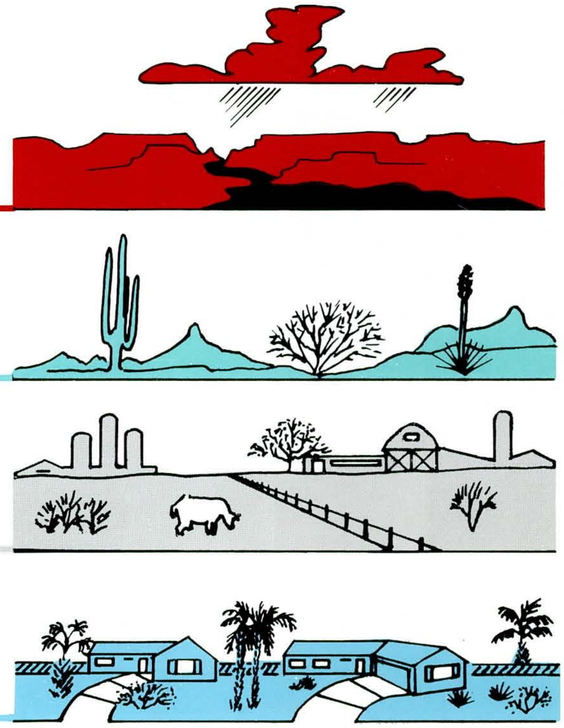

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

HYDROLOGIC ANALYSIS FOR SOUTH MOUNTAIN
DISTRIBUTARY FLOW AREA

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Prepared for:
Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, Az. 85009

Prepared by:
Julie J. Riemenschneider
Professional Associate
Flood Control District of Maricopa County
Engineering Division, Data Collection Branch
December 1996

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Abbreviations

ac.	Acres
cfs	Cubic Feet per Second
DDM	Drainage Design Manual
DDMS	Drainage Design Menu System
DTHETA (DRY)	Soil Moisture Deficit at the start of rain
FCDMC	Flood Control District Maricopa County
ft.	Feet
ft^2	Square Feet
hr.	Hour
IA	Initial Abstraction
in.	Inches
Kb	Basin Roughness
mi.	Miles
mi^2	Square Miles
PSIF	Wetting from Capillary Suction
R	Storage Coefficient
Tc	Time of Concentration
XKSAT	Hydraulic Conductivity at Natural Saturation

INTRODUCTION

South Mountain distributary flow area (SMDFA) is located in the western portion of South Mountain Park (Figure 1). SMDFA is bounded on the north and south by the South Mountains, and on the west by the Gila River Indian Reservation. The SMDFA watershed drains from the east to the west and runs through the Gila River Indian Reservation where it empties into the Gila River.

SMDFA is an ephemeral system with a watershed that drains an approximate 1.98 square mile area. There is one primary channel of flow, with the exception of a merging tributary from the south in the upper watershed. This main channel is deeply incised in the upper watershed becoming less incised as it approaches the apex. After the apex the channel disperses into several shallow channels.

The purpose of this report is to compile a hydrologic analysis of the SMDFA watershed. A hydrologic model will be generated for the watershed and compared to actual historic data for accuracy. In addition, 100-year discharge values will be calculated for the channel at the apex.

Watershed Description

Geology:

The western portion of South Mountain is composed of Precambrian metamorphic and granitic rocks, including the Estrella Gneiss and Komatke Granite. Estrella Gneiss comprises the majority of rock with the Komatke Granite intruding into it. The area has many north-northwest trending mid-Tertiary dikes. These intrusive dikes are composed of granite and diorite (French, 1992).

Topography:

The elevation in the watershed ranges from approximately 2500 feet in the mountains to 1420 feet at the hydrologic apex. There are three main types of topography in the watershed; they are mountains, hillslopes and valley floor. The mountains are steep and rugged with little soil and vegetation. Although, the hillslopes are less steep and have some vegetation on them the soil is shallow. The valley floor, along the channel above the apex is predominately alluvial fill and slopes gently from the east to the west along the distributary flow. On the valley floor soil is deeper and vegetation is more prevalent.

Vegetation:

Vegetation in the watershed is fairly homogeneous with less vegetation on the mountains and hillslopes than in the valley floor. The mountains are sparsely vegetated with saguaro cacti and creosote bushes. Hillslopes have a mixture of saguaro and cholla cacti, mesquite trees and creosote bushes. Valley floor cover is composed of saguaro and cholla cacti, creosote bushes, mesquite and palo verde trees. Trees and bushes are greater in number around the channels. Grasses are seasonal and very limited in the valley floor.

Soils:

Soils in the study area have been divided into two groups using the Soil Conservation Service (S.C.S.) Soil Survey for Maricopa County, Arizona (Central Part) and through field observation (Figure 2).

The mountain and steeper hillslope areas have been designated as Rock outcrop - Cherioni complex (RS). Rock outcrop can account for 65% of this unit with Cherioni being 20% and Gachado 15%. Cherioni is a gravelly loamy soil and Gachado is a sandy clay loam (S.C.S., 1977). In the watershed the connected rock outcrop was estimated at 65% for all RS soil units.

The valley floor areas have been designated Cherioni-Rock outcrop complex (CO). The rock outcrop can account for 20% of the unit with Cherioni being 50% and 30% being composed of Gachado, Pinal, Gunsight and Rillito loams (S.C.S., 1977). Through field observation 0% of this unit was interpreted to be connected rock outcrop in the watershed.

Land Use:

All of the study area is located in South Mountain Park. The park has been designated for recreational uses only, which includes hiking, biking and horse riding. Wildlife grazes on the land.

Watershed:

The watershed encompasses an area approximately 1.98 square miles. The watershed has been divided into three subbasins; subbasin 1, subbasin 2 and subbasin 3 (Figure 1 and 2). Subbasin 1 has an area of 0.6745 square miles, subbasin 2 an area of 0.76282 square miles and subbasin 3 an area of 0.5376 square miles. Subbasin 1 is located in the eastern portion of the watershed with subbasin 3, containing the hydrologic apex, located in the west.

Watershed Modeling

Methodology:

The methodologies used for this report come from the Drainage Design Manual (DDM) for Maricopa County, Arizona Volume I Hydrology, January 1995, the Drainage Design Menu System (DDMS) January 1995 taken from the DDM, and the Corps of Engineers' HEC-1 computer model version 4, September 1990. The following methods were used in the model;

Runoff conversion: Clark Unit Hydrograph
Losses: Green and Ampt
Routing: Normal Depth and Muskingum-Cunge.

Rainfall:

Rainfall depths were estimated from figures in chapter 2 of the DDM, except for 1 Hour and 2 Hour rainfall depths which were hand calculated (Appendix A).

In this study three design storms and one historic storm were used for analysis. The design storms were the SCS Type II 24-Hour storm, the 6-Hour Queen Creek storm and the 2-Hour FCD retention storm. The historic storm was recorded on November 1, 1995 at South Mountain gages 6560 and 35. The design storm precipitation values were aerially reduced in the DDMS by the following methods: 1) the 24-Hour storm was reduced by the National Weather Service HYDRO-40 method, 2) the 6-Hour storm was reduced by the Queen Creek Curve, 3) the 2-Hour storm was reduced by using Osborn's curve from the Walnut Gulch study.

Physical Parameters:

Soil: Using a planimeter the area of soil was calculated for each subbasin.

Lengths/Slopes: The lengths and slopes of the three subbasins were taken from Hydrologic Analysis for South Mountain Distributary Flow area, 1990 report written by Steve Waters (Appendix B).

Soil Loss Calculations: A combination of the S.C.S. soil survey and field observations were used to estimate the amount of rock outcrop for the RS and CO soil units. This percentage was used for RTIMP. The XKSAT (hydraulic conductivity at natural saturation) value was taken from Appendix B in the DDM. PSIF (wetting from capillary suction) and DTHETA (DRY)(soil moisture deficit at the start of rainfall) were estimated from the graphed Figure 4.3 in the DDM (Appendix B). These values were then used to calculated XKSAT, PSIF, DTHETA (DRY) and RTIMP for each subbasin. Initial abstraction (IA) was calculated for each basin using values from Table 4.1 in the DDM (Appendix B).

Basin roughness: Basin roughness (Kb) was calculated using the following formula: Kb = m log A + b, where A is drainage area and m and b equation parameters were taken from Table 3.1 in the DDM.

Routing:

Normal Depth and Muskingum-Cunge routing were used in all storms. Lengths and slopes were taken from the 1990 Hydrologic report for South Mountain. In the 1990 report the cross-sections were estimated with a hand level and tape measure. Manning's "n" values are from Chow and were also taken from the 1990 report. Transmission losses were estimated at 2 in/hr for the lower reach only.

Hydrographs:

The Clark Unit Hydrograph Method was used for runoff conversions. Times of Concentration (Tc) and Storage Coefficients (R) were calculated by DDMS for the design storms (Appendix C) and hand calculated for the historic storm (Appendix D).

Results:

Design storm discharges ranged from 301 cfs for the 2-year, 6-hour storm to 4201 cfs for the 100-year, 2-hour storm using Normal Depth routing and from 303 cfs for the 2-year, 6-hour storm to 4286 cfs for the 100-year, 2-hour storm using Muskingum-Cunge routing (Appendix C). Discharge values were higher using the Normal Depth routing method for the 6 and 24-Hour storms but lower for the 2-Hour storm. The historic storm produced a discharge close to the 2-year, 24-hour storm using both routing methods (Appendix D). Comparing the 100-year design storms to the 100-Year Flood Frequency Analysis for Maricopa County indicated that the 6 and 24-Hour storms discharge fell near the average for watersheds of this size (Appendix E). The 2-Hour design storm discharge was higher than average but below the maximum discharge, and slightly higher than the discharge per square mile value computed for the 1.75 sq. mi. "Salt River Tributary at South Mountain" watershed which shares the eastern watershed boundary with SMDFA. The 2-Hour design storms are probably the most reliable for SMDFA. The combination of high intensity rainfall and poorly absorbant soil create a high amount of runoff, which was indicated by the historic storm.

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French, R. H., and CH2M HILL, 1992, Alluvial Fan Data Collection and Monitoring Study for the Flood Control District of Maricopa County.

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____, 1952, Topographic Quadrangle Map for Laveen, Az (1:24,000).

____, 1952, Topographic Quadrangle Map for Lone Butte, Az (1:24,000).

Figures

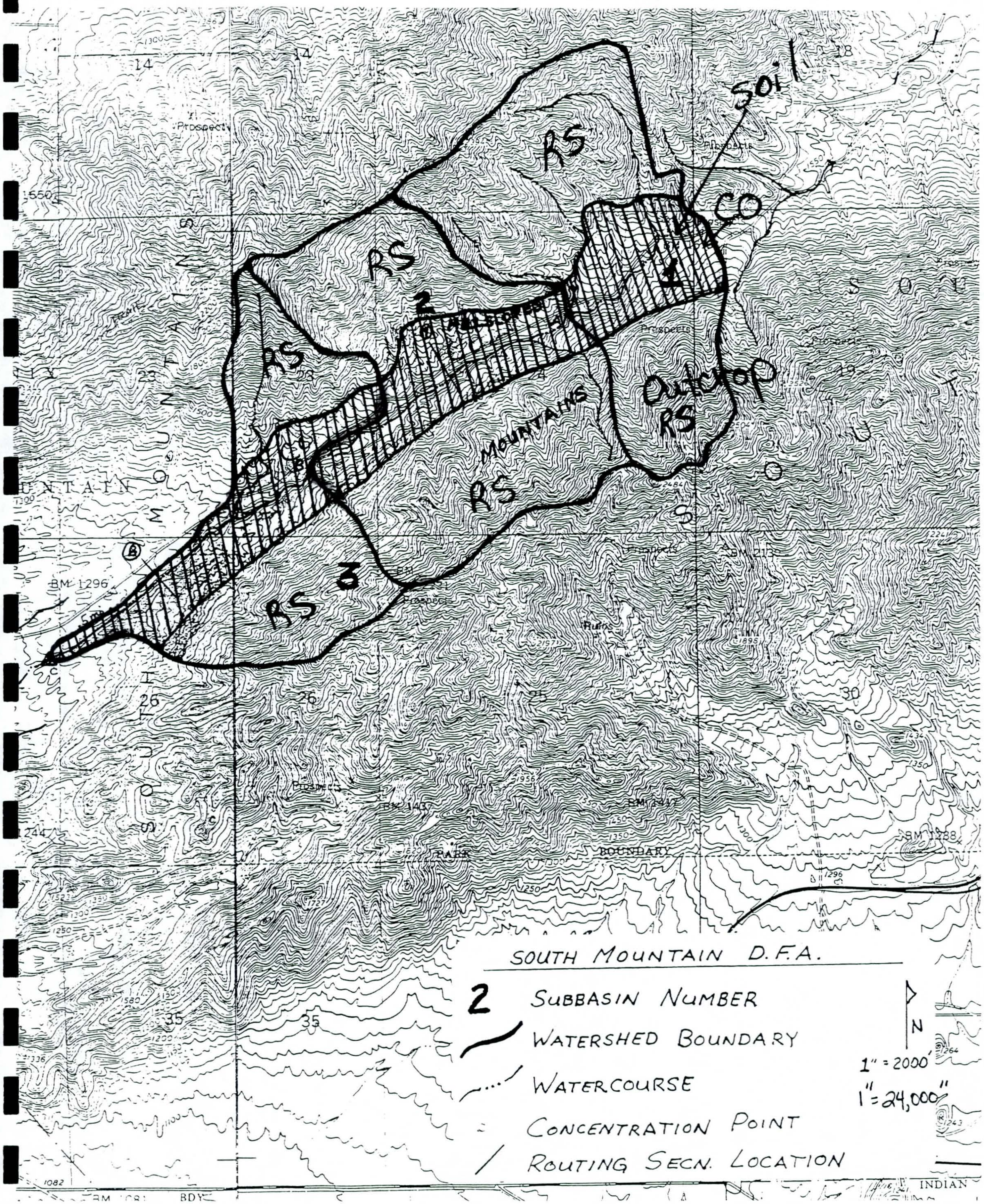


Figure 2: The watershed has three subbasins with two different soil units.

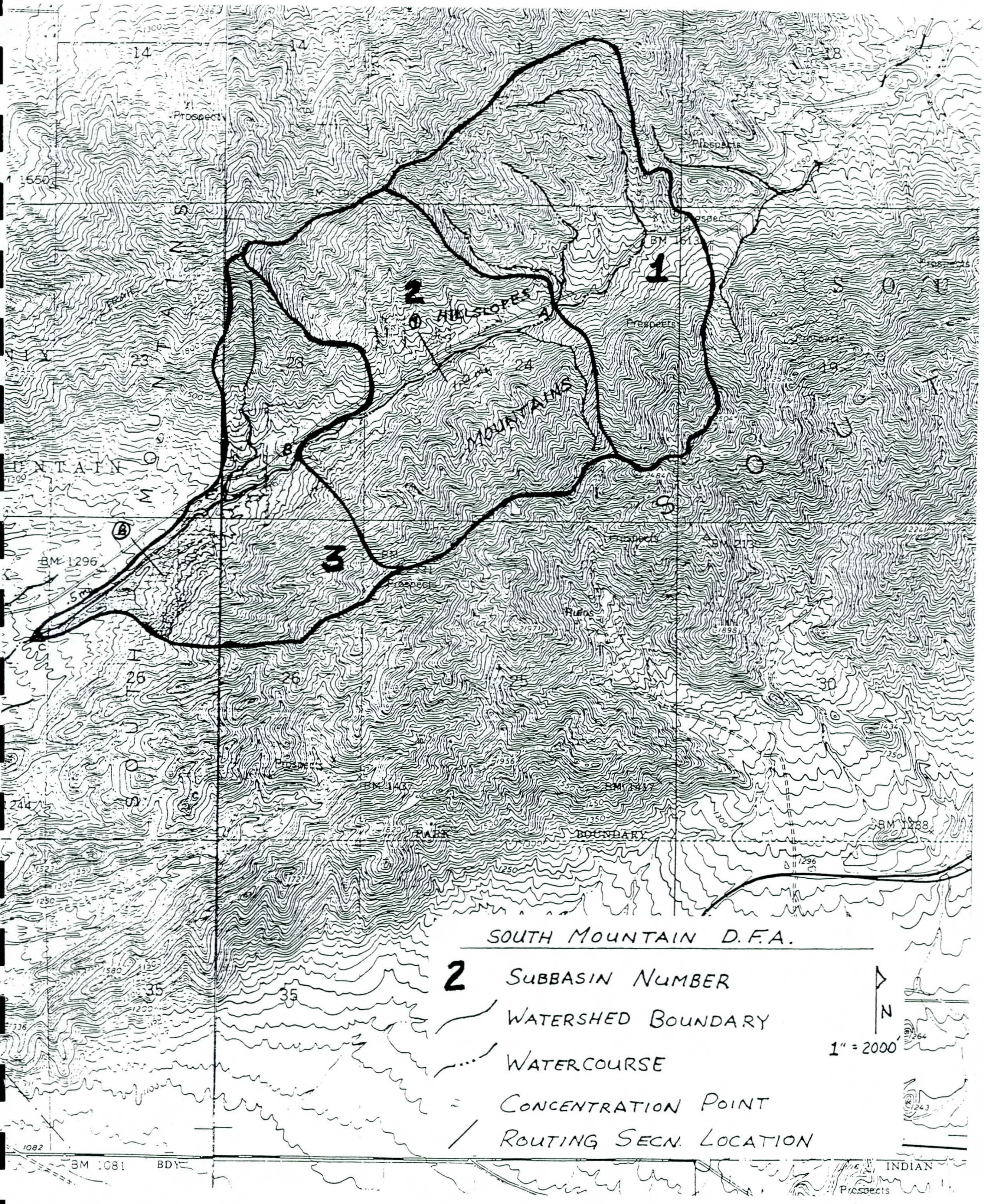


Figure 1: South Mountain distributary flow is located in the western portion of South Mountain Park.

Appendix A

Rainfall

Return period (Years)	2 hour	6 hour	24 hour
2	1.03	1.25	1.60
5	1.45	1.80	2.20
10	1.80	2.10	2.60
25	2.20	2.70	3.20
50	2.55	3.00	3.60
100	2.89	3.40	4.10

1 Hour Calculations

P^1_2 = -0.011 + 0.942 [(2yr 6hr)^2 / 2yr 24hr]
P^1_2 = -0.011 + 0.942 [(1.25)^2 / 1.60] = **0.91 in.**

P^1_{100} = 0.494 + 0.755 [(100yr 6hr)^2 / 100yr 24hr]
p^1_{100} = 0.494 + 0.755 [(3.40)^2 / 4.10] = **2.62 in.**

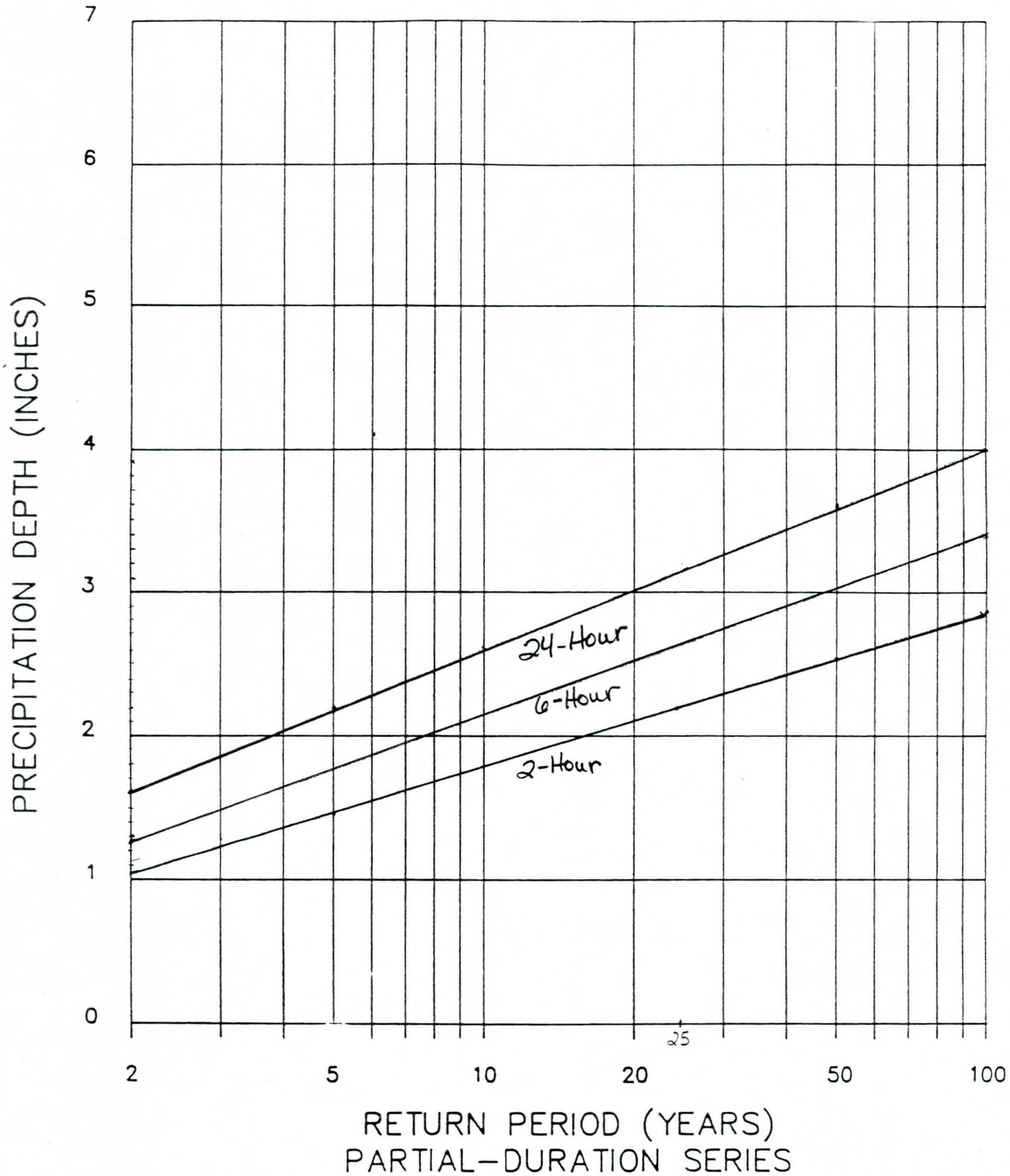
2 Hour Calculations

P^2_2 = 0.341 (2yr 6hr) + 0.659 (2yr 1hr]
P^2_2 = 0.341 (1.25) + 0.659 (0.91) = **1.03 in.**

P^2_{100} = 0.341 (100yr 6hr)+ 0.659 (100yr 1hr]
P^2_{100} = 0.341 (3.40) + 0.659 (2.62) = **2.89 in.**

Distributions - Aerial Reduction Method

2 Hour = FCD Detention Storm (Walnut Gulch)
6 Hour = FCD Queen Creek (Queen Creek)
24 Hour = SCS Type II (National Weather Service HYDRO-40)



Precipitation Depth versus Return Period for Partial-Duration Series

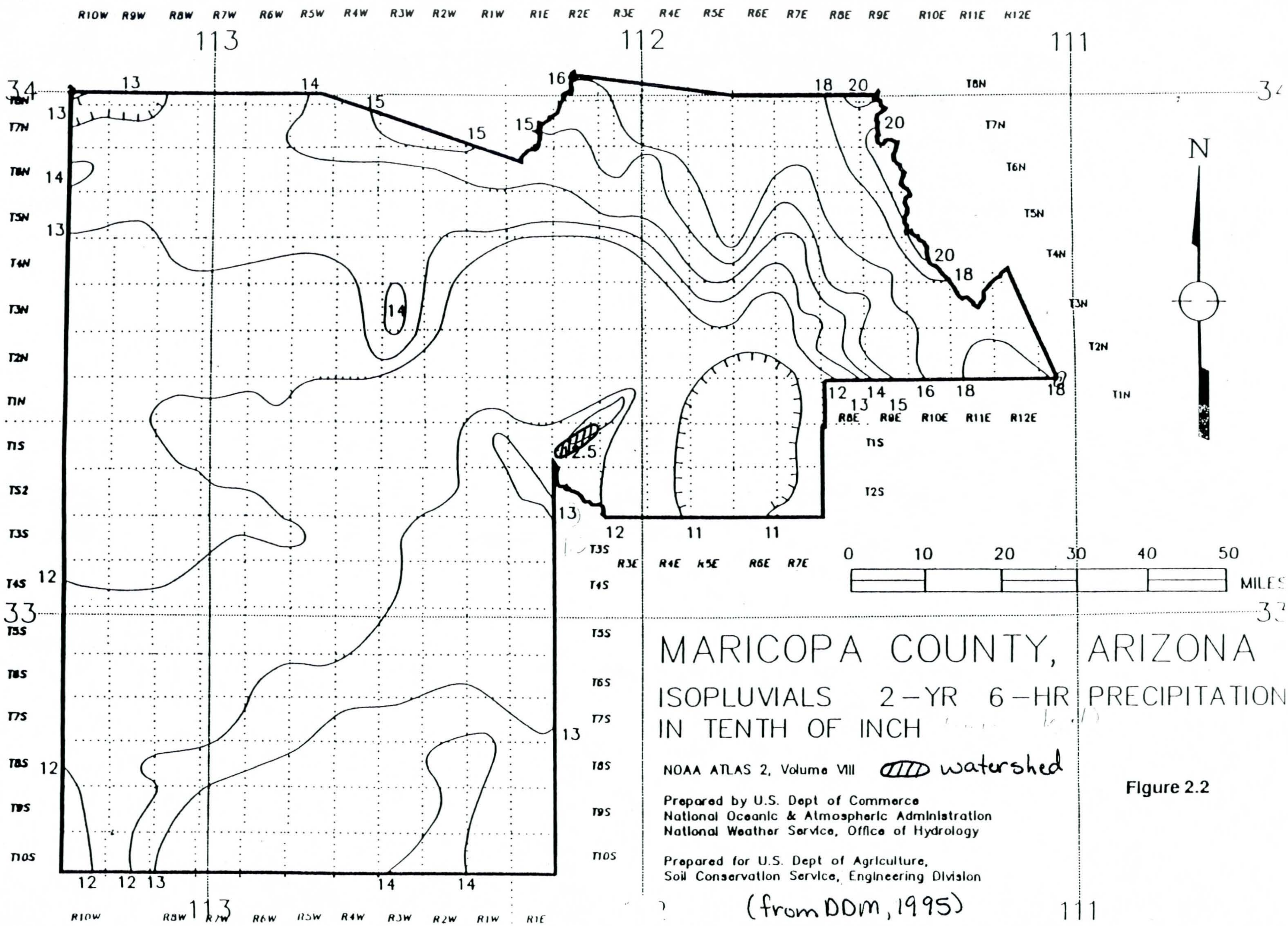
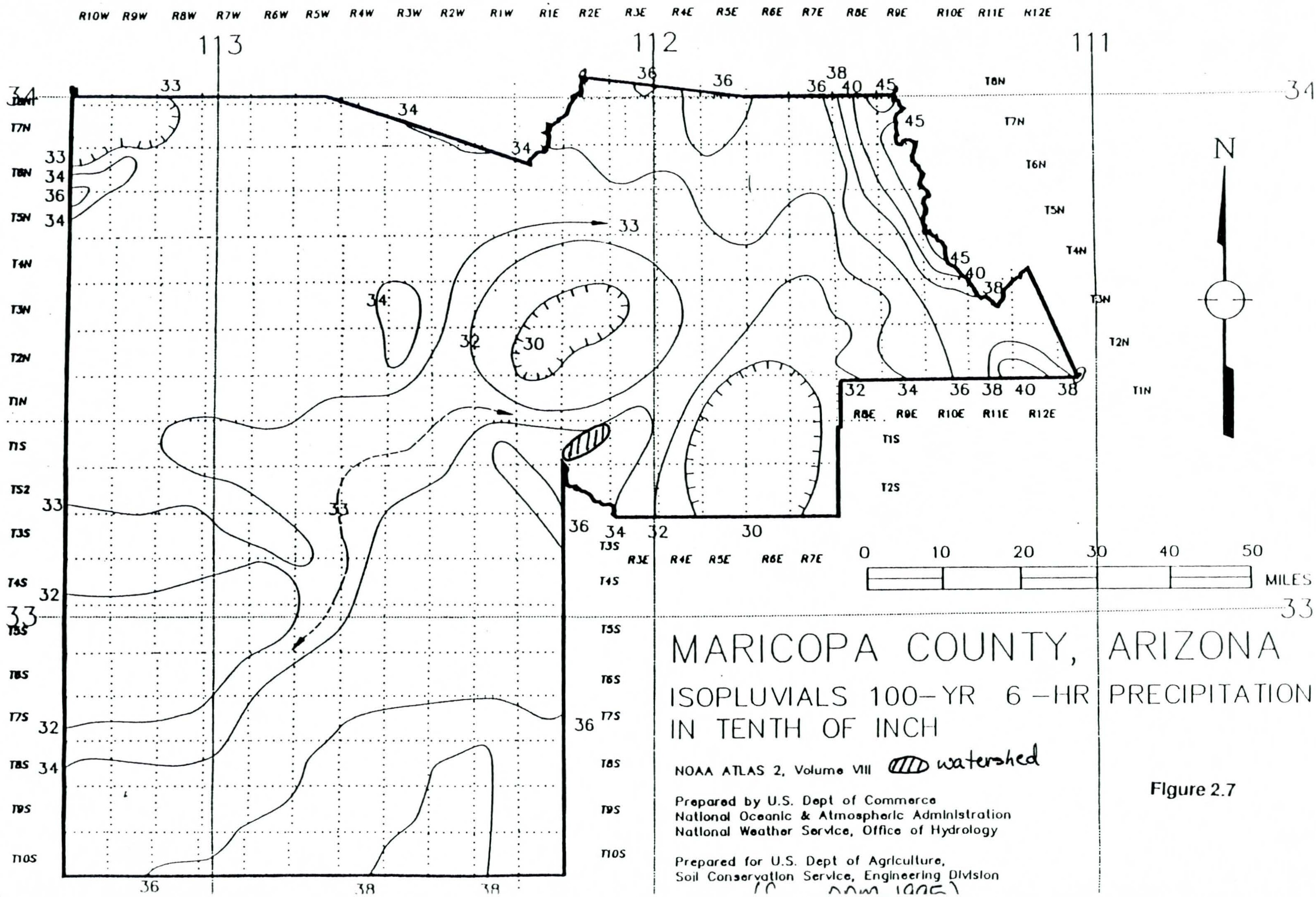


Figure 2.2

(from DDM, 1995)



R10W R9W R8W R7W R6W R5W R4W R3W R2W R1W R1E R2E R3E R4E R5E R6E R7E R8E R9E R10E R11E R12E
113
112
111
34
33
T8N T7N T6N T5N T4N T3N T2N T1N
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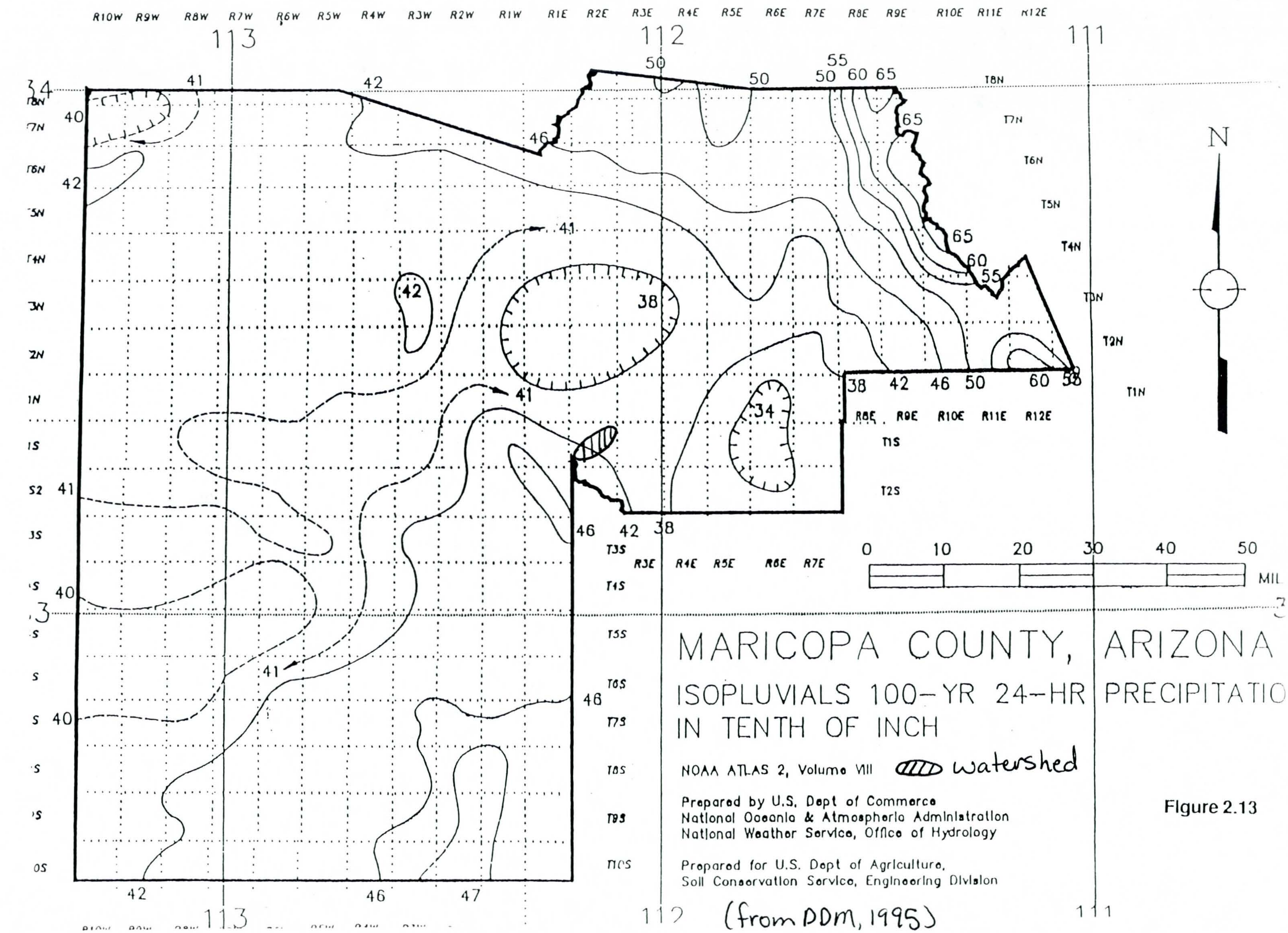
N
0 10 20 30 40 50
MILES
MARICOPA COUNTY, ARIZONA
ISOPLUVIALS 100-YR 6-HR PRECIPITATION
IN TENTH OF INCH
NOAA ATLAS 2, Volume VIII
watershed
Prepared by U.S. Dept of Commerce
National Oceanic & Atmospheric Administration
National Weather Service, Office of Hydrology
Prepared for U.S. Dept of Agriculture,
Soil Conservation Service, Engineering Division

Figure 2.7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111
T8N T7N T6N T5N T4N T3N T2N T1N
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IN TENTH OF INCH
NOAA ATLAS 2, Volume VIII
watershed
Prepared by U.S. Dept of Commerce
National Oceanic & Atmospheric Administration
National Weather Service, Office of Hydrology
Prepared for U.S. Dept of Agriculture,
Soil Conservation Service, Engineering Division
(from DDM, 1995)

Figure 2.13

Appendix B

Soils per Subbasins

The soils are part of the SCS Soil Survey for Maricopa County - Central Part and where measured off a topography map with a scale of 1:24,000 using a planimeter.

Subbasin 1

RS = 14523528.7 ft^2
CO = 4278008.5 ft^2
(conversions)
RS = 14523528.7 ft^2 (1 mi^2 / 27,878,400. ft^2) = 0.5210 mi^2
CO = 4278008.5 ft^2 (1 mi^2 / 27,878,400.) = 0.1535 mi^2

RS = 0.5210 mi^2 = 77.2%
Co = 0.1535 mi^2 = 22.8%
Total = 0.6745 mi^2

Subbasin 2

RS = 16021865. ft^2
CO = 5394010.6 ft^2
(conversions)
RS = 16021865. ft^2 (1 mi^2 / 27,878,400. ft^2) = 0.5747 mi^2
Co = 5394010.6 ft^2 (1 mi^2 / 27,878,400. ft^2) = 0.1935 mi^2

RS = 0.5747 mi2 = 74.8%
CO = 0.1935 mi2 = 25.2%
Total = 0.7682 mi2

Subbasin 3

RS = 9780519.2 ft^2
CO = 5208010.2 ft^2
(conversion)
RS = 9780519.2 ft^2 (1 mi^2 / 27,878,400. ft^2) = 0.3508 mi^2
CO = 5208010.2 ft^2 (1 mi^2 / 27,878,400. ft^2) = 0.1868 mi^2

RS = 0.3508 mi^2 = 65.3%
CO = 0.1868 mi^2 = 34.7%
Total = 0.5376 mi^2

The length and slope information were taken from Hydrologic Analysis for South Mountian Distributary Flow Area, 1990 report written by Steve Waters.

Lengths

Subbasin 1 = 3.063in (2000ft/in) (1 / 5280mi/ft) = 1.160 mi
Subbasin 2 = 3.438in (2000ft/in) (1 / 5280mi/ft) = 1.302 mi
Subbasin 3 = 3.875in (2000ft/in) (1 / 5280mi/ft) = 1.468 mi

Slopes

Subbasin 1 = 2200 - 1520 = 680ft / 1.160mi = 586ft/mi Adjusted = 311 ft/mi
Subbasin 2 = 2250 - 1380 = 870ft / 1.302mi = 668ft/mi Adjusted = 315 ft/mi
Subbasin 3 = 2200 - 1250 = 950ft / 1.468mi = 647ft/mi Adjusted = 315 ft/mi

Soil Descriptions
The numbers are taken from the Drainage Design Manuel unless otherwise indicated.

RS =	65% outcrop 20% Cherioni (gravelly loam) 15% Gachado (sandy clay loam)
XKSAT =	.40 in/hr
PSIF =	4.0 in
DTHETA =	.35 in
RTIMP =	65% (assumed from field observations)

CO =	20% outcrop 50% Cherioni (gravelly loam) 30% VG loam (Gachado - clay loam, Pinal - loam, Gunsight - sandy loam and Rillito - sandy loam)
XKSAT =	.29 in/hr
PSIF =	4.5 in
DTHETA =	.35 in
RTIMP =	0% (assumed from field observations)

Soil Loss Calculations for the Subbasins

Subasin 1

XKSAT =	.772(.40) + .228(.29) = 0.37 in/hr
PSIF =	.772(4.0) + .228(4.5) = 4.11 in
DTHETA (DRY) =	.772(.35) + .228(.35) = 0.35 in
RTIMP =	.772(.65) + .228(0)= .5018 or 50.18%

Subbasin 2

XSAT =	.748(.40) + .252(.29) = 0.37 in/hr
PSIF =	.748(4.0) + .252(4.5) = 4.13 in
DTHETA (DRY) =	.748(.35) + .252(.35) = 0.35 in
RTIMP =	.748(.65) = .252(0) = .4862 or 48.62%

Subbasin 3

XKSAT =	.653(.40) + .347(.29) = 0.36 in/hr
PSIF =	.653(4.0) + .347(4.5) = 4.17 in
DTHETA (DRY) =	.653(.35) + .347(.35) = 0.35 in
RTIMP =	.653(.65) + .347(0) = .4244 or 42.44%

Map Unit No.	Soil Name	USDA Soil Texture	% of Map Unit	Control Horizon Depth, inches	Table 4.2 Textural Class	XKS' inc. hour
Cb	Carrizo	Gravelly Sandy Loam	85	0-5	Sandy Loam	0.40
	Maripo	Sandy Loam	3		Sandy Loam	
	Brios	Loamy Sand	3		Loamy Sand	
	Antho	Sandy Loam	3		Sandy Loam	
	Vint	Fine Sandy Loam	3		Loam	
	Aguait	Loam	3		Loam	
CeD	Carrizo	Gravelly Sandy Loam	60	0-5	Sandy Loam	0.19
	Ebon	Very Cobbly Clay Loam	30	2-13	Sandy Clay Loam	
	Tremant	Gravelly Clay Loam	10		Sandy Clay Loam	
CF	Carrizo	Sandy Loam	45	0-5	Sandy Loam	0.50
	Brios	Sandy Loam	35	0-14	Sandy Loam	
	Vint	Loamy Sand	20	0-60	Loamy Sand	
Cg	Casa Grande	Loam	85	1-3	Loam	0.24
	Laveen	Loam	3.75		Loam	
	Harqua	Gravelly Clay Loam	3.75		Sandy Clay Loam	
	Valencia	Sandy Loam	3.75		Sandy Loam	
	Tucson	Loam	3.75		Loam	
Ch	Casa Grande	Loam	85	0-3	Loam	0.24
	Laveen	Loam	3.75		Loam	
	Estrella	Loam	3.75		Loam	
	Harqua	Gravelly Clay Loam	3.75		Sandy Clay Loam	
	Tucson	Loam	3.75		Loam	
Ck	Casa Grande	Loam	75	0-3	Loam	0.30
	Laveen	Loam	8.33		Loam	
	Harqua	Gravelly Sandy Loam	8.33		Sandy Loam	
	Dune Land	Loamy Sand	8.33		Loamy Sand	
Cm	Casa Grande	Loam	40	1-3	Loam	0.26
	Laveen	Loam	40	0-15	Loam	
	Gilman	Loam	6.67		Loam	
	Coolidge	Sandy Loam	6.67		Sandy Loam	
	Estrella	Loam	6.67		Loam	
Cn	Cashion	Clay	80	0-27	Clay	0.01
	Gadsden	Clay	5		Clay	
	Avondale	Clay Loam	5		Clay Loam	
	Wintersburg	Clay Loam	5		Clay Loam	
	Glenbar	Clay Loam	5		Clay Loam	
CO	Cherioni	Very Gravelly Loam	62.5	0-6	Sandy Loam	0.29
	Rock Outcrop		20			
	Gachado	Very Gravelly Clay Loam	9.38		Sandy Clay Loam	
	Pinal	Loam	9.38		Loam	
	Gunsight	Loam	9.38		Loam	
	Rillito	Loam	9.38		Loam	

(from DDM, 1995)

Map Unit No.	Soil Name	USDA Soil Texture	% of Map Unit	Control Horizon Depth, Inches	Table 4.2 Textural Class	XKSAT inc hour
RS	Rock Outcrop	—	65	—		0.40
	Cherioni	Very Gravelly Loam	67	1-6	Sandy Loam	
	Gachado	Very Gravelly Loam	33		Sandy Loam	
Ta	Toltec	Loam	90	0-12	Loam	0.25
	Gilman	Loam	3.33		Loam	
	Laveen	Loam	3.33		Loam	
	Tucson	Loam	3.33		Loam	
TB	Torrifluvents	Sandy Loam	100	0-60	Sandy Loam	0.40
Tc	Torriorthents					
TD	Torripsamments	Loamy Sand	100	0-60	Loamy Sand	1.20
	Torrifluvents					
Te	Tremant	Loam	85	0-12	Loam	0.25
	Rillito	Loam	5		Loam	
	Laveen	Loam	5		Loam	
	Mohall	Loam	5		Loam	
TfA	Tremant	Gravelly Loam	85	0-12	Sandy Loam	0.37
	Tremant	Gravelly Sandy Loam	3		Sandy Loam	
	Laveen	Loam	3		Loam	
	Rillito	Gravelly Loam	3		Sandy Loam	
	Mohall	Loam	3		Loam	
	Harqua	Gravelly Clay Loam	3		Sandy Clay Loam	
TfB	Tremant	Gravelly Loam	85	0-12	Sandy Loam	0.36
	Harqua	Gravelly Clay Loam	3.75		Sandy Clay Loam	
	Rillito	Loam	3.75		Loam	
	Gunsight	Gravelly Loam	3.75		Sandy Loam	
	Laveen	Loam	3.75		Loam	
Tg	Tremant	Clay Loam	85	0-12	Clay Loam	0.04
	Mohall	Clay Loam	3		Clay Loam	
	Vecont	Clay	3		Clay	
	Laveen	Loam	3		Loam	
	Harqua	Gravelly Clay Loam	3		Sandy Clay Loam	
	Rillito	Loam	3		Loam	
Th	Tremant	Clay Loam	85	1-8	Clay Loam	0.04
	Rillito	Loam	3		Loam	
	Mohall	Clay	3		Clay	
	Laveen	Loam	3		Loam	
	Pinamt	Gravelly Clay Loam	3		Sandy Clay Loam	
	Harqua	Gravelly Clay Loam	3		Sandy Clay Loam	

(from DDM, 1995)

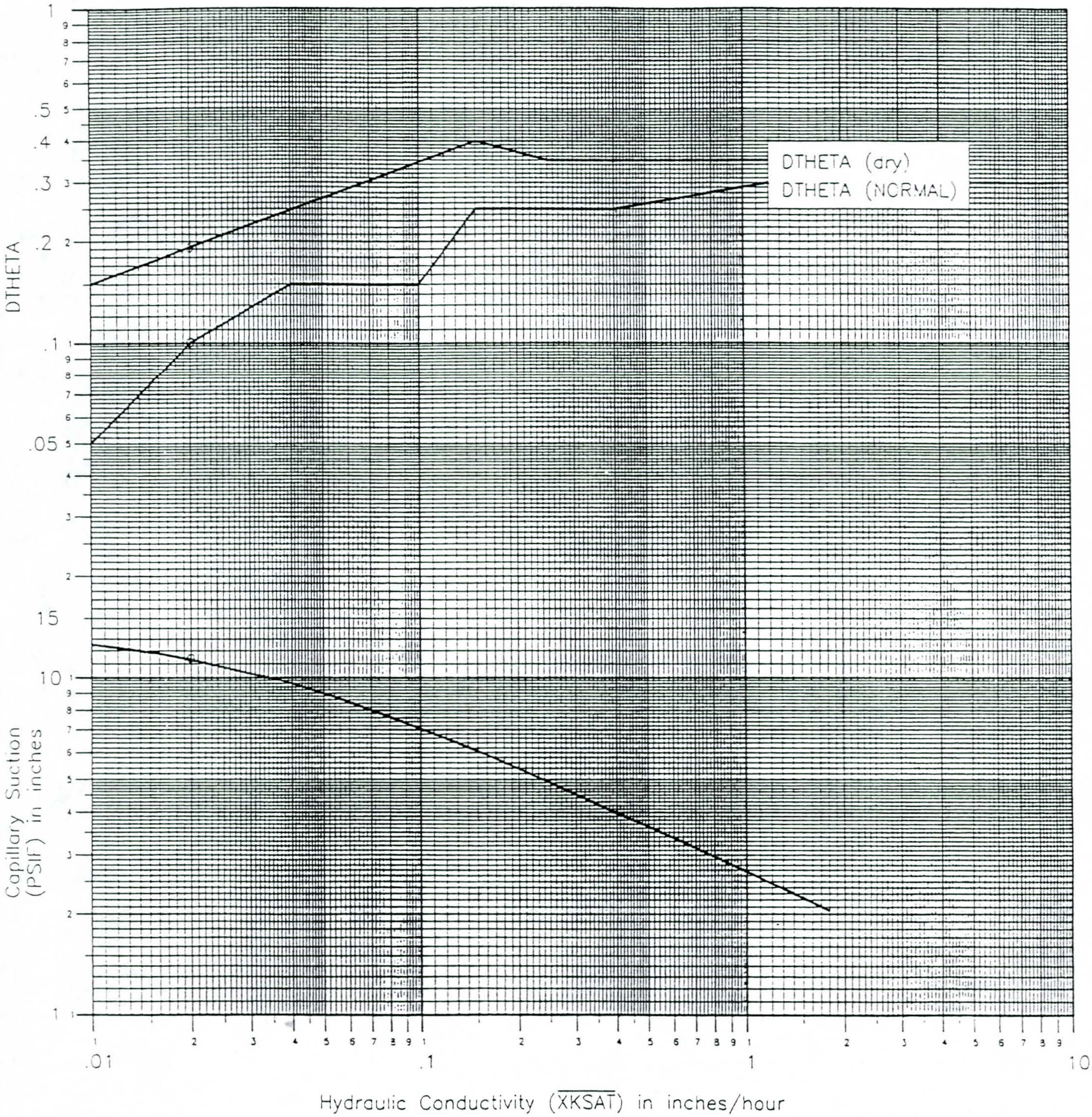


Figure 4.3
Composite Values of PSIF and DTHETA as a function of XKSAT
(To be used for area-weighted averaging of Green and Ampt parameters.)

(from ODM, 1995)

LAND USE
This information was taken from the 1990 report.

Subbasin 1
Hillslopes = 1.05/4.74 = 22.1%
Mountains = 77.9%

Subbasin 2
Hillslopes = 1.16/5.44 = 21.3%
Mountains = 78.7%

Subbasin 3
Hillslopes = 1.59/3.751 = 42.4%
Mountains = 57.6%

Basin Roughness (Kb)
Subbasin drainage areas have been adjusted since 1990 report.

Subbasin 1 Drainage Area: 0.6745 mi2 (640 acres / 1 mi2) = 431.68 ac
Subbasin 2 Drainage Area: 0.7682 mi2 (640 acres / 1 mi2) = 491.65 ac
Subbasin 3 Drainage Area: 0.5376 mi2 (640 acres / 1 mi2) = 344.06 ac

Kb
Subbasin 1: Kb = .221[-.025(log 432) + .15] + .779[-.03(log 432) + .2] = .113
Subbasin 2: Kb = .213[-.025(log 492) + .15] + .787[-.03(log 492) + .2] = .111
Subbasin 3: Kb = .424[-.025(log 344) + .15] + .576[-.03(log 344) + .2] = .108

Initial Abstraction (IA)
Subbasin 1: IA = .221(.15) + .779(.25) = .23in
Subbasin 2: IA = .231(.15) + .787(.25) = .23in
Subbasin 3: IA = .424(.15) + .576(.25) = .21in

Vegetation Adjustment
Assumed Vegetation Cover: Hillslopes = 30% (1.22) and Mountians = 20% (1.11)

Subbasin 1: Adj = .221(1.22) + .779(1.11) = 1.134
Subbasin 2: Adj = .213(1.22) + .787(1.11) = 1.133
Subbasin 3: Adj = .424(1.22) + .576(1.11) = 1.157

XKSAT values have been adjusted since 1990 report.
Subbasin 1: XKSAT = 1.134(.37) = 0.42 in/hr
Subbasin 2: XKSAT = 1.133(.34) = 0.39 in/hr
Subbasin 3: XKSAT = 1.157(.33) = 0.38 in/hr

Table 3.1
Equation for Estimating K_b in the Tc Equation

$K_b = m \log A + b$
Where A is drainage area, in acres

Type	Description	Typical Applications	Equation Parameters m	Equation Parameters b
A	Minimal roughness: Relatively smooth and/or well graded and uniform land surfaces. Surface runoff is sheet flow.	Commercial/ industrial areas Residential area Parks and golf courses	–0.00625	0.04
B	Moderately low roughness: Land surfaces have irregularly spaced roughness elements that protrude from the surface but the overall character of the surface is relatively uniform. Surface runoff is predominately sheet flow around the roughness elements.	Agricultural fields Pastures Desert rangelands Undeveloped urban lands	–0.01375	0.08
C	Moderately high roughness: Land surfaces that have significant large- to medium-sized roughness elements and/or poorly graded land surfaces that cause the flow to be diverted around the roughness elements. Surface runoff is sheet flow for short distances draining into meandering drainage paths.	Hillslopes Brushy alluvial fans Hilly rangeland Disturbed land, mining, etc. Forests with underbrush	–0.025	0.15
D	Maximum roughness: Rough land surfaces with torturous flow paths. Surface runoff is concentrated in numerous short flow paths that are often oblique to the main flow direction.	Mountains Some wetlands	–0.030	0.20

3.3 Assumptions

Application of the Rational Equation requires consideration of the following:

1. The peak discharge rate corresponding to a given intensity would occur only if the rainfall duration is at least equal to the time of concentration.

2. The calculated runoff is directly proportional to the rainfall intensity.

3. The frequency of occurrence for the peak discharge is the same as the frequency for the rainfall producing that event.

4. The runoff coefficient increases as storm frequency decreases.

(from DDM, 1995)

4.2 Surface Retention Loss

Surface retention loss, as used herein, is the summation of all rainfall losses other than infiltration. The major component of surface retention loss is depression storage; relatively minor components of surface retention loss are due to interception and evaporation, as previously discussed. Depression storage is considered to occur in two forms. First, in-place depression storage occurs at, and in the near vicinity of, the raindrop impact. The mechanism for this depression storage is the microrelief of the soil and soil cover. The second form of depression storage is the retention of surface runoff that occurs away from the point of raindrop impact in surface depressions such as puddles, roadway gutters and swales, roofs, irrigation bordered fields and lawns, and so forth.

A relatively minor contribution by interception is also considered as a part of the total surface retention loss. Estimates of surface retention loss are difficult to obtain and are a function of the physiography and land-use of the area.

The surface retention loss on impervious surfaces has been estimated to be in the range 0.0625 inch to 0.125 inch by Tholin and Keefer (1960), 0.11 inch for 1 percent slope to 0.06 inch for 2.5 percent slopes by Viessman (1967), and 0.04 inch based on rainfall-runoff data for an urban watershed in Albuquerque by Sabol (1983). Hicks (1944) provides estimates of surface retention losses during intense storms as 0.20 inch for sand, 0.15 inch for loam, and 0.10 inch for clay. Tholin and Keefer (1960) estimated the surface retention loss for turf to be between 0.25 to 0.50 inch. Based on rainfall simulator studies on undeveloped alluvial plains in the Albuquerque area, the surface retention loss was estimated as 0.1 to 0.2 inch (Sabol and others, 1982a). Rainfall simulator studies in New Mexico result in estimates of 0.39 inch for eastern plains rangelands and 0.09 inch for pinon-juniper hillslopes (Sabol and others, 1982b). Surface retention losses for various land-uses and surface cover conditions in Maricopa County have been extrapolated from these reported estimates and these are shown in Table 4.1.

Table 4.1
Surface Retention Loss for Various Land Surfaces in Maricopa County

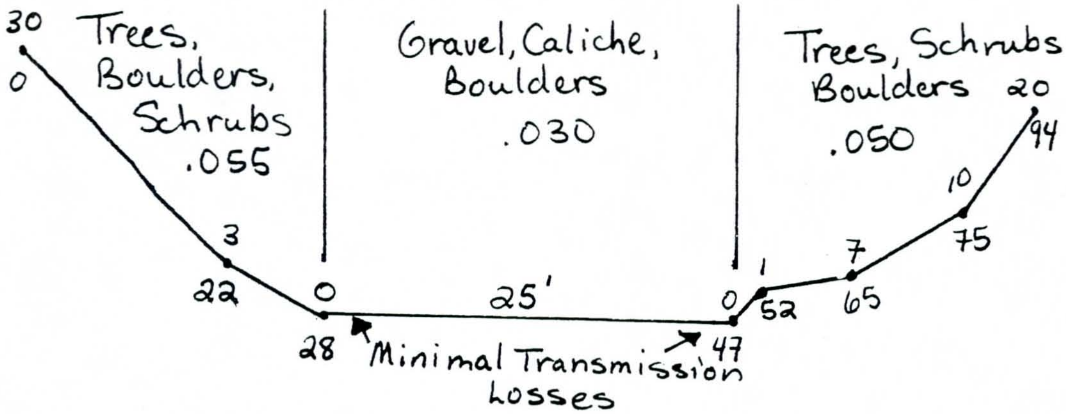
Land-use and/or Surface Cover (1)	Surface Retention Loss IA, Inches (2)
Natural	
Desert and rangeland, flat slope	0.35
Hillslopes, Sonoran Desert	0.15
Mountain, with vegetated surface	0.25
Developed (Residential and Commercial)	
Lawn and turf	0.20
Desert landscape	0.10
Pavement	0.05
Agricultural	
Tilled fields and irrigated pasture	0.50

(from DDM, 1995)

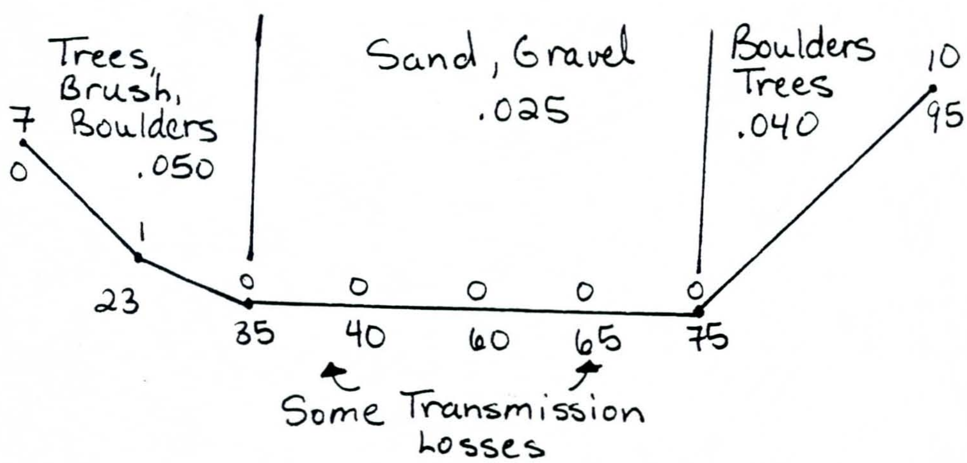
Appendix C

Routing
This information was taken from the 1990 report

Section A: (1.0mi southwest of 3 points, facing downstream)



Section B: ($^1/_2$mi north of Apex, facing downstream)



Reach A-B :
Length = 5000ft
Slope = 1520 - 1380 / 5000 = .0280ft/ft

Reach B-C:
Length = 5375ft
Slope = 1380 - 1250 /5375 = .0242ft/ft

Tc and R

Information from Hec-1 model runs using Normal Depth Routing

2 Hour

	2	5	10	25	50	100
Sub1	.950/.492	.654/.325	.558/.273	.467/.224	.421/.199	.383/.180
Sub2	1.033/.550	.708/.362	.604/.303	.508/.250	.454/.221	.417/.201
Sub3	1.163/.847	.775/.540	.654/.448	.546/.366	.488/.323	.446/.292

6 Hour

	2	5	10	25	50	100
Sub1	1.029/.538	.775/.393	.667/.332	.558/.273	.504/.244	.467/.224
Sub2	1.117/.600	.837/.436	.712/.364	.600/.301	.538/.266	.496/.244
Sub3	1.267/.932	.921/.654	.771/.537	.637/.435	.571/.385	.525/.351

24 Hour

	2	5	10	25	50	100
Sub1	.813/.414	.646/.321	.579/.284	.508/.246	.467/.224	.438/.208
Sub2	.883/.462	.700/.357	.625/.315	.550/.273	.500/.246	.467/.228
Sub3	.971/.694	.762/.531	.679/.467	.596/.404	.538/.360	.496/.329

Discharge [in cubic feet per second (cfs)]

Normal Depth Routing

2 Hour Storm

	2yr	5yr	10yr	25yr	50yr	100yr
Sub1	163	449	681	1039	1339	1649
R1-2	155	428	657	1000	1276	1591
Sub2	167	470	721	1000	1422	1766
HC2	320	885	1366	2100	2698	3357
R2-3	306	842	1302	2006	2579	3222
Sub3	82	251	393	620	814	1023
HC3	387	1090	1691	2624	3393	4201

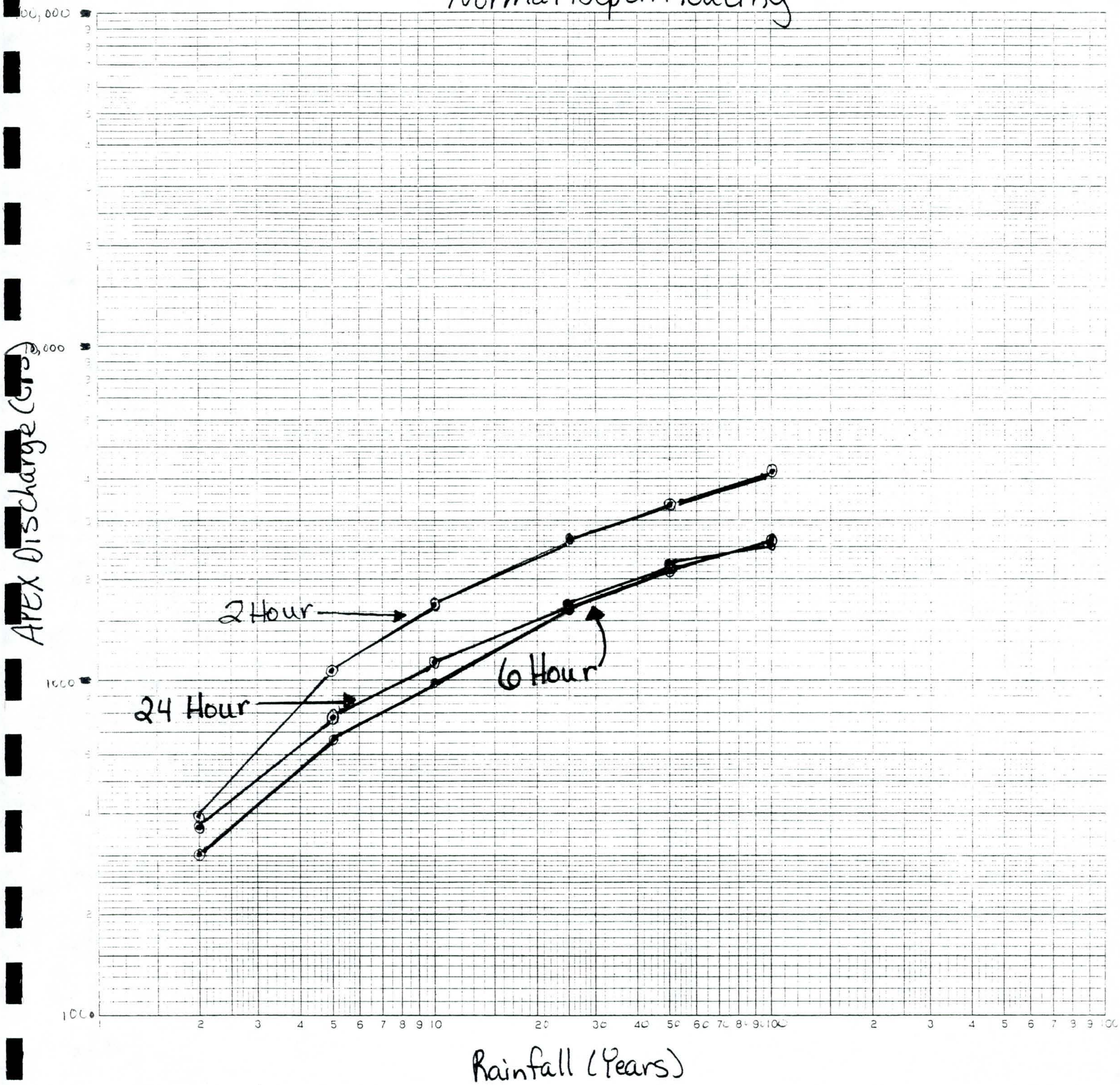
6 Hour Storm

	2yr	5yr	10yr	25yr	50yr	100yr
Sub1	121	264	399	622	803	979
R1-2	118	253	378	608	782	957
Sub2	126	283	427	668	876	1072
HC2	244	526	789	1277	1644	2029
R2-3	239	517	767	1241	1608	1984
Sub3	62	150	236	388	515	646
HC3	301	664	995	1625	2123	2612

24 Hour Storm

	2yr	5yr	10yr	25yr	50yr	100yr
Sub1	154	337	465	677	849	1035
R1-2	144	307	445	647	817	988
Sub2	159	350	500	720	915	1111
HC2	301	648	914	1346	1732	2051
R2-3	285	613	869	1277	1661	1966
Sub3	82	189	271	402	524	652
HC3	364	797	1123	1648	2161	2599

Normal Depth Routing



Full Logarithmic, 3 × 3 Cycles

Tc and R
Information from Hec-1 model runs using Muskingum-Cunge Routing

2 Hour

	2	5	10	25	50	100
Sub1	.950/.492	.654/.325	.558/.273	.467/.224	.421/.199	.383/.180
Sub2	1.033/.550	.708/.362	.604/.303	.508/.250	.454/.221	.417/.201
Sub3	1.163/.847	.7751/.540	.654/.448	.546/.366	.488/.323	.446/.292

6 Hour

	2	5	10	25	50	100
Sub1	.950/.492	.654/.325	.558/.273	.467/.224	.421/.199	.383/.180
Sub2	1.029/.538	.837/.436	.712/.364	.600/.301	.538/.266	.496/.244
Sub3	1.267/.932	.921/.654	.771/.537	.637/.435	.571/.385	.525/.351

24 Hour

	2	5	10	25	50	100
Sub1	.813/.414	.646/.321	.579/.284	.508/.246	.467/.224	.438/.208
Sub2	.883/.462	.700/.357	.625/.315	.550/.273	.500/.246	.467/.228
Sub3	.971/.694	.762/.531	.679/.467	.596/.404	.538/.360	.496/.329

Discharge from Hec-1 model runs [in cubic feet per second (cfs)]

Muskingum-Cunge Routing

2 Hour Storm

	2yr	5yr	10yr	25yr	50yr	100yr
Sub1	164	444	672	1033	1328	1640
R1-2	165	453	689	1043	1325	1613
Sub2	169	469	714	1101	1411	1757
HC2	331	903	1369	2095	2736	3300
R2-3	333	905	1372	2108	2723	3273
Sub3	82	250	391	618	811	1013
HC3	414	1147	1742	2679	3506	4286

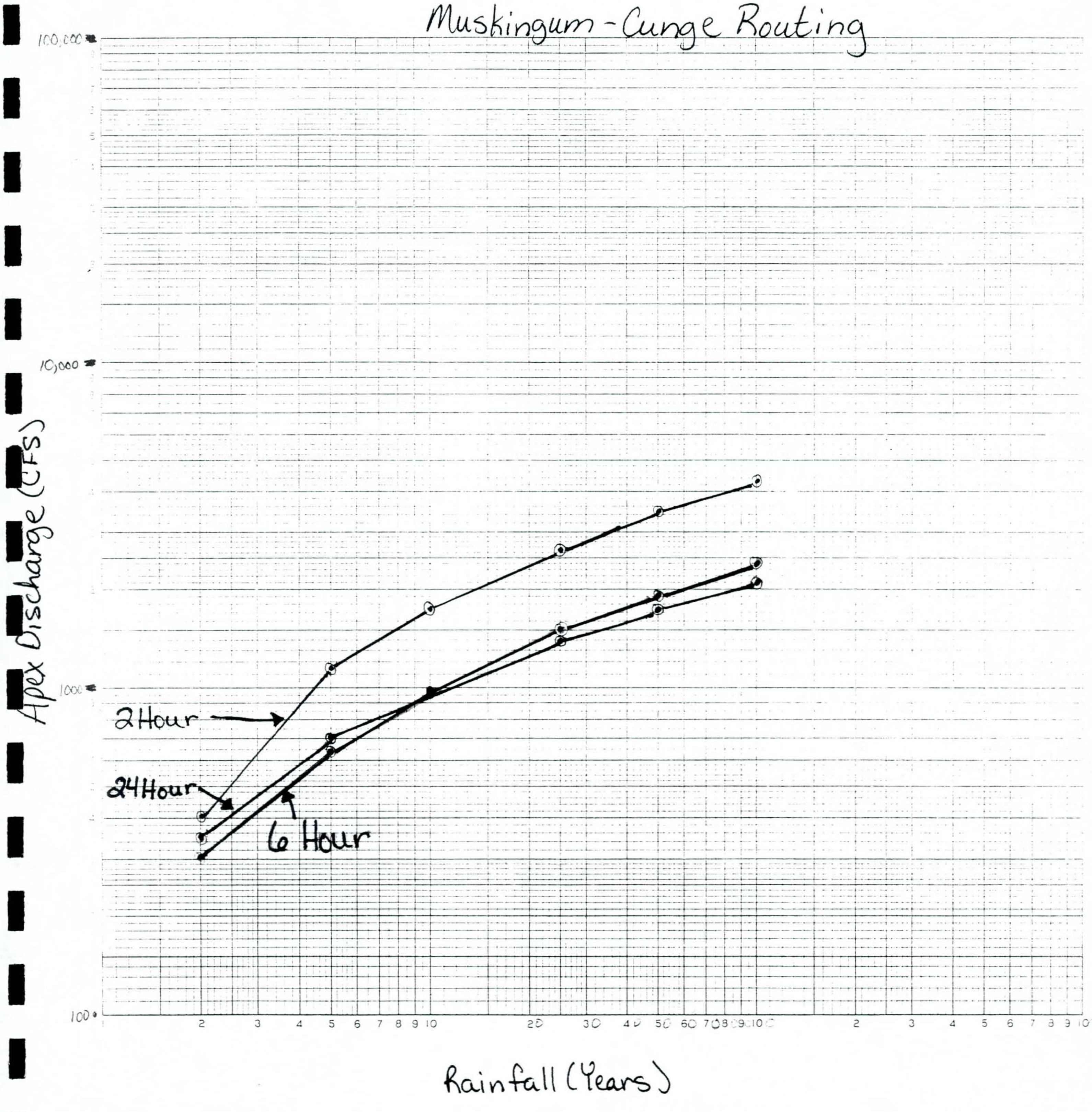
6 Hour Storm

	2yr	5yr	10yr	25yr	50yr	100yr
Sub1	118	250	386	589	763	920
R1-2	118	246	368	570	715	897
Sub2	125	265	415	627	832	1023
HC2	243	511	765	1183	1546	1920
R2-3	241	510	769	1124	1510	1795
Sub3	62	144	225	378	484	617
HC3	303	647	991	1502	1989	2405

24 Hour Storm

	2yr	5yr	10yr	25yr	50yr	100yr
Sub1	137	304	409	541	697	846
R1-2	135	273	388	554	669	754
Sub2	146	324	450	607	748	919
HC2	281	597	838	1161	1394	1563
R2-3	278	536	726	1049	1323	1563
Sub3	81	172	254	368	460	543
HC3	346	694	973	1417	1783	2106

Muskingum-Cunge Routing



Full Logarithmic, 3 × 3 Cycles

SAMPLE INPUT
Normal Depth

```
ID
ID DDM MCUHP1 SOUTH MOUNTAIN FAN
IT     3                     300
IO     3
*DIAGRAM
* DDM    ***** Preserved *****
KK  SUB1
KM SUB-BASIN SUB1
KM 2-HOUR RAINFALL DISTRIBUTION WAS USED TO FIND TC & R FOR THIS BASIN
KM THIS BASIN USED RAINFALL REDUCTION FACTOR OF 1.000
KM   L = 1.16  Kb = .112  Adj. Slope =  313.2
BA  .675
IN     5
KM RAINFALL DEPTH OF 2.92 WAS SPACIALLY REDUCED AS SHOWN BY THE PB RECORD
PB 2.920
KM THE FOLLOWING PC RECORD USED A 2-HOUR RAINFALL DISTRIBUTION
PC  .000    .011    .018    .023    .028    .032    .046    .071    .100    .137
PC  .176    .232    .327    .601    .743    .863    .901    .930    .954    .962
PC  .970    .979    .982    .992   1.000
LG  .230    .350   4.110    .430  31.800
UC  .387    .182
UA     0       3       5       8      12      20      43      75      90      96
UA   100
* DDM    ***** Preserved *****
KK R1-2
KM ROUTE HYDROGRAPH FOR SUB1 THROUGH SUB2 USING NORMAL DEPTH ROUTING
KO     1       2
RS      2       FLOW     0
RC  .055    .030    .050    5000    .0280
RX     0      22      28      47      52      65      75      94
RY    30       3       0       0       1       7      10      20
* DDM    ***** Preserved *****
KK  SUB2
KM SUB-BASIN SUB2
KM 2-HOUR RAINFALL DISTRIBUTION WAS USED TO FIND TC & R FOR THIS BASIN
KM THIS BASIN USED RAINFALL REDUCTION FACTOR OF 1.000
KM   L = 1.30  Kb = .111  Adj. Slope =  315.0
BA  .768
LG  .230    .350   4.130    .430  36.500
UC  .417    .201
UA     0       3       5       8      12      20      43      75      90      96
UA   100
```

cont'd

```
* DDM    ***** Preserved *****
KK   HC2
KM COMBINE HYDROGRAPHS FROM SUBASIN 1 AND SUBASIN 2
HC      2
* DDM    ***** Preserved *****
KK  R2-3
KM ROUTE HYDROGRAPH HC2 THROUGH SUB3 USING NORMAL DEPTH ROUTING
KO      1       2
RS      2     FLOW       0
RC   .050    .025    .040    5375   .0242
RX      0      23      35      40      60      65      75      95
RY      7       1       0       0       0       0       0      10
RL      2
* DDM    ***** Preserved *****
KK  SUB3
KM SUB-BASIN SUB3
KM 2-HOUR RAINFALL DISTRIBUTION WAS USED TO FIND TC & R FOR THIS BASIN
KM THIS BASIN USED RAINFALL REDUCTION FACTOR OF 1.000
KM    L = 1.47  Kb = .107  Adj. Slope =  315.0
BA   .538
LG   .210    .350   4.170    .420  74.000
UC   .412    .268
UA      0       3       5       8      12      20      43      75      90      96
UA    100
* DDM    ***** Preserved *****
KK   HC3
KM COMBINE HYDROGRAPH R1-2 THROUGH SUBASIN 3
HC      2
ZZ
```

SAMPLE INPUT

Muskingum-Cunge

```
ID
ID DDM MCUHP1 SOUTH MOUNTAIN FAN
IT      5                      300
IO      3
*DIAGRAM
* DDM    ***** Preserved *****
KK  SUB1
KM SUB-BASIN SUB1
KM 2-HOUR RAINFALL DISTRIBUTION WAS USED TO FIND TC & R FOR THIS BASIN
KM THIS BASIN USED RAINFALL REDUCTION FACTOR OF 1.000
KM   L = 1.16  Kb = .112  Adj. Slope =  313.2
BA  .675
IN      5
KM RAINFALL DEPTH OF 2.92 WAS SPACIALLY REDUCED AS SHOWN BY THE PB RECORD
PB 2.920
KM THE FOLLOWING PC RECORD USED A 2-HOUR RAINFALL DISTRIBUTION
PC  .000    .011    .018    .023    .028    .032    .046    .071    .100    .137
PC  .176    .232    .327    .601    .743    .863    .901    .930    .954    .962
PC  .970    .979    .982    .992   1.000
LG  .230    .350   4.110    .430  31.800
UC  .387    .182
UA     0       3       5       8      12      20      43      75      90      96
UA   100
* DDM    ***** Preserved *****
KK R1-2
KM ROUTE HYDROGRAPH FOR SUB1 THROUGH SUB2 USING MUSKINGUM-CUNGE ROUTING
KO      1       2
RD  5000   .0280    .030            TRAP
RC  .055    .030    .050    5000   .0280
RX     0      22      28      47      52      65      75      94
RY    30       3       0       0       1       7      10      20
* DDM    ***** Preserved *****
KK  SUB2
KM SUB-BASIN SUB2
KM 2-HOUR RAINFALL DISTRIBUTION WAS USED TO FIND TC & R FOR THIS BASIN
KM THIS BASIN USED RAINFALL REDUCTION FACTOR OF 1.000
KM   L = 1.30  Kb = .111  Adj. Slope =  315.0
BA  .768
LG  .230    .350   4.130    .430  36.500
UC  .417    .201
UA     0       3       5       8      12      20      43      75      90      96
UA   100
```

Cont'd

```
* DDM    ***** Preserved *****
KK   HC2
KM COMBINE HYDROGRAPHS FROM SUBASIN 1 AND SUBASIN 2
HC      2
* DDM    ***** Preserved *****
KK  R2-3
KM ROUTE HYDROGRAPH HC2 THROUGH SUB3 USING MUSKINGUM-CUNGE ROUTING
KO      1       2
RD  5375   .0242    .025            TRAP
RC  .050    .025    .040    5375   .0242
RX      0      23      35      40      60      65      75      95
RY      7       1       0       0       0       0       0      10
RL      2
* DDM    ***** Preserved *****
KK  SUB3
KM SUB-BASIN SUB3
KM 2-HOUR RAINFALL DISTRIBUTION WAS USED TO FIND TC & R FOR THIS BASIN
KM THIS BASIN USED RAINFALL REDUCTION FACTOR OF 1.000
KM   L = 1.47  Kb = .107  Adj. Slope =  315.0
BA  .538
LG  .210    .350   4.170    .420  74.000
UC  .412    .268
UA      0       3       5       8      12      20      43      75      90      96
UA    100
* DDM    ***** Preserved *****
KK   HC3
KM COMBINE HYDROGRAPH R1-2 THROUGH SUBASIN 3
HC      2
ZZ
```

Appendix D

Historic Storm Event

Rainfall: South Mountain Fan gages recorded a storm event on November 1-2, 1995 which produced 1.38 inches of rain in 6 hours.

DeviceID	6560	35
StatType	rain	rain
DataType	precip	precip
Units	in	in
11/02/95		
0045	0.00	0.00
0030	0.04	0.00
0015	0.00	0.00
11/01/95		
2400	0.00	0.00
2345	0.00	0.00
2330	0.08	0.00
2315	0.00	0.00
2300	0.08	0.00
2245	0.08	0.00
2230	0.00	0.00
2215	0.04	0.00
2200	0.04	0.00
2145	0.04	0.00
2130	0.16	0.00
2115	0.04	0.00
2100	0.00	0.00
2045	0.12	0.00
2030	0.28	0.00
2015	0.04	0.00
2000	0.08	0.00
1945	0.00	0.00
1930	0.00	0.00
1915	0.00	0.00
1900	0.00	0.00
1845	0.08	0.00
1830	0.16	0.00
1815	0.04	0.00
1800	0.00	0.00
1745	0.00	0.00
1730	0.00	0.00
1715	0.00	0.00
1700	0.00	0.00
1645	0.00	0.00
1630	0.00	0.00
1615	0.00	0.00
1600	0.00	0.00
1545	0.00	0.00
1530	0.00	0.00
1515	0.00	0.00
1500	0.00	0.00
1445	0.00	0.00
1430	0.00	0.00
1415	0.00	0.00
1400	0.00	0.00
1345	0.00	0.00
1330	0.00	0.00
1315	0.00	0.00
1300	0.00	0.00

1245	0.00	0.00
1230	0.00	0.00
1215	0.00	0.00
1200	0.00	0.00
1145	0.00	0.00
1130	0.00	0.00
1115	0.00	0.00
1100	0.00	0.00
1045	0.00	0.00
1030	0.00	0.00
1015	0.00	0.00
1000	0.00	0.00
0945	0.00	0.00
0930	0.00	0.39
0915	0.00	0.17
0900	0.00	0.01
0845	0.00	0.01
0830	0.00	0.03
0815	0.00	0.00
0800	0.00	0.00
0745	0.00	0.06
0730	0.00	0.26
0715	0.00	0.00
0700	0.00	0.00
TOTALS:	1.38	0.93

Historic Storm Discharge Using Hec-1(cfs)

Normal Depth Routing

6 Hour Storm

	cfs
Sub1	144
R1-2	140
Sub2	151
HC2	289
R2-3	275
Sub3	76
HC3	351

Muskingum-Cunge Routing

6 Hour Storm

	cfs
Sub1	142
R1-2	133
Sub2	149
HC2	279
R2-3	278
Sub3	74
HC3	353

Historic Storm Discharge from Pressure Transducer 6563

Date	Time	feet	Discharge (cfs)
11/1/96	22:43:12	0.10	1
11/1/96	22:31:12	0.20	3
11/1/96	22:22:12	0.30	5
11/1/96	22:01:42	0.50	10
11/1/96	21:58:12	0.60	13
11/1/96	21:46:12	0.85	21
11/1/96	21:28:12	1.08	37
11/1/96	21:22:12	1.40	111
11/1/96	21:19:22	1.50	155
11/1/96	21:13:12	1.73	279
11/1/96	21:04:12	1.88	349
11/1/96	20:58:12	1.70	268
11/1/96	12:16:21	0.00	0

To calculate Tc and R for the Historic
Storm event on November 1, 1995 a isohyetal map was generated for the study area. The three subbasins were added to the map enabling calculations to be completed that indicated the amount of rainfall each subbasin received. The following indicates how subbasin 3 was calculated.

First, the area in each section was measured to figure out the percent area per rainfall (see isohyetal map).

Section A
(1600ft) (5400ft) = 8,640,000 ft = 44%
Section B
(1600ft) (3700ft) = 5,920,000 ft = 30%
Section C
(1600ft) (2600ft) = 4,160,000 ft = 21%
Section D
(1000ft) (1000ft) = 1,000,000 ft = 5%

Total area = 19,720,000

Second, that percent was multiplied to the average rainfall for that section.

Average Rain	Percent	Actual Rainfall/Section
1.05	44%	.462
1.15	30%	.345
1.25	21%	.2625
1.34	5%	.067

Total Rainfall in Subbasin 3 1.14 inches

Third, normalize the gage data for that basin by picking 8 points of maximum rain and dividing by their total.

Time	Rainfall	Normalization
2145	.04	.05
2130	.16	.21
2115	.04	.05
2100	.00	.0
2045	.12	.16
2030	.28	.37
2015	.04	.05
2000	.08	.11
Total	.76	100%

Fourth, take your rainfall amount and multiply by normalization number to get exact amount of rain per time increment (15 mins for this study).

Time	Total Rainfall	Normalization	Actual Rainfall Amount
2000	1.14	.11	.12
2015	1.14	.05	.06
2030	1.14	.37	.42
2045	1.14	.16	.18
2100	1.14	.00	.00
2115	1.14	.05	.06
2130	1.14	.21	.24
2145	1.14	.05	.06

Fifth, take the actual rainfall amount and plug it into the Tc and R calculation sheet (see following pages).

CREST GAGE LOCATIONS & NUMBERS

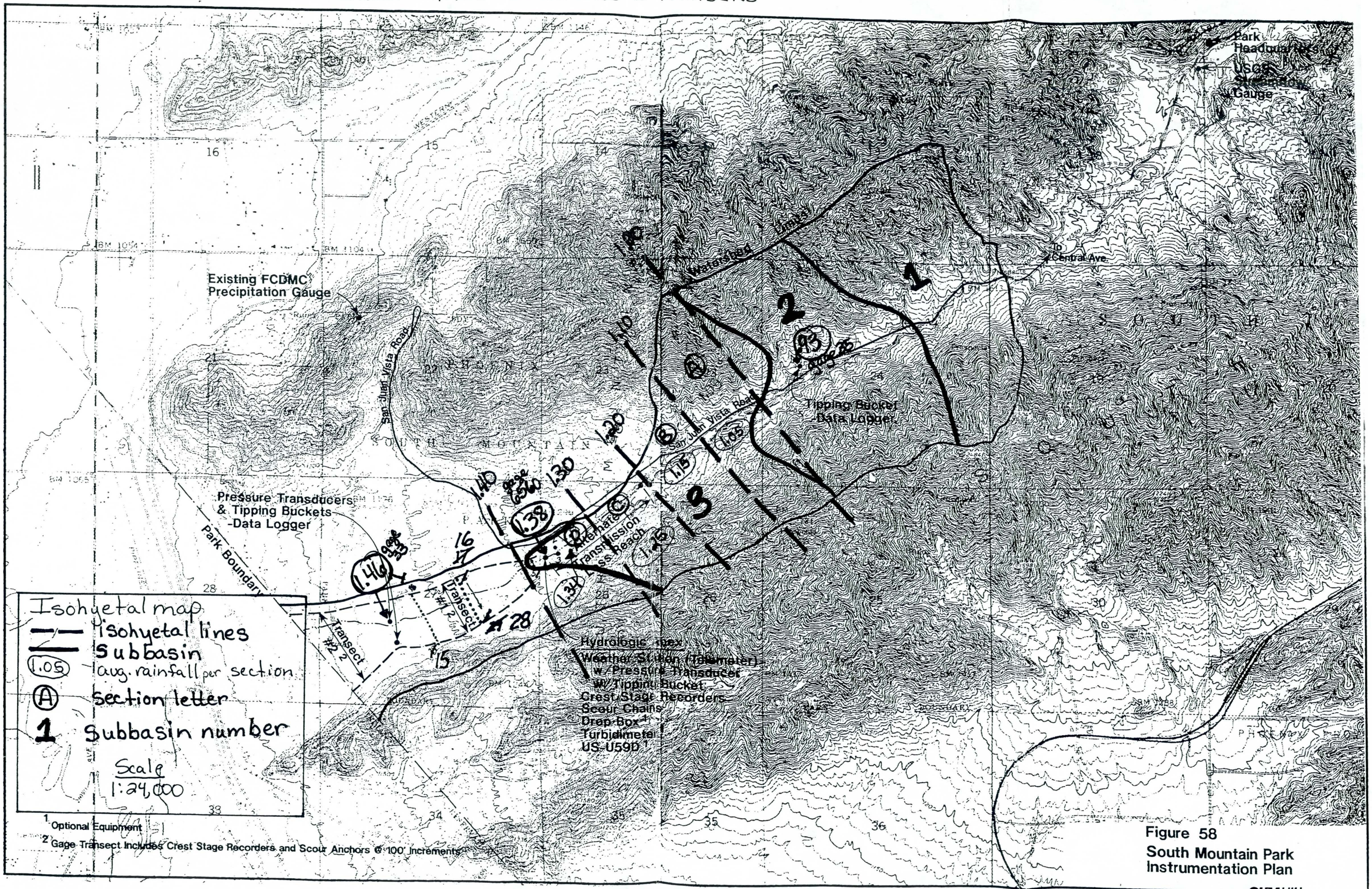


Figure 58
South Mountain Park
Instrumentation Plan

CALCULATION OF Tc & R

Calculated by: [illegible] Date: ______
Checked by: ______ Project: Alluvia Fan

Watershed: [illegible] 3
Rainfall Frequency: ____ - yr Duration: 6 - hr. Pattern #: ______

Rainfall Loss Method:
Historic Storm 11-1-95

[✓] Green & Ampt Method
[ ] IL + ULR by soil texture
[ ] IL + ULR by hydrologic soil group

Tabulate Period of Peak Rainfall Excess

Clock Time @ end of Increm.	Increm. Excess in.
2000	.12
2015	.06
2030	.42
2045	.18
2100	.00
2115	.06
2130	.24
2145	.06

Rearrange Incremental Excesses in Order of Decreasing Average Intensity

Accum. Time hr./min.	Increm. Excess in.	Accum. Excess in.	Avg. Excess Intensity in./hr. (i)
15	.42	.42	1.68
30	.24	.66	1.32
45	.18	.84	1.12
60	.12	.96	.96
75	.06	1.02	.816
90	.06	1.08	.72
105	.06	1.14	.651
120	.00	1.14	.57

A = 0.5376 sq.mi.
L = 1.468 mi.
S = 315 ft/mi.

Kb = m [log(A * 640)]+ b
Kb = (-0.025) log (.5376*640) + (0.15)
Kb = 0.0866

$Tc = 11.4\ L^{.50}\ Kb^{.52}\ S^{-.31}\ i^{-.38}$

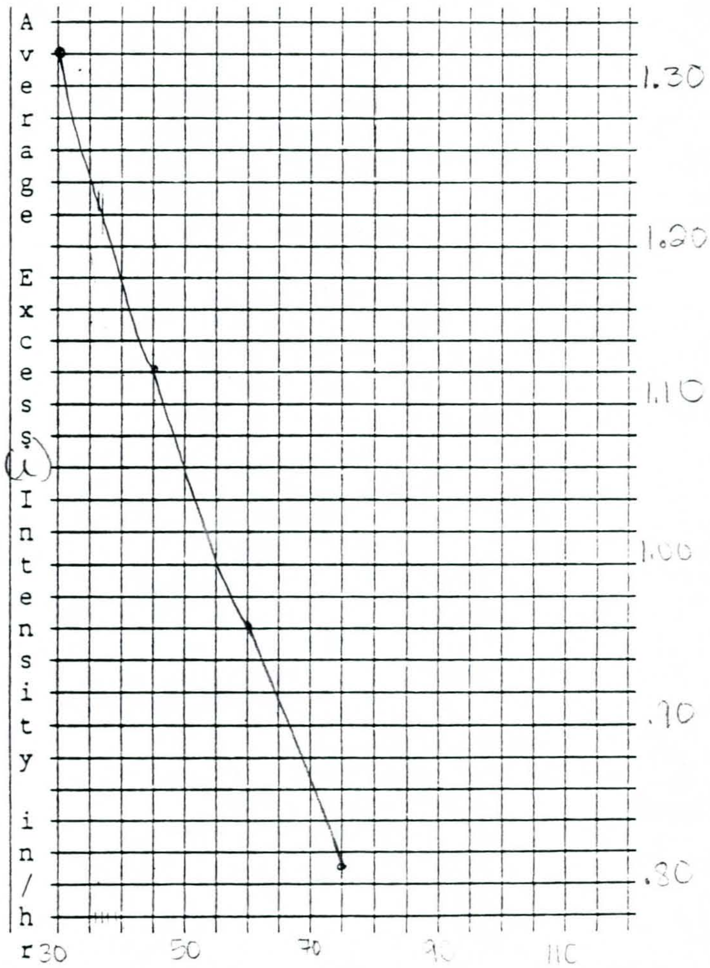
$Tc = (.651)\ i^{-.38}$

Trial Tc	i	Calc. Tc
60	.96	39.7
40	1.18	36.7
37	1.22	36.2
36	1.23	36.1

Tc = 0.6 hr. 36min

$R = .37\ Tc^{1.11}\ A^{-.57}\ L^{.80}$

R = .406 hr.



Time (Tc) (hr./min.)

CALCULATION OF Tc & R

Calculated by: JJK Date: ______
Checked by: ______ Project: Alluvial Fan

Watershed: South mtn subbasin 2
Rainfall Frequency: ____ - yr Duration: 6 - hr. Pattern #: ______

Rainfall Loss Method: Historic Storm 1-1-95
[✓] Green & Ampt Method
[ ] IL + ULR by soil texture
[ ] IL + ULR by hydrologic soil group

Tabulate Period of Peak Rainfall Excess

Clock Time @ end of Increm.	Increm. Excess in.
0745	.08
0800	.00
0815	.00
0830	.04
0845	.02
0900	.02
0915	.23
0930	.54

Rearrange Incremental Excesses in Order of Decreasing Average Intensity

Accum. Time hr./min.	Increm. Excess in.	Accum. Excess in.	Avg. Excess Intensity (i) in./hr.
15	.54	.54	2.16
30	.23	.77	1.54
45	.08	.85	1.13
60	.04	.89	.89
75	.02	.91	.728
90	.02	.93	.62
105	.00	.93	.571
120	.00	.93	.465

A = 0.7682 sq.mi.
L = 1.302 mi.
S = 315 ft/mi.

$Kb = m\,[\log(A * 640)] + b$

$Kb = (-0.025)\log(0.7682*640) + (0.15)$

Kb = .0827

$Tc = 11.4\,L^{.50}\,Kb^{.52}\,S^{-.31}\,i^{-.38}$

$Tc = (.598)\,i^{-.38}$

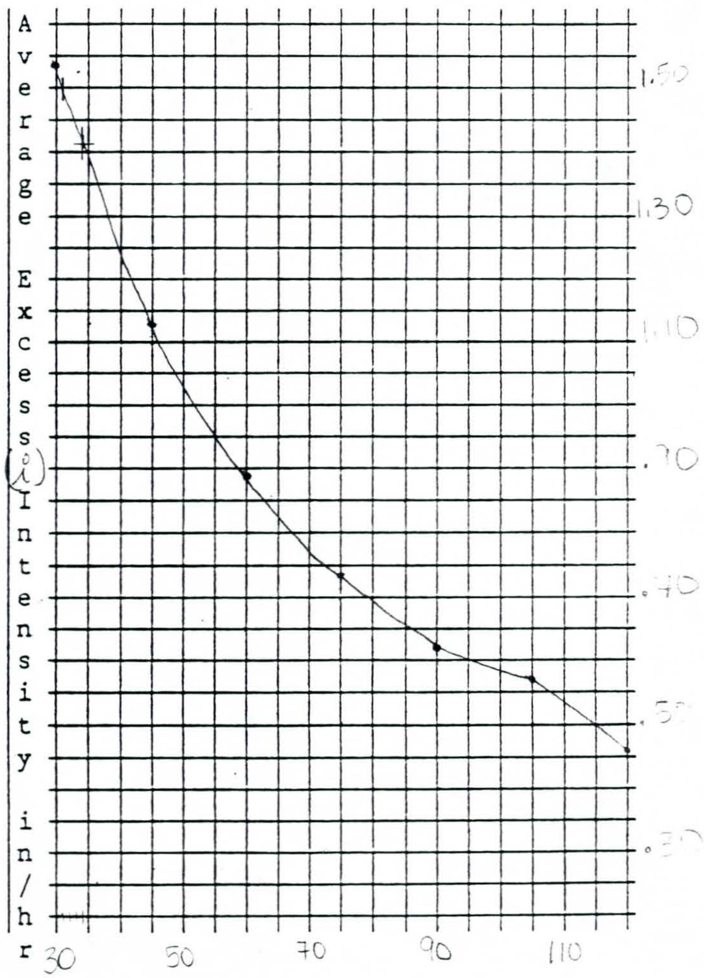
Trial Tc	i	Calc. Tc
45	1.13	34.3
34	1.41	31.4
31	1.50	30.7

30.7 = 31

Tc = .517 hr. 31 min

$R = .37\,Tc^{1.11}\,A^{-.57}\,L^{.80}$

R = .255 hr.



CALCULATION OF Tc & R

Calculated by: [signature] Date:

Checked by: Project: Alluvial Fan

Watershed: South Mt. Subbasin 1

Rainfall Frequency: ____ - yr Duration: 6 - hr. Pattern #: ____

Rainfall Loss Method: Historic Storm 11-1-95

[ ] Green & Ampt Method

[ ] IL + ULR by soil texture

[ ] IL + ULR by hydrologic soil group

(Same as Subbasin 2)

Tabulate Period of Peak Rainfall Excess

Clock Time @ end of Increm.	Increm. Excess in.
0745	.08
0800	.00
0815	.00
0830	.04
0845	.02
0900	.02
0915	.23
0930	.54

Rearrange Incremental Excesses in Order of Decreasing Average Intensity

Accum. Time hr./min.	Increm. Excess in.	Accum. Excess in.	Avg. Excess Intensity (i) in./hr.
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45	.08	.85	1.13
60	.04	.89	.89
75	.02	.91	.728
90	.02	.93	.62
105	.00	.93	.571
120	.00	.93	.465

A = 0.6745 sq.mi.

L = 1.160 mi.

S = 311 ft/mi.

Kb = m [log(A * 640)]+ b

Kb = (-0.025) log (0.6745*640) + (0.15)

Kb = .0841

$$Tc = 11.4\, L^{.50}\, Kb^{.52}\, S^{-.31}\, i^{-.38}$$

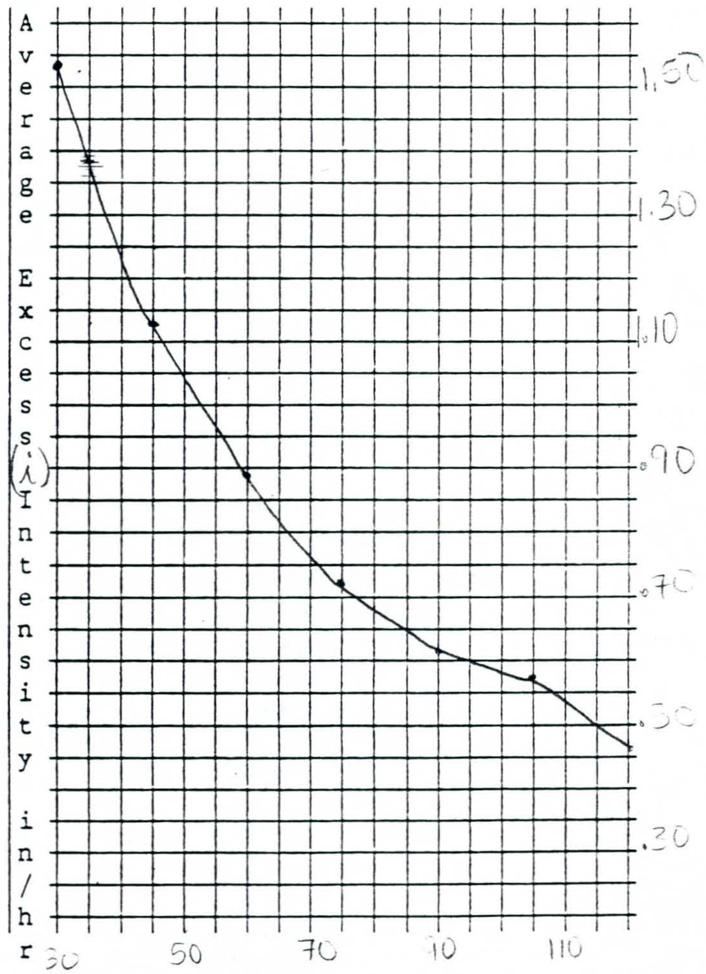
$$Tc = (.572)\, i^{-.38}$$

Trial Tc	i	Calc. Tc
35	1.37	30.4
30	1.54	29.1

Tc = .483 hr. 29 min

$$R = .37\, Tc^{1.11}\, A^{-.57}\, L^{.80}$$

R = .233 hr.

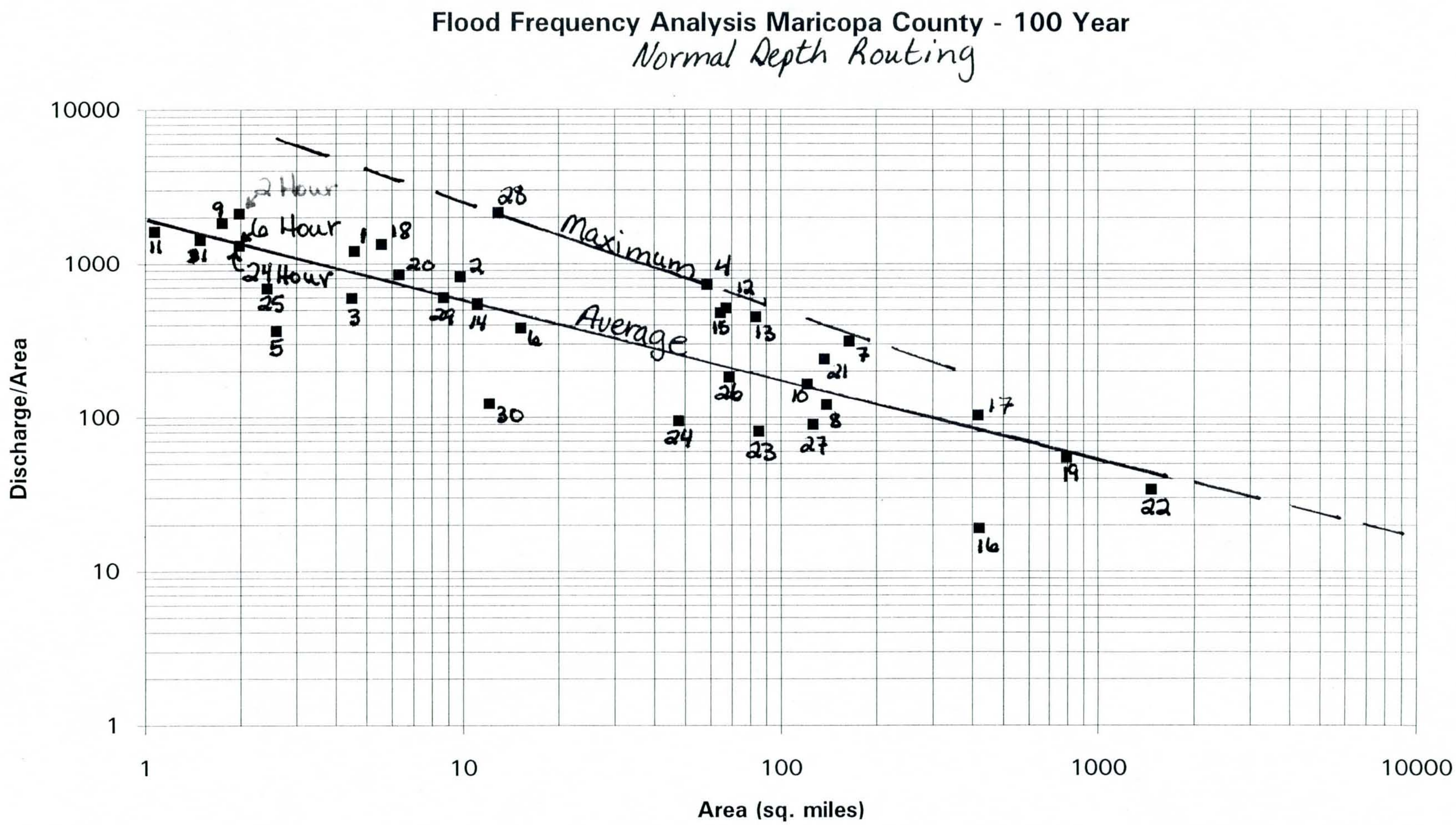


Appendix E

FREQUENCY TABLE 2

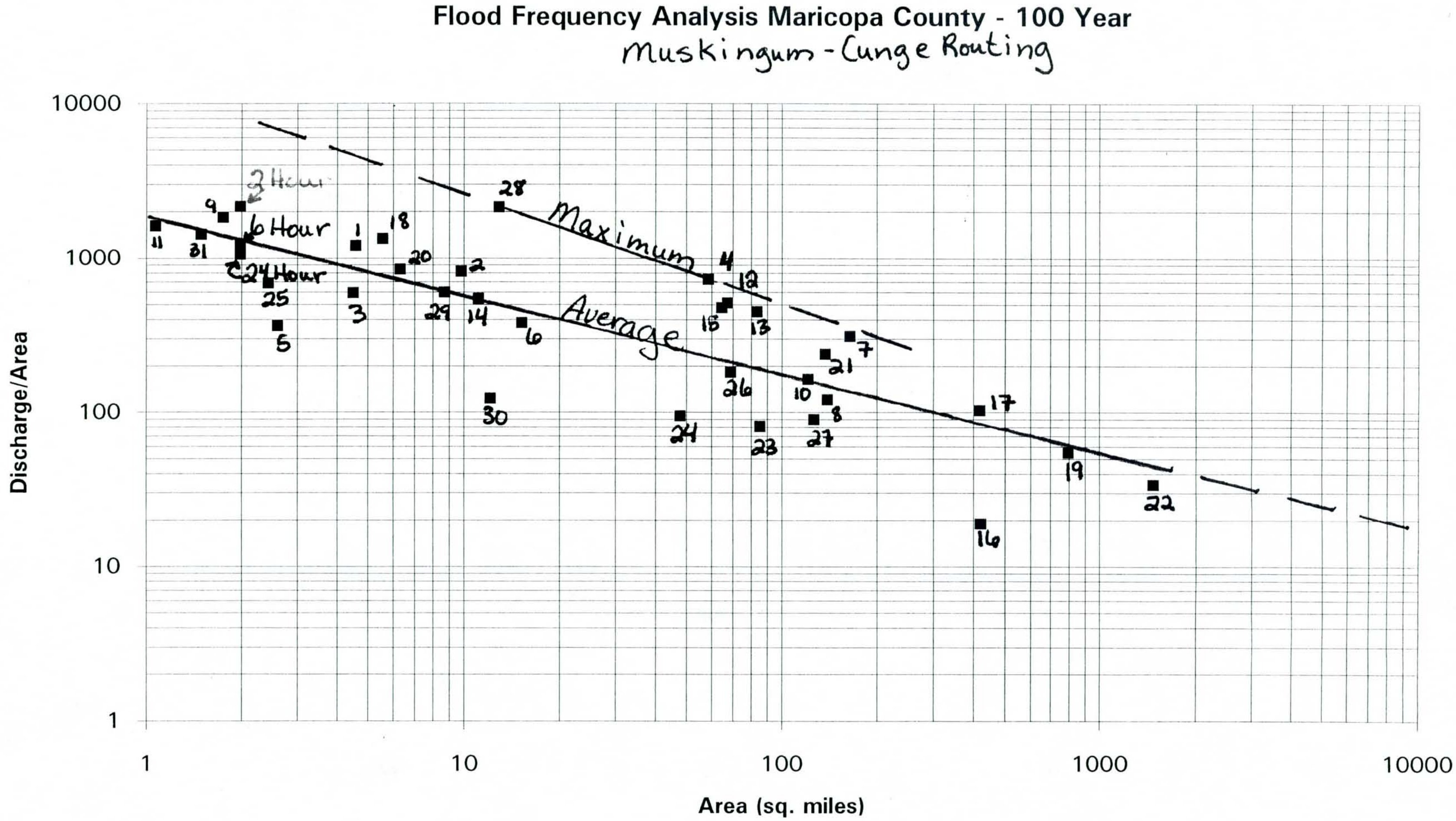
	GAGE	gage number	avg slope	AREA	Q100/A	Q-2	Q-5	Q-10	Q-25	Q-50	Q-100
1	WEST SYCAMORE CREEK MCFARLAND	09510070	260.00	4.58	1,207	36	268	702	1,840	3,330	5,530
2	WEST SYCAMORE CR. SUNFLOWER	09510080	353.00	9.80	819	101	519	1,190	2,840	4,920	8,030
3	EAST SYCAMORE CR. SUNFLOWER	09510100	370.00	4.49	595	43	196	428	978	1,660	2,670
4	SYCAMORE SUNLFOWER	09510150	58.60	52.30	816	1,050	4,050	8,160	17,200	27,800	42,700
5	CAMP CREEK SUNFLOWER	09510170	498.00	2.60	365	117	262	390	588	759	950
6	ROCK CREEK SUNFLOWER	09510180	412.00	15.20	381	507	1,340	2,130	3,400	4,530	5,790
7	SYCAMORE NEAR FT. MCDOWELL	09510200	116.00	164.00	313	2,020	6,650	12,300	23,500	35,500	51,400
8	INDIAN BEND WASH AT AZ CANAL	09512100	60.00	139.00	121	378	1,440	2,950	6,400	10,600	16,800
9	SALT RIVER TRIB. SOUTH MNT	09512200	244.00	1.75	1,840	22	171	448	1,140	2,000	3,220
10	CAVE CREEK NEAR CAVE CREEK	09512300	123.00	121.00	165	1,740	4,320	6,870	11,200	15,200	20,000
11	AGUA FRIA TRIB #2, ROCK SPRNGS	09512700	173.00	1.07	1,617	309	565	781	1,110	1,400	1,730
12	NEW RIVER NEAR ROCK SPRINGS	09513780	140.00	67.30	514	2,170	6,260	10,600	18,200	25,600	34,600
13	NEW RIVER AT NEW RIVER	09513800	105.00	83.30	450	3,150	7,880	12,600	20,600	28,300	37,500
14	DEADMAN WASH AT STATE 69	09513820	124.00	11.10	547	250	846	1,550	2,900	4,300	6,070
15	SKUNK CREEK AT I-17	09513860	49.20	64.60	480	967	3,570	6,910	13,700	21,200	31,000
16	WATERMAN WASH, 2.4 ABOVE GILA	09514200	21.20	420.00	19	1,330	2,420	3,380	4,880	6,240	7,840
17	HASSAYAMPA AT BOX DAMSITE	09515500	71.00	417.00	103	3,180	8,480	13,900	23,300	32,270	43,000
18	HARTMAN WASH AT US 60	09515800	71.60	5.57	1,338	218	796	1,550	3,150	4,960	7,450
19	HASSAYAMPA AT MORRISTOWN	09516500	84.90	796.00	55	2,670	7,180	12,200	21,500	31,300	43,900
20	OX WASH AT US 60	09516600	101.00	6.31	845	194	662	1,240	2,400	3,660	5,330
21	JACKRABBIT WASH (WICK-TONO)	09516800	34.40	137.00	240	547	2,440	5,300	12,100	20,500	32,900
22	HASSAYAMPA OLD US 80	09517000	39.90	1,470.00	34	2,720	7,470	12,900	23,400	34,500	49,300
23	TIGER WASH NEAR AGUILA	09517280	35.20	85.20	81	1,010	2,120	3,060	4,450	5,630	6,910
24	WINTERS WASH DS OF AIRLINE RD	09517400	83.70	47.80	95	857	1,540	2,120	2,980	3,720	4,560
25	RAINBOW WASH TRIB. AT US 80	09519600	34.40	2.43	687	484	748	945	1,220	1,440	1,670
26	BENDER WASH ALONG I-8	09519750	73.90	68.80	183	466	1,740	3,270	6,150	9,040	12,600
27	SAUCEDA WASH AT STATE 85	09519760	46.70	126.00	90	584	1,880	3,310	5,870	8,350	11,400
28	WINDMILL WASH	09519780	64.40	12.90	2,140	155	1,160	3,120	8,550	16,000	27,600
29	MILITARY WASH AT STATE 80	09520100	56.00	8.70	600	124	468	946	2,030	3,330	5,220
30	BLACK GAP WASH AT STATE 85	09520200	21.80	12.10	123	392	672	868	1,120	1,300	1,490
31	CRATER RANGE WASH AT STATE 85	09520230	64.00	1.49	1,430	102	329	587	1,060	1,540	2,130

(from U.S.G.S, 1989)



6 Hour = 1319 CFS/sq. miles
24 Hour = 1313 CFS/sq. miles

Graph composed from Frequency Table 2 comparing the Normal Depth routing 100 year design storms to the 100 year Flood Frequency Analysis for Maricopa County.



6 Hour = 1215 CFS/sq. miles
24 Hour = 1313 CFS/sq. miles

Graph composed from Frequency Table 2 comparing the Muskingum-Cunge routing 100 year design storms to the 100 year Flood Frequency Analysis for Maricopa County.