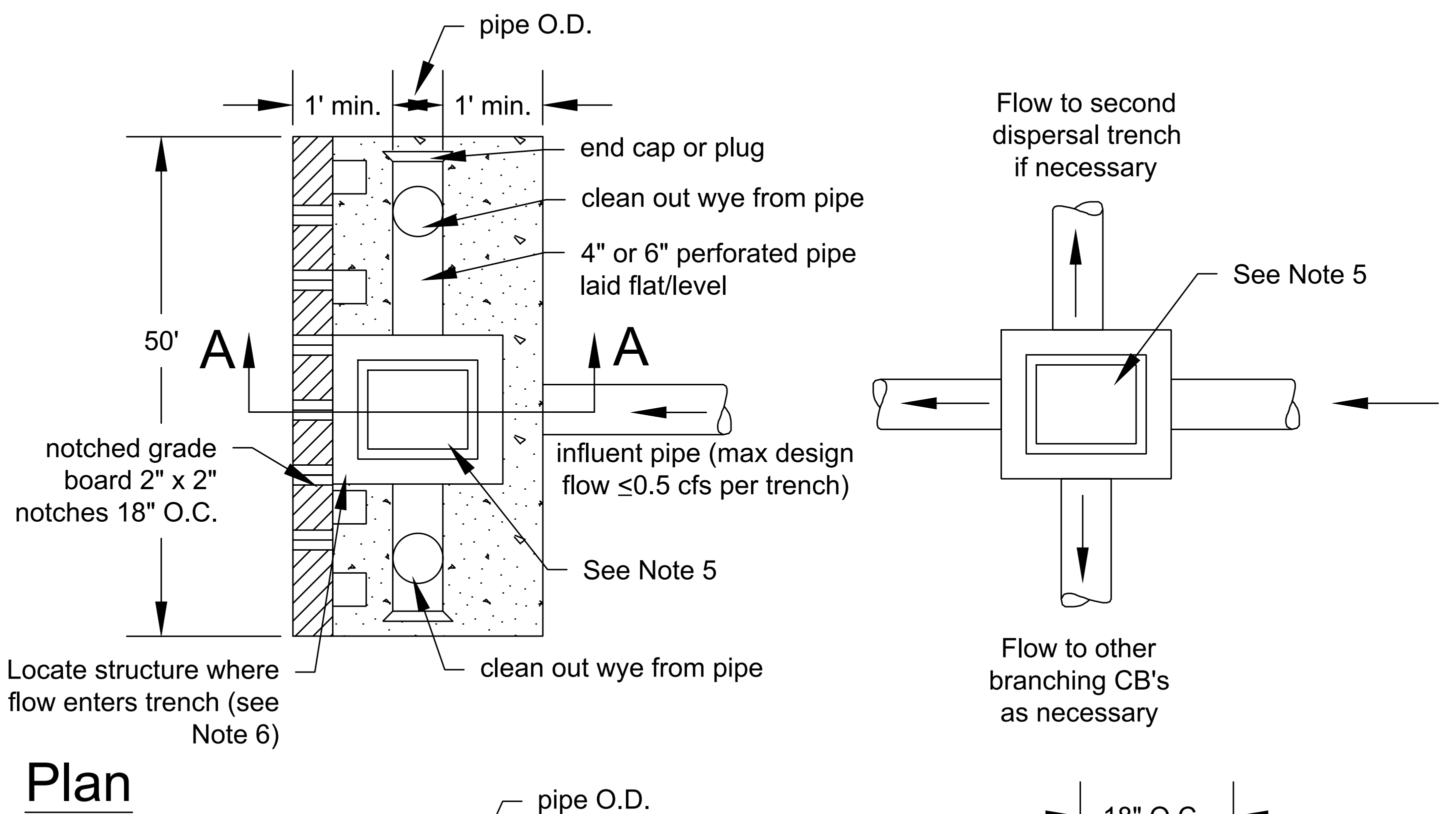
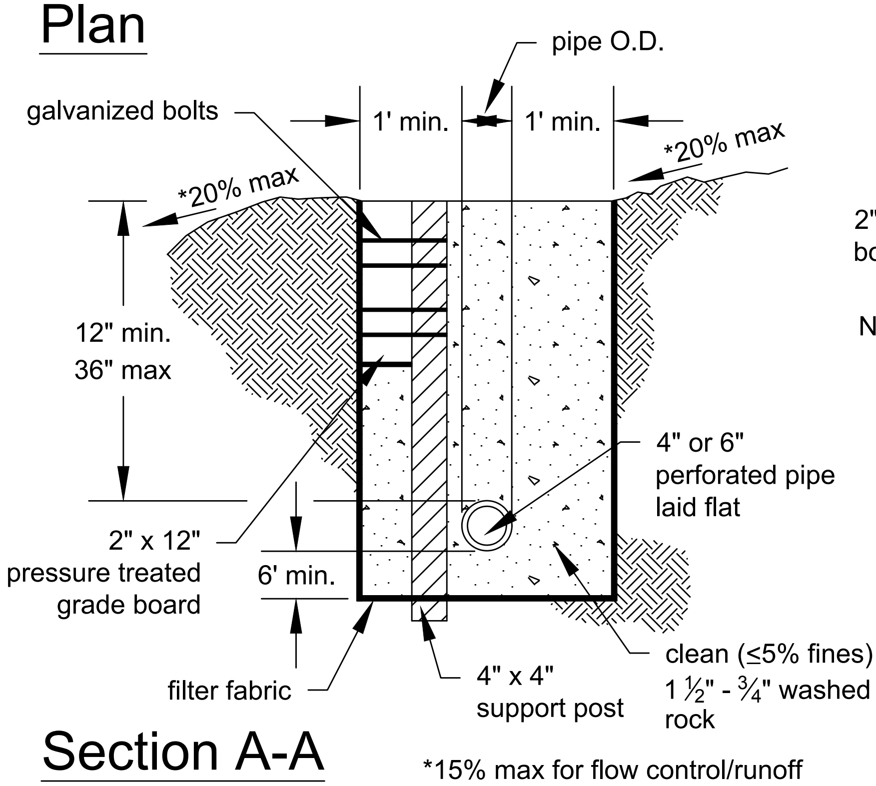
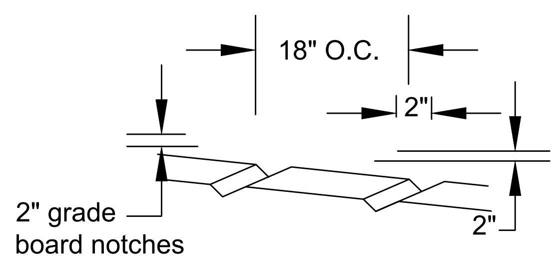
Figure 3.2
Example of a covered, bermed and plumbed area - side view

March 2020





*15% max for flow control/runoff treatment in rural areas.



Notes:

1. This trench shall be constructed so as to prevent point discharge and/or erosion.
2. Trenches may be placed no closer than 50 feet to one another. (100 feet along flowline)
3. Trench and grade board must be level. Align to follow contours of site.
4. Support post spacing as required by soil conditions to ensure grade board remains level.
5. For roof area less than or equal to 700 square feet, structure shall be a small catch basin, yard drain, or Type 1 CB with with solid cover or equivalent as approved by the County.
6. Structure shall be set back a minimum of 5 feet from building foundation.

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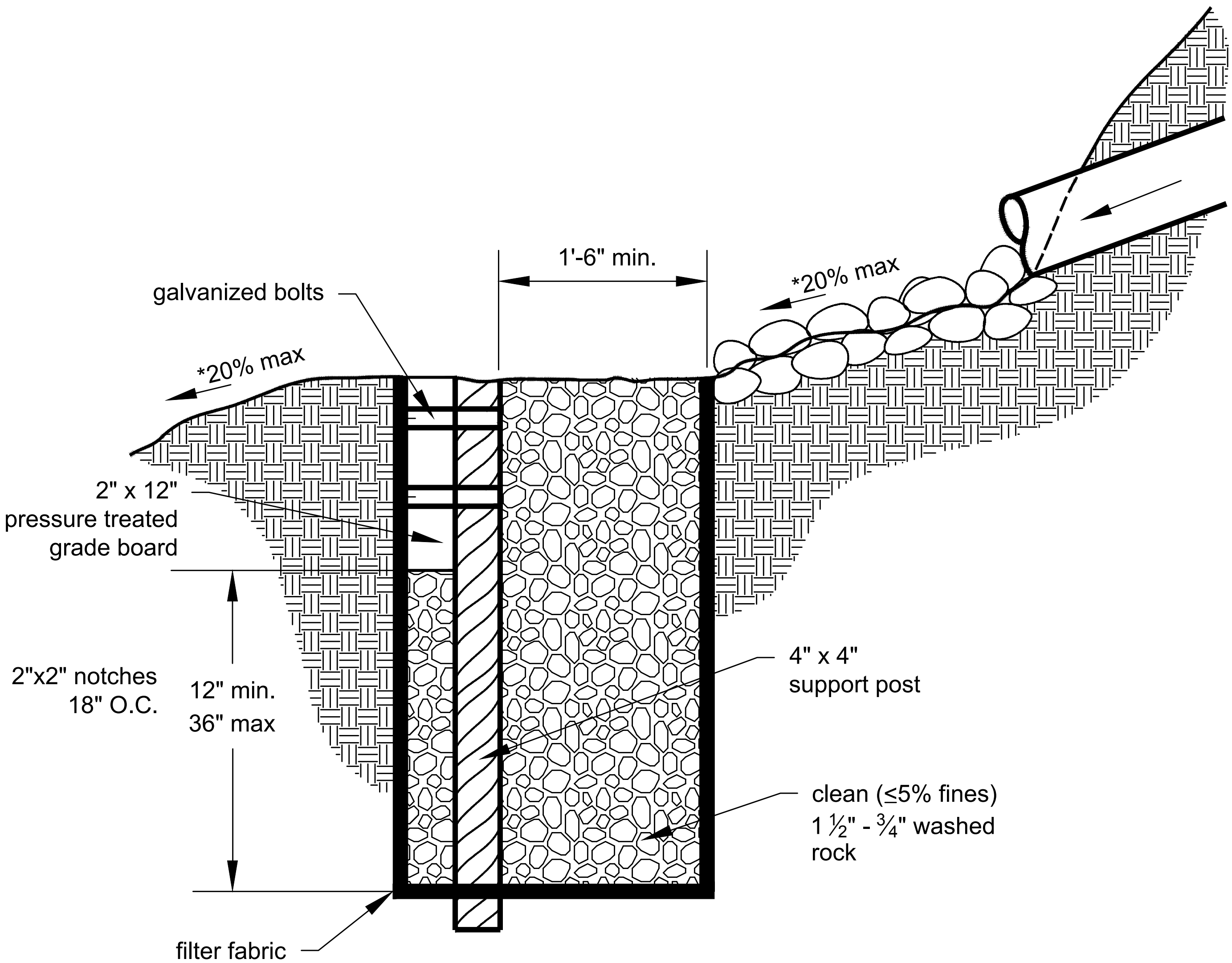
Figure 4.1
Flow Dispersion Trench

March 2020



*15% max for flow control/runoff
treatment in rural areas.

Section A-A

Notes:

1. This trench shall be constructed so as to prevent point discharge and/or erosion.
2. Trenches may be placed no closer than 50 feet to one another. (100 feet along flowline)
3. Trench and grade board must be level. Align to follow contours of site.
4. Support post spacing as required by soil conditions to ensure grade board remains level.

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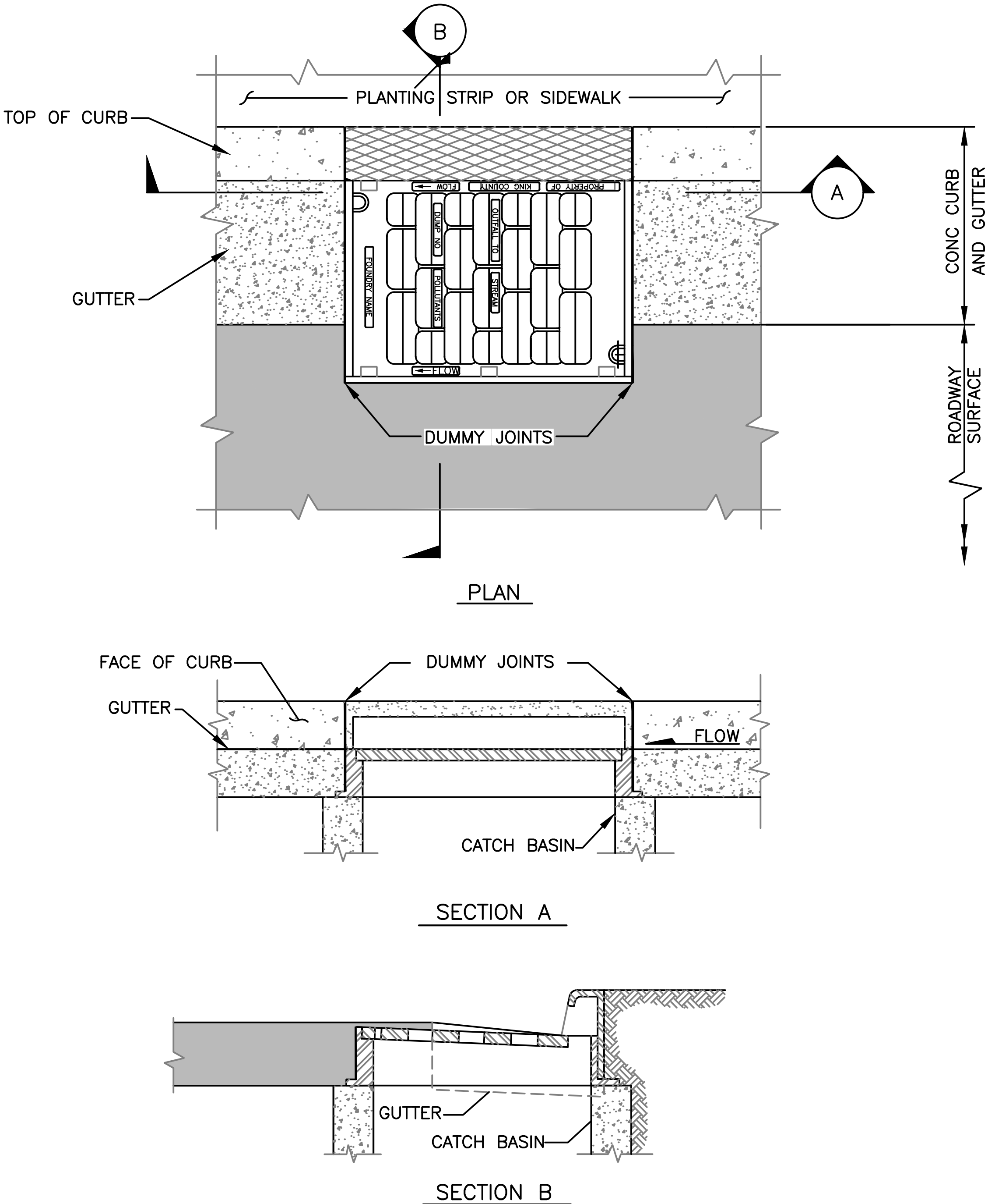
Figure 4.2
Alternative Flow Dispersion Trench

March 2020



NOTES:

1. SET TO GRADE AND CONSTRUCT ROAD AND GUTTER TO BE FLUSH WITH FRAME.
2. SEE SEC. 3.04 FOR JOINT REQUIREMENTS.
3. SEE WSDOT/APWA STANDARD SPECIFICATIONS SECTION 9–05.15 FOR METAL GRATINGS REQUIREMENTS.

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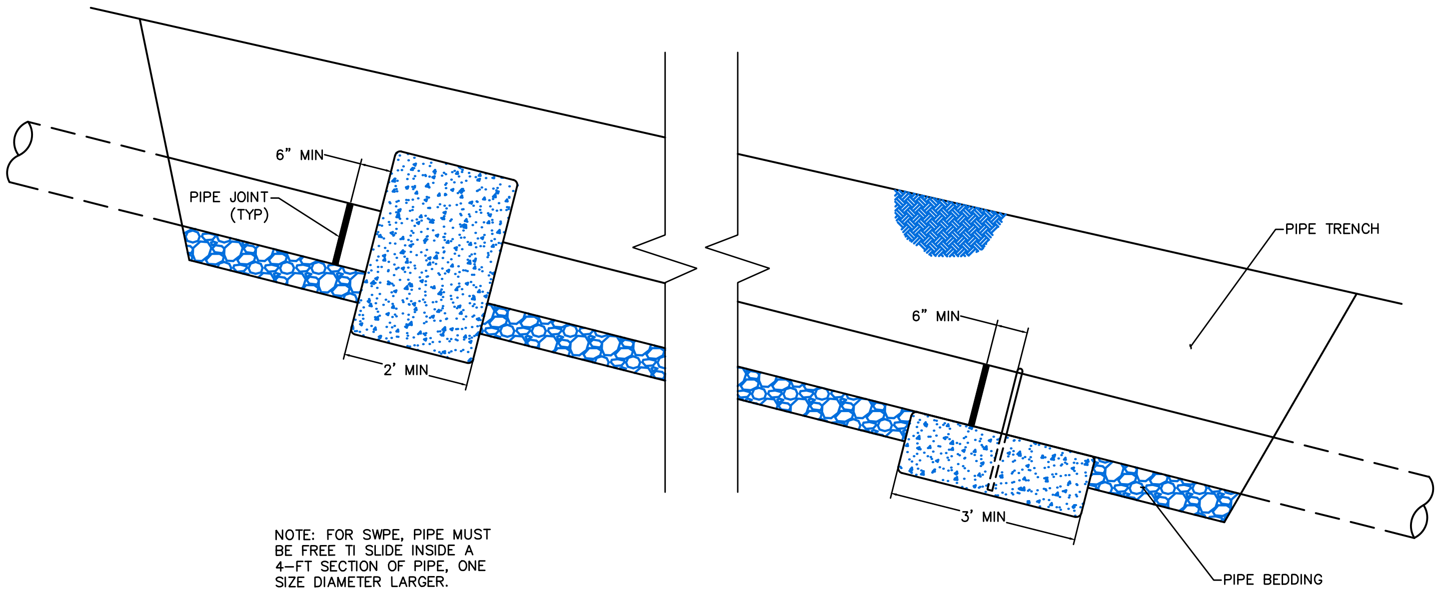
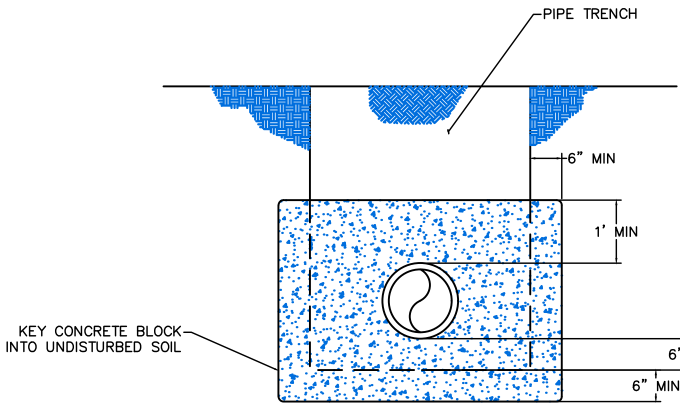
Figure 4.3
Through-Curb Inlet

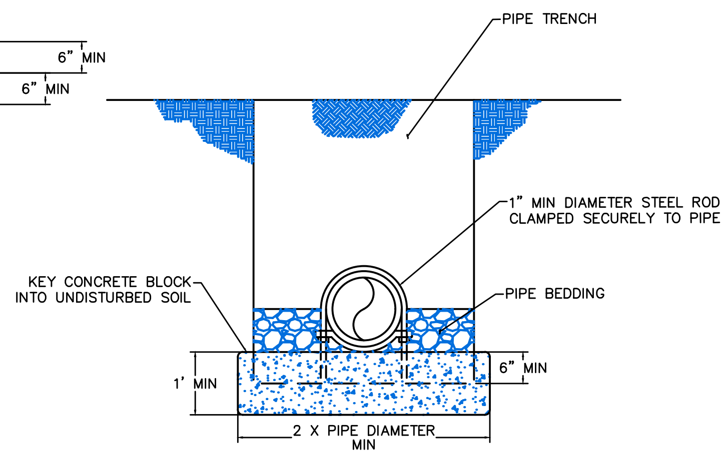
March 2020



SWPE PIPE ANCHOR DETAIL
NTS



SECTION A-A
NTS

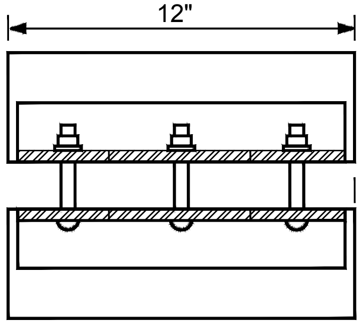


SECTION B-B
NTS

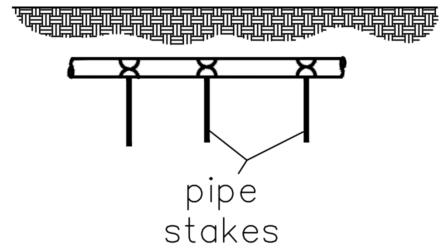
KITSAP COUNTY 18 57 WASHINGTON

Figure 4.4
Pipe Anchor Detail

March 2020



Smooth Coupling Band
for Smooth Pipe



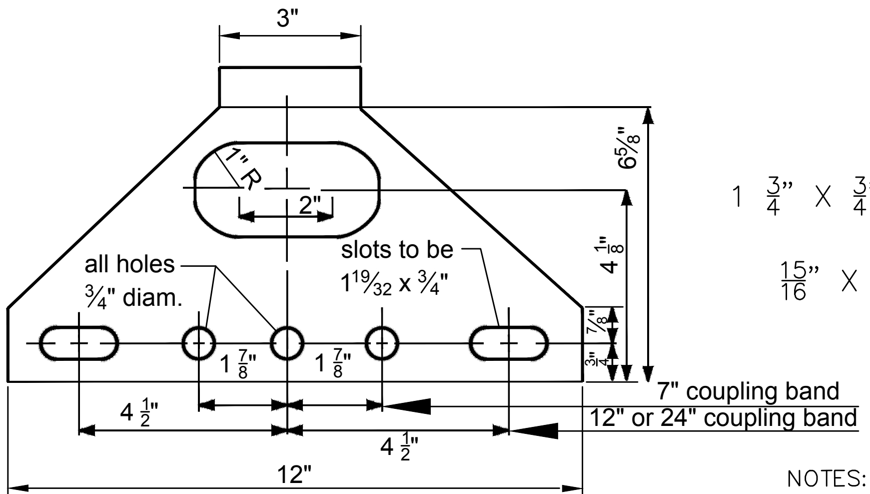
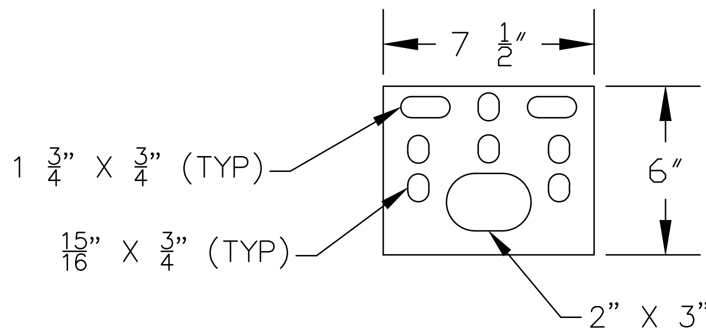
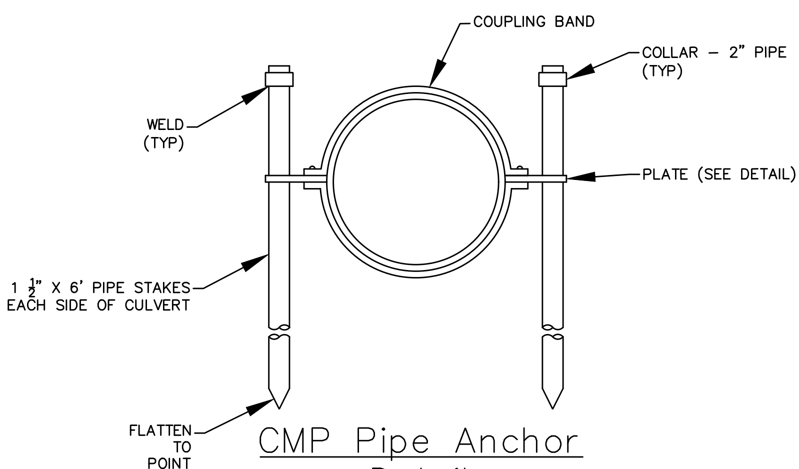


Plate Detail





CMP Pipe Anchor
Detail

NTS

NOTES:

1. STAKES AND PLATES SHALL BE GALVANIZED PER ASTM A 36 AND A 153.
2. THE SMOOTH COUPLING BAND SHALL BE PER WSDOT STD PLANS B–60.20–01 AND B–60.20–01 AND USED IN COMBINATION WITH CONCRETE PIPE.
3. CONCRETE PIPE WITHOUT A BELL AND SPIGOT CONNECTION SHALL NOT BE INSTALLED ON GRADES IN EXCESS OF 20%.
4. THE FIRST ANCHOR SHALL BE INSTALLED ON TEH FIRST SECTION OF THE LOWER END OF THE PIPE; THE REMAINING ANCHORS SHALL BE EVENLY SPACED THROUGHOUT THE INSTALLATION.
5. IF THE PIPE BEING INSTALLED HAS A MANHOLE OR CATCH BASIN ON THE LOWER END OF THE PIPE, THE FIRST PIPE ANCHOR MAY BE ELIMINATED.
6. WHEN CMP IS USED, THE ANCHORS MAY BE ATTACHED TO THE COUPLING BANDS USED TO JOIN THE PIPE AS LONG AS THE SPECIFIED SPACING IS NOT EXCEEDED.
7. ALL PIPE ANCHORS SHALL BE SECURELY INSTALLED BEFORE BACKFILLING AROUND THE PIPE.

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Figure 4.5
Corrugated Metal Pipe Coupling Anchor Assembly

March 2020

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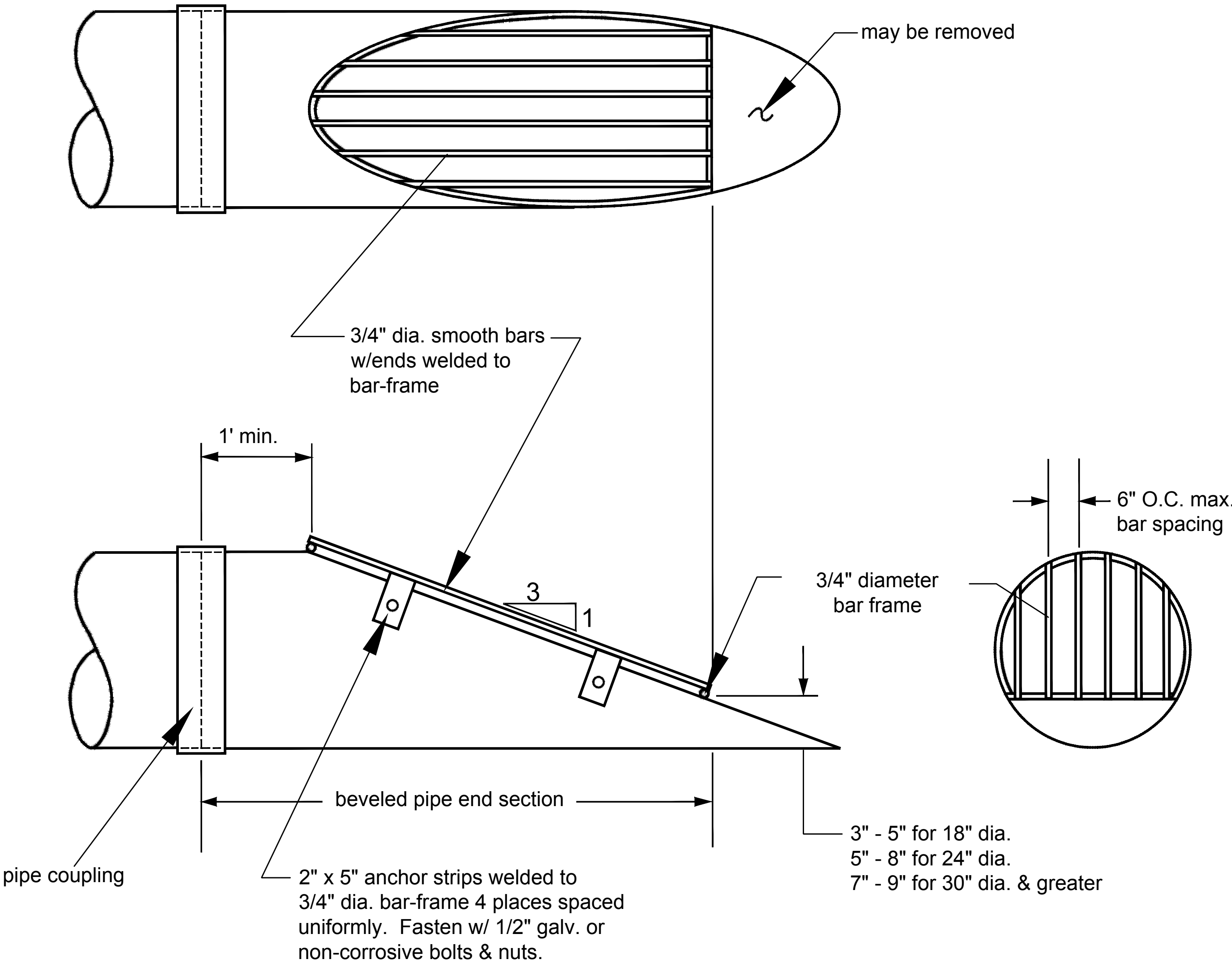


NOTES:

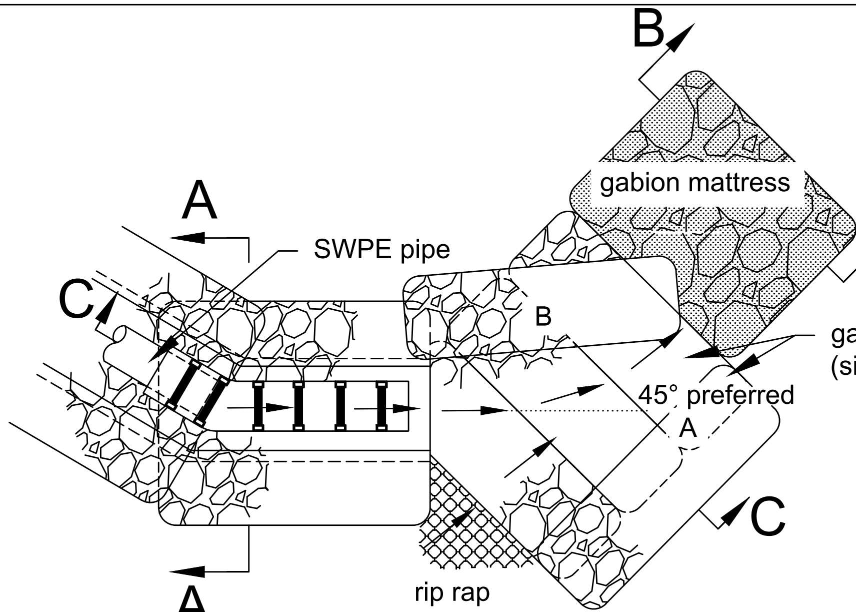
1. CMP or LCPE pipe end-section shown; for concrete pipe beveled end section, see KCRS drawing No. 2-001.
2. All steel parts must be galvanized and asphalt coated (treatment 1 or better).

KITSAP COUNTY WASHINGTON 1857

Figure 4.6
Debris Barrier (In Road Right-of-Way)

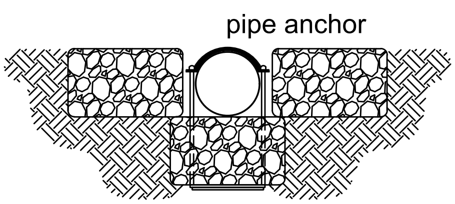
March 2020

\\herrera.local\hecnet\seattle\proj\Y2019\19-07028-000\CAD\Source\102419_Kitsap\Dwgs Files\Files_from_KingCo\New with template\Fig4.6DebrisBarrierInROW.dwg

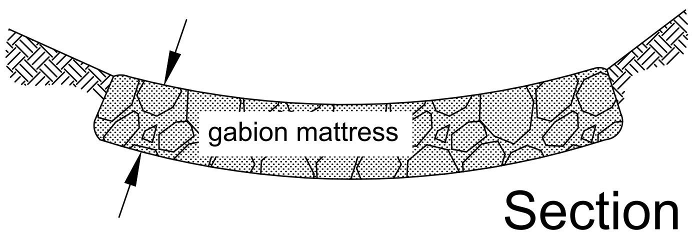


Plan View

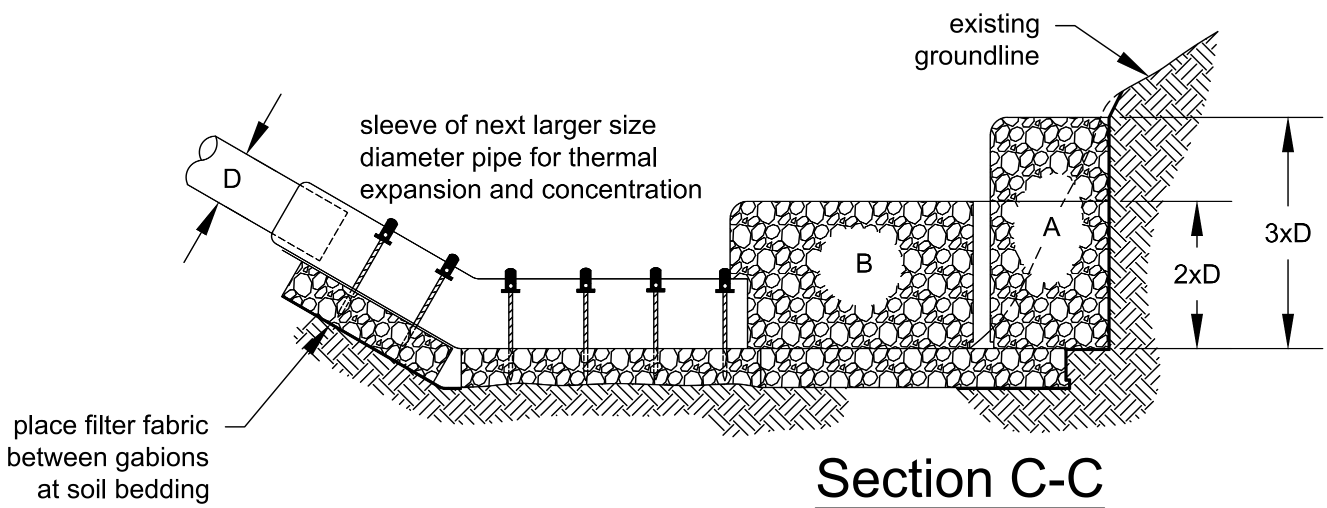
NOTE: If pipe discharges perpendicular to stream, or gabions are located within the ordinary high water mark (OHWM) or will be subject to abrasion from upstream sediments, a four-sided gabion basket located outside the OHWM should be considered.



Section A-A



Section B-B



Section C-C

NOTE TO SCALE

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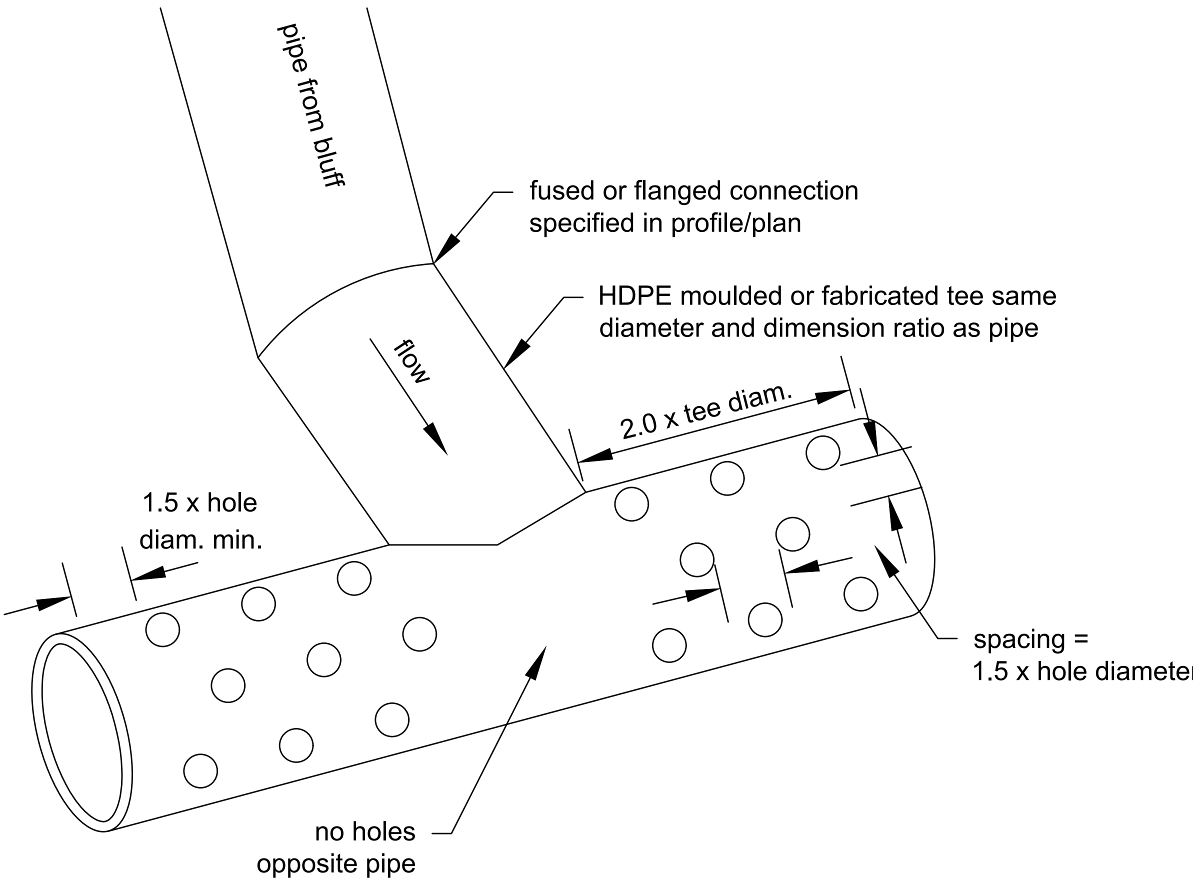
Figure 4.7
Gabion Outfall Detail

March 2020



Drill holes in front half of tee only.
Hole diameter (inches) = tee diameter (inches) divided by 6
(ex. 6 inch tee = 1 inch holes
18 inch tee = 3 inch holes)

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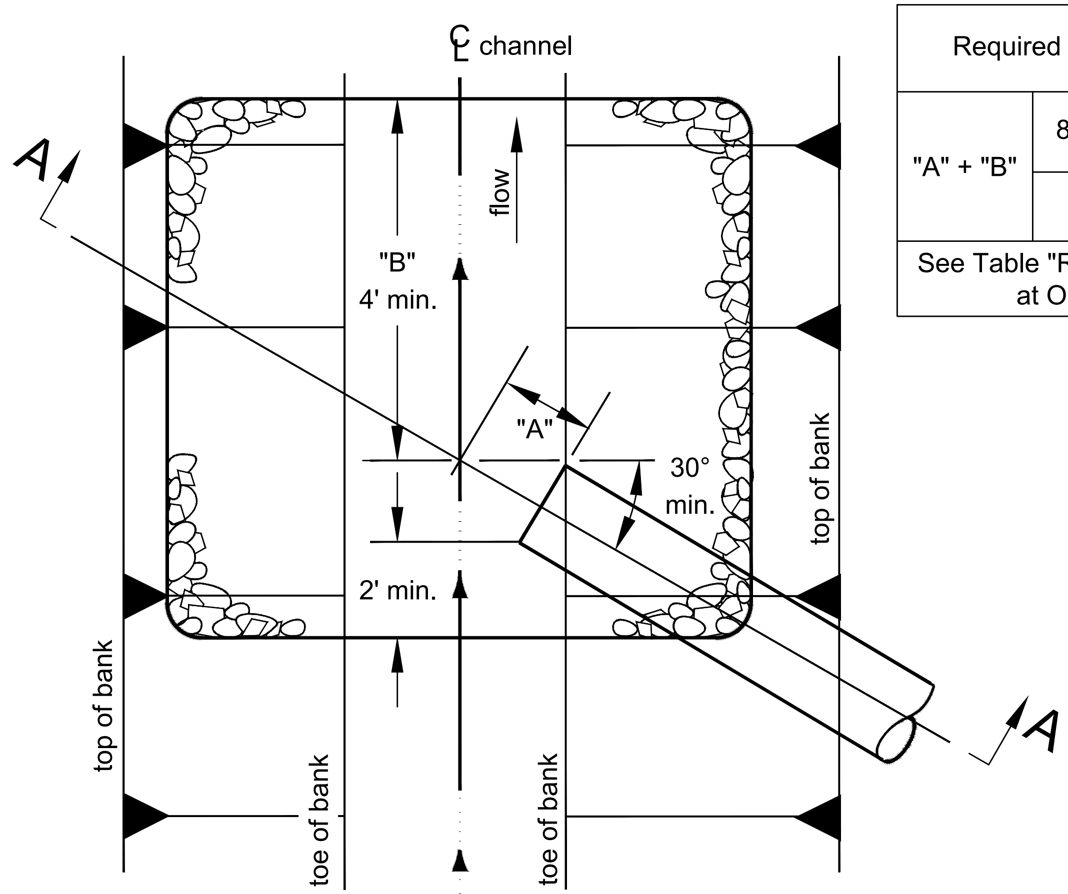
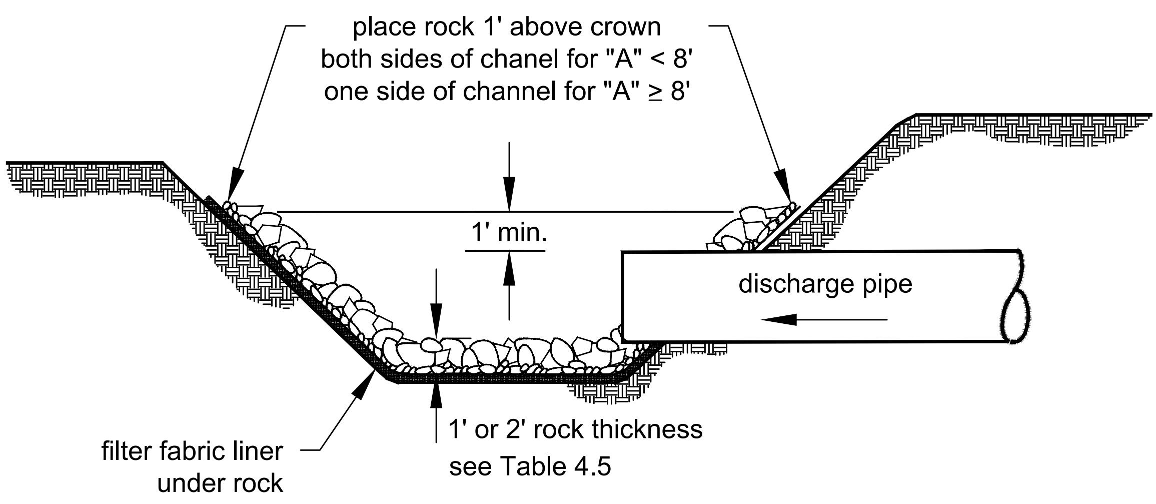
Figure 4.8
Diffuser TEE
(an example of energy dissipating end feature)

March 2020

Required Dimensions	
"A" + "B"	8' for rock lining
	12' for rip rap
See Table "Rock Protection at Outfalls"	



Plan

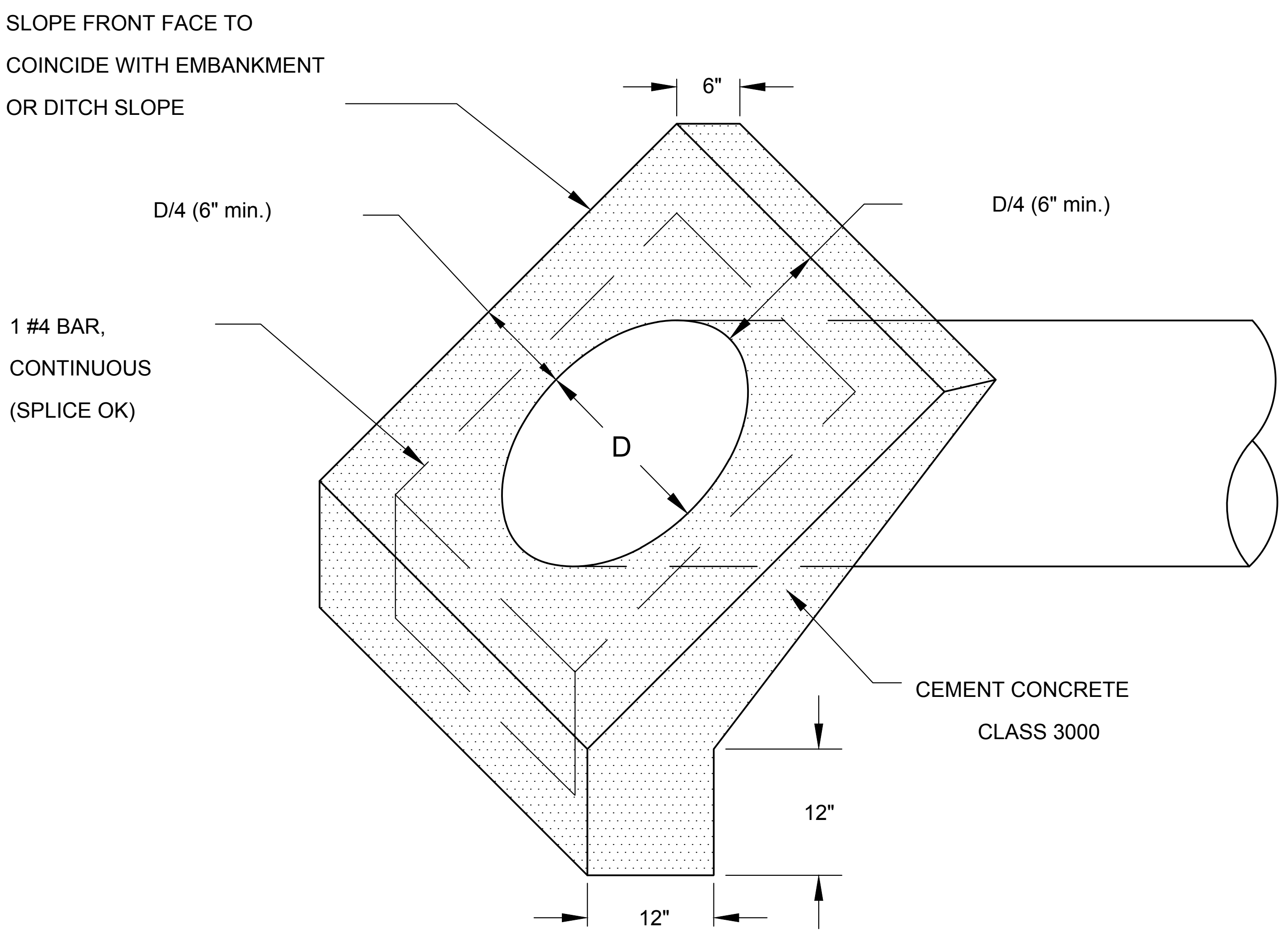


Section A-A

NOT TO SCALE

Figure 4.9
Pipe/Culvert Outfall Discharge Protection

March 2020



NOTE:

REINFORCING STEEL SHALL HAVE 1 1/2 INCH CLEAR COVER TO ALL CONCRETE SURFACES AND SHALL BE GRADE 40 OR GRADE 60.

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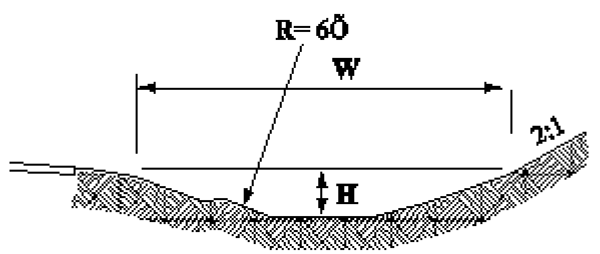
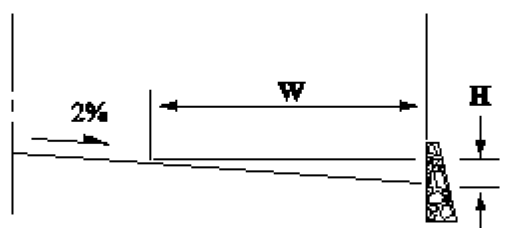
Figure 4.10
Concrete End Protection

March 2020

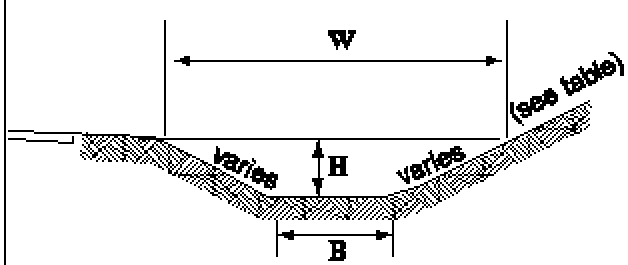
NO.	DIMENSIONS				HYDRAULICS			
	Side Slopes	B	H	W	A	WP	R	$R^{(2/3)}$
D-1	--	--	6.5"	5'-0"	1.84	5.16	0.356	0.502
D-1C	--	--	6"	25'-0"	6.25	25.5	0.245	0.392
D-2A	1.5:1	2'-0"	1'-0"	5'-0"	3.5	5.61	0.624	0.731
B	2:01	2'-0"	1'-0"	6'-0"	4	6.47	0.618	0.726
C	3:01	2'-0"	1'-0"	8'-0"	5	8.32	0.601	0.712
D-3A	1.5:1	3'-0"	1'-6"	7'-6"	7.88	8.41	0.937	0.957
B	2:01	3'-0"	1'-6"	9'-0"	9	9.71	0.927	0.951
C	3:01	3'-0"	1'-6"	12'-0"	11.25	12.49	0.901	0.933
D-4A	1.5:1	3'-0"	2'-0"	9'-0"	12	10.21	1.175	1.114
B	2:01	3'-0"	2'-0"	11'-0"	14	11.94	1.172	1.112
C	3:01	3'-0"	2'-0"	15'-0"	18	15.65	1.15	1.098
D-5A	1.5:1	4'-0"	3'-0"	13'-0"	25.5	13.82	1.846	1.505
B	2:01	4'-0"	3'-0"	16'-0"	30	16.42	1.827	1.495
C	3:01	4'-0"	3'-0"	22'-0"	39	21.97	1.775	1.466
D-6A	2:01	--	1'-0"	4'-0"	2	4.47	0.447	0.585
B	3:01	--	1'-0"	6'-0"	3	6.32	0.474	0.608
D-7A	2:01	--	2'-0"	8'-0"	8	8.94	0.894	0.928
B	3:01	--	2'-0"	12'-0"	12	12.65	0.949	0.965
D-8A	2:01	--	3'-0"	12'-0"	18	13.42	1.342	1.216
B	3:01	--	3'-0"	18'-0"	27	18.97	1.423	1.265
D-9	7:01	--	1'-0"	14'-0"	7	14.14	0.495	0.626
D-10	7:01	--	2'-0"	28'-0"	28	28.28	0.99	0.993
D-11	7:01	--	3'-0"	42'-0"	63	42.43	1.485	1.302



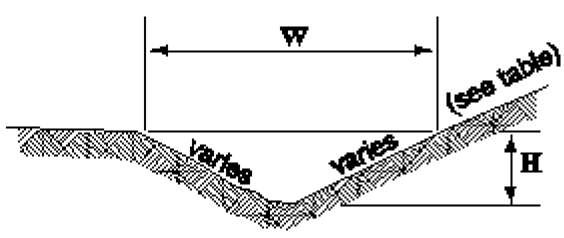
D-1 Segmental (parabolic)



D-1c Curbed crowned street



D-2, D-3, D-4, D-5 Trapezoidal



Isosceles triangular D-6 through D-11

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Figure 4.11
Ditches – Common Sections

March 2020

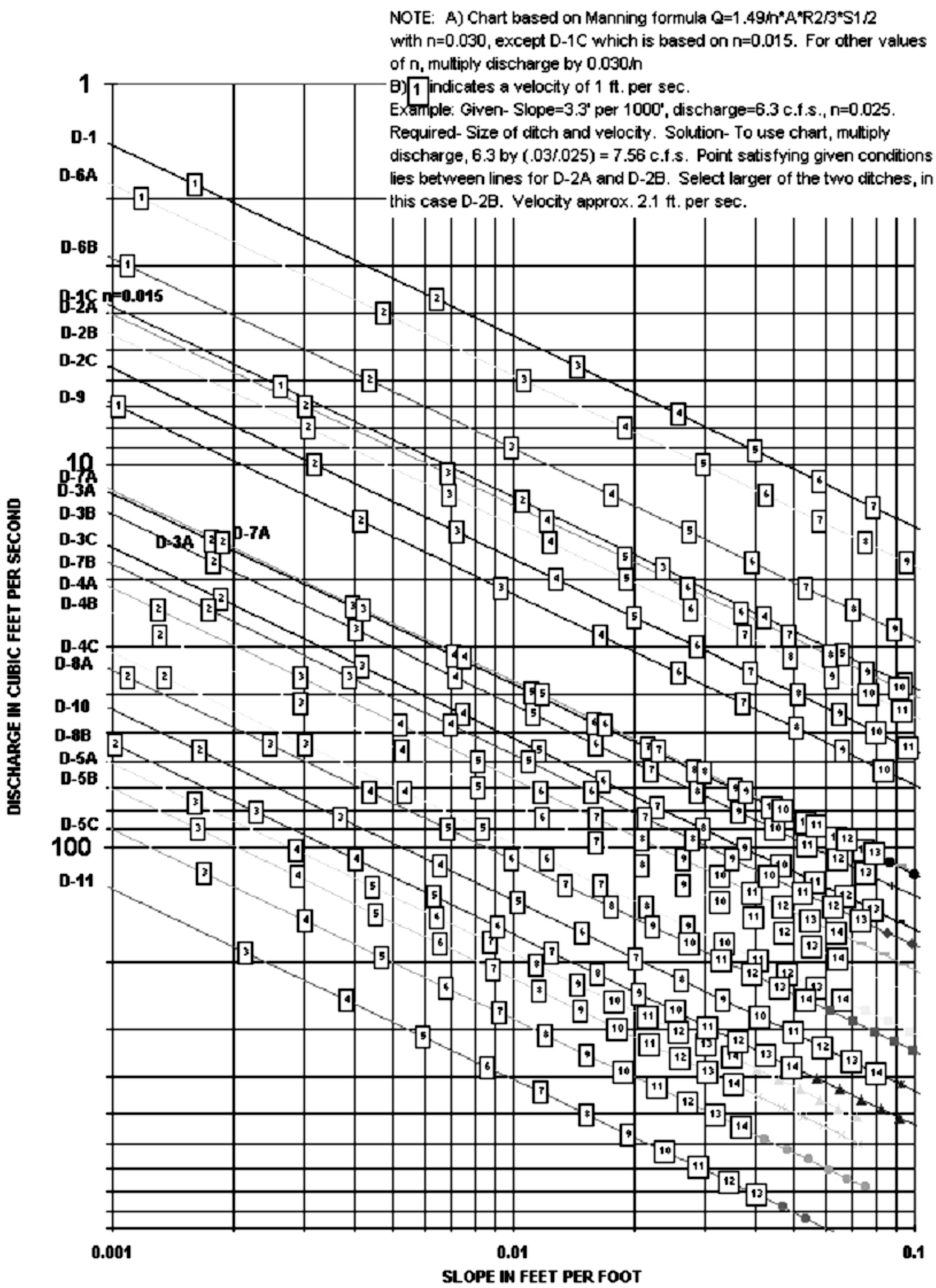
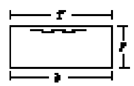
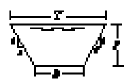
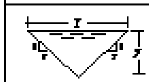
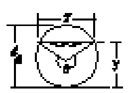
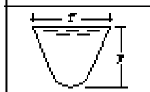
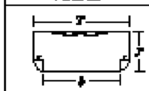
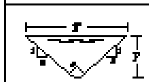


Figure 4.12
Drainage Ditches – Common Sections

Figure 4.13
Geometric Elements of Common Sections

Section	Area A	Wetted perimeter P	Hydraulic radius R	Top width W	Hydraulic depth D	Section factor Z
 Rectangle	by	$b+2y$	$\frac{by}{b+2y}$	b	y	$by^{1.5}$
 Trapezoid	$(b+zy)y$	$b+2y\sqrt{1+z^2}$	$\frac{(b+zy)y}{b+2y\sqrt{1+z^2}}$	$b+2zy$	$\frac{(b+zy)y}{b+2zy}$	$\frac{[(b+zy)y]^{1.5}}{\sqrt{b+2zy}}$
 Triangle	zy^2	$2y\sqrt{1+z^2}$	$\frac{zy}{2\sqrt{1+z^2}}$	$2zy$	$\frac{1}{2}y$	$\frac{\sqrt{2}}{2}zy^{2.5}$
 Circle	$\frac{1}{8}(\theta - \sin\theta)d_0^2$	$\frac{1}{2}\theta d_0$	$\frac{1}{4}\left(1-\frac{\sin\theta}{\theta}\right)d_0$	$(\sin\frac{1}{2}\theta)d_0$ or $2\sqrt{y(d_0-y)}$	$\frac{1}{8}\left(\frac{\theta-\sin\theta}{\sin\frac{1}{2}\theta}\right)d_0$	$\frac{\sqrt{2}}{32}\frac{(\theta-\sin\theta)^{1.5}}{(\sin\frac{1}{2}\theta)^{0.5}}d_0^{2.5}$
 Parabola	$\frac{2}{3}Ty$	$T+\frac{8y^2}{3T}$ *	$\frac{2T^2y}{3T^2+8y^2}$ *	$\frac{3A}{2y}$	$\frac{2}{3}y$	$\frac{2}{9}\sqrt{6}Ty^{1.5}$
 Round-cornered Rectangle (y>r)	$(\frac{\pi}{2}-2)r^2+(b+2r)y$	$(\pi-2)r+b+2y$	$\frac{(\frac{\pi}{2}-2)r^2+(b+2r)y}{(\pi-2)r+b+2y}$	$b+2r$	$\frac{(\frac{\pi}{2}-2)r^2}{(b+2r)}+y$	$\frac{[(\frac{\pi}{2}-2)r^2+(b+2r)y]^{1.5}}{\sqrt{b+2y}}$
 Round-bottomed Triangle	$\frac{T^2}{4z}-\frac{r^2}{z}(1-z\cot^{-1}z)$	$\frac{T}{z}\sqrt{1+z^2}-\frac{2r}{z}(1-z\cot^{-1}z)$	$\frac{A}{P}$	$2[z(y-r)+r\sqrt{1+z^2}]$	$\frac{A}{T}$	$A\sqrt{\frac{A}{T}}$

*Satisfactory approximation for the interval 0<x"1, where x=4y/T. When x>1, use the exact expression $P=(\frac{T}{2})\left[\sqrt{1+x^2}+\frac{1}{x}\ln\left(x+\sqrt{1+x^2}\right)\right]$

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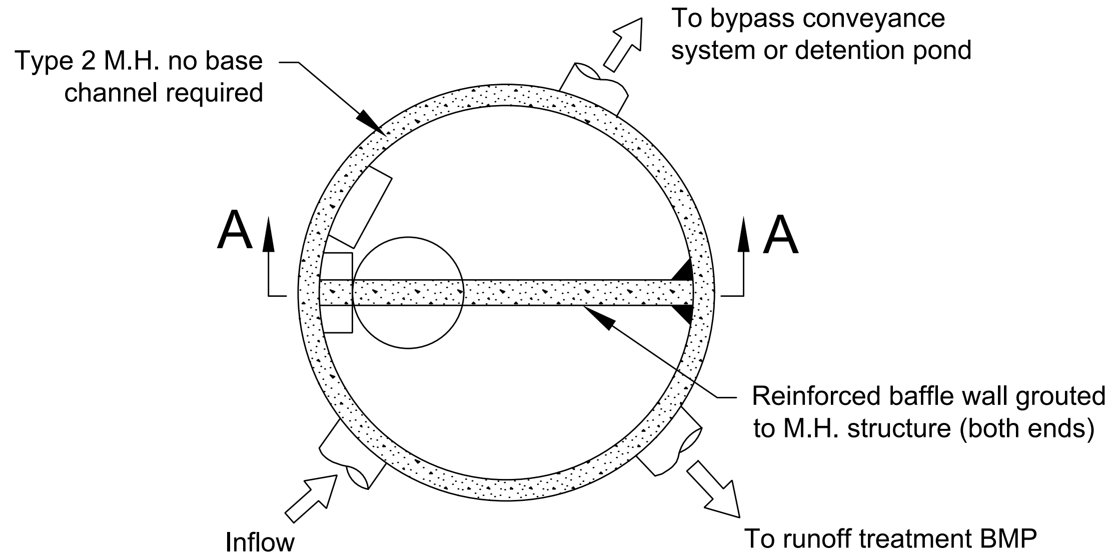
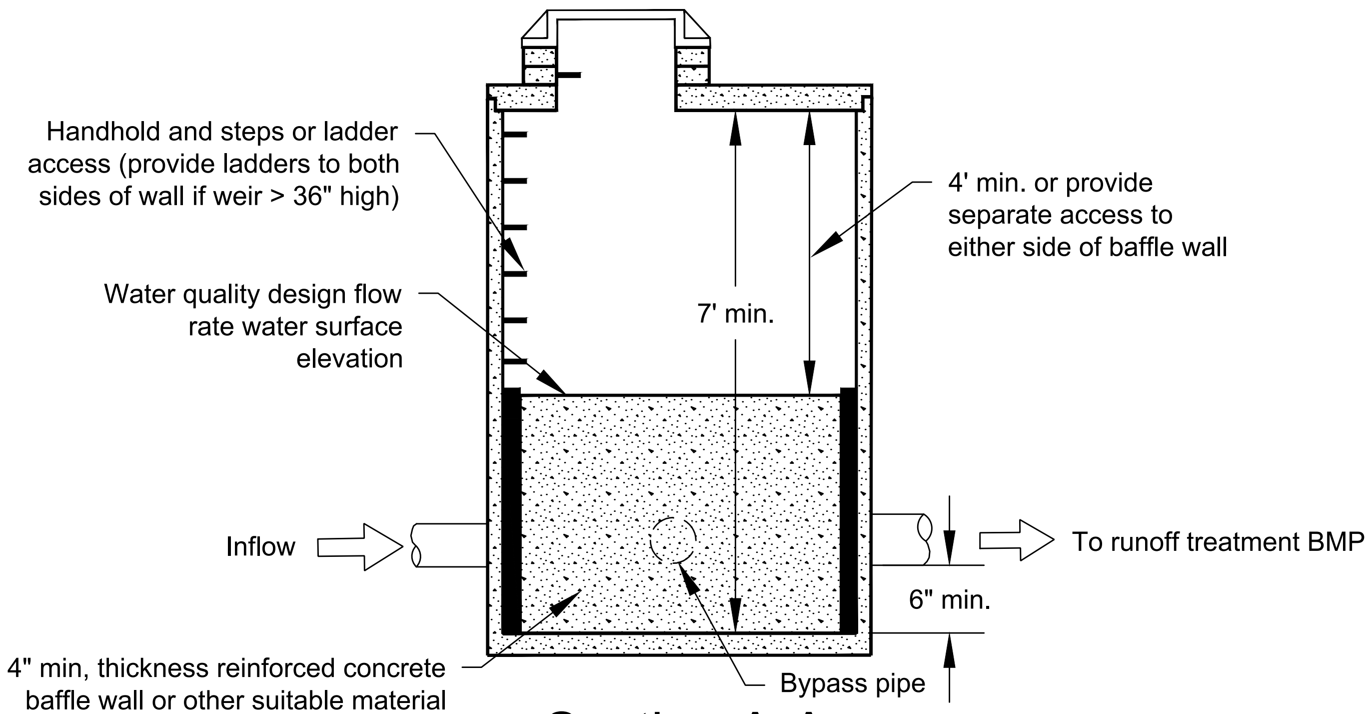


Plan View



Section A-A

Note: The outlet pipe to the Runoff Treatment BMP may require an orifice plate installed on the outlet to control the water quality design flow rate water surface elevation (weir height). The water quality design flow rate water surface elevation should be set to provide a minimum headwater/diameter ratio of 2.0 on the outlet pipe.

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Figure 4.14
Flow Splitter, Option A

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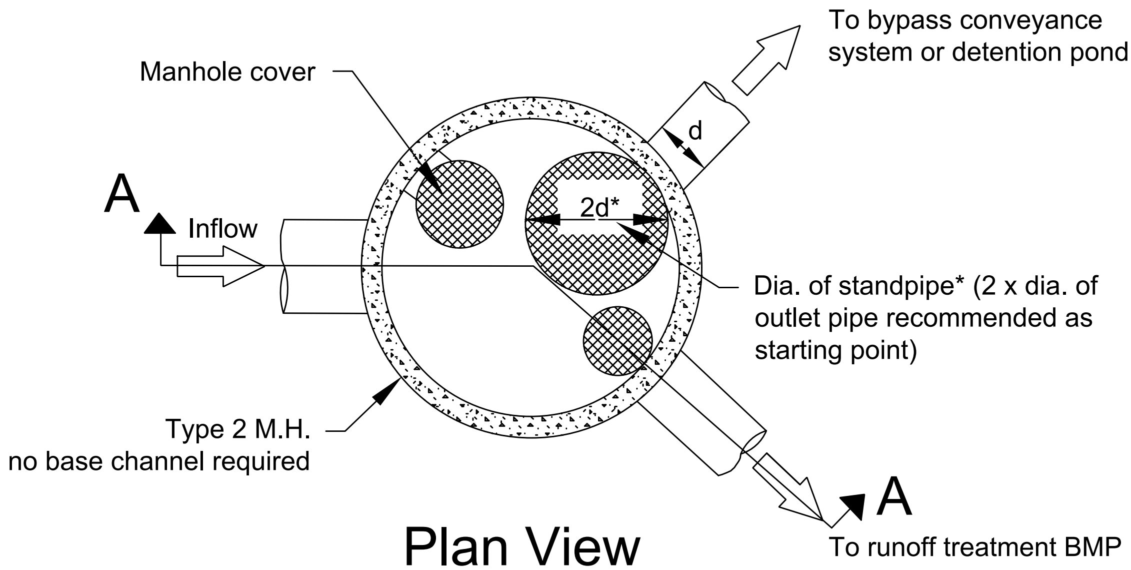
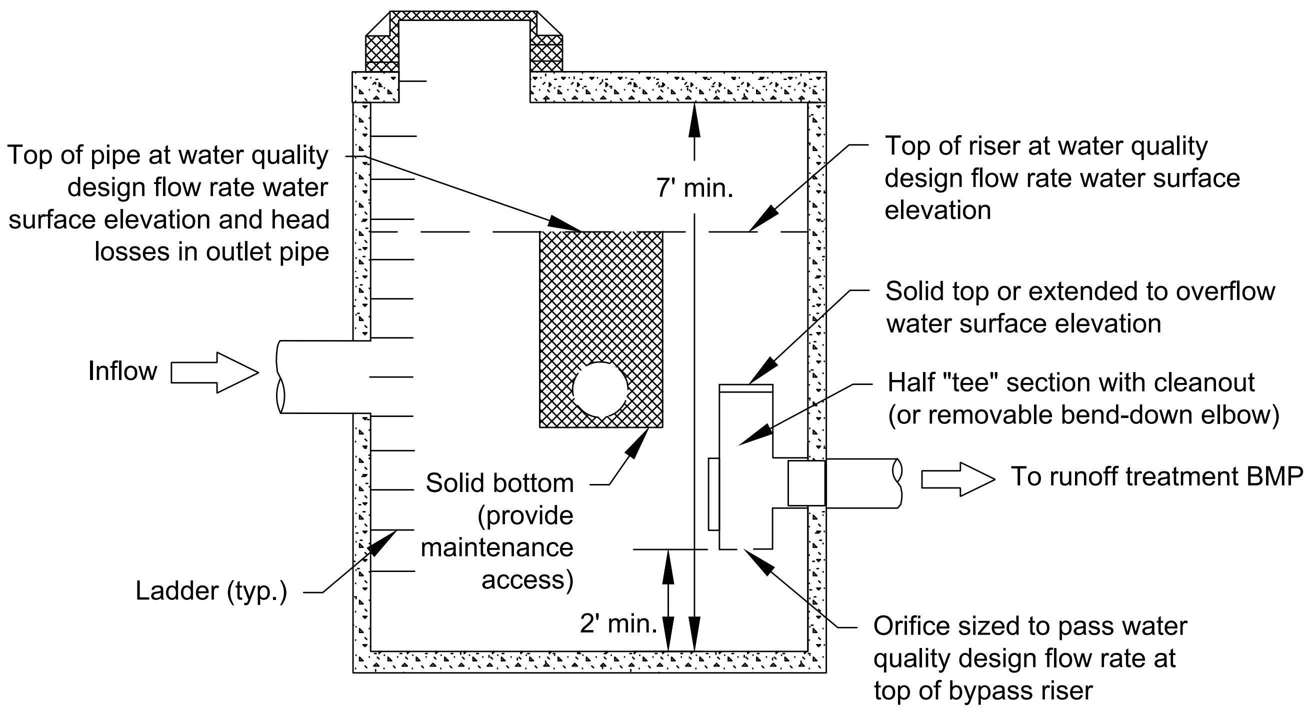


Plan View



Section A-A

*Note: Diameter of standpipe (2d) should be large enough to minimize head above water quality design water surface and to keep water quality design flows from increasing more than 10% during 100-year flows.

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Figure 4.15
Flow Splitter, Option B

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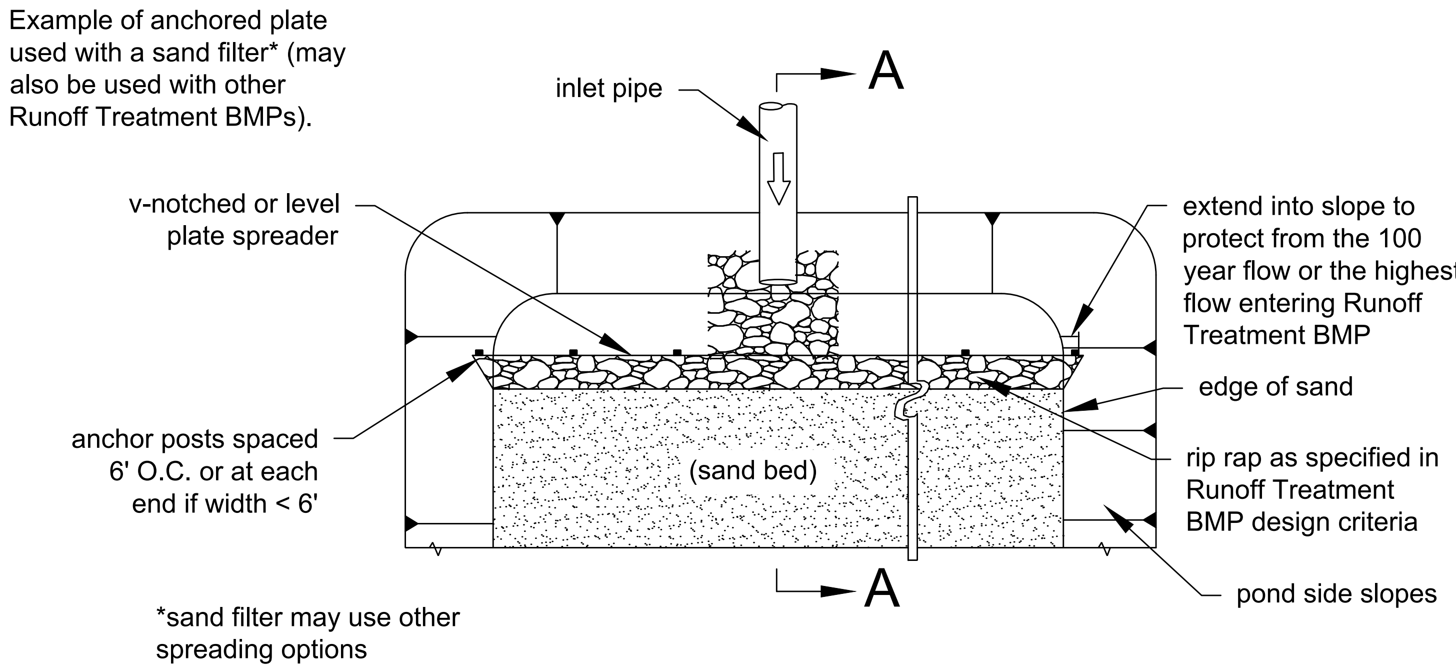
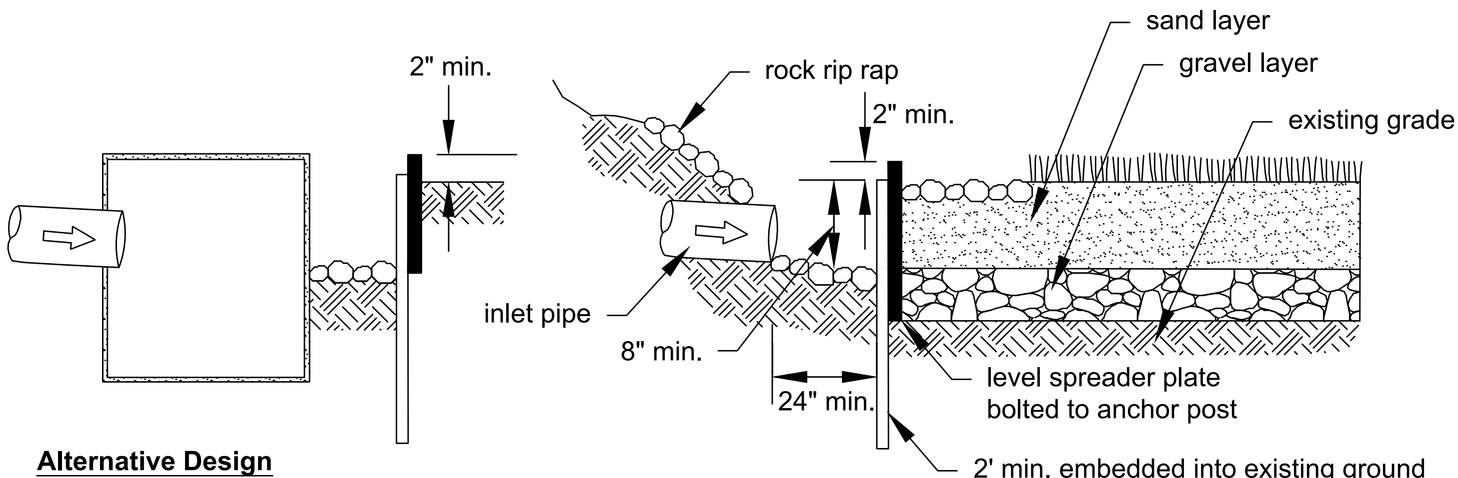


Plan View



Alternative Design
Catch basin recommended for higher flow situations (generally for inflow velocities of 5 fps or greater for 100 year storm).

Section A-A

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Figure 4.16
Flow Spreader Option A: Anchored Plate

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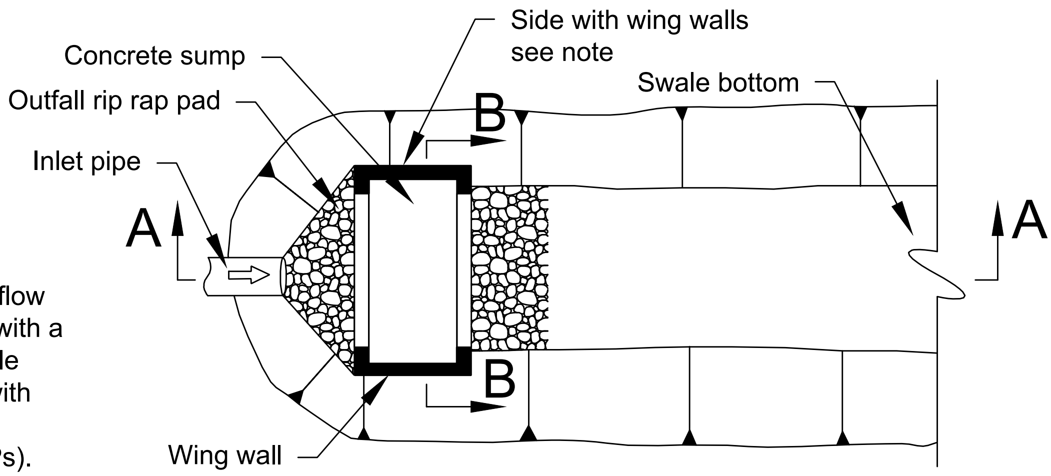
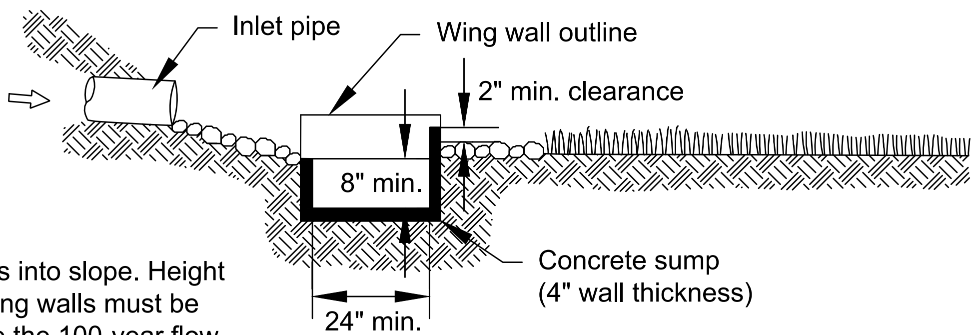
Example of a concrete sump flow spreader used with a biofiltration swale (may be used with other Runoff Treatment BMPs).

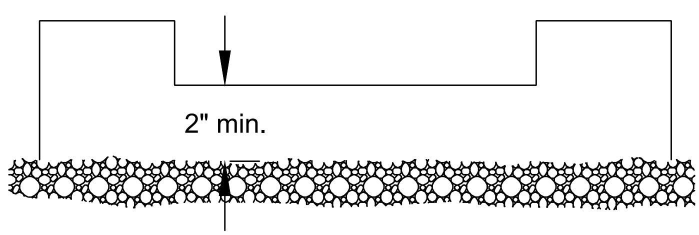


Plan View



Note: Extend sides into slope. Height of side wall and wing walls must be sufficient to handle the 100-year flow or the highest flow entering the BMP.

Section A-A



Section B-B

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Figure 4.17
Flow Spreader Option B: Concrete Sump Box

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\\herrera.local\hecnet\seattle\proj\Y2019\19-07028-000\CAD\Dwg\Final CAD files\Fig4.17FlowSpreaderOptionBConcreteSumpBox.dwg

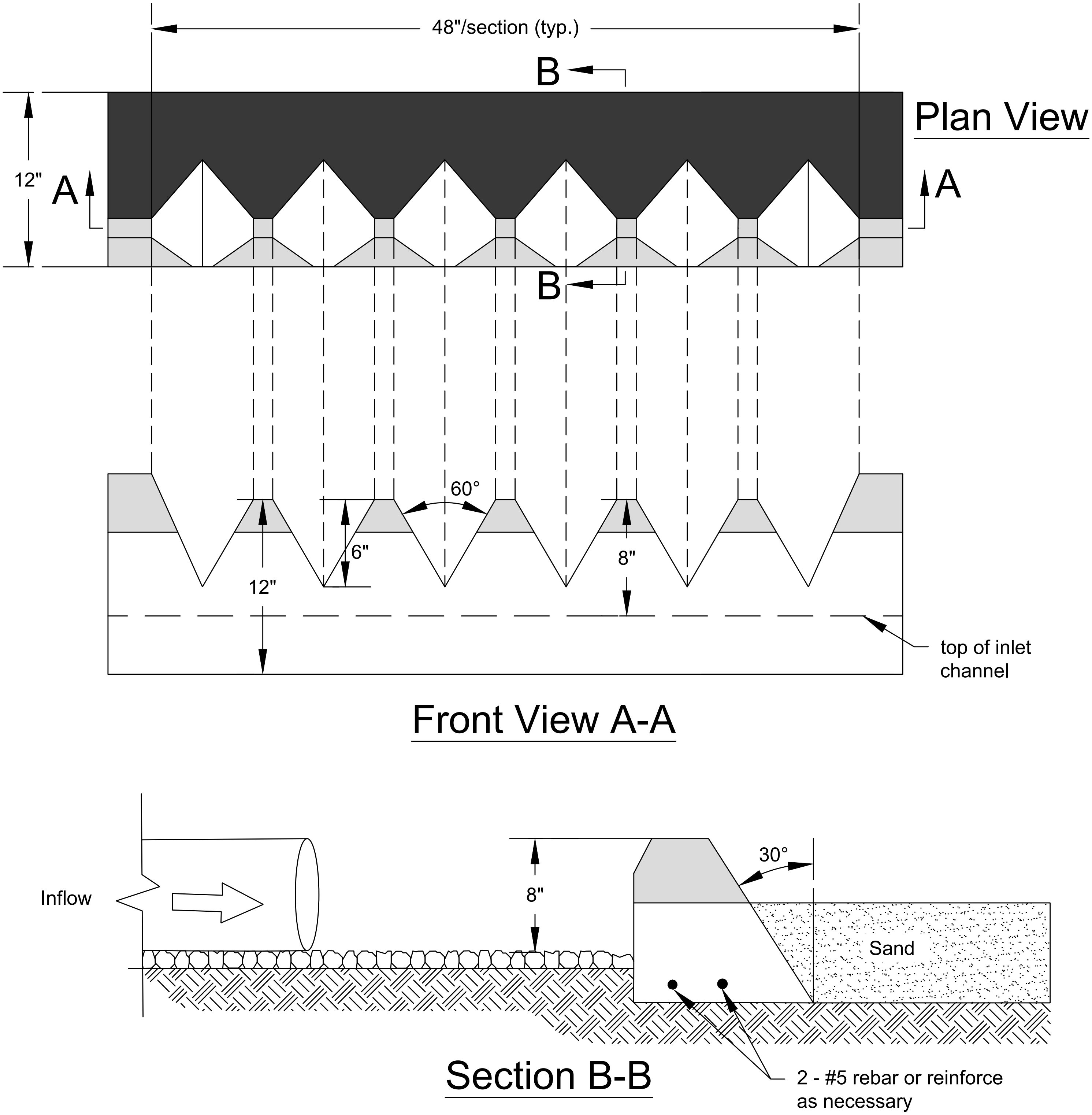

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Figure 4.18
Flow Spreader Option C: Notched Curb Spreader

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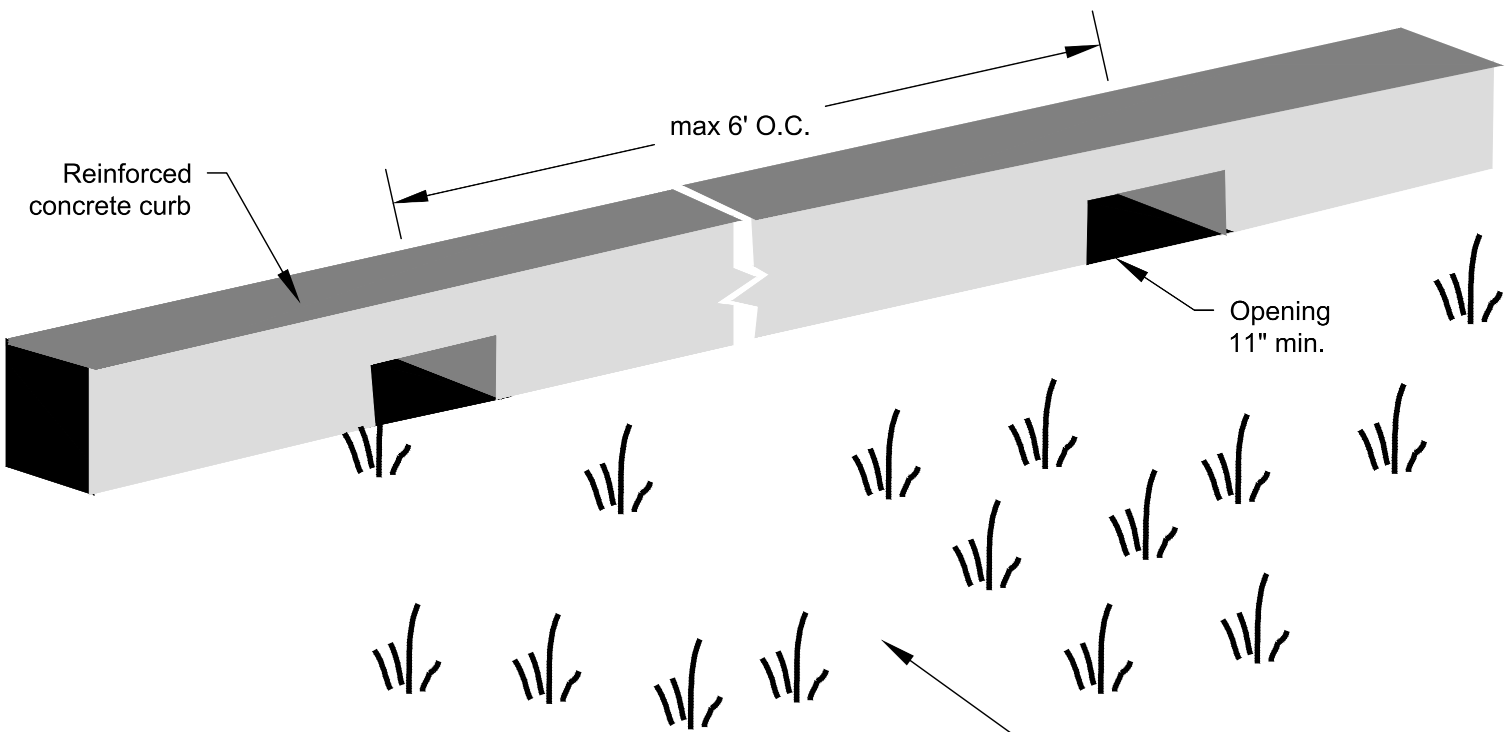

Curb Port

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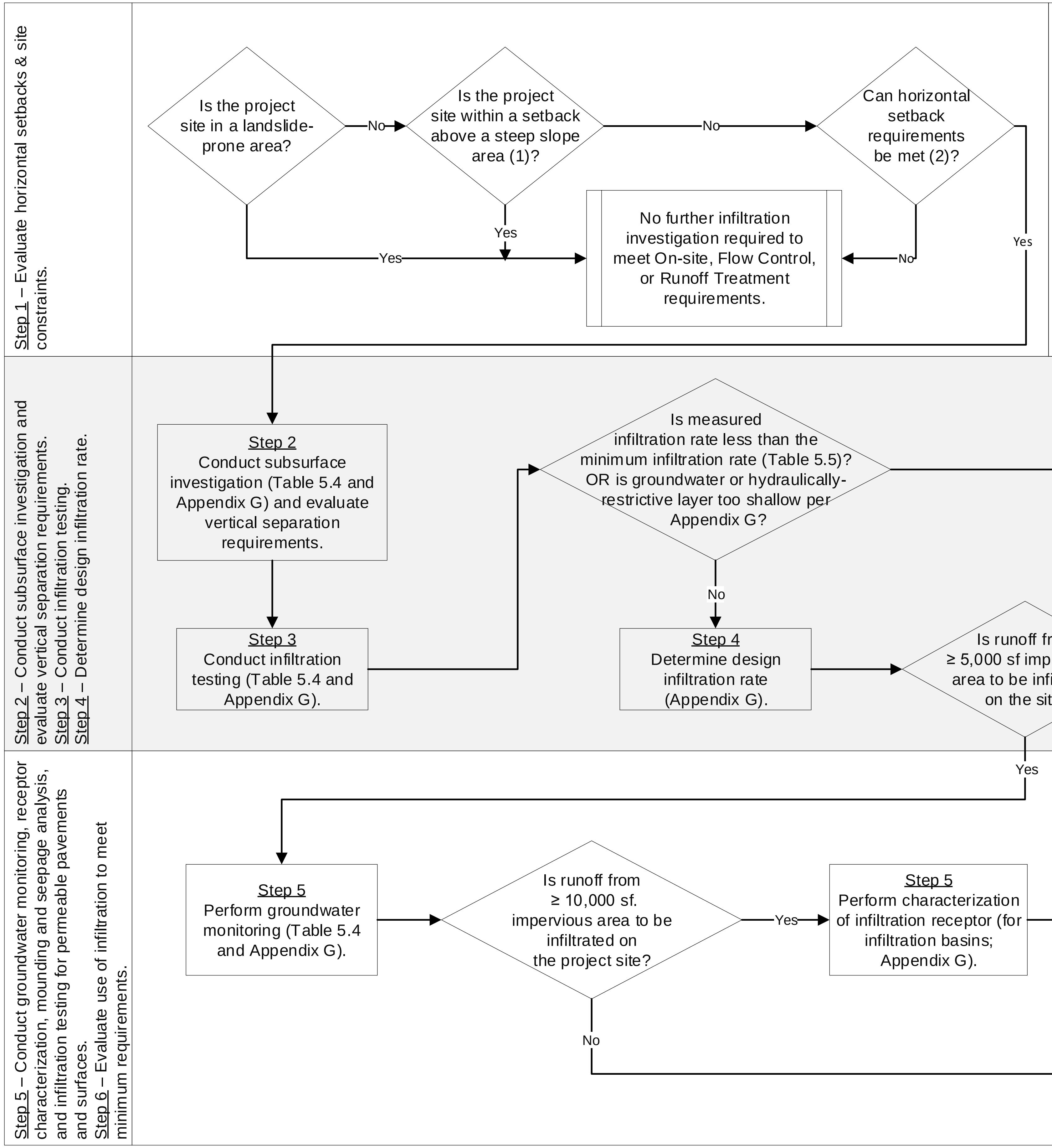
Figure 4.19
Flow Spreader Option D: Through-Curb Port

March 2020

March 2020

Figure 5.1
Infiltration Feasibility Flow Chart



1. Setback is 10 times the height of the steep slope area to a maximum of 500 feet above a steep slope area.
2. Horizontal Setbacks include:
   - 10 feet from property lines (may be reduced from right of way with County approval)
   - 10 feet from another infiltration facility
   - 5 feet from building without basement and 10 feet from building with basement when infiltrating < 5,000 sf impervious surface
   - 5 feet from building and 10 feet from building with basement between 1H:1V slope from bottom of BMP when infiltrating ≥ 5,000 sf impervious surface
   - 100 feet of a contaminated site or landfill (active or closed)
   - Where soil and/or groundwater containment problems have been identified
   - Within groundwater protection area
   - 10 feet from petroleum, chemical or hazardous waste storage tank of 1,100 gallons or less
   - 100 feet from petroleum, chemical or hazardous waste storage tank > 1,100 gallons
   - 100 from drinking water wells, septic tanks, and drain fields
   - 100 feet from open water features and designated landslide hazards
   - 200 feet from springs and flowing artesian wells used for drinking water supply. Infiltration BMPs upgradient of drinking wster supplies shall comply with Health Department requirements
   - 50 feet from the top of any slope over 20%
   - See Table 5-1 for Horizontal Setback requirements for on-site systems
   - See Table 5-2 for Horizontal Setback requirements for private/public wells

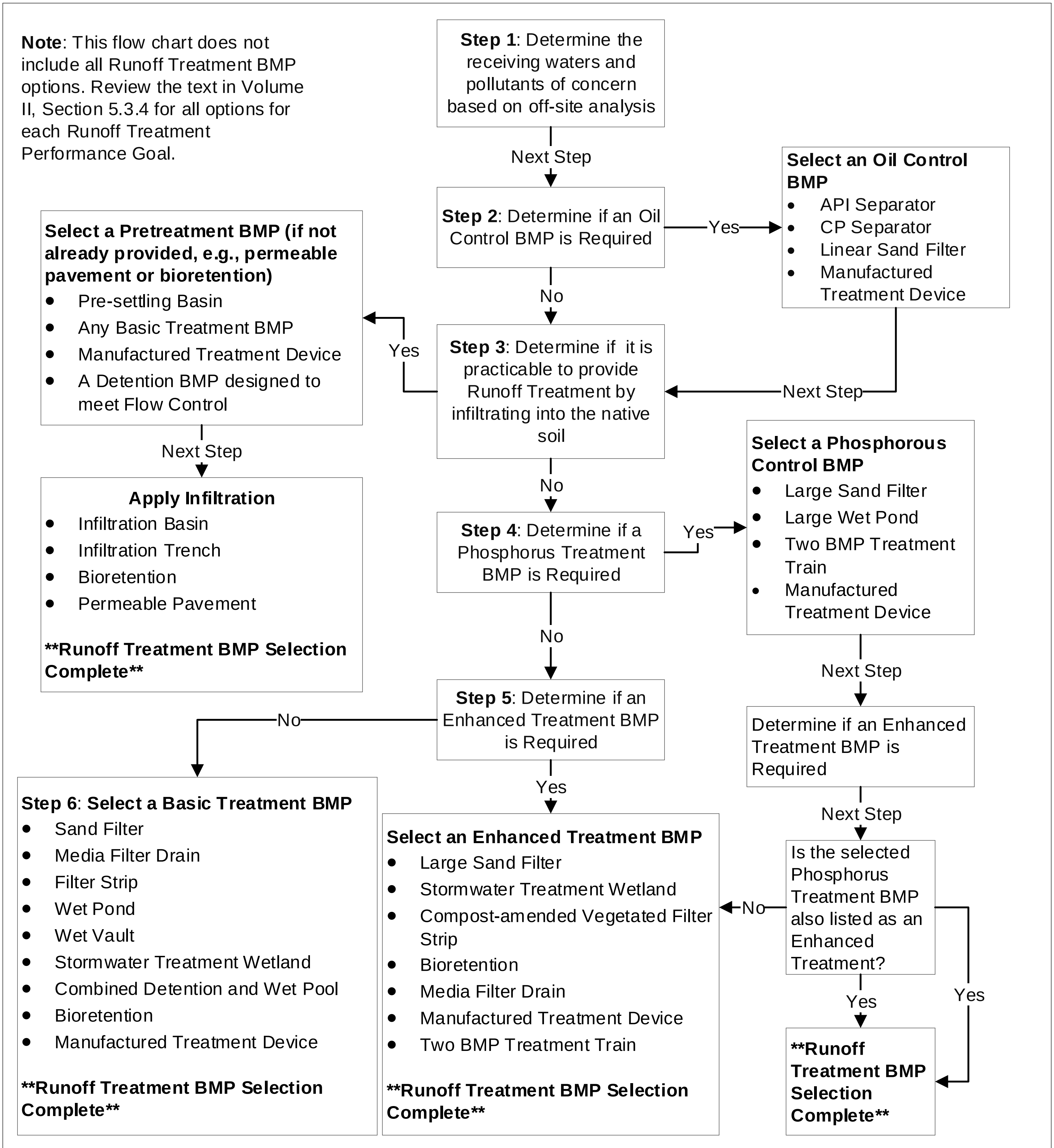


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Figure 5.2
Runoff Treatment BMP Selection Flow Chart

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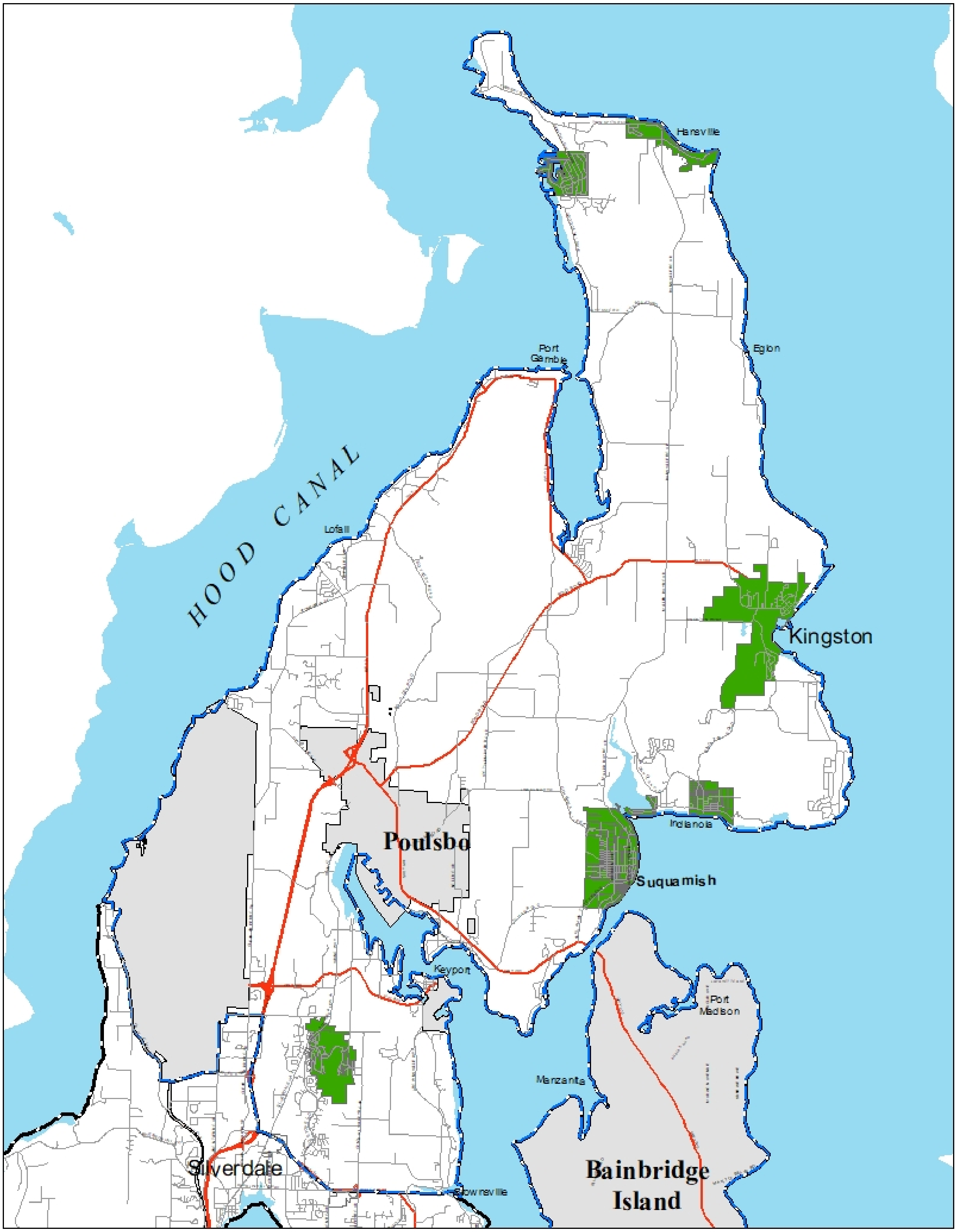


Figure 8.1
Critical Drainage Areas
Commissioner District 1

March 2020

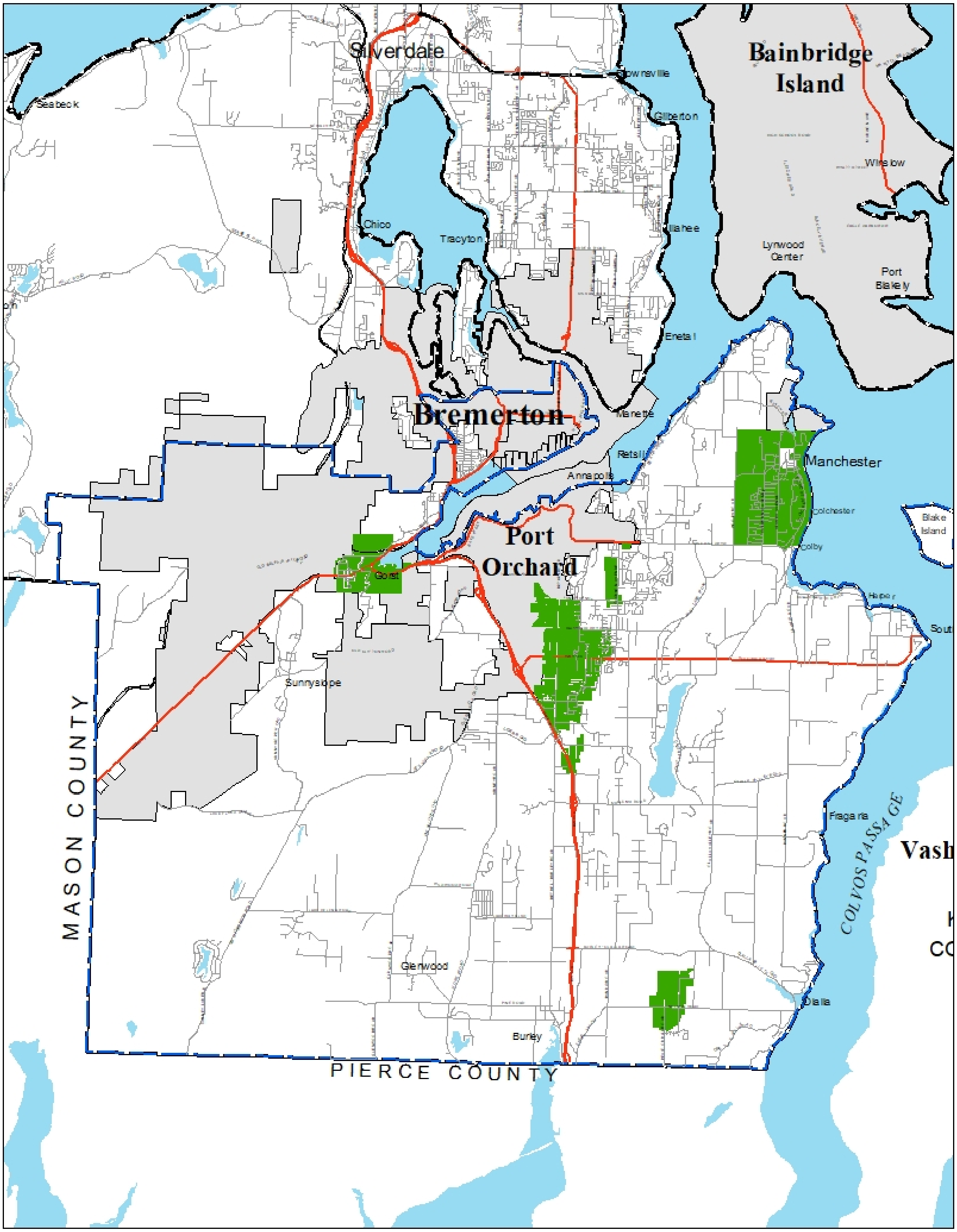


Figure 8.2
Critical Drainage Areas
Commissioner District 2

March 2020

Figure 8.3
Critical Drainage Areas
Commissioner District 3

March 2020

Appendix F Figures

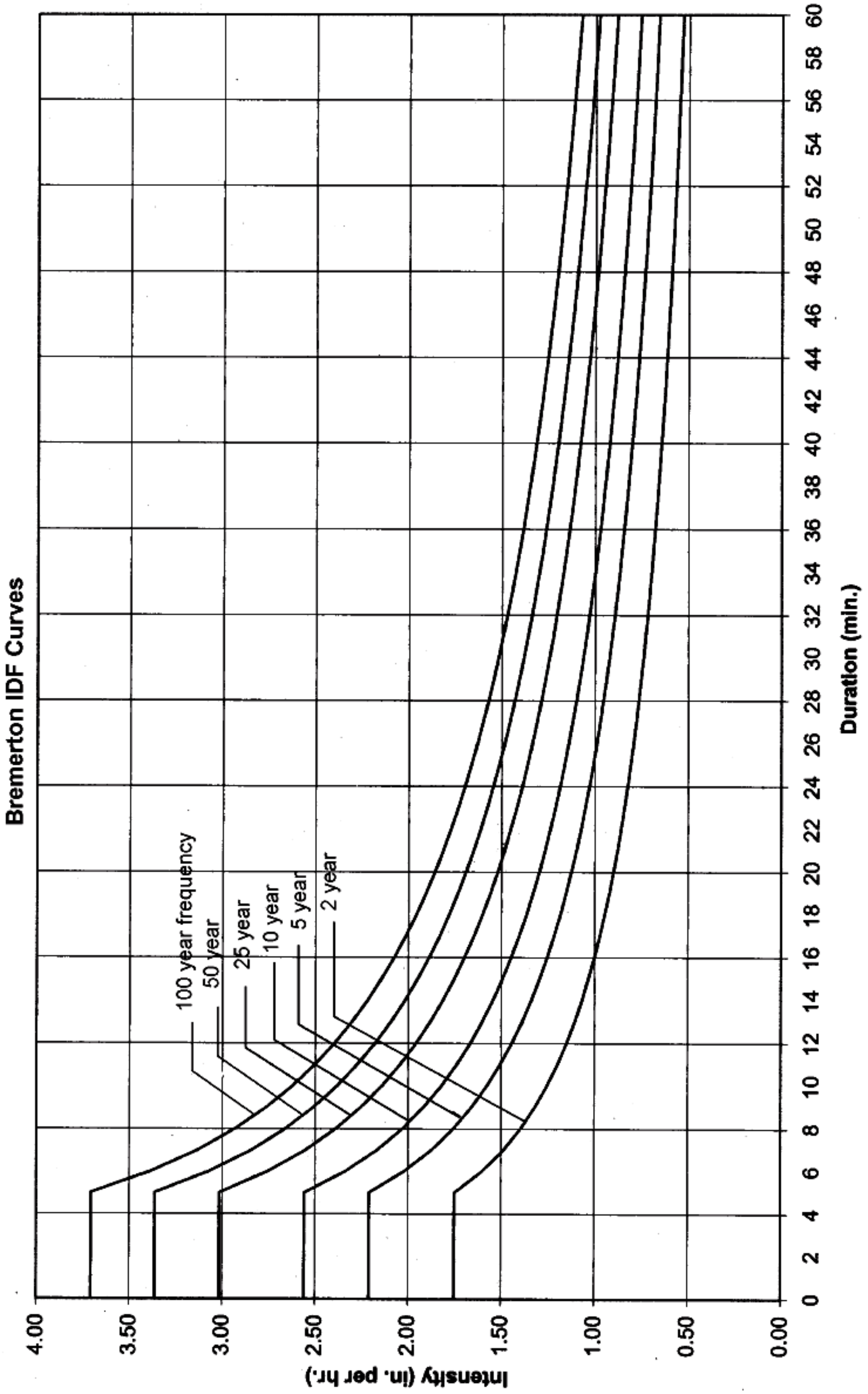
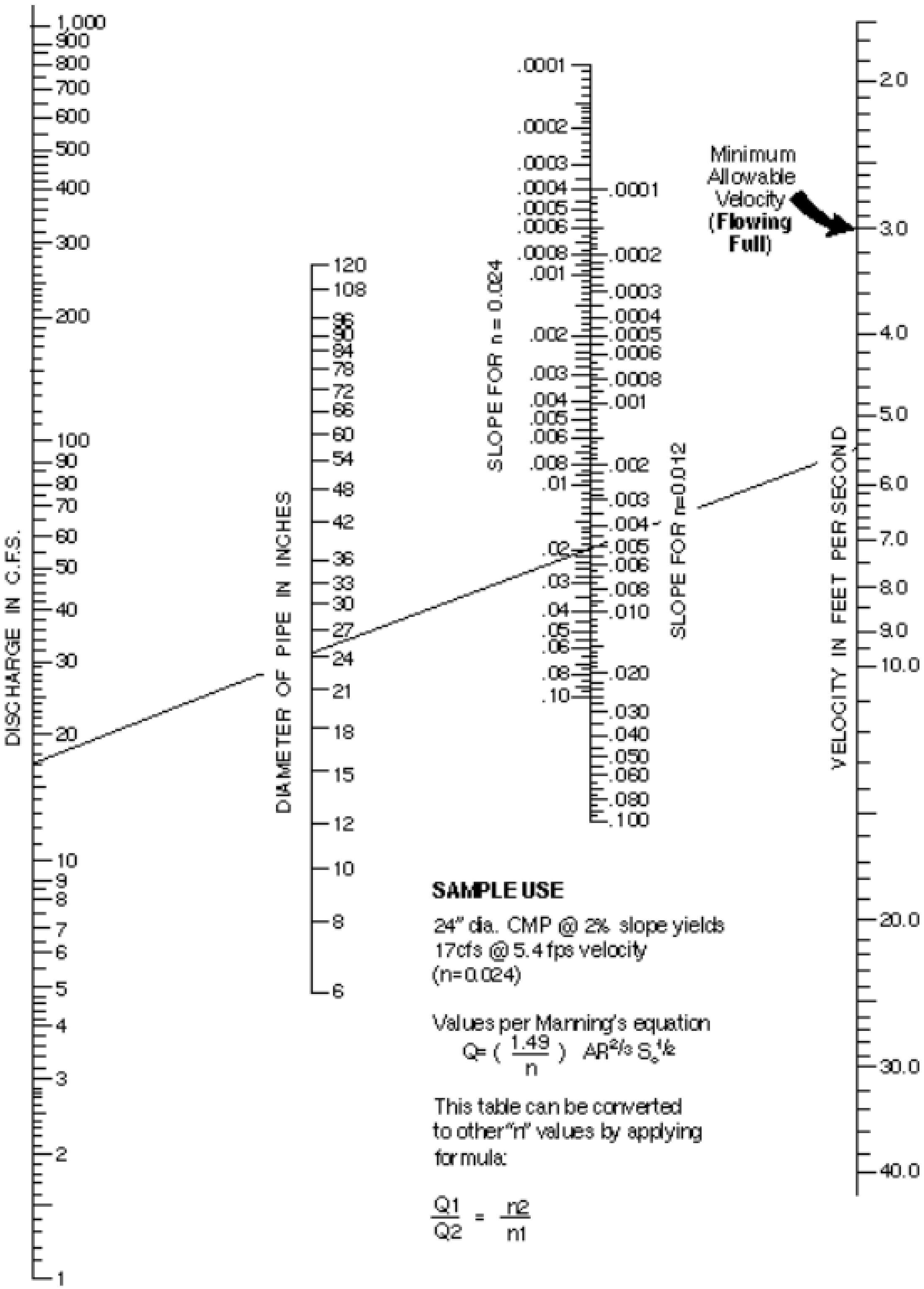


Figure F.1
Rainfall Intensity-Duration Curves

March 2020



SAMPLE USE

24" dia. CMP @ 2% slope yields
17cfs @ 5.4 fps velocity
(n=0.024)

Values per Manning's equation

$$Q = \left(\frac{1.49}{n}\right) AR^{2/3} S_o^{1/2}$$

This table can be converted to other "n" values by applying formula:

$$\frac{Q1}{Q2} = \frac{n2}{n1}$$

Figure F.2
Nomograph for Sizing Circular Drains Flowing Full

March 2020

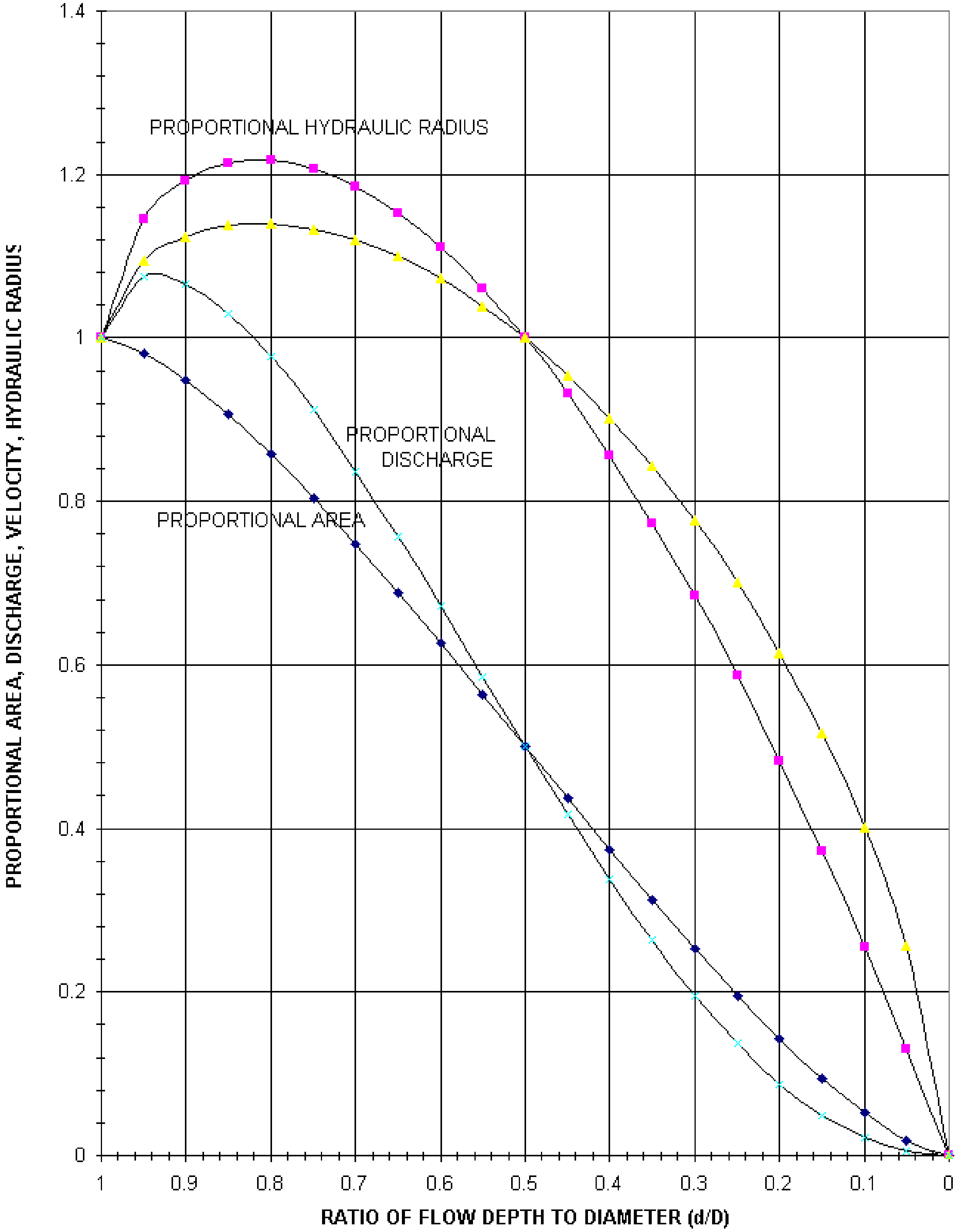


Figure F.3
Circular Channel Ratios

March 2020

Pipe Segment CB to CB		(1) Q (cfs)	(2) Lngth (ft)	(3) Pipe Size	(4) ÒnÓ Value	(5) Outlet Elev (ft)	(6) Inlet Elev (ft)	(7) Barrel Area (sq. ft)	(8) Barrel Vel (fps)	(9) Barrel Vel Head (ft)	(10) TW Elev (ft)	(11) Fric-tion Loss (ft)	(12) Entr HGL Elev (ft)	(13) Entr Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlt Cntrl Elev (ft)	(16) Inlet Cntrl Elev (ft)	(17) Appr Vel Head (ft)	(18) Bend Head Loss (ft)	(19) Junc Head Loss (ft)	(20) HW Elev (ft)

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Figure F.4
Backwater Calculation Sheet

Column (1) - Design flow to be conveyed by pipe segment.

Column (2) - Length of pipe segment.

Column (3) - Pipe Size; indicate pipe diameter or span x rise.

Column (4) - Manning's "*n*" value.

Column (5) - Outlet Elevation of pipe segment.

Column (6) - Inlet Elevation of pipe segment.

Column (7) - Barrel Area; this is the full cross-sectional area of the pipe.

Column (8) - Barrel Velocity; this is the full velocity in the pipe as determined by:

$V = Q/A$ or Col.(8) = Col.(1) / Col.(7)

Column (9) - Barrel Velocity Head = $V^2/2g$ or $(\text{Col.}(8))^2/2g$

where $g = 32.2$ ft/sec^2 (acceleration due to gravity)

Column (10) - Tailwater (TW) Elevation; this is the water surface elevation at the outlet of the pipe segment. If the pipe's outlet is not submerged by the TW and the TW depth is less than $(D+d_c)/2$, set TW equal to $(D+d_c)/2$ to keep the analysis simple and still obtain reasonable results (D = pipe barrel height and d_c = critical depth, both in feet. See Figure F.14 for determination of d_c).

Column (11) - Friction Loss = S_f x L [or S_f x Col.(2)]
where S_f is the friction slope or head loss per linear foot of pipe as determined by Manning's equation expressed in the form:

$S_f = (nV)^2/2.22\ R^{1.33}$

Column (12) - Hydraulic Grade Line (HGL) Elevation just inside the entrance of the pipe barrel; this is determined by adding the friction loss to the TW elevation:

Col.(12) = Col.(11) + Col.(10)

If this elevation falls below the pipe's inlet crown, it no longer represents the true HGL when computed in this manner. The true HGL will fall somewhere between the pipe's crown and either normal flow depth or critical flow depth, whichever is greater. To keep the analysis simple and still obtain reasonable results (i.e., erring on the conservative side), set the HGL elevation equal to the crown elevation.

Column (13) - Entrance Head Loss = K_e x $V^2/2g$ [or K_e x Col.(9)]
where K_e = Entrance Loss Coefficient (from Table F.4). This is the head lost due to flow contractions at the pipe entrance.

Column (14) - Exit Head Loss = 1.0 x $V^2/2g$ or 1.0 x Col.(9)

This is the velocity head lost or transferred downstream.

Column (15) - Outlet Control Elevation = Col.(12) + Col.(13) + Col.(14)

This is the maximum headwater elevation assuming the pipe's barrel and inlet/outlet characteristics are controlling capacity. It does not include structure losses or approach velocity considerations.

Column (16) - Inlet Control Elevation (see Appendix F for computation of inlet control on culverts); this is the maximum headwater elevation assuming the pipe's inlet is controlling capacity. It does not include structure losses or approach velocity considerations.

Column (17) - Approach Velocity Head; this is the amount of head/energy being supplied by the discharge from an upstream pipe or channel section, which serves to reduce the headwater elevation. If the discharge is from a pipe, the approach velocity head is equal to the barrel velocity head computed for the upstream pipe. If the upstream pipe outlet is significantly higher in elevation (as in a drop manhole) or lower in elevation such that its discharge energy would be dissipated, an approach velocity head of zero should be assumed.

Column (18) - Bend Head Loss = K_b x $V^2/2g$ [or K_b x Col.(17)]
where K_b = Bend Loss Coefficient (from Figure F.7). This is the loss of head/energy required to change direction of flow in an access structure.

Column (19) - Junction Head Loss. This is the loss in head/energy that results from the turbulence created when two or more streams are merged into one within the access structure. Figure F.8 may be used to determine this loss, or it may be computed using the following equations derived from Figure F.8:

Junction Head Loss = K_j x $V^2/2g$ [or K_j x Col.(17)]

where K_j is the Junction Loss Coefficient determined by:

$K_j = (Q_3/Q_1)/(1.18 + 0.63(Q_3/Q_1))$

Column (20) - Headwater (HW) Elevation; this is determined by combining the energy heads in Columns 17, 18, and 19 with the highest control elevation in either Column 15 or 16, as follows:

Col.(20) = Col.(15 or 16) - Col.(17) + Col.(18) + Col.(19)

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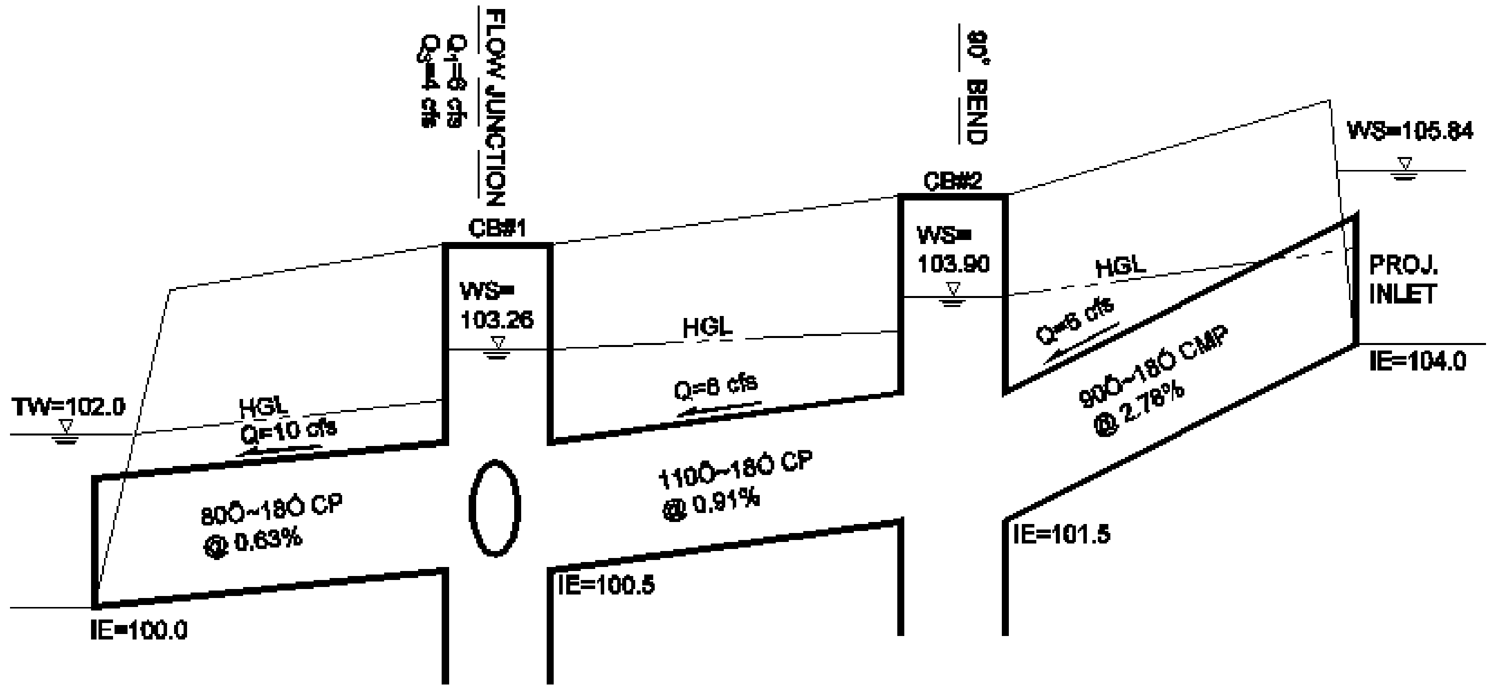
Figure F.5
Backwater Calculation Sheet Notes



B A C K W A T E R   C A L C U L A T I O N   S H E E T

(15), (16): Select the greater elevation

Pipe Segment CB to CB		(1) Q (cfs)	(2) Length (ft)	(3) Pipe Size	(4) ÒnÓ Value	(5) Outlet Elev (ft)	(6) Inlet Elev (ft)	(7) Barrel Area (sqft)	(8) Barrel Vel (fps)	(9) Barrel Vel Head (ft)	(10) TW Elev (ft)	(11) Fric-tion Loss (ft)	(12) Entr HGL Elev (ft)	(13) Entr Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlt Contr Elev (ft)	(16) Inlet Contr Elev (ft)	(17) Appr Vel Head (ft)	(18) Bend Head Loss (ft)	(19) Junc Head Loss (ft)	(20) HW Elev (ft)
Out fall	1	10	80	18Ó	0.012	100.00	100.50	1.77	5.66	0.50	102.00	0.62	102.62	0.25	0.50	103.37	102.75	-0.18	0.002	0.07	103.26
1	2	6	110	18Ó	0.012	100.50	101.50	1.77	3.39	0.18	103.26	0.31	103.57	0.09	0.18	103.84	102.95	-0.18	0.24	0.0	103.90
2	Inlet	6	90	18Ó	0.024	101.50	104.00	1.77	3.39	0.18	103.90	1.00	(104.9) 105.5	0.18	0.18	105.84	105.60	-0.0	0.0	0.0	105.84

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Figure F.6
Backwater Pipe Calculation Example

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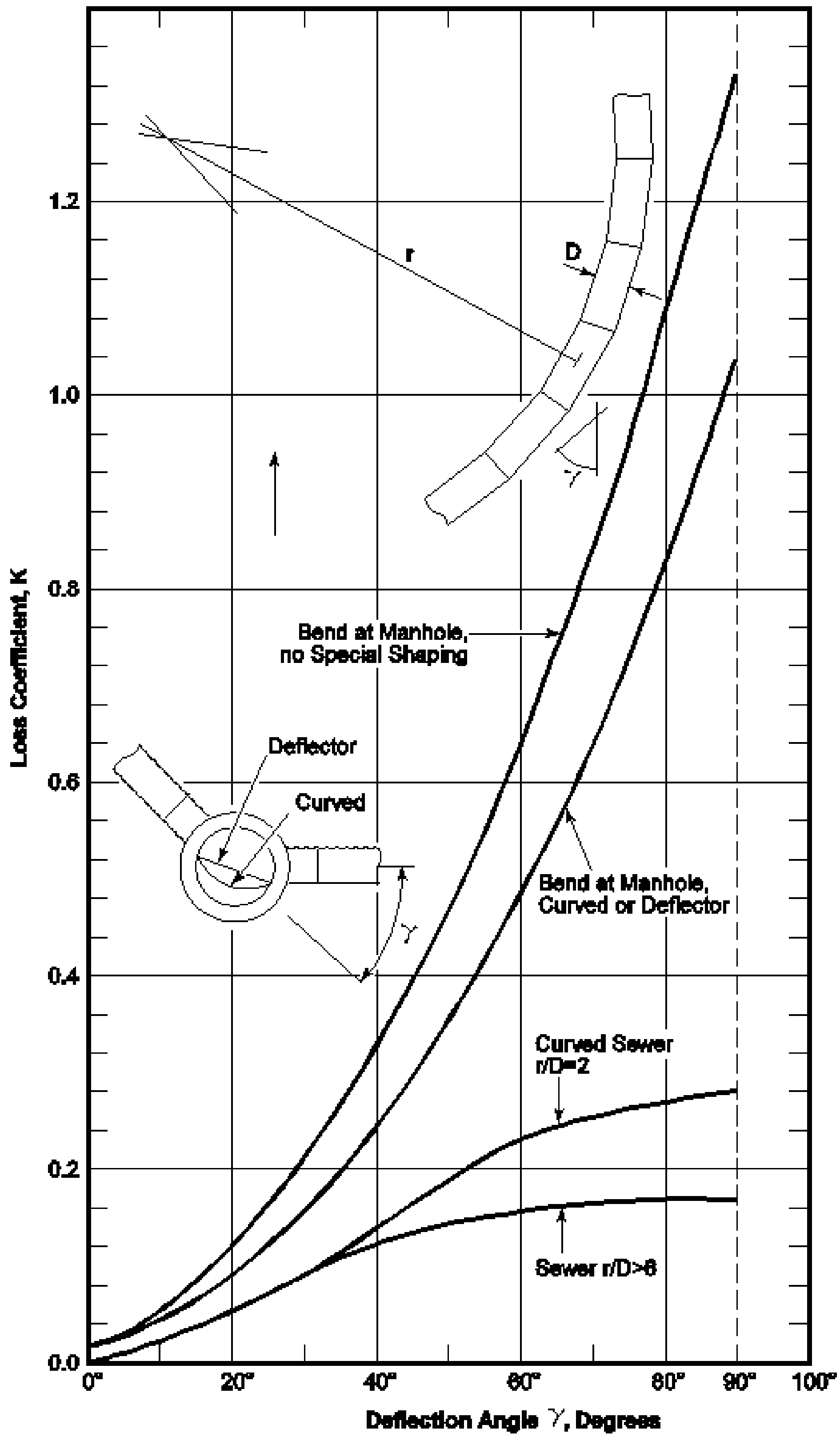

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Figure F.7
Bend Head Losses in Structure

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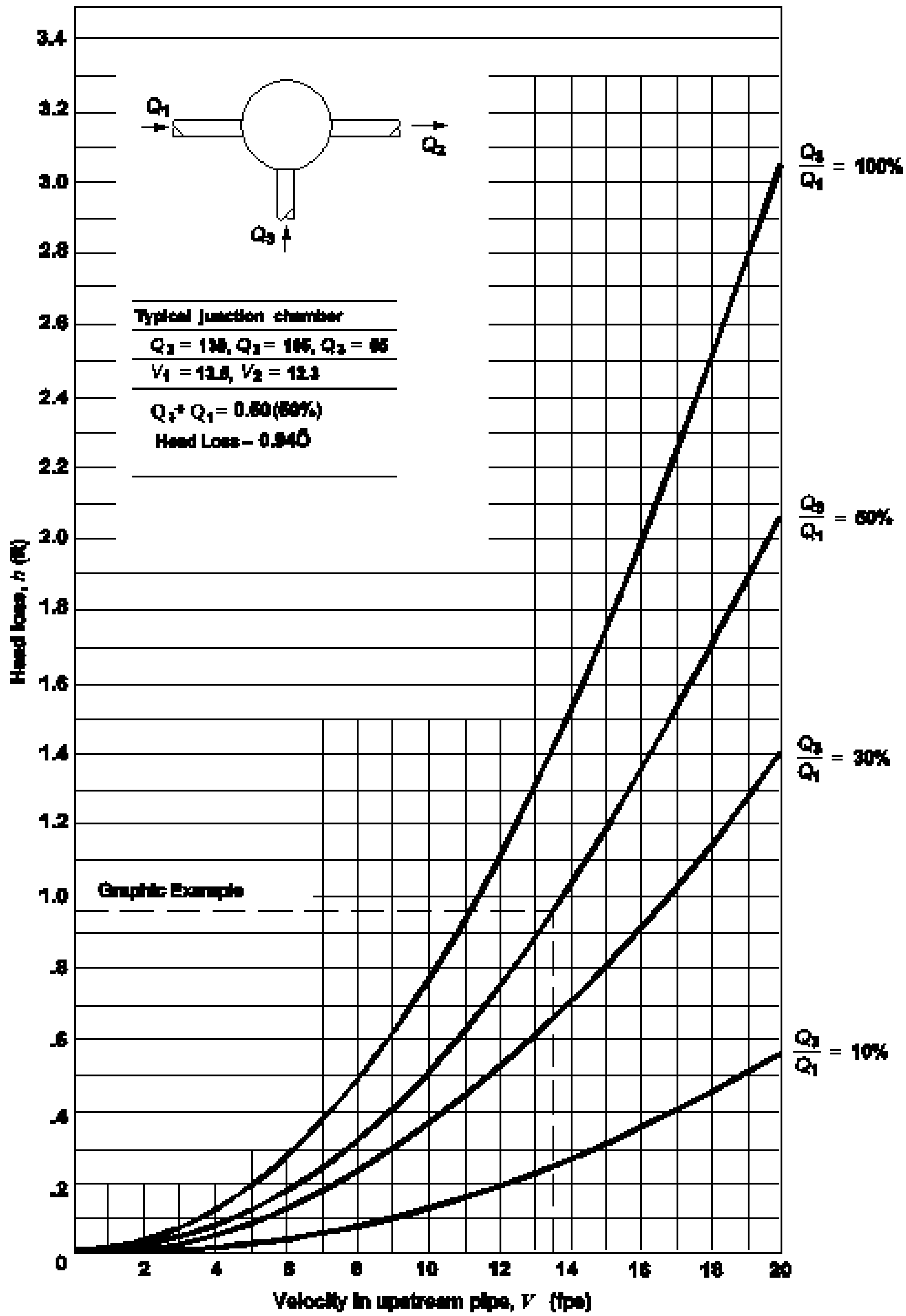

Source: Baltimore County Department of Public Works

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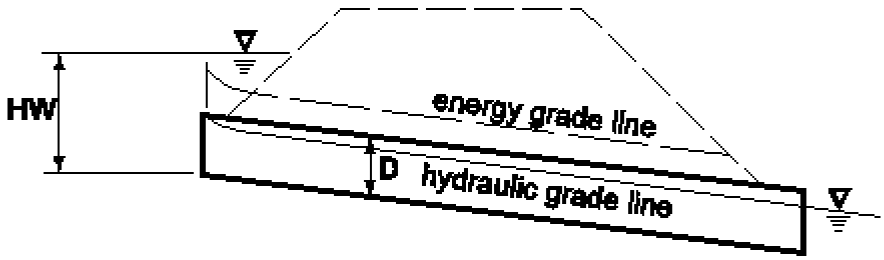
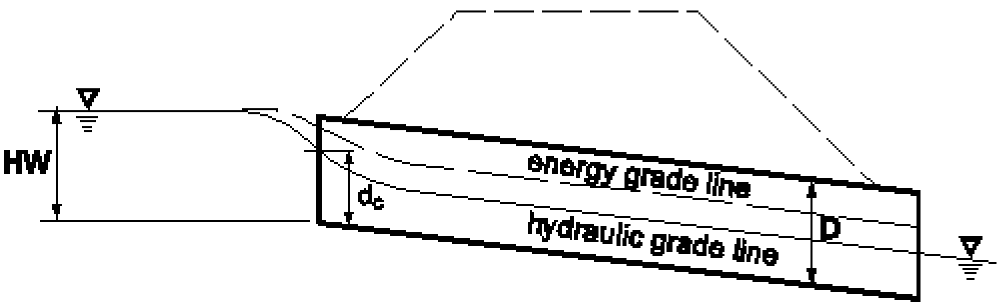
Figure F.8
Junction Head Loss in Structure

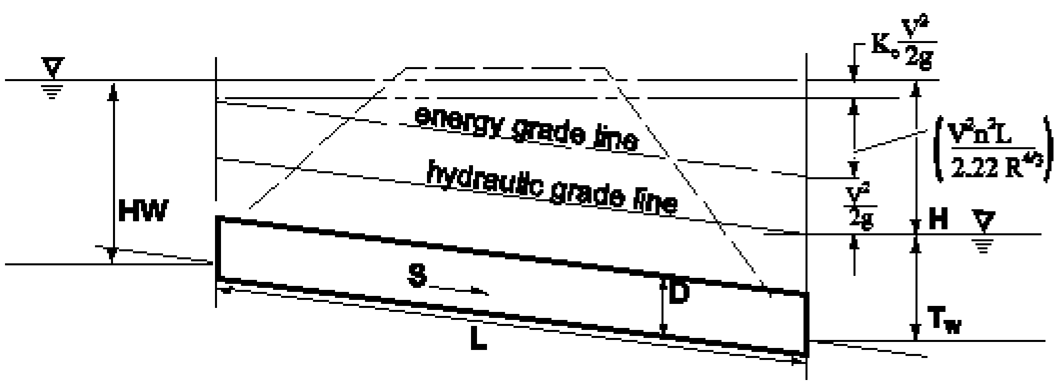
March 2020



Inlet Control - Submerged Inlet



Inlet Control - Unsubmerged Inlet



Outlet Control - Submerged Inlet and Outlet

NOTE: See FHWA no. 5 for other possible conditions

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Figure F.9
Inlet/Outlet Control Conditions

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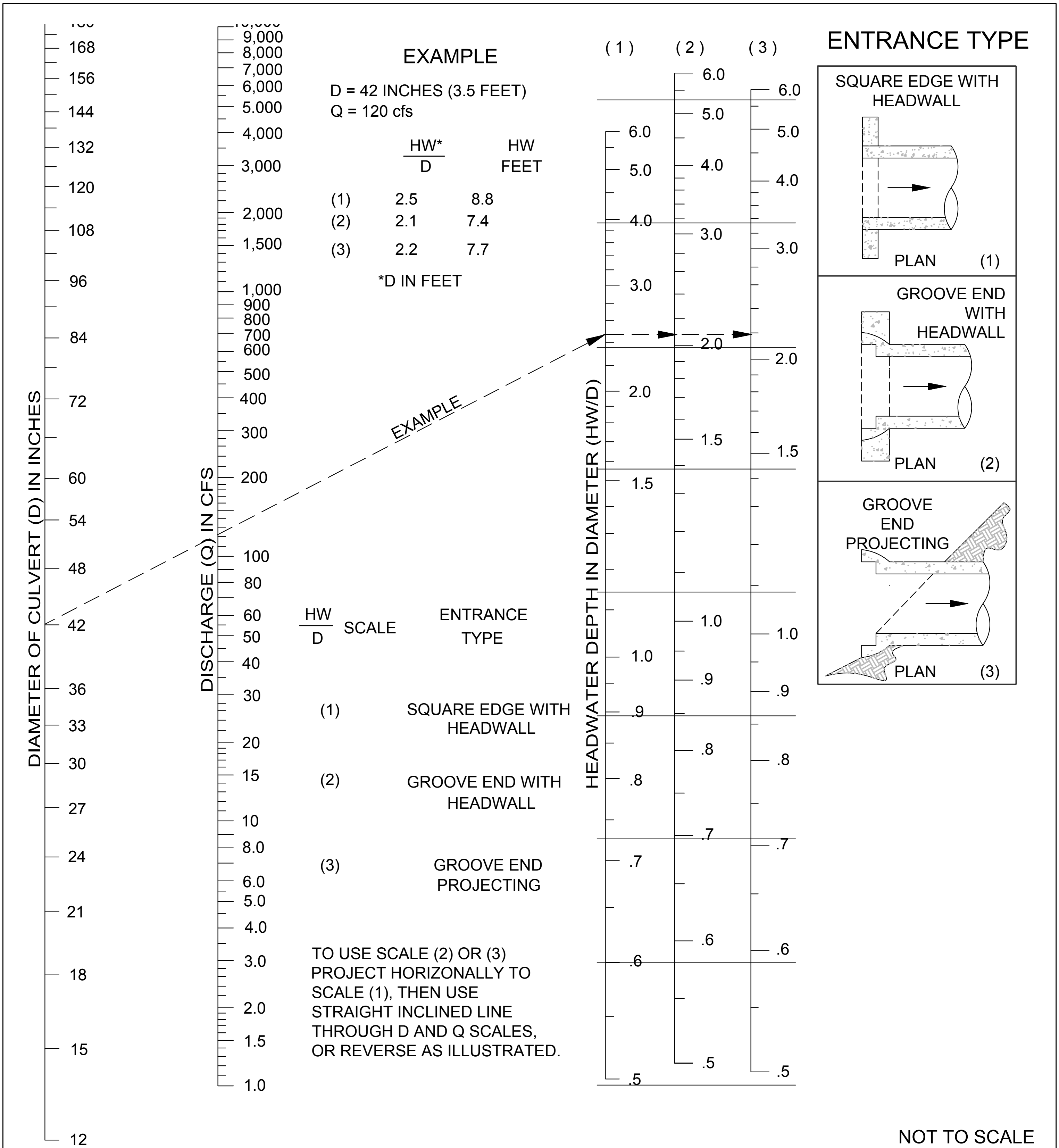

Figure F.10
Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control

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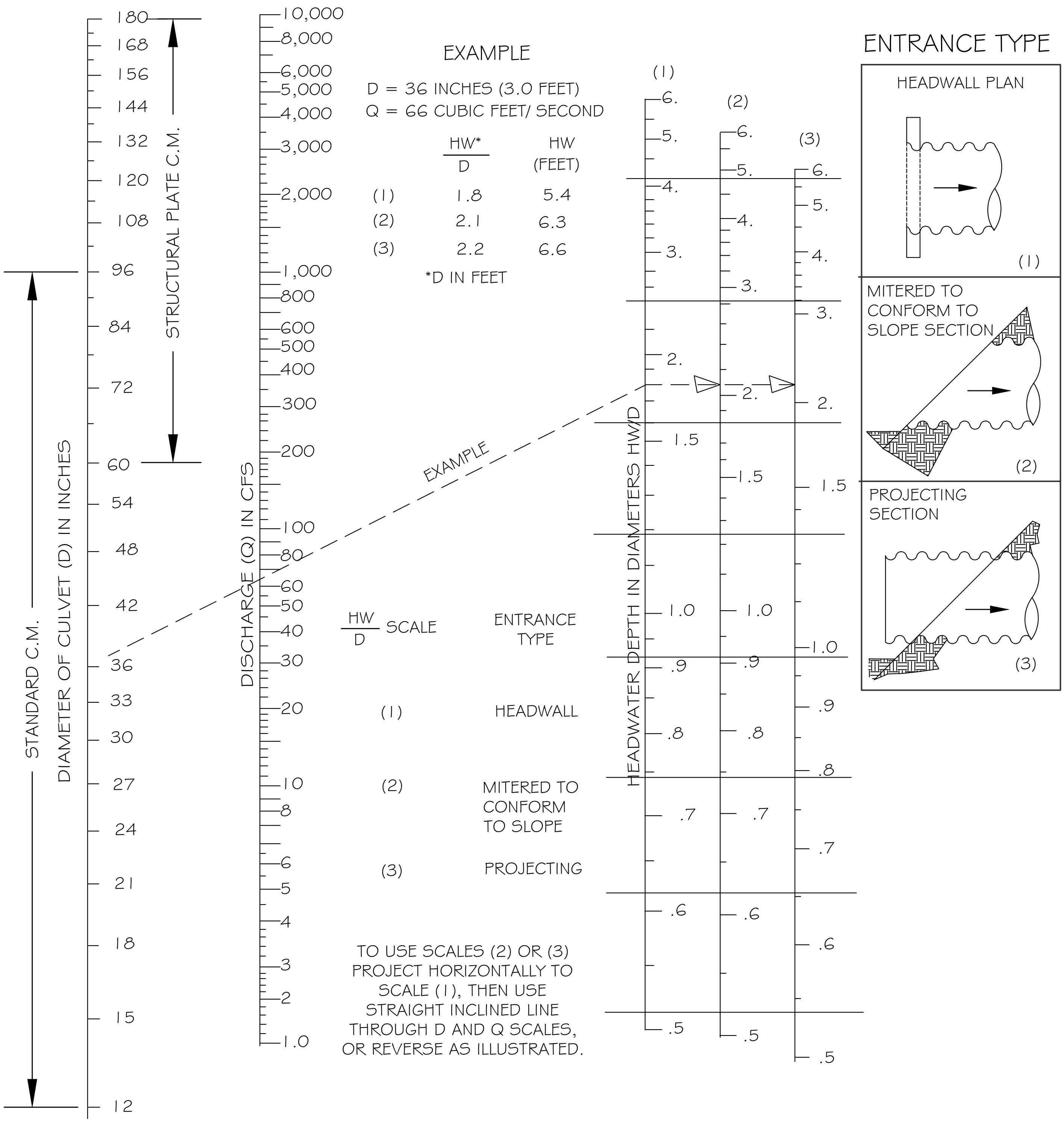

NOT TO SCALE

Figure F.11
Headwater Depth for Corrugated Pipe Culverts with Inlet Control

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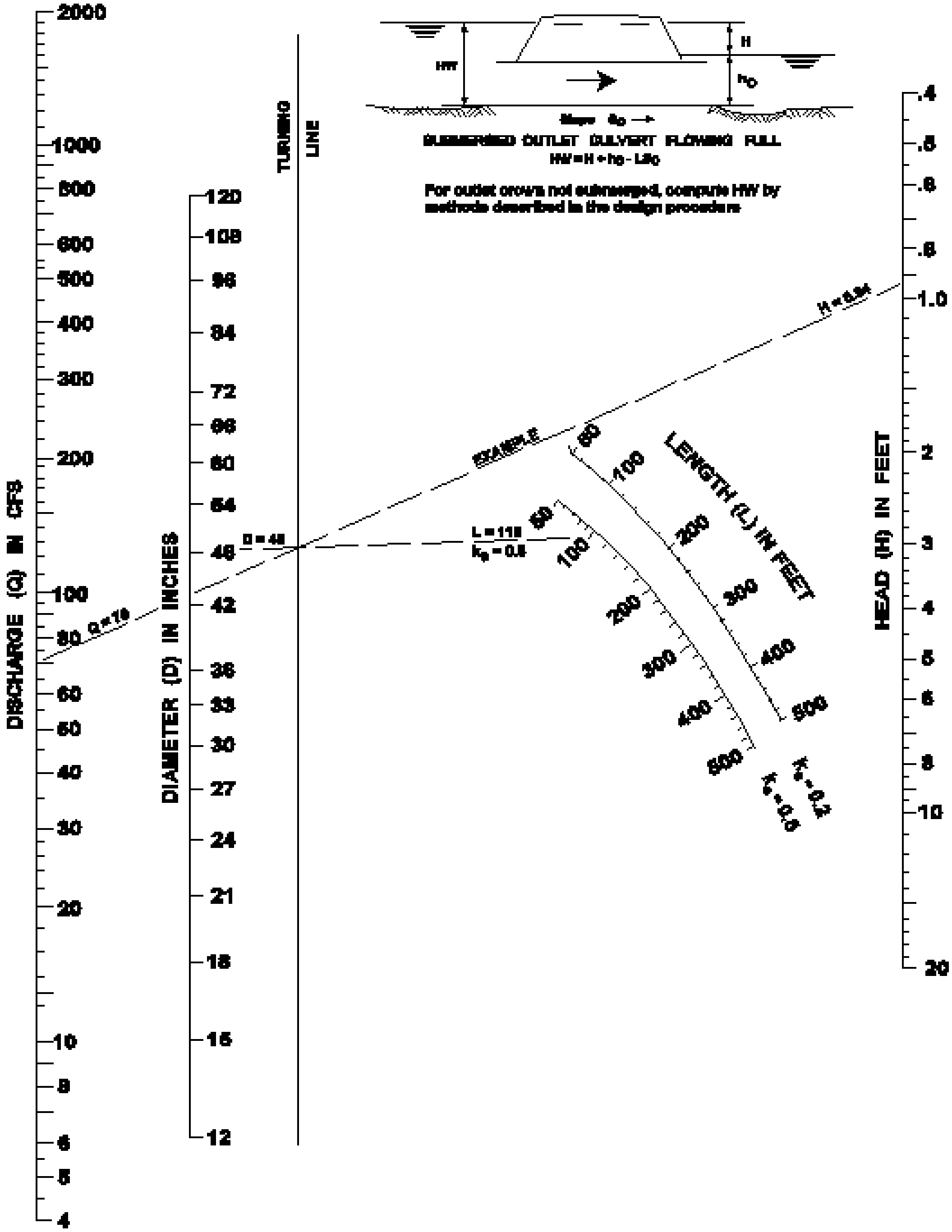

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Figure F.12
Head for Culverts (Pipe with n=0.012) Flowing Full with Outlet Control

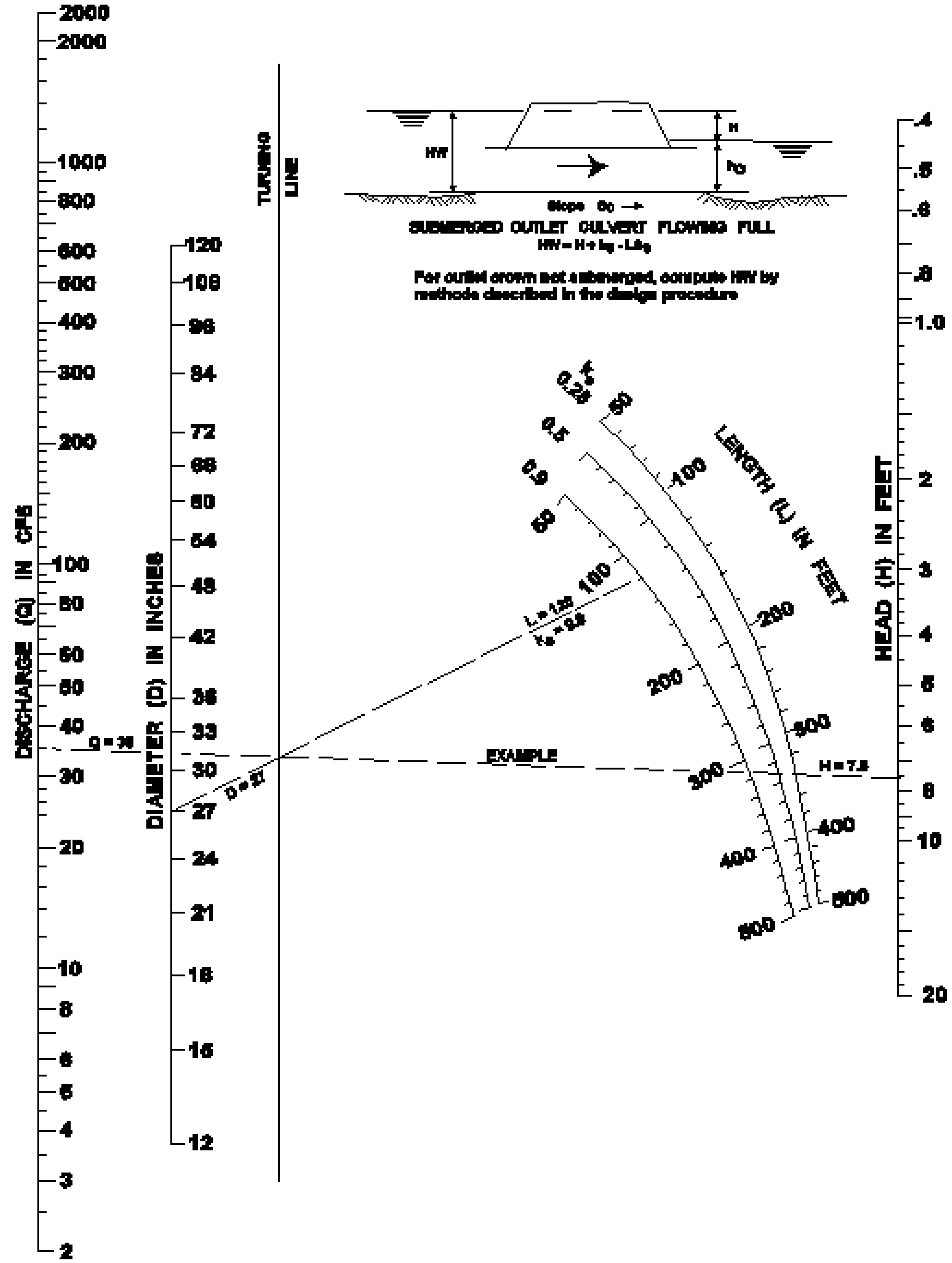
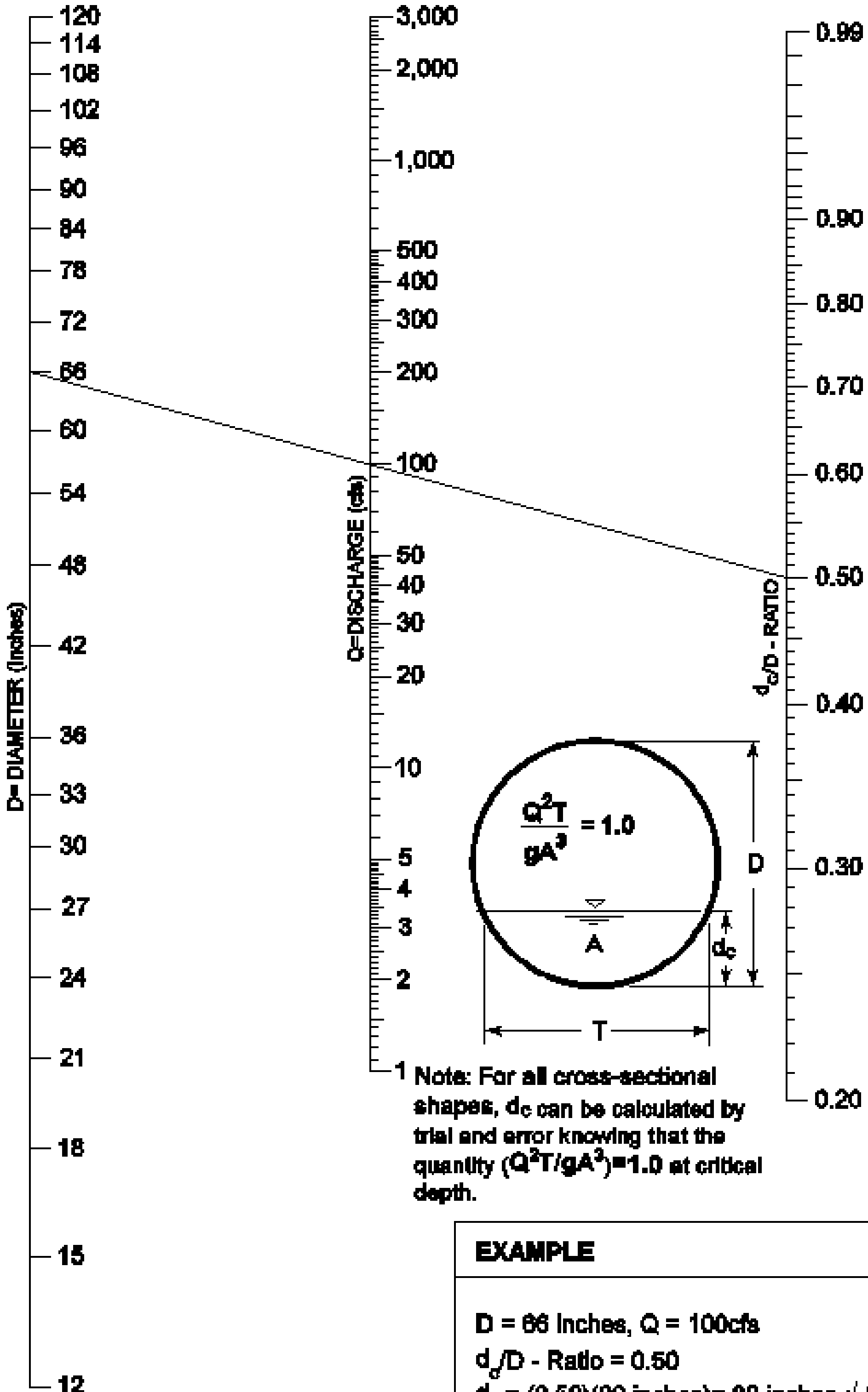


Figure F.13
Head for Culverts (Pipe with n=0.024) Flowing Full with Outlet Control

March 2020



Note: For all cross-sectional shapes, d_c can be calculated by trial and error knowing that the quantity $(Q^2T/gA^3)=1.0$ at critical depth.

EXAMPLE

D = 66 Inches, Q = 100cfs

d_c/D - Ratio = 0.50

d_c = (0.50)(66 inches)= 33 inches √ (12 inches/ft)

d_c= 2.75 feet

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Figure F.14
Critical Depth of Flow for Circular Culverts

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Q = ______ n = ______ S_o = ______ α = ______ Y_n = ______

y	A	R	$R^{4/3}$	V	$\alpha V^2/2g$	E	ΔE	S_f	$\bar{S}_f$	$S_o - \bar{S}_f$	Δx	x
-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13

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Figure F.15
Open Channel Flow Profile Computation

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y	A	R	$R^{4/3}$	V	$\alpha V^2/2g$	E	ΔE	S_f	$\bar{S}_f$	$S_o - \bar{S}_f$	Δx	x
-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13
6	72	2.68	3.72	0.42	0.0031	6.0031	-	0.00002	-	-	-	-
5.5	60.5	2.46	3.31	0.5	0.004	5.504	0.499	0.00003	0.000025	0.00698	71.5	71.5
5	50	2.24	2.92	0.6	0.0064	5.0064	0.4976	0.00005	0.00004	0.00696	71.49	142.99
4.5	40.5	2.01	2.54	0.74	0.0098	4.5098	0.4966	0.00009	0.00007	0.00693	71.64	214.63
4	32	1.79	2.17	0.94	0.0157	4.0157	0.4941	0.00016	0.000127	0.00687	71.89	286.52
3.5	24.5	1.57	1.82	1.22	0.0268	3.5268	0.4889	0.00033	0.000246	0.00675	72.38	358.9
3	18	1.34	1.48	1.67	0.0496	3.0496	0.4772	0.00076	0.000547	0.00645	73.95	432.85
2.5	12.5	1.12	1.16	2.4	0.1029	2.6029	0.4467	0.00201	0.001387	0.00561	79.58	512.43
2	8	0.89	0.86	3.75	0.2511	2.2511	0.3518	0.00663	0.00432	0.00268	131.27	643.7

The step computations are carried out as shown in the above table. The values in each column of the table are explained as follows:

Col. 1. Depth of flow (ft) assigned from 6 to 2 feet

Col. 2. Water area (ft^2) corresponding to depth y in Col. 1

Col. 3 Hydraulic radius (ft) corresponding to y in Col. 1

Col. 4. Four-thirds power of the hydraulic radius

Col. 5. Mean velocity (fps) obtained by dividing Q (30 cfs) by the water area in Col. 2

Col. 6. Velocity head (ft)

Col. 7. Specific energy (ft) obtained by adding the velocity head in Col. 6 to depth of flow in Col. 1

Col. 8. Change of specific energy (ft) equal to the difference between the E value in Col. 7 and that of the previous step.

Col. 9. Friction slope S_f, computed from V as given in Col. 5 and $R^{4/3}$ in Col. 4

Col.10. Average friction slope between the steps, equal to the arithmetic mean of the friction slope just computed in Col. 9 and that of the previous step

Col.11. Difference between the bottom slope, S_o, and the average friction slope, S_f

Col.12. Length of the reach (ft) between the consecutive steps;
Computed by $x = E/(S_o - S_f)$ or by dividing the value in Col. 8 by the value in Col. 11

Col.13. Distance from the beginning point to the section under consideration. This is equal to the cumulative sum of the values in Col. 12 computed for previous steps.

Figure F.16
Open Channel Flow Profile Computation (Example)

March 2020

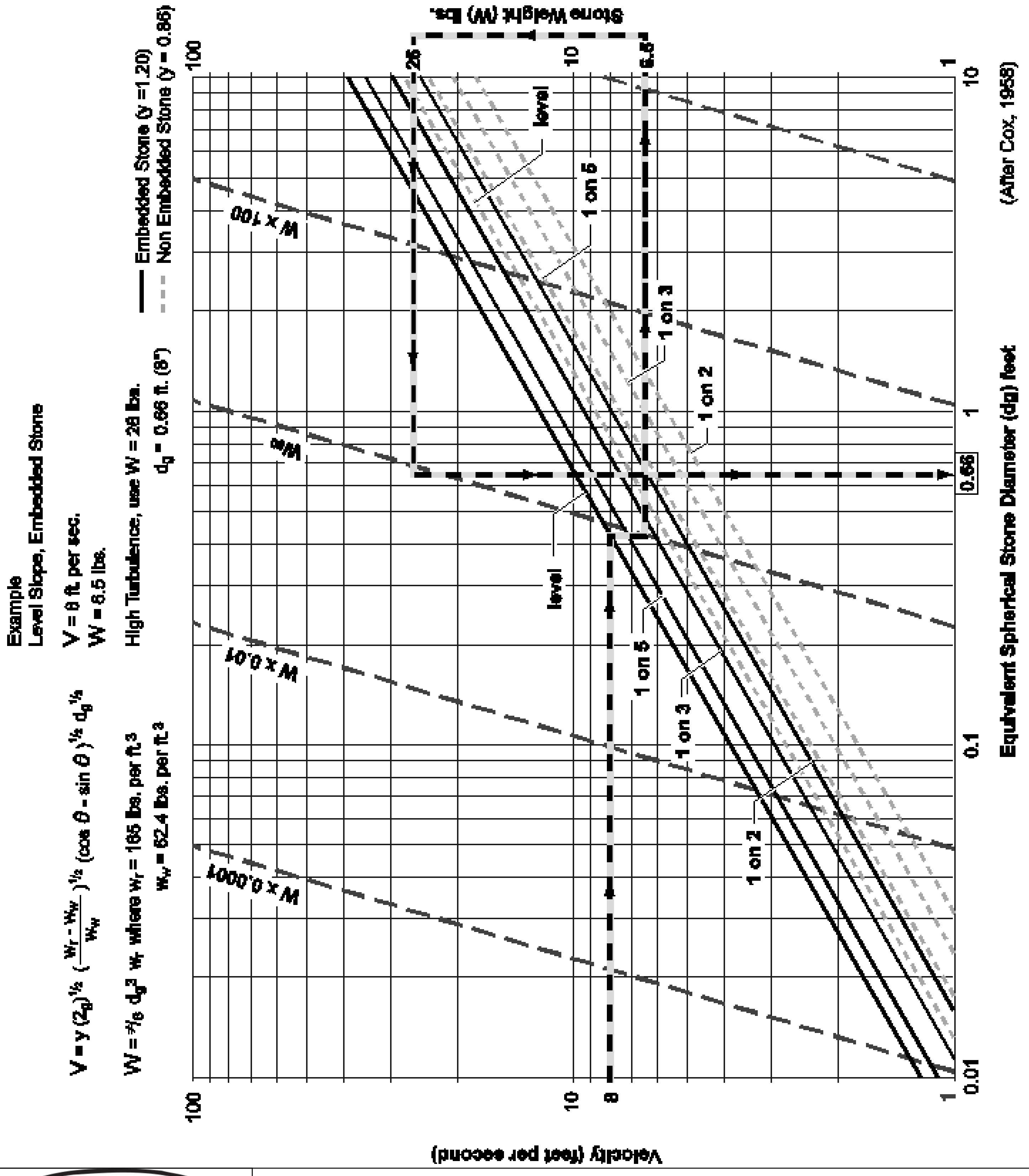

Figure F.17
Mean Channel Velocity vs Medium Stone Weight and Equivalent Stone Diameter

March 2020

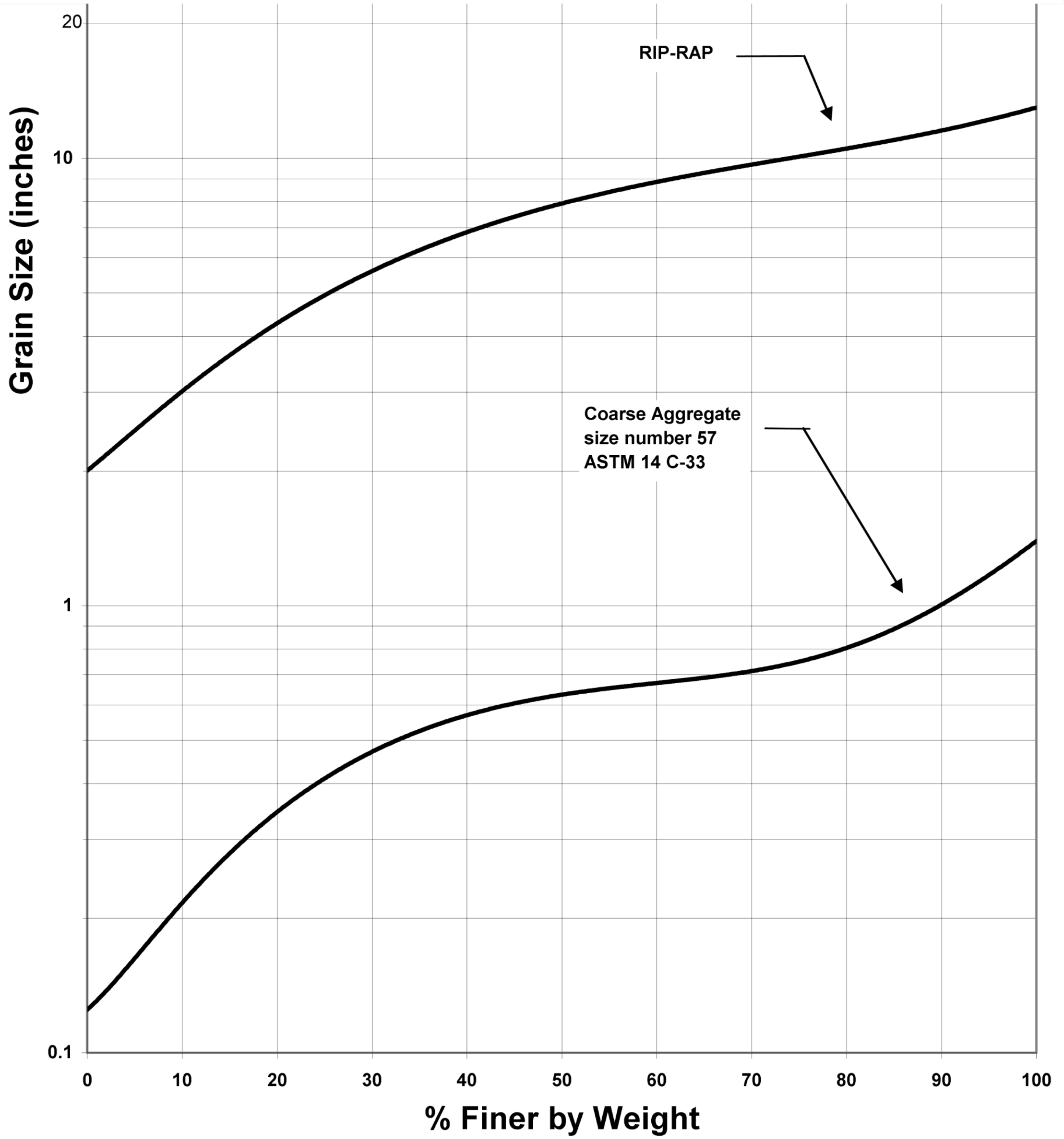

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Figure F.18
Riprap/Filter Example Gradation Curve

March 2020