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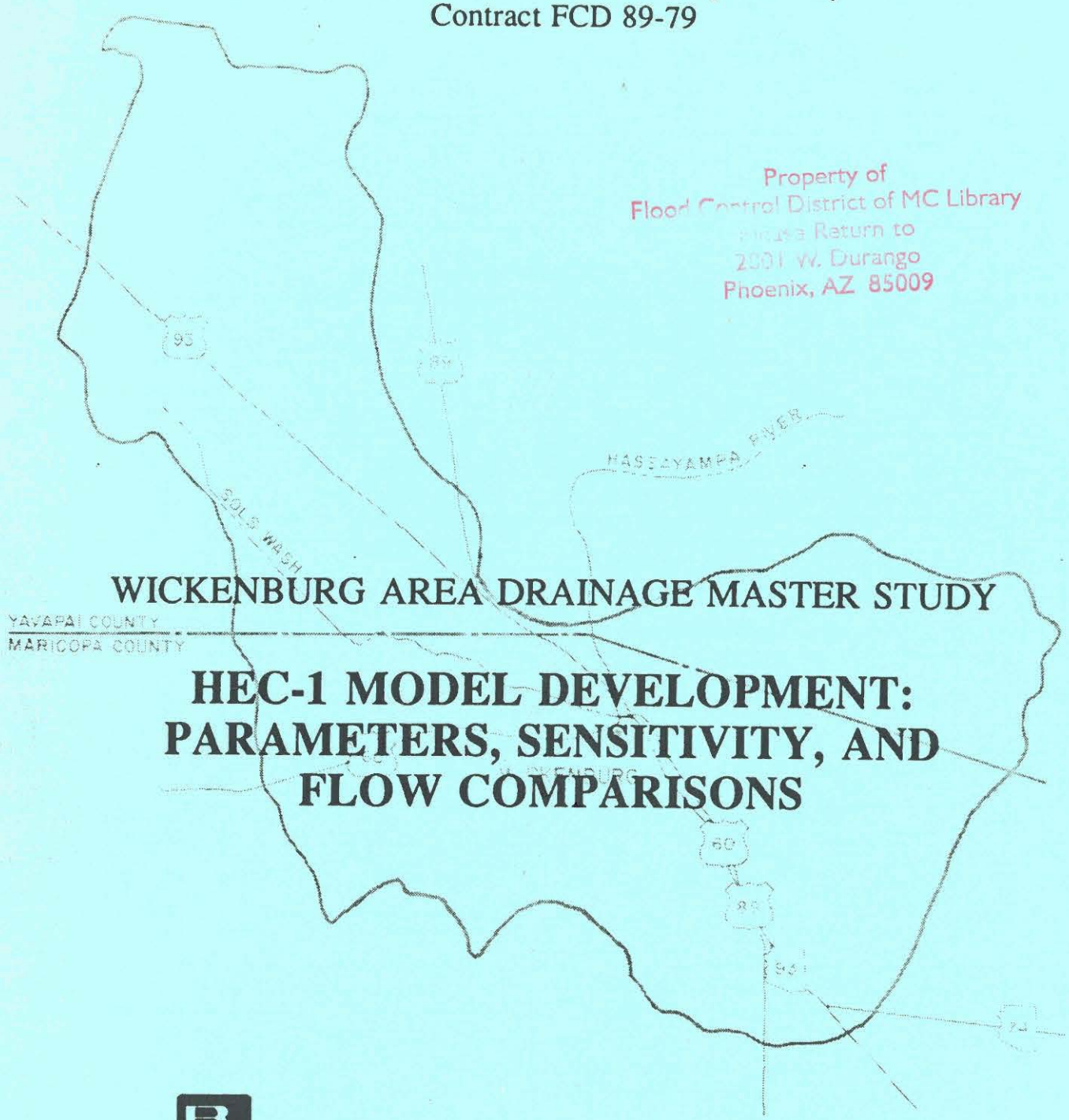

WICKENBURG AREA DRAINAGE MASTER STUDY

HEC-1 MODEL DEVELOPMENT: PARAMETERS, SENSITIVITY, AND FLOW COMPARISONS

BLACK & VEATCH
Progress By Design
Project No. 17676

COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE
CVL No. 1197-02

April, 1991

BLACK & VEATCH

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April 23, 1991

Flood Control District of Maricopa County
3335 W. Durango
Phoenix, AZ 85009

Subject: Wickenburg ADMS
Hydrology Reports

Attention: Mr. Greg Rodzenko

Gentlemen:

We are herewith submitting a final draft copy of the following documents for your review and comment:

1. Watershed Hydrology Report (Sols Wash included)
2. HEC-1 Model Development Report

We have incorporated comments from your office staff throughout the preparation of these draft reports. We welcome your final comments and revisions before final reproduction. Our internal review and quality control will continue during your review.

Please note that while the District is performing the review, we will be preparing a second report which will exclude the Sols Wash main channel sub areas. As we discussed, the second report will be used for the FEMA submittal.

Should you have any questions regarding this submittal, please contact us.

Sincerely,

Black & Veatch

David R. Mahaffay, P.E.
Project Director

COE & VAN LOO
Consultants, Inc.

Ashok C. Patel, P.E., R.L.S.
Project Manager

cc: Les Lampe (B&V)
Dick French (DRI)

Wickenburg Area Drainage Master Study
HEC-1 Model Development
Parameters, Sensitivity, and Flow Comparisons

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Figure 2 Sub-Basin Boundaries: Sols Wash Tributaries

Figure 3 Sub-Basin Boundaries: Hartman Wash

Figure 4 Soil Unit Boundaries: Hartman Wash

Figure 5 Sub-Basin Boundaries: Ox Wash

Figure 6 Soil Unit Boundaries: Ox Wash

1.0 Purpose and Scope

The purpose of this report is to document the development of the HEC-1 model for the Wickenburg Area Drainage Master Study. Included in model development are the establishment of basic model parameters, an examination of the sensitivity of model peak flows to several calibration parameters, and finally a comparison of the flows computed by the model with flow from frequency analyses of gauge data.

This report is limited to descriptions of the methods used to determine the appropriate modeling approach for the Study Area. The investigations have been limited to small drainage areas (0.32-6.8 sq. mi.) that represent two different hydrologic conditions in the Study Area. The final model of the entire watershed will be presented in the *Hydrology Report for the Wickenburg Area Drainage Master Study*. Modeling details were submitted to the Flood Control District of Maricopa County on March 6, 1991 as part of the Watershed Delineation Review.

2.0 Basic Model Parameters

Test computer models were developed to determine if the computed discharges are reasonable and to identify the sensitivity of the procedure to different unit hydrograph methods, precipitation distributions, and to methods of estimating the parameter L_{ca}.

2.1 Base Conditions.

Little San Domingo Wash (wash "S"), and three small tributaries of Sols Wash (washes AH3, AH4, and AH5) were selected for testing basic parameters. These watersheds represent two different hydrologic conditions encountered in the Study Area. Little San Domingo Wash (Figure 1) is a small tributary of the Hassayampa River near the southern limit of the Study Area. Most of the watershed lies in the Wickenburg Mountains. The watershed is subdivided into two sub-basins designated S1 and S2.

The tributaries of Sols Wash shown on Figure 2 represent conditions more typical of the Sols Wash area. Most of the watershed lies on the slightly gentler slopes at the base of the Vulture Mountains.

All models are based on:

Precipitation data from NOAA Atlas 2.
Topography available from USGS 7.5-minute maps.
Lag times and Clark storage coefficient from Hydrologic Design Manual for Maricopa County.
Losses computed using the Green-Ampt routines in HEC-1 with loss parameters computed using methods from the Hydrologic Design Manual for Maricopa County.

The hydrologic input parameters based on topographic data and soil information are summarized in Table 1.

2.2 Test Procedures

2.2.1 Unit Hydrograph

Tests were conducted to assess the applicability of the Clark Unit Hydrograph, the Phoenix Valley S-Graph, and the Phoenix Mountain S-Graph to the Study Area. The District's Hydrologic Design Manual (Ref. 1) recommends using the Clark Unit Hydrograph for sub-basins with tributary areas less than 5 square miles, and an S-Graph procedure for sub-basins with areas larger than 5 square miles. However, the District also recognizes that this limitation is a general guideline (Ref. 2), since the Clark Method is also dependent on other hydrologic parameters. According to District hydrologists, the Clark Method should not be used on sub-basins with time of concentration (Tc) values greater than 50 or 60 minutes.

Sub-basins with tributary areas ranging from 0.9 to 6.8 sq mi were modeled using the three methods described above. Tc values calculated for the Clark Method ranged from 35 to 89 min, with most values greater than 70 min. On this basis, the Clark Method does not appear appropriate for much of the Study Area. The Phoenix Valley S-Graph was developed for use in urbanized areas with watercourse slopes of 20 to 30 ft per mile. Watercourse slopes for the modeled sub-basins range from 76 to 288 ft per mile. Since these values are to be expected throughout the Study Area, the Phoenix Valley S-Graph does not appear appropriate. The hydrologic parameters for the sub-basins all fell within an acceptable range for the Phoenix Mountain S-Graph method.

2.2.2 Storm Duration

Watersheds were modeled using the 6-hour FCDMC and the 24-hour SCS Type-II rainfall distributions. The peak discharges from the models are shown in Table 2.

2.2.3 Lag Time

Watersheds were modeled to assess the sensitivity of lag time values and computed peak flows to different methods of estimating L_{ca}, the point on the main channel opposite the watershed centroid. For this assessment, L_{ca} was calculated as a percentage of the total watercourse length (L). The first models assume that Lca = .5(L). The second models assume that Lca = .6(L). The consequent variation in

lag time is 6% to 10%, and the resulting variation in peak flow is 4% to 6%. Lag times and peak flows are shown in Table 3.

2.3 Conclusions

2.3.1 Unit Hydrograph

The three unit hydrograph procedures produced a wide range of results. Based on the limitations described in Section 3.2.1, our judgement and discussions with the District, the Phoenix Mountain S-Graph procedure will be used for the Wickenburg ADMS.

2.3.2 Storm Duration

Under some conditions, models using the 6-hour FCDMC rainfall distribution may calculate peaks higher than the 24-hour SCS Type-II distribution. The SCS Type-II distribution is typically used to assess the effects of storage on the system. As the 6-hour distribution produced lower peaks in this situation, the 24-hour SCS Type-II distribution will be used for all hydrologic analyses.

2.3.3 Lag Time

The results indicate that lag time values and calculated peak flows are not sensitive to changes in L_{ca}. Therefore, any accuracy lost by visual estimation of sub-basin centroids will not significantly affect lag time values and calculated peak flows.

3.0 Calibration Parameter Sensitivity

Tests were performed to determine the sensitivity of the HEC-1 computed peak discharges to variations in values for RTIMP and Kn.

3.1 Base Conditions

Hartman Wash and Ox Wash were selected for the testing of peak flows to several calibration parameters. These washes represent the two different hydrologic conditions encountered in the Study Area.

Hartman Wash (Figures 3 and 4) is a tributary of Sols Wash, lying mostly on the gentle slopes at the base of the Vulture Mountains. The 5.41 square mile watershed is subdivided into three sub-basins denoted 150, 155, and 160.

Ox Wash (Figures 5 and 6) is a tributary of the Hassayampa River. The 6.1 sq mi) watershed lies mostly in the Wickenburg Mountains.

As with the basic model parameters tests, all HEC-1 modeling was based on:

Precipitation data from NOAA Atlas 2
Topography from USGS 7.5-minute maps
Lag times from the Hydrologic Design Manual for Maricopa County
Green and Ampt loss parameters computed using methods from the Hydrologic Design Manual for Maricopa County

The HEC-1 input parameters for Hartman Wash and Ox Wash based on topographic and soil data are summarized in Tables 4 and 5.

3.2 Test Procedures

3.2.1 RTIMP

To evaluate the effect of RTIMP on computed peak discharges, values of up to 50 were added to the base run RTIMP percentages. For example, for a base run RTIMP value of 10 percent, a test run value of up to 60 percent would be used. This represents an increase of 500% over the base run value.

3.2.2 Kn

Kn represents the average Manning's n value for all watercourses in the sub-basin. It reflects sub-basin hydraulic efficiency in the initial runoff hydrograph. Sensitivity of peak flows to Kn values was determined by changing all of the base run Kn values to 0.30. As the base run Kn values ranged from 0.35 to 0.40, this represents a change of between 14 and 25 percent.

3.2.3 IA, Manning's n

In addition to testing the model's sensitivity to changes in RTIMP and Kn, combinations of different IA and Manning's n values were tested to observe their effect on the computed discharges. These changes in Manning's n apply to the model's routines that route hydrographs through specific channels.

3.3 Conclusions

3.3.1 RTIMP

Peak discharges are insensitive to changes in RTIMP. Adding 15 to the base run RTIMP values in Hartman Wash (an increase of at least 188 percent) resulted in only a 7 percent increase in peak discharge. Similarly for Ox Wash, adding 50 to the base run RTIMP values (an increase of at least 550 percent) resulted in only a 28 percent increase in peak flow. The results of the sensitivity tests are summarized in Tables 6 and 7.

3.3.2 Kn

Peak discharges are somewhat sensitive to changes in Kn. Flows in Hartman Wash increased 7 percent over base run values, and those in Ox Wash increased by 17 percent. Thus the selection of Kn values is more critical in calibrating the HEC-1 model than is the selection of RTIMP.

3.3.3 IA and Manning's n

The HEC-1 model is insensitive to both IA and to Manning's n values, as shown in Tables 6 and 7. The effect of Manning's n on peak discharges is not only a function of magnitude but is also a function of routing reach lengths and the number of routings. Nevertheless, although the Hartman Wash model has one route

and the Ox Wash model has two, Manning's n has little effect on the final peak discharges.

4.0 Flow Comparisons

To verify the reasonableness of the HEC-1 model results, the peak flows from each run of the sensitivity test were compared to flows resulting from the FCDMC's analysis of USGS gaged data (Ref. 3) as well as from a USGS analysis of the gage data. Tables 8 and 9 summarize the results of these comparisons by showing the HEC-1 computed peak flows as a percentage of the FCDMC and USGS flows.

Accounting for the uncertainty of extrapolating 100-year flows from fewer than 20 years of data, the HEC-1 peak discharges are reasonable compared to the FCDMC and USGS Q_{100} figures.

REFERENCES

1. Flood Control District of Maricopa County, Special Projects Branch, Hydrology Division, Hydrologic Design Manual for Maricopa County, Arizona, September 1990.

2. Telephone conversation with Davar Khalili on December 19, 1990.

3. Flood Control District of Maricopa County, Hydrology - Scottsdale Alluvial Fan (unpublished document).

TABLE 1

HYDROLOGIC INPUT PARAMETERS

Concentration Point	AREA (sq mi)	Green & Ampt Parameters:					Tc (Clark)			LAG	
		IA	DTHETA (Dry)	PSIF (in)	XKSAT (M/M)	RTIMP (%)	LENGTH (mi)	K_D	SLOPE (ft/mi)	LAG* (min)	Kn
S1	4.6	0.15	0.31	3.81	0.31	8.70	7.9	.063	122	109	.05
S2	1.6	0.15	0.30	4.18	0.47	0.00	3.3	.075	76	63	.05
S	6.2	--	--	--	--	--	--	--	--	--	--
AH3	6.79	0.15	0.31	5.8	0.32	3.55	8.48	.059	90	80	.04
AH4	0.89	0.15	0.32	5.2	0.32	1.10	1.97	.081	288	21	.04
AH5	2.85	0.15	0.30	5.9	0.30	4.71	4.55	.068	83	50	.04

* Note: Basin lag was calculated using equation 5.11 on pg. 79 of the Hydrologic Design Manual for Maricopa County, Arizona with C=20km, p=0.5 and m=0.38.

TABLE 2

UNIT HYDROGRAPH/STORM DURATION TEST RESULTS
100-yr Flows (cfs)

Concentration Point	AREA (Sq Mi)	6-HOUR FCDMC DISTRIBUTION				24-HOUR SCS II DISTRIBUTION			FEMA	CBA (TR-20) (Ref 3)
		CLARK	S-GRAPH VALLEY	S-GRAPH MOUNTAIN		CLARK	S-GRAPH VALLEY	S-GRAPH MOUNTAIN	(Ref 2)	
S1	4.6	2128	2179	1897		2289	2352	2056	---	---
S2	1.6	646	846	728		730	1047	901	---	---
S	6.2	2740	2533	2311		3019	2738	2529	3090	---
AH3	6.8	---	---	---		2955	3463	2951	---	2417
AH4	0.9	---	---	---		822	1132	982	---	942
AH5	2.9	---	---	---		1215	2086	1799	---	1810

TABLE 3

LAG TIME AND PEAK FLOW SENSITIVITY TO L_{ca}

100-yr 24-hr SCS Type II Distribution
Phoenix Mountain S-Graph

Concentration Point	TEST 1 L_{ca} is 50% of L		TEST 2 L_{ca} is 60% of L		Q from TEST 2 as a % of Q from TEST 1
	Lag (min)	Q (cfs)	Lag (min)	Q (cfs)	
S1	107	2087	114	1987	95%
S2	60	936	65	880	94%
S	--	2562	--	2436	95%
AH3	80	2951	85	2841	96%
AH4	21	982	23	939	96%
AH5	50	1799	54	1729	96%

L_{ca} - The length along watercourse to a point opposite the centroid
L - Length of watercourse

TABLE 4

HEC-1 INPUT PARAMETERS:
HARTMAN WASH (5.41 sq mi)

SUBBASIN	AREA (sq mi)	LENGTH (mi)	Lca (%)	SLOPE (ft/mi)	GREEN & AMPT PARAMETERS				
					IA (in)	DTHETA (DRY)	PSIF (in)	XKSAT (in/hr)	RTIMP (%)
AI150	1.98	3.50	48.6	73.1	0.15	0.30	3.75	0.29	7.7
AI155	1.51	3.03	53.1	82.4	0.15	0.29	3.51	0.26	8.0
AI160	1.92	3.41	44.6	74.1	0.15	0.31	4.02	0.35	1.1

TABLE 5

HEC-1 INPUT PARAMETERS:
OX WASH (6.2 sq mi)

SUBBASIN	AREA (sq mi)	LENGTH (mi)	Lca (%)	SLOPE (ft/mi)	GREEN & AMPT PARAMETERS				
					IA (in)	DTHETA (DRY)	PSIF (in)	XKSAT (in/hr)	RTIMP (%)
SV2	3.16	3.56	42.0	127.9	0.15	0.30	3.70	0.25	9.1
SV4	0.74	2.22	63.0	85.6	0.15	0.32	4.16	0.38	3.5
SV10	1.72	2.67	50.0	128.5	0.15	0.32	3.86	0.33	7.5
SV16	0.48	1.36	43.0	109.2	0.15	0.33	4.20	0.45	4.3
SV20	0.32	1.69	51.0	92.4	0.15	0.29	3.64	0.28	6.0

TABLE 6

SENSITIVITY TESTS: HARTMAN WASH AT U.S. HWY 60 (5.41 sq. mi.)

Run #	Peak Q_{100}		IA (in)	RTIMP	Kn	Manning - n		
	(cfs)	(csm)				LOB	CHAN	ROB
1	3556	657	0.15	+ 0	0.035	0.040	0.025	0.040
2	3803	703	0.15	+ 15%	0.035	0.040	0.025	0.040
3	3803	703	0.15	--	0.030	0.040	0.025	0.040
4	3932	727	0.15	--	0.030	0.033	0.025	0.033
5	4223	781	0.15	+ 15%	0.030	0.033	0.025	0.033

(-) Indicates not changed from Base Run.

TABLE 7

SENSITIVITY TESTS: OX WASH (6.1 SQ. MI.)

Run #	Peak Q_{100}		IA (in)	RTIMP	Kn	Manning - n		
	(cfs)	(csm)				LOB	CHAN	ROB
1	3950	648	0.15	+ 0	0.040	0.045	0.030	0.045
2	5057	829	--	+ 50%	--	--	--	--
3	3970	651	0.10	--	--	--	--	--
4	4610	756	0.10	+ 30%	--	--	--	--
5	3990	654	0.05	--	--	--	--	--
6	4640	760	--	--	0.030	--	--	--
7	5010	821	--	+ 15%	0.030	--	--	--
8	5150	844	--	+ 15%	0.030	0.035	0.030	0.035
9	5260	862	--	--	--	- No Routings -		

(-) Indicates not changed from Base Run; vegetation cover was estimated at 15% for Hill Conditions/Landuse.

Note: Based on Gage Data $Q_{100\ yr.}$ = 5330 cfs (6.3 sq. mi.) or 846 CSM.

TABLE 8

FLOW SUMMARY: HARTMAN WASH AT U.S. HWY 60
(5.41 sq mi)

	HEC-1 Peak Q		HEC-1 Peak Q Percentages			
Run #	(cfs)	(csm)	FCDMC (1) Q_{100} = 1442 csm	Maricopa Co. (2) Average Q_{100} = 700 csm	Maricopa Co. (2) Maximum Q_{100} = 1360 csm	USGS (3) Q_{100} = 1377 csm
1	3554	657	46	94	48	48
2	3803	703	49	100	52	51
3	3803	703	49	100	52	51
4	3933	727	50	104	53	53
5	4225	781	54	112	57	57

(1) & (2) Maricopa County Flood Control Analysis of USGS Gage Data as presented in Hydrology - Scottsdale Alluvial Fan (Ref. 3). (1) Refers to data given in Table 1 specifically for Hartman Wash (Q_{100} = 7300 cfs). (2) "Average" and "Maximum" csm values are from Figure 1 for area = 5.41 mi^2.

(3) Based on USGS data for Hartman Wash (1964-1979).

TABLE 9

FLOW SUMMARY: OX WASH
(6.1 sq mi)

	HEC-1 Peak Q		HEC-1 Peak Q Percentages			
Run #	(cfs)	(csm)	FCDMC (1) Q_{100} = 754 csm	Maricopa Co. (2) Average Q_{100} = 680 csm	Maricopa Co. (2) Maximum Q_{100} = 1350 csm	USGS (3) Q_{100} = 846 csm
1	3950	648	86%	95%	48%	77%
2	5057	829	110%	128%	61%	98%
3	3970	651	86%	96%	48%	77%
4	4610	756	100%	111%	56%	89%
5	3990	654	87%	96%	48%	77%
6	4640	760	101%	112%	56%	90%
7	5010	821	109%	121%	61%	97%
8	5150	844	112%	124%	63%	100%
9	5260	862	114%	127%	64%	102%

(1) & (2) Maricopa County Flood Control Analysis of USGS Gage Data as presented in Hydrology - Scottsdale Alluvial Fan (Ref. 3). (1) Refers to data given in Table 1 specifically for Ox Wash (Q_{100} = 4600 cfs). The "Average" and "Maximum" CSM values are from Figure 1 for area = 6.1 mi^2.

(3) Based on USGS data for Ox Wash (1960-1979).

N.T.S.

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WICKENBURG ADMS FCD 89-79

SUB-BASIN BOUNDARIES:
LITTLE SAN DOMINGO WASH

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FIGURE 1

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
WICKENBURG ADMS FCD 89-79

SUB-BASIN BOUNDARIES:
SOLS WASH TRIBUTARIES

BLACK & VEATCH
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1991

FIGURE 2

N.T.S.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
WICKENBURG ADMS FCD 89-79

SUB-BASIN BOUNDARIES:
HARTMAN WASH

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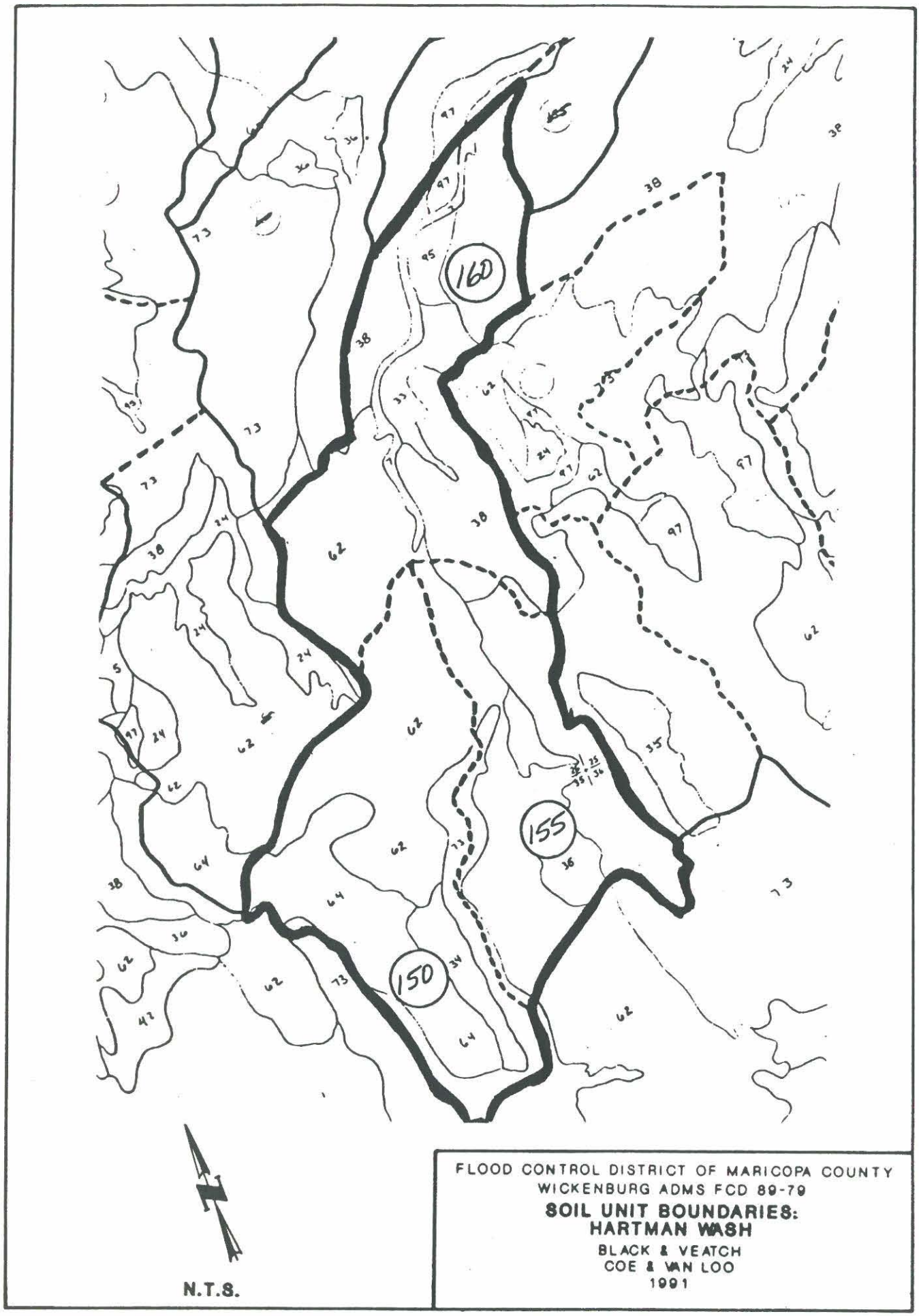
FIGURE 3


160
155
150
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FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
WICKENBURG ADMS FCD 89-79
SOIL UNIT BOUNDARIES:
HARTMAN WASH
BLACK & VEATCH
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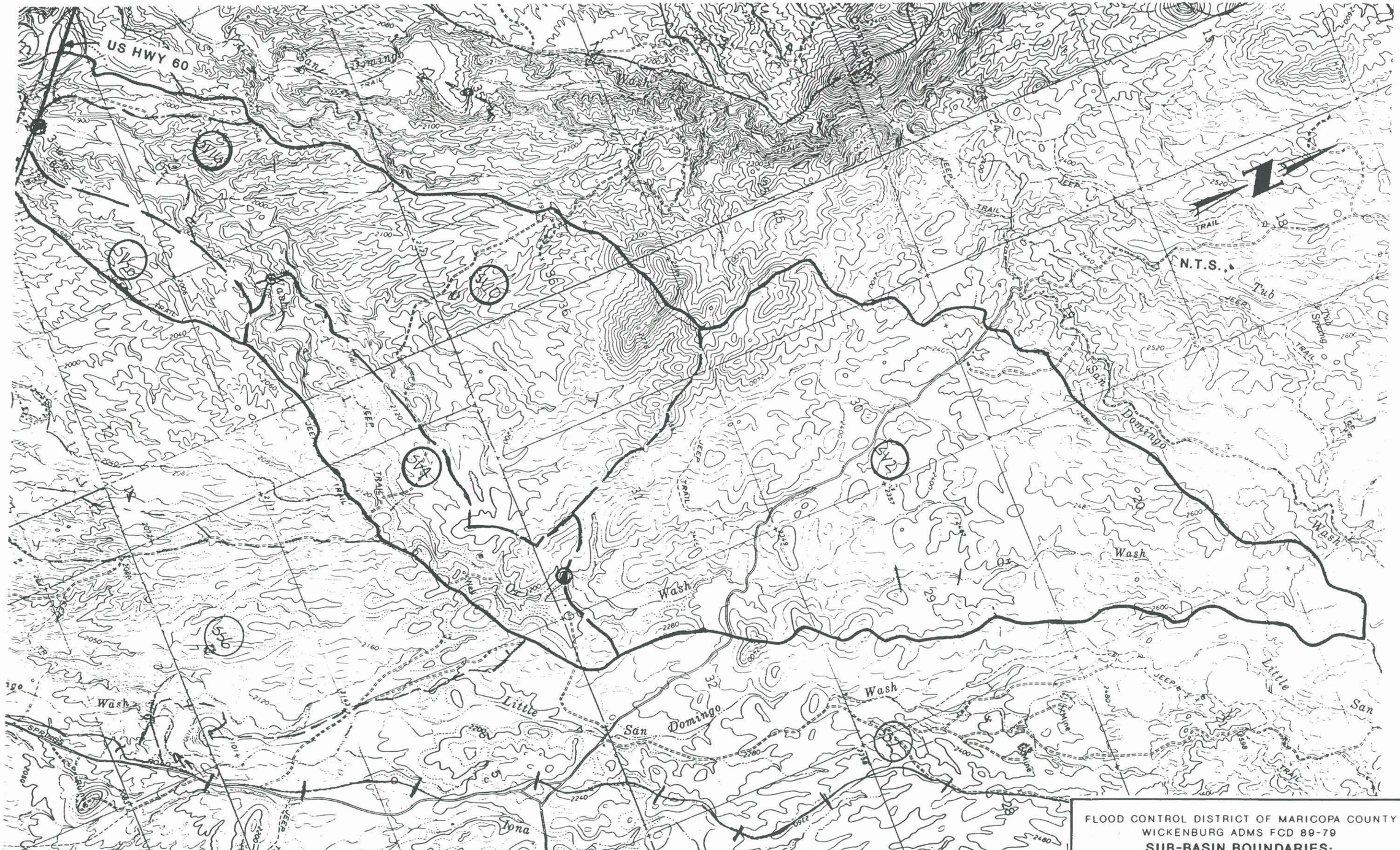
FIGURE 4



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SUB-BASIN BOUNDARIES:
OX WASH

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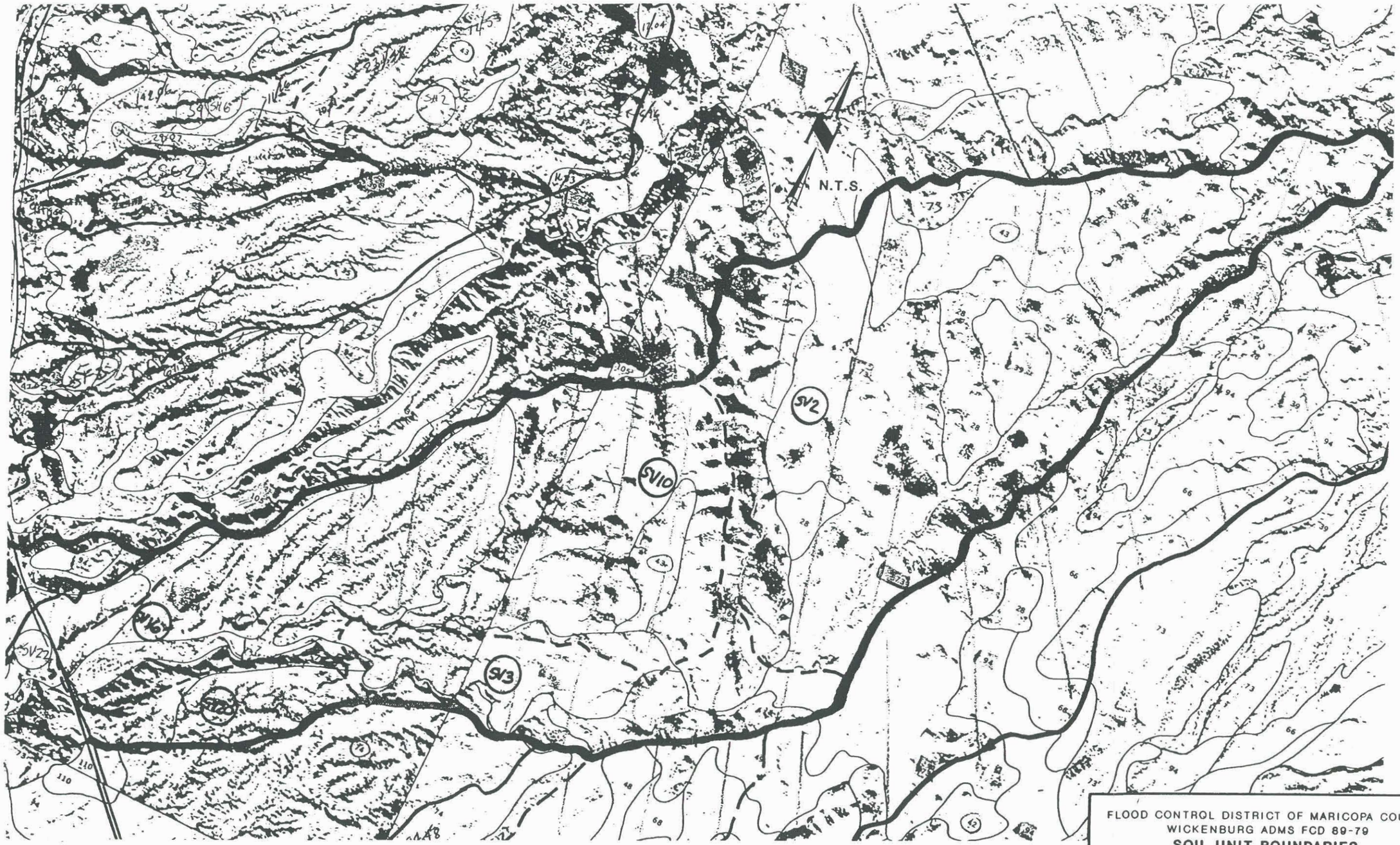
FIGURE 5



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SOIL UNIT BOUNDARIES:
OX WASH

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FIGURE 6