N Value Determination Report

CAP Overchutes
Agua Fria Floodplain Delineation Study

for

Flood Control District of Maricopa County
FCD 90-09

Prepared by

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February 1991

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CAP OVERCHUTES
AGUA FRIA FLOODPLAIN DELINEATION STUDY
DERIVATION OF MANNING'S "n"

Methodology

The roughness coefficients derived in this study were estimated by the use of the following materials:

1. Aerial Photographs - 1:18,000 contact prints of flight used for base mapping.
2. Photographs taken during field reconnaissance trips.
3. Video Tapes that were filmed during field reconnaissance trips.
4. Reference documents as listed below
    a) Manning's Roughness Coefficients for Stream Channels and Floodplains in Maricopa County, Arizona, Preliminary Draft, USGS Open-File Report Az120-682, July, 1990.
    b) Roughness Coefficients for Stream Channels in Arizona, USGS Open-file Report, February, 1973.
    c) Open Channel Hydraulics, V.T. Chow, McGraw-Hill, 1959.

The method outlined within Reference a) was used to determine the roughness values for this project. This method consists of establishing a base value for the area based on the soil type and then making adjustments to the base value due to the degree of channel irregularity, variations in the channel's cross section, effects of obstructions, vegetation, and degree of meandering. The adjustments are made to the base value through addition or multiplication by a factor to arrive at a composite value. These composite values were then checked against similar sites within the same reference and also against values contained within references b) and c).

Base Value Determination

Reference a) contains a detailed analysis of the derivation of roughness coefficients for the Agua Fria River within the same basic area as this study. The two locations sited as examples are Agua Fria River below alignment of U.S. Highway 74 and Agua Fria River below Jomax Road. In both cases the material has been described as coarse sand and gravel. From photographic examination, the bed materials seem to be of a similar nature with the materials that make up the stream beds within our study area. A base value of 0.025 was used in the sited cases and seems consistent with the conditions found for the subject watercourses.

Adjustments to Base Value

The streams under consideration in this study are, for the most part, well shaped with fairly straight and uniform banks. No adjustment to the base value has been added at any location due to either degree of irregularity or variation in the channel cross section.

Negligible obstructions in the channels were found with the exception of immediately upstream of the Beardsly canal crossing. In this area, upstream from concentration point M, water leaking from the canal crossing overhead has promoted the growth of salt cedars within the channel. An adjustment of .005 was added to the base value due to the obstruction caused by the trees and their roots within the channel. This adjustment only considered the channel obstruction and was not inclusive of the effects of the vegetation itself.

Vegetation was found mainly along the channel banks as evidenced by both the photographs and aerial photography contained in this report. The density of the number of trees along the bank seems to reflect the full range of a medium classification as defined in Table 2 from reference a (Appendix A). Inspection of the aerial photographs was used to determine where within the range each segment of the channels should fall. For most of the study an adjustment value of 0.01 was used. In areas where a higher density of bank coverage exists the adjustment factor was increased accordingly. At the location below the Beardsly canal where the salt cedars exist within the channel an adjustment of .025 was used.

Spot roughness values within the streams range from a low of .035 to a maximum value of .055. These roughness coefficients are in general agreement with similar condition values listed in references a and b. Copies of the tables from these references have been included in appendix B and C respectively.

Weighted Reach Roughness Values

The composite roughness factors identified by the procedures above have been shown on plate 1 in the back of this report. The roughness coefficient required for the various reach lengths within the HEC-1 computer program's normal depth channel routing procedure were computed by estimating the percentage of each roughness coefficient in a specific channel reach and determining a weighted average. This procedure has been shown in Table 1 of this report.

The values determined for the reach lengths within the subject watersheds vary from a minimum of .035 to a maximum of .043. These values appear to be consistent with sited values from the other references. Copies of the tables from these sited reports have been included in Appendix B and Appendix C respectively.

TABLE 1

Manning's "n" Determination

Stream Name: Caterpillar Tank Wash

REACH	BASE "n"	OBSTRUCTION ADJUSTMENT	VEGETATION ADJUSTMENT	COMPOSITE "n"	PERCENT REACH	REACH "n"
EAtoEB	0.025		0.025	0.050	5%	
	0.025		0.010	0.035	75%	
	0.025		0.020	0.045	20%	
					100%	0.038
EBtoEC	0.025		0.020	0.045	15%	
	0.025		0.015	0.040	85%	
					100%	0.041
ECtoED	0.025		0.020	0.045	5%	
	0.025		0.015	0.040	90%	
	0.025		0.025	0.050	5%	
					100%	0.041
EDtoEE	0.025		0.025	0.050	10%	
	0.025		0.020	0.045	40%	
	0.025		0.015	0.040	50%	
					100%	0.043

Stream Name: White Peak Wash

REACH	BASE "n"	OBSTRUCTION ADJUSTMENT	VEGETATION ADJUSTMENT	COMPOSITE "n"	PERCENT REACH	REACH "n"
FTOI	0.025		0.010	0.035	100%	0.035
FTOH	0.025		0.010	0.035	100%	0.035
ITOJ	0.025		0.015	0.040	100%	0.040

Stream Name: West Tributary to White Peak Wash

REACH	BASE "n"	OBSTRUCTION ADJUSTMENT	VEGETATION ADJUSTMENT	COMPOSITE "n"	PERCENT REACH	REACH "n"
GTOH	0.025		0.010	0.035	100%	0.035

Stream Name: Twin Buttes Wash

REACH	BASE "n"	OBSTRUCTION ADJUSTMENT	VEGETATION ADJUSTMENT	COMPOSITE "n"	PERCENT REACH	REACH "n"
ATOB	0.025		0.010	0.035	100%	0.035
BTOC	0.025		0.015	0.040	80%	
	0.025		0.020	0.045	20%	
					100%	0.041
CTOD	0.025		0.010	0.035	80%	
	0.025		0.015	0.040	20%	
					100%	0.036
DTOE	0.025		0.015	0.040	100%	0.040
ETOJ	0.025		0.010	0.035	100%	0.035
JTOK	0.025		0.015	0.040	100%	0.040
KTOL	0.025		0.010	0.035	100%	0.035
LTOM	0.025		0.010	0.035	75%	
	0.025	0.005	0.025	0.055	25%	
					100%	0.040
MTON	0.025		0.010	0.035	95%	
	0.025	0.005	0.025	0.055	5%	
					100%	0.036

Stream Name: East Garambullo Wash

REACH	BASE "n"	OBSTRUCTION ADJUSTMENT	VEGETATION ADJUSTMENT	COMPOSITE "n"	PERCENT REACH	REACH "n"
QTOE	0.025		0.015	0.040	100%	0.040

Stream Name: West Garambullo Wash

REACH	BASE "n"	OBSTRUCTION ADJUSTMENT	VEGETATION ADJUSTMENT	COMPOSITE "n"	PERCENT REACH	REACH "n"
PTOE	0.025		0.015	0.040	100%	0.040

Upstream of CAP use .035 for channels due to little tree growth and only small scattered bushes.

Upper watershed of West Wash

Base n = .025 heavier vegitation in area of culvert outlet then light and confined to banks only. composite "n" = .035 downstream and .045 at outlet.

Area immediately downstream of the 4-72" pipe culvert

Area immediately upstream of the 4-72" pipe culvert on West Wash

Base value = .025 use .02 adjustment as ponding area is very high in this area. Velocity is low. composite "n" = .045

Upstream view of the 4-72" pipe culvert

Downstream view of the 4-72" pipe culvert

West Wash at the crossing of jeep trail (looking north)

Well shaped channel with fairly straight and uniform banks. Base value of .025. Vegitation along banks only. Adjustment = .015 composite "n"= .040

West Wash at the crossing of jeep trail (looking south)

Evidence of clayey layer beneath the channel bed of West Wash

West Wash crossing Beardsley Canal

Base n value = .025 channel is straight and uniform. Salt Cedars create minor obstruction (+.005) assume .025 adjustment for Vegetation. composite "n" = .055

Base n value = .025 Channel is straight and uniform. Some vegitation on banks, adjustment = .010. composite "n" = .035

West Wash immediately downstream of Beardsley Canal

Downstream view of the 72" pipe culvert

East Wash channel between the 72" pipe culvert and the cattle pond

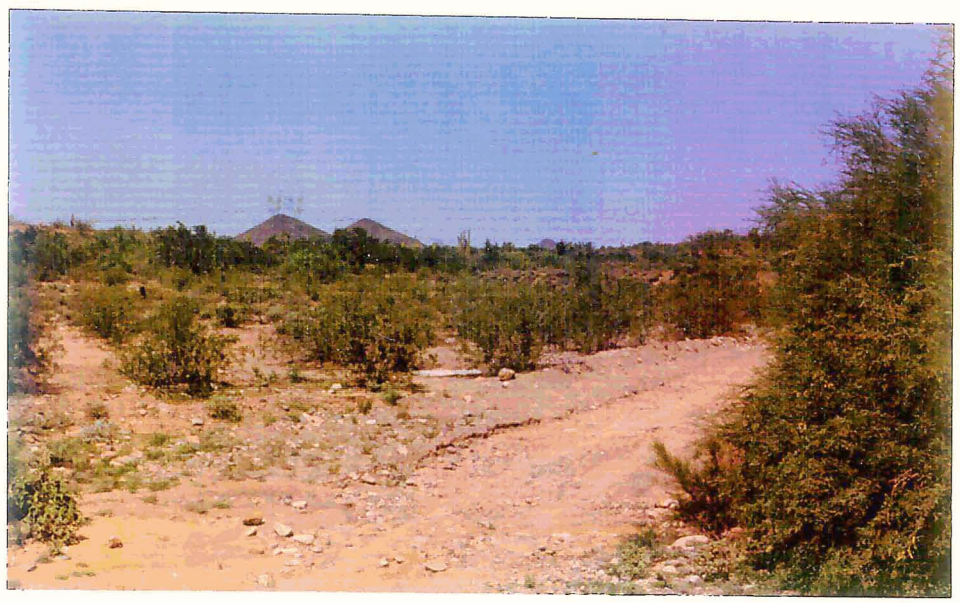
Base value = .025
adjustment for vegitation = .015
composite "n" = .040

Existing cattle pond downstream of the CAP Canal

Watershed downstream of the cattle pond (looking south)

Base value = .025, very light vegetive cover along banks, composite "n" = .035

East watershed boundary at the entrance of the CAP tunnel (looking east)



East Wash immediately upstream of Beardsley Canal

Base value = .025, scattered brush in channel and along banks, composite "n" = .040

East Wash crossing Beardsley Canal

East Wash immediately downstream of Beardsley Canal

Base value = .025 adjustment for vegetation =.025 in immediate vicinity of crossing. Composite "n" = .050

APPENDIX A

Mannings N Adjustment Factors
and Basis for Base N Determination
from Manning's Roughness Coefficients
for Stream Channels and Floodplains
in Maricopa County, Arizona,
USGS, July 1990

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.

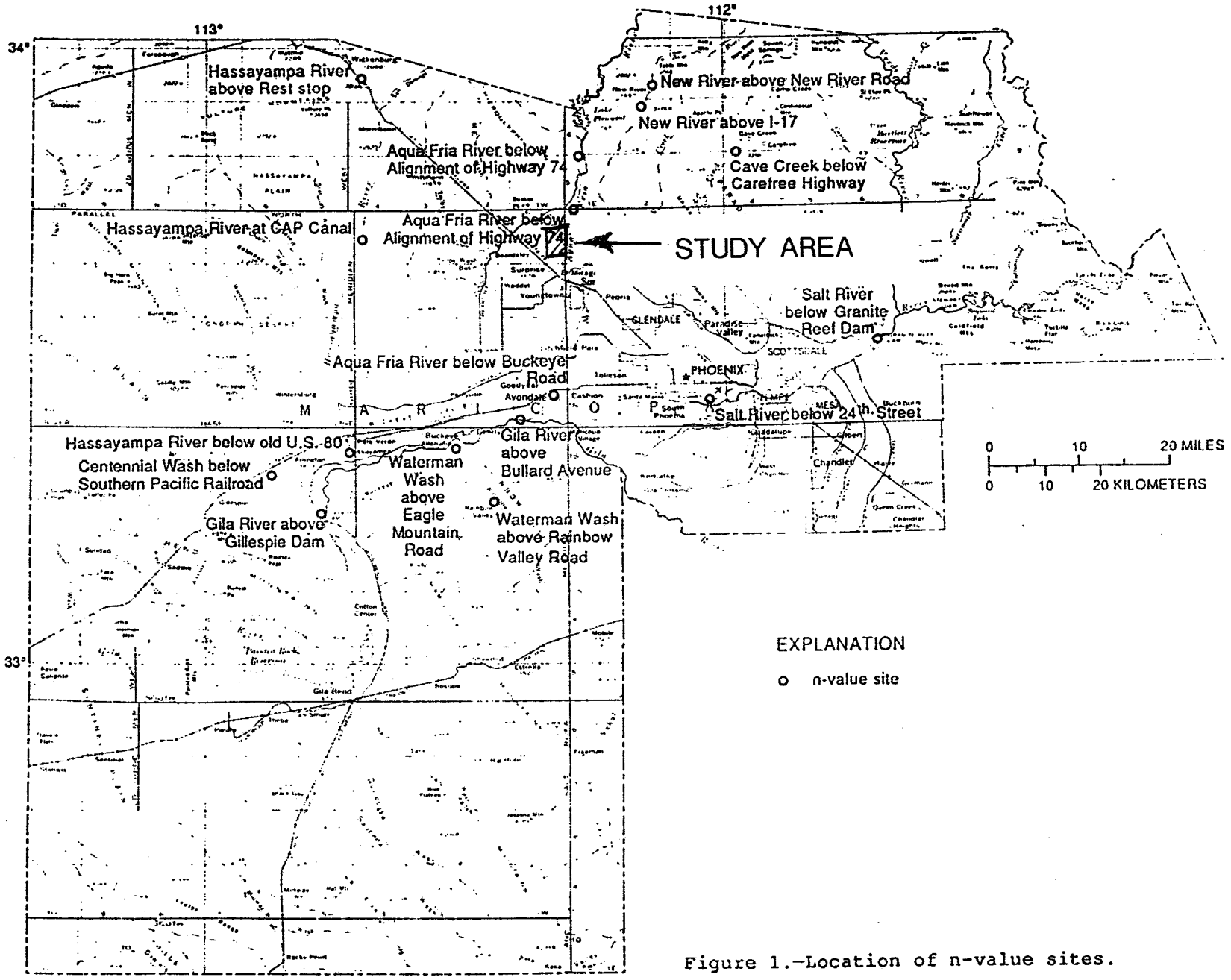


Figure 1.—Location of n-value sites.

AGUA FRIA RIVER BELOW ALIGNMENT OF HIGHWAY 74

Location of cross section: 500 ft downstream from road crossing.

Description of channel: Bed material is sand and gravel; banks are generally clean and uniform. Right edge of main channel is uneven, and small overflow channel adjacent to right edge of main channel contains brush and trees and a local rough area. Overflow area is undulant and has scattered brush and trees. Small channel along right bank is a tributary that enters the river a short distance upstream.

Subdivision of cross section and evaluation of *n*: Cross section was subdivided on the basis of shape at the right edge of main channel. Composite *n* value was computed for main channel because of the distinct difference in roughness between the clear part of the section and the vegetated part along the right edge. The small channel along the right bank was considered part of the overflow area (not subdivided) because it is a local condition.

AGUA FRIA RIVER BELOW ALIGNMENT OF U.S. HIGHWAY 74--Continued

Table 15.--Components and weighted and composite values of Manning's roughness coefficient

[Dashes indicate a roughness coefficient of zero]

10-Year Flood

Subarea A

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = .003 n2 = ---- n3 = ----	
.80	= n = .028 =	.022
	nb = .025 n1 = .005 n2 = ---- n3 = .040	
.20	= n = .070 =	.014
1.00		0.036

Subarea B

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = .005 n2 = ---- n3 = .025 n = .055	

100-Year Flood

Subarea A

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = --- n2 = ---- n3 = ----	
.80	= n = .025 =	.020
	nb = .025 n1 = ---- n2 = ---- n3 = .035	
.20	= n = .060 =	.012
1.00		0.032

Subarea B

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = .005 n2 = ---- n3 = .015 n = .045	

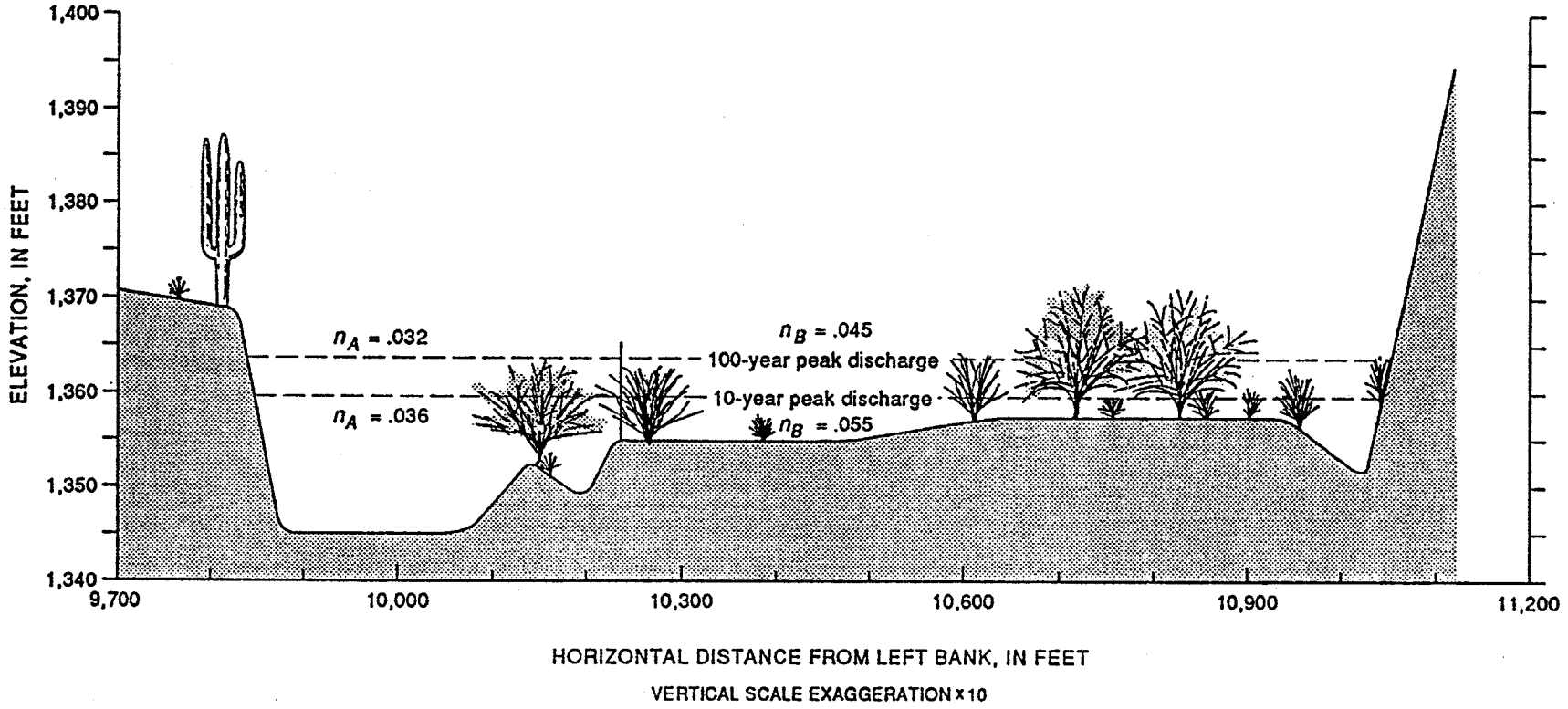


Figure 15.—Aqua Fria below Alignment of Hwy 74.

AGUA FRIA RIVER BELOW JOMAX ROAD

Location of cross section: 800 ft downstream from road crossing.

Description of channel: Bed material is coarse sand and gravel, banks are smooth and uniform and has scattered growth of weeds. Overflow areas have uneven surface and scattered low-growing brush and weeds.

Subdivision of cross section and evaluation of *n*: Cross section was subdivided on the basis of shape at either edge of main channel. Small deep channels represent a local condition that may not be present at adjacent sections.

AUGA FRIA RIVER BELOW JOMAX ROAD--Continued

Table 16.--Components and weighted and composite values of Manning's roughness coefficient

[Dashes indicate a roughness coefficient of zero]

10-Year Flood

Subarea A

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = ---- n2 = .033 n3 = ---- n = .028	

Subarea B

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = .003 n2 = ---- n3 = .015 n = .043	

Subarea C

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = .003 n2 = ---- n3 = .005 n = .033	

100-Year Flood

Subarea A

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = .003 n2 = ---- n3 = .005 n = .033	

Subarea B

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = ---- n2 = ---- n3 = ---- n = .025	

Subarea C

Part of subarea from left end	Components	Weighted and composite values
	nb = .025 n1 = .003 n2 = ---- n3 = .005 n = .033	

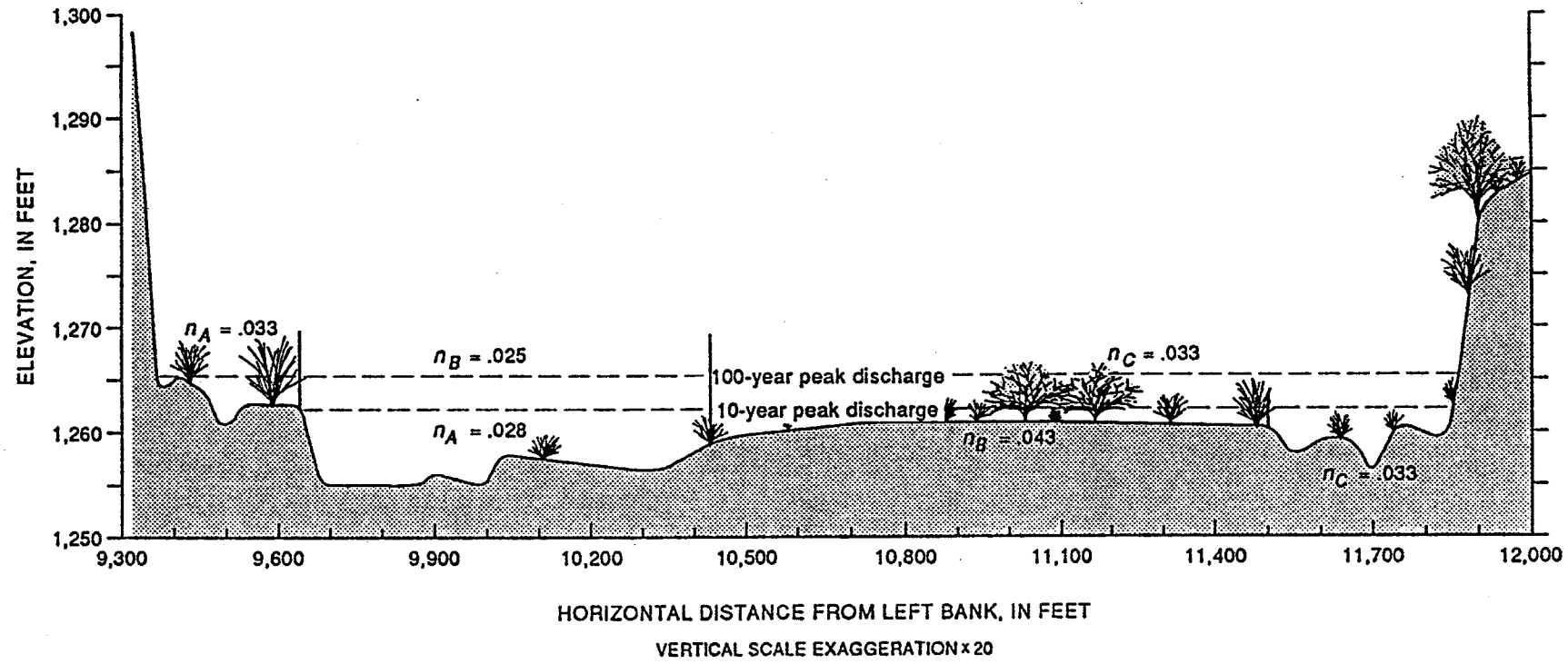


Figure 16.—Aqua Fria River below Jomax Road.

APPENDIX B

Comparison Table from USGS Open File Report
(February 1973)

Table 3.--Values of "n" for constructed channels and flood plains
(Modified from Chow, 1959)

Type of channel and description	"n" value		
	Minimum	Normal	Maximum
A. LINED OR BUILT-UP CHANNELS			
a. Concrete			
1. Finished	0.011	0.013	0.016
2. Unfinished	.014	.017	.020
b. Gravel bottom with sides of			
1. Formed concrete	.017	.020	.025
2. Random stone in mortar	.020	.023	.026
3. Dry rubble or riprap	.023	.033	.036
c. Vegetal lining	.030	----------	.500
B. EXCAVATED OR DREDGED CHANNELS			
a. Earth, straight and uniform			
1. Clean, after weathering	.018	.022	.025
2. Gravel, uniform section, clean	.022	.025	.030
3. With short grass, few weeds	.022	.027	.033
b. Earth, winding and sluggish			
1. No vegetation	.023	.025	.030
2. Grass, some weeds	.025	.030	.033
3. Dense weeds or aquatic plants in deep channels	.030	.035	.040
4. Earth bottom and rubble sides	.028	.030	.035
5. Stony bottom and weedy banks	.025	.035	.040
6. Cobble bottom and clean sides	.030	.040	.050
c. Dragline-excavated or dredged			
1. No vegetation	.025	.028	.033
2. Light brush on banks	.035	.050	.060
d. Rock cuts			
1. Smooth and uniform	.025	.035	.040
2. Jagged and irregular	.035	.040	.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as depth of flow	.050	.080	.120
2. Clean bottom, brush on sides	.040	.050	.080
3. Dense brush, high stage	.080	.100	.140
C. FLOOD PLAINS			
a. Pasture, on smooth ground, no brush[1]			
1. Short grass	.025	.030	.035
2. High grass	.030	.035	.050
b. Cultivated areas[1]			
1. No crop	.020	.030	.040
2. Mature row crops, such as small vegetables	.025	.030	.045
3. Mature field crops, depth of flow at least twice the height of vegetation	.030	.040	.050
4. Dense field crops in full leaf, such as corn or cotton, depth of flow less than height of vegetation	.050	----------	.100
c. Brush[1]			
1. Scattered brush, heavy weeds	.035	.050	.070
2. Light brush and trees, in winter	.035	.050	.060
3. Light brush and trees, in summer	.040	.060	.080
4. Medium to dense brush, in winter	.045	.070	.110
5. Medium to dense brush, in summer	.070	.100	.160
d. Trees			
1. Cleared land with tree stumps, no sprouts	.030	.040	.050
2. Same as 1 with heavy growth of sprouts	.050	.060	.080
3. Heavy stand of timber, few down trees, little undergrowth, stage below branches	.060	.080	.120
4. Same as 3, but with stage reaching branches	.080	.100	.160
5. Dense willow, mesquite, and saltcedar	.100	.150	.200

[1] Shallow depths accompanied by an irregular ground surface in pastureland or brushland and by deep furrows perpendicular to the flow in cultivated fields can increase the "n" values by as much as 0.02.

APPENDIX C

Comparison Table and Photos from V.T. Chow
Open Channel Hydraulics, 1959

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

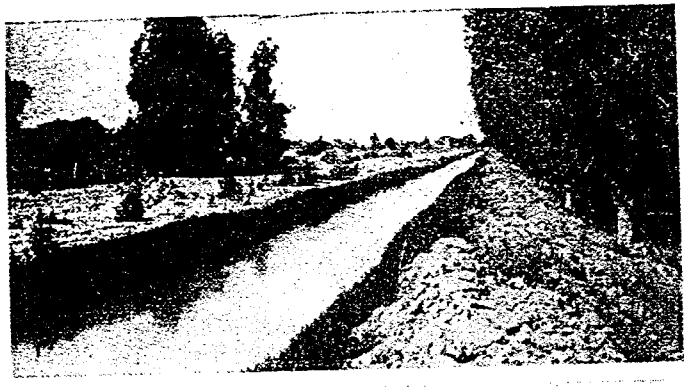
Type of channel and description	Minimum	Normal	Maximum
C. EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	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
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

FROM V.T. CHOW , OPEN CHANNEL HYDRAULICS, 1959

(13)



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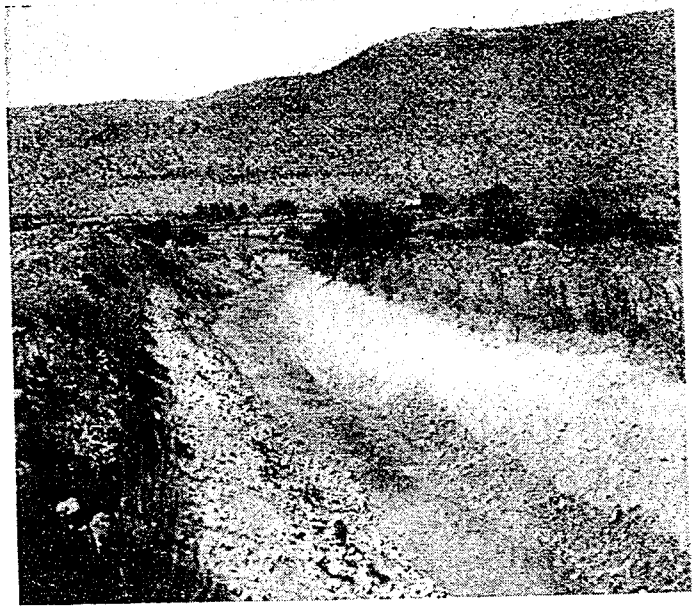


(15)

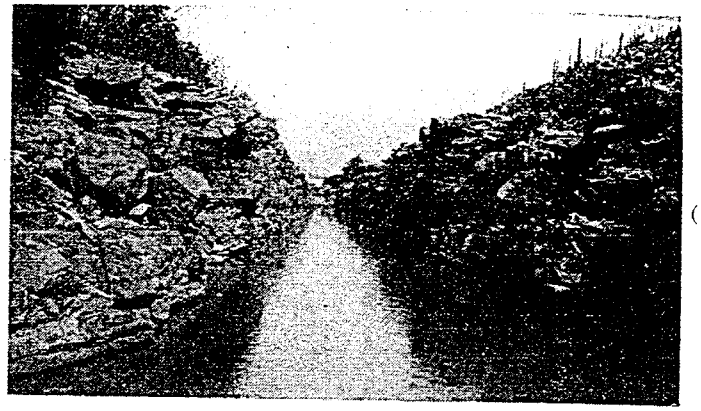
FIG. 5-5 (13–15)

13. $n = 0.029$. Earth canal excavated in alluvial silt soil, with deposits of sand on bottom and growth of grass.

14. $n = 0.030$. Canal with large-cobblestone bed.

15. $n = 0.035$. Natural channel, somewhat irregular side slopes; fairly even, clean and regular bottom; in light gray silty clay to light tan silt loam; very little variation in cross section.

(16)



(17)

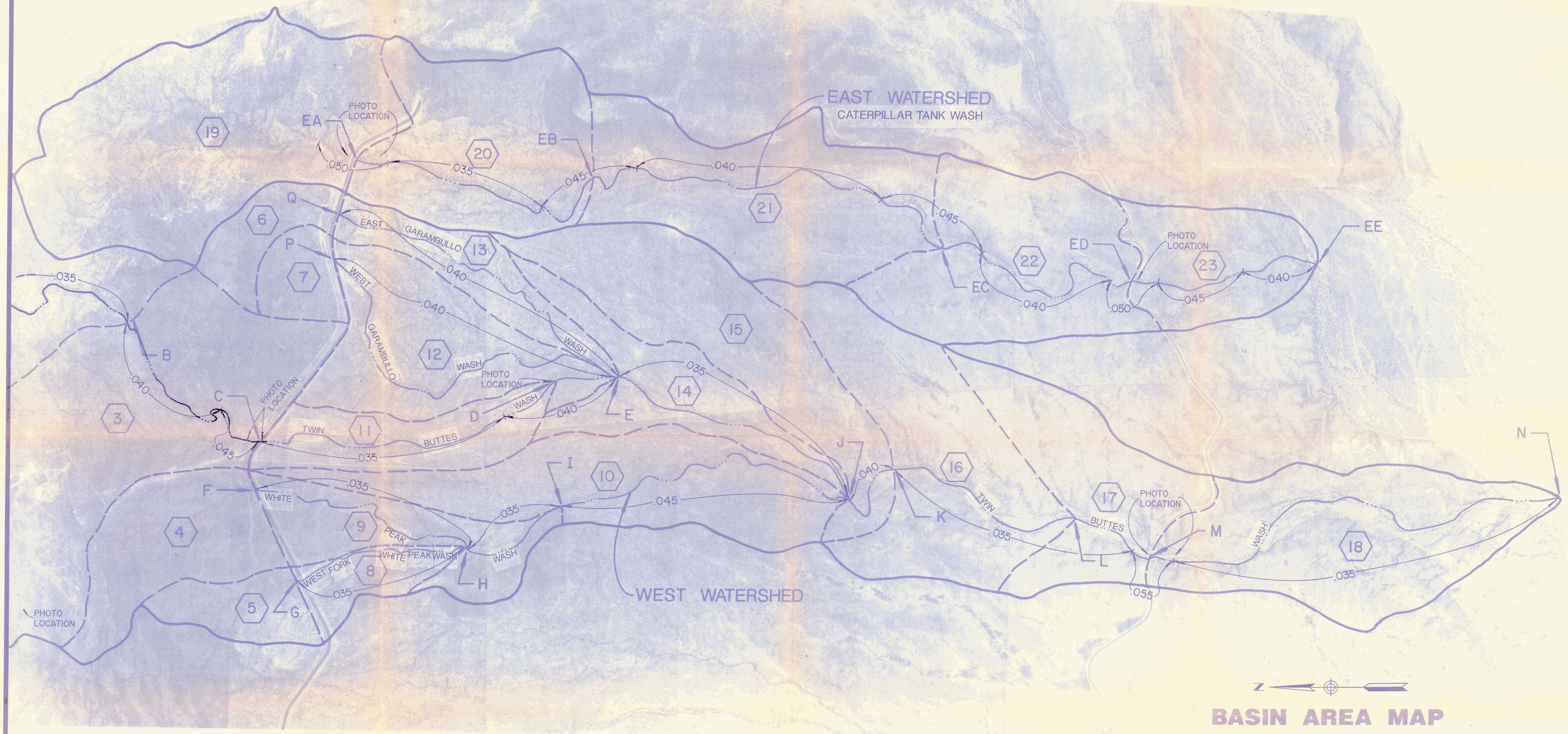
(18)

FIG. 5-5 (16–18)

16. $n = 0.040$. Rock channel excavated by explosives.

17. $n = 0.040$. Ditch in clay and sandy loam; irregular side slopes, bottom, and cross section; grass on slopes.

18. $n = 0.045$. Dredge channel, irregular side slopes and bottom, in black, waxy clay at top to yellow clay at bottom, sides covered with small saplings and brush, slight and gradual variations in cross section.



BASIN AREA MAP

ACK ENGINEERS, INC.

PLATE 1