

## New England District, U.S. Army Corps of Engineers, Regulatory Division Openness Ratio Spreadsheet

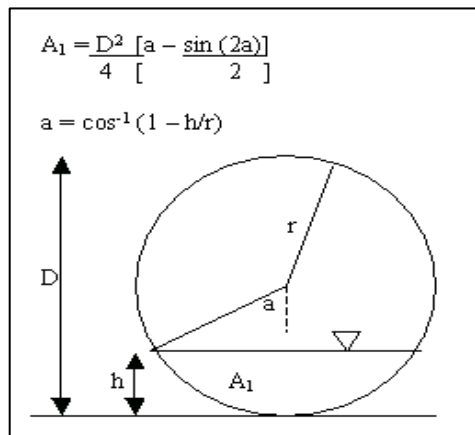
- Openness Ratio (OR) is calculated by dividing a culvert's cross-sectional area by its length:  $OR = \frac{x\text{-sec area}}{\text{length}}$
- Along with other criteria, the MA PGP, General Condition 21, states that to qualify for the Category 1 (non-reporting):
  1. New permanent stream crossings must have an  $OR \geq .25$   
 $OR = .25 = \frac{(x\text{-sec area})}{\text{culvert length}}$  or  $OR = .25 = \frac{[(x\text{-sec culvert area pre-embed}) - \text{embedded area}]}{\text{culvert length}}$
  2. Round culverts must be embedded at least 25%
- The chart below provides the diameter needed to meet the .25 OR for various culvert lengths, accounting for the embedded area, when embedding 25%. All calculations must be done in meters. The conversion to feet is provided.
- The Corps uses the .25 OR as a guide for Category 2 projects reviews.

Required Diameter for .25 OR & 25% Embedment					
Length		Required Open Area		Required Diameter	
(FT)	(M)	(FT <sup>2</sup> )	(M <sup>2</sup> )	(FT)	(M)
6	1.83	4.92	0.46	2.79	0.85
8	2.44	6.56	0.61	3.23	0.98
10	3.05	8.20	0.76	3.61	1.10
12	3.66	9.84	0.91	3.95	1.21
14	4.27	11.48	1.07	4.27	1.30
16	4.88	13.12	1.22	4.56	1.39
18	5.49	14.76	1.37	4.84	1.48
20	6.10	16.40	1.52	5.10	1.56
22	6.71	18.04	1.68	5.35	1.63
24	7.32	19.68	1.83	5.59	1.70
26	7.93	21.32	1.98	5.82	1.77
28	8.54	22.96	2.13	6.04	1.84
30	9.15	24.60	2.29	6.25	1.91
32	9.76	26.24	2.44	6.45	1.97
34	10.37	27.88	2.59	6.65	2.03
36	10.98	29.52	2.74	6.85	2.09
38	11.59	31.16	2.90	7.03	2.14
40	12.20	32.80	3.05	7.22	2.20
42	12.80	34.44	3.20	7.39	2.25
44	13.41	36.08	3.35	7.57	2.31
46	14.02	37.72	3.51	7.74	2.36
48	14.63	39.36	3.66	7.90	2.41
50	15.24	41.00	3.81	8.07	2.46

### Derivation

1. The MA PGP, Category 1 requires:
  - \* 25% culvert embedment (= .25 x culvert diameter)
  - \* .25 openness ratio

2. Embedded area calculated as follows:



Notes:

- \* a is in radians
- \*  $a = 60^\circ = 1.05$  radians, if  $h = .25D$
- \*  $A_1$  = embedded area

3.  $OR = .25 = \frac{[(x\text{-sec culvert area pre-embed}) - \text{embedded area}]}{\text{culvert length}}$

where:

- \* x-sec area =  $\frac{\pi D^2}{4}$
- \* embedded area for 25% embed =  $.62D^2/4 = (A_1)$
- \* culvert length = L

Therefore:

$$.25 = \frac{\frac{\pi D^2}{4} - .62D^2/4}{L}$$

or

$$D = .63L^{1/2}$$