

Appendix I

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Appendix II

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Appendix III

| <u>TYPE OF SURFACE</u> | <u>RUNOFF COEFFICIENT</u> |
|---------------------------------------------|---------------------------|
| <u>Non-Urban Areas</u> | |
| Bare Earth | 0.55 |
| Steep Grassed Areas (slope 2:1) | 0.60 |
| Turf Meadows | 0.25 |
| Forested Areas | 0.20 |
| Cultivated Fields | 0.30 |
| <u>Urban Areas</u> | |
| All Watertight Roof Surfaces | 0.90 |
| Pavement (concrete, asphalt) | 0.85 |
| Gravel | 0.85 |
| Impervious Soils (Heavy) | 0.55 |
| Impervious Soils (with turf) | 0.45 |
| Slightly Pervious Soil | 0.25 |
| Slightly Pervious Soil (with turf) | 0.20 |
| Moderately Pervious Soil | 0.15 |
| Moderately Pervious Soil (with turf) | 0.10 |
| Business, Commercial & Industrial | 0.85 |
| Apartments & Townhouses | 0.70 |
| Schools & Churches | 0.55 |
| Single Family Lots < 10,000 ft ² | 0.45 |
| Lots < 12,000 ft ² | 0.45 |
| Lots < 17,000 ft ² | 0.40 |
| Lots > ½ Acre | 0.35 |
| Park, Cemetery or Unimproved Area | 0.30 |

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Table 3.1.1 (TR-55 Table 3-1) : Runoff Coefficient's for use in the Rational Method calculations for Pipe, Channel and Detention Design

Worksheet 3: Time of Concentration (T_C) or travel time (T_t)

| | | |
|----------|---------|------|
| Project | By | Date |
| Location | Checked | Date |

Check one: Present Developed

Check one: T_C T_t through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_C only)

| | | | | |
|------------------------------------------------------------------------------|------------|--|---|---|
| | Segment ID | | | |
| 1. Surface description (table 3-1) | | | | |
| 2. Manning's roughness coefficient, n (table 3-1) | | | | |
| 3. Flow length, L (total L + 300 ft) ft | | | | |
| 4. Two-year 24-hour rainfall, P_2 in | | | | |
| 5. Land slope, s ft/ft | | | | |
| 6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t hr | | | + | = |

Shallow concentrated flow

| | | | | |
|-----------------------------------------------------|------------|--|---|---|
| | Segment ID | | | |
| 7. Surface description (paved or unpaved) | | | | |
| 8. Flow length, L ft | | | | |
| 9. Watercourse slope, s ft/ft | | | | |
| 10. Average velocity, V (figure 3-1) ft/s | | | | |
| 11. $T_t = \frac{L}{3600 V}$ Compute T_t hr | | | + | = |

Channel flow

| | | | | |
|-------------------------------------------------------------------------------------|------------|--|---|---|
| | Segment ID | | | |
| 12. Cross sectional flow area, a ft ² | | | | |
| 13. Wetted perimeter, p_w ft | | | | |
| 14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r ft | | | | |
| 15. Channel slope, s ft/ft | | | | |
| 16. Manning's roughness coefficient, n | | | | |
| 17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V ft/s | | | | |
| 18. Flow length, L ft | | | | |
| 19. $T_t = \frac{L}{3600 V}$ Compute T_t hr | | | + | = |
| 20. Watershed or subarea T_C or T_t (add T_t in steps 6, 11, and 19) Hr | | | | |

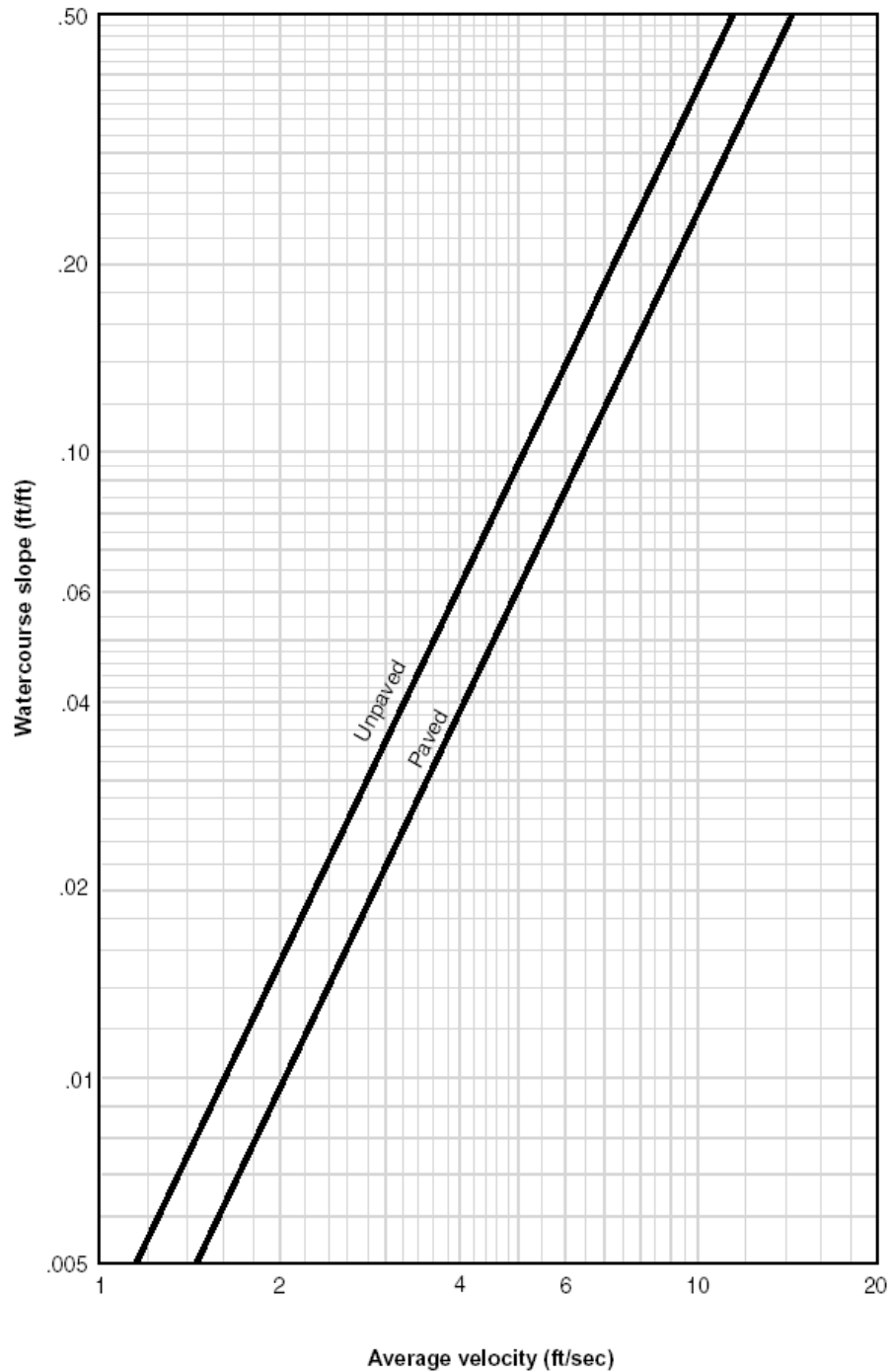
Worksheet 3.2.1: Time of Concentration or Travel Time Worksheet

| <u>SURFACE DESCRIPTION</u> | <u>n</u> |
|-----------------------------------------------------------|-----------------|
| Smooth Surfaces (concrete, asphalt, gravel, bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated Soils: | |
| Residue cover \leq 20% | 0.06 |
| Residue cover $>$ 20% | 0.17 |
| Grass: | |
| Short Grass Praire | 0.15 |
| Dense Grass | 0.24 |
| Bermuda Grass | 0.41 |
| Range (natural) | 0.13 |
| Woods: | |
| Light Underbrush | 0.40 |
| Dense Underbrush | 0.80 |

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Table 3.2.2 (TR-55 Table 3-1): Roughness coefficient's (Manning's n) for sheet flow to be used in Time-of-Concentration calculations

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



3-2

(210-VI-TR-55, Second Ed., June 1986)

Figure 3.2.3 (TR-55 Figure 3-1): Average Velocities for Estimating Travel Time for Shallow Concentrated Flow.

Worksheet 2: Runoff curve number

| Project | By | Date | | | | |
|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|------------------|---|---|----------------------------------------------------------------------------------------------------------------------|----------------------|
| Location | Checked | Date | | | | |
| Check one: <input type="checkbox"/> Present <input type="checkbox"/> Developed | | | | | | |
| 1. Runoff curve number | | | | | | |
| Soil name and hydrologic group (appendix A) | Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio) | CN ^{1/} | | | Area <input type="checkbox"/> acres <input type="checkbox"/> mi ² <input type="checkbox"/> % | Product of CN x area |
| | | Table 2.2 | - | - | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| ^{1/} Use only one CN source per line | | | | | Totals ➡ | |
| CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = _____ = _____ ; | | | | | Use CN ➡ | |

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Worksheet 3.3.1 (TR-55 Worksheet 2): Runoff Curve Number Worksheet

Table 2-2a Runoff curve numbers for urban areas^{1/}

| Cover description | Average percent impervious area ^{2/} | Curve numbers for hydrologic soil group | | | |
|--------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-----------------------------------------|----|----|----|
| | | A | B | C | D |
| <i>Fully developed urban areas (vegetation established)</i> | | | | | |
| Open space (lawns, parks, golf courses, cemeteries, etc.) ^{3/} : | | | | | |
| Poor condition (grass cover < 50%) | | 68 | 79 | 86 | 89 |
| Fair condition (grass cover 50% to 75%) | | 49 | 69 | 79 | 84 |
| Good condition (grass cover > 75%) | | 39 | 61 | 74 | 80 |
| Impervious areas: | | | | | |
| Paved parking lots, roofs, driveways, etc. (excluding right-of-way) | | 98 | 98 | 98 | 98 |
| Streets and roads: | | | | | |
| Paved; curbs and storm sewers (excluding right-of-way) | | 98 | 98 | 98 | 98 |
| Paved; open ditches (including right-of-way) | | 83 | 89 | 92 | 93 |
| Gravel (including right-of-way) | | 76 | 85 | 89 | 91 |
| Dirt (including right-of-way) | | 72 | 82 | 87 | 89 |
| Western desert urban areas: | | | | | |
| Natural desert landscaping (pervious areas only) ^{4/} | | 63 | 77 | 85 | 88 |
| Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders) | | 96 | 96 | 96 | 96 |
| Urban districts: | | | | | |
| Commercial and business | 85 | 89 | 92 | 94 | 95 |
| Industrial | 72 | 81 | 88 | 91 | 93 |
| Residential districts by average lot size: | | | | | |
| 1/8 acre or less (town houses) | 65 | 77 | 85 | 90 | 92 |
| 1/4 acre | 38 | 61 | 75 | 83 | 87 |
| 1/3 acre | 30 | 57 | 72 | 81 | 86 |
| 1/2 acre | 25 | 54 | 70 | 80 | 85 |
| 1 acre | 20 | 51 | 68 | 79 | 84 |
| 2 acres | 12 | 46 | 65 | 77 | 82 |
| <i>Developing urban areas</i> | | | | | |
| Newly graded areas (pervious areas only, no vegetation) ^{5/} | | 77 | 86 | 91 | 94 |
| Idle lands (CN's are determined using cover types similar to those in table 2-2c). | | | | | |

¹ Average runoff condition, and $I_a = 0.2S$.

² The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

³ CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

⁴ Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

⁵ Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 3.3.2 (TR-55 Table 2-2a): Runoff Curve Numbers for Urban Areas

Table 2-2b Runoff curve numbers for cultivated agricultural lands ^{1/}

| Cover description | | | Curve numbers for hydrologic soil group | | | |
|------------------------------------------------------|----------------------------|------------------------------------|-----------------------------------------|----|----|----|
| Cover type | Treatment ^{2/} | Hydrologic condition ^{3/} | A | B | C | D |
| Fallow | Bare soil | — | 77 | 86 | 91 | 94 |
| | Crop residue cover (CR) | Poor | 76 | 85 | 90 | 93 |
| | | Good | 74 | 83 | 88 | 90 |
| Row crops | Straight row (SR) | Poor | 72 | 81 | 88 | 91 |
| | | Good | 67 | 78 | 85 | 89 |
| | SR + CR | Poor | 71 | 80 | 87 | 90 |
| | | Good | 64 | 75 | 82 | 85 |
| | Contoured (C) | Poor | 70 | 79 | 84 | 88 |
| | | Good | 65 | 75 | 82 | 86 |
| | C + CR | Poor | 69 | 78 | 83 | 87 |
| | | Good | 64 | 74 | 81 | 85 |
| | Contoured & terraced (C&T) | Poor | 66 | 74 | 80 | 82 |
| | | Good | 62 | 71 | 78 | 81 |
| | C&T+ CR | Poor | 65 | 73 | 79 | 81 |
| Good | | 61 | 70 | 77 | 80 | |
| Small grain | SR | Poor | 65 | 76 | 84 | 88 |
| | | Good | 63 | 75 | 83 | 87 |
| | SR + CR | Poor | 64 | 75 | 83 | 86 |
| | | Good | 60 | 72 | 80 | 84 |
| | C | Poor | 63 | 74 | 82 | 85 |
| | | Good | 61 | 73 | 81 | 84 |
| | C + CR | Poor | 62 | 73 | 81 | 84 |
| | | Good | 60 | 72 | 80 | 83 |
| | C&T | Poor | 61 | 72 | 79 | 82 |
| | | Good | 59 | 70 | 78 | 81 |
| | C&T+ CR | Poor | 60 | 71 | 78 | 81 |
| Good | | 58 | 69 | 77 | 80 | |
| Close-seeded or broadcast legumes or rotation meadow | SR | Poor | 66 | 77 | 85 | 89 |
| | | Good | 58 | 72 | 81 | 85 |
| | C | Poor | 64 | 75 | 83 | 85 |
| | | Good | 55 | 69 | 78 | 83 |
| | C&T | Poor | 63 | 73 | 80 | 83 |
| | | Good | 51 | 67 | 76 | 80 |

^{1/} Average runoff condition, and $I_a=0.2S$ ^{2/} Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.^{3/} Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good $\geq 20\%$), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 3.3.3 (TR-55 Table 2-2b): Runoff Curve Numbers for Cultivated Agricultural Lands

Table 2-2c Runoff curve numbers for other agricultural lands ^{1/}

| Cover description | Hydrologic condition | Curve numbers for hydrologic soil group | | | |
|------------------------------------------------------------------------------|----------------------|-----------------------------------------|----|----|----|
| | | A | B | C | D |
| Pasture, grassland, or range—continuous forage for grazing. ^{2/} | Poor | 68 | 79 | 86 | 89 |
| | Fair | 49 | 69 | 79 | 84 |
| | Good | 39 | 61 | 74 | 80 |
| Meadow—continuous grass, protected from grazing and generally mowed for hay. | — | 30 | 58 | 71 | 78 |
| Brush—brush-weed-grass mixture with brush the major element. ^{3/} | Poor | 48 | 67 | 77 | 83 |
| | Fair | 35 | 56 | 70 | 77 |
| | Good | 30 ^{4/} | 48 | 65 | 73 |
| Woods—grass combination (orchard or tree farm). ^{5/} | Poor | 57 | 73 | 82 | 86 |
| | Fair | 43 | 65 | 76 | 82 |
| | Good | 32 | 58 | 72 | 79 |
| Woods. ^{6/} | Poor | 45 | 66 | 77 | 83 |
| | Fair | 36 | 60 | 73 | 79 |
| | Good | 30 ^{4/} | 55 | 70 | 77 |
| Farmsteads—buildings, lanes, driveways, and surrounding lots. | — | 59 | 74 | 82 | 86 |

¹ Average runoff condition, and $I_a = 0.2S$.

² *Poor*: <50% ground cover or heavily grazed with no mulch.

Fair: 50 to 75% ground cover and not heavily grazed.

Good: > 75% ground cover and lightly or only occasionally grazed.

³ *Poor*: <50% ground cover.

Fair: 50 to 75% ground cover.

Good: >75% ground cover.

⁴ Actual curve number is less than 30; use CN = 30 for runoff computations.

⁵ CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

⁶ *Poor*: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.

Fair: Woods are grazed but not burned, and some forest litter covers the soil.

Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 3.3.4 (TR-55 Table 2-2c): Runoff Curve Numbers for Other Agricultural Lands

| Return Period | a | b | N | R² |
|----------------------|----------|----------|----------|----------------------|
| 2 | 32.852 | 7 | 0.7780 | 0.99966 |
| 5 | 46.060 | 8 | 0.7859 | 0.99958 |
| 10 | 56.974 | 9 | 0.7953 | 0.99952 |
| 25 | 72.739 | 10 | 0.8115 | 0.99942 |
| 50 | 84.475 | 11 | 0.8147 | 0.99940 |
| 100 | 92.718 | 11 | 0.8145 | 0.99942 |

Table 3.4.1.1: IDF EQUATION VALUES

| | | Return Period – Rainfall Intensity (in/hr) | | | | | |
|--------------|----------------|---------------------------------------------------|----------|-----------|-----------|-----------|------------|
| Hours | Minutes | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.08 | 5 | 4.75 | 6.14 | 6.99 | 8.08 | 8.83 | 9.69 |
| 0.17 | 10 | 3.63 | 4.75 | 5.48 | 6.40 | 7.07 | 7.77 |
| 0.25 | 15 | 2.97 | 3.92 | 4.55 | 5.34 | 5.94 | 6.53 |
| 0.5 | 30 | 1.98 | 2.64 | 3.09 | 3.65 | 4.10 | 4.50 |
| 1 | 60 | 1.25 | 1.67 | 1.96 | 2.31 | 2.62 | 2.88 |
| 2 | 120 | 0.76 | 1.02 | 1.20 | 1.40 | 1.59 | 1.75 |
| 3 | 180 | 0.56 | 0.75 | 0.88 | 1.03 | 1.17 | 1.29 |
| 6 | 360 | 0.33 | 0.44 | 0.52 | 0.60 | 0.68 | 0.75 |
| 12 | 720 | 0.20 | 0.26 | 0.30 | 0.35 | 0.39 | 0.43 |
| 24 | 1440 | 0.11 | 0.15 | 0.17 | 0.20 | 0.22 | 0.25 |

Table 3.4.1.2: IDF Table

| | | Return Period – Rainfall Depth (in) | | | | | |
|--------------|----------------|--------------------------------------------|----------|-----------|-----------|-----------|------------|
| Hours | Minutes | 2 | 5 | 10 | 25 | 50 | 100 |
| 0.08 | 5 | 0.40 | 0.51 | 0.58 | 0.67 | 0.74 | 0.81 |
| 0.17 | 10 | 0.61 | 0.79 | 0.91 | 1.07 | 1.18 | 1.30 |
| 0.25 | 15 | 0.74 | 0.98 | 1.14 | 1.34 | 1.49 | 1.63 |
| 0.5 | 30 | 0.99 | 1.32 | 1.55 | 1.83 | 2.05 | 2.25 |
| 1 | 60 | 1.25 | 1.67 | 1.96 | 2.31 | 2.62 | 2.88 |
| 2 | 120 | 1.52 | 2.04 | 2.40 | 2.80 | 3.18 | 3.50 |
| 3 | 180 | 1.68 | 2.25 | 2.64 | 3.09 | 3.51 | 3.87 |
| 6 | 360 | 1.98 | 2.64 | 3.12 | 3.60 | 4.08 | 4.50 |
| 12 | 720 | 2.40 | 3.12 | 3.60 | 4.20 | 4.68 | 5.16 |
| 24 | 1440 | 2.64 | 3.60 | 4.08 | 4.80 | 5.28 | 6.00 |

Table 3.4.2.1: IDD Table

| Cumulative Storm Rainfall (percent) for Given Storm Type | | | | |
|-----------------------------------------------------------------|-----------------------|------------------------|-----------------------|------------------------|
| Cumulative Storm Time (Percent) | First Quartile | Second Quartile | Third Quartile | Fourth Quartile |
| 5 | 16 | 3 | 3 | 2 |
| 10 | 33 | 8 | 6 | 5 |
| 15 | 43 | 12 | 9 | 8 |
| 20 | 52 | 16 | 12 | 10 |
| 25 | 60 | 22 | 15 | 13 |
| 30 | 66 | 29 | 19 | 16 |
| 35 | 71 | 39 | 23 | 19 |
| 40 | 75 | 51 | 27 | 22 |
| 45 | 79 | 62 | 32 | 25 |
| 50 | 82 | 70 | 38 | 28 |
| 55 | 84 | 76 | 45 | 32 |
| 60 | 86 | 81 | 57 | 35 |
| 65 | 88 | 85 | 70 | 39 |
| 70 | 90 | 88 | 79 | 45 |
| 75 | 92 | 91 | 85 | 51 |
| 80 | 94 | 93 | 89 | 59 |
| 85 | 96 | 95 | 92 | 72 |
| 90 | 97 | 97 | 95 | 84 |
| 95 | 98 | 98 | 97 | 92 |

(SOURCE: Rainfall Frequency Atlas of the Midwest by Huff and Angel)

Table 3.4.3.1: Median Time Distributions of Heavy Storm Rainfall at a Point

Appendix IV

| <u>Pipe Material</u> | <u>Manning's n</u> |
|------------------------------------------------|---------------------------|
| Concrete Pipe | 0.012 |
| Concrete Boxes | 0.012 |
| Corrugated Metal Pipe or Pipe Arch | |
| 2 2/3" x 1/2" Helical Corrugation | 0.022 |
| 2 2/3" x 1/2" Annular Corrugation | 0.022 |
| 15" to 36" | 0.025 |
| 42" to 96" | 0.024 |
| 3" x 1" Corrugation | 0.027 |
| 5" x 1" Corrugation | 0.025 |
| Structural Plate Pipe or Pipe Arch | |
| 6" x 2" Corrugation | 0.033 |
| 9" x 2 1/2" Corrugation | 0.035 |
| Spiral Ribbed Corrugated Metal Pipe | 0.013 |
| Smooth High Density Polyethylene (HDPE) | 0.012 |
| Smooth Lined Interior Polyvinyl Chloride (PVC) | 0.012 |
| Smooth Interior Corrugated HDPE | 0.012 |
| Ductile Iron Pipe | 0.012 |

Table 4.2.1.1: Manning's "n" Values for Pipes

| <u>Type of Gutter or Pavement</u> | <u>Manning's "n"</u> |
|---------------------------------------------------------------------------------------------------|----------------------|
| Concrete | 0.012 |
| Asphalt Pavement: | |
| Smooth Texture | 0.013 |
| Rough Texture | 0.016 |
| Concrete Gutter – Asphalt Pavement: | |
| Smooth | 0.013 |
| Rough | 0.015 |
| Concrete Pavement: | |
| Float Finish | 0.014 |
| Broom Finish | 0.016 |
| For Gutters with small slope, where sediment may Accumulate, increase the "n" values above by: | 0.002 |

USDOT, FHWA, HDS-3 (1961)

Table 4.3.2.2: Roughness coefficient's (Manning's n) for Street and Pavement Gutters

| <u>Open Channel Surface Material</u> | <u>n</u> |
|--------------------------------------|------------------|
| Concrete | 0.012 |
| Gravel Bottom with sides | - Concrete |
| | - Mortared Stone |
| | - Rip-Rap |
| Natural Stream Channels: | |
| Clean, Straight Stream | 0.030 |
| Clean, Winding Stream | 0.040 |
| Winding with weeds and pools | 0.050 |
| With Heavy Brush and Timbers | 0.100 |
| Flood Plains: | |
| Pasture | 0.035 |
| Field Crops | 0.040 |
| Light Brush and Weeds | 0.050 |
| Dense Brush | 0.070 |
| Dense Trees | 0.100 |

Chow, 1959

Table 4.4.1.1: Roughness coefficient's (Manning's n) for Open Channel Surfaces

Typical Maximum Velocities for Open Channel Linings

| Open Channel Lining Material | Desirable Maximum Velocity (ft/s) |
|--------------------------------------------------|------------------------------------------|
| Concrete, Trowel Finish | 15 |
| Concrete, Broom or Float Finish | 15 |
| Rip-Rap | 10 |
| Gabions | 10 |
| New Earth (Uniform, Sodded, Clay) | 3-5 |
| Existing Earth (Fairly Uniform, With Some Weeds) | 3-5 |
| Dense Weeds | 3-5 |
| Swale with Grass | 3-5 |

Table 4.4.2.1: Desirable Maximum Velocities for Open Channel Linings

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