Waterway Design for Flat Waterways with Out-of-Bank Flow

For waterways and adjacent cropland with slopes of 1 percent or less, out-of-bank flow will be permitted if the flow will not cause erosion. The minimum capacity of the vegetated portion of the waterway shall be the expected runoff from a 2-year - 24-hour storm. The velocity of the flow outside of the vegetated waterway based on the runoff expected from a 10-year - 24-hour storm will not exceed 1.5 fps for easily eroded soils or 2.0 fps for not easily eroded soils, as defined on page IA7-12(2). Following are the minimum steps which must be documented in the design for these waterways:

1. Design grade must be 1 percent or less.
2. Document the texture of the topsoil layer of the soil.
3. Determine the allowable out-of-bank flow depth from Table 1 on page IA7-12(2).
4. Design vegetated waterway for Q_2 using the HP41 waterway program or OHIO waterway design software.
5. Determine the dimensions of the waterway to carry Q_{10}:
    - For trapazoidal waterways, use the same B, Z, and S to solve for the depth. The depth for the Q_{10} flow must be less than or equal to the sum of the waterway depth for the Q_2 flow plus the allowable out-of-bank flow depth (d_1).
    - For parobolic waterways, increase the waterway top width for the Q_2 flow by 6 feet (suggested based on past experience) and solve for the required waterway depth for the Q_{10} flow using the OHIO waterway design software or the HP41 waterway program. Compare the top width (designated T_{10}) with T_a from the following equation:

        $T_a = \{(T_2^2 \times D_{10})/D_2\}^{0.5}$ where T_2 is the top width of the waterway for the Q_2 flow, D_2 is the depth of the waterway for the Q_2 flow, and D_{10} is the required depth for capacity determined for Q_{10}.

        1. Compare T_{10} and T_a. If the difference is more than 1 foot, adjust the top width (T_{10}) and solve again for T_a. If the difference is less than 1 foot, proceed.

        2. The depth (D_{10}) must be less than or equal to the sum of the waterway depth for the Q_2 flow plus the allowable out-of-bank flow depth (d_1).

For example designs see pages IA7-12(3) to IA7-12(8).

Often is is not possible to design waterways with reasonable dimensions that also meet all of the requirements of the standard. In those cases it has been possible and is acceptable to design waterways based on a capacity which is somewhat larger than Q_2 but less than Q_{10}.

TABLE 1. Maximum depths in feet for nonerosive flows (d_1).

Rows parallel to waterway (n = 0.035)		
S	V_{max} = 1.5 fps*	V_{max} = 2.0 fps**
0.1 %	1.18	1.82
0.2 %	0.70	1.08
0.3 %	0.52	0.80
0.4 %	0.42	0.64
0.5 %	0.35	0.54
0.6 %	0.31	0.47
0.7 %	0.27	0.42
0.8 %	0.25	0.38
0.9 %	0.23	0.35
1.0 %	0.21	0.32

Rows perpendicular to waterway (n = 0.040)		
S	V_{max} = 1.5 fps*	V_{max} = 2.0 fps**
0.1 %	1.44	2.22
0.2 %	0.86	1.32
0.3 %	0.63	0.97
0.4 %	0.51	0.79
0.5 %	0.43	0.66
0.6 %	0.38	0.58
0.7 %	0.34	0.52
0.8 %	0.30	0.47
0.9 %	0.28	0.43
1.0 %	0.26	0.40

* For erosive soils. (Soils classified as sand, silt, sandy loam, loamy sand, silt loam, and loam.)

** For non-erosive soils. (Soils classified as sandy clay, sandy clay loam, clay loam, silty clay loam, silty clay, and clay.)

EXAMPLE 1.

Design a waterway for a field in Story County, Iowa. The drainage area of the waterway is measured to be 88 acres and the runoff curve number is calculated to be 78. The survey indicates that the waterway slope is 1.0 percent. The hydraulic length of the watershed is 2,450 feet and the average watershed slope is 2.6 percent. The producer has indicated that the rows will run perpendicular to the waterway and that he will not normally mow the waterway. Try a trapazoidal waterway.

Step 1. The waterway is 1.0 percent. It is allowable to use this procedure.

Step 2. The peak discharges from the OHIO program are: (See page IA7-12(4))

Q_2 = 67 cfs
Q_{10} = 145 cfs

See page IA7-12(5) for the waterway design.

Step 3. The Soil texture for Webster soil is clay loam.

Step 4. The allowable flow depth for out-of bank flow is 0.40 feet. (See Table 1)

Step 5. Dimensions of Q_{10} waterway. (See page 7-12(5))

D_{10} = 2.2 and $D_2 + d_1 = 1.8 + 0.40 = 2.2$; $2.2 \leq 2.2$, so the design meets all of the requirements.

Construct a trapazoidal waterway with a 10 feet bottom width, 8:1 side slopes, and 1.8 feet deep.

OH-Ver-3.0

US Department of Agriculture
Soil Conservation Service

RUNOFF COMPUTATION SHEET

prepared for

Waterway Example

in

Story County, Iowa

Designer : DFR
Date : 01/20/99

Checker KMZ
Date 1/20/99

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Waterway

Land Use and Condition		Acres by hydrologic soil group ac. A	ac. B	ac. C	ac. D
Row Crops					
Straight row - good residue	Poor	69	80x78	84	87
Farmsteads	----	59	5x74	82	86
Roads, Including rights-of-way					
Hard Surface	----	74	3x84	90	92

Watershed Slope = 2.6 % Drainage Area = 88.0 acres Curve Number = 78
Watershed Length = 2450 ft. Tc = 0.72 hr. Rainfall Type = II

Frequency	24-hr rainfall	Runoff	Peak discharge	Ia/P
2 - yr.	3.1 in.	1.20 in.	67 cfs.	0.18
5 - yr.	4.0 in.	1.89 in.	109 cfs.	0.14
10 - yr.	4.7 in.	2.46 in.	145 cfs.	0.12
25 - yr.	5.4 in.	3.05 in.	182 cfs.	0.10
50 - yr.	6.0 in.	3.58 in.	216 cfs.	0.09
100 - yr.	6.6 in.	4.11 in.	250 cfs.	0.09
- yr.	0.0 in.	0.00 in.	0 cfs.	0.00

Drainage curves : Qa = 26.4 cfs. Qc = 9.5 cfs.
Qb = 14.7 cfs. Qd = 6.2 cfs.

OH-Ver 4.01

US Department of Agriculture
Soil Conservation Service

A TRAPEZOIDAL GRASSED WATERWAY DESIGN

prepared for

Example No. 1

in

Story County, Iowa

Designer : DFR
Date : 01/22/99

Checker : DFR
Date : 4/22/99

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Reach	RET	Q cfs	Slope %	BW ft	SS	-Capacity- TW-2 ft	D-2 ft	V-2 fps	-Stability- TW-1 ft	D-1 ft	V-1 fps	Area ac
0+00 to 16+50	B/D	67	1.00	10.0	8:1	38.7	1.8	1.5	28.7	1.2	3.0	1.47
0+00 to 16+50	B/D	145	1.00	10.0	8:1	44.9	2.2	2.4	35.0	1.6	4.1	1.70

EXAMPLE 2.

Design a reach of a parabolic waterway for a field in Grundy County, Iowa. The drainage area of the waterway is measured to be 477 acres and the runoff curve number is calculated to be 78. The survey indicates that the waterway slope is 0.3 percent. The hydraulic length of the watershed is 8,800 feet and the average watershed slope is 2.4 percent. The producer has indicated that the rows will run parallel to the waterway and that he will normally mow the waterway.

Step 1. The waterway is 0.3 percent, which is less than 1 percent; therefore, it is allowable to use this procedure.

Step 2. The peak discharges from the OHIO program are: (See page IA7-12(7))

Q_2 = 182 cfs
Q_{10} = 382 cfs

See page IA7-12(8) for the waterway design.

Step 3. The Soil texture for Clyde soil is silty clay loam.

Step 4. The allowable flow depth for out-of bank flow is 0.80 feet. (See Table 1)

Step 5. Dimensions of Q_{10} waterway.

Try T_{10} = 86 feet.

$T_a = \{(T_2^2 \times D_{10})/D_2\}^{0.5}$

$T_a = (80^2 \times 2.5/2.0)^{0.5} = 89.44$ – No good!!

Try T_{10} = 90 feet.

$T_a = (80^2 \times 2.5/2.0)^{0.5} = 89.44$ – Ok!

$D_{10} = 2.5$ & $D_2 + d_1 = 2.0 + .80 = 2.80$, $2.5 < 2.80$, so the design meets all of the requirements.

Construct a parabolic waterway 80 feet wide and 2.0 feet deep.

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US Department of Agriculture
Soil Conservation Service

RUNOFF COMPUTATION SHEET

prepared for

Waterway Example 2

in

Grundy County, Iowa

Designer : DFR
Date : 01/20/99

Checker AG3
Date 1/20/99

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Waterway

Land Use and Condition		Acres by hydrologic soil group ac. A	ac. B	ac. C	ac. D
Row Crops					
Straight row - good residue	Poor	69	459x78	84	87
Farmsteads	----	59	10x74	82	86
Roads, Including rights-of-way					
Dirt	----	72	8x82	87	89

Watershed Slope = 2.4 % Drainage Area = 477.0 acres Curve Number = 78
Watershed Length = 8800 ft. Tc = 2.07 hr. Rainfall Type = II

Frequency	24-hr rainfall	Runoff	Peak discharge	Ia/P
2 - yr.	3.1 in.	1.20 in.	182 cfs.	0.18
5 - yr.	4.0 in.	1.89 in.	298 cfs.	0.14
10 - yr.	4.6 in.	2.38 in.	382 cfs.	0.12
25 - yr.	5.3 in.	2.97 in.	484 cfs.	0.11
50 - yr.	5.8 in.	3.40 in.	559 cfs.	0.10
100 - yr.	6.5 in.	4.02 in.	668 cfs.	0.09
- yr.	0.0 in.	0.00 in.	0 cfs.	0.00

Drainage curves : Qa = 126.9 cfs. Qc = 36.2 cfs.
Qb = 69.0 cfs. Qd = 23.2 cfs.

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US Department of Agriculture
Soil Conservation Service

A PARABOLIC GRASSED WATERWAY DESIGN

prepared for

Waterway Example

in

Grundy County, Iowa

Designer : DFR
Date : 01/20/99

Checker : [signature]
Date : 1/20/99

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No. 2

Reach	RET	Q cfs	Slope %	-Capacity- TW-2 ft	D-2 ft	V-2 fps	-Stability- TW-1 ft	D-1 ft	V-1 fps	Area ac
6+00 to 15+00	C/D	182	0.30	80.0	2.0	1.7	74.9	1.7	2.1	1.65
6+00 to 15+00	C/D	382	0.30	86.0	2.5	2.6	81.6	2.3	3.1	1.78
6+00 to 15+00	C/D	382	0.30	90.0	2.5	2.6	85.3	2.2	3.0	1.86