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 from conservation structures or other water concentrations without causing erosion or flooding
- Stabilize existing and prevent future gully erosion
- Protect and improve water quality

CONDITIONS WHERE PRACTICE APPLIES

This practice applies if the following or similar conditions exist:

1. Concentrated runoff, steep grades, wetness, prolonged base flow, seepage, or piping is such that a lining is needed to control erosion.
2. Use by people or animals preclude vegetation as suitable cover.
3. Limited space is available for design width, which requires higher velocities and lining.
4. Soils are highly erosive or other soil or climatic conditions preclude using vegetation only.

CRITERIA

General Criteria Applicable to All Purposes

Laws, rules, and regulations. This practice shall conform to all federal, state, and local laws, rules, and regulations. Laws, rules, and regulations of particular concern include those involving water rights, land use, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.

Capacity. The maximum capacity of the waterway flowing at designed depth shall not exceed 200 cubic feet second (cfs). The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year, 24-hour frequency storm. Velocity shall be computed by using Manning's equation with a roughness coefficient "n" value as follows:

Lining	"n" Value
Concrete	
Trowel finish	0.012 - 0.014
Float finish	0.013 - 0.017
Shotcrete	0.016 - 0.022
Mortared-in-place flagstone	0.020 - 0.025
Riprap (angular rock) [1/]	$n = 0.047(D_{50} S)^{0.147}$
Synthetic turf reinforcement fabrics and grid pavers	Manufacturer's recommendations

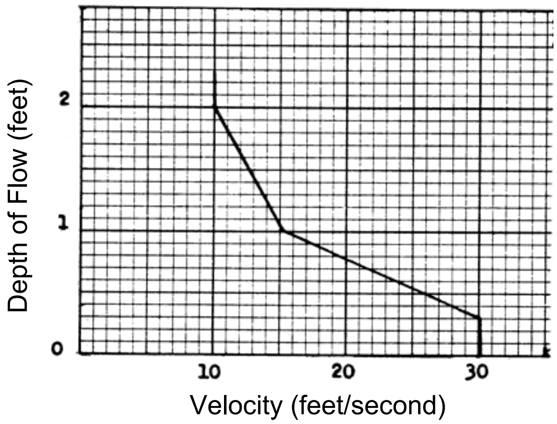
[1/] Applies on slopes between 2 and 40 percent with a rock mantle thickness of 2 x D_{50} where:
D_{50} = median rock diameter (inches)
S = lined section slope (feet/feet) ($.02 \le S \le .4$)

Velocity. Maximum design velocity and rock gradation limits for rock-riprap-lined channel sections shall be determined using Appendix 16A in Chapter 16 of National Engineering

Handbook Part 650, *Engineering Field Handbook*, unless a detailed design analysis appropriate to the specific slope, flow depth, and hydraulic conditions indicate that a higher velocity is acceptable.

Maximum design velocity for concrete-lined sections should not exceed those using Figure 1.

Figure 1. Maximum velocity versus depth of flow for concrete-lined channels



Maximum design velocity for synthetic turf reinforcement fabrics and grid pavers shall not exceed manufacturer's recommendations.

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 process. This design process is from Design of Rock Chutes by Robinson, Rice, and Kadavy.

For channel slopes between 2 percent and 10 percent:

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

For channel slopes between 10 percent and 40 percent:

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

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

D_{50} = Particle size for which 50 percent of the sample is finer (inches)

S = Bed slope (feet/foot)

z = Flow depth (feet)

q = Unit discharge (cubic feet second/foot) (Total discharge / Bottom width)

Except for short transition sections, channel slopes in the range of 0.7 to 1.3 of the critical slope at the given discharge must be avoided unless the channel is straight. Velocities exceeding critical velocity shall be restricted to straight reaches.

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

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

Lining	Side Slope
Nonreinforced concrete:	
Hand-placed, formed concrete:	
Height of lining - 1.5 feet or less	Vertical
Hand-placed, screeded concrete or mortared-in-place flagstone:	
Height of lining - less that 2 feet	1:1
Height of lining - more than 2 feet	2:1
Slip form concrete:	
Height of lining - less than 3 feet	1:1
Riprap (angular rock)	2:1
Synthetic turf reinforcement fabrics	2:1
Grid pavers	1:1

Cross section. The cross section shall be parabolic or trapezoidal. A cross section made of monolithic concrete may be rectangular.

Freeboard. The minimum freeboard for lined waterways or outlets shall be 0.25 foot 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 as follows:

Concrete	4 inches (In most problem areas, minimum thickness shall be 5 inches with welded wire reinforcement.)
Rock riprap	Maximum stone size plus thickness of filter or bedding
Flagstone	4 inches (including mortar bed)
Synthetic turf reinforcement fabrics and grid pavers	Manufacturer's recommendations

Lining durability. Use of non-reinforced concrete or mortared flagstone linings shall be made only on low shrink-swell soils that are well-drained or where subgrade drainage facilities are installed.

Related structures. Side inlets, drop structures, and energy dissipators shall meet the hydraulic and structural requirements for the site.

Outlets. All lined waterways and outlets shall have stable outlets with adequate capacity to prevent erosion and flooding damages.

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 American Association of State Highway Transportation Officials (AASHTO) M 288, Section 7.3.

Filters or bedding. Filters or bedding shall be used where appropriate to prevent piping. Drains shall be used to reduce uplift pressure and to collect water, as required. Filters, bedding, and drains shall be designed according to Natural Resources Conservation Service (NRCS) standards. Weep holes may be used with drains if needed.

Concrete. Concrete used for lining shall be proportioned so that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense, durable product shall be required. Specify a mix that can be certified as suitable to produce a minimum strength of 3,000 pounds per square inch at 28 days.

Contraction joints. Contraction joints in concrete linings, if required, shall be formed transversely to a depth of about 1/3 the thickness of the lining at a uniform spacing in the range of 10 to 15 feet. Provide welded wire reinforcement or other uniform support to the joint to prevent unequal settlement.

CONSIDERATIONS

Cultural resources need to be considered when planning this practice. Where appropriate, local cultural values need to be incorporated into the practice design in a technically sound manner.

Consider adding widths of appropriate vegetation to the sides of the waterway for wildlife habitat.

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 (for example riparian areas, wooded tracts, and wetlands).

Provide livestock and vehicular crossings as necessary to prevent damage to the waterway. Crossing design shall not interfere with design flow capacity.

Establish filter strips on each side of the waterway to improve water quality.

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. An adequate safety factor should be incorporated.

PLANS AND SPECIFICATIONS

Plans and specifications for lined waterways or outlets shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An operation and maintenance plan shall be provided to and reviewed with the landowner. The plan shall 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.

Lined waterways shall be inspected regularly, especially following heavy rains. Damaged areas shall be repaired immediately. Remove sediment deposits to maintain capacity of lined waterways.

Landowners should be advised to avoid areas where forbs have been established when applying herbicides. Avoid using waterways as turn-rows during tillage and cultivation operations. Prescribed burning and mowing may be appropriate to enhance wildlife values but must be conducted to avoid peak nesting seasons and reduced winter cover. Control noxious weeds. Do not use as a field road. Avoid crossing with heavy equipment.

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.