AS OF MAY 2025 CHAPTER 6.7 CONTAINS THE PREVIOUS EDITION OF BOTH GRASSED SWALES AND ROCK LINED CHANNELS. IT WILL BE UPDATED AT A LATER DATE.

4.1 Grassed Swale

Description

Grassed swales are constructed channels shaped and established with suitable vegetation in order to convey stormwater runoff without allowing channel erosion.

Condition Where Practice Applies

This practice is applicable where added capacity and protection by vegetation are needed to control erosion from concentrated runoff, to improve drainage, or to convey stormwater.

This practice applies generally to small channels having flow only during storm events.

This practice is not applicable in larger ephemeral streams where grass cannot be established and maintained. ~~Chapter 3 Stream Channel Rehabilitation or further channel restoration resources should be referenced for larger channels having seasonal low perennial flow~~.

Use caution when design flow for the swale is greater than 100 cubic feet per second (cfs) from a 10-yr.-frequency storm. Generally, grassed swales are suitable for drainage areas less than 100 acres in flat to gently rolling terrain. In steeper terrain, it may be more difficult even on smaller drainage areas to design a stable waterway.

Planning Considerations

Constructed Channels vs. Natural Drainageways

Discretion must be used when replacing natural channels with constructed channels. Natural drainage systems, even small intermittent and ephemeral drainageways, provide many hydraulic and environmental benefits not duplicated by constructed channels. See the introduction to Stream Practices for more discussion of natural channel design.

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for grassed swales that are located adjacent to a stream. It is best to contact your local Soil and Water Conservation District (SWCD) office to determine what both agencies' permit requirements are for your project.

Water Quality

Grassed swales are designed to reduce erosion and therefore provide a limited water quality benefit. Swales may be modified to store a water quality volume by adding weirs or check dams in order to detain and treat runoff for a minimum of 24 hours.

Stable Outlet

The swale should not be constructed until a suitable stable outlet is in place, and upstream erosion control is in place.

Design Criteria

Grassed swales shall be planned, designed and constructed to comply with all Federal, State, and local laws and regulations.

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the swale during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

The channel's capacity shall be adequate to carry the peak rate of runoff from a 10-yr. frequency storm prior to out of bank flow. Out of bank flows may be permitted in short sections of a reach to facilitate alignment or to minimize grade changes, as long as positive drainage to the swale is maintained, and flow will continue along the swale re-entering the swale prior to reaching the outlet. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. Grassed swales designed to protect residences and businesses, shall have out of bank capacity to carry the peak rate of runoff prior to flow inside adjacent planned residences or businesses.

Cross Section Shape

- *Parabolic channels* most closely approximate natural flow characteristics at low as well as high flows. Although generally preferred for esthetic reasons, design and construction procedures are more complex.
- *Trapezoidal channels* often are used where the quantity of water to be carried is large and velocities high. Channels constructed to treat stormwater runoff should be trapezoidal in shape to promote settling and infiltration. Side slopes that are 3 to 1 or flatter are recommended. Consider future maintenance when designing the shape of trapezoidal channels.

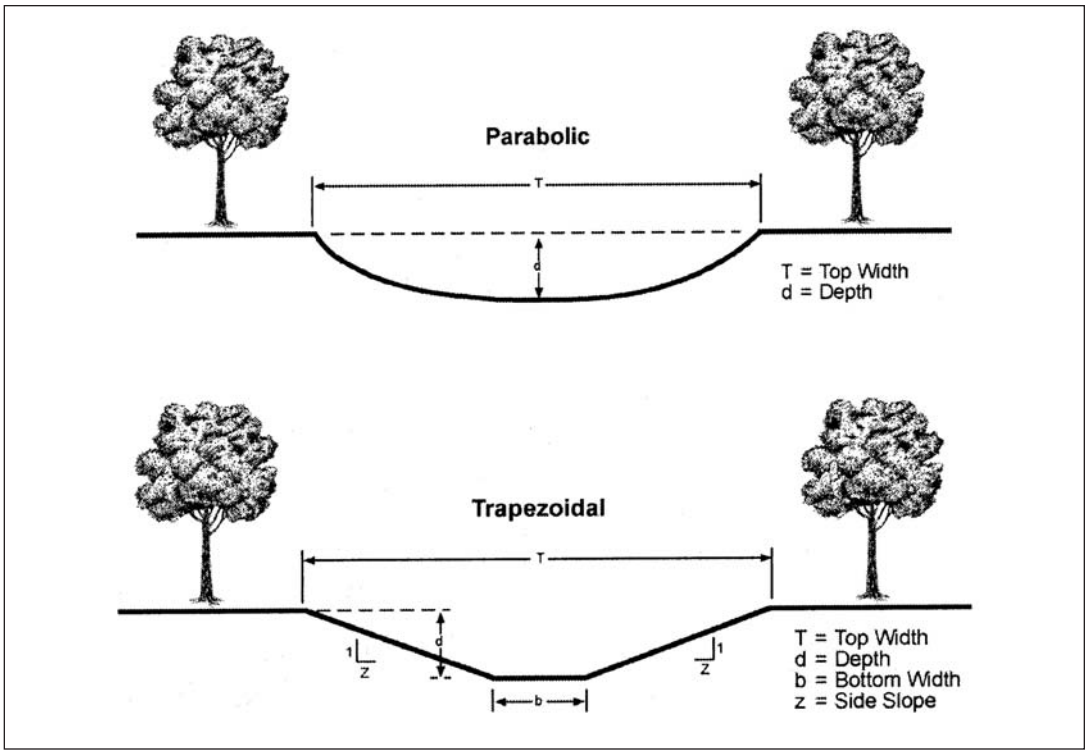


Figure 4.1.1

Special Considerations

Where out-of-bank flow would not cause erosion, property damage or flood damage, no minimum size channel is required. These conditions will most often occur in areas with little slope and established woody vegetation.

Design Velocity of Vegetative Lining:

Channels shall be designed so that the velocity of flow expected from a 10-year frequency storm does not exceed the permissible velocity for the type of lining used (see the table below). Manning's Equation or other suitable method should be used to determine design velocity.

Table 4.1.1 Grass Lining

Maximum Flow Velocity for a 10-Yr. Frequency Storm				
Soil		Maximum Velocity (fps)		
Texture	Type	Seed & mulch	Seed & Matting	Sod
Sand, Silt, Sandy Loam, Silt Loam	Sand	1.5	3.0	3.5
Silty Clay Loam, Sandy Clay Loam	Firm Loam	2.0	4.0	4.0
Clay	Clay	2.5	4.0	5.0
N/A	Gravel	3.5	5.0	6.0
N/A	Weathering Shale	4.5	5.0	N/A

Note: Generally soil texture can be determined from soil surveys. For channels on fill, soils should be tested.

Establishing Vegetation

All grassed swales shall be vegetated or otherwise stabilized, as soon as possible after construction. Stabilization should be done according to the appropriate Standards and Specifications for Vegetative Practices (e.g. Permanent Seeding, Mulching, Matting)

- *For design velocities of less than 3.5 fps,* seeding and mulching may be used for the establishment of the desired vegetation. Mulch netting should be used to protect the seeding during establishment. It is recommended that when conditions permit temporary diversion or other means be used to prevent water from entering the grassed swale during the establishment of vegetation.
- *For design velocities of more than 3.5 fps,* the grassed swale shall be stabilized with seeding protected by erosion control matting or blankets, or with sod. It is recommended that when conditions permit temporary diversion or other means be used to prevent water from entering the grassed swale during the establishment of vegetation.

Check Dams

Check dams may be incorporated to increase channel stability by decreasing flow velocities, and reducing erosion and headcutting. Check dams are grade control structures constructed out of durable material (i.e. rock riprap) across the swale cross section to prevent headcutting. Check dams should be used where they will not be considered a nuisance or create a high maintenance burden. See Chapter __ - Water Quality Swale for planning and design details that could be used to maximizing the detention time within the grassed swale to enhance water quality benefits.

Drainage

Designs for a site having prolonged flows, a high water table, or seepage problems shall include Subsurface Drains, Rock Lined Waterway, or other suitable measures to avoid saturated conditions. ~~See Chapter 4, part 7 Subsurface Drains and Chapter 4, part 3 Rock Lined Channel, for planning and design details.~~

Offset subsurface drains at least _ of the designed top width from the centerline of the swale. The drain's flowline should be at least 1 foot below the centerline grade and maintain at least 2 feet of cover. Subsurface drains should be installed on both sides of the swale if a high water table or other site conditions will create wetness on both sides. Orifice plates or other acceptable means should be used to prevent pressure flow in the subsurface drain as necessary.

Outlets

All grassed swales shall have a stable outlet with adequate capacity to prevent ponding or flooding damages.

In cases where the grassed swale outlets into a larger ditch or stream with a continual or seasonal base flow, protection of that portion of the grassed waterway / conveyance channel / swale affected by this wet condition is necessary. This may be accomplished by installation of use of a rock lined outlet or grade stabilization structure (see rock channel protection).

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover, and associated structural components such as inlets, outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the channel after construction
- Protect the channel from damage by equipment and traffic
- Fertilize annually to and maintain a vigorous stand of grass
- Mow the channel regularly to maintain a healthy and vigorous stand of grass
- Inspect grassed swales regularly, especially following heavy rains
- Repair damage to channels immediately. Damaged areas will be filled, compacted, and seeded immediately. All broken subsurface drains should be repaired
- Remove sediment deposits to maintain capacity of grassed swale. Seed and mulch any bare areas that develop. Note: excessive deposition or erosion of the swale may indicate the need to consider changes to the current design that will be appropriate to the water and sediment transport.
- Easements should be obtained to ensure the channel is maintained as constructed.

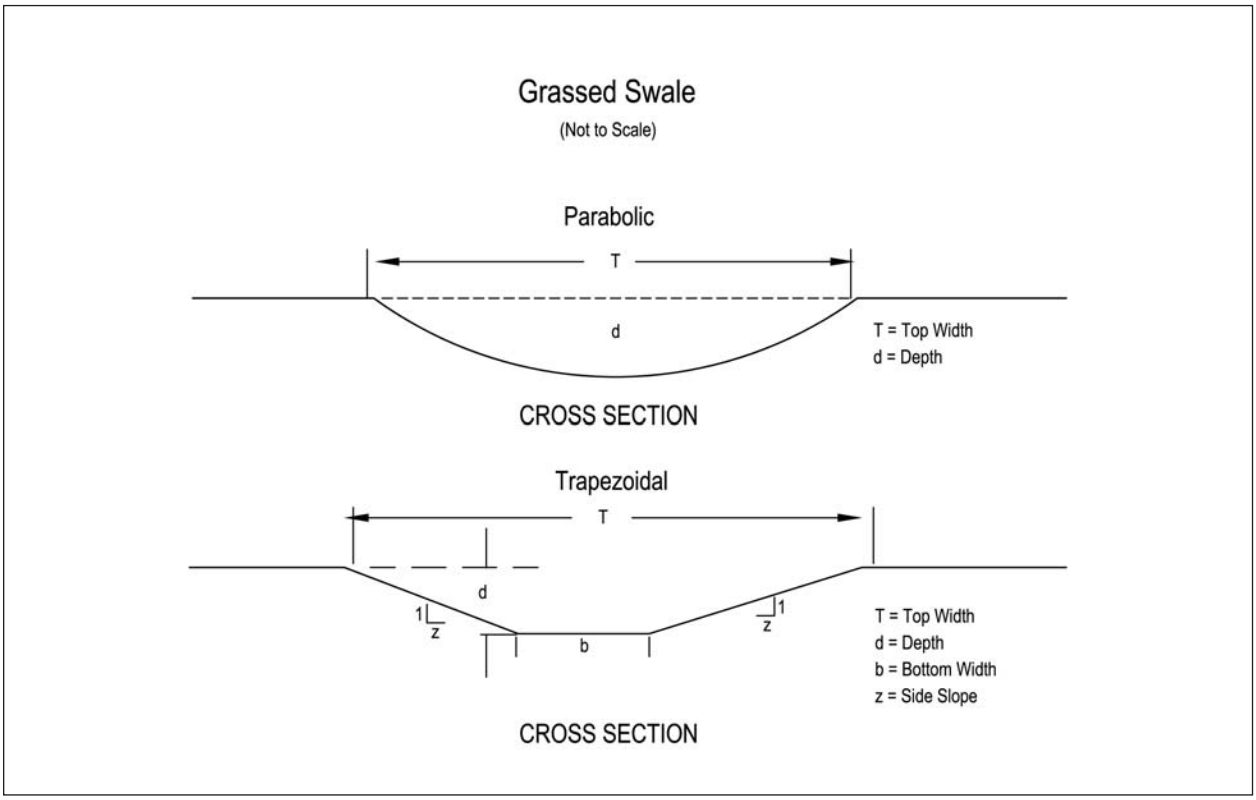
References

Additional guidance for evaluation, planning, and design of grassed swales is given in:

- NRCS Ohio Practice Standard 412, Grassed Waterway.
- NRCS Engineering Field Handbook (EFH) Part 650, Chapter 7 - Grassed Waterways.
- Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

Specifications
for

Grassed Swale



1. All trees, brush, stumps, and other unsuitable material shall be removed from the site.
2. The channel shall be excavated and shaped to the proper grade and cross section.
3. Fill material used in the construction of the channel shall be well compacted in uniform layers not exceeding 9 inches using the wheel treads or tracks of the construction equipment to prevent unequal settlement.
4. Excess earth shall be graded or disposed of so that it will not restrict flow to the channel or interfere with its functioning.
5. Stabilization shall be done according to the appropriate specifications for permanent seeding, vegetative practices, sodding and matting.
6. Construction shall be sequenced so that newly constructed channels are stabilized prior to becoming operational. To aid in the establishment of vegetation, surface water may be prevented from entering the newly constructed channel through the establishment period.
7. Gullies that may form in the channel or other erosion damage that occurs before the grass lining becomes established shall be repaired without delay.

4.3 Rock Lined Channel

Description

A channel that is shaped or graded and protected with an erosion resistant rock riprap underlain with filter or bedding material used to convey stormwater runoff without allowing channel erosion. Rock channel protection provides for the safe conveyance of runoff from areas of concentrated flow without damage from erosion or flooding, where vegetated waterway / conveyance channel / swales would be inadequate. Rock lined channel may also be necessary to control seepage, piping, and sloughing or slides. The riprap section extends up the side slopes to designed depth. The earth above the rock should be vegetated or otherwise protected.

Conditions Where Practice Applies

This practice applies where the following conditions exist:

- Concentrated runoff will cause erosion unless a liner is provided
- Steep grades, wetness, seepage, prolonged base flow, or piping would cause erosion
- Damage by vehicles or animals will make the establishment or maintenance of vegetation difficult
- Soils are highly erosive or other soil or climatic conditions preclude the use of vegetation
- Velocities are expected that will erode the channel or outlet without protection

Caution should be used when design flow greater than 100 cubic feet per second (cfs) from a 10-yr.-frequency storm is expected. Chapter __ - Stream Channel Restoration, should be referenced for planning and design of larger channels.

Planning Considerations

Permits

A construction permit may be required by the local government. Additionally, the U.S. Army Corps of Engineers and the Ohio Environmental Protection Agency, through Sections 404 and 401, respectively, of the Clean Water Act, may require a permit for rock lined channel / outlet that are located adjacent to a stream. It is best to contact your local Soil and Water Conservation District (SWCD) office to determine what both agencies' permit requirements are for your project.

Water Quality

Rock lined channels and outlet protection provide water quality benefits by providing channel stability, prevention of excessive erosion, and limiting subsequent downstream sedimentation.

Design Criteria

Runoff

Runoff computation will be based upon the most severe soil and cover conditions that will exist in the area draining into the channel during the planned life of the structure. Use the NRCS Technical Release 55 (TR 55) or other suitable method shall be used to determine peak rate of runoff.

Capacity

The design capacity of the rock lined channel shall be adequate to carry the peak rate of runoff from a 10-yr. frequency storm. Where high-hazard conditions exist, higher frequency storms should be chosen to provide protection compatible with conditions. The rock-lined channel must have design capacity as required if it to be used as an outlet for a grassed waterway, diversion, terrace, or other measure. Capacity shall be computed using Manning's Equation with a coefficient of roughness "n" listed in the "rock size" table below.

Rock-lined channels / outlets shall be designed by accepted engineering methods such as the Federal Highway Administration Circular No. 15 or Figure 2-1 (Maximum depth of Flow for Riprap Lined Channels) that can be used to determine rock size using flow depth and velocity obtained from Manning's equation. Procedures are also available in the NRCS Engineering Field Handbook.

Velocity

Table 4.3.1 Maximum Design Velocity

Design Flow Depth	Maximum Velocity
0 - 0.5 ft	25 fps
0.5 – 1.0 ft	15 fps
> 1.0 ft	10 fps

Cross Section Shape

The cross sectional shape of rock lined waterway / outlets shall be parabolic, trapezoidal, or triangular.

- *Parabolic channels* most closely approximate natural flow characteristics at low as well as high flows. Although generally preferred for esthetic reasons, design and construction procedures are more complex.
- *Trapezoidal channels* often are used where the quantity of water to be carried is large and velocities high. The steepest permissible side slopes, horizontal to vertical, shall be 2 to 1.
- *Triangular shaped channels* generally is used where the quantity of water to be handled is relatively small, such as roadside ditches. The steepest permissible side slopes, horizontal to vertical, shall be 2 to 1.

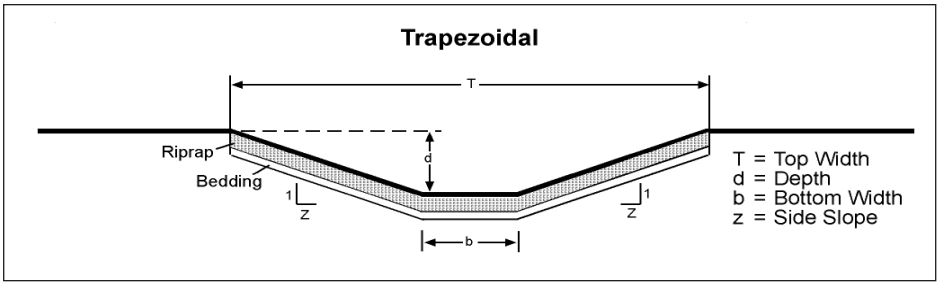


Figure 4.3.1

Rock Lining

The rock-lined channel shall consist of the rock riprap layer and an underlying filter or bedding. Minimum thickness of the rock riprap layer shall be the maximum stone size. Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing and thawing. Figure 4.3.2 gives the maximum depth of flow for riprap lined channels. Rock riprap must have a well-graded distribution and be placed in a to obtain a solid, compact layer of riprap. This may require some hand placing and tamping with construction equipment. Spreading gravel or soil over top of the placed riprap surface will fill the voids by interlocking the riprap together.

Filter or Granular Bedding

Filter or granular bedding must be placed beneath all riprap to prevent the underlying soil from eroding and undermining the riprap, and to collect seepage and base flow. Minimum bedding thickness shall be 4 inches. Use of large size riprap may necessitate the use of a thicker bedding layer or 2 differently sized bedding layers. Care should be taken to select a granular bedding that that is suitable with the subgrade material.

Table 4.3.2 Rock Riprap Size

Type of Rock or Riprap (ODOT)	"n" value	Size of Rock	
		50% by weight	85% by weight
Type D	.036	> 6 in.	3 - 12 in.
Type C	.04	> 12 in.	6 - 18 in.
Type B	.043	> 18 in.	12 - 24 in.
Type A	.045	> 24 in.	18 - 30 in.

Adjustments to Naturalize Rock Lining

In order to more closely reflect the nature of the bed of a natural channel, smaller size graded stone may be used to fill the voids left in typical riprap applications.

Besides channel shape and pattern, typical rock lined channels depart from the flow behavior of natural channels by having to much pore space in the rock. Therefore regular flow is often entirely below the surface. This will be improved by extending the gradation of stone down to the gravel-sized material. This addition will increase velocity and reduce capacity slightly; therefore corresponding adjustments should be made.

Geotextile

Geotextile may be used as a filter to be placed beneath the riprap to prevent piping of the soil where wetness, seepage, or prolonged base flow is the reason for lining the channel with riprap. If design of the rock lined channel results in high velocities and steep grades, granular bedding should be used instead of geotextile. Care should be taken to properly anchor the geotextile to prevent unraveling under flowing water. Geotextile shall be woven or nonwoven monofilament yarn and shall meet Class I criteria in the attached table "Requirements for Geotextile".

Maintenance

A maintenance program shall be established to maintain capacity, vegetative cover above the riprap, and associated structural components such as inlets, outlets, and tile lines. Items to consider in the maintenance program include:

- Determine responsible party to inspect and maintain the channel after construction
- Protect the channel from damage by equipment, traffic, or livestock
- Fertilize the vegetated area annually to and maintain a vigorous stand of grass
- Mow the vegetated area to maintain a healthy and vigorous stand of grass.
- Repair damage to channels immediately. Missing riprap should be replaced as soon as possible. All broken subsurface drains should be repaired. Seed and mulch any bare areas that develop.
- Remove sediment and debris that have accumulated.
- Easements, or other means, should be obtained to ensure the channel is maintained as constructed

References

Additional guidance for evaluation, planning, and design of rock lined channels is given in:

- National Cooperative Highway Research Program Report 108 – Tentative Design Procedure for Riprap – Lined Channels
- NRCS Ohio Practice Standard 468, Lined Waterway Or Outlet
- NRCS Engineering Field Handbook, Chapter 6 - Structures
- NRCS Design Note 24, Guide for Use of Geotextiles

Table 4.3.3 Requirements for Geotextiles

Property	Test method	Woven - Class I	Nonwoven - Class I
Tensile strength (pounds) 1/	ASTM D 4632 grab test	200 minimum in any principal direction	180 minimum
Elongation at failure (percent) 1/	ASTM D 4632 grab test	<50	≥ 50
Puncture (pounds) 1/	ASTM D 4833	90 minimum	80 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified, but no smaller than 0.212 mm (#70) 2/	As specified max. #40 2/
Percent open area (percent)	CWO-02215-86	4.0 minimum	----------
Permitivity sec-1	ASTM D 4491	0.10 minimum	0.70 minimum

1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.
Note: CWO is a USACE reference.

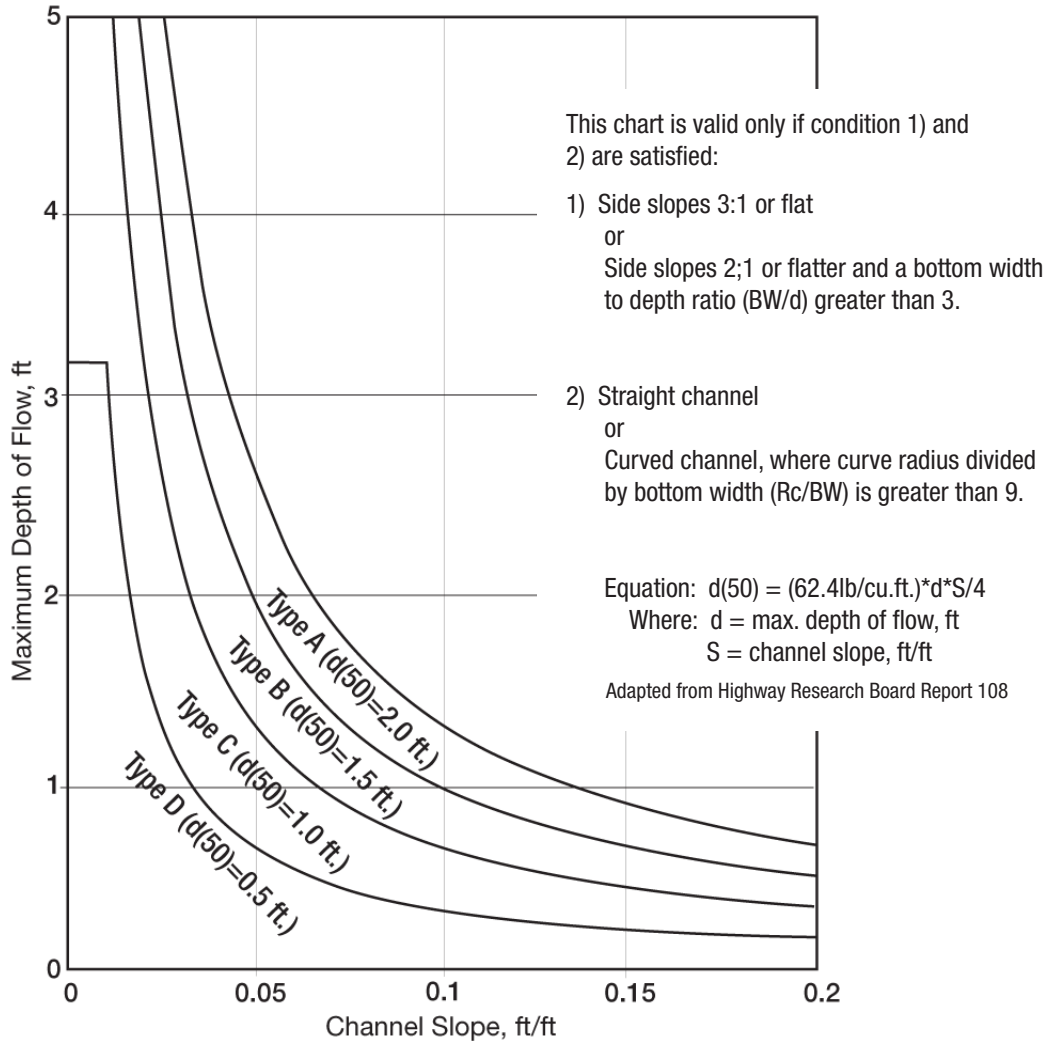
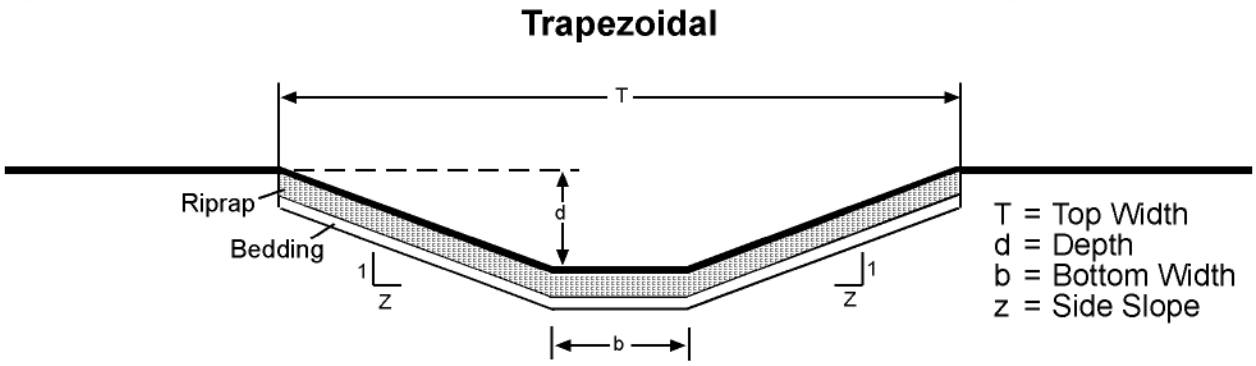


Figure 4.3.2 Maximum Depth of Flow for Riprap Lined Channels

Specifications
for

Rock Lined Channel



1. Subgrade for the filter and riprap shall be prepared to the required lines and grades as shown on the plan. The subgrade shall be cleared of all trees, stumps, roots, sod, loose rock, or other material.
2. Riprap shall conform to the grading limits as shown on the plan.
3. No abrupt deviations from the design grade or horizontal alignment shall be permitted.
4. Geotextile shall be securely anchored according to manufacturers recommendations.
5. Geotextile shall be laid with the long dimension parallel to the direction of flow and shall be laid loosely but without wrinkles and creases. Where joints are necessary, strips shall be placed to provide a 12-in. minimum overlap, with the upstream strip overlapping the downstream strip.
6. Gravel bedding shall be ODOT No. 67's or 57's unless shown differently on the drawings.
7. Riprap may be placed by equipment but shall be placed in a manner to prevent slippage or damage to the geotextile.
8. Riprap shall be placed by a method that does not cause segregation of sizes. Extensive pushing with a dozer causes segregation and shall be avoided by delivering riprap near its final location within the channel.
9. Construction shall be sequenced so that riprap channel protection is placed and functional without delays when the channel becomes operational.
10. All disturbed areas will be vegetated as soon as practical.