Stormwater Conveyance Channel

Definition

A stormwater conveyance channel is a permanent waterway, designed to convey stormwater runoff. The channel is lined with vegetation or riprap, or, in limited cases, gabions, which extend up the side slopes to design flow depth. This practice provides a means of transporting concentrated surface runoff without causing erosion or flooding. Channels, including road ditches, that are constructed as part of a development to transport surface runoff, generally are included in this practice. This practice does *not* apply to natural waterways.

Pollutants Controlled and Impacts

Properly designed storm water conveyance channels are effective in preventing erosion caused by concentrated flows. They can significantly reduce or eliminate sediment loads originating in the channel area.

This practice has limited ability to remove pollutants such as nutrients, bacteria, biological oxygen demand, and sediment. These pollutants should be controlled with other BMPs.

Application

Land Use
This BMP potentially applies to all land uses where channels are constructed, but is most common in urban and urbanizing areas, and along roads.

Soil/Topography/Climate
Channel design and stability will differ depending on the soil type and topography. On hilly terrain, for example, velocities may most often be such that grass-lined channels won't work effectively and riprap will be needed instead. If deep cuts are required on hilly terrain, an above-ground channel may be impractical. In such a situation, you may want to consider downdrains or some other type of Grade Stabilization Structure.

When to Apply
Apply whenever stormwater runoff is resulting in erosive channels or gullies.

Where to Apply
Apply where it is necessary to construct channels for stormwater management purposes, including:

- where steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion.
- where high property values or adjacent facilities warrant extra cost to contain design runoff in a limited space.
- in recreational areas, along road sides or in other areas where gullies have occurred. See Exhibit 1 for an example of an application in roadside ditches.

Relationship With Other BMPs

This BMP addresses the proper way to design channels which will be used for stormwater conveyance. The key BMPs which will be referred to for lining the channel are Grassed Waterways and Riprap. Gabions are included in the Slope/Shoreline Stabilization BMP. For concrete flumes and downdrains, refer to the Grade Stabilization Structures BMP. All channels should discharge through a Stabilized Outlet.

Specifications

Planning Considerations:

1. The design of a channel is based primarily on the volume and velocity of flow expected in the channel. The intent is to design the waterway so that it has adequate capacity and sufficient erosion resistance. Use Appendix 1 or other acceptable methods to determine the peak runoff.
2. Determine the slope of the channel.
3. Determine the soil type using field soil tests or soil surveys. Knowledge of soil type is important in completing the design.

Design Considerations:

The design of stormwater conveyance channels should be done by registered professional engineers.

Shape:

There are two types of channels to choose from: parabolic and trapezoidal (see Exhibit 2). Parabolic channels are more similar to the shape of natural channels and are often used where space is available for a wide, shallow channel to allow low velocities. Trapezoidal channels are normally used where deeper channels are needed to carry large flows. Trapezoidal design works well with riprap or other structural linings, and tends to revert to a parabolic shape over time. **V-shaped channels are not to be used** because they are similar to the shape of gullies.

Side Slopes:

Vegetated slopes in urban areas should be 4:1 or flatter for maintenance reasons. Slopes can be steeper for structurally lined channels as long as they are within the capability of the soil and structural lining. For trapezoidal channels with a bottom width greater than 15 feet, the center should be lowered 0.5 foot to prevent meandering during low flows.

Capacity:

Unless local stormwater requirements indicate otherwise, all stormwater channels should be designed to contain at least the peak flow from a 10-year frequency storm. In areas where flooding of the channel will cause damage to property owners, the channel capacity should be increased. The capacity of the channel should not exceed the capacity of the outlet area. Property damage or safety hazards may result if channel capacity is exceeded.

Extra capacity may be needed for areas where sediment is expected to accumulate. An extra 0.3 to 0.5 foot of depth is recommended.

Velocity:
Channels should be designed so that the velocity of flow expected from the design storm does not exceed the permissible velocity for the type of lining used. Permissible velocities for grass-lined channels are given in the Grassed Waterways BMP. Information on selecting the proper stone size and gradation for riprap-lined channels is given in the Riprap BMP. Design velocities should be appropriate for the type of liner selected. See "Channel Linings," below.

Depth:
The design water surface elevation of a channel receiving water from Diversions or other tributary channels should be equal to or less than the design water surface elevation of the diversion or other tributary channel at the point of intersection.

Cross Sections:
The top width of parabolic and grass-lined channels should not exceed 30 feet, and the bottom width of trapezoidal, grass-lined channels should not exceed 15 feet unless multiple or divided waterways, riprap center, or other means are provided to control meandering of low flows.

Freeboard:
Where good vegetative cover cannot be grown adjacent to the lined side slopes, a minimum freeboard of 1 foot above design flow depth should be incorporated into the lined waterway.

Channel Linings:
If flows are expected to be 6 cfs or less, consider using Grassed Waterways. If flows are expected to be over 6 cfs, consider using Riprap. If flows or slopes are such that riprap cannot be used, consider using gabions (see the Slope/Shoreline Stabilization BMP). Concrete applications, including flumes and downdrains are included in the Grade Stabilization Structures BMP.

It is important to follow the design and installation procedures for the type of liner selected--follow the specifications in the chosen BMP.

Outlet:
All channels should discharge through a Stabilized Outlet. The outlet should be designed so that it will handle the expected runoff velocities and volumes from the channel without resulting in scouring. An energy dissipator may be needed if it is determined that flow velocities exceed the allowable velocity of the receiving channel.

Upstream Areas:
If the channel is below a high sediment-producing area, sediment should be trapped before it enters the channel (see Sediment Basin) or the area stabilized with vegetation.

Design Procedures:
The following information is needed to design lined waterways:

* Expected runoff volume (see Appendix 1)
* Desired channel capacity
* Slope of the channel
* The type of cross-sectional design of channel (trapezoidal or parabolic)
* The type of lining

* Design depth or design cross sectional area

1. Based on the expected peak runoff, determine which type of liner is best for the waterway. Use the table below:

peak flow < 6 cfs	consider Grassed Waterways and refer to that BMP for design specifications.
peak flow > 6 cfs	use Riprap wherever possible. Only use gabions where riprap is not feasible. See the Slope/Shoreline Stabilization BMP for information on gabions. If it is necessary to use concrete, refer to the Grade Stabilization BMP for design specifications. Concrete is not the preferred material for stormwater conveyance.

2. Choose a channel shape and approximate design dimensions. Use the dimensions in the formulas in Exhibit 2 to determine cross sectional area, A, and hydraulic radius, R, based on the expected design flow. In the formulas that we provided, all units are in feet.

3. Determine the appropriate Manning's "n" value for the chosen liner. Use the table below:

   Riprap -- Select the D_{50} stone size first and use Exhibit 3 to determine "n" for use in the Manning's formula in Exhibit 4.

   Gabions -- use 0.30

   Where two or more channel slopes occur at the site, choose the appropriate "n" value and bottom width for each slope and provide a smooth transitional section at least 15 feet long between the various design sections.

4. Use Exhibit 4 and solve the Manning formula for velocity.

5. Multiply the velocity found in step 4 times the cross sectional area, A, found in step 2 to determine design flow, Q.

6. Compare the design flow to the calculated runoff. The design flow should be greater than the calculated runoff by no more than 10%. If the design flow is not within this range, modify the shape of the channel to obtain a better cross sectional area and try this procedure again.

Example Problem for Riprap-lined Channels:

Situation:

A city engineer is designing a riprap-lined channel that will flow through a city park. The calculated runoff capacity is 15 cubic feet per second. A trapezoidal channel with a 3:1 side slope and a bottom width of 2 feet is desired. The channel slope will be 2%. The size of stone to be used has a D_{50} value of 4 inches. This means that 50% of the stone to be used (by weight) is smaller than 4 inches in diameter.

i. In order to calculate cross-sectional area (A) and the hydraulic radius (R), either the depth (d) or top width (T) must be determined. Choose a depth of 1 foot to start. Then from Exhibit 2, b= 2, d= 1, and Z= 3. Using these values A= 5 square feet, and R= 0.60 feet.

ii. Use Exhibit 3 to find the "n" value for D_{50} = 4-inch stone. Since depth of flow equals 1 foot, the "n" value is 0.041 from the chart.

iii. Use Exhibit 3 to find the velocity (V), or calculate V using the formula. In our example, using "n", R and S, this is 3.6 feet per second.

iv. To find the flow (Q) for this design, multiply the area (5) by the velocity (3.6). This gives 18.2 cubic feet per second, which is adequate capacity for the expected flow, but because the design flow is much less, velocities may be extremely low. Choose a smaller depth and try to get within 10% of the design flow. In this case, a depth of 0.95 feet would correspond to a flow of 16.3 cfs, which is within 10% of the design flow and therefore a better design.

Construction Considerations:

1. Excavate the channel using proper Grading Practices, and following the design.

2. Compact all fills to prevent unequal settlement. Any soil that is removed and not used as part of the waterway should be disposed of following specifications in the Spoil Piles BMP.

3. Install the channel liner based on specifications in the appropriate BMP.

Maintenance

At a minimum, check all constructed channels after each storm which meets or exceeds the design storm. On riprap-lined waterways, check for scouring below the riprap layer, and be sure the stones have not been dislodged by the flow.

Particular attention should be paid to the outlet of the channel. If erosion is occurring at the outlet, appropriate energy dissipation measures should be taken.

Sediment should be removed from riprap-lined channels if it reduces the capacity of the channel.

Exhibits

Exhibit 1: Roadside Ditch with Armored Channel. Connecticut Guidelines for Soil Erosion and Sediment Control, 1985.

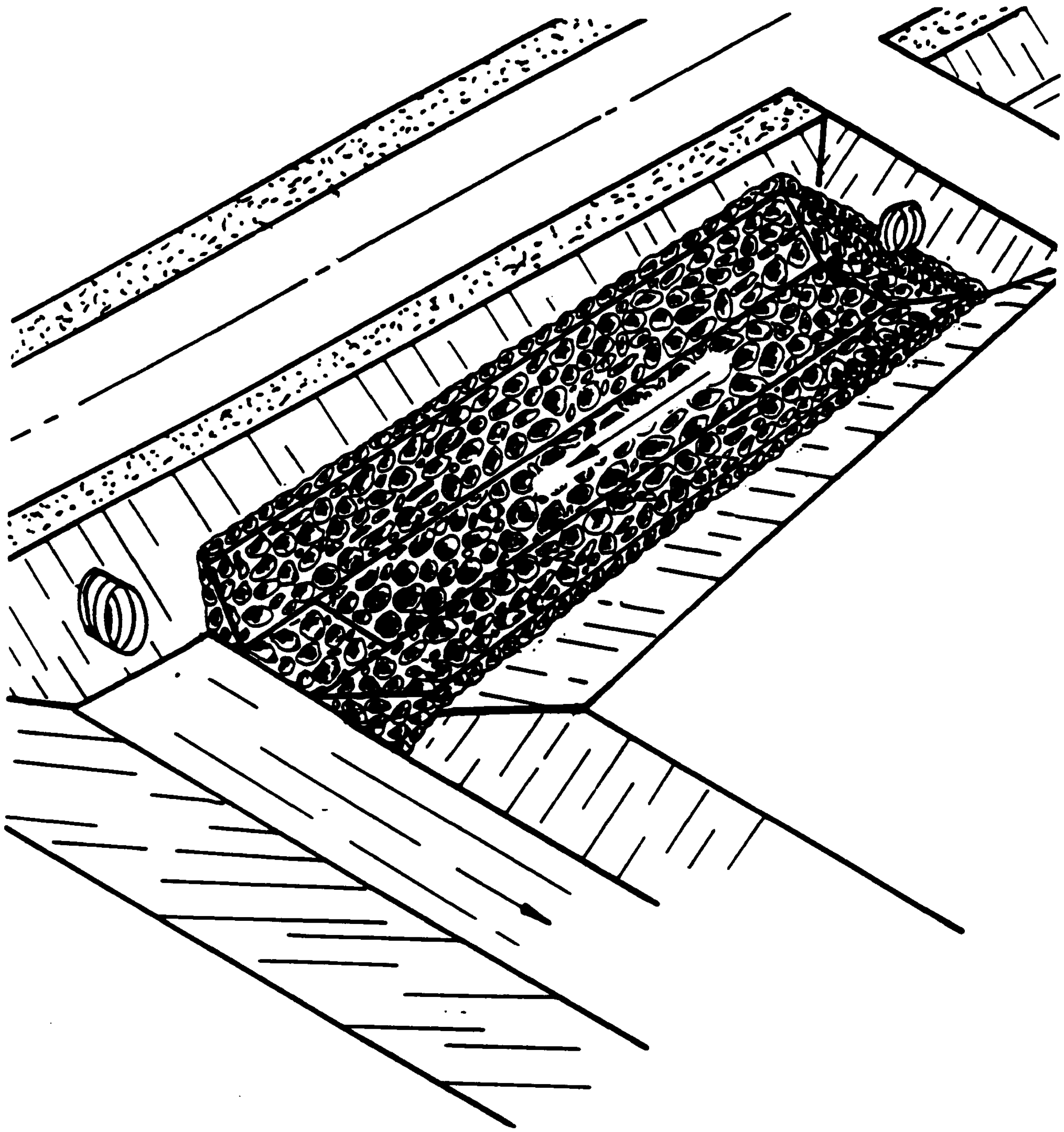
Exhibit 2: Channel Geometry. Modified from Connecticut Guidelines for Soil Erosion and Sediment Control, 1985, as copied from USDA, SCS, Storrs, Conn.

Exhibit 3: Values of n for Riprap-Lined Channels, D_{50} vs. depth of flow. Protecting Water Quality in Urban Areas. Minnesota Pollution Control Agency, Division of Water Quality. 1989.

Exhibit 4: Solution of the Manning Formula. Protecting water Quality in Urban Areas. Minnesota Pollution Control Agency, Division of Water Quality, 1989.

Exhibit 1

Roadside Ditch with Armored Channel

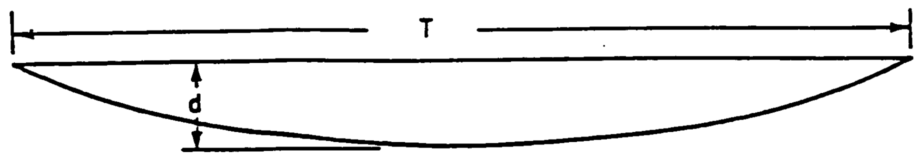


Source: Connecticut Guidelines for Soil Erosion and Sediment Control, 1985.

Exhibit 2

Channel Geometry

Parabolic Shape

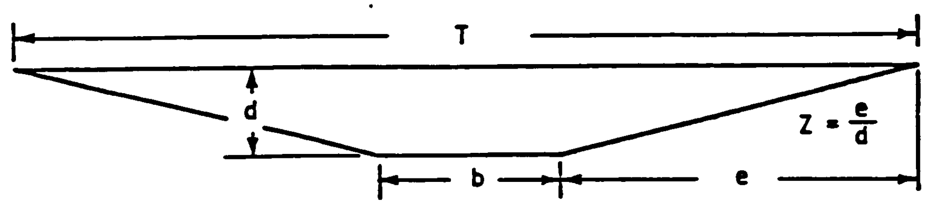


Cross-Sectional Area (A) = $\frac{2}{3}Td$

Top Width (T) = $\frac{1.5\,A}{d}$

Hydraulic Radius = $\frac{T^2 d}{1.5T^2 + 4d^2}$

Trapezoidal Shape



Cross-Sectional Area (A) = $bd + Zd^2$

Top Width (T) = $b + 2dZ$

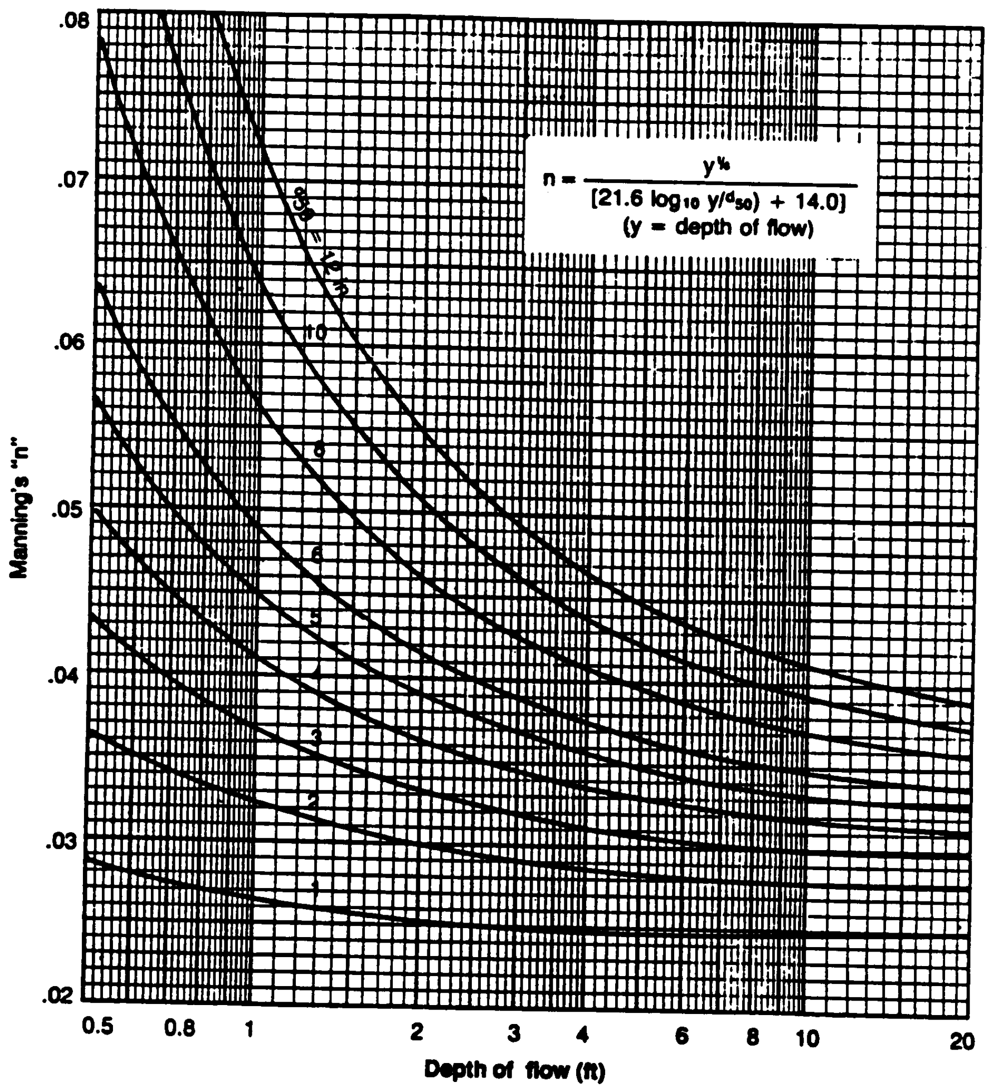
Hydraulic Radius = $\frac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}}$

Z = slope

Adapted from: U.S. Department of Agriculture, Soil Conservation Service, Storrs, Connecticut.

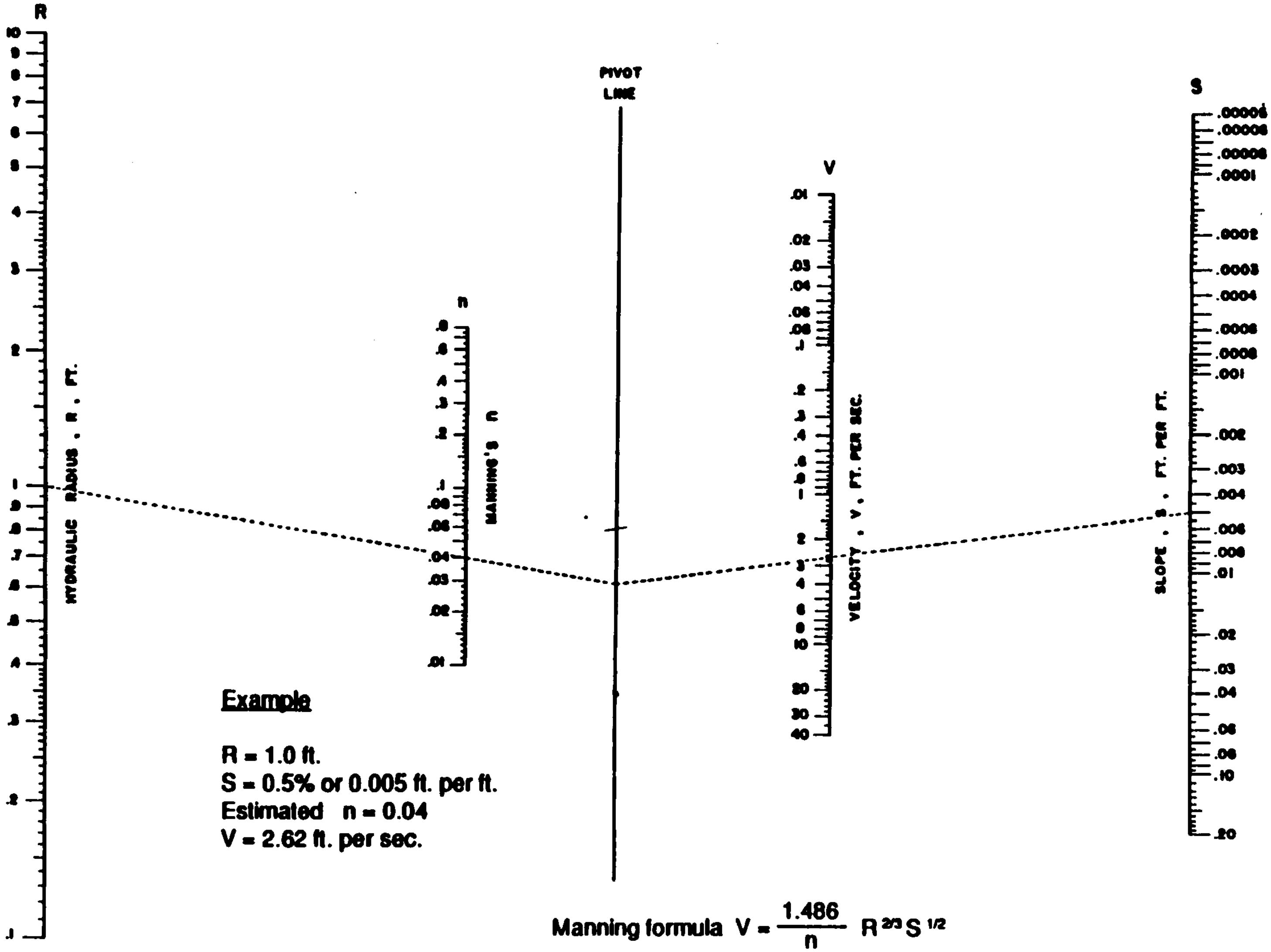
Exhibit 3

Values for n for Riprap-lined Channels, d_{50} vs. Depth of Flow



Source: Protecting Water Quality in Urban Areas, Minnesota Pollution Control Agency, Division of Water Quality, 1989.

Exhibit 4
Solution of the Manning Formula



Source: Protection Water Quality in Urban Areas, Minnesota Pollution Control Agency, Division of Water Quality, 1989.