Maine Department of Transportation

Environmental Office

Design Guidance

Title: Culvert Sizing	Issue Date: May 21, 2015
Discipline: Hydrology	
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Background:

There is a real likelihood of increased peak flows over the expected life spans of structures now being installed (e.g., 80 – 100 years for reinforced concrete pipe). The challenge is to size structures so that they protect public safety and system integrity now as well as at the end of their useful life. The proposed standard delivers this resilience in a manner consistent with engineering practice and responsible allocation of department resources.

The current standard for sizing large culverts has $H_w/D <= 1.5$ at the 50-year peak flow (Q50). This standard has "worked" over the more recent historical recent, with remarkably rare failures of designed structures attributable to inadequate capacity.

Guidance:

There is concern that this design approach will not hold up under a scenario of increasing peak flows. Therefore, a new large culvert design is proposed, with preference given to sizing for Hw/D = 1 at the 100-year peak flow event (Q100). Peak flow hydrology equations are typically updated on a 20-year cycle. Thus, an 80-year culvert might experience 100 years of increasing peak flows. Using a 0.5 mi^2 watershed example, the old standard would give 4-ft diameter while the proposed standard would give 5-ft diameter ($H_w/D = 1$ and Q100). This 5-ft pipe has $H_w/D = 1.5$ at a flow that is 80% greater than the design Q100. Even with an 80% increase in design peak flow, the 5-ft pipe would be performing the same as the 4-ft pipe designed for unchanging "old" hydrology. Thus, the proposed standard delivers a level of resilience that is directly comparable to the current design standard that has "worked" over the period of historical engineering design (since the mid-60's or so).

To satisfy the regulatory requirement for an alternatives analysis and to show consideration of habitat for Atlantic salmon, Eastern brook trout, and other cold water aquatic species, each crossing project should consider sizing at the following hierarchy: 1.2 times the bankfull stream width (bfw), Q100, and Q50. In addition to the hydrological justification provided above, sizing structures at 1.2 bfw with either natural bottom (i.e. 3-sided structures) or stream simulation substrate design in the pipe is the regulatory preference and often results in a more streamlined resource agency review. Design selection should be based on the best engineering outcome, the best environmental outcome, and cost efficiency.

Preliminary

Culvert-Sizing Tables

Table A1. Preliminary Large Culvert Sizing (Round Diameter in ft) for 100-Year Flow Event from Combinations of Watershed Area and Wetlands for Natural Streams, culvert not embedded.

Watershed Area A (mi^2)	**NWI Wetlands W (%) (STORNWI from StreamStats)**						**BFW**	**1.2 x BFW**
(DRNAREA from StreamStats)	**0**	**5**	**10**	**15**	**20**	**25**		
< 0.25	3	3	3	3	3	3	3	3.6
0.25	4.5	4	3.5	3.5	3	3	3.7	4.5
0.50	5	5	4.5	4	4	3.5	5.3	6.4
0.75	6	6	5	4.5	4.5	4	6.6	7.9
1.00	7	6	6	5	4.5	4.5	7.7	9.2
1.25	7	7	6	6	5	4.5	8.6	10.3
1.50	8	7	6	6	5	5	9.5	11.4
1.75	8	7	7	6	6	5	10.3	12.3
2.00	8	8	7	7	6	5	11.0	13.2
2.25	9	8	7	7	6	6	11.7	14.0
2.50	9	8	8	7	6	6	12.4	14.8
2.75	9	9	8	7	7	6	13.0	15.6
3.00	10	9	8	7	7	6	13.6	16.3

Notes: sized for $H_w/D \simeq 1$ (approx.) at Q_{100}, not embedded; BFW = Bankfull Width

Table A2. Preliminary Large Culvert Sizing (Round Diameter in ft) for 100-Year Flow Event from Combinations of Watershed Area and Wetlands, adjusted for 25% embedment, for Natural Streams.

Watershed Area A (mi^2)	**NWI Wetlands W (%)**	**(STORNWI from StreamStats)**					**BFW**	**1.2 x BFW**
(DRNAREA from StreamStats)	**0**	**5**	**10**	**15**	**20**	**25**		
< 0.25	3.5	3.5	3.5	3.5	3.5	3.5	3	3.6
0.25	5	4.5	4.5	3.5	3.5	3.5	3.7	4.5
0.50	6	5	5	4.5	4	4	5.3	6.4
0.75	7	6	6	5	5	4.5	6.6	7.9
1.00	8	7	6	6	5	5	7.7	9.2
1.25	8	7	7	6	6	5	8.6	10.3
1.50	9	8	7	7	6	6	9.5	11.4
1.75	9	8	8	7	6	6	10.3	12.3
2.00	9	9	8	7	7	6	11.0	13.2
2.25	10	9	8	8	7	6	11.7	14.0
2.50	10	9	9	8	7	7	12.4	14.8
2.75	10	10	9	8	7	7	13.0	15.6
3.00	10	10	9	8	8	7	13.6	16.3

Notes: sized for $H_w/D \simeq 1$ (approx.) at Q_{100}, embedded 0.25 x D; BFW = Bankfull Width

Table A3. Preliminary Cross-Culvert Sizing (Round Diameter in ft) for 50-Year Flow Event from Combinations of Watershed Area and Wetlands for Natural Streams, culvert not embedded.

Watershed Area A (mi^2)	**NWI Wetlands W (%) (STORNWI from StreamStats)**						**BFW**	**1.2 x BFW**
(DRNAREA from StreamStats)	**0**	**5**	**10**	**15**	**20**	**25**		
< 0.25	3	3	3	3	2.5	2.5	3	3.6
0.25	3.5	3.5	3	3	2.5	2.5	3.7	4.5
0.50	4.5	4	4	3.5	3	3	5.3	6.4
0.75			4.5	4	3.5	3.5	6.6	7.9
1.00				4.5	4	3.5	7.7	9.2
1.25					4.5	4	8.6	10.3
1.50					4.5	4	9.5	11.4
1.75						4.5	10.3	12.3
2.00						4.5	11.0	13.2
2.25							11.7	14.0
2.50							12.4	14.8
2.75							13.0	15.6
3.00							13.6	16.3

Notes: sized for $H_w/D \simeq 1.5$ (approx.) at Q_{50}, not embedded; BFW = Bankfull Width; if blank cell, use Table A1 or A2.

Table A4. Preliminary Cross-Culvert Sizing (Round Diameter in ft) for 50-Year Flow Event from Combinations of Watershed Area and Wetlands for Natural Streams, adjusted for 25% embedment.

Watershed Area A (mi^2)	**NWI Wetlands W (%) (STORNWI from StreamStats)**						**BFW**	**1.2 x BFW**
(DRNAREA from StreamStats)	**0**	**5**	**10**	**15**	**20**	**25**		
< 0.25	3.5	3.5	3.5	3.5	3	3	3	3.6
0.25	4	3.5	3.5	3.5	3	3	3.7	4.5
0.50	4.5	4	4	3.5	3	3	5.3	6.4
0.75				4.5	4	3.5	6.6	7.9
1.00					4.5	4	7.7	9.2
1.25						4.5	8.6	10.3
1.50						4.5	9.5	11.4
1.75							10.3	12.3
2.00							11.0	13.2
2.25							11.7	14.0
2.50							12.4	14.8
2.75							13.0	15.6
3.00							13.6	16.3

Notes: sized for $H_w/D \simeq 1.5$ (approx.) at Q_{50}, embedded 0.25 x D; BFW = Bankfull Width; if blank cell use Table A1 or A2.

Notes and Instructions for Using Tables – Preliminary Culvert Sizing

1) ***These Tables are For Preliminary Scoping / Sizing Only. Final Design should be prepared by an engineer using HY-8 culvert software.***

2) Tables A1 and A2 are based on round CMP, inlet control, $H_w/D = 1$ at Q_{100} (100-year flow event). Tables A3 and A4 are based on round CMP, inlet control, $H_w/D = 1.5$ at Q_{50} (50-year flow event).

3) Q_{100} calculated as $Q_{100} = 238.781 \times A^{0.817} \times 10^{(-0.018W)}$, Q_{50} calculated as $Q_{50} = 204.174 \times A^{0.816} \times 10^{(-0.018W)}$ (from Maine regression equations by Lombard & Hodgkins, 2015). Use table only for natural streams in undeveloped watersheds. Not appropriate for urban applications or storm water conveyances.

4) Use StreamStats to generate Basin Characteristics Report.

5) Obtain watershed area A (in square miles; listed as DRNAREA in Basin Report) and NWI wetlands W (as percent; listed as STORNWI in Basin Report).

6) Start with Table A4 (culvert embedded 25% of D). If indicated culvert size will not fit, use Table A3 (culvert not embedded). If culvert diameter is not indicated (blank cell) for watershed area and wetlands, use Tables A1 and A2.

7) Look up round pipe diameter (in feet) in appropriate table. When more than halfway between listed watershed area A and/or NWI wetlands W, go to next larger diameter.

8) Other pipe shapes may be used (arch or elliptical), as long as open end areas are equivalent to the round pipe diameter from Table A1.

9) Culverts sized with these tables may not be in compliance with other State and Federal permitting requirements, for example, stream width (Bankfull Width = BFW) sizing for fish passage. Always check with Maine Dept. of Inland Fisheries and Wildlife.

10) Permitting may require that culverts are backfilled with Engineered Streambed Material (ESM) in order to create a nature-like streambed. This backfill will reduce the nominal culvert capacity. A Professional Engineer should be retained to design a stable ESM and to confirm that the effective hydraulic capacity at Q_{100} is preserved. If backfilling, use Table A2 to account for lost capacity. Do not backfill culverts smaller than D = 6’.

11) Examples:

a. A = 0.75 mi^2, W = 10% . Look up diameter D = 5-ft unembedded, 6-ft embedded.

b. A = 1.35 mi^2, W = 7%. Look up diameter D = 7 ft unembedded, 7-ft embedded.

References:

Lombard, P.J., and Hodgkins, G.A., 2015, Peak flow regression equations for small, ungaged streams in Maine—Comparing map-based to field-based variables: U.S. Geological Survey Scientific Investigations Report 2015–5049, 12 p., http://dx.doi.org/10.3133/sir20155049 .

U.S. Geological Survey, 2015, The StreamStats program for Maine, online at http://water.usgs.gov/osw/streamstats/maine.html.

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