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 precludes vegetation as suitable cover.
3. 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

Legal Criteria

Federal, State and Local Laws. All planned activities shall comply with all federal, state, and local laws and regulations. All permits shall be obtained before starting construction.

Cultural Resources. Ground disturbing activities have the potential to affect significant cultural resources. Complete a cultural resources review prior to ground disturbing activities to assure that existing cultural resources will not be adversely impacted.

General Criteria Applicable to All Purposes

Capacity. The maximum capacity of the waterway flowing at designed depth shall not exceed 200 ft^3/s. 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 Formula with a coefficient of roughness "n" as follows:

Lining	"n" Value
Concrete	
Trowel finish	0.011– 0.015
Float finish	0.013 - 0.016
Shotcrete	0.016 – 0.025
Flagstone	0.020 – 0.025
1/ Riprap - (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% with a rock mantle thickness of 2 x D_{50} where:

D_{50} = median rock diameter (in.),

S = lined section slope (ft./ft.) ($.02 \le S \le 0.4$)

Velocity. Maximum design velocity and rock gradation limits for rock riprap-lined channel sections shall be determined using National Engineering Handbook (NEH), Part 650, Engineering Field Handbook, Chapter 16, Appendix 16A, or NEH 654.14C, unless a detailed design analysis appropriate to the specific slope, flow depth and hydraulic

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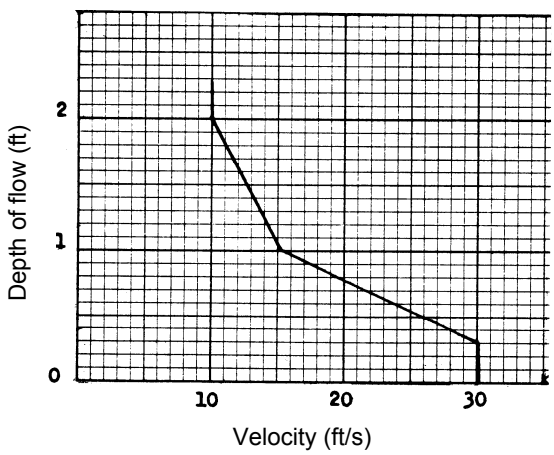
conditions indicate that a higher velocity is acceptable.

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% and 10%:

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

For channel slopes between 10% and 40%:

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

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

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, $ft^3/s/ft$

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 NEH 654.14C

Waterways or outlets with supercritical flow 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:

Lining	Side Slopes (H):(V)
Nonreinforced Concrete	
Hand-placed, formed 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 feet	1:1
Hand-placed screeded concrete or mortared in place flagstone, 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

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

Freeboard. The minimum freeboard for lined waterways or outlets shall 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 shall be:

Lining	Thickness
Concrete	4 inches (minimum thickness shall be 5 inches if the liner is reinforced)
Flagstone	4 inches including mortar bed
Rock riprap	Maximum stone size plus thickness of filter or bedding
Synthetic Turf Reinforcement Fabrics and Grid Pavers	Manufacturer's Recommendations

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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.

Toe-walls. Use toe-walls at the beginning and end of the lining. For concrete or rock riprap, toe-walls shall be of sufficient depth below the bottom of the lining (minimum 24 inches or 1.5 times the thickness whichever is greater) and thickness (minimum of 6 inches) to prevent undermining and extended the full width of the lining. Toe walls for synthetic turf reinforcement fabric shall be as recommended by the manufacturer.

Cutoff walls. Use cutoff walls on all concrete lined waterways and outlets. The cutoff walls shall be placed at intervals along the length of the concrete to intercept any seepage and prevent piping under the concrete. The cutoff walls shall extend a minimum of 24 inches below the lining bottom and shall be a minimum of 6 inches thick. Extend the cutoff walls the full width of the lining.

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. Provide for energy dissipation as needed.

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 AASHTO M288, Section 7.3., NEH 654.14D, or NRCS Design Note 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 NEH Part 633, Chapter 26. 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.

Contraction joints. Contraction joints in concrete linings, if required, shall be formed transversely to a depth of about one-third 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.

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 NEH 654.14I and NEH 654.14K.

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 (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

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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 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 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.

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. Adequate safety factor should be incorporated.

Lined waterways may increase flow velocities and peak discharge rates to downstream properties and systems. Flow dissipaters and/or structures may be necessary to mimic historical conditions.

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:

- Location of lined waterway or outlet
- 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.
- Details and location of toe walls, cutoff walls, etc.,.
- Type and quality of materials used to line the waterway or outlet.
- Thickness of liner.
- Subgrade preparation.
- Seepage control details.
- Disposal requirements for excess soil material.
- Site specific construction specifications that describe the installation of the lined waterway or outlet. Include specification for control of concentrated flow during construction.

OPERATION AND MAINTENANCE

An operation and maintenance plan shall be provided to and reviewed with the landowner. A maintenance program shall be established to maintain waterway capacity and outlet stability.

The plan shall include the following items and others as appropriate.

Lining damaged by machinery or erosion must be repaired promptly.

Inspect lined waterways 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

AASHTO M288. 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 Filters.

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

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

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

ASSOCIATED PRACTICES

GA NRCS Conservation Practice Standard, Diversion (362)

GA NRCS Conservation Practice Standard, Grade Stabilization (410)

GA NRCS Conservation Practice Standard, Integrated Pest Management (595)

GA NRCS Conservation Practice Standard, Nutrient Management (590)

GA NRCS Conservation Practice Standard, Roof Runoff Structure (558)

GA NRCS Conservation Practice Standard, Structure for Water Control (587)

GA NRCS Conservation Practice Standard, Surface Drainage, Field Ditch (607)

GA NRCS Conservation Practice Standard, Surface Drainage, Main or Lateral (608)

GA NRCS Conservation Practice Standard, Terrace (600)

NRCS Conservation Practice Standard, Land Reclamation, Abandoned Mined Land (543)

NRCS Conservation Practice Standard, Land Reclamation, Currently Mined Land (544)

NRCS Conservation Practice Standard, Stormwater Runoff Control (570)

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