Rip Rap

Source: Mississippi State University

BENEFITS

	L	M	H
Flow Control		■	■
Erosion Control		■	■
Sediment Control			
Runoff Reduction			
Flow Diversion			

Description: Rip rap is a common method of protecting a channel downstream of a storm sewer or culvert outlet from erosion. A layer of crushed stone placed on the bottom and sides of the channel protects the channel and dissipates the energy of the high velocity flow.

Typical Uses: Used at the outlet of storm sewer pipes, roadway and driveway culverts, and at any point concentrated runoff enters a channel.

Advantages:
• Widely used method of erosion protection.
• Materials are readily available in most areas.
• Effective at reducing scour when properly designed and installed.

Limitations:
• Commonly undersized.
• Not aesthetically pleasing.
• May not be adequate for flows from large pipes (>48 inches).
• May be higher cost due to limited availability of stone.

Longevity: Temporary or permanent

SUDAS Specifications: Refer to Section 9040, 2.09 and 3.13

A. Description/Uses

The most common method of protecting a channel at an outlet is to place a layer of crushed stone along the bottom and sides of the channel. The purpose of the stone is to protect the channel until the outlet flow loses sufficient velocity and energy, so that erosion will not occur in the downstream channel. Rip rap is provided by constructing a blanket of crushed stone, to a specified depth at the outlet. The layer of the stone is constructed so that the top is flush with the invert elevation of the outlet pipe. The stone should be placed on a layer of engineering fabric to protect the underlying soil from the erosive action of the churning water.

For larger pipes, or for discharges from pipes with large head pressures, greater protection may be required. Additional protection can be provided by constructing a rock-lined plunge pool, stilling basin, or through the use of concrete energy dissipaters (see Chapter 2 - Stormwater).

B. Design Considerations

The following design information only applies to the design of rock protection at outlets. It does not apply to rock lining of channels or streams. In addition, the design of rock plunge pools or stilling basins, and other types of energy dissipaters is not covered in this section. Refer to the Federal Highway Administration Hydraulic Engineering Circular No. 14 (HEC-14), "Hydraulic Design of Energy Dissipators for Culverts and Channels" for information on designing these structures.

The Iowa DOT Culvert Program (version 2.0) includes three methods of designing rock protection at the outlet of culverts. The methods include HEC-14 rip rap basins, U.S. Army Corps of Engineers scour hole design and U.S. Bureau of Reclamation plunge basin design. This program is available online and can be obtained from the Iowa DOT's Bridges and Structures Bureau.

The steps below describe the method of designing rip rap:

1. **Tailwater Depth:** The first step is to find the tailwater depth at the pipe outlet, corresponding to the appropriate design-year storm event for the outlet structure (see Chapter 2 - Stormwater) for design criteria for various structures). Normally, the tailwater depth is found by determining the normal depth in the channel using Manning's equation (see Chapter 2 - Stormwater). If downstream restrictions such as a culvert, dam or channel constriction exist, a more thorough analysis is required.

   If the tailwater is less than half of the discharge flow depth (pipe diameter or box height if flowing full) it is classified as a *minimum tailwater condition.* If the tailwater is greater than or equal to half of the discharge flow depth, it is classified as a *maximum tailwater condition.* The tailwater condition will determine which figure (Figure 7E-10.03 or 7E-10.04) to use to find the necessary rock size and apron dimensions.

   Pipes that outlet onto flat areas without a well-defined channel can be assumed to have a minimum tailwater condition.

   If the tailwater condition cannot be easily determined for a channel, the apron should be designed for the maximum tailwater condition as a conservative approach.

2. **Stone Size:** As the discharge flows over the crushed stone, the flow imposes shear stresses on the individual stones. Since the stones are only held in place by the force of gravity, they must have sufficient mass to prevent them from being dislodged by the force of the flowing water. For rip rap design, the crushed stone material is selected based upon its average, or d_{50}, diameter. The d_{50}

diameter represents the size at which half of the individual stones (by weight) are smaller than the specified diameter.

The d_{50} diameter is determined with Figure 7E-10.03 or 7E-10.04, for the appropriate tailwater condition. This value represents the minimum average diameter of stone necessary to resist the anticipated flows.

a. **Pipes Flowing Full:** The appropriate figure is entered along the x-axis at the design discharge. A vertical line is projected to the curve for the appropriate pipe diameter in the lower set of curves. From this point, a horizontal projection is made to the right, and the minimum d_{50} diameter is read.

b. **Partially Full Pipes and Box Culverts:** Using the depth of flow and velocity at the outlet, the intersection of d and v in the lower portion of the appropriate figure is found. From this point, a horizontal projection is made to the right, and the minimum d_{50} diameter is read.

Most crushed stone used for outlet protection is specified by weight, not by diameter. The following table lists the standard SUDAS and Iowa DOT revetment and erosion stone weights and corresponding d_{50} diameters. These gradations are also shown on Figures 7E-10.03 and 7E-10.04. Alternative gradations may be selected and specified if available from local aggregate suppliers.

Table 7E-10.01: Standard Revetment and Erosion Stone Properties

Standard Classification	d_{50} Weight (lbs)	Average d_{50} Diameter[1] (feet)	Maximum Weight (lbs)	Avg. max. Diameter[1] (feet)
Class A Revetment Stone	125[2]	1.1[2]	400	1.7
Class B Revetment Stone	275	1.5	650	2.0
Class D & E Revetment Stone	90	1.0	250	1.4
Erosion Stone	---	0.5	---	0.75

[1] Diameters based upon an assumed specific gravity of 2.65.
[2] Approximate values for design purposes. Actual d_{50} value is not specified. (d_{75} = 75 lbs).

3. **Apron Length:** A sufficient length of protection must be provided in order to reduce the velocity and energy of the flow to the level anticipated in the downstream channel. This length is dependent on the volume and velocity of the flow at the discharge point. It is also dependent on the tailwater condition of the downstream channel. The length, L_a, is found from Figure 7E-10.03 or 7E-10.04 for the appropriate tailwater condition.

From the intersection of discharge and pipe diameter, or for velocity and flow depth found in the previous step, a vertical line is projected to the appropriate discharge depth/pipe diameter in the upper set of curves. From this intersection, a horizontal line is projected to the left to determine the minimum length of rock protection required.

4. **Apron Width:** For pipes that discharge into a well-defined channel, the width of the apron should extend to the top of the bank, or at least 1-foot above the maximum tailwater depth, whichever is less, along the entire length of the apron.

For outlets that discharge onto flat areas, the width of the apron at the upstream end of the culvert should be three times the diameter of the pipe, or equal to the width of the concrete pipe apron if one is provided. The width of the apron at the downstream end should be equal to the length of the apron, L_a, plus the diameter of the pipe, D.

5. **Apron Depth:** The depth of the apron should be equal to one and one-half times the maximum stone diameter (see Table 7E-10.01 for maximum diameter).

    The channel downstream of the rock apron must be analyzed to ensure that existing or proposed channel liner is sufficient and that it will not be eroded under the anticipated flow depths. Methods for analyzing channel liners can be found in Section 7E-23.

C. Application

Outlet protection should be considered at all pipe and culvert outlets. Rip rap is an easily constructed method of protection and is sufficient for many situations.

D. Maintenance

After installation, rock aprons should be inspected regularly. Special attention should be paid to the end of the apron, as it transitions to a natural channel. If scour or erosion is occurring at this junction, the apron should be extended, and additional stabilization methods may be required.

Figure 7E-10.01: Rip Rap Apron for Pipe Outlet into Channel
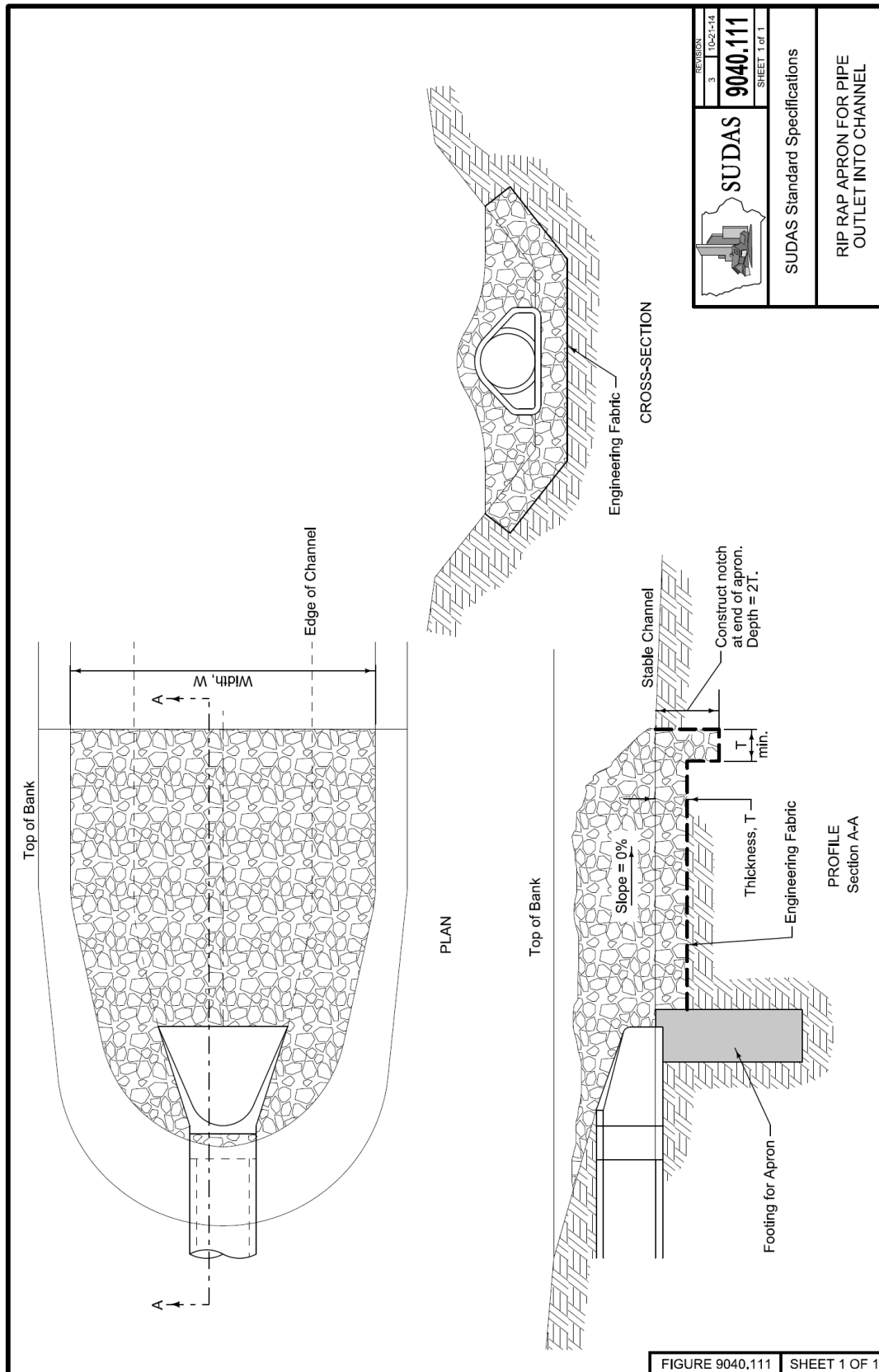([SUDAS Specifications Figure 9040.111](#))

Figure 7E-10.02: Rip Rap Apron for Pipe Outlet onto Flat Ground
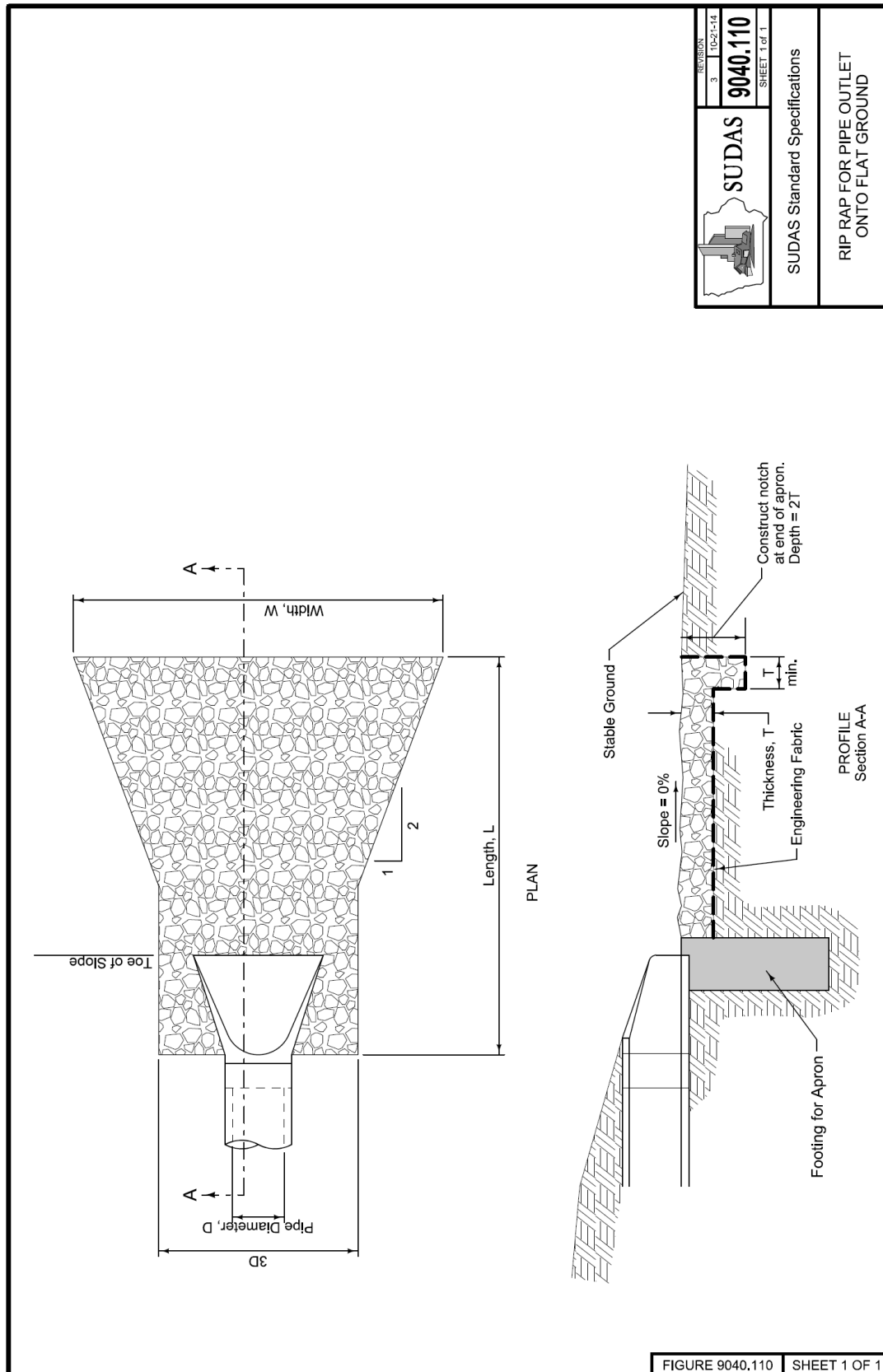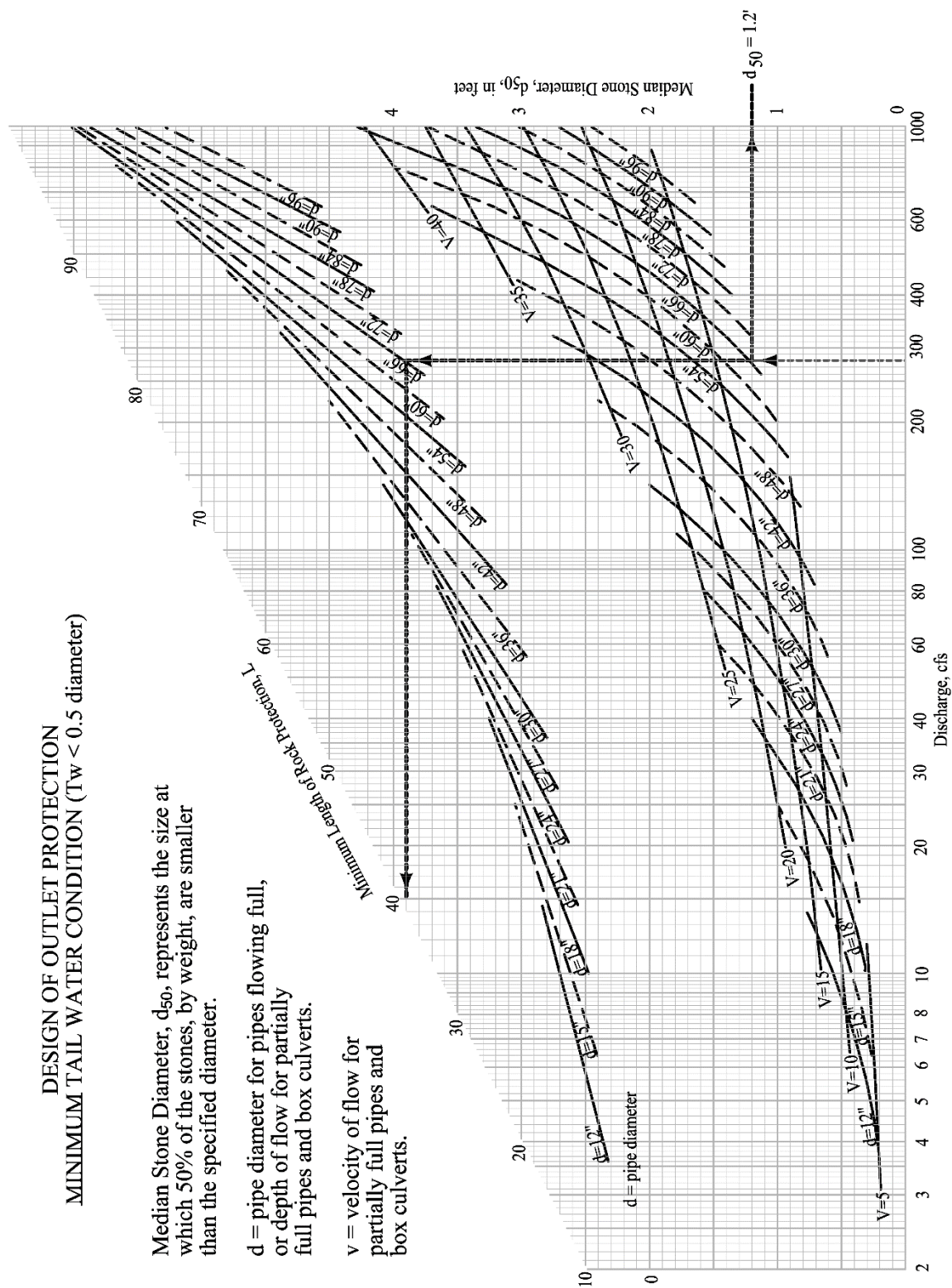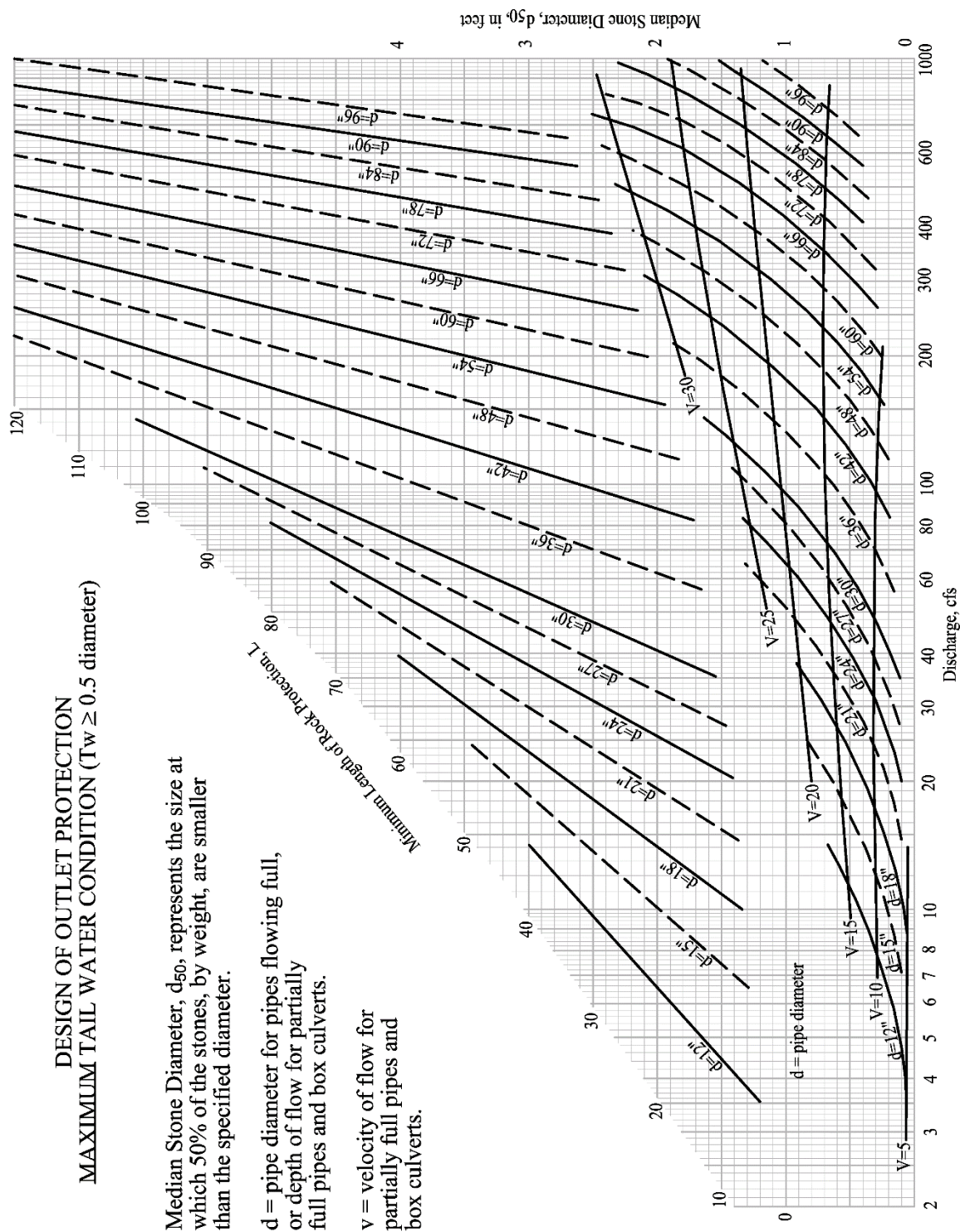(SUDAS Specifications Figure 9040.110)

Figure 7E-10.03: Design of Outlet Protection, <u>Minimum</u> Tailwater Condition

Source: USDA NRCS, 2004

Figure 7E-10.04: Design of Outlet Protection, <u>Maximum</u> Tailwater Condition

Source: USDA NRCS, 2004