Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

LINED WATERWAY OR OUTLET

CODE 468

(ft)

DEFINITION

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

PURPOSE

This practice is used to accomplish one or more of the following purposes:

- Provide safe conveyance of runoff from conservation practices or other flow concentrations without causing erosion or flooding
- Prevent or stabilize existing gully erosion or scour
- Protect and improve water quality

CONDITIONS WHERE PRACTICE APPLIES

This practice applies if conditions similar to one or more of the following exist:

- Concentrated runoff, pipe flow, steep grades, wetness, prolonged base flow, seepage, or piping is such that a lining is needed to prevent erosion
- Use by people or animals precludes vegetation as suitable cover
- Site restrictions necessitate limited waterway or outlet widths with design velocities that require lining protection
- Soils are highly erosive or other soil or climatic conditions preclude using vegetation only

CRITERIA

General Criteria Applicable to All Purposes

Capacity

The minimum capacity must be adequate to carry the peak rate of runoff from a 10-year, 24-hour frequency storm with the following exceptions:

- When the lined waterway or outlet slope is less than 1 percent, minimum design capacity may be reduced to the capacity of the waterway leading to it
- When the immediate downstream conveyance capacity of the channel, structure, or pipe is less than that resulting from a 10-year, 24-hour frequency storm, minimum design capacity may be reduced to the capacity of downstream conveyance

For a lined outlet downstream of a pipe, provide a lined waterway or outlet adequate to contain the outflow from the design flow event.

Velocity
Compute velocity using Manning's equation with a coefficient of roughness appropriate for the selected lining material.

Design maximum velocity and rock gradation limits for rock riprap-lined channel sections and outlets from concentrated flow area using the National Engineering Handbook (NEH) (Title 210), Part 650, Chapter 16, Appendix 16A, "Size Determination for Rock Riprap," or 210-NEH, Part 654, Technical Supplement (TS) 14C, "Stone Sizing Criteria," unless a detailed design analysis appropriate to the specific slope, flow depth, and hydraulic conditions indicate that a higher velocity is acceptable.

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

For concrete lined channels, use figure 1 to determine the maximum design velocity.

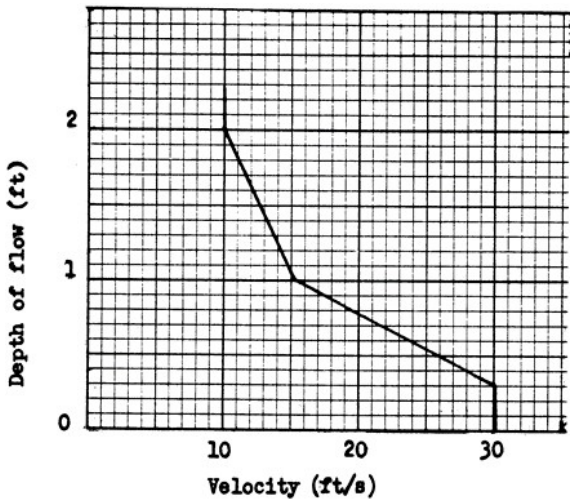

Figure 1. Maximum velocity versus depth of flow for concrete-lined channels

Avoid channel slopes between 0.7 and 1.3 of the critical slope except for short transition sections. Restrict supercritical flow to straight reaches. Waterways or outlets with supercritical flow must discharge into an energy dissipator to reduce discharge velocity to less than critical.

Cross section
The cross section of the lined waterway or outlet with a defined channel must be triangular, parabolic, or trapezoidal. A cross section made of monolithic concrete may be rectangular.

Freeboard
The minimum freeboard for lined waterways or outlets must be 0.25 feet 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.

Side slope
The steepest permissible side slopes must not exceed the values given in table 1.

Table 1. Steepest permissible side slopes for each material type.

Material	Slope (horizontal to vertical)
Nonreinforced concrete	
Height of lining, 1.5 ft or less	Vertical

Material	Slope (horizontal to vertical)
Hand-placed screeded concrete or mortared-in-place flagstone	
Height of lining, less than 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

Lining thickness
Minimum lining thickness must not be less than indicated in table 2.

Table 2. Minimum lining thickness for various materials.

Material	Lining Thickness
Concrete	4 in. (minimum thickness is 5 in. if the liner is reinforced)
Rock riprap	Maximum stone size plus thickness of filter or bedding
Flagstone	4 in., including mortar bed
Synthetic turf reinforcement fabrics and grid pavers	Manufacturer's recommendations

Lining durability
Nonreinforced concrete or mortared flagstone linings may only be used in areas of low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.

Related structures
Side inlets, drop structures, and energy dissipators must meet the hydraulic and structural requirements for the site. Grade stabilization structures must meet the criteria of NRCS Conservation Practice Standard (CPS) Grade Stabilization Structure (Code 410).

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

Geotextiles
Use geotextiles 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. Specify geotextile requirements in accordance with the American Association of State Highway and Transportation Officials (AASHTO) M288, Section 7.3; 210-NEH-654-TS 14D, "Geosynthetics in Stream Restoration"; or NRCS 210-Technical Note, Design Engineering, Design Note 24, "Guide for the Use of Geotextiles."

Install and anchor turf reinforcement mats in accordance with manufacturer's recommendations and ensure intimate contact between mesh and base soil.

Filters or bedding
Use filters or bedding to prevent piping, where appropriate. Use drains to reduce uplift pressure and to collect water, as required. Design filters, bedding, and drains in accordance with 210-NEH, Part 633, Chapter 26, "Gradation Design of Sand and Gravel Filters." Weep holes may be used with drains if needed.

Concrete
Proportion concrete so that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense, durable product is required. Specify a mix that can be certified as suitable to

produce a minimum strength (28 day) of 3,000 pounds per square inch. Specify requirements for curing in the construction specifications.

Contraction joints
Contraction joints in concrete linings, if required, must be formed transversely to a depth of approximately one-third the thickness of the lining, at a uniform spacing between 8 to 15 feet. Provide steel reinforcement or other uniform support to the joint to prevent unequal settlement.

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.

Articulating concrete block revetment
Design articulating concrete block revetment using 210-NEH-654-TS 14L, "Use of Articulating Concrete Block Revetment Systems for Systems for Stream Restoration and Stabilization Projects."

Tractive stress
Tractive stress may be used as an alternative to velocity criteria for design of the selected lining material.

Compute maximum shear stress using U.S. Army Corp of Engineers Engineer Research and Development Center (ERDC)-TN-EMRRP-SR-29, "Stability Thresholds for Stream Restoration Materials."

Do not exceed manufacturer's recommendations for maximum shear stress for the lining material.

CONSIDERATIONS

Incorporate trees, shrubs, forbs, and grasses 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. Maintain the flow channel free from obstruction. Guidance on the use of plantings is available in 210-NEH-654-TS 14I, "Streambank Soil Bioengineering" and 14K, "Streambank Armor Protection with Stone Structures," and in NRCS CPS Streambank and Shoreline Protection (Code 580).

Cultural resources need to be considered when planning this practice. Where appropriate, local cultural values need to be incorporated into 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. Crossing design must not interfere with design-flow capacity. Guidance can be found in NRCS CPS Stream Crossing (Code 578).

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.

General Considerations for Fish and Wildlife Resources
This practice may impact important fish and wildlife habitats such as streams, creeks, riparian areas, floodplains, and wetlands.

Seepage from unlined waterways may benefit wetlands, migratory bird habitat, and floodplain recharge. Consider site-specific resource concerns with regard to efficient water delivery and instream flow as compared to wetland habitat benefits.

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

Consider mesh size of 0.2 inches or smaller where turf reinforcement mats are used to reduce impacts on fish and wildlife.

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 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.

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

PLANS AND SPECIFICATIONS

Prepare plans and specifications for lined waterways or outlets that describe the requirements for applying the practice to achieve its intended purpose(s).

As a minimum the plans and specifications must include—

- A plan view of the layout of the lined waterway or outlet.
- Typical cross section of the lined waterway or outlet.
- Profile of the lined waterway or outlet.
- Specifications for the lining material.
- Disposal requirements for excess soil material.
- Site-specific construction specifications that describe the installation of the lined waterway or outlet. Include a specification for control of concentrated flow during construction if required.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for use by the client. As a minimum, the plan shall address the following items:

- Regular inspection of lined waterways, especially following heavy rains. Promptly repair damaged areas and remove sediment deposits to maintain capacity of lined waterways.
- Control noxious weeds. Avoid areas where forbs have been established when applying herbicides.
- Avoid using the lined 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.
- Do not use the lined waterway as a field road.
- Avoid crossing the lined waterway or outlet with heavy equipment.

REFERENCES

American Association of State Highway and Transportation Officials. 2017. AASHTO M 288, Standard Specification for Geotextile Specification for Highway Applications. Washington, D.C.

Barton, C. and K. Kinkead. 2005. Do Erosion Control and Snakes Mesh? Journal of Soil and Water Conservation 60(2): 33A-35A. https://www.researchgate.net/profile/Christopher_Barton2/publication/255220745_Do_erosion_control_and_snakes_mesh/links/55df7bf108aecb1a7cc1a2c6/Do-erosion-control-and-snakes-mesh.pdf

Fischenich, J.C. 2001. Stability Thresholds for Stream Restoration Materials. Ecosystem Management and Restoration Research Program Technical Notes Collection, ERDC TN-EMRRP-SR-29. U.S. Army Engineer Research and Development Center, Vicksburg, MS. https://www.spa.usace.army.mil/Portals/16/docs/civilworks/regulatory/Stream%20Information%20and%20Management/ERDC%20Stability%20Thresholds.pdf

Miller, S.J., J.C. Fischenich, and C.I. Thornton. 2012. Stability Thresholds and Performance Standards for Flexible Lining Materials in Channel and Slope Restoration Applications. Ecosystem Management and Restoration Research Program Technical Notes Collection, ERDC TN-EMRRP-EBA-13. U.S. Army Engineer Research and Development Center, Vicksburg, MS. https://erdc-library.erdc.dren.mil/jspui/bitstream/11681/3944/1/ERDC-TN-EMRRP-EBA-13.pdf

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. 2007. National Engineering Handbook (Title 210), Part 654, Stream Restoration Design. Washington, D.C. https://directives.sc.egov.usda.gov/

USDA NRCS. 1996. National Engineering Handbook (Title 210), Part 650, Chapter 16, Streambank and Shoreline Protection. Washington, D.C. https://directives.sc.egov.usda.gov/

USDA NRCS. 1984. National Engineering Handbook (Title 210), Part 650, Chapter 3, Hydraulics. Washington, D.C. https://directives.sc.egov.usda.gov/

USDA NRCS. 2017. National Engineering Handbook (Title 210), Part 633, Chapter 26, Gradation Design of Sand and Gravel Filers. Washinton, D.C. https://directives.sc.egov.usda.gov/

USDA NRCS. 1991. Technical Note (Title 210), Design Engineering, Design Note 24, Guide for the Use of Geotextiles. Washington, D.C. https://directives.sc.egov.usda.gov/

USDA NRCS. n.d. “Insects and Pollinators.” Accessed June 10, 2019. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/pollinate/