Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

LINED WATERWAY OR OUTLET

CODE 468

(ft)

DEFINITION

A waterway or conveyance channel having an erosion-resistant lining of concrete, stone, synthetic turf reinforcement fabrics, or other flexible 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 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

Plan, design, and construct the terrace to meet all Federal, State, Tribal, and local regulations.

Capacity

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

- 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.

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 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, refer to NEH Part 650, Chapter 3 — Hydraulics to determine the maximum design velocity.

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 conveyance channels with supercritical flow must discharge into an energy dissipator to reduce discharge velocity to less than critical.

Evaluate the effects of velocity on aquatic organism passage including depth, slope, air entrainment, screening, swimming and leaping performance for target species, etc.) to minimize negative impacts.

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.

Cross section
Design the lined waterway or conveyance with a defined cross section that is triangular, parabolic, or trapezoidal. If monolithic concrete is used as a lining the cross 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
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	2 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	1.5 times maximum stone size
Flagstone	4 in., including mortar bed
Synthetic turf reinforcement fabrics and grid pavers	Manufacturer's recommendations

Lining durability
Only use nonreinforced concrete or mortared flagstone linings in areas of low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.

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

Outlets
Provide a stable outlet with adequate capacity to prevent erosion and flooding damages for all lined waterways and conveyance channels.

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; NRCS 210-NEH,Part 654, Technical Supplement 14D, "Geosynthetics in Stream Restoration."

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 and to serve as a leveling base, where appropriate. Use drains to reduce hydraulic 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." Use weep holes 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. Design a dense, durable product. 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 per 210-NEH Part 642 Construction Specification 31 or Construction Specification 32 as appropriate.

Thermal movement in concrete linings
Contraction joints and expansion joints are used to address thermal movement in concrete linings. If joints are required in concrete linings, form or sawcut transversely to a depth of approximately one-third the thickness of the lining, at a uniform spacing to produce panels that are as square as possible and not to exceed a length to width ratio of 1 1/2 to 1. For joint spacing that is greater than 15 feet, provide load transfer devices or other uniform support to the joint to prevent unequal settlement.

Site selection and subgrade preparation
Avoid or protect important fish and wildlife habitat, such as woody cover or wetlands, if possible, when siting the lined waterway or conveyance channel. Retain trees and shrubs or plant them in the periphery of the grassed portion of the lined waterways when they are incorporated in the design, so they do not interfere with hydraulic functions and roots do not damage the lined portion of the waterway.

Provide a stable, uniform foundation for the waterway lining by properly preparing the site. Grade the site to remove any rutting or uneven surfaces and to provide good surface drainage throughout the construction period and the design life of the lined waterway or conveyance channel. If desired, use proof rolling as a method 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.”

CONSIDERATIONS

Consider climate change impact on determining channel’s capacity.

Consider impacts on downstream source water due to erosion and sediment load and impacts on important fish and wildlife habitats such as streams, creeks, riparian areas, groundwater, and wetlands. Consider providing an increased level of designed treatment for sites with high priority areas for source water protection or are upstream of community drinking water withdrawal sites.

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).

Filter strips established on each side of the waterway may improve water quality.

Consider livestock and vehicular crossings, as necessary, to prevent damage to the waterway. Design crossing design minimize interference with design-flow capacity. Guidance can be found in NRCS CPS Stream Crossing (Code 578).

Consider reinforcement of concrete liners 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.

Evaluate aquatic organism passage concerns (e.g., velocity, depth, slope, air entrainment, screening, etc.) to minimize negative impacts. Consider swimming and leaping performance for target species.

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

Consider incorporating plant selections that benefit pollinators 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 conveyance channel.
- Typical cross section of the lined waterway or conveyance channel.
- Profile of the lined waterway or conveyance channel.
- 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 the lined waterway, especially following heavy rains or large flow events. Promptly repair damages and remove sediment deposits to maintain capacity of the lined waterway.
- Control noxious weeds in the lined waterway or conveyance channel.
- Avoid areas where forbs have been established in the adjacent planted areas when applying herbicides.
- Avoid using the lined waterway as turn-rows during tillage and cultivation operations.
- Do not use the lined waterway as a field road.
- Avoid crossing the lined waterway or conveyance channel with heavy equipment.

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