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 concentrated flow areas and prevent future gully erosion.
- Protect and improve water quality.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies if the following or similar conditions exist:

- Concentrated runoff, steep grades, wetness, prolonged base flow, seepage, or piping is such that a lining is needed to control erosion.
- Use by people or animals preclude vegetation as suitable cover.
- Limited space is available for design width, which requires higher velocities and lining.
- 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 minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year, 24-hour frequency storm—except when the waterway or outlet is constructed to reduce flooding or as part of an animal waste system. The minimum capacity shall be adequate to carry the peak runoff from a 25-year, 24-hour frequency storm for designs involving animal waste systems or flood reduction. Velocity shall be computed by using Manning's equation with a roughness coefficient "*n*" value as follows:

Lining	"*n*" Value
Concrete	
Trowel finish	0.01 - 0.015
Float finish	0.013 - 0.016
Shotcrete	0.016 - 0.025
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 size (inches)
S = Lined channel bed slope (foot/foot) ($.02 \leq S \leq .4$)

Freeboard. The minimum freeboard for lined waterways or outlets shall be 0.25 foot above the maximum designed flow depth 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.

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

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

Non-reinforced 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 than 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

Rock riprap.....2:1

Synthetic turf reinforcement fabrics 2:1

Grid pavers.....1:1

Lining thickness. Minimum lining thickness shall be as follows:

Concrete ..... 4 inches (minimum thickness shall be 5 inches if the liner is reinforced)

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 only be used on soils with less than 30% clay content, that are well drained, or where subgrade drainage facilities are installed.

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

Outlets. All lined waterways and outlets shall have a stable outlet with adequate capacity to prevent erosion and flooding damages. Waterways or outlets with supercritical flow shall discharge into an energy dissipater to reduce discharge velocity to less than critical. The dissipater may be a level apron with a minimum length of 10 feet or other suitable design (St. Anthony Falls [SAF] basins or impact basins) as required to achieve subcritical velocity.

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; Technical Supplement 14D in National Engineering Handbook Part 654 (NEH 654), *Stream Restoration Design*; or Technical Note, Title 210–Engineering, Design Engineering Note No. 24, "Guide for the Use of Geotextiles."

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 Chapter 26 in National Engineering Handbook Part 633 (NEH 633), *Soil Engineering*. Weep holes may be used with drains if needed.

Criteria Applicable to Rock-Riprap-Lined Channels

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 (NEH 650), *Engineering Field Handbook*, or Technical Supplement 14C in NEH 654 unless a detailed design analysis appropriate to the specific slope, flow depth, and hydraulic conditions indicate that a higher velocity is acceptable.

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 the American Society of Agricultural Engineers (ASAE) paper, "Design of Rock Chutes," by K. M. Robinson, C. E. Rice, and K. C. Kadavy.

For channel slopes between 2 percent and 10 percent:

$$D_{50} = [q\,(S)^{1.5} / 4.75\,(10)^{-3}]^{0.53}$$

For channel slopes between 10 percent and 40 percent:

$$D_{50} = [q\,(S)^{0.58} / 3.93\,(10)^{-2}]^{0.53}$$

For any slope:

$$z = [n\,(q) / 1.486\,(S)^{0.50}]^{0.6}$$

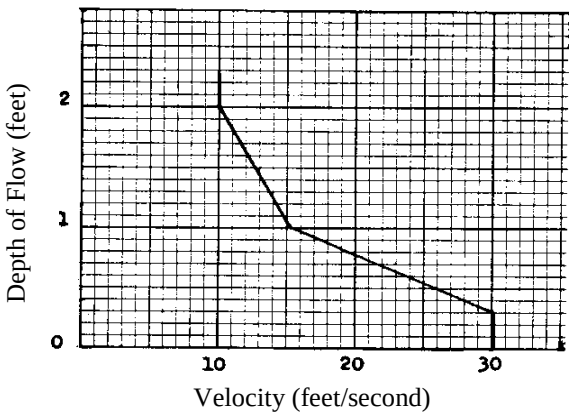
Where: D_{50} = Median rock size (inches)
S = Lined channel bed slope (foot/foot)
z = Flow depth (feet)
q = Unit discharge (cubic feet second/foot) (Total discharge / Bottom width)

Avoid channel slopes between 0.7 and 1.3 of the critical slope except for short transition sections. Supercritical flow shall be restricted to straight reaches. Design guidance on the use of this equation is available in Technical Supplement 14C in NEH 654.

Criteria Applicable to Concrete-Lined Channels

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



The cross section for channels that are lined with concrete or grid pavers shall be adequate to meet the maximum design velocity requirements.

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 8 to 15 feet. Provide steel reinforcement or other uniform support to the joint to prevent unequal settlement.

Criteria Applicable to Turf-Reinforcement-Lined Channels

Maximum design velocity and shear stress for synthetic turf reinforcement fabrics (mats) shall not exceed manufacturer's recommendations. Designs developed using product software will be based on the channel being stable for each limiting condition during the peak flow from the design storms shown in Table 1 using the appropriate vegetation density and retardance class. A minimum safety factor of 1.2 is required for all of the conditions analyzed to account for the increased shear stress of the hydraulic jump on the vegetation, mat, and substrate.

Designs developed using hydraulic stress calculations will have a minimum safety factor of 2.2 to determine the minimum permissible shear stress of the turf reinforcement mat (TRM).

Vegetation establishment is a critical portion of waterways and outlets lined with turf reinforcement. Vegetation should be established in accordance with the criteria for a grassed waterway in Conservation Practice Standard 342, Critical Area Planting.

Table 1–Design storms for stability of TRM-lined channels

Design Objective	Design Storm Frequency	Retardance Class	Vegetation Density	Limiting Condition or Phase
Erosion control	2-year	E	Poor	Unvegetated and underlying substrate
Flooding or animal waste	5-year	E	Poor	Unvegetated and underlying substrate
Erosion control	10-year	B[1/]	Fair to good	Fully vegetated
Flooding or animal waste	25-year	B[1/]	Fair to good	Fully vegetated

[1/] Retardance Class C can be used in counties where adjusted curve numbers ARC I + 0.4 (II-I) and ARC I + 0.2 (II-I) are allowed.

SITE AND SUBGRADE PREPARATION

Proper site preparation is necessary to provide a stable, uniform foundation for the waterway lining. The site should be graded to remove any rutting or uneven surfaces and to provide good surface drainage throughout the construction period and the design life of the waterway or outlet. Proof rolling can be used to identify soft pockets of soil, additional rutting, or other soil conditions that require removal and replacement by compacted soil to provide a uniform surface for base, subbase, or concrete liner.

CONSIDERATIONS

Streambank soil bioengineering. Trees, shrubs, forbs, and grasses can be incorporated into or adjacent to the lined portions of the channel. This may improve aesthetics and habitat benefits as well as reduce erosion potential. Plantings are especially beneficial where the channel transitions to natural ground. However, such plantings are not appropriate in all circumstances. Guidance on the use of plantings is available in Technical Supplement 14I in NEH 654 and Technical Supplement 14K in NEH 654.

Fish and wildlife resources. This practice may impact important fish and wildlife habitats such as streams, creeks, riparian areas, floodplains, and wetlands.

Aquatic organism passage concerns (such as velocity, depth, slope, air entrainment, screening, etc.) should be evaluated to minimize negative impacts. Swimming and leaping performance for target species should be considered.

Important fish and 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 that they do not interfere with hydraulic functions and the 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.

Plant selections that benefit pollinators should be incorporated into the design. Waterways with these wildlife features are more beneficial when connecting other habitat types (such as riparian areas, wooded tracts, and wetlands).

Other 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.
- Filter strips established on each side of the waterway may improve water quality.
- Consideration should be given to livestock and vehicular crossings as necessary to prevent damage to the waterway. The crossing design shall not interfere with design flow capacity.

- Reinforcement of concrete liners should be considered where high pore water pressures exist in the subgrade, movement of the subgrade may occur, or in reaches where failure would endanger public safety or property.

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(s).

As a minimum, the plans and specifications shall include the following:

- A plan view of the layout of the lined waterway or outlet.
- A typical cross section of the lined waterway or outlet.
- A profile of the lined waterway or outlet.
- Disposal requirements for excess soil material.
- Site-specific construction specifications that describe the installation of the lined waterway or outlet. Include specifications for control of concentrated flow during construction.

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 the 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

AASHTO M 288, Standard Specification for Geotextile Specification for Highway Applications.

National Engineering Handbook Part 654, *Stream Restoration Design*, August 2007.

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

National Engineering Handbook Part 633, *Soil Engineering*, Chapter 26, "Gradation Design of Sand and Gravel Filers."

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

USDA NRCS, Technical Note, Title 210–Engineering, Design Engineering Note No. 24, "Guide for the Use of Geotextiles." 1991.

USDA NRCS, Pollinator Conservation. http://www.plant-materials.nrcs.usda.gov/news/features/pollinatorconservation.html (accessed August 20, 2009).