NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

LINED WATERWAY OR OUTLET
(ft.)
CODE 468

DEFINITION

A waterway or outlet having an erosion-resistant lining of concrete, stone, synthetic turf reinforcement fabrics, or other permanent material.

PURPOSE

This practice may be applied as part of a resource management system to support one or more of the following purposes:

Provide for safe conveyance of runoff without causing erosion or flooding.

Stabilize or prevent gully erosion.

Protect and improve water quality.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies if the following or similar conditions exist:

A lining is needed to control erosion caused by concentrated runoff, steep grades, wetness, prolonged base flow, seepage, or piping.

Higher velocities are required because waterway width is limited by site conditions.

Suitable vegetation cannot be maintained because of use by people or animals.

Soil or climatic conditions limit vegetation.

CRITERIA

Laws and Regulations. This practice must conform to all federal, state, and local laws and regulations. Laws and regulations of particular concern include those involving drainage and water rights, zoning, land use, pollution control, property easements, wetlands, Waters of the United States, preservation of cultural resources, and endangered species.

Capacity. Capacity of the waterway flowing at design depth shall not exceed 200 cubic feet per second. Minimum waterway capacity shall be the peak rate of runoff from a 10-year frequency, 24-hour duration storm. Velocity shall be computed using Manning's Formula with coefficient of roughness "n" from Figure 1.

Figure 1. Manning's "n"

Lining	"n" Value
Concrete, Trowel finish	0.012 – 0.014
Concrete, Float finish	0.013 – 0.017
Shotcrete	0.016 – 0.022
Flagstone	0.020 – 0.025
1/ Riprap - (Angular Rock)	$n = 0.047(D_{50}\,S)^{0.147}$
Synthetic Turf Reinforcement Fabrics and Grid Pavers	Manufacturer's recommendations

1/ Applies on slopes between 2 and 40 percent with a rock mantle thickness of 2 x D_{50} where:
D_{50} = median rock diameter (inch),
S = lined section slope (ft./ft.) ($.02 \le S \le .4$)

Velocity. Velocities exceeding critical velocity shall be restricted to straight reaches. Except for straight channels and short transition sections, flow in the range of 0.7 to 1.3 of critical slope must be avoided.

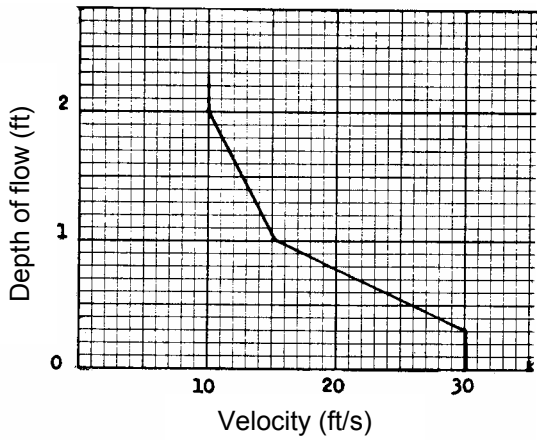
Waterways or outlets with velocities exceeding critical velocity shall discharge into an energy dissipator to reduce discharge velocity to less than critical.

Synthetic turf, reinforcement fabric, and grid paver maximum design velocity shall not exceed manufacturer's recommendations.

Concrete-lined channel maximum velocity should not exceed those in Figure 2.

Conservation practice standards are reviewed periodically and updated if needed. The current version of this standard is posted on our website at www.sd.nrcs.usda.gov or may be obtained at your local Natural Resources Conservation Service.

Figure 2. Maximum velocity versus depth of flow for concrete-lined channels



Rock-lined channel maximum velocity and rock gradation shall be determined using Appendix 16A, Engineering Field Handbook unless a detailed design analysis is completed considering bed slope, and flow conditions.

Stable rock sizes and flow depths for rock-lined channels having gradients between 2 percent and 40 percent may be determined using the following detailed design analysis (**Design of Rock Chutes** by Robinson, Rice, and Kadavy).

For channel slopes between 2% and 10%:

$$D_{50} = [q\,(S)^{1.5}/4.75(10)^{-3}]^{1/1.89}$$

For channel slopes between 10% and 40%:

$$D_{50} = [q\,(S)^{0.58}/3.93(10)^{-2}]^{1/1.89}$$

$$z = [n(q\,)/1.486(S)^{0.50}]^{3/5}$$

D_{50} = Particle size (inch) for which 50% of the sample is finer.
S = Bed slope, feet drop / foot length
z = Flow depth, feet
q = Unit discharge, ft^3/second/foot width (Total discharge÷Bottom width)

Side slope. The steepest permissible side slopes, horizontal to vertical, shall be:

Nonreinforced concrete:
Hand-placed, formed concrete
Height of lining, 1.5 ft or less ..... Vertical
Hand-placed screeded concrete
Height of lining, less that 2 ft ..... 1 to 1
Height of lining, more than 2 ft ..... 2 to 1
Slip form concrete:
Height of lining, less than 3 ft ..... 1 to 1
Rock riprap ..... 2 to 1
Synthetic Turf Reinforcement Fabrics . 2 to 1
Grid Pavers…… 1 to 1

Cross section. The cross section shall be triangular, parabolic, or trapezoidal except monolithic concrete may be rectangular.

Freeboard. The minimum freeboard for lined waterways or outlets shall be 0.25 ft. above design high water in areas where erosion-resistant vegetation cannot be grown adjacent to the paved or reinforced side slopes. No freeboard is required if vegetation can be grown and maintained.

Lining thickness. Minimum lining thickness shall be:

Concrete..... 4 in. (5 inch, reinforced with welded wire fabric in problem areas.)
Rock riprap..... Maximum stone size plus thickness of filter or bedding
Synthetic Turf Reinforcement Fabrics Manufacturer's and Grid Pavers Recommendations

Lining Durability. Use of non-reinforced concrete linings shall be made only on well drained, low shrink-swell soils or where subgrade drainage is installed.

Related structures. Side inlets, drop structures, and energy dissipators shall resist site hydraulic and structural conditions.

Outlets. Lined waterways and outlets shall have a stable outlet with adequate capacity to prevent erosion and flood damage.

Geotextiles. Geotextiles shall be used where appropriate as a separator between rock, flagstone, or concrete linings and soil to prevent migration of soil particles from the subgrade, through the lining material. Geotextiles shall be designed according to AASHTO M288, Section 7.3.

Filters or bedding. Filters or bedding shall be used where appropriate to prevent piping or soil migration, to reduce uplift pressure, or to collect seepage. Filters, bedding, and drains shall be designed to perform the needed function. Provide weep holes or collection pipes as needed.

Concrete. Concrete shall have minimum compressive strength of 3,000 pounds per square inch, be plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense durable product is required.

Contraction joints. Provide contraction joints in concrete linings as required. Joints may be formed or cut transversely to a depth of about one-third the thickness of the lining at a uniform spacing in the range of 10 to 15 feet. Support joints to prevent unequal settlement.

CONSIDERATIONS

Designs should consider cultural resources and local cultural values.

Consider adding filter strips or buffers to the sides of the waterway for wildlife habitat or to improve water quality.

Important wildlife habitat, such as woody cover or wetlands, should be avoided or protected if possible when siting the lined waterway. If trees and shrubs are incorporated, they should be retained or planted in the periphery of the grassed portion of the lined waterways so they do not interfere with hydraulic functions and roots do not damage the lined portion of the waterway. Mid- or tall bunch grasses and perennial forbs may also be planted along waterway margins to improve wildlife habitat. Waterways with these wildlife features are more beneficial when connecting other habitat types; e.g., riparian areas, wooded tracts, and wetlands.

Prescribed burning and mowing may be appropriate to enhance wildlife values, but must be conducted to avoid peak nesting seasons and reduced winter cover.

Provide livestock and vehicular crossings as necessary to prevent damage to the waterway. Crossing design must not reduce design flow capacity.

When designing riprap linings and specifying rock gradations, consider that rock delivered to the site is often segregated by size or does not conform exactly to the specified gradation. Adequate safety factor should be incorporated.

PLANS AND SPECIFICATIONS

Plans and specifications for this practice shall meet this standard and include requirements needed to achieve the purpose(s).

OPERATION AND MAINTENANCE (O&M)

An O&M plan shall be provided to and reviewed with the owner/operator. Include the following items and others as appropriate.

A maintenance program shall be established to maintain waterway capacity and outlet stability. Lining damaged by machinery or erosion must be repaired promptly.

Inspect waterways regularly, especially following heavy rains. Repair damaged areas and remove sediment deposits to maintain capacity.

Avoid using waterways as turn-rows during tillage and cultivation operations. Do not use as a field road. Avoid crossing with heavy equipment.

Control noxious weeds. Advise owner/operators to avoid forbs when applying herbicides.

REFERENCES

National Engineering Handbook, Part 650, Engineering Field Handbook: Chapter 16, Streambank and Shoreline Protection.

Robinson, K.M., C.E. Rice, and K.C. Kadavy. 1998. Design of Rock Chutes. Transactions of ASAE, Vol. 41(3): 621-626.