"DETERMINING MANNING"S COEFFICIENT OF ROUGHNESS, "n"

This supplement describes a method for estimating the roughness coefficient n for use in hydraulic computations associated with natural streams, floodways and similar streams. The procedure proposed applies to the estimation of n in Manning's formula. This formula is now widely used, it is simpler to apply than other widely recognized formulas and has been shown to be reliable.

Manning's formula is empirical. The roughness coefficient n is used to quantitatively express the degree of retardation of flow. The value of n indicates not only the roughness of the sides and bottom of the channel, but also all other types of irregularities of the channel and profile. In short, n is used to indicate the net effect of all factors causing retardation of flow in a reach of channel under consideration.

There seems to have developed a tendency to regard the selection of n for natural channels as either an arbitrary or an intuitive process. This probably results from the rather cursory treatment of the roughness coefficient in most of the more widely used hydraulic textbooks and handbooks. The fact is that the estimation of n requires the exercise of critical judgment in the evaluation of the primary factors affecting n. These factors are: irregularity of the surfaces of the channel sides and bottom; variations in shape and size of cross sections; obstructions; vegetation; meandering of the channel.

The need for realistic estimates of n justifies the adoption of a systematic procedure for making the estimates.

Procedure for estimating n. The general procedure for estimating n involves; first, the selection of a basic value of n for a straight, uniform, smooth channel in the natural materials involved; then, through critical consideration of the factors listed above, the selection of a modifying value associated with each factor. The modifying values are added to the basic value to obtain n for the channel under consideration.

In the selection of the modifying values associated with the 5 primary factors it is important that each factor be examined and considered independently. In considering each factor, it should be kept in mind that n represents a quantitative expression of retardation of flow. Turbulence of flow can, in a sense, be visualized as a measure or indicator of retardance. Therefore, in each case, more critical judgment may be exercised if it is recognized that as conditions associated with any factor change so as to induce greater turbulence, there should be an increase in the modifying value. A discussion and tabulated guide to the selection of modifying values for each factor is given under the following procedural steps.

1st step. Selection of basic n value. This step requires the selection of a basic n value for a straight, uniform, smooth channel in the natural materials involved. The selection involves consideration of what may be regarded as a hypothetical channel. The conditions of straight alignment, uniform cross section, and smooth side and bottom surfaces without vegetation should be kept in mind. Thus the basic n will be visualized as varying only with the materials forming the sides and bottom of the channel. The minimum values of n shown by reported test results for the best channels in earth are in the range from 0.016 to 0.018. Practical limitations associated with maintaining smooth and uniform channels in earth for any appreciable period indicate that 0.02 is a realistic basic n. The basic n, as it is intended for use in this procedure, for natural or excavated channels, may be selected from the table below. Where the bottom and sides of a channel are of different materials this fact may be recognized in selecting the basic n.

Character of channel	Basic n
Channels in earth	0.02
Channels cut into rock	0.025
Channels in fine gravel	0.024
Channels in coarse gravel	0.028

2nd step. Selection of modifying value for surface irregularity. The selection is to be based on the degree of roughness or irregularity of the surfaces of channel sides and bottom. Consider the actual surface irregularity; first, in relation to the degree of surface smoothness obtainable with the natural materials involved, and second, in relation to the depths of flow under consideration. Actual surface irregularity comparable to the best surface to be expected of the natural materials involved calls for a modifying value of zero. Higher degrees of irregularity induce turbulence and call for increased modifying values. The table below may be used as a guide to the selection.

Degree of irregularity	Surfaces comparable to	Modifying value
Smooth	The best obtainable for the materials involved.	0.000
Minor	Good dredged channels; slightly eroded or scoured side slopes of canals or drainage channels.	0.005
Moderate	Fair to poor dredged channels; moderately sloughed or eroded side slopes of canals or drainage channels.	0.010
Severe	Badly sloughed banks of natural channels; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged and irregular surfaces of channels excavated in rock.	0.020

3rd step. Selection of modifying value for variations in shape and size of cross sections. In considering changes in size of cross sections judge the approximate magnitude of increase and decrease in successive cross sections as compared to the average. Changes of considerable magnitude, if they are gradual and uniform, do not cause significant turbulence. The greater turbulence is associated with alternating large and small sections where the changes are abrupt. The degree of effect of size changes may be best visualized by considering it as depending primarily on the frequency with which large and small sections alternate and secondarily on the magnitude of the changes.

In the case of shape variations, consider the degree to which the changes cause the greatest depth of flow to move from side to side of the channel. Shape changes causing the greatest turbulence are those for which shifts of the main flow from side to side occur in distances short enough to produce eddies and upstream currents in the shallower portions of those sections where the maximum depth of flow is near either side. Selection of modifying values may be based on the following guide:

Character of variations in size and shape of cross sections	Modifying value
Changes in size or shape occurring gradually	0.000
Large and small sections alternating occasionally or shape changes causing occasional shifting of main flow from side to side	0.005
Large and small sections alternating frequently or shape changes causing frequent shifting of main flow from side to side	0.010 to 0.015

4th step. Selection of modifying value for obstructions. The selection is to be based on the presence and characteristics of obstructions such as debris deposits, stumps, exposed roots, boulders, fallen and lodged logs. Care should be taken that conditions considered in other steps are not re-evaluated or double-counted by this step.

In judging the relative effect of obstructions, consider: the degree to which the obstructions occupy or reduce the average cross sectional area at various stages; the character of obstructions, (sharp-edged or angular objects induce greater turbulence than curved, smooth-surfaced objects); the position and spacing of obstructions transversely and longitudinally in the reach under consideration. The following table may be used as a guide to the selection.

Relative effect of obstructions	Modifying value
Negligible	0.000
Minor	0.010 to 0.015
Appreciable	0.020 to 0.030
Severe	0.040 to 0.060

5th step. Selection of modifying value for vegetation. The retarding effect of vegetation is probably due primarily to the turbulence induced as the water flows around and between the limbs, stems and foliage, and secondarily to reduction in cross section. As depth and velocity increase, the force of the flowing water tends to bend the vegetation. Therefore, the ability of vegetation to cause turbulence is partly related to its resistance to bending force. Furthermore, the amount and character of foliage; that is, the growing season condition versus dormant season condition is important. In judging the retarding effect of vegetation, critical consideration should be given to the following: the height in relation to depth of flow; the capacity to resist bending; the degree to which the cross section is occupied or blocked out; the transverse and longitudinal distribution of vegetation of different types, densities and heights in the reach under consideration. The following table may be used as a guide to the selection:

Vegetation and flow conditions comparable to:	Degree of effect on n	Range in modifying value
Dense growths of flexible turf grasses or weeds, of which Bermuda and blue grasses are examples, where the average depth of flow is 2 to 3 times the height of vegetation.	Low	0.005 to 0.010
Supple seedling tree switches such as willow, cottonwood or salt cedar where the average depth of flow is 3 to 4 times the height of the vegetation.		
Turf grasses where the average depth of flow is 1 to 2 times the height of vegetation.		
Stemmy grasses, weeds or tree seedlings with moderate cover where the average depth of flow is 2 to 3 times the height of vegetation.	Medium	0.010 to 0.025
Brushy growths, moderately dense, similar to willows 1 to 2 years old, dormant season, along side slopes of channel with no significant vegetation along the channel bottom, where the hydraulic radius is greater than 2 feet.		

Turf grasses where the average depth of flow is about equal to the height of vegetation. Dormant season, willow or cottonwood trees 8 to 10 years old, intergrown with some weeds and brush, none of the vegetation in foliage, where the hydraulic radius is greater than 2 feet. Growing season, bushy willows about 1 year old intergrown with some weeds in full foliage along side slopes, no significant vegetation along channel bottom, where hydraulic radius is greater than 2 feet.	High	0.025 to 0.050
Turf grasses where the average depth of flow is less than one half the height of vegetation. Growing season, bushy willows about 1 year old, intergrown with weeds in full foliage along side slopes; dense growth of cattails along channel bottom; any value of hydraulic radius up to 10 or 15 feet. Growing season; trees intergrown with weeds and brush, all in full foliage; any value of hydraulic radius up to 10 or 15 feet.	Very high	0.050 to 0.100

A further basis for judgment in the selection of the modifying value for vegetation may be found in Table 1 which contains descriptions and data for actual cases where n has been determined. In each of the cases listed in Table 1 the data were such that the increase in n due to vegetation could be determined within reasonably close limits.

<u>6th step</u>. Determination of the modifying value for meandering of channel. The modifying value for meandering may be estimated as follows: Add the basic n for Step 1 and the modifying values of Steps 2 through 5 to obtain the subtotal of n_s.

Let ℓ_s = the straight length of the reach under consideration.

ℓ_m = the meander length of the channel in the reach.

Compute modifying value for meandering in accordance with the following table

Ratio ℓ_m/ℓ_s	Degree of meandering	Modifying value
1.0 to 1.2	Minor	0.000
1.2 to 1.5	Appreciable	0.15 n_s
1.5 and greater	Severe	0.30 n_s

Where lengths for computing the approximate value of ℓ_m/ℓ_s are not readily obtainable the degree of meandering can usually be judged reasonably well.

7th step. Computation of n for the reach. The value of n for the reach is obtained by adding the values determined in Steps 1 through 6. An illustration of the estimation of n is given in Example 1.

Dealing with cases where both channel and flood plain flow occurs.

Work with natural streams and floodways often requires consideration of a wide range of discharges. At the higher stages both channel and overbank or flood plain flow are involved. Usually the conditions are such that the channel and flood plain will have different degrees of retardance and, therefore, different n values. In such cases the hydraulic computations will be improved by dividing the cross sections into parts or subdivisions having different n values.

The reason for and effect of subdividing cross sections is to permit the composite n for the reach to vary with stage above the bankfull stage. This effect is illustrated by Example 2. The usual practice is to divide the cross section into two parts; one subdivision being the channel portion and the other the flood plain. More than two subdivisions may be made if conditions indicate wide variations of n. However, in view of the practical aspects of the problem, more than three subdivisions would not normally be justified.

In estimating n for the channel subdivision, all of the factors discussed above and all of the procedural steps would be considered. Although conditions might indicate some variation of n with stage in the channel, it is recommended that an average value of n be selected for use in the hydraulic computations for all stages.

In the case of flood plain subdivisions, the estimate of n would consider all factors except meandering. That is, the estimate would employ all of the procedural steps except Step 6. Flood plain n values will normally be somewhat greater than the channel values. Agricultural flood plain conditions are not likely to indicate an n less than 0.05 to 0.06. Many cases will justify values in the 0.07 to 0.09 range and cases calling for values as high as 0.15 to 0.20 may be encountered. These higher values apply primarily because of the relatively shallow depths of flow. The two factors requiring most careful consideration are obstructions and vegetation. Many agricultural flood plains have fairly dense networks of fences to be evaluated as obstructions in Step 4. Vegetation probably would be judged on the basis of growing season conditions.

Field and office work.

It is suggested that field parties record adequate notes on field conditions pertinent to the five factors affecting n at the time cross section surveys are being made. The actual estimates of n may then be made in the office. This will require training of both field and office personnel. The conditions to be covered by field notes and considered in the estimate of n apply to a reach of channel and flood plain. It is not adequate to consider only those conditions in the immediate vicinity of a cross section. Note the sketch on Figure B.1. With cross sections located as shown, field notes should describe the channel and flood plain conditions through the reach indicated as a basis for estimating the n values (assuming subdivided sections) to be incorporated in the hydraulic computations at Section 2.

Figure B.2 shows a sample set of notes that illustrate the type of field information to be recorded as a basis for estimating n. Field men should be trained to recognize and record in brief statements those conditions that are necessary for realistic evaluation of the five factors discussed under procedural Steps 1 to 6.

Example 1. Estimation of n for a reach.

This example is based on a case where n has been determined so that comparison between the estimated and actual n can be shown.

Channel: Camp Creek dredged channel near Seymour, Illinois; see USDA Technical Bulletin No. 129, Plate 29-C for photograph and Table 9, page 86, for data.

Description: Course straight; 661 feet long. Cross section, very little variation in shape; variation in size moderate, but changes not abrupt. Side slopes fairly regular, bottom uneven and irregular. Soil, lower part yellowish gray clay; upper part, light gray silty clay loam. Condition, side slopes covered with heavy growth of poplar trees 2 to 3 inches in diameter, large willows and climbing vines; thick growth of water weed on bottom; summer condition with vegetation in full foliage.

Average cross section approximates a trapezoid with side slopes about 1.5 to 1 and bottom width about 10 feet. At bankfull stage, average depth and surface width are about 8.5 and 40 feet respectively.

Step	Remarks	Modifying values
1	Soil materials indicate minimum basic n.	0.02
2	Description indicates moderate irregularity.	0.01
3.	Changes in size and shape judged insignificant.	0.00
4.	No obstructions indicated.	0.00
5.	Description indicates very high effect of vegetation.	0.08
6.	Reach described as straight.	0.00
	Total estimated n	0.11

USDA Technical Bulletin No. 129, Table 9, page 96, gives the following determined values for n for this channel: for average depth of 4.6 feet n = 0.095; for average depth of 7.3 feet n = 0.104.

Example 2. Effect of subdividing cross sections.

The sole purpose of this example is to illustrate the effect of subdividing sections on the value of n for the complete section. It is not an illustration of hydraulic computations for determining water surface profiles or stage-discharge relationships.

This illustration is based on the following:

1. An actual stream cross section for which curves showing depth versus area and depth versus hydraulic radius for the channel and flood plain subdivisions and for the complete section are plotted on Figure B.3. Values of n are: for the channel subdivision 0.04; for the flood plain subdivision 0.08.

2. The conditions of uniform, steady flow are assumed.

   Manning's formula is handled in accordance with Leach's method. See Handbook of Hydraulics, McGraw-Hill Book Company, 3rd edition, page 534; 4th edition, page 8-65.

Notation:

Q = discharge - cfs

a = cross section area - $ft.^2$

r = hydraulic radius, ft.

p = wetted perimeter, ft.

s_o = channel slope, ft. per ft.

n = roughness coefficient

$$Q = \frac{1.486}{n} \; a \; r^{2/3} \; s_o^{\;1/2} \qquad (B.1)$$

Let $K_d = \frac{1.486}{n} \; a \; r^{2/3}$, then

$$Q = K_d \; s_o^{\;1/2} \qquad (B.2)$$

Assume the conditions are such that it is desirable to recognize more than one subdivision, each having a different n. Let subscripts 1, 2, and 3 refer to the section subdivisions and subscript t to the total section.

From equation B.2

$$Q = \left(K_{d1} + K_{d2} + K_{d3} - - - - + K_{dn}\right) s_o^{\;1/2} = \Sigma K_d \; s_o^{\;1/2} \qquad (B.3)$$

Also: $\frac{Q}{s_o^{\;1/2}} = \Sigma K_d = \frac{1.486}{n_t} \; a_t \; r_t^{\;2/3}$; therefore

$$n_t = \frac{1.486 \; a_t \; r_t^{\;2/3}}{\Sigma K_d} \qquad (B.4)$$

Table B.2 shows the computations for Example 2 and Figure B.3 shows a plot of roughness coefficient for the complete section versus depth.

In natural streams n normally shows a minor decrease as stage increases up to, or somewhat above, the bankfull stage, then appreciably increases as overbank stage increases. When n is significantly different for different parts of the cross section, subdivision of the cross section, as a basis for making the computations, automatically causes n_t to vary with stage above the bankfull stage. This is true although n_t is not computed in methods for determining water surface profiles. Note on Figure B.3 that n_t, which has been computed in Example 2 for illustrative purposes, shows considerable increase with stage above the 10-foot depth and that this increase is automatically recognized by subdivision of the cross section.

The plot of hydraulic radius on Figure B.3 illustrates a typical characteristic of natural streams. Note that the hydraulic radius for the complete section increases up to bankfull depth, then decreases through a limited range of depth, and again increases as depth of overbank flow increases.

This example also illustrates that recognition of high retardance for flood plain subdivisions by the use of relatively high n values does not cause n for the complete section, n_t, to be unreasonably high. In this case, the channel and flood plain are assigned n values of 0.04 and 0.08. The value of n_t ranges up to 0.072 as shown by Table B.2 and Figure B.3.

Table B.1 **Examples** of effect of vegetation on n. (Sheet 1 of 3)

Example No.	Names and Descriptions of Channels. Names, Plates and Tables Refer to USDA Technical Bulletin No. 129, November 1929	Range in mean velocity	Range in hydraulic radius	Average value n	Modifying value
1.	Fountain Head dredged channel near Champaign, Illinois; Plate 31-B and C, Table 9. Average cross section of channel resembles a parabola. At bankfull stage depth about 8 ft., top width about 30 feet.	2.09 to 2.59	1.73 to 2.42		
	a. Dormant season. Dry weeds on side slopes, no vegetation on bottom. Retarding effect of vegetation negligible.			0.031	
	b. Growing season, otherwise vegetation same as above. Heavy growth of weeds and grass in full foliage on side slopes.			0.037	0.006
2.	Cummins Lake dredged channel near Gould, Arkansas; Plate 18-B and C, Table 7. Average cross section of channel resembles a parabola. At bankfull stage depth about 13 ft., top width about 75 feet.	0.53 to 1.82	2.41 to 6.23		
	a. Side slopes moderately irregular from erosion and sloughing; estimated n for channel without vegetation 0.035.				
	b. Dormant season. Willows about one year old and 6 to 10 feet high continuous along side slopes except for about the upper third of sides. No growth in a strip about 20 feet wide along bottom. No foliage.			0.056	0.021
	c. Growing season, otherwise vegetation same as above. Willows and some weeds in full foliage. No vegetation along bottom.			0.072	0.037

Table B.1 Examples of effect of vegetation on n. (Sheet 2 of 3)

Example No.	Names and Descriptions of Channels. Names, Plates and Tables Refer to USDA Technical Bulletin No. 129, November 1929	Range in mean velocity	Range in hydraulic radius	Average value n	Modifying value
3.	Lateral Ditch No. 15 near Bement, Illinois; Plate 30-A, B and C, Table 9. Average cross section is practically a trapezoid with wide slopes about 1.1 and bottom width and depth each about 10 feet.	0.28 to 1.71	1.16 to 5.61		
	a. Dormant season. Dead weeds practically flat on side slopes; no dead growth in bottom.			0.033	
	b. Dormant season. Bushy willows about 1 year old and dead weeds on side slopes. No vegetation along bottom of channel. No foliage.			0.055	0.022
	c. Growing season. Vegetation same as b, above, except willows and weeds in full foliage. No vegetation on bottom.			0.072	0.039
	d. Growing season. Bushy willows and weeds in full foliage along side slopes. Dense growth of cattails along bottom.			0.119	0.086
	Ditch No. 18 of Cypress Creek drainage district near Arkansas City, Arkansas; Plate 17-B and C, Table 7. Average cross section is approximately triangular; at bankfull stage depth about 13 ft., top width about 70 feet.	0.47 to 1.08	1.91 to 6.23		
	a. Dredged channel about 8 years old. Side slopes moderately irregular. Estimated n for the channel without vegetation 0.035.				
	b. Dormant season. Practically the entire reach covered with trees, mostly willows and cottonwoods. Some dry weeds and brush. No foliage.			0.061	0.026

Table B.1 Examples of effect of vegetation on n. (Sheet 3 of 3)

Example No.	Names and Descriptions of Channels. Names, Plates and Tables Refer to USDA Technical Bulletin No. 129, November 1929.	Range in mean velocity	Range in hydraulic radius	Average value n	Modifying value
	c. Growing season. Vegetation described under b; in full foliage.			0.103	0.068
5.	Lake Fork special dredged channel near Bement, Illinois; Plate 25-A, B, and C, Table 9. Average cross section is approximately parabolic; at bankfull stage depth about 13 ft., top width about 65 to 70 feet.	0.79 to 1.65	3.55 to 7.33		
	a. Dormant season. Channel cleared; practically no vegetation of any type in channel.			0.031	
	b. Dormant season. Densely growing, bushy willows continuous along side slopes; some poplar saplings scattered among willows. No growth in a strip 20 to 30 feet wide along bottom. No foliage.			0.071	0.040
	c. Growing season. Vegetation described under b; in full foliage.			0.092	0.061
6.	Ditch No. 1 of Little River drainage district near Chafee, Missouri; Plate 21-B and C, Table 8. Average cross section trapezoidal, side slopes about 1.1, bottom width about 10 ft., depth about 8 feet.	0.68 to 1.51	2.00 to 4.26		
	a. Channel newly cleared, practically no vegetation			0.031	
	b. Dormant season. Dense, bushy willows continuous along side slopes; no foliage. No vegetation along bottom of channel.			0.071	0.040

Table B.2 Computations for Example 2.

Depth	a_1	r_1	$r_1^{2/3}$	K_{d1}	a_2	r_2	$r_2^{2/3}$	K_{d2}	ΣK_d	a_t	r_t	$r_t^{2/3}$	K	n_t
0.0	0	0.00	0.000	0	0	0.00	0.000	0	0	0	0.00	0.000	0	0.000
4.7	90	3.33	2.230	7450	0	0.00	0.000	0	7450	90	3.33	2.230	298	0.040
7.8	180	5.29	3.036	20250	0	0.00	0.000	0	20250	180	5.29	3.036	810	0.040
9.7	240	7.06	3.680	31900	750	1.06	1.040	14500	46400	990	1.31	1.197	1760	0.038
11.7	300	8.82	4.269	47500	2238	2.88	2.024	84000	131500	2538	3.14	2.144	8090	0.062
13.7	360	10.59	4.822	64400	3853	4.58	2.758	197000	261400	4213	4.82	2.854	17850	0.069
16.7	450	13.22	5.591	93400	6488	7.08	3.687	444000	537400	6938	7.30	3.763	38750	0.072

$$K_{d1} = \frac{1.486}{0.040} a_1 r_1^{2/3} = 37.15 a_1 r_1^{2/3}$$

$$K_{d2} = \frac{1.486}{0.080} a_2 r_2^{2/3} = 18.58 a_2 r_2^{2/3}$$

$$K = 1.486 a_t r_t^{2/3}$$

$$n_t = \frac{K}{K_d}$$

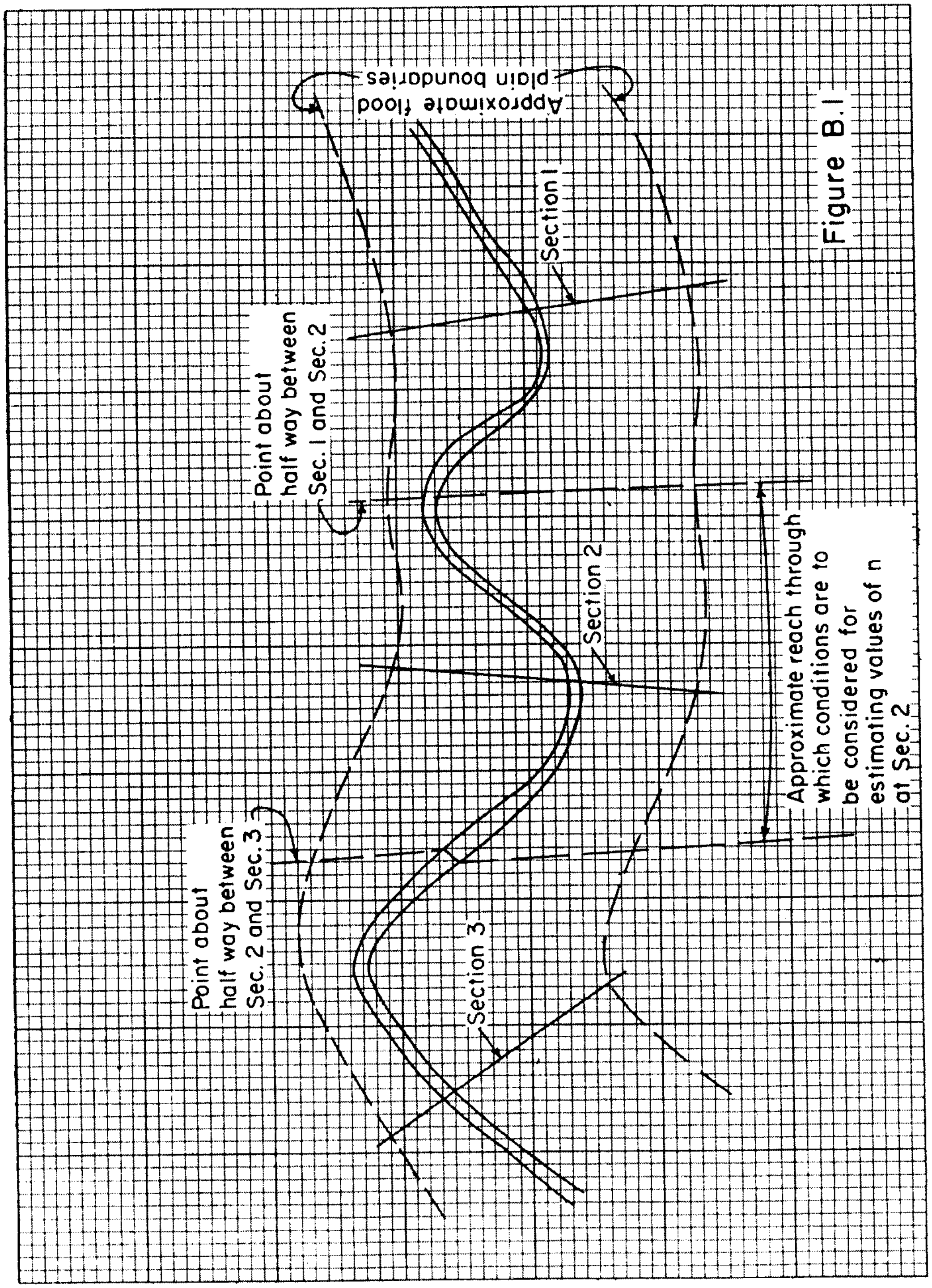
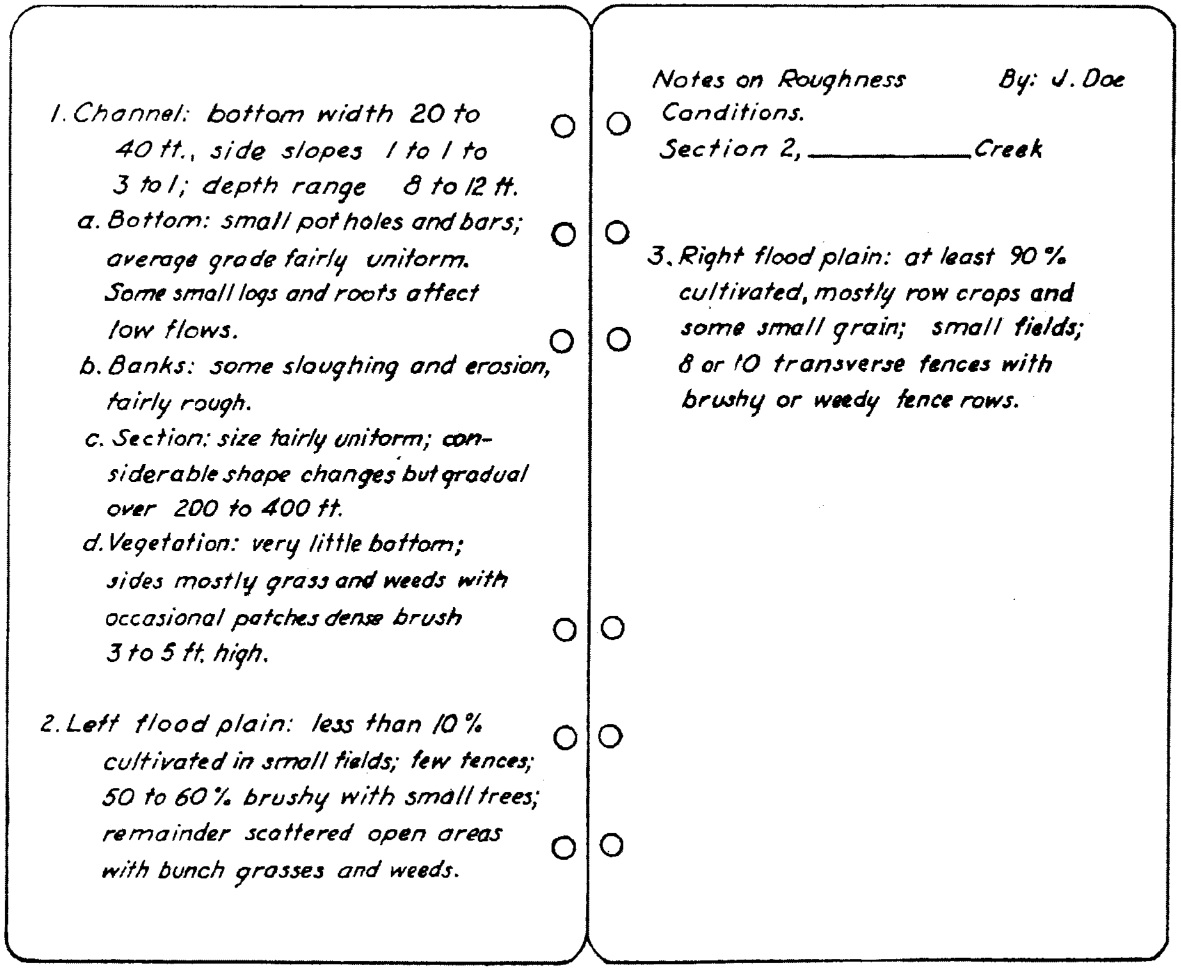

Approximate flood
plain boundaries
Section 1
Point about
half way between
Sec. 1 and Sec. 2
Section 2
Approximate reach through
which conditions are to
be considered for
estimating values of n
at Sec. 2
Point about
half way between
Sec. 2 and Sec. 3
Section 3

Figure B.1

Figure B.2 Sample notes on roughness conditions.



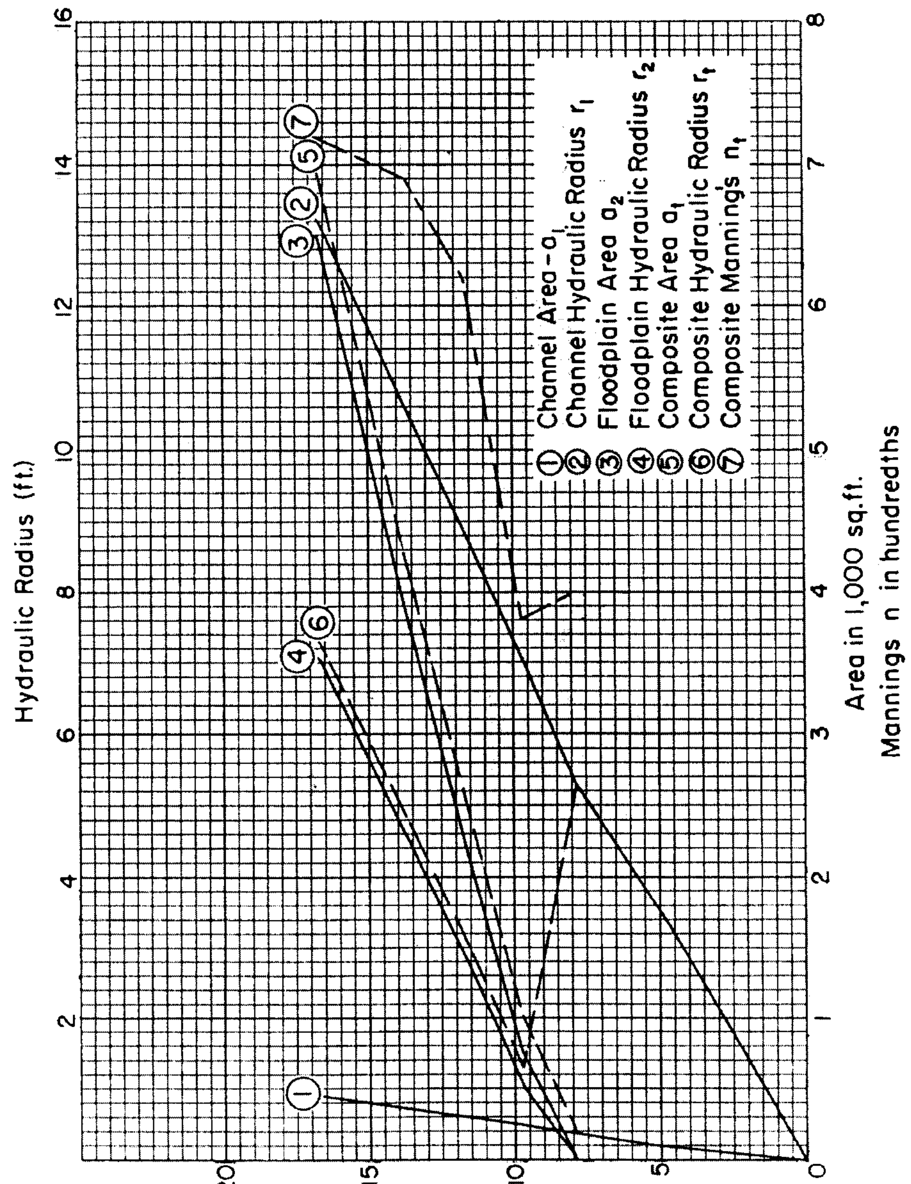

Hydraulic Radius (ft.)
Depth (ft.)
Area in 1,000 sq.ft.
Mannings n in hundredths
① Channel Area - a_1
② Channel Hydraulic Radius r_1
③ Floodplain Area a_2
④ Floodplain Hydraulic Radius r_2
⑤ Composite Area a_t
⑥ Composite Hydraulic Radius r_t
⑦ Composite Mannings n_t
0
2
4
6
8
10
12
14
16
1
2
3
4
5
6
7
8
5
10
15
20

Figure B.3

CHANNEL COEFFICIENT OF ROUGHNESS DETERMINATION
Manning's "n" value

Project/Site Name ____________________ Prepared By __________

Watershed ____________________ Checked By __________

Tributary ____________________

Date ____________

Cross Section					
1. Basic "n" Earth .020 Rock .025 Fine Gravel .028					
2. Irregular or Roughness of Channel Sides & Bottom Smooth .000 Minor .005 Moderate .010 Severe .020					
3. Changes in Size and Shape of Cross Section Gradual Changes .000 Occasional changes .005 Freq. & Wide Var. .010-.015					
4. Effect of Obstruction Negligible .000 Minor .015 Appreciable .030 Severe .060					
5. Effect of Vegetation Low Retardance .005-.010 Medium Retardance .010-.025 High Retardance .025-.050 Very High Retardance .050-.100					
SUBTOTAL, n_s					
6. Degree of Meandering Minor .000 Appreciable $.15 \times n_s$ Severe $.30 \times n_s$					
TOTAL, n					
Overbank Cover					
Channel Length					
Valley Length					

Typical Values for Manning's n

Type and Description of Channel[1]	n Values		
	Min.	Design	Max.
Channels, Lined			
Asphaltic concrete, machine placed		0.014	
Asphalt, exposed prefabricated		0.015	
Concrete	0.012	0.015	0.018
Concrete, trowel finish	0.012		0.014
Concrete, float finish	0.013		0.017
Concrete, gunite	0.016		0.022
Concrete, rubble	0.016		0.029
Flagstone	0.020		0.025
Metal, smooth (flumes)	0.011		0.015
Metal, corrugated	0.021	0.024	0.026
Plastic	0.012		0.014
Shotcrete	0.016		0.017
Wood, planed (flumes)	0.009	0.012	0.016
Wood, unplanned (flumes)	0.011	0.013	0.015
Channels, Earth			
Earth bottom, rubble sides	0.028	0.032	0.035
Drainage ditches, large, no vegetation			
a. <2.5 hydraulic radius	0.040		0.045
b. 2.5-4.0 hydraulic radius	0.035		0.040
c. 4.0-5.0 hydraulic radius	0.030		0.035
d. >5.0 hydraulic radius	0.025		0.030
Small drainage ditches	0.035	0.040	0.040
Stony bed, weeds on bank	0.025	0.035	0.040
Straight and uniform, clean (no vegetation)	0.017	0.022	0.025
Straight and uniform, with short grass, few weeds	0.022	0.027	0.033
Winding, sluggish, no vegetation	0.023	0.025	0.030
Stony bottom and weedy banks	0.025	0.035	0.040
Channels not maintained, clean bottom, brush on sides	0.040	0.050	0.080
Natural Streams			
a. Clean, straight bank, full stage, no rifts or deep pools	0.025		0.033
b. Same as "a" but some weeds and stones	0.030		0.040
c. Winding, some pools and shoals, clean	0.033		0.045
d. Same as "c", some weeds and stones	0.035		0.050
e. Same as "d" but lower stages, more ineffective slopes and sections	0.040		0.055
f. Same as "d" but more stones	0.045		0.060
g. Sluggish reaches, weedy, deep pools	0.050		0.080
h. Very weedy reaches	0.075		0.150
Rock Riprap (D_{50}*)	***$n=0.04D^{1/6}$*****		
2-inch diameter (0.17 feet)		0.030	
4-inch diameter (0.33 feet)		0.033	
6-inch diameter (0.50 feet)		0.036	
8-inch diameter (0.67 feet)		0.037	
10-inch diameter (0.83 feet)		0.039	
12-inch diameter (1.00 foot)		0.040	

Type and Description of Conduits	n Values		
	Min.	Design	Max.
Pipe			
Asbestos cement		0.009	
Cast iron, coated	0.011	0.013	0.014
Cast iron, uncoated	0.012		0.015
Clay or concrete drain tile (4-12 in.)	0.010	0.0108	0.020
Concrete	0.010	0.014	0.017
Metal, corrugated	0.021	0.025	0.0255
Steel, riveted and spiral	0.013	0.016	0.017
Vitrified sewer pipe	0.010	0.014	0.017
Wood stave	0.010	0.013	
Wrought iron, black	0.012		0.015
Wrought iron, galvanized	0.013	0.016	0.017
Subsurface Drains and Conduits			
Corrugated plastic tubing			
a. 3 to 8 inch diameter		0.015	
b. 10 t 12 inch diameter		0.017	
c. >12 inch diameter		0.020	
Smooth plastic, unperforated	0.010		0.012
Smooth plastic, perforated	0.010		0.012
Annular corrugated metal	0.021		0.025
Helical corrugated	0.015		0.020
Concrete	0.012		0.017
Vitrified sewer pipe	0.013		0.015
Clay drainage tile	0.012		0.014

* Where "D" is diameter of rock, the size of which is such that by weight, 50% is larger and 50% is smaller than this diameter.

** D in feet.

[1]References:

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