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SEDIMENT AND EROSION DESIGN GUIDE

Prepared for

Albuquerque Metropolitan Arroyo
Flood Control Authority
(AMAFCA)

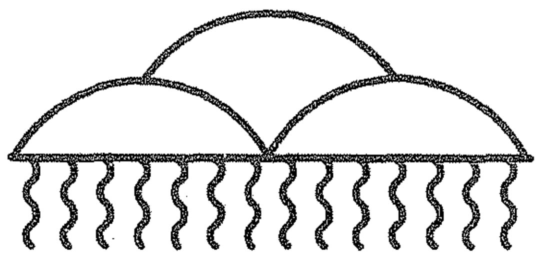

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Table 3.1. Base Values of Manning's n (n_b).				
	Median size, bed material		Base n value	
Channel or floodplain type	Millimeters	Inches	Benson and Dalrymple	Chow
Sand channels				
(Only for upper regime flow where grain roughness is predominant)	0.2	----	0.012	----
	0.3	----	0.017	----
	0.4	----	0.020	----
	0.5	----	0.022	----
	0.6	----	0.023	----
	0.8	----	0.025	----
	1.0	----	0.026	----
Stable channels and flood plains				
Concrete	----	----	0.012 - 0.018	0.011
Rock cut	----	----	----	0.025
Firm soil	----	----	0.025 - 0.032	0.020
Coarse sand	1 - 2	----	0.026 - 0.035	----
Fine gravel	----	----	----	0.024
Gravel	2 - 64	0.08 - 2.5	0.028 - 0.035	----
Coarse gravel	----	----	----	0.026
Cobble	64 - 256	2.5 - 10.1	0.030 - 0.050	----
Boulder	< 256	< 10.1	0.040 - 0.070	----

Table 3.2. Adjustment Factors for the Determination of n Values for Channels.

Conditions	n Value	Remarks
n_1 - Cross Section Irregularity		
Smooth	0	Smoothest Channel
Minor	0.001-0.005	Slightly Eroded Side Slopes
Moderate	0.006-0.010	Moderately Rough Bed and Banks
Severe	0.011-0.020	Badly Sloughed and Scalloped Banks
n_2 - Variation in Cross-Sectional Shape and Size		
Gradual	0	Gradual Changes
Alternating Occasionally	0.001-0.015	Occasional Shifts From Large to Small Sections
Alternating Frequently	0.010-0.015	Frequent Changes in Cross-Sectional Shape
n_3 - Obstructions		
Negligible	0-0.004	Obstructions < 5% of Cross Section Area
Minor	0.005-0.015	Obstructions < 15% of Cross Section Area
Appreciable	0.020-0.030	Obstructions 15-50% of Cross Section Area
Severe	0.040-0.060	Obstructions > 50% of Cross Section Area
n_4 - Vegetation		
Small	0.002-0.010	Flow Depth > 2x Vegetation Height
Medium	0.010-0.025	Flow Depth > Vegetation Height
Large	0.025-0.050	Flow Depth < Vegetation Height
Very Large	0.050-0.100	Flow Depth < 0.5 Vegetation Height
M - Sinuosity *		
Minor	1.0	Sinuosity < 1.2
Appreciable	1.15	1.2 Sinuosity < 1.5
Severe	1.30	Sinuosity > 1.5

*Sinuosity is the ratio of channel length to down-valley length.

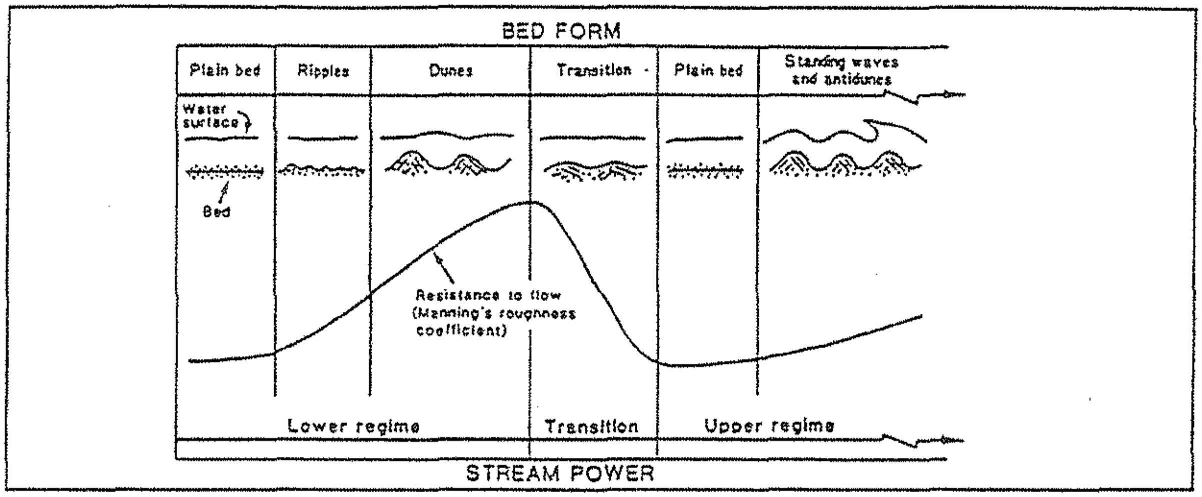

Figure 3.3. Relative resistance in sand-bed channels (after Arcement & Schneider, 1984).

$$F_g = \frac{V}{\sqrt{(S_g - 1) g D_{50}}} \tag{3.15}$$

and

$$F_g' = \frac{1.74}{S^{1/3}} \tag{3.16}$$

where
- v = channel velocity, in feet per second
- S_g = specific gravity of the sediment
- g = acceleration of gravity = 32.2 feet / sec^2

When $F_g \leq F'_g$, use the lower regime equation (Equation 3.12) and when $F_g > F'_g$, use the upper regime equation (Equation 3.13). **For arroyos in the Albuquerque area, upper regime flow can be expected under most conditions.**

Burkham and Dawdy (1976) showed that the Limerinos equation could be used in sand-bed streams provided the regime was plane bed. In that analysis, they extended the range of relative roughness parameter to $R/D_{84}>600$. For a 2-foot deep channel, this results in a range of D_{84} up to 1 mm; a condition commonly met in Albuquerque area arroyos. The Limerinos equation is discussed in the following section on coarse-bed channels.

Resistance to flow in coarse-bed channels. In gravel and cobble-bed channels, including riprap lined channels where the depth of flow is more than 2 to 3 times the size of the larger particles in the bed, resistance to flow can be estimated from either the Strickler relation given by (Anderson et al., 1970):

$$n = 0.04\, D_{50}^{1/6} \tag{3.17}$$

where D_{50} = median size of the bed material, in feet,

or from the Limerinos (1970) equation given by:

$$n = \frac{0.0926 R^{1/6}}{1.16+2.0\log\left(\frac{R}{D_{84}}\right)} \tag{3.18}$$

where D_{84} = bed material size for percent of the particles, by weight, are smaller.

When only the D_{50} of the bed material is available, the following formulation of the Limerinos equation, as presented in the roadside channels section of the HYDRAIN computer program (FHWA, 1992), can be used.

$$n = \frac{0.0926\ R^{1/6}}{0.796 + 1.85\ \log\ (R/D_{50})} \tag{3.18a}$$

In Equations 3.18 and 3.18a, all dimensions are in feet. Flow depth, Y_0, may be substituted for the hydraulic radius, (R), in wide channels (i.e., width-depth ratio > 10).

For purposes of this Design Guide, it is recommended that the Limerinos equation (3.18 and 3.18a) be used in preference to Strickler's relation (3.17).

As an alternative, the n-value can be selected from Table 3.1. Since the roughness can vary significantly with flow depth in coarse-bed channels, it is advisable to verify the selected value by use of one of the above equations if flow depth or velocities will significantly affect the design. Other relations for the coarse bed case can be found in Richardson et al. (1990).

Resistance to flow on floodplains. Arcement and Schneider (1984) modified Equation 3.11 for use in estimating n-values for floodplains. The correction factor for sinuosity, m, becomes 1.0 for this case and the correction for variations in channel size and shape (n_2) is assumed to be zero. Equation 3.11, adapted for use on floodplains, becomes:

$$n = n_b + n_1 + n_3 + n_4 \tag{3.19}$$

where n_b = base value of n for a bare soil surface

Selection of the base value for floodplains is the same as for channels. It is recommended that the user of this Design Guide refer to Arcement and Schneider (1984) for a detailed discussion of factors that affect flow resistance in floodplains.

Resistance to flow in concrete-lined channels. For concrete-lined channels carrying little or no sediment, the boundary roughness values can be selected from Table 3.1, or other appropriate references for concrete roughness (e.g., USCOE, 1991). When the channel carries a significant sediment load, the bed roughness may increase to values consistent with an alluvial channel. If the sediment transport capacity is significantly greater than the supply, most of the sediment particles are expected to be suspended above the bed and no adjustment to the roughness is required. As the sediment supply approaches the transport capacity, a layer of sediment will deposit and move along the bed which will impact channel roughness similar to an alluvial channel. If the sediment supply is greater than the transport capacity, aggradation will occur and the channel capacity and water surface must be adjusted accordingly. For this case, a composite n-value can be estimated using either the conveyance weighting or equal velocity methods. The conveyance weighting method is described by:

$$n_c = \frac{A_t R_t^{2/3}}{\sum \frac{A_i R_i^{2/3}}{n_i}} \tag{3.20}$$

where the subscripts i and t refer to individual subsections across the cross section and the total cross section (see **Figure 3.4**), respectively and n_c is the composite n-value. The conveyance weighting method given by Equation 3.20 is recommended for purposes of this Design Guide when the Manning's equation is used for the hydraulic computations. Other compositing methods are also available; details can be found in USCOE (1991). Of these, the Equal Velocity Method, proposed by Horton and independently by Einstein (Chow, 1959) provides a good approximation for trapezoidal channels, although the method may not be as accurate as Equation 3.20. The Horton or Einstein method is given by: