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 may be applied as part of a resource management system to support 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

Design and install measures according to a site-specific plan in accordance with all local, State, Tribal, and Federal laws and regulations. Apply measures that are compatible with improvements planned or being carried out by others.

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.
- When the lined waterway or outlet protects components of manure management systems, the minimum design capacity shall convey the peak discharge from a 25-year, 24-hour frequency storm.

Velocity. Compute velocity using Manning's Equation with a coefficient of roughness appropriate for the selected lining material. See Table 1.

Table 1. Manning's "n" Values

Lining	"n" Value
Concrete – trowel finish	0.0110 – 00.015
Concrete – float finish	0.013 – 0.016
Shotcrete	0.016 – 0.025
Flagstone	0.020 – 0.025
Riprap[1] (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 (in.)
S = lined section slope (ft. / ft.) ($.02 \leq S \leq 0.4$)

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), Part 650, Engineering Field Handbook, Chapter 16, Appendix 16A; or NEH 654, Technical Supplement 14C, unless a detailed design analysis appropriate to the specific slope, flow depth, and hydraulic conditions indicate that a higher velocity is acceptable.

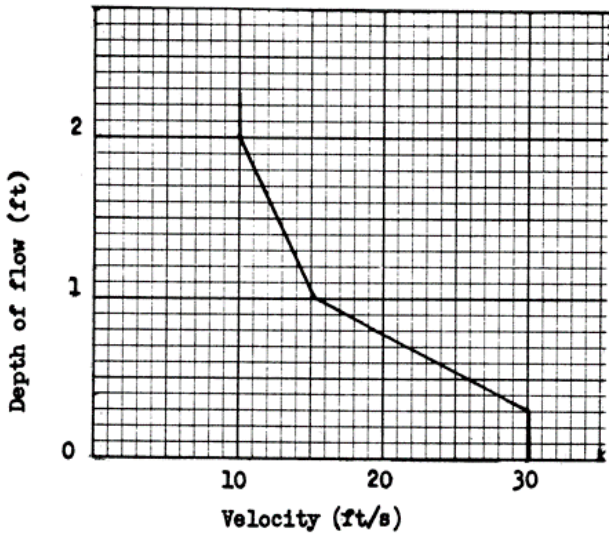
Do not exceed manufacturer's recommendations for maximum design velocity for synthetic turf reinforcement fabrics and grid pavers.

Maximum design velocity for concrete-lined sections using Figure 1.

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

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



Rock Riprap Linings. The following criteria apply to all rock riprap linings:

- Stable rock sizes and flow depths for rock-lined channels having gradients between 2 percent and 40 percent shall be determined using the process from Design of Rock Chutes by Robinson, Rice, and Kadavy.

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

  For channel slopes between 2% and 10%:
  $D_{50} = (FS)(SF)[q(S)^{1.5}/4.75(10)^{-3}]^{0.53}$

  For channel slopes between 10% and 40%:
  $D_{50} = (FS)(SF)[q(S)^{0.58}/3.93(10)^{-2}]^{0.53}$

  Where:

  D_{50} = Particle size for which 50% (by weight) of the sample is finer, in.

  S = Bed slope, ft. / ft.
  z = Flow depth, ft.
  n=Manning's roughness coefficient
  q = Unit discharge, $ft^3/s/ft$.

- Rock shall meet the material requirements of Wisconsin Construction Specification 9, Loose Rock Riprap.
- A minimum factor of safety (FS) of 1.2 shall be used to size the rock.
- A shape factor (SF) of 1.0 shall be used for cubical rock.
- An additional shape factor (SF) of 1.4 shall be used for spherical rock.

- The cross section of the completed lined waterway shall be trapezoidal. Side slopes shall be 2 horizontal to 1 vertical or flatter.
- The rock-lined slope shall be on slopes between 2 percent and 40 percent.
- The minimum depth for the rock riprap linings shall be the design flow depth needed to pass the design flow through a trapezoidal-shaped plus freeboard.
- The minimum rock thickness shall be 2 times the D_{50} rock size.
- A geotextile must be placed beneath the rock. If a sand-gravel bedding is used, the bedding thickness shall be a minimum of 2 inches and placed beneath the geotextile.
- The rock gradation shall be as shown in Table 2.

Table 2. Rock Gradation

Percent Passing	Size[1] (in.)
100	$1.5 \times D_{50} - 2.0 \times D_{50}$
85	$1.3 \times D_{50} - 1.8 \times D_{50}$
50	$1.0 \times D_{50} - 1.5 \times D_{50}$
10	$0.8 \times D_{50} - 1.3 \times D_{50}$

[1]Round up to nearest inch.

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

The steepest permissible side slopes, horizontal to vertical (h:v), shall be as listed in Table 5.

Table 5. Steepest Permissible Side Slopes

Lining Material	Side Slope (h:v)
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 Height of lining, more than 2 feet	 1:1 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

*Non-reinforced concrete.

Freeboard. The minimum freeboard for lined waterways or outlets must 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 must not be less than:

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 Wisconsin NRCS Conservation Practice Standard (WI NRCS CPS), Grade Stabilization Structures (Code 410). Crossings must meet the criteria in WI NRCS CPS, Stream Crossing (Code 578).

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.; NEH 654, Technical Supplement 14D; or NRCS Design Note 24, "Guide for the Use of Geotextiles."

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 NEH Part 633, Chapter 26. 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.

CONSIDERATIONS

Incorporate trees, shrubs, forbs, and grasses 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 NEH 654, Technical Supplement 14I and 14K.

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.

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).

Other Considerations

- 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.
- 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

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

AASHTO M288. Standard Specification for Geotextile Specification for Highway Applications.

National Engineering Handbook (NEH), Part 654, Stream Restoration Design, August 2007.

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

NEH, Part 650, Engineering Field Handbook: Chapter 3, Hydraulics.

NEH, 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 Guide for the Use of Geotextiles. Design Note 24 (210-VI-DN-24, 1991).

USDA, NRCS, Pollinator Conservation. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/pollinate/ (accessed July 20, 2016).