APPENDIX A - HYDRAULIC ROUGHNESS (MANNING'S n) VALUES OF CONDUITS AND CHANNELS

This appendix lists Manning's roughness (n) values for various conduits and channels, as follows:

Sources:
- Chow, Ven Te, "Open-Channel Hydraulics," 1959
- FHWA, "Design of Urban Highway Drainage, The State of the Art," 1979
- FHWA, "Hydraulic Design Series No. 3, Design Charts for Open-Channel Flow," 1961
- FHWA, "Hydraulic Engineering Circular No. 15, Design of Roadside Channels with Flexible Linings," 1988
- FHWA, "Hydraulic Engineering Circular No. 22, Urban Drainage Design Manual," 1996
- ODOT, "Memo to Designers, Helical Corrugated Pipe," 1992

TABLE 1: CONDUITS

Conduit	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
A. Concrete or asbestos-cement pipe	0.011	0.013	0.015
B. Metal pipe or pipe-arch with annular corrugations			
1. 2-2/3-inch x ½-inch corrugations			
a. Plain or fully coated	. . . . .	0.024	. . . . .
b. Paved invert (range represents 25 and 50 percent of circumference paved, with larger n value representing 25 percent paved)			
1. Full flow depth	0.018	. . . . .	0.021
2. Flow 80 percent of depth	0.016	. . . . .	0.021
3. Flow 60 percent of depth	0.013	. . . . .	0.019
2. 3-inch x 1-inch corrugations	. . . . .	0.027	. . . . .
3. 6-inch x 2-inch corrugations	. . . . .	0.032	. . . . .
C. Smooth walled helical spiral rib pipe	0.012	. . . . .	0.013
D. Corrugated metal subdrain	0.017	0.019	0.021
E. Plastic pipe			
1. Smooth	0.011	. . . . .	0.015
2. Corrugated	. . . . .	0.024	. . . . .
F. Metal pipe or pipe arch with helically wound corrugations			
1. Smaller pipes			
12 inch	. . . . .	0.013	. . . . .
15 inch	. . . . .	0.014	. . . . .
18 *inch*	. . . . .	0.015	. . . . .

Conduit	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
21 inch	. . . . .	0.016	. . . . .
24 inch	. . . . .	0.017	. . . . .
27 inch	. . . . .	0.018	. . . . .
30 inch	. . . . .	0.019	. . . . .
33 inch	. . . . .	0.020	. . . . .
36 inch	. . . . .	0.021	. . . . .
42 inch	. . . . .	0.022	. . . . .
48 inch	. . . . .	0.023	. . . . .
2. Diameters larger than 48 inches with 2-2/3-inch x 1/2-inchcorrugations	. . . . .	0.024	. . . . .
3. Diameters larger than 48 inches with 3-inch x 1-inch corrugations	. . . . .	0.027	. . . . .
G. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
H. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
I. Steel pipe, welded	0.010	0.012	0.014
J. Brick			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
K. Common clay drainage tile	0.011	0.013	0.017
L. Vitrified clay sewer	0.011	0.014	0.017

Conduit	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
M. Sanitary sewer, coated with sewage slime, with bends and connections	0.012	0.013	0.016
N. Monolithic concrete			
1. Wood forms, rough	0.015	0.017	0.020
2. Wood forms, smooth	0.012	0.014	0.016
3. Steel forms	0.012	0.013	0.014
O. Rubble masonry, cemented	0.018	0.025	0.030
P. Laminated treated wood	0.015	0.017	0.020

TABLE 2: GUTTERS AND PAVEMENTS

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
A. Concrete gutter, troweled finish *	. . . . .	0.012	. . . . .
B. Asphalt pavement			
1. Smooth texture	. . . . .	0.013	. . . . .
2. Rough texture	. . . . .	0.016	. . . . .
3. ODOT Standard Curb, Low Profile Mountable Curb, Monolithic Curb and Sidewalk, and Mountable Curb	. . . . .	0.016**	. . . . .
C. Concrete gutter with asphalt pavement			
1. Smooth	. . . . .	0.013	. . . . .
2. Rough	. . . . .	0.015	. . . . .
3. ODOT Curb and Gutter, Mountable Curb and Gutter, and Valley Gutter	. . . . .	0.014	. . . . .
D. Concrete pavement			
1. Float finish	. . . . .	0.014	. . . . .
2. Broom finish	. . . . .	0.016	. . . . .
3. ODOT Standard Curb, Low Profile Mountable Curb, Monolithic Curb and Sidewalk, and Mountable Curb	. . . . .	0.016**	. . . . .
E. Brick	. . . . .	0.016	. . . . .
F. For gutters listed above with small slope, where sediment may accumulate, increase above values of n by	. . . . .	0.002	. . . . .

* Flow contained within gutter.

* * The most common value used for gutters with Asphalt bottoms on ODOT project is 0.016

TABLE 3: SMALLER ARTIFICIAL CHANNELS

Values are for artificial channels with flows of 50 cubic feet per second or less. Roughness values vary with depth, as follows:

- Minimum values are for flow depths greater than 2 feet.
- Normal values are for depths between 6 inches and 2 feet.
- Maximum values are for flow depths less than 6 inches.

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
A. Rigid Linings			
1. Concrete	0.013	0.013	0.015
2. Grouted riprap	0.028	0.030	0.040
3. Stone masonry	0.030	0.032	0.042
4. Soil cement	0.020	0.022	0.025
5. Asphalt	0.016	0.016	0.018
B. Unlined			
1. Bare soil	0.020	0.020	0.023
2. Rock cut	0.025	0.035	0.045
C. Temporary			
1. Woven paper net	0.015	0.015	0.016
2. Jute net	0.019	0.022	0.028
3. Fiberglass roving	0.019	0.021	0.028
4. Straw with net	0.025	0.033	0.065
5. Curled wood mat	0.028	0.035	0.066

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
6. Synthetic mat	0.021	0.025	0.036
D. Grass (See pages 8-12 through 8-16 of this chapter.)			
E. Riprap			
1. ODOT Class 50	0.036	0.070	0.106
2. ODOT Class 100	0.039	0.075	. . . . .

Note: Roughness values vary with depth. See previous page.

TABLE 4: LINED ARTIFICIAL CHANNELS

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
A. Concrete, with surfaces as indicated:			
1. Formed, no finish	0.014	0.017	0.020
2. Trowel finish	0.011	0.013	0.015
3. Float finish	0.013	0.015	0.016
4. Finished, with gravel on bottom	0.015	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	. . . . .
8. On irregular excavated rock	0.022	0.027	. . . . .
B. Concrete, bottom float finished, sides as indicated:			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry	0.020	0.025	0.030
4. Cement rubble masonry, plastered	0.016	0.020	0.024
5. Dry rubble or riprap	0.020	0.030	0.035
C. Gravel bottom, sides as indicated:			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
D. Glazed brick	0.011	0.013	0.015
E. Brick in cement mortar	0.012	0.015	0.018

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
F. Asphalt			
1. Smooth	. . . . .	0.013	. . . . .
2. Rough	. . . . .	0.016	. . . . .
G. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
H. Cemented masonry rubble	0.017	0.025	0.030
I. Dry masonry rubble	0.023	0.032	0.035

Note: Values are for straight alignment.

TABLE 5: EXCAVATED ARTIFICIAL CHANNELS

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
A. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
B. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
C. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
D. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
E. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
3. Clean bottom, brush on sides, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

Note: Values are for excavated or dredged channels with natural linings.

TABLE 6: HIGHWAY CHANNELS AND SWALES WITH MAINTAINED VEGETATION

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
Range of roughness values represents flow velocities from 2 to 6 feet per second with the higher roughness values representing the 2 feet per second flow velocity.			
A. Depth of flow up to 0.7 feet			
1. Grass			
a. Mowed to 2 inches	0.045	. . . . .	0.07
b. Length 2 inches to 6 inches	0.05	. . . . .	0.09
2. Grass, good stand			
a. Length about 12 inches	0.09	. . . . .	0.18
b. Length about 24 inches	0.15	. . . . .	0.30
3. Grass, fair stand			
a. Length about 12 inches	0.08	. . . . .	0.14
b. Length about 24 inches	0.13	. . . . .	0.25
B. Depth of flow 0.7 feet to 1.5 feet			
1. Grass			
a. Mowed to 2 inches	0.035	. . . . .	0.05
b. Length 2 inches to 6 inches	0.04	. . . . .	0.06
2. Grass, good stand			
a. Length about 12 inches	0.07	. . . . .	0.12
b. Length about 24 inches	0.10	. . . . .	0.20
3. Grass, fair stand			
a. Length about 12 inches	0.06	. . . . .	0.10
b. Length about 24 inches	0.09	. . . . .	0.17

TABLE 7: NATURAL CHANNELS AND FLOODPLAINS

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
A. Minor streams (top width at flood stage less than 100 feet)			
1. Streams on plain			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, irregular slopes and sections with more ineffective flow area	0.040	0.048	0.055
f. Same as d, but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070
B. Floodplains			
1. Pasture, no brush			
a. Short grass	0.025	0.030	0.035
b. High grass	0.030	0.035	0.050
2. Cultivated areas			
a. No crop	0.020	0.030	0.040
b. Mature row crops	0.025	0.035	0.045

Channel	HYDRAULIC ROUGHNESS (MANNING'S n) VALUES		
	Minimum	**Normal**	**Maximum**
c. Mature field crops	0.030	0.040	0.050
3. Brush			
a. Scattered brush, heavy weeds	0.035	0.050	0.070
b. Light brush and trees, in winter	0.035	0.050	0.060
c. Light brush and trees, in summer	0.040	0.060	0.080
d. Medium to dense brush, in winter	0.045	0.070	0.110
e. Medium to dense brush, in summer	0.070	0.100	0.160
4. Trees			
a. Dense willows, summer, straight	0.110	0.150	0.200
b. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
c. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
d. Heavy stand of timber, a few down trees, little undergrowth,flood stage below branches	0.080	0.100	0.120
e. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
C. Major streams (top width at flood stage more than 100 feet). The n values are less than those of minor streams with similar description because banks offer less effective resistance.			
1. Regular section with no boulders or brush	0.025	. . . . .	0.060
2. Irregular and rough section	0.035	. . . . .	0.100