University of Missouri Extension

G1606, Reviewed October 1993

Culverts and Flood Gates

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The tables in this publication may be used to find culvert and flood gate size for bottomland drainage up to 640 acres.

A formula frequently used for calculating drainage flow rates of cultivated areas from one to one hundred square miles area in the Midwest is:

$Q = 37\ M^{.833}$ where

M = square miles of watershed area

Q = design flow rate in cubic feet per second. This corresponds to the "C" drainage curve.

The exponent (.833) being less than 1.0 implies that as the area increases (M gets larger), the flow rate per square mile is decreasing, even though the total flow rate is increasing. Local ponding near the outlet is expected. For small acreages, very little damage is expected provided the outlet can flow freely. If outlets are closed due to high stage outside the levee area, then the period of ponding increases and no drainage may occur. In some cases pump drainage may be necessary.

Use of a formula such as the one given has developed from practical field experience with drainage in several states. It is usually used on areas above two sections in drainage area.

Table 1 lists flow rates calculated from the formula above and simpler 2 inches per day and 1-1/2 inches per day rates. It is evident from the table that areas less than a half section might be figured at 2 inches per day and areas between one-half and one section can be figured at 1-1/2 inches per day.

Table 1
Design flow rates

Area		Design flow rate, cfs		
Acres	**Square miles**	**$Q = 37M^{.833}$**	**2 inches per day (acres/12)**	**1.5 inches per day (acres/16)**
40	0.0625 (1/16)	3.7	3.3	

64	0.1	5.4	5.3	
80	0.125 (1/8)	6.5	6.7	
120	0.1875 (3/16)	9.2	10.0	
128	0.2	9.7	10.7	
160	0.25 (1/4)	11.7	13.3	
192	0.3	13.6	16.0	
200	0.3125 (5/16)	14.0	16.7	
240	0.375 (3/8)	16.3	20.0	
256	0.4	17.2	21.3	
280	0.4375 (7/16)	18.6	20.0	17.5
320	0.5 (1/2)	20.8	26.7	20.0
360	0.5625 (9/16)	22.9	30.0	22.5
384	0.6	24.2	32.0	24.0
400	0.625 (5/8)	25.0	33.3	25.0
440	0.6875 (11/16)	27.1	36.7	27.5
448	0.7	27.5	37.3	28.0
480	0.75 (3/4)	29.1	40.0	30.0
512	0.8	30.7	42.7	32.0
520	0.8125 (13/16)	31.1	43.3	32.5
560	0.875	33.1	46.7	35.0
576	0.9	33.9	48.0	36.0
600	0.9375 (15/16)	35.1	50.0	37.5
640	1.0	37.0	53.3	40.0

The Natural Resources Conservation Service in Missouri uses a 4 inches per day design flow rate up to 60 acres. Double the values in the 2 inches per day column if you use this criteria. If no ponding near the outlet is the goal, then the higher rates must be used. The final choice will be influenced by the price of the installation.

If some hill land drainage must be handled by the same culvert, double the hill land acreage and add that number to the number of bottomland acres. Then choose a design flow rate.

G1518 gives a procedure for estimating runoff from small watersheds. The assumptions and factors are explained in the first column of that publication. Using that procedure, the peak rate of runoff for a six month return period for 80 acres of row cropland in Callaway county on an average soil similar to Shelby loam, in infiltration characteristics with average 0.5 percent slope, and outlet near a corner, can be expected to be:

Q = 205 x 1 x 1 x 0.5 x 1 x 1 x 1 x 0.2 = 20.5 cfs.

Our design flow rate from Table 1 for drainage culvert and gate selection is 6.7 cfs for 2 inches per day or 13.3 cfs for 4 inches per day. This suggests temporary ponding will occur as often as twice a year on the average.

Select the appropriate culvert size. The flow rate through the culverts follows a square root law:

Q = C A x the square root of 2 gh

Q = flow rate in cubic feet per second
A = cross section area of the culvert
g = gravitational constant, 32.2 feet per second^2
h = head on the culvert, feet
C = a coefficient that varies with both diameter and length of culverts. Values used are from King's *Handbook of Hydraulics,* fifth edition, Table 4-11 for corrugated metal pipe.

Table 2 gives some of the possible flow rates. The assumptions here are full pipe flow and culvert lengths of 50 feet and 100 feet. The low head condition is water depth of 1.5 feet above the top of the culvert plus one-half the diameter for the 50-foot culvert and 2 feet above culvert top plus one-half the diameter for the 100-foot culvert. The higher head condition in Table 2 is 3.5 feet above the top of the tube plus one-half the diameter for the 50-foot culvert and 4 feet plus one-half the diameter for the 100-foot culvert.

Table 2
Culvert flow rates, cfs

Tube diameter	Length	50 feet	100 feet	50 feet	100 feet
	Head	1.5 feet + D/2	2.0 feet + D/2	3.5 feet + D/2	4.0 feet + D/2
12 inches	1.0	3.5	2.9	4.9	3.9
15 inches	1.25	6.2	5.3	8.6	7.0
18 inches	1.5	10.0	8.5	13.8	11.1
21 inches	1.75	14.8	16.3	20.1	16.6

24 inches	2.0	21.1	17.9	28.3	23.1
30 inches	2.5	37.2	32.6	46.2	39.4
36 inches	3.0	59.9	52.0	77.4	65.2
42 inches	3.5	94.1	77.7	112.0	96.8
48 inches	4.0	122.6	108.9	153.7	133.4

At low head a canopy or hood inlet or horizontal baffle will be necessary to cause full pipe flow. Without some entrance control, the normal swirling action of the water will entrap air and reduce capacity.

Many possible head conditions may prevail in a field installation. The sketches suggest some of the possible arrangements. In drainage work, the head is normally changing continually. After runoff ceases, the head gradually falls to zero. The head to use in the table may be thought of as average or nondamaging head.

Head is measured from the level of water above the entrance to the level of water above the outlet or to the center line of the outlet opening, whichever is higher.

If a swinging gate is to be used to prevent floodwaters backing into a field, the culvert should slope less than 1 percent. The flood gate can be adjusted to close by gravity if the culvert is no steeper. If there is sufficient difference in elevation between the field level and usual outlet discharge level, a drop entrance may be used in lieu of a steep slope for the culvert. This makes effective use of the available head.

Where the available head is quite limited, consider parallel small culverts rather than a single large tube. The sketch below illustrates the reason. Tubes flowing partially full carry only a fraction of the flow in the tables.

If seepage problems are expected, anti-seep collars may be needed. Seepage problems are expected where water is ponded for long periods. They also occur if the bottom half of the culvert is not carefully backfilled during construction.

Levees are frequently poorly constructed. Excess seepage or failure of the levee after a few days of saturation frequently occurs.

Coarse sandy soils should not be used for levees. Minimum standards for small projects should include a 4-foot top width and 2:1 side slopes or flatter. Dozer-built levees should be built in 6 inch lifts, with each lift spread and smoothed with the dozer blade and tractor tracks.

If farm machinery must travel on the levee, the top width should be 12 feet at time of construction. If the levee must stand more than 4 feet of backwater, then it must be very carefully built. Consider using rubber-tired carryscraper equipment for earth moving to give extra compaction as it travels the length of the levee while loaded.

G1606, reviewed October 1993

Related MU Extension publications

- G1506, Design Criteria for Diversions
  http://extension.missouri.edu/publications/DisplayPub.aspx?P=G1506
- G1518, Estimating Peak Rates of Runoff From Small Watersheds
  http://extension.missouri.edu/publications/DisplayPub.aspx?P=G1518
- G1520, Discharge Capacity Tables for Canopy, Hood, Morning Glory and Drop Inlet Spillways
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