Flood Control District of Maricopa County
Contract FCD 89-79

WICKENBURG AREA DRAINAGE MASTER STUDY

TECHNICAL DOCUMENTATION REPORT

HYDROLOGIC ANALYSES

FLOODLAIN DELINEATION

Submitted to the
Federal Emergency Management Agency
on Behalf of the
Flood Control District of Maricopa County

BLACK & VEATCH
PROGRESS BY DESIGN

Project No. 17676

COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

CVL No. 1197-02

May 1994

Flood Control District of Maricopa County
Contract FCD 89-79

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Preface

The Director of the Arizona Department of Water Resources (ADWR) has established technical documentation standards for floodplain delineation studies submitted to the ADWR or the Federal Emergency Management Agency by communities, counties, or individuals in Arizona. This report is in accordance with the technical documentation standards as set forth in the ADWR publication entitled *Instructions for Organizing and Submitting Technical Documentation for Flood Studies* (ADWR, September 1991).

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I. Abstract

i Section 1 - General Information

1a & b) Communities involved in this study.

Community (1A)	NFIP Number (1B)
Maricopa County, Unincorporated Areas	040037
Wickenburg, Town of	040056

1c) County where communities are located (1C): Maricopa County

1d) State where communities are located: Arizona (AZ)

1e) Date that study was accepted by FEMA: February 21, 1995

1f) • This study was prepared for:

Agency: Flood Control District of Maricopa County (FCDMC)
Address: 2801 W. Durango Street
Phoenix, AZ 85009
Phone No: (602) 506-1501
Project Manager: Mr. Greg Rodzenko
Project No: FCD 89-79

• This floodplain delineation study was prepared by:

Study Contractor: Black & Veatch, Inc.
Address: 2111 East Highland Avenue, Suite 305
Phoenix, AZ
Phone No: (602) 381-4400
Project Manager: Mr. David Mahaffay, P.E.
Project No: 17676

Sub-Consultant: Coe & Van Loo Consultants, Inc.
Address: 4550 N. 12th Street
Phoenix, AZ 85014
Phone No: (602) 264-6831
Project Manager: Mr. David W. Dust, P.E.
Project No: 1197-020

• Survey and aerial mapping for this study was prepared by:

Sub-Consultant: McLain Harbers Co., Inc.
Address: 720 W. Prince Road
Tucson, AZ 85705
Phone No: (602) 887-7272
Project Manager: Mr. Lee Harbers

Sub-Consultant:	Western Air Maps, Inc.
Address:	13001 West 95th Street Lenexa, Kansas 66215
Phone No:	(913) 888-5266
Project Manger:	Mr. Scott Perkins

Sub-Consultant:	Morrison-Mairle/CSSA
Address:	4621 North 16th Street, Suite D-401 Phoenix, Arizona 85016
Phone No:	(602) 277-2828
Project Manager:	Mr. James Spring

1g) FEMA Technical Evaluation Contractor (TEC)

Company: _____

Contact: _____

Phone No: _____

1h) FEMA Regional Reviewer

Contact: _____

Phone No: _____

1i) State Reviewer:

Contact: N/A

Phone No: N/A

1j) Community Reviewer

Agency: Flood Control District of Maricopa County (FCDMC)

Contact: Mr. Greg Rodzenko

Phone No: (602) 506-1501

1k) Names of Watercourses Analyzed

Since many of the washes delineated in this study are un-named, identification letters (i.e., ID letters) were assigned to each wash delineated in this study. (Note: EPA Reach numbers have not been established for any of the washes in this study.)

ID Letter(s)	Watercourse Name	FIRM Panel #
a	Amir Wash	235 & 255
b	Calamity Wash	255
c	Blue Tanks Wash	255
d	Monarch Wash & Tributaries	270
e	Mockingbird Wash and Tributaries	255
f	Un-Named Wash (#1)	270
g	Un-Named Wash (#2)	270
h	Un-Named Wash (#3)	270
i	Un-Named Wash (#4)	270
j	Un-Named Wash (#5)	270
k	Un-Named Wash (#6)	265 & 270
l	Un-Named Wash (#7)	260 & 265
m	Un-Named Wash (#8)	255 & 265
n	Un-Named Wash (#11)	255
o	Un-Named Wash (#12)	255
p	Un-Named Wash (#13)	255
q	Un-Named Wash (#14)	255
r	Cemetery Wash and Tributaries	235 & 255
s	Little San Domingo Wash	660 & 680
t	San Domingo Wash	270
v	Ox Wash	270
w	Turtleback Wash	255
aa	Powder House Wash	255
ab	Flying E Wash and Tributaries	235
ad	Sunset Wash	255
ae	Sunny Cove Wash	255
af	Un-Named Wash (#9)	255
ag	Un-Named Wash (#10)	255
ah	Sols Wash Tributaries: Four Un-Named Washes	230 & 255
ai	Hartman Wash	230 & 255

1l) Type of Study: All watercourses were evaluated as riverine watercourses, with ponding areas at various locations.

ii Section 2 - Mapping Information

2a&b) The following USGS maps cover the study area and were used in the hydrologic analysis:

U.S. Geological Survey, 7.5 Minute Series (Topographic)
Congress SW Quadrangle, 1968, field checked 1969
Flores Quadrangle, 1968, field checked 1969
Morgan Butte Quadrangle, 1968, field checked 1969
Outlaw Hill Quadrangle, 1984, field checked 1986
Red Picacho Quadrangle, 1962, field checked 1964
Sam Powell Peak Quadrangle, 1968, field checked 1969
Vulture Peak Quadrangle, Provisional Edition, 1990
Wickenburg Quadrangle, 1962, field checked 1964
Wickenburg SW Quadrangle, 1962, field checked 1964
Wildcat Well Quadrangle, 1984, field checked 1986
Wittman Quadrangle, 1962, field checked 1965

U.S. Geological Survey, 30 x 60 Minute Series (Topographic)
Phoenix North Quadrangle, 1988
Salome Quadrangle, 1984

U.S. Bureau of Land Management 30 x 60 Minute Series (Topographic)
Bradshaw Mountains Quadrangle, 1984
Alamo Lake Quadrangle, 1979

iii Section 3 - Hydrologic Analysis

3a) Hydrologic computations were performed using the HEC-1 Flood Hydrograph Package: February 1981, Revised August, 1988 (Vendors: NTIS and Dodson & Associates). The study area encompasses approximately 146 square miles of watershed. For the purposes of this study, the study area has been divided into the following smaller study areas:

- Sols Wash Area (Drainage Area = 46 sq. mi.);
- West tributaries to the Hassayampa River (Drainage Area = 17 sq. mi.); and
- East tributaries to the Hassayampa River (Drainage Area = 83 sq. mi.).

3b&c) The SCS Type II - 24 hour rainfall distribution, the Green-Ampt initial abstraction algorithm; and the Phoenix Mountain S-Graph algorithm were used in the HEC-1 computations in this study.

3d) The peak discharges computed for each of the watercourses are given in Tables I-1, I-2, & I-3.

Table I-1: Sols Wash Area
HEC-1 Output Summary:
Peak Flows (cfs)

		STORM RETURN PERIOD (years)				
HEC-1 ID	DESCRIPTION	2	10	25	50	100
SA	Amir Wash	19	593	935	1222	1500
SAH65	Sols Wash Tributary AH2	530	2838	4026	5001	6031
CAH96	Sols Wash Tributary AH3	279	1795	2662	3360	4046
SAH100	Sols Wash Tributary AH4	89	441	618	763	907
SAH120	Sols Wash Tributary AH5	282	1070	1463	1787	2129
CAI162	Hartman Wash @ Hwy 60	400	1897	2509	3056	3641
CAI171	Hartman Wash Outflow	297	2018	2772	3312	3802
SAB180	Twin Peaks Wash	221	650	866	1049	1231
SAB190	Yucca Tank	360	1095	1464	1776	2085
CAB186	Twin Peaks Wash Outflow	287	1022	1424	1759	2099
SAB200	George's Tank	148	466	627	761	896
CAB206	Flying E Tank	345	1124	1506	1829	2152
CAB208	Flying E Wash @ Hwy 60	889	3494	4769	5856	6943
CAB211	Flying E Wash Outflow	811	3732	5244	6479	7708

Table I-2: West Tributaries Area
HEC-1 Output Summary:
Peak Flows (cfs)

		STORM RETURN PERIOD (years)				
HEC-1 ID	DESCRIPTION	2	10	25	50	100
RAD4	Sunset Wash	0	0	0	0	0
RAE12	Sunny Cove Wash	0	0	0	0	0
CAD16	Sunny Cove Wash	34	271	409	506	600
SAG2	Unnamed Wash # 10	37	138	194	233	272
CR52	Cemetery Wash	780	3250	4848	5968	7251
SQ2	Unnamed Wash # 14	112	317	428	507	584
CW8	Turtleback Wash	773	2359	3206	3816	4412
CW22	Turtleback Wash	859	2659	3649	4408	5180

Table I-3: East Tributaries Area
HEC-1 Output Summary:
Peak Flows (cfs)

		STORM RETURN PERIOD (years)				
HEC-1 ID	DESCRIPTION	2	10	25	50	100
SP	Unnamed Wash # 13	209	498	666	781	898
CC22	Blue Tank Wash	712	2253	2909	3448	4071
SN	Unnamed Wash # 11	124	251	325	377	429
CAA17	Powder House Wash	473	1164	1564	1839	2114
SAF	Unnamed Wash # 9	124	246	319	369	420
CB12	Calamity Wash	427	1559	2252	2713	3098
SO	Unnamed Wash # 12	519	1126	1480	1735	1995
CE22	Mockingbird Wash	410	1729	2522	3001	3459
SM	Unnamed Wash # 8	110	227	295	343	390
SL	Unnamed Wash # 7	190	447	596	699	802
CK17	Unnamed Wash # 6	539	1317	1805	2153	2508
SJ	Unnamed Wash # 5	113	270	361	424	488
CI17	Unnamed Wash # 4	380	976	1320	1556	1795
CD24	Monarch Wash	651	2068	2744	3280	3832
CH8	Unnamed Wash # 3	433	896	1179	1394	1631
SG2	Unnamed Wash # 2	94	274	380	453	526
SF2	Unnamed Wash # 1	72	183	251	298	345
CT30	San Domingo Wash	1771	5983	8841	10780	12760
CV24	Ox Wash	976	2232	3116	3773	4447
CS22	Little San Domingo Wash	582	1668	2279	2847	3403

3e) There is insufficient gauge data available for direct calibration of the computer models; however, Table I-4 is a listing of the gauge data available.

Table I-4: Available USGS Gauge Data

Wash ID	Station No.	Name	D.A. Sq. Mi.	Record Period
v	516600	Ox Wash near Morristown	7.44	1963-1979
ac	515800	Hartman Wash near Wickenburg	5.57	1964-1979

3f) The 24-hour point precipitation depths used in this study are based on NOAA Atlas 2, Volume VIII (1973) isopluvial mapping and listed in Table I-5.

Table I-5: 24 Hour Point Precipitation Values

Return Frequency	Sols Wash Area (inches)	West Tributaries Area (inches)	East Tributaries Area (inches)
2 year	1.60	1.61	1.91
10 year	2.70	2.68	2.85
25 year	3.30	3.30	3.43
50 year	3.80	3.74	3.84
100 year	4.30	4.19	4.25

3g) In accordance with FCDMC drainage policy, the point precipitation values were adjusted with areal reduction factors obtained from NOAA Technical Memorandum NWS-HYDRO 40 (1984). The aerial reduction factors and adjusted point precipitation values are given in Table I-6.

Table I-6

Sols Wash Area
Areal Precipitation Reduction Data

Watershed Area (sq mi)	Areal Reduction Factor	24-Hour Precipitation Depth (inches)				
		100-Year	50-Year	25-Year	10-Year	2-Year
0.0	1.00	4.30	3.80	3.30	2.70	1.60
3.0	0.98	4.21	3.72	3.23	2.65	1.57
10.0	0.96	4.13	3.65	3.17	2.59	1.54
20.0	0.92	3.96	3.50	3.04	2.48	1.47
30.0	0.90	3.87	3.42	2.97	2.43	1.44
50.0	0.88	3.78	3.34	2.90	2.38	1.41
100.0	0.85	3.66	3.23	2.81	2.30	1.36

West Tributaries Area
Areal Precipitation Reduction Data

Watershed Area (sq mi)	Areal Reduction Factor	24-Hour Precipitation Depth (inches)				
		100-Year	50-Year	25-Year	10-Year	2-Year
0.0	1.00	4.19	3.74	3.30	2.68	1.61
3.0	0.98	4.11	3.67	3.23	2.63	1.58
10.0	0.96	4.02	3.59	3.17	2.57	1.55

East Tributaries Area
Areal Precipitation Reduction Data

Watershed Area (sq mi)	Areal Reduction Factor	24-Hour Precipitation Depth (inches)				
		100-Year	50-Year	25-Year	10-Year	2-Year
0.0	1.00	4.25	3.84	3.43	2.85	1.91
3.0	0.98	4.17	3.76	3.36	2.79	1.87
10.0	0.96	4.08	3.69	3.29	2.74	1.83
20.0	0.92	3.91	3.53	3.16	2.62	1.76

iv Section 4 - Hydraulic Analyses

4a) Hydraulic analyses were performed using HEC-2: Version 4.6.2 - May 1991 (Vendors: NTIS and Dodson & Associates, Inc.).

4b) All water surface computations were performed in the "subcritical" mode and all floodplain delineations correspond to computed subcritical or critical depths.

4c) Water surface profiles were calculated for the 100 year event.

4d) The washes delineated in this study exhibit a wide range of geomorphologic and hydraulic characteristics. Therefore, several criteria and methodologies were used to determine floodway boundaries. Initially, floodway limits were evaluated using HEC-2 encroachment methods 4 & 6 as specified with ET-cards. The floodway limits for natural watercourses were then evaluated and revised where appropriate, based on the following criteria.

The floodway boundaries may have been set equal to the floodplain boundaries in locations where:

- the watercourse is braided and the main channel can laterally migrate throughout the floodplain;
- the watercourse is confined within steep canyon walls;
- encroaching on the floodplain resulted in a significant increase in either the overbank or channel velocities; or
- the main channel and/or low flow channels can laterally migrate within backwater areas upstream of roadway and/or railroad culverts.

4e) Several unique hydraulic conditions or features were identified along the watercourses delineated in this study. The following is a summary of the unique conditions or features for the watercourses evaluated in this study; whereas, detailed descriptions and supplemental calculations are given in Appendix 1.1.

- Critical Depth: Nearly all of the washes evaluated in this study have relatively steep bed slopes; hence, the subcritical water surface profiles computed with HEC-2 often default to critical depth.
- Bridges/Culverts: To evaluate hydraulic conditions at bridges and culverts, the HEC-2 normal bridge, special bridge, and special culvert options have been used where appropriate. In several locations, U.S. Highway 60 has

divided roadway and dual bridges/culverts. If required, supplemental computations were used to set water surface elevations when HEC-2 computations inadequately simulated flow over the roadways.

- Hassayampa River Floodplain: Most of the watercourses evaluated in this study are tributaries to the Hassayampa River. Hence, at the confluences, the Hassayampa River floodplain extends into the tributaries and is shown on the floodplain delineation maps. At the confluence the Hassayampa River floodplain is typically at a higher elevation than the water surface elevation computed for the tributary at the confluence.
- Drop Structures: There are three significant drop structures within the study area. These structures are located at the outlet of U.S. Highway 60 culverts for Wash V - Ox Wash, Wash S - Little San Domingo Wash and Wash AI - Hartman Wash.
- Retention Basins/Tanks: For hydraulic analyses, the study area includes two flood control detention facilities (Sunset Dam; Sunny Cove Dam) and three small stock watering tanks (Yucca Tank, George's Tank, Flying E Tank).

  Sunset Dam and Sunny Cove Dam were constructed in 1975-1976 based on SCS design. Peak flows were established using the design rating curve for each dam's spillway.

  Yucca Tank is not considered in the hydraulic analysis, as the dam lies upstream of the study limit. No construction data is available.

  Flying E Tank is a side-channel storage facility, and is not considered in the hydraulic analysis. No construction data is available. Low flow is diverted by a low (1 ft.) obstruction into storage. Higher flows continue into the channel.

  George's Tank is a run-of-river storage tank. No construction data is available. There is no constructed spillway. The top of dam is 7 ft. higher than an area along the west edge of the tank just south of a rock formation that serves as the left abutment for the earth fill dam. A summary of the conditions and analyses for this area is included as a special problems report entitled George's Tank Breakout.

- Non-engineered Levees/Berms: Non-engineered levees/berms were identified at various locations. Typically, these levees/berms are one to three feet in height, composed of non-compacted material, irregular in shape, and lack any discernible erosion protection. Hence, it was assumed that the levees/berms would fail completely when overtopped.
- Flow Break-outs: At various locations, minor flow break-outs and/or divided flow can occur. Typically, these break-outs only occur over short distances (i.e. less than 500 feet); hence, normal depth calculations were used to estimate flow splits and appropriate flooding depths along the minor or secondary channels.
- Decreasing Peak Discharges: The results of the hydrologic analyses indicate that there are several washes, located in the East Tributaries Area, where the computed 100-year peak discharge is lower at the downstream limit of the wash than at some upstream locations. This decrease in the computed 100-year peak discharge is significant in some cases. Several physical and hydrologic factors can contribute in making the computed peak discharge decrease in the downstream direction.
- Computed Water Surface Elevation Below Ground Contours: At a few locations along some of the small washes, the computed water surface elevation is at a lower elevation than the ground contour elevation. This can occur, since the HEC-2 cross section data is more accurate than the contour mapping. However, this condition only occurs in locations where the computed flow depth is less than one half of the mapping contour interval. In locations where the computed water surface elevation is below the ground contour elevation, a flow depth is also indicated on the mapping to help clarify the flooding conditions at that location.

1.0 General Documentation & Correspondence

1.1 Special Problem Reports

Several unique hydrologic/hydraulic conditions were identified in the course of this floodplain delineation study. General Special Problems encountered during the hydraulic analysis phase of the study are documented in Section 4.5 of this report; whereas, Specific Special Problem reports, which may include supplemental computations, are given in Appendix 1.1

1.2 Contact Reports

Contact reports or summaries of telephone conversations, pertinent to this study, are given in Appendix 1.2.

1.3 Meeting Minutes

Meeting minutes pertinent to this study are given in Appendix 1.3.

1.4 General Correspondence

Copies of public notices and correspondence with community representatives, FEMA, and other agencies are given in Appendix 1.4.

1.5 Scope of Work

The Scope of Work for this study, as developed by the FCDMC, is given in Appendix 1.5. It is important to note that various elements of the scope of work were revised during the course of the study.

2.0 Mapping & Survey Information

2.1 Description of Mapping

The floodplain delineation Work Maps for this study are 1" = 200' topographic maps, with 2 or 4 foot contour intervals. In general, 2 foot contour interval mapping was prepared for the Town of Wickenburg and areas adjacent to the Town; whereas, 4 foot contour interval mapping was prepared for outlying areas. Detailed control survey information for the mapping prepared for this study is given in Appendix 2.1.

2.2 Map Indices

The floodplain delineation work maps include three map indices. The Master Index Map (Sheet 2/137) illustrates the washes evaluated in the study and the limits of the East and West Area Index Maps. The East and West Area Index Maps (Sheets 3&4 of 137) indicate ERM locations and sheet numbers for the floodplain delineation work maps. Index maps for the study are given in Appendix 2.2.

2.3 Survey Field Notes

As indicated in the abstract (item 1f), survey services for this study were provided by McLain Harber Co., Inc. and Morrison-Maierle/CSSA. The control survey data for this study are given in Appendix 2.1.

2.4 Watershed Mapping

USGS quadrangle maps (ie, 7.5 minute series maps) were used to delineate and illustrate the watershed boundaries for the washes delineated in this study. During the watershed delineation process, the 1" = 200' scale mapping and site visits were also used to aid in the delineation of the watershed boundaries. The watershed delineation maps are given in Appendix 3.0; however, the following USGS maps cover the study area and were used in the hydrologic analysis:

U.S. Geological Survey, 7.5 Minute Series (Topographic)
- Congress SW Quadrangle, 1968, field checked 1969
- Flores Quadrangle, 1968, field checked 1969
- Morgan Butte Quadrangle, 1968, field checked 1969
- Outlaw Hill Quadrangle, 1984, field checked 1986
- Red Picacho Quadrangle, 1962, field checked 1964
- Sam Powell Peak Quadrangle, 1968, field checked 1969
- Vulture Peak Quadrangle, Provisional Edition, 1990
- Wickenburg Quadrangle, 1962, field checked 1964
- Wickenburg SW Quadrangle, 1962, field checked 1964
- Wildcat Well Quadrangle, 1984, field checked 1986
- Wittman Quadrangle, 1962, field checked 1965

2.5-2.8 Floodplain Delineation Mapping

The floodplain delineation work maps for this study are 1" = 200' topographic maps, with 2 and 4 foot contour intervals. In general, 2 foot contour interval mapping was prepared for the Town of Wickenburg and adjacent areas; whereas, 4 foot contour interval mapping was prepared for outlying areas. The Index maps and/or the floodplain delineation maps indicate:

a) Community boundaries;

b) Street and highway names/numbers;

c) Cross section alignments with river mile and letter designation;

d) Computed water surface elevations;

e) Computed 100 year peak discharges;

f) Floodplain and floodway boundaries; and

g) Current Hassayampa River floodplain boundaries.

The floodplain delineation maps, with index maps, are given in Appendix 4.32.

3.0 Hydrologic Analyses

3.1-3.5 Methodology & Background

The Wickenburg study area encompasses approximately 146 square miles of watershed. Based on geographic and hydrologic considerations, the study area has been divided into the following smaller study areas:

- Sols Wash Area (D.A. = 46 sq. mi.);
- West Tributaries to the Hassayampa River (D.A. = 17 sq. mi.); and
- East Tributaries to the Hassayampa River (D.A. = 83 sq. mi.).

Hydrologic computations were performed using the HEC-1 Flood Hydrograph Package: February 1981 - Revised August 1988, as distributed by NTIS and Dodson & Associates, Inc. The SCS Type II - 24 hour rainfall distribution, the Green-Ampt initial abstractions algorithm, and the Phoenix Mountain S-Graph were used in the HEC-1 computations for this study.

The hydrologic analyses for the study area are documented in detail in Appendix 3.0 - Watershed Hydrology Report: Volumes I, IIa, and IIb. Therefore, only a summary of the results of the hydrologic analyses is presented herein.

3.5 Summary of Results

The results of the hydrologic analyses are summarized in Tables 3-1 through 3-8 as follows.

- Table 3-1: 24-Hour Point Precipitation Values as obtained from NOAA Atlas 2, Volume VIII (1973).
- Table 3-2: Depth-Area Factors, as obtained from NOAA Technical Memorandum NWS-HYDRO 40 (1984).
- Table 3-3: Sols Wash Area - Peak Flows
- Table 3-4: West Tributaries Area - Peak Flows
- Table 3-5: East Tributaries Area - Peak Flows

Table 3-1: 24-Hour Point Precipitation Values

Return Frequency	Sols Wash Area (inches)	West Tributaries Area (inches)	East Tributaries Area (inches)
2 year	1.60	1.61	1.91
10 year	2.70	2.68	2.85
25 year	3.30	3.30	3.43
50 year	3.80	3.74	3.84
100 year	4.30	4.19	4.25

Table 3-2: Depth-Area Factors

Watershed Area (Square Miles)	Depth-Area Factor
0.0	1.00
3.0	0.98
10.0	0.96
20.0	0.92
30.0	0.90
50.0	0.88
100.0	0.85
150.0	0.83

Table 3-3: Sols Wash Area
HEC-1 Output Summary:
Peak Flows (cfs)

		STORM RETURN PERIOD (years)				
HEC-1 ID	DESCRIPTION	2	10	25	50	100
SA	Amir Wash	19	593	935	1222	1500
SAH65	Sols Wash Tributary AH2	530	2838	4026	5001	6031
SAH80	Sols Wash Tributary AH3	279	979	1330	1620	1908
CAH86	Sols Wash Tributary AH3	174	1177	1753	2253	2741
SAH90	Rt. Bank Tributary to AH3	282	877	1176	1429	1680
CAH96	Sols Wash Tributary AH3	279	1795	2662	3360	4046
SAH100	Sols Wash Tributary AH4	89	441	618	763	907
SAH120	Sols Wash Tributary AH5	282	1070	1463	1787	2129
CAI162	Hartman Wash @ Hwy 60	400	1897	2509	3056	3641
CAI167	Hartman Wash	384	2013	2587	3096	3660
CAI171	Hartman Wash Outflow	297	2018	2772	3312	3802
SAB180	Twin Peaks Wash	221	650	866	1049	1231
SAB190	Yucca Tank	360	1095	1464	1776	2085
CAB186	Twin Peaks Wash Outflow	287	1022	1424	1759	2099
SAB200	George's Tank	148	466	627	761	896
CAB206	Flying E Tank	345	1124	1506	1829	2152
CAB208	Flying E Wash @ Hwy 60	889	3494	4769	5856	6943
CAB211	Flying E Wash Outflow	811	3732	5244	6479	7708

Table 3-4: West Tributaries Area
HEC-1 Output Summary:
Peak Flows (cfs)

		STORM RETURN PERIOD (years)				
HEC-1 ID	DESCRIPTION	2	10	25	50	100
RAD4	Sunset Wash	0	0	0	0	0
RAE12	Sunny Cove Wash	0	0	0	0	0
CAD16	Sunny Cove Wash	34	271	409	506	600
SAG2	Unnamed Wash # 10	37	138	194	233	272
CR6	Cemetery Wash	290	917	1252	1491	1724
CR12	Cemetery Wash	388	1542	2001	2392	2797
CR20	Cemetery Wash	309	954	1303	1551	1793
CR28	Cemetery Wash	531	1710	2364	2839	3304
CR34	Cemetery Wash	694	3084	4373	5317	6308
CR40	Cemetery Wash	743	3362	4766	5776	6870
CR46	Cemetery Wash	783	3399	4947	6088	7299
CR52	Cemetery Wash	780	3250	4848	5968	7251
SQ2	Unnamed Wash # 14	112	317	428	507	584
SW2	Turtleback Wash	381	1020	1375	1628	1873
CW8	Turtleback Wash	773	2359	3206	3816	4412
CW16	Turtleback Wash	863	2757	3695	4469	5244
CW22	Turtleback Wash	859	2659	3649	4408	5180

Table 3-5: East Tributaries Area HEC-1 Output Summary: Peak Flows (cfs)

		STORM RETURN PERIOD (years)				
HEC-1 ID	DESCRIPTION	2	10	25	50	100
SP	Unnamed Wash # 13	209	498	666	781	898
SC5	Blue Tank Wash	653	1513	2011	2358	2732
CC12	Blue Tank Wash	695	2114	3018	3654	4290
CC17	Blue Tank Wash	714	2258	2938	3488	4140
CC22	Blue Tank Wash	712	2253	2909	3448	4071
SN	Unnamed Wash # 11	124	251	325	377	429
CAA12	Powder House Wash	480	1127	1508	1768	2034
CAA17	Powder House Wash	473	1164	1564	1839	2114
SAF	Unnamed Wash # 9	124	246	319	369	420
SB5	Calamity Wash	328	1195	1710	2062	2415
CB12	Calamity Wash	427	1559	2252	2713	3098
SO	Unnamed Wash # 12	519	1126	1480	1735	1995
CE12	Mockingbird Wash	232	578	779	917	1056
SE15	Mockingbird Wash	318	1225	1792	2182	2567
CE19	Mockingbird Wash	362	1480	2158	2496	2754
CE22	Mockingbird Wash	410	1729	2522	3001	3459
SM	Unnamed Wash # 8	110	227	295	343	390
SL	Unnamed Wash # 7	190	447	596	699	802
CK12	Unnamed Wash # 6	423	966	1286	1509	1739
CK17	Unnamed Wash # 6	539	1317	1805	2153	2508
SJ	Unnamed Wash # 5	113	270	361	424	488
CI12	Unnamed Wash # 4	385	926	1241	1458	1684
CI17	Unnamed Wash # 4	380	976	1320	1556	1795
CD12	Monarch Wash	692	2169	3042	3656	4245
CD17	Monarch Wash	644	2021	2700	3231	3774
CD24	Monarch Wash	651	2068	2744	3280	3832
SH2	Unnamed Wash # 3	440	982	1301	1521	1742
CH8	Unnamed Wash # 3	433	896	1179	1394	1631
SG2	Unnamed Wash # 2	94	274	380	453	526
SF2	Unnamed Wash # 1	72	183	251	298	345
ST2	San Domingo Wash	907	2499	3418	4052	4682

Table 3-5: East Tributaries Area HEC-1 Output Summary: Peak Flows (cfs)

		STORM RETURN PERIOD (years)				
HEC-1 ID	DESCRIPTION	2	10	25	50	100
CT8	San Domingo Wash	1236	3797	5349	6489	7621
CT11	San Domingo Wash	1471	5015	7315	8978	10655
CT14	San Domingo Wash	1781	6061	8729	10646	12612
CT17	San Domingo Wash	1789	6090	8906	10878	12911
CT24	San Domingo Wash	1827	6042	9020	11093	13242
CT30	San Domingo Wash	1771	5983	8841	10780	12760
SV2	Ox Wash	911	1910	2494	2902	3315
CV6	Ox Wash	880	1806	2455	2917	3390
CV12	Ox Wash	1027	2268	3099	3738	4406
CV18	Ox Wash	976	2228	3084	3734	4402
CV24	Ox Wash	976	2232	3116	3773	4447
SS2	Little San Domingo Wash	691	1585	2106	2467	2849
CS8	Little San Domingo Wash	608	1653	2302	2756	3224
CS16	Little San Domingo Wash	589	1692	2302	2786	3299
CS22	Little San Domingo Wash	582	1668	2279	2847	3403

4.0 Hydraulic Analysis

4.1 Methodology

Water surface profiles have been computed for the water courses listed in Table 4-1 using the HEC-2 computer program - Version 4.6.2 (May, 1991). Subcritical water surface profiles have been computed for the 100 year event.

All of the watercourses are tributaries to the Hassayampa River or Sols Wash. The Hassayampa River and Sols Wash have 530 and 100 square miles of watershed upstream of the study area, respectively. Hence, the probability of significant coincidental flow in the Hassayampa River or Sols Wash is negligible, due to the relatively short duration of runoff events. Therefore, the "slope-area" method was used to compute the starting water surface elevations (WSEL). As indicated in the HEC-2 file comment cards, the first cross section in each data file is located in the Hassayampa River or Sols Wash, unless otherwise specified in the HEC-2 file.

Table 4-1a: Washes in the Wickenburg Area Drainage Master Study

Wash Name	ID Letter(s)	Study Reach Description	Study Reach Length (miles)
SOLS WASH AREA			
Amir Wash	a	From the Hassayampa River northwest for 3.5 mi±	3.52
Flying E Wash & Tributaries	ab	From Sols Wash southwest for 5 mi. ±	15.71
Sols Wash Tributaries	ah2 - ah5	Four un-named tributaries to Sols Wash	19.32
Hartman Wash	ai	From Sols Wash southwest for 13.5 mi. ±	13.57
		Subtotal - Sols Wash Area	52.12
WEST TRIBUTARIES AREA			
Unnamed Wash #14	q	From the Hassayampa River southwest for 1 mi. ±	1.04
Cemetery Wash & Tributaries	r	From the Hassayampa River southwest for 5 mi. ±	12.16
Turtleback Wash	w	From the Hassayampa River southwest for 2 mi. ±	1.96
Sunset Wash	ad	From the Hassayampa River southwest for 1.5 mi. ±	1.41
Sunny Cove Wash	ae	From Sunset Wash southwest for 3 mi. ±	2.76
Unnamed Wash #10	ag	From southwest for 1 mi. ± to the Hassayampa River	0.88
		Subtotal - West Tributaries Area	20.18

Table 4-1b: Washes in the Wickenburg Area Drainage Master Study

Wash Name	ID Letter(s)	Study Reach Description	Study Reach Length (miles)
EAST TRIBUTARIES AREA		EAST TRIBUTARIES AREA	
Calamity Wash	b	From the Hassayampa River northeast for 2.2 mi. ±	2.21
Blue Tanks Wash	c	From the Hassayampa River northeast for 1 mi. ±	0.94
Monarch Wash	d	From the Hassayampa River northeast for 4 mi. ±	3.89
Mockingbird Wash	e	From the Hassayampa River northeast for 3.5 mi. ±	3.36
Unnamed Wash #1 & Tributary	f	From the Hassayampa River northeast for 1 mi. ±	1.40
Unnamed Wash #2	g	From the Hassayampa River northeast for 1 mi. ±	1.03
Unnamed Wash #3	h	From the Hassayampa River northeast for 1.8 mi. ±	1.78
Unnamed Wash #4	i	From the Hassayampa River northeast for 1.2 mi. ±	1.23
Unnamed Wash #5	j	From the Hassayampa River northeast for 0.6 mi. ±	0.61
Unnamed Wash #6 & Tributary	k	From the Hassayampa River northeast for 4 mi. ±	4.54
Unnamed Wash #7	l	From the Hassayampa River northeast for 1.5 mi. ±	1.52
Unnamed Wash #8	m	From the Hassayampa River northeast for .9 mi. ±	0.85
Unnamed Wash #11	n	From the Hassayampa River northeast for 0.6 mi. ±	0.60
Unnamed Wash #12	o	From the Hassayampa River northeast for 1.6 mi. ±	1.55
Unnamed Wash #13	p	From the Hassayampa River northeast for 0.8 mi. ±	0.81
Little San Domingo Wash	s	From the Hassayampa River northeast for 3.8 mi. ±	3.82
San Domingo Wash	t	From the Hassayampa River northeast for 2.2 mi. ±	2.22
Ox Wash	v	From the Hassayampa River northeast for 2 mi. ±	1.99
Powder House Wash & Tributaries	aa	From the Hassayampa River northeast for 3 mi. ±	3.13
Unnamed Wash #9	af	From the Hassayampa River northeast for 0.9 mi. ±	0.9
		Subtotal East Tributaries Area	38.38
		TOTAL	110.68

4.2 Parameter Estimation

4.2.1 Manning -n Values

The Wickenburg Area Drainage Master Study (ADMS) involves the evaluation of approximately 110 miles of watercourses. The watercourses evaluated in this study encompass a relatively wide range of channel and overbank characteristics. To evaluate appropriate Manning-n values for the watercourses, several reconnaissance investigations of the watercourses were conducted by engineers and hydrologists from Black and Veatch (B&V), Coe and Van Loo (CVL), and the Flood Control District of Maricopa County (FCDMC).

Based on the findings of the reconnaissance investigations, seven general channel and overbank conditions were identified. Ranges of appropriate Manning-n values were then computed for each of the seven general channel and overbank conditions.

Manning -n values were estimated by first selecting a base n-value and then adjusting this value based on channel or overbank characteristics. Tables 4-2 and 4-3 list base n-values and corresponding adjustment values, as documented in *Estimating Manning's Roughness Coefficients for Stream Channels and Floodplains in Maricopa County, Arizona* (Thomsen & Hjalmarson, 1991).

The base n-values, adjustment values, and the corresponding adjusted n-values for the general channel and overbank conditions are listed in Table 4-4. The seven general channel and overbank conditions are illustrated in photographs as listed in Table 4-5. In conclusion, the n-values listed in Table 4-4 and the photographs listed in Table 4-5 have been used as a guide for selecting the Manning-n values used to delineate 100-year floodplains for the watercourses evaluated in the Wickenburg ADMS.

Table 4-2 - Base Values of Manning's n for Stable Channels

(Modified from Aldridge and Garrett, 1973, Table 1)

Channel Material	Size of Bed Material		Base *n* Values	
	Millimeters	Inches	Benson & Dalrymple (1967)[1]	Chow (1959)[2]
Concrete	--------	--------	0.012-0.018	0.011
Rock cut	--------	--------	--------	0.025
Firm soil	--------	--------	.025-.032	.020
Coarse sand	1-2	--------	.026-.035	--------
Fine gravel	--------	--------	--------	.024
Gravel	2-64	0.08-2.5	.028-.035	--------
Coarse gravel	--------	--------	--------	.028
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 4-3 - Adjustment Factors 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	.001-.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

Table 4-3 - Adjustment Factors for the Determination of Overall Manning's n Values
(Continued)

Channel Conditions	Manning's n Adjustment[1]	Example
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.
Medium	.010-.025	Grass or 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 or 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.

Table 4-3 - Adjustment Factors for the Determination of Overall Manning's n Values
(Continued)

Channel Conditions	Manning's n Adjustment[1]	Example
Variations in Channel Cross Section		
Gradual	.000	Size and shape of cross sections change gradually
Alternating	.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	.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.
Degree of Meandering[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 meander 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 4-2) 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. The adjustment is a multiplier.

Table 4-4 - Wickenburg ADMS Floodplain Delineation Study
Adjusted Manning -n Values

Equation for computing adjusted Manning -n values (Thomsen & Hjalmarson, 1991):

$n = M(nb + n1 + n2 + n3 + n4)$ Where:

- nb = base value of n for a straight uniform channel (0.012 to 0.070)
- n1 = n - value adjustment for surface irregularities (0.0 to 0.020)
- n2 = n - value adjustment for obstructions (0.0 to 0.060)
- n3 = n - value adjustment for vegetation (0.002 to 0.10)
- n4 = n - value adjustment for variations in cross section (0.0 to 0.015)
- M = degree of meandering adjustment factor (1.0 to 1.3)

Channel or Overbank Descriptions	Base n - Value (nb)	Irregularity n - Value (n1)	Obstruction n - Value (n2)	Vegetation n - Value (n3)	Variation Value (n4)	Meander Factor (M)	Adjusted "n" Value (n)
1. Clean, straight channels with sand/gravel beds (Photos 1.1 & 1.2)	0.025 to 0.026	0.000 to 0.001	0.000 to 0.002	0.000 to 0.001	0.000	1.00	0.025 to 0.030
2. Braided channels with sand/gravel beds (Photos 2.1 & 2.2)	0.025 to 0.028	0.000 to 0.002	0.005 to 0.008	0.000 to 0.002	0.000	1.00	0.030 to 0.040
3. Steep channels with cobble/boulder beds (Photo 3.1)	0.030 to 0.050	0.004 to 0.007	0.000 to 0.008	0.000 to 0.001	0.002	1.10	0.040 to 0.075
4. Moderately vegetated overbanks (Photos 4.1 & 4.2)	0.025 to 0.028	0.000 to 0.002	0.005 to 0.010	0.005 to 0.010	0.000	1.00	0.035 to 0.050
5. Densely vegetated overbanks (Photos 5.1 & 5.2)	0.025 to 0.028	0.000 to 0.002	0.010 to 0.010	0.010 to 0.030	0.005	1.00	0.050 to 0.075
6. Channels at culvert and dip crossings (Photos 6.1 & 6.2)	0.015 to 0.018	0.000 to 0.000	0.000 to 0.005	0.000 to 0.002	0.000	1.00	0.015 to 0.025
7. Street and urban channels (Photos 7.1 & 7.2)	0.015 to 0.020	0.000 to 0.000	0.000 to 0.002	0.000 to 0.003	0.000	1.00	0.015 to 0.025

Table 4-5 - Channel and Overbank Descriptions

Photograph	Channel or Overbank Description	Page
1.1 & 1.2	Clean, Straight Channels with Sand/Gravel Beds n = 0.025 to 0.030	4-10
2.1 & 2.2	Braided Channels with Sand/Gravel Beds n = 0.030 to 0.040	4-11
3.1	Steep Channels with Cobble/Boulder Beds n = 0.040 to 0.075	4-12
4.1 & 4.2	Moderately Vegetated Overbanks n = 0.035 to 0.050	4-13
5.1 & 5.2	Densely Vegetated Overbanks n = 0.050 to 0.075	4-14
6.1 & 6.2	Culvert and Dip Crossings n = 0.015 to 0.025	4-15
7.1 & 7.2	Street and Urban Watercourses n = 0.015 to 0.025	4-16

CLEAN, STRAIGHT CHANNELS WITH SAND/GRAVEL BEDS
n = 0.025 to 0.030

Photo 1.1: Blue Tank Wash 1,600 feet upstream of Jack Burden Road, looking upstream.

Photo 1.2: Hartman Wash upstream of Old U.S. Highway 60, looking upstream.

BRAIDED CHANNELS
WITH SAND/GRAVEL BEDS
n = 0.030 to 0.040

Photo 2.1: Calamity Wash near U.S. Highway 60-89, looking upstream.

Photo 2.2: Flying E Wash near AT&SF Railroad, looking upstream.

STEEP CHANNELS
WITH COBBLE/BOULDER BEDS
n = 0.040 to 0.075

Photo 3.1: Wash J 500 feet upstream of U.S. Highway 60-89, looking upstream.

MODERATELY VEGETATED OVERBANKS
n = 0.035 to 0.050

Photo 4.1: Calamity Wash near County Line, looking at left bank.

Photo 4.2: Casandro Wash at U.S. Highway 60, looking downstream.

DENSELY VEGETATED OVERBANKS
n = 0.050 to 0.075

Photo 5.1: Powder House Wash 1,000 feet south of County line, looking at left bank.

Photo 5.2: Hartman Wash Upstream of Old U.S. Highway 60, looking downstream at right bank.

CULVERT AND DIP CROSSINGS
n = 0.015 to 0.025

Photo 6.1: Wash L at U.S. Highway 60-89.

Photo 6.2: Cemetery Wash, looking upstream.

STREET AND URBAN WATERCOURSES
n = 0.015 to 0.025

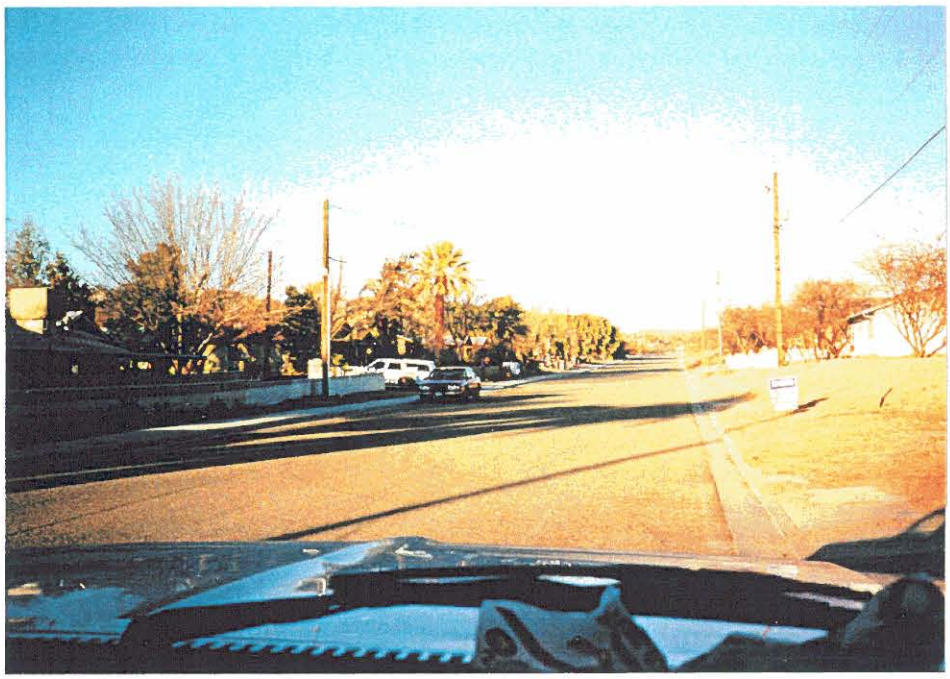

Photo 7.1: Powder House Wash, looking upstream on Constellation Road.

Photo 7.2: Flying E Wash near trailer park south of U.S. Highway 60, looking downstream.

4.2.2 Expansion and Contraction Coefficients

The following contraction and expansion coefficients were used in this study for the conditions indicated. These values are consistent with those listed in the HEC-2 User's Manual (HEC, 1990), and *Computer-Assisted Floodplain Hydrology & Hydraulics* by D.H. Hoggan (1989).

Conditions	Contraction Coefficient	Expansion Coefficient
Gradual Transitions	0.1	0.3
Moderately Abrupt Transitions at Bridges & Natural Features	0.3	0.5
Abrupt Transitions at Culverts & Natural Features	0.6	0.8

4.2.3 Hydraulic Jump/Drop Analysis

There are three significant drop structures within the study area. These structures are located at the outlet of U.S. Highway 60 culverts for Wash V - Ox Wash, Wash S - Little San Domingo Wash, and Wash AI - Hartman Wash. It is anticipated that significant hydraulic jumps will occur at these locations. However, the floodplains at these locations are confined by steep canyon walls; hence, further analyses have not been conducted to evaluate the specific characteristics of the hydraulic jumps.

4.3 Cross Section Description

Each of the cross sections used in the HEC-2 analyses for each of the watercourses have been plotted and are included with the HEC-2 analyses in Appendices 4.1 thru 4.30. The cross section plots illustrate or indicate the floodway/floodplain water surfaces, encroachment stations (ET-data), ground points (GR-data), Manning-n values, computed water surface elevations, and bridges/culverts.

4.3.1 Channels and Overbanks

The washes delineated in this study exhibit a wide range of geomorphologic and hydraulic characteristics, as indicated in Photographs 1.1 thru 7.2 - Section 4.2.1. In many locations, the watercourses are braided and the main channels can laterally migrate within the floodplain; whereas, in other locations the wash is confined within steep canyon walls composed of relatively erosion resistant strata.

4.4 Calibration

There are no active gauging stations located along the washes evaluated in this study. Therefore, there is insufficient data to perform HEC-2 model calibrations.

4.5 Special Problems/Solutions

Several unique hydraulic conditions or features (i.e. Special Problems) were identified along the watercourses delineated in the study. Two categories of Special Problems were identified during the course of this study. The first category of Special Problems includes General Special Problems that occur along two or more of the watercourses evaluated in this study. The General Special Problems are documented herein; whereas, the Specific Special Problem reports, which may include supplemental computations, are given in Appendix 1.1.

The General Special Problems identified during the hydrologic/hydraulic analyses in this study are as follows:

- Critical Depth: Nearly all of the washes evaluated in this study have relatively steep bed slopes; hence, the subcritical water surface profiles computed with HEC-2 often default to critical depth. The floodplains delineated in this study correspond to subcritical water surface profiles.
- Hassayampa River Floodplain: Most of the watercourses evaluated in this study are tributaries to the Hassayampa River. Hence, at the confluences, the Hassayampa River floodplain extends into the tributaries and is shown on the floodplain delineation maps. Typically, the Hassayampa River floodplain is at a higher elevation than the water surface elevation computed for the tributary at the confluence.
- Decreasing Peak Discharges: The results of the hydrologic analyses indicate that there are several washes, in the East Tributaries Area, where the computed 100-year peak discharge is less at the downstream limit of the wash than at some upstream locations. This decrease in the computed 100-year peak discharge is significant in some cases. Several physical and hydrological factors can contribute in making the computed peak discharge decrease in the downstream direction. The following physical and hydrological factors have been identified in this study:

  a) Shape of the Watershed: As indicated in Appendix 3.0, the majority of the East Area watersheds are shaped such that most of the watershed is draining into the

wash at a point well upstream of the downstream limit of the wash; hence, very little additional flow enters the wash in the lower reaches.

b) Peak Attenuation During Routing: In the East Tributaries Area washes, peak attenuation during routing can be significant primarily due to the typically short duration of the peak discharge and the channel characteristics of the washes.

c) Unit Hydrograph: In the semi-arid southwest, major flow events are typically short-duration events with high peak discharges. The Phoenix Mountain S-Graph, a dimensionless form of a unit hydrograph, reflects this characteristic. As a result, the computed runoff hydrograph for a sub-basin will be such that the peak discharge will have a short duration. When two hydrographs with short duration peaks are combined, it is possible that the peaks will not be additive and the composite hydrograph will have two peaks as opposed to one large peak. This is the case for many washes.

A combination of the three conditions described above can result in making the computed peak discharge lower at the downstream limit of the wash than at some upstream location.

- Computed Water Surface Elevation Below Ground Contours: At a few locations along some of the small washes, the computed water surface elevation is at a lower elevation than the ground contour elevation. This can occur, since the HEC-2 cross section data is more accurate than the contour mapping. However, this condition only occurs in locations where the computed flow depth is less than one half of the mapping contour interval. In locations where the computed water surface elevation is below the ground contour elevation, a flow depth is also indicated on the mapping to help clarify the flooding conditions at that location.

4.6 Floodway Determination

The washes delineated in this study exhibit a wide range of geomorphologic and hydraulic characteristics. Therefore, several criteria and methodologies were used to determine floodway boundaries. Initially, floodway limits were evaluated using HEC-2 encroachment methods 4 & 6 as specified with ET-cards. The floodway limits for natural watercourses were then evaluated and revised where appropriate, based on the following criteria.

The floodway boundaries may have been set equal to the floodplain boundaries in locations where:

- the watercourse is braided and the main channel has laterally migrated within the floodplain;
- the watercourse is confined within steep canyon walls;
- encroaching on the floodplain resulted in a significant increase in either the overbank or channel velocities; or
- the main channel and/or low flow channels show evidence of migrating within backwater areas upstream of roadway and/or railroad culverts.

4.7 Final Results/Computer Runs

The final HEC-2 models for each of the washes evaluated in this study are given in Appendices listed in Table 4-7.

4.8 Final Results on Diskettes

The final HEC-2 models are given in digital form on 3.5" diskettes in Appendix 4.31.

Table 4-7a: Washes in the Wickenburg Area Drainage Master Study Appendices Listing for HEC-2 Models

Wash Name	ID Letter(s)	Study Reach Description	Appendix
SOLS WASH AREA			
Amir Wash	a	From the Hassayampa River northwest for 3.5 mi. ±	4.1
Flying E Wash & Tributaries	ab	From Sols Wash southwest for 5 mi. ±	4.2
Un-Named Sols Wash Tributary	ah2	From Sols Wash west for 2.5 mi. ±	4.3
Un-Named Sols Wash Tributary	ah3	From Sols Wash southwest for 6 mi. ±	4.4
Un-Named Sols Wash Tributary	ah4	From Sols Wash southwest for 1.5 mi. ±	4.5
Un-Named Sols Wash Tributary	ah5	From Sols Wash southwest for 4 mi. ±	4.6
Hartman Wash	ai	From Sols Wash southwest for 13.5 mi. ±	4.7
WEST TRIBUTARIES AREA			
Unnamed Wash #14	q	From the Hassayampa River southwest for 1 mi. ±	5.1
Cemetery Wash & Tributaries	r	From the Hassayampa River southwest for 6 mi. ±	5.2
Turtleback Wash	w	From the Hassayampa River southwest for 2 mi. ±	5.3
Sunset Wash	ad	From the Hassayampa River southwest for 1.5 mi. ±	5.4
Sunny Cove Wash	ae	From Sunset Wash southwest for 3 mi. ±	5.5
Unnamed Wash #10	ag	From the Hassayampa River southwest for 1 mi. ±	5.6

Table 4-7b: Washes in the Wickenburg Area Drainage Master Study Appendices Listing for HEC-2 Models

Wash Name	ID Letter(s)	Study Reach Description	Appendix
EAST TRIBUTARIES AREA		EAST TRIBUTARIES AREA	
Calamity Wash	b	From the Hassayampa River northeast for 2.2 mi. ±	6.1
Blue Tanks Wash	c	From the Hassayampa River northeast for 1 mi. ±	6.2
Monarch Wash	d	From the Hassayampa River northeast for 4 mi. ±	6.3
Mockingbird Wash	e	From the Hassayampa River northeast for 3.5 mi. ±	6.4
Unnamed Wash #1 & Tributary	f	From the Hassayampa River northeast for 1 mi. ±	6.5
Unnamed Wash #2	g	From the Hassayampa River northeast for 1 mi. ±	6.6
Unnamed Wash #3	h	From the Hassayampa River northeast for 1.8 mi. ±	6.7
Unnamed Wash #4	i	From the Hassayampa River northeast for 1.2 mi. ±	6.8
Unnamed Wash #5	j	From the Hassayampa River northeast for 0.6 mi. ±	6.9
Unnamed Wash #6 & Tributary	k	From the Hassayampa River northeast for 4 mi. ±	6.10
Unnamed Wash #7	l	From the Hassayampa River northeast for 1.5 mi. ±	6.11
Unnamed Wash #8	m	From the Hassayampa River northeast for .9 mi. ±	6.12
Unnamed Wash #11	n	From the Hassayampa River northeast for .6 mi. ±	6.13
Unnamed Wash #12	o	From the Hassayampa River northeast for 1.6 mi. ±	6.14
Unnamed Wash #13	p	From the Hassayampa River northeast for 0.8 mi. ±	6.15
Little San Domingo Wash	s	From the Hassayampa River northeast for 3.8 mi. ±	6.16
San Domingo Wash	t	From the Hassayampa River northeast for 2.2 mi. ±	6.17
Ox Wash	v	From the Hassayampa River northeast for 2 mi. ±	6.18
Powder House Wash & Tributaries	aa	From the Hassayampa River northeast for 3 mi. ±	6.19
Unnamed Wash #9	af	From the Hassayampa River northeast for 0.9 mi. ±	6.20

5.0 Erosion/Sediment Transport Analyses

The erosion/sediment transport characteristics, of the washes evaluated in this study, were not quantitatively analyzed. However, the washes geomorphologic characteristics were considered during the floodway delineation phase of this study, as documented in Section 4.6 of this report.

6.0 Reference Materials

6.1-6.2 Previous Studies

6.5 References

Aldridge, B.N. and Garrett, J.M., *Roughness Coefficients for Streams in Arizona,* U.S. Geological Survey Open-File Report 78-3, 87 p., 1973.

CBA, *Hydrologic Analysis of Sols Wash*, Incorporated Town of Wickenburg, Arizona, November, 1985.

Chow, V.T., *Open Channel Hydraulics*, New York, McGraw-Hill, 680 p., 1959.

Federal Emergency Management Agency, *Flood Insurance Study: Maricopa County and Incorporated Areas: Volumes 1-7*, Revised September 4, 1991.

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

Hoggan, D.H., *Computer Assisted Floodplain Hydrology & Hydraulics*, New York, McGraw-Hill, 1989.

Thomsen, B.W., and Hjalmarson H.W., "Estimated Manning's Roughness Coefficients for Stream Channels and Floodplains in Maricopa County, AZ," Prepared by the U.S. Geological Survey, Prepared for the Flood Control District of Maricopa County, April 1991.

U.S. Army Corps of Engineers, The Hydrologic Engineering Center, *HEC-1 Flood Hydrograph Package*, August 2, 1988.

U.S. Army Corps of Engineers, *Floodplain Information Study for Maricopa County, Arizona, Volume IV, Wickenburg Report*, December, 1965.

U.S. Department of Agriculture, Soil Conservation Service, *Printout of the TR-20 for Sunset and Sunnycove Washes*, 1971.

U.S. Department of Agriculture, Soil Conservation Service, *Soil Survey of Maricopa County, Arizona, Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona*, April 1986.

U.S. Department of Agriculture, Soil Conservation Service, *Soil Survey of Yavapai County, Arizona, Western Part*, March, 1976.

U.S. Department of Agriculture, Soil Conservation Service, *Sunset and Sunnycove Pipelines*, June, 1975.

U.S. Department of Agriculture, Soil Conservation Service, *Sunset Floodwater Retarding Structure*, September, 1976.

U.S. Department of Agriculture, Soil Conservation Service, *Watershed Work Plan, Wickenburg Watershed, Maricopa & Yavapai Counties, Arizona*, December, 1974.

U.S. Department of Agriculture, Soil Conservation Service, *Wickenburg W.P.P. AZ, Sunset FRS, Sunnycove FRS & Pipeline, Hydrology*, September, 1969.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, *ATLAS 2, Volume VIII: Precipitation - Frequency Atlas of the Western United States*, 1973.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, *NOAA Technical Memorandum NWS HYDRO-40: Depth-Area Ratios in the Semi-Arid Southwest United States*, August, 1984.

7.0 Cross Referencing and Labeling Information

7.1 Other Studies Impacted

The results of this study impacts the current Flood Insurance Study for Maricopa County (FEMA, Sept. 1991) and the corresponding Flood Insurance Rate Maps (i.e. FIRM's). This study includes restudies for washes that are currently delineated based on both approximate methods and detailed analyses, as listed in Table 7-1.

Table 7-1: Restudied Washes

ID Letter(s)	Watercourse Name	FIRM Panel #	Type of Previous Study
a	Amir Wash	235 & 255	Approximate
b	Calamity Wash	255	Approximate
c	Blue Tanks Wash	255	Approximate
e	Mockingbird Wash and Tributaries	255	Detailed (0.7 mi)
n	Un-Named Wash (#11)	255	Approximate
o	Un-Named Wash (#12)	255	Approximate
q	Un-Named Wash (#14)	255	Approximate
r	Cemetery Wash and Tributaries	235 & 255	Approximate
s	Little San Domingo Wash	660 & 680	Detailed (0.7 mi)
t	San Domingo Wash	270	Approximate
aa	Powder House Wash	255	Detailed (1.1 mi)
ab	Flying E Wash and Tributaries	235	Detailed (0.6 mi)
ad	Sunset Wash	255	Approximate
ae	Sunny Cove Wash	255	Approximate
ai	Hartman Wash	230 & 255	Approximate

The previous approximate studies involved delineating flood prone and ponding areas as Zone A. The previous detailed studies involved the delineation of "AE" zones; however, the study reaches of the previous detailed studies are relatively short and are limited primarily to urbanized areas and/or highway crossings.

7.2 Key to Cross Section Labeling

Cross section identification numbers correspond to river miles upstream from a major confluence and appear on the floodplain delineation mapping and in the HEC-2 output.