From Hydraulic Engineering Circular No. 22, Third Edition
URBAN DRAINAGE DESIGN MANUAL
USDOT & FHWA Pub No FHWA-NHI-10-009 September 2009

Table 3-2. Manning's Roughness Coefficient (n) for Overland Sheet Flow.[6]

Surface Description	n
Smooth asphalt	0.011
Smooth concrete	0.012
Ordinary concrete lining	0.013
Good wood	0.014
Brick with cement mortar	0.014
Vitrified clay	0.015
Cast iron	0.015
Corrugated metal pipe	0.024
Cement rubble surface	0.024
Fallow (no residue)	0.05
Cultivated soils	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Range (natural)	0.13
Grass	
Short grass prairie	0.15
Dense grasses	0.24
Bermuda grass	0.41
Woods*	
Light underbrush	0.40
Dense underbrush	0.80

*When selecting n, consider cover to a height of about 30 mm. This is only part of the plant cover that will obstruct sheet flow.

Shallow Concentrated Flow Velocity. After short distances of at most 130 m (400 ft), sheet flow tends to concentrate in rills and then gullies of increasing proportions. Such flow is usually referred to as shallow concentrated flow. The velocity of such flow can be estimated using a relationship between velocity and slope as follows[6]:

$$V = K_u\, k\, S_p^{0.5} \qquad (3\text{-}4)$$

where:

K_u = 1.0 (3.28 in English units)
V = Velocity, m/s (ft/s)
k = Intercept coefficient (Table 3-3)
S_p = Slope, percent

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Table 3-3. Intercept Coefficients for Velocity vs. Slope Relationship of Equation 3-4.[6]

Land Cover/Flow Regime	k
Forest with heavy ground litter; hay meadow (overland flow)	0.076
Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland (overland flow)	0.152
Short grass pasture (overland flow)	0.213
Cultivated straight row (overland flow)	0.274
Nearly bare and untilled (overland flow); alluvial fans in western mountain regions	0.305
Grassed waterway (shallow concentrated flow)	0.457
Unpaved (shallow concentrated flow)	0.491
Paved area (shallow concentrated flow); small upland gullies	0.619

Open Channel and Pipe Flow Velocity. Flow in gullies empties into channels or pipes. Open channels are assumed to begin where either the blue stream line shows on USGS quadrangle sheets or the channel is visible on aerial photographs. Cross-section geometry and roughness should be obtained for all channel reaches in the watershed. Manning's equation can be used to estimate average flow velocities in pipes and open channels as follows:

$$V = (K_u/n)\, R^{2/3}\, S^{1/2} \qquad (3\text{-}5)$$

where:

- n = Roughness coefficient (see Table 3-4)
- V = Velocity, m/s (ft/s)
- R = Hydraulic radius (defined as the flow area divided by the wetted perimeter), m (ft)
- S = Slope, m/m (ft/ft)
- K_u = Units conversion factor equal to 1 (1.49 in English units)

For a circular pipe flowing full, the hydraulic radius is one-fourth of the diameter. For a wide rectangular channel (W > 10 d), the hydraulic radius is approximately equal to the depth. The travel time is then calculated as follows:

$$T_{ti} = L / (60\, V) \qquad (3\text{-}6)$$

where:

- T_{ti} = Travel time for Segment I, min
- L = Flow length for Segment I, m (ft)
- V = Velocity for Segment I, m/s (ft/s)