Report on Manning's "n" Values

GILA BEND AREA FLOODPLAIN DELINEATION STUDY
FCD 90-67

Sand Tank Wash
Scott Avenue Wash
Bender Wash
Unnamed Tributary of Bender Wash (No. 1)
Unnamed Tributary of No. 1 (No. 2)

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

Registered Professional Engineer (Civil)
CERTIFICATE NO.
18705
JAMES E.
MISCHLER
Date Signed 11/6/91
ARIZONA, U.S.A.

Prepared By:

Burgess & Niple, Inc.
5025 East Washington, Suite 212
Phoenix, Arizona
(602) 244-8100

October, 1991

On October 4, 1991, engineers from Burgess & Niple, Inc. and the Flood Control District of Maricopa County made a reconnaissance field trip to select Manning's "n" values for use in backwater modeling of Sand Tank Wash from Indian Road (North Line of Section 24, T.5S., R.5W.) to Interstate 8; Scott Avenue Wash from Watermelon Road to Interstate 8; Bender Wash from its mouth at Sand Tank Wash to Interstate 8; an Unnamed Tributary of Bender Wash (No. 1) from the Gila Bend Canal Drainage Channel to the East Line of Section 9, T.6S., R.4W.; and an Unnamed Tributary of No. 1 from the Gila Bend Canal Drainage Channel to the East Line of Section 4, T.6S., R.4W.

Manning's "n" values were selected based on visual observations for the channel and overbanks using, as a guide, the preliminary draft (7-3-90.2) of "Manning's Roughness Coefficients for Stream Channels and Floodplains in Maricopa County, Arizona", USGS. A copy of pertinent portions of the draft report is included in the Appendix of this report.

The following report will illustrate with photos the selected Manning's "n" values.

In general, channel bottoms are relatively clear of vegetation and were assigned coefficients of 0.03 to 0.035. Channel banks and bars are more heavily vegetated, with coefficients near 0.05 for the immediate side slopes and 0.03 to 0.04 in the overbank areas.

Roughness coefficients have been assigned to sub-elements of individual cross-sections based upon the field reconnaissance and comparison with aerial photographs. Roughness coefficients are included in the HEC-2 computer model by use of NC or NH cards.

Photo No. 1 (9101-25)
Looking upstream at Interstate 8.
"n" = 0.030 for channel

Photo No. 2 (9101-27)
Looking downstream from Interstate 8.
"n" = 0.030 for channel
"n" = 0.035 for left and right overbanks

Photo No. 3 (9101-30)
Looking downstream from Main Street.
"n" = 0.030 for channel
"n" = 0.035 for left and right overbanks

Photo No. 4 (9101-31)
Looking upstream from Gila Bend Canal.
"n" = 0.030 for channel
"n" = 0.035 for left and right overbanks

Photo No. 5 (9102-17)
Looking upstream at Southern Pacific Railroad.
"n" = 0.025 for channel
"n" = 0.060 for left and right overbanks

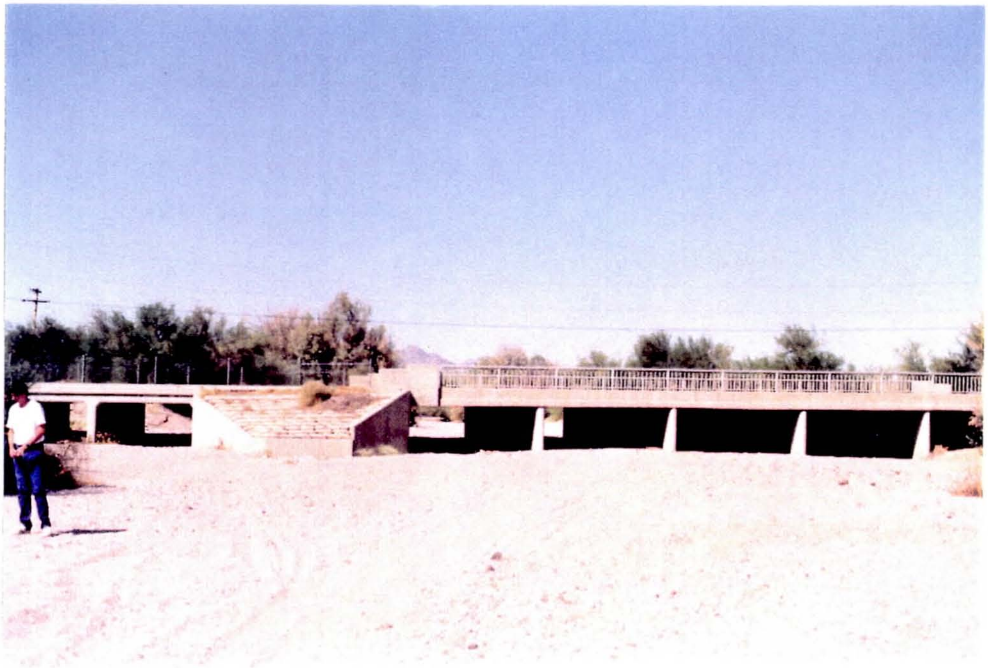


Photo No. 6 (9102-18)
Looking downstream at Highway 80.
"n" = 0.025 for channel

SAND TANK WASH

Photo No. 7 (9103-1)
Looking downstream from Papago Street.
"n" = 0.030 for channel
"n" = 0.060 for left and right banks
"n" = 0.040 for left and right overbanks

Photo No. 8 (9103-4)
Looking downstream from Indian Road. (South line Sec. 30, T.5S., R.4W.)
"n" = 0.030 for channel
"n" = 0.060 for left and right banks
"n" = 0.040 for left and right overbanks

Photo No. 9 (9103-5)
Looking upstream from Watermelon Road
"n" = 0.030 for channel
"n" = 0.060 for left and right banks
"n" = 0.040 for left and right overbanks

Photo No. 10 (9103-7)
Looking upstream from mid-section line of Sec. 24, T.5S., R.5W.
"n" = 0.030 for channel
"n" = 0.060 for left overbank
"n" = 0.040 for right overbank

Photo No. 11 (9103-8)
Looking upstream from Indian Road. (North line Sec. 24., T.5S., R.5W.)
"n" = 0.035 for channel
"n" = 0.060 for left and right overbanks

SCOTT AVENUE WASH

Photo No. 12 (9102-4)
Looking upstream at Interstate 8.
"n" = 0.035 for channel

Photo No. 13 (9102-3)
Looking downstream from East Line of Sec. 1 T.6S., R.5W.
"n" = 0.050 for channel
"n" = 0.035 for left and right overbanks

Photo No. 14 (9102-7)
Looking downstream from Martin Avenue.
"n" = 0.050 for channel
"n" = 0.035 for left and right overbanks

SCOTT AVENUE
WASH

Photo No. 15 (9102-9)
Looking upstream at
Tucson, Cornelia and Gila
Bend Railroad.
"n" = 0.045 for channel

Photo No. 16 (9102-12)
Looking downstream at
Gila Bend Canal.
"n" = 0.045 for channel

Photo No. 17 (9102-15)
Looking downstream at
Southern Pacific Railroad.
"n" = 0.035 for channel

SCOTT AVENUE WASH

Photo No. 18 (9103-23)
Looking downstream at Highway 80.
"n" = 0.030 for channel

Photo No. 19 (9103-21)
Looking upstream behind service station on North side of Highway 80.
"n" = 0.080 for channel

Photo No. 20 (9103-18)
Looking downstream from Papago Street.
"n" = 0.040 for channel
"n" = 0.035 for left and right overbanks

SCOTT AVENUE WASH

Photo No. 21 (9103-16)
Looking upstream from Richards Street.
"n" = 0.050 for channel
"n" = 0.035 for left and right overbanks

Photo No. 22 (9103-13)
Looking upstream from Indian Road (North line of Sec. 36, T.5S., R.5W.)
"n" = 0.070 for channel
"n" = 0.035 for left and right overbanks

Photo No. 23 (9103-10)
Looking upstream from Watermelon Road.
"n" = 0.040 for channel
"n" = 0.040 for left and right overbanks

Photo No. 24 (9102-13)
Looking upstream at
Interstate 8.
"n" = 0.030 for channel

Photo No. 25 (9102-14)
Looking downstream from
Interstate 8.
"n" = 0.030 for channel
"n" = 0.035 for left and
right overbanks

Photo No. 26 (9101-22)
Looking upstream from
mid-section line of Sec. 6,
T.6S., R.4W.
"n" = 0.030 for channel
"n" = 0.030 for left and
right overbanks

BENDER WASH

Photo No. 27 (9101-20)
Looking upstream from Main Street.
"n" = 0.035 for channel
"n" = 0.030 for left and right overbanks

Photo No. 28 (9101-33)
Looking downstream at Gila Bend Canal.
"n" = 0.035 for channel

Photo No. 29 (9102-22)
Looking upstream at Gila Bend Canal.
"n" = 0.030 for channel

BENDER WASH

Photo No. 30 (9102-20)
Looking upstream at
Southern Pacific Railroad.
"n" = 0.035 for channel

Photo No. 31 (9102-19)
Looking upstream at
Highway 80.
"n" = 0.035 for channel

Photo No. 32 (9102-23)
Looking upstream from
confluence of Sand Tank
Wash.
"n" = 0.030 for channel
"n" = 0.035 for left and
right overbanks

UNNAMED TRIBUTARY #1

Photo No. 33 (9101-7)
Looking downstream at Frontage Road.
"n" = 0.045 for channel

Photo No. 34 (9101-8)
Looking downstream from Frontage Road.
"n" = 0.045 for channel
"n" = 0.035 for left and right overbanks

Photo No. 35 (9101-9)
Looking downstream at Ramp E.
"n" = 0.045 for channel

**UNNAMED
TRIBUTARY #1**

Photo No. 36 (9101-11)
Looking downstream at
Interstate 8.
"n" = 0.035 for channel

Photo No. 37 (9101-13)
Looking downstream at
Ramp A-B Crossroad.
"n" = 0.030 for channel

Photo No. 38 (9101-14)
Looking downstream at
Ramp C.
"n" = 0.035 for channel

UNNAMED TRIBUTARY #1

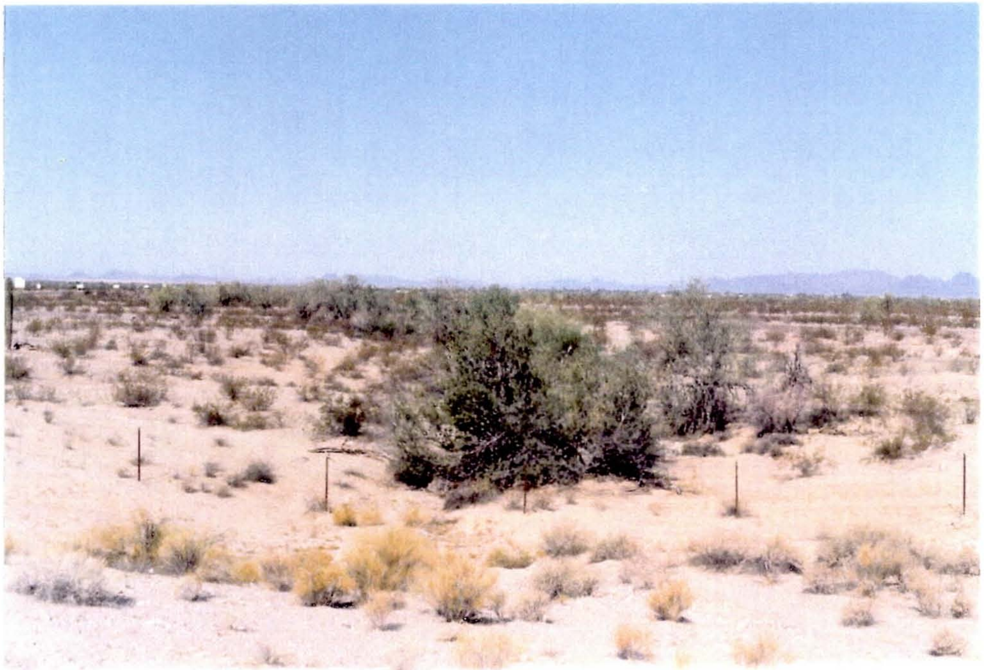


Photo No. 39 (9101-15)
Looking downstream from Ramp C.
"n" = 0.035 for channel
"n" = 0.030 for left and right overbanks

Photo No. 40 (9101-18)
Looking upstream from Main Street.
"n" = 0.035 for channel
"n" = 0.030 for left and right overbanks

Photo No. 41 (9101-36)
Looking upstream from Gila Bend Canal Drainage Channel.
"n" = 0.035 for channel
"n" = 0.035 for left and right overbanks

UNNAMED TRIBUTARY #2

Photo No. 42 (9101-4)
Looking downstream from East Line of Section 4, T.6S., R.4W.
"n" = 0.040 for channel
"n" = 0.035 for left and right overbanks

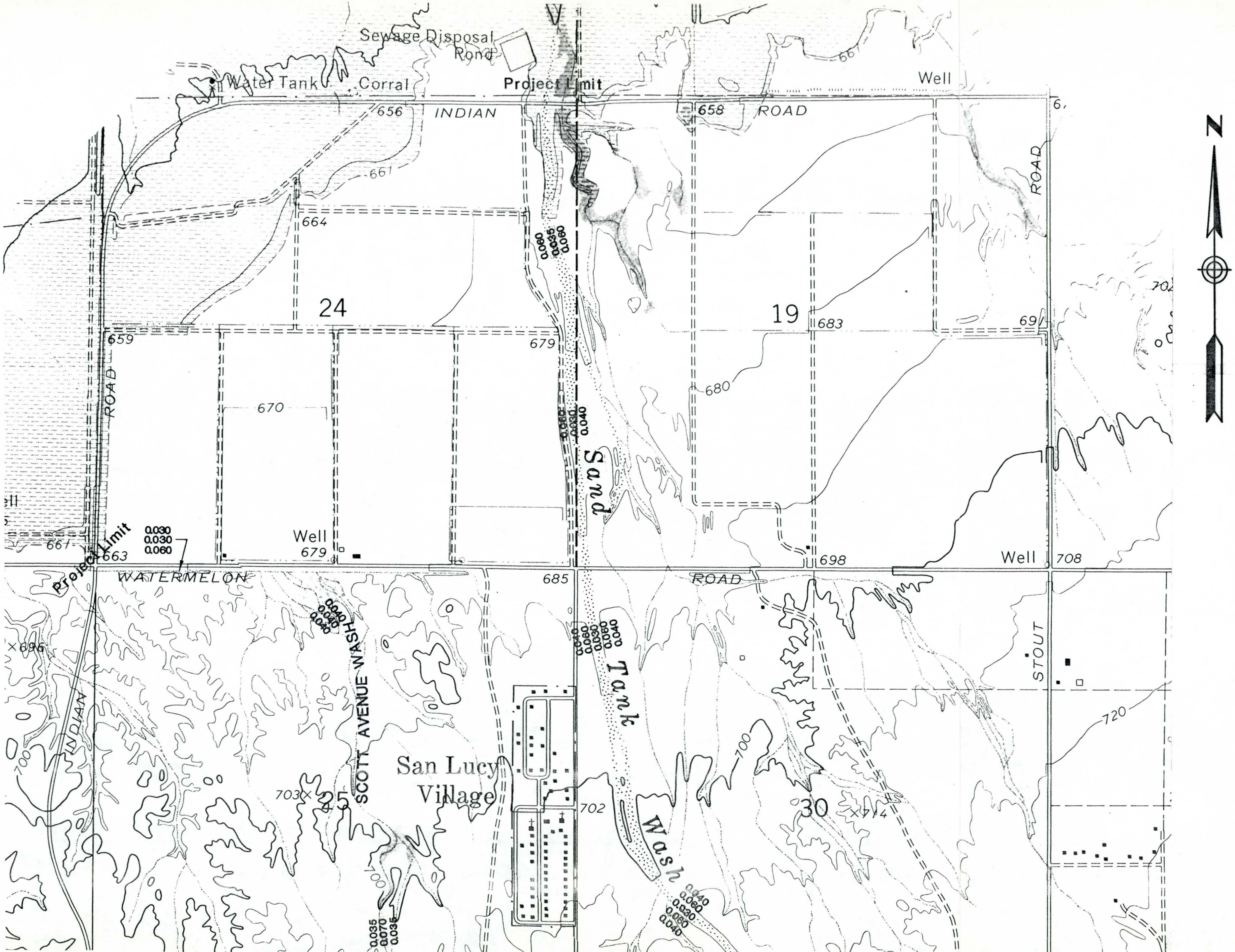
Photo No. 43 (9101-3)
Looking upstream from Business Route 8.
"n" = 0.035 for channel
"n" = 0.035 for left and right overbanks

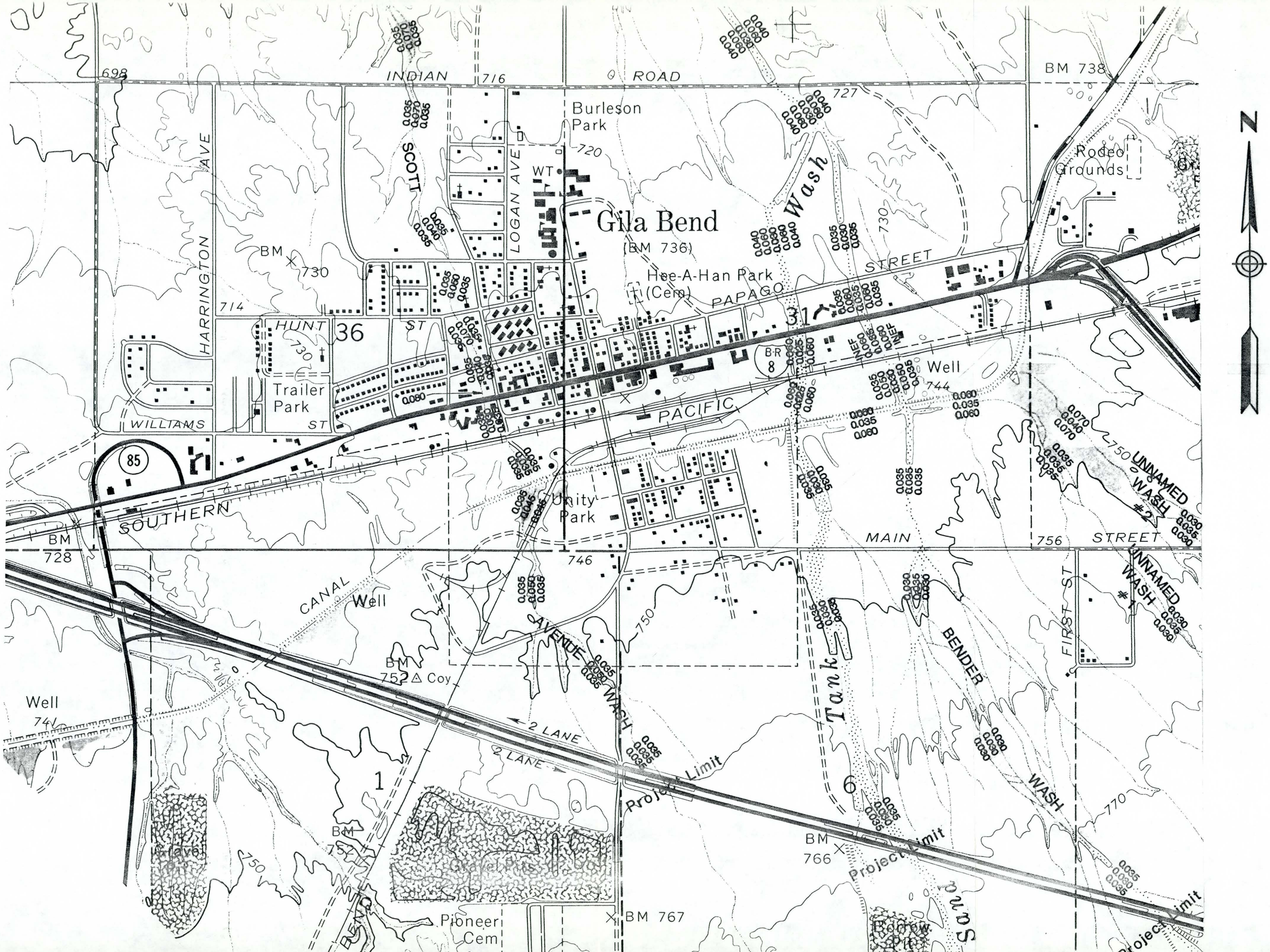
Photo No. 44 (9101-2)
Looking downstream at Business Route 8.
"n" = 0.035 for channel

UNNAMED TRIBUTARY #2

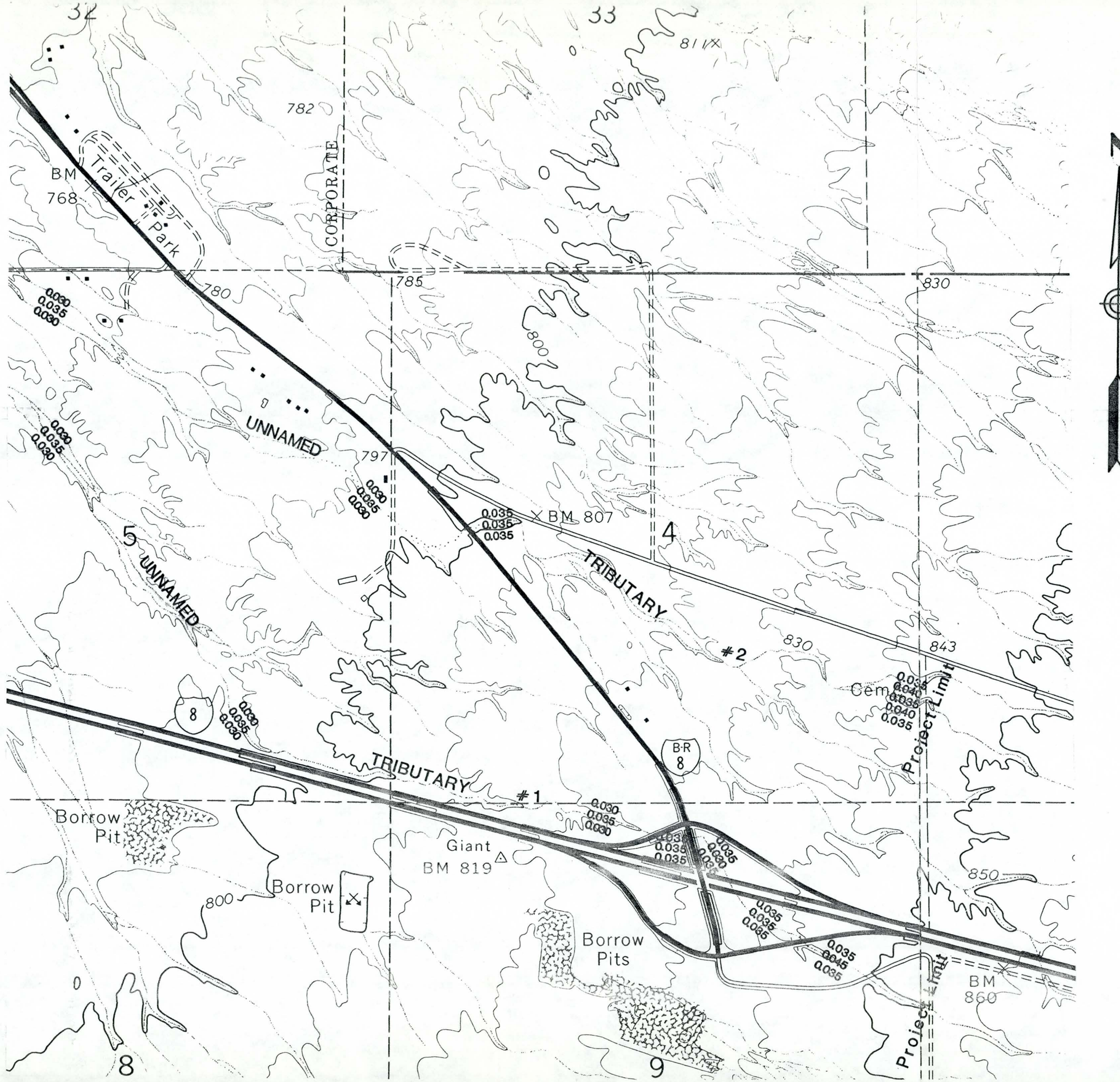
Photo No. 45 (9101-17)
Looking upstream from Main Street.
"n" = 0.035 for channel
"n" = 0.030 for left and right overbanks

Photo No. 46 (9101-37)
Looking upstream from Gila Bend Canal Drainage Channel.
"n" = 0.040 for channel
"n" = 0.070 for left and right overbanks


Sewage Disposal Pond
Water Tank
Corral
Project Limit
Well
INDIAN ROAD
656
658
661
664
24
19
659
679
683
691
670
680
ROAD
0.060
0.035
0.060
0.030
0.040
Sand Tank Wash
Well
663
698
708
685
WATERMELON ROAD
SCOTT AVENUE WASH
STOUT
San Lucy Village
703
25
702
30
714
696
700
720
0.070
0.035
N



N
INDIAN ROAD
BM 738
Burleson Park
Gila Bend
(BM 736)
Hee-A-Han Park
(Cem)
Rodeo Grounds
SCOTT
LOGAN AVE
HARRINGTON AVE
WT
Wash
STREET
PAPAGO
HUNT ST
36
31
Trailer Park
WILLIAMS ST
85
BR 8
PACIFIC
SOUTHERN
Well
Unity Park
MAIN STREET
UNNAMED WASH #2
UNNAMED WASH #1
FIRST ST
CANAL
Well
BM 752 Coy
AVENUE WASH
Tank
BENDER WASH
2 LANE
Project Limit
1
6
Well
Gravel Pit
Gravel Pits
Pioneer Cem
BEND
BM 767
BM 766
Borrow Pit
Sand
BM 728
BM 730
BM 752



32
33
811
782
CORPORATE
BM
768
Trailer Park
780
785
830
800
UNNAMED
797
0.030
0.035
0.030
0.035
0.035
0.035
BM 807
4
5
UNNAMED
TRIBUTARY
#2
830
843
Cem
0.035
0.040
0.035
0.040
0.035
Project Limit
8
B·R
8
TRIBUTARY
#1
Borrow
Pit
Giant
BM 819
850
800
Borrow
Pit
Borrow
Pits
BM
860
Project Limit
8
9
N

APPENDIX

MANNING'S ROUGHNESS COEFFICIENTS FOR STREAM CHANNELS AND FLOOD PLAINS IN MARICOPA COUNTY, ARIZONA

By

B.W. Thomsen and H.W. Hjalmarson

INTRODUCTION

Computations of flow in open channels require evaluation of roughness characteristics of the channel. Roughness coefficients represent the resistance to flow and cannot be quantitatively determined by direct measurement or calculation. Values of roughness coefficients have been computed for many artificial surfaces and typical natural channels and have been verified for selected channel sites. Characteristics of natural channels and the factors that affect channel roughness, however, vary greatly, and the combination of these factors are numerous. Selection of roughness coefficients for natural channels, therefore, requires judgment and skill that is acquired mainly through experience.

The purpose of this report is to provide estimates of roughness coefficients for 16 sites in Maricopa County, Arizona (fig. 1), and to provide guidelines in evaluating roughness coefficients. The work was done in cooperation with the Maricopa County Flood Control District. Maps and channel data were furnished by Maricopa County Flood Control district. The material presented is based mainly on the work of Chow (1959), Barnes (1964), Aldridge and Garrett (1973), and Arcement and Schneider (1984) and was adapted to fit the desert channels of Maricopa County. Adaptations are based on the experience of the authors in river hydraulics in the deserts of the southwestern United States.

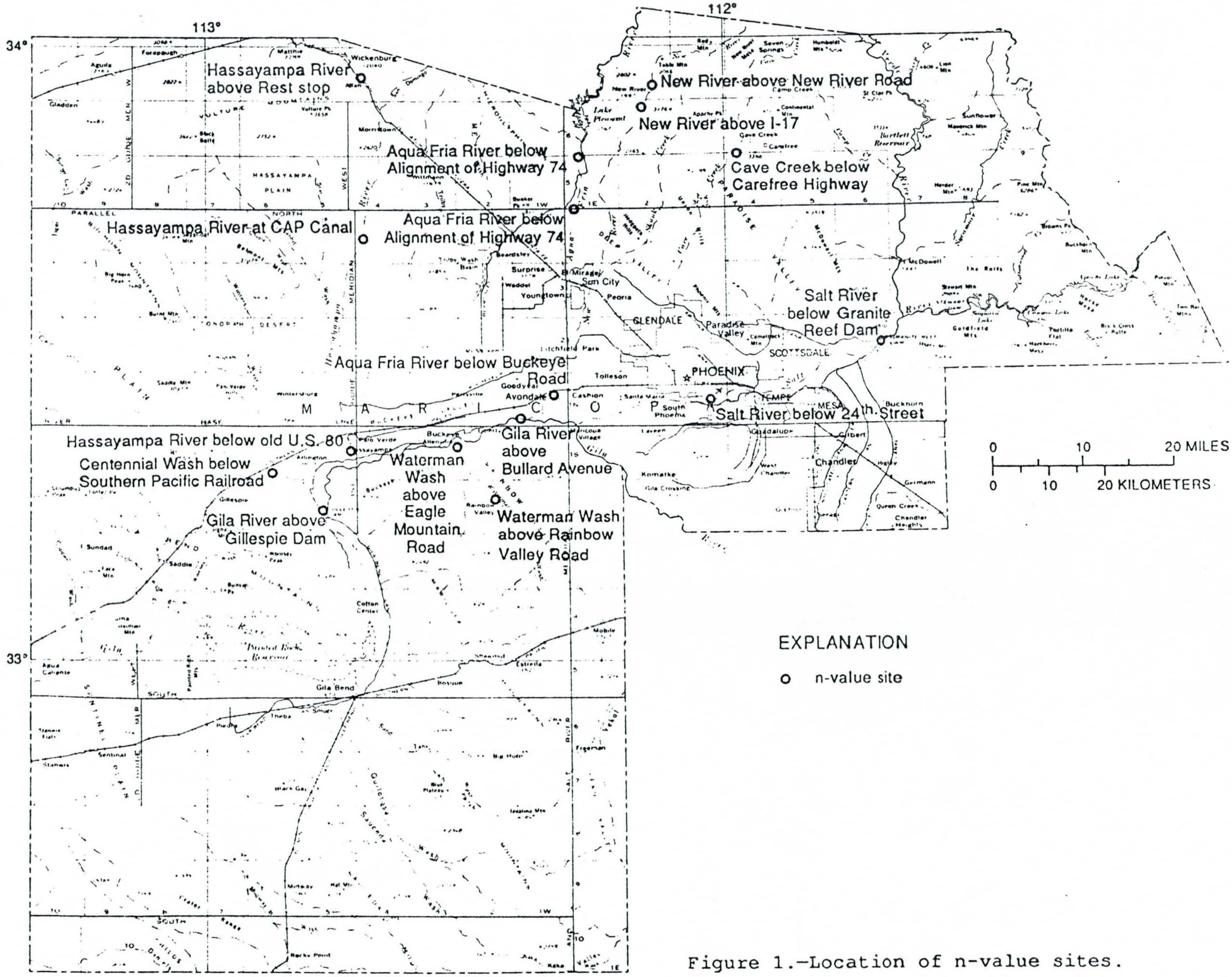


Figure 1.—Location of n-value sites.

The Manning equation in the following form is commonly used to compute discharge in natural channels:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}, \qquad (1)$$

where

Q = discharge, in cubic feet per second,

A = cross-section area of channel, in square feet,

R = hydraulic radius, A/P (P, wetted perimeter, in feet), in feet,

S = energy gradient, and

n = roughness coefficient.

The equation was developed for conditions of uniform flow in which the water-surface profile and energy gradient are parallel to the streambed and the area, depth, and velocity are constant throughout the reach. The equation was assumed to be valid for nonuniform reaches if the energy gradient is modified to reflect only the losses resulting from boundary friction (Barnes, 1967). Use of the Manning equation in discharge computations generally involves the concept of channel conveyance. Conveyance, K, is defined as

$$K = \frac{1.486}{n} AR^{2/3} \qquad (2)$$

and is a measure of the carrying capacity of the channel. When the conveyance concept is used, Manning's equation is reduced to

$$Q = KS^{1/2}, \qquad (3)$$

where S is the energy gradient. The energy gradient for a reach of nonuniform channel can be expressed as

$$S = \frac{h_f}{L}, \qquad (4)$$

where

h_f = energy loss due to boundary friction in the reach and

L = length of the reach.

The main components of h_f are the difference in water-surface elevation and the difference in velocity head at the ends of the reach.

Roughness factors and nonuniformities in channel geometry cause the velocity in a given cross section of channel to vary from point to point. As a result of nonuniform distribution of velocities, the true velocity head (h_v) generally is greater than the value computed from the expression

$$h_v = \frac{V^2}{2g}, \qquad (5)$$

where

V = mean velocity in the cross section and

g = acceleration of gravity.

The ratios of the true velocity head to the velocity head computed on the basis of the mean velocity is the velocity-head coefficient, alpha. For reasonably straight channels with uniformly shaped cross section, the effect of nonuniform velocity distribution on the computed velocity head is small, and for convenience in the absence of a more suitable method, the coefficient is assumed to be unity (Chow, 1959). A detailed study of the velocity-head coefficient, alpha, in natural channels showed a significant correlation between alpha and channel roughness for channels without overbank flow. Variation in the horizontal distribution of velocity had a greater effect on the value of alpha than variation in the vertical. Computed values of alpha at 894 sites ranged from 1.03 to 4.70, and the median value for trapezoidal channels was 1.40 (Hulsing and others, 1966). In the computation of water-surface profiles in open channels, the value of alpha is assumed to be 1.0 if the section is not subdivided (Davidian, 1984). In subdivided channels the value of alpha is computed as

$$\alpha = \frac{\Sigma(k_i^3/a_i^2)}{K_T^3/A_T^2}, \tag{6}$$

where

k_i = conveyance of individual subsections,

a_i = area of individual subsections,

K_T = conveyance of entire cross section, and

A_T = area of entire cross section.

The Manning roughness coefficient, n, is a measure of the flow resistance or relative roughness of a channel or overflow area. The flow resistance is affected by many factors including bed material, cross-section irregularities, depth of flow, vegetation, channel alignment, channel shape, obstructions, suspended material, and bedload. In general, all factors that cause turbulence and retardance of flow tend to increase the roughness coefficient (Jarrett, 1984). Channel roughness also is directly related to channel slope (Riggs, 1976; Jarrett, 1984). The relation of roughness to slope results, in part, from the interrelation between channel slope and bed-material particle size. For similar bed material, however, channels with low gradients have lower roughness coefficients than channels with high gradients (Jarrett, 1984). The direct relation between channel roughness and channel slope is not evident in low-gradient channels where high roughness coefficients result from vegetation. Roughness coefficients as great as 0.20 have been verified for channels with low gradients and dense vegetation (Arcement and Schneider, 1984). For vegetation that will bend under the force of flowing water, the relation between roughness and gradient can be inversely related. Steep slope causes greater velocity that bends and flattens vegetation if depths of flow are sufficient and results in lower *n* values. Because of the relation between channel slope and size of bed material, the effect of slope on *n* values is taken into account in the selection of base *n* values.

A common method of selecting the roughness coefficient, *n*, is to first select a base value of *n* for the bed material (table 1). The base values of *n* are for a straight uniform channel of a given bed material. Cross-section irregularities, channel alignment, obstructions, vegetation, and other factors that increase roughness are accounted for by adding increments of roughness to the base value of *n*. Ranges of adjustments for the factors that may add to channel roughness are shown in table 2. In selecting a base value for *n*, the stability of the bed material must be considered. A stable channel is one that remains relatively unchanged through the range in flow. A sand channel is one in which the bed has an

Table 1.--*Base values of Manning's n for stable channels*
[Modified from Aldridge and Garrett, 1973, table 1]

Channel material	Size of bed material: Millimeters	Size of bed material: Inches	Base *n* values: Benson and Dalrymple (1967)[1]	Base *n* values: Chow (1959)[2]
Concrete..............	-------	--------	0.012-0.018	0.011
Rock cut..............	-------	--------	-----------	.025
Firm soil.............	-------	--------	.025- .032	.020
Coarse sand...........	1-2	--------	.025- .035	-----
Fine gravel...........	-------	--------	-----------	.024
Gravel................	2-64	0.08-2.5	.028- .035	-----
Coarse gravel.........	-------	--------	-----------	.026
Cobble................	64-256	2.5-10.0	.030- .050	-----
Boulder...............	>256	>10.0	.040- .070	-----

[1]Straight uniform channel.
[2]Smoothest channel attainable in indicated material.

Table 2.--Adjustment factor for the determination of overall Manning's n values

[Modified from Chow, 1959]

Channel conditions	Manning's n adjustment[1]	Example
Degree of irregularity:		
Smooth	0.000	Smoothest channel attainable in given bed material.
Minor	0.001-0.005	Channels with slightly eroded or scoured side slopes.
Moderate	.006- .010	Channels with moderately sloughed or eroded side slopes.
Severe	.011- .020	Channels with badly sloughed banks; unshaped, jagged, and irregular surfaces of channels in rock.
Variations in channel cross section:		
Gradual	.000	Size and shape of cross sections change gradually.
Alternating occasionally	.001- .005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross-sectional shape.
Alternating frequently	.010- .015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-sectional shape.
Effects of obstruction[2]:		
Negligible	.000- .004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
Minor	.005- .015	Obstructions occupy 5 to 15 percent of the cross-sectional area and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects than are used for sharp-edged angular objects.
Appreciable	.020- .030	Obstructions occupy from 15 to 50 percent of the cross-sectional area or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
Severe	.040- .060	Obstructions occupy more than 50 percent of the cross-sectional area or the space between obstructions is small enough to cause turbulence across most of the cross section.
Vegetation:		
Small	.002- .010	Dense growths of flexible turf grass, such as Bermuda, or weeds where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrow weed, or saltcedar where the average depth of flow is at least three times the height of the vegetation.

See footnotes at end of table.

Table 2.--Adjustment factor for the determination of overall Manning's n values--Continued

Channel conditions	Manning's n adjustment[1]	Example
Medium	.010- 0.25	Grass of weeds where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings where the average depth of flow is from two to three times the height of the vegetation; moderately dense brush, similar to 1- to 2-year-old saltcedar in the dormant season, along the banks and no significant vegetation along the channel bottoms where the hydraulic radius exceeds 2 feet.
Large	.025- .050	Turf grass of weeds where the average depth to flow is about equal to the height of vegetation; small trees intergrown with some weeds and brush where the hydraulic radius exceeds 2 feet.
Very large	.050- .100	Turf grass or weeds where the average depth of flow is less than half the height of vegetation; small bushy trees intergrown with weeds along side slopes of dense cattails growing along channel bottom; trees intergrown with weeds and brush.
Degree of meadering[3]:		
Minor	1.00	Ratio of the meander length to the straight length of the channel reach is 1.0 to 1.2.
Appreciable	1.15	Ratio of the meader length to the straight length of channel is 1.2 to 1.5
Severe	1.30	Ratio of the meander length to the straight length of channel is greater than 1.5

[1]Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value (table 1) before multiplying by the adjustment for meander.

[2]Conditions considered in other steps must not be reevaluated or duplicated in this section.

[3]Adjustment values apply to flow confined in the channel and do not apply where downvalley flow crosses meanders.

unlimited supply of sand. Sand by definition has a size range of 0.062 to 2 mm (millimeters). For floodflows in sand channels with moveable beds, roughness mainly is a function of the size of the bed material as shown in the following table (Benson and Dalrymple, 1967, p. 22).

Median grain size, millimeters	Manning's *n*
0.2	0.012
.3	.017
.4	.020
.5	.022
.6	.023
.8	.025
1.0	.026

Stream channels in Maricopa County generally are sandy in the low-flow part of the channel where flows are common. Higher parts of the channel beds and the channel banks commonly are stabilized by gravel, cobbles, and boulders, and (or) to some extent by vegetation.

Depth of flow must be considered in selection of *n* values. The effect of roughness elements on and near the channel bottom tend to diminish as the depth of flow increases. The effect of vegetation on *n* values depends greatly on the depth of flow and to some extent on the flexibility of the vegetation. If the flow is of sufficient depth to submerge and (or) flatten the vegetation, *n* values will be lowered. Density of vegetation below the high-water level and the alignment of vegetation relative to direction of flow also affect *n* values.

Generally an n value is selected for a cross section that is typical of a reach of channel and takes into consideration the roughness in the reach. If two or more cross sections are being considered, the reach that applies to a given section extends halfway to the next section. In this study, channel data including maps showing cross-section locations were furnished by Maricopa County Flood Control District. A cross section for each of the 16 sites was selected on the basis of the following criteria: (1) cross section should be located so that visual inspection is reasonably convenient; (2) cross section should be within a natural reach—a reach that is minimally affected by roads, bridges, and other structures that may obstruct floodflow; and (3) cross section should contain roughness elements typical of the reach. Widths of the cross sections range from a few hundred feet to a few thousand feet. Some sections have a distinct main channel and overflow areas; others are one large trapezoidal section. General procedure for determining n values was to first select a base value of n for the bed material (table 1) followed by selection of n-value adjustments for channel irregularities and alignment, obstructions, vegetation, and other factors (table 2). In this procedure, the value of n was computed by

$$n = n_b + n_1 + n_2 + n_3 , \quad (7)$$

where

n_b = base value of n for a straight uniform channel,

n_1 = value for surface irregularities,

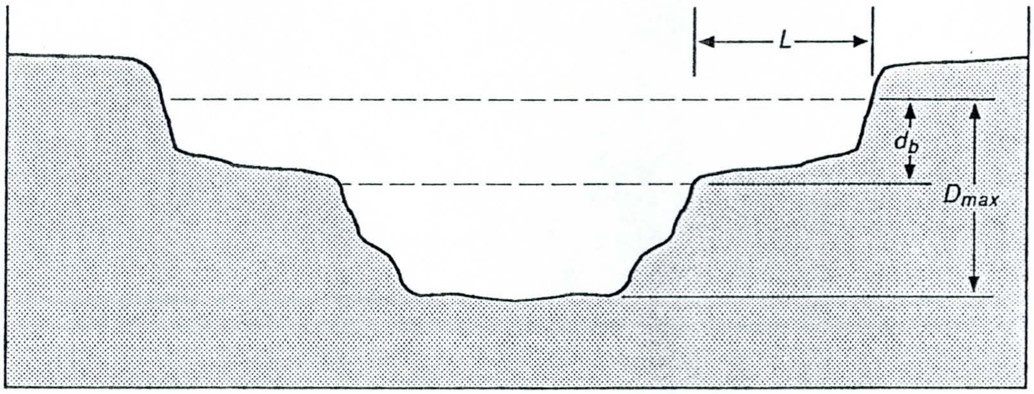
n_2 = value for obstruction, and

n_3 = value for vegetation.

In the tables for the individual cross section, dashes indicate that a roughness coefficient of zero was used.

Sections with distinct changes in shape were divided into subsections, and *n* values were determined separately for each subsection. Subdivision was done primarily for major breaks in cross-sectional geometry and was based on the criteria to subdivide if the main channel depth was more than twice the depth at the stream edge of the overflow area (fig. 2). Values of *n* for overflow areas were estimated from table 2 in some instances. For sections or subsections with a nonuniform distribution of vegetation, a composite *n* was computed by using weighted values for segments having different roughness. Where sections were divided into segments of equal roughness, dividing lines were selected to parallel the general flow line and to represent the average contact between segments of different roughness. Composite *n* values were computed by using weighted values of either area (A) or wetted perimeter (P). Weighting was done by estimating area or wetted perimeter for each segment of channel and assigning weighting factors that were proportional to the total area or wetted perimeter. The general rule for deciding which weighting method to use is as follows: Use area weighting where vegetation is dense and occupies a distinct part of the cross section. Use wetted-perimeter weighting where the roughness factor for each segment is the result of low-lying boundary material.

Where overflow areas are cultivated fields, *n* values are for fields without crops. Values of *n* for fields with crops should be based on the work of Chow (1959). Fields of mature cotton plants are comparable to dense brush in summer; defoliated cotton to medium to dense brush in winter (fig. 3).



Subdivide if D_{max} is greater than or equal to $2d_b$

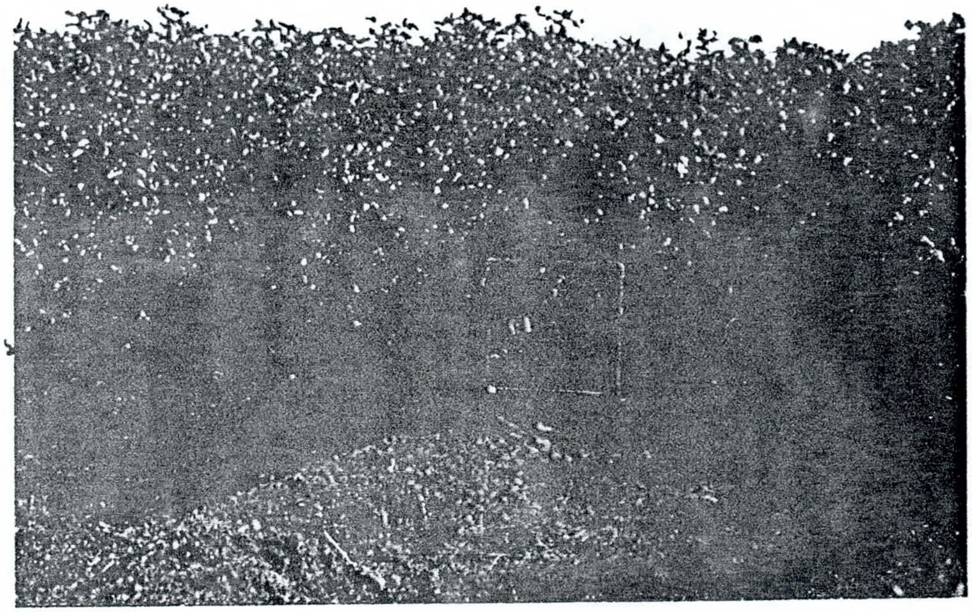
Subdivide if D_{max} is approximately equal to $2d_b$
and if L/d_b is equal to or greater than 5

L = width of flood plain
d_b = depth of flow on flood plain, in feet
D_{max} = maximum depth of flow in cross section, in feet

Modified from Davidian (1984)

Figure 2.—Subdivision criteria commonly used for streams in Maricopa County, Arizona.

√ W 6/4/90



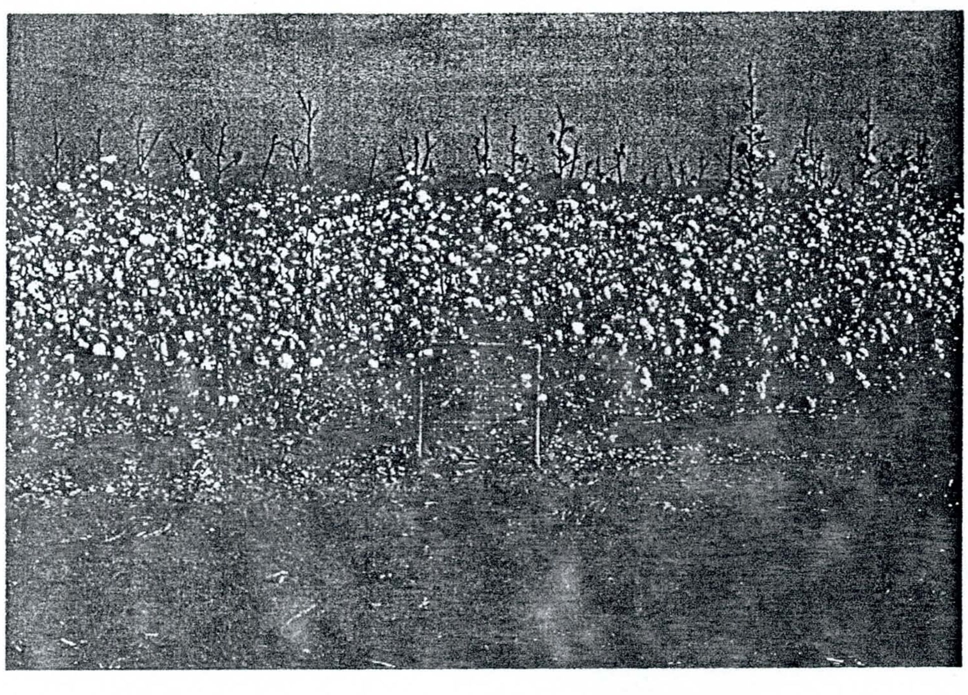


Figure 3.--Comparison of cotton fields.

Fields of alfalfa are comparable to field crops with *n* value depending on height of the crop and depth of water (table 3). The value of *n* generally varies with the stage of submergence of the vegetation. In all instances, *n* values associated with cultivated fields will be subject to change with time.

Photographs include an overview showing the location of cross section and additional photographs show major items that affect the *n* value. The frame square grid in several photographs is 1.5 ft (outside dimension) on a side with an internal square of 1 ft on a side and grid spacing of 1 in. or about 25 mm. Cross-section diagrams show approximate elevation of the 10-year and 100-year flood levels, appropriate subdivisions, and selected *n* values.

The major adjustments to the base value of *n* used in this report are for cross-section characteristics. Other adjustment for the reach characteristics between cross sections that include changes in shape and size of cross sections and channel meandering are not given. Procedures for evaluating the adjustment factors for the reach characteristics are given in several publications including Chow (1959), Aldridge and Garrett (1973), and Jarrett (1985a).

Table 3.--*Values of Manning's n for flood plains*

[Modified from Chow, 1959]

Description	Minimum	Normal	Maximum
Pasture, no brush:			
Short grass	0.025	0.030	0.035
High grass	.030	.035	.050
Cultivated areas:			
No crop	.020	.030	.040
Mature row crops	.025	.035	.045
Mature field crops	.030	.040	.050
Brush:			
Scattered brush, heavy weeds	.035	.050	.070
Light brush and trees, in winter	.035	.050	.060
Light brush and trees, in summer	.040	.060	.080
Medium to dense brush, in winter	.045	.070	.110
Medium to dense brush, in summer	.070	.100	.160
Trees:			
Dense willows, summer, straight	.110	.150	.200
Cleared land with tree stumps, no sprouts	.030	.040	.050
Same as above, but heavy growth of sprouts	.050	.060	.080
Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	.080	.100	.120
Same as above, but with flood stage reaching branches	.100	.120	.160