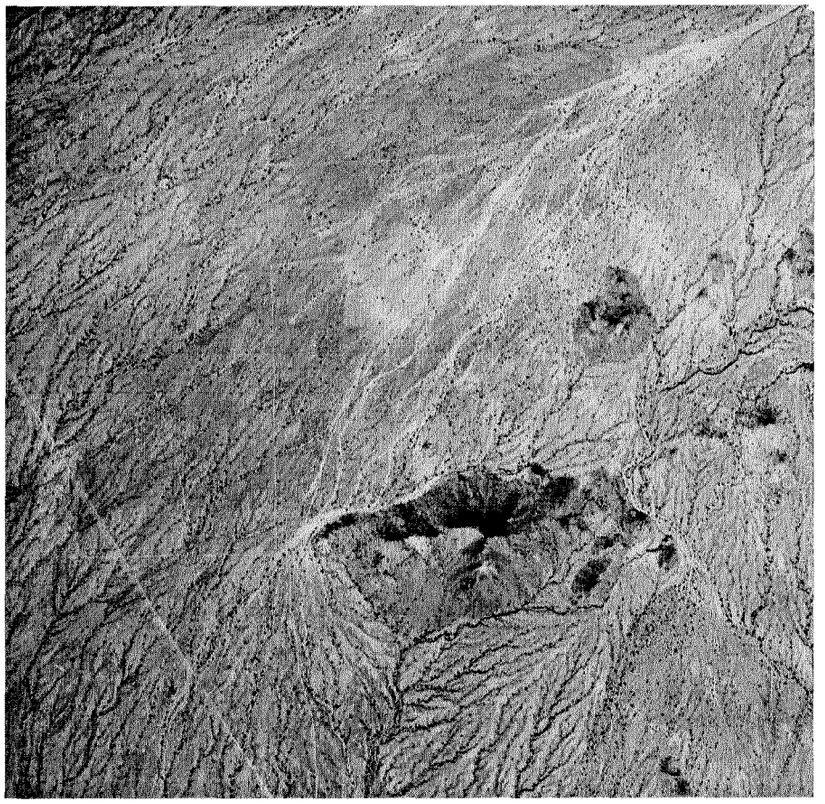
APPROXIMATE FLOODPLAIN DELINEATION STUDY
for
WHITE TANK FAN
(Site 36 - Hjalmarson and Kemna, 1992)

FCD CONTRACT NO. 99-02
Assignment No. 2

TECHNICAL DATA NOTEBOOK

July 2000, revised Dec. 2001



Prepared for:

Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009
(602) 506-1501

By:

WOOD/PATEL

In association with:

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HYDROLOGY & GEOMORPHOLOGY, INC.

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Federal Emergency Management Agency

Washington, D.C. 20472

AUG 16 2002

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

IN REPLY REFER TO:
Case No.: 02-09-386P

The Honorable Dusty Hull
Mayor, Town of Buckeye
100 North Apache Road, Suite A
Buckeye, AZ 85326

Community: Town of Buckeye, AZ
Community No: 040039
Panels Affected: 04013C1545 G, 1575 E, 2020 G, and 2025 G
Effective Date of This Revision: **SEP 16 2002**

102-I-C

Dear Mayor Hull:

This responds to a request that the Federal Emergency Management Agency (FEMA) revise the effective Flood Insurance Rate Map (FIRM) for Maricopa County, Arizona and Incorporated Areas (the effective FIRM for your community), in accordance with Part 65 of the National Flood Insurance Program (NFIP) regulations. In a letter dated December 28, 2001, Mr. Tim Murphy P.E., C.F.M., Delineation Branch Manager, Flood Control District of Maricopa County, requested that FEMA revise the FIRM to show the effects of a floodplain delineation study along the White Tank alluvial fan. This study was performed in accordance with the guidelines set forth in FEMA's publication entitled *Guidelines for Determining Flood Hazards on Alluvial Fans*, dated February 23, 2000. These guidelines were subsequently incorporated into the FEMA publication entitled *Guidelines and Specifications for Flood Hazard Mapping Partners*, dated February 2002, which superseded the previous document.

All data required to complete our review of this request were submitted with letters from Mr. Murphy.

We have completed our review of the submitted data and the flood data shown on the effective FIRM. We have revised the FIRM to modify the floodplain boundary delineations and zone designations of the flood having a 1-percent chance of being equaled or exceeded in any given year (base flood) along the White Tank alluvial fan from Interstate Highway 10 (I-10) to the hydrographic apex, located approximately 24,000 feet upstream of I-10. The affected areas previously were designated Zone X (shaded), areas that would be inundated by the base flood with average depths less than 1.0 foot. As a result of the new study, Special Flood Hazard Areas (SFHAs), areas that would be inundated by the base flood, were added to the FIRM. The active and inactive areas of the alluvial fan, where an approximate study was performed, have been designated Zone A, Zone A (Active Alluvial Fan Flooding – Administrative Floodway), Zone A (Inactive Alluvial Fan Flooding – Administrative Floodway), and Zone A (Inactive Alluvial Fan Flooding), respectively, SFHAs with no Base Flood Elevations determined that are subject to active and inactive alluvial fan flooding as those terms are defined in the above-referenced FEMA *Guidelines*. As a result of the modifications, approximately 5.8 square miles of new floodplain within the White Tank alluvial fan were delineated, including administrative flood hazard zones defined by the Flood Control District of Maricopa County for local management of flood hazards on the alluvial fan. The modifications are shown on the enclosed annotated copies of FIRM Panels 04013C1545 G, 04013C1575 E, 04013C2020 G, and 04013C2025 G. This Letter of Map Revision (LOMR) hereby revises the above-referenced panels of the effective FIRM dated July 19, 2001.

Because this revision request also affects the unincorporated areas of Maricopa County, a separate LOMR for that community was issued on the same date as this LOMR.

The modifications are effective as of the date shown above. The map panels as listed above and as modified by this letter will be used for all flood insurance policies and renewals issued for your community.

A review of the determination made by this LOMR and any requests to alter this determination should be made within 30 days. Any request to alter the determination must be based on scientific or technical data.

We will not physically revise and republish the FIRM and Flood Insurance Study (FIS) report for your community to reflect the modifications made by this LOMR at this time. When changes to the previously cited FIRM panels and FIS report warrant physical revision and republication in the future, we will incorporate the modifications made by this LOMR at that time.

This LOMR is based on minimum floodplain management criteria established under the NFIP. Your community is responsible for approving all floodplain development and for ensuring all necessary permits required by Federal or State law have been received. State, county, and community officials, based on knowledge of local conditions and in the interest of safety, may set higher standards for construction in the SFHA. If the State, county, or community has adopted more restrictive or comprehensive floodplain management criteria, these criteria take precedence over the minimum NFIP criteria.

Because this LOMR will not be printed and distributed to primary users, such as local insurance agents and mortgage lenders, your community will serve as a repository for these new data. We encourage you to disseminate the information reflected by this LOMR throughout the community, so that interested persons, such as property owners, local insurance agents, and mortgage lenders, may benefit from the information. We also encourage you to prepare a related article for publication in your community's local newspaper. This article should describe the changes that have been made and the assistance that officials of your community will give to interested persons by providing these data and interpreting the NFIP maps.

This determination has been made pursuant to Section 206 of the Flood Disaster Protection Act of 1973 (Public Law 93-234) and is in accordance with the National Flood Insurance Act of 1968, as amended (Title XIII of the Housing and Urban Development Act of 1968, Public Law 90-448), 42 U.S.C. 4001-4128, and 44 CFR Part 65. Pursuant to Section 1361 of the National Flood Insurance Act of 1968, as amended, communities participating in the NFIP are required to adopt and enforce floodplain management regulations that meet or exceed minimum NFIP criteria. These criteria are the minimum requirements and do not supersede any State or local requirements of a more stringent nature. This includes adoption of the effective FIRM to which the regulations apply and the modifications described in this LOMR. Our records show that your community has met this requirement.

A Consultation Coordination Officer (CCO) has been designated to assist your community. The CCO will be the primary liaison between your community and FEMA. For information regarding your CCO, please contact:

Mr. Jack Eldridge
Chief, Community Mitigation Programs Branch
Federal Emergency Management Agency, Region IX
1111 Broadway Street, Suite 1200
Oakland, CA 94607-4052
(510) 627-7184

If you have any questions regarding floodplain management regulations for your community or the NFIP in general, please call the CCO for your community at the telephone number cited above. If you have any questions regarding this LOMR, please call our Map Assistance Center, toll free, at 1-877-FEMA MAP (1-877-336-2627).

Sincerely,

Max H. Yuan, P.E., Project Engineer
Hazards Study Branch
Federal Insurance and
Mitigation Administration

For: Matthew B. Miller, P.E., Chief
Hazards Study Branch
Federal Insurance and
Mitigation Administration

Enclosures

cc: The Honorable Don Stapley
Chairman, Maricopa County
Board of Supervisors

Mr. Joseph Blanton
Town Manager
Town of Buckeye

Ms. Shanna Yager
Branch Manager
Floodplain Administrator
Flood Control District of
Maricopa County

Mr. Tim Murphy, P.E., C.F.M.
Delineation Branch Manager
Flood Control District of
Maricopa County

Mr. Victor Calderón
NFIP Coordinator
Arizona Division of Emergency
Management

Federal Emergency Management Agency
Washington, D.C. 20472

AUG 16 2002

FLOOD CONTROL DISTRICT
RECEIVED
AUG 22 02
CH & GM | FINANCE
PIO | LANDS
ADMIN | C & M
REG | P & PM
ENG | FILE
CONTRACTS
ACCOUNTING
SRY

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

IN REPLY REFER TO:
Case No.: 02-09-386P

The Honorable Don Stapley
Chairman, Maricopa County
Board of Supervisors
301West Jefferson, 10th Floor
Phoenix, AZ 85003

Community: Maricopa County, AZ
Community No: 040037
Panels Affected: 04013C1545 G, 1575 E,
2020 G, and 2025 G
Effective Date of
This Revision: SEP 16 2002

102-I-C

Dear Mr. Stapley:

This responds to a request that the Federal Emergency Management Agency (FEMA) revise the effective Flood Insurance Rate Map (FIRM) for Maricopa County, Arizona and Incorporated Areas, in accordance with Part 65 of the National Flood Insurance Program (NFIP) regulations. In a letter dated December 28, 2001, Mr. Tim Murphy P.E., C.F.M., Delineation Branch Manager, Flood Control District of Maricopa County, requested that FEMA revise the FIRM to show the effects of a floodplain delineation study along the White Tank alluvial fan. This study was performed in accordance with the guidelines set forth in FEMA's publication entitled *Guidelines for Determining Flood Hazards on Alluvial Fans*, dated February 23, 2000. These guidelines were subsequently incorporated into the FEMA publication entitled *Guidelines and Specifications for Flood Hazard Mapping Partners*, dated February 2002, which superseded the previous document.

All data required to complete our review of this request were submitted with letters from Mr. Murphy.

We have completed our review of the submitted data and the flood data shown on the effective FIRM. We have revised the FIRM to modify the floodplain boundary delineations and zone designations of the flood having a 1-percent chance of being equaled or exceeded in any given year (base flood) along the White Tank alluvial fan from Interstate Highway 10 (I-10) to the hydrographic apex, located approximately 24,000 feet upstream of I-10. The affected areas previously were designated Zone X (shaded), areas that would be inundated by the base flood with average depths less than 1.0 foot. As a result of the new study, Special Flood Hazard Areas (SFHAs), areas that would be inundated by the base flood, were added to the FIRM. The active and inactive areas of the alluvial fan, where an approximate study was performed, have been designated Zone A, Zone A (Active Alluvial Fan Flooding – Administrative Floodway), Zone A (Inactive Alluvial Fan Flooding – Administrative Floodway), and Zone A (Inactive Alluvial Fan Flooding), respectively, SFHAs with no Base Flood Elevations determined that are subject to active and inactive alluvial fan flooding as those terms are defined in the above-referenced FEMA *Guidelines*. As a result of the modifications, approximately 5.8 square miles of new floodplain within the White Tank alluvial fan were delineated, including administrative flood hazard zones defined by the Flood Control District of Maricopa County for local management of flood hazards on the alluvial fan. The modifications are shown on the enclosed annotated copies of FIRM Panels 04013C1545 G, 04013C1575 E, 04013C2020 G, and 04013C2025 G. This Letter of Map Revision (LOMR) hereby revises the above-referenced panels of the effective FIRM dated July 19, 2001.

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Sincerely,

Max H. Yuan, P.E., Project Engineer
Hazards Study Branch
Federal Insurance and
Mitigation Administration

For: Matthew B. Miller, P.E., Chief
Hazards Study Branch
Federal Insurance and
Mitigation Administration

Enclosures

cc: The Honorable Dusty Hull
Mayor, Town of Buckeye

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Flood Control District of
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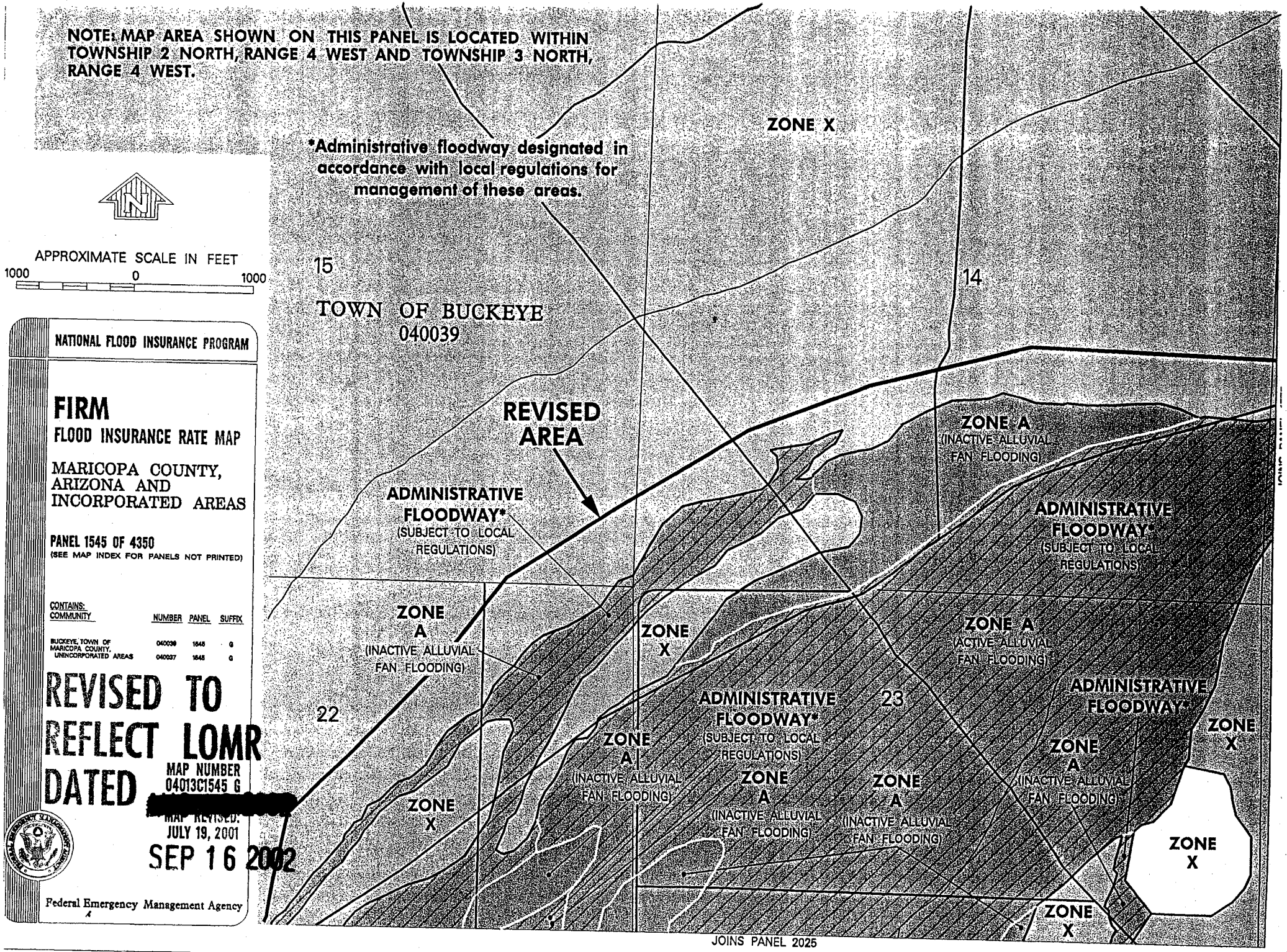
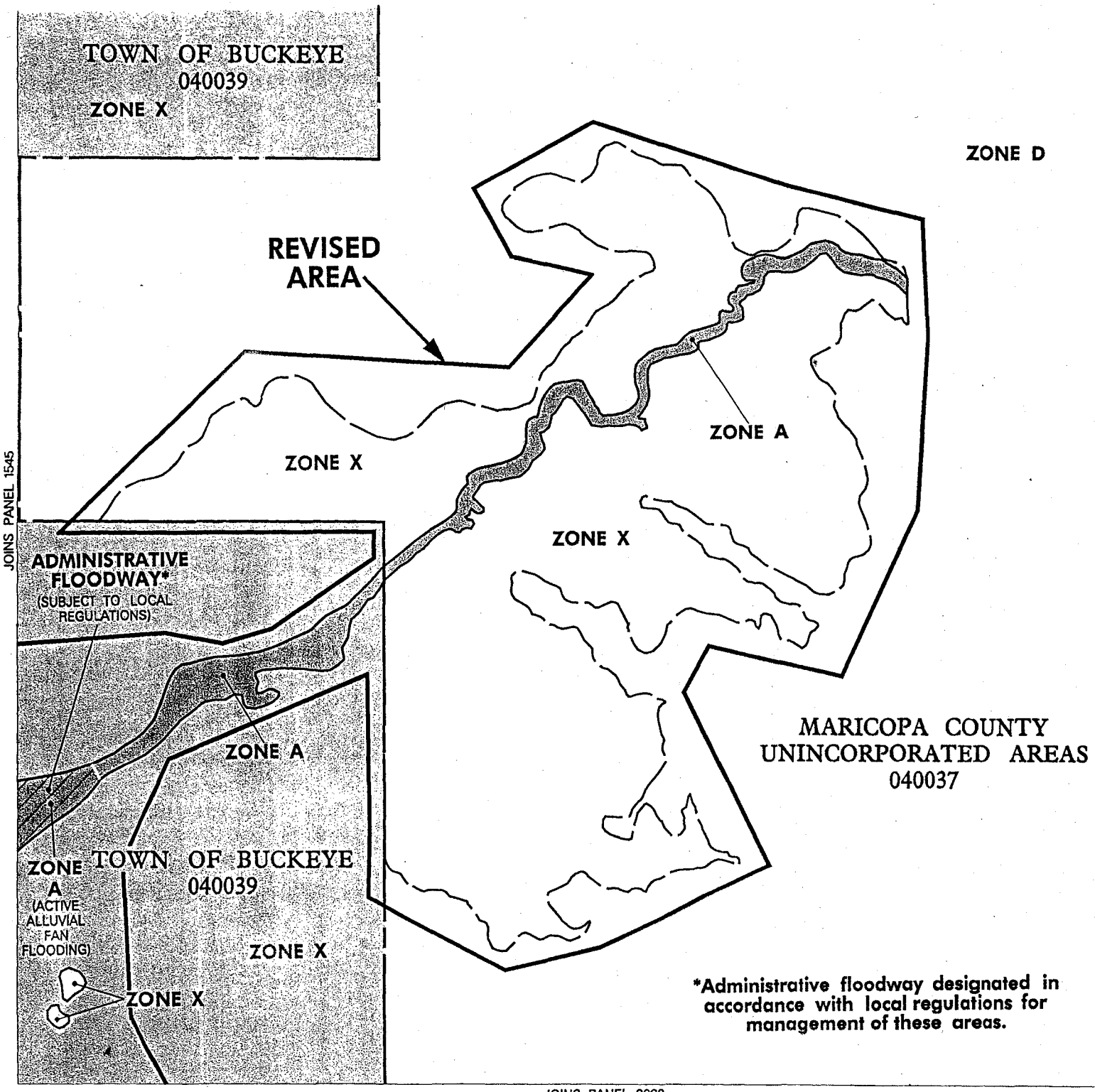
Arizona Division of Emergency
Management


NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 2 NORTH, RANGE 4 WEST AND TOWNSHIP 3 NORTH, RANGE 4 WEST.
*Administrative floodway designated in accordance with local regulations for management of these areas.
APPROXIMATE SCALE IN FEET
1000 0 1000
NATIONAL FLOOD INSURANCE PROGRAM
FIRM
FLOOD INSURANCE RATE MAP
MARICOPA COUNTY, ARIZONA AND INCORPORATED AREAS
PANEL 1545 OF 4350
(SEE MAP INDEX FOR PANELS NOT PRINTED)
CONTAINS:
COMMUNITY NUMBER PANEL SUFFIX
BUCKEYE, TOWN OF 040039 1545 G
MARICOPA COUNTY, UNINCORPORATED AREAS 040037 1545 G
REVISED TO REFLECT LOMR DATED
MAP NUMBER 04013C1545 G
MAP REVISED: JULY 19, 2001
SEP 16 2002
Federal Emergency Management Agency
15
14
TOWN OF BUCKEYE 040039
REVISED AREA
ZONE X
ZONE A (INACTIVE ALLUVIAL FAN FLOODING)
ADMINISTRATIVE FLOODWAY* (SUBJECT TO LOCAL REGULATIONS)
ZONE A (INACTIVE ALLUVIAL FAN FLOODING)
ZONE X
ZONE A (ACTIVE ALLUVIAL FAN FLOODING)
22
23
ADMINISTRATIVE FLOODWAY* (SUBJECT TO LOCAL REGULATIONS)
ZONE A (INACTIVE ALLUVIAL FAN FLOODING)
ZONE A (INACTIVE ALLUVIAL FAN FLOODING)
ZONE A (INACTIVE ALLUVIAL FAN FLOODING)
ZONE X
ZONE X
ZONE X
JOINS PANEL 2025



APPROXIMATE SCALE IN FEET

2000 0 2000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

MARICOPA COUNTY, ARIZONA AND INCORPORATED AREAS

PANEL 1575 OF 4350

(SEE MAP INDEX FOR PANELS NOT PRINTED)

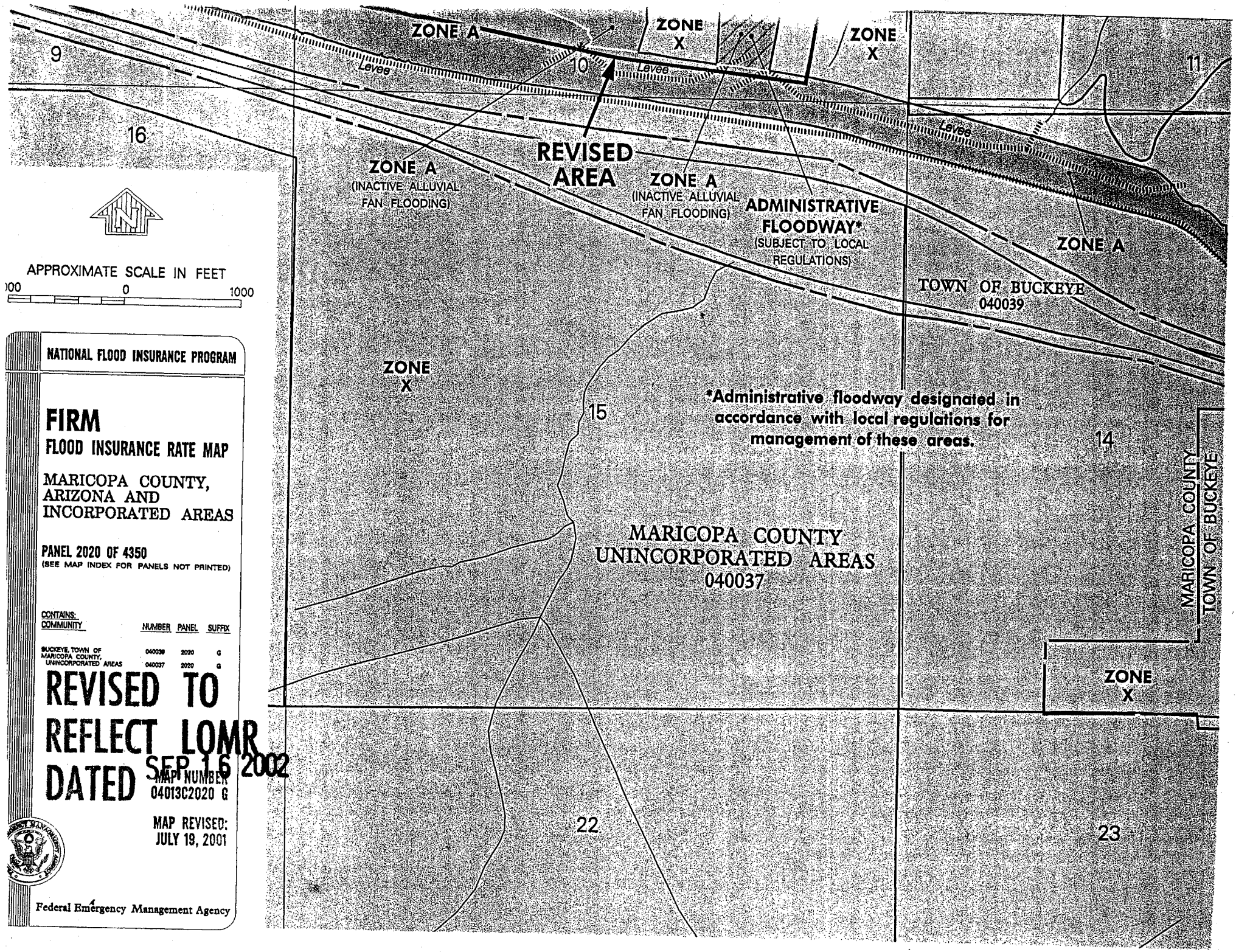
CONTAINS: COMMUNITY	NUMBER	PANEL	SUFFIX
BUCKEYE, TOWN OF	040039	1545	E
MARICOPA COUNTY, UNINCORPORATED AREAS	040037		

REVISED TO REFLECT LOMR DATED SEP 16 2002

MAP NUMBER
04013C1575 E

MAP REVISED:
JULY 19, 2001

Federal Emergency Management Agency



APPROXIMATE SCALE IN FEET

000 0 1000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

MARICOPA COUNTY, ARIZONA AND INCORPORATED AREAS

PANEL 2020 OF 4350
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS: COMMUNITY	NUMBER	PANEL	SUFFIX
BUCKEYE, TOWN OF	040039	2020	G
MARICOPA COUNTY, UNINCORPORATED AREAS	040037	2020	G

REVISED TO REFLECT LOMR DATED SEP 16 2002

MAP NUMBER
04013C2020 G

MAP REVISED:
JULY 19, 2001

Federal Emergency Management Agency

APPROXIMATE SCALE IN FEET
2000 0 2000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

MARICOPA COUNTY, ARIZONA AND INCORPORATED AREAS

PANEL 2025 OF 4350
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS: COMMUNITY	NUMBER	PANEL	SUFFIX
BUCKEYE, TOWN OF	040039	2025	G
MARICOPA COUNTY, UNINCORPORATED AREAS	040037	2025	G

REVISED TO REFLECT LOMR DATED SEP 16 2002

MAP NUMBER
04013C2025 G
MAP REVISED:
JULY 19, 2001

Federal Emergency Management Agency

*Administrative floodway designated in accordance with local regulations for management of these areas.

NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 1 NORTH, RANGE 4 WEST AND TOWNSHIP 2 NORTH, RANGE 4 WEST.

TOWN OF BUCKEYE 040039

MARICOPA COUNTY UNINCORPORATED AREAS 040037

REVISED AREA

JOINS PANEL 1545

JOINS PANEL 2005

JOINS PANEL 2030

JOINS PANEL 2020

INCORPORATE LIMITS

MCDOWELL

TONOPAH

SALOME

VAN BUREN STREET

HIGHWAY

AVENUE

293RD

VERDE ROAD

PALO

TURNER ROAD

OGLESBY ROAD

Buckeye F.R.S.

Levee

ROAD

NATIONAL FLOOD INSURANCE PROGRAM
FEMA MAP COORDINATION CONTRACTOR

June 17, 2002

Mr. Tim Murphy, P.E.
Delineation Branch Manager
Flood Control District
of Maricopa County
2801 West Durango Street
Phoenix, AZ 85009-6399

IN REPLY REFER TO:
Case No.: 02-09-386P
Communities: Town of Buckeye and Maricopa County, AZ
Community Nos.: 040039 and 040037

316-ACK.FEX

Dear Mr. Murphy:

This responds to your submittal dated April 8, 2002, concerning a December 28, 2001, request that the Federal Emergency Management Agency (FEMA) issue a revision to the Flood Insurance Rate Map (FIRM) for Maricopa County, Arizona and Incorporated Areas. Pertinent information about the request is listed below.

Identifier:	White Tank Fan, Site 36
Flooding Source:	White Tank Fan
FIRM Panel(s) Affected:	04013C1550 G, 1575 G, 2020 G, and 2025 G

As you may know, FEMA has implemented a procedure to recover costs associated with reviewing and processing requests for modifications to published flood information and maps. However, because your request is based on a detailed hydrologic or hydraulic study conducted by a Federal, State, or local agency to replace an approximate study conducted by FEMA and shown on the flood map, no fees will be assessed for our review.

We have completed an inventory of the items that you submitted. We have received all the data we require to begin a detailed technical review of your request. If additional data are required, we will inform you within 30 days of the date of this letter.

If you have general questions about your request, FEMA policy, or the National Flood Insurance Program, please call the FEMA Map Assistance Center, toll free, at 1-877-FEMA MAP (1-877-336-2627). If you have specific questions concerning your request, please call the Revisions Coordinator for your State, Pernille Buch-Pedersen, who may be reached at (703) 317-6224.

Sincerely,

Andrea L. Ryon

Andrea L. Ryon, P.E., Director
Engineering Division
Michael Baker Jr., Inc.

cc: Mr. Joseph Blanton
Town Manager
Town of Buckeye

Mr. Ted Lehman, P.E.
JE Fuller Hydrology &
Geomorphology, Inc.

3601 Eisenhower Avenue, Alexandria, Virginia 22304-6425 PH: 703.960.8800 FX: 703.960.9125

Michael Baker Jr., Inc., under contract with the FEDERAL EMERGENCY MANAGEMENT AGENCY, is a Map Coordination Contractor for the National Flood Insurance Program

APPROXIMATE
FLOODPLAIN DELINEATION STUDY
for
WHITE TANK FAN

(Site 36 - Hjalmarson and Kemna, 1992)

FCD CONTRACT NO. 99-02

Assignment No. 2

TECHNICAL DATA NOTEBOOK

July 2000
Revised Dec. 2001

Prepared for:

Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009
(602) 506-1501

By:

WOOD, PATEL & ASSOCIATES, INC.

In association with:

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HYDROLOGY & GEOMORPHOLOGY, INC.

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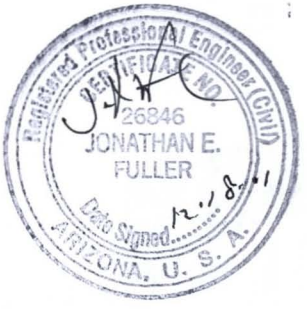

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Figure 6B.9 Historical Channel Changes Downstream of the Hydrographic Apex, 1942-1999 End of Sec. 6B
Figure 6B.10 Historical Channel Changes On the Middle Piedmont, 1949-1999 End of Sec. 6B
Figure 6B.11 Historical Channel Changes On the Lower Piedmont, Area 1, 1949-1999 End of Sec. 6B
Figure 6B.12 Historical Channel Changes On the Lower Piedmont, Area 2, 1949-1999 End of Sec. 6B
Figure 6B.13 Stage 2 – Identification of Stable and Unstable Areas End of Sec. 6B
Figure 6B.14 Stage 3 – 100-Year Approximate Floodplain End of Sec. 6B
Figure 6B.15 Comparison of 100-yr Flood Hazards with AZGS Assessment End of Sec. 6B
Figure 6B.16 AZGS Surficial Geology and Flood Hazard Assessment End of Sec. 6B
Figure 7.1 Electronic Redline of Affected FIRM Panels 7-2

SECTION 1: INTRODUCTION

1.1 Purpose of study

The purpose of this floodplain delineation study is to identify and delineate the 100-year floodplain for portions of the White Tank alluvial fan whose apex is identified as Site 36 in Hjalmarson and Kemna (1992) in T1N, R4W and T2N, R4W in Maricopa County, Arizona using approximate methods. The name, Site 36, will be used frequently in this report to refer to the alluvial fan which is the subject of this report to distinguish it from other alluvial fans on the western piedmont of the White Tank Mountains. This study incorporates the methods for assessment of piedmont flood hazards as outlined in *Piedmont Flood Hazard Assessment Manual for Maricopa County (PFHAM)* (Hjalmarson, 1998) and for alluvial fans in the *Guidelines for Determining Flood Hazards on Alluvial Fans (FEMA Guidelines)* (FEMA, 2000). A geomorphic approach will be the predominant mode of analysis for the approximate flood hazard delineation.

1.2 Authority for study

JE Fuller / Hydrology and Geomorphology, Inc. (JEF) performed this study under subcontract for Wood, Patel and Associates who were contracted with the Flood Control District of Maricopa County (FCDMC). JEF's Project Manager for this project was Jonathan E. Fuller, P.E., P.H. The Project Manager for Wood/Patel was Ashok Patel, P.E.. The contract number is FCD 99-02, Assignment No. 2. FCDMC is located at 2801 West Durango Street, Phoenix, AZ 85009 (602) 506-1501. The Project Manager for the FCDMC was Joe Tram, P.E..

1.3 Location of study reach

The study area is located in west-central Maricopa County, Arizona, just north of Interstate 10 and east of the Hassayampa River (see Figure 1.1 and Figure 1.2). The total watershed is 5.7 square miles near the hydrographic apex of the alluvial fan. Downstream from this point the wash diverges rapidly into numerous branches. The approximate floodplain delineation covers areas of the piedmont at risk of flooding from the Site 36 wash and its distributaries south to the Buckeye Flood Retarding Structure No. 1 along Interstate 10 and west to the Sun Valley Parkway. The Site 36 alluvial fan extends west beyond Sun Valley Parkway, but flood hazards for that portion of the piedmont were not mapped as part of this study.

The climate in the study area is semi-arid desert with an average annual precipitation of generally less than 10 inches. Annual rainfall amounts generally increase with increasing elevation within watersheds near the study area. Precipitation is typically divided between two seasons with comparable rainfall amounts: summer and winter. The summer storms are associated with warm, moist tropical air masses that enter the state from the Gulf of Mexico and Gulf of California, producing moderate to intense localized thundershowers. Winter precipitation usually originates from the Pacific Ocean and produces light to moderate precipitation over relatively large areas. A third source of significant precipitation are from dissipating tropical storm and/or hurricane remnants. These storms generally occur in late September and early October. These dissipating storms generate moderate to high rainfall intensities that can last for many hours.

1.4 Methodology

This study incorporates the methods for assessment of piedmont flood hazards as outlined in *PFHAM* and the *FEMA Guidelines*. These two documents were published in response to the National Research Council's *Alluvial Fan* Flooding report (NRC, 1996). Both also rely heavily on the definitions and methods outline in the NRC report. The *FEMA Guidelines* are targeted at determination of flood hazards on alluvial fan landforms. The *PFHAM,* which is recommended for use in Maricopa County, Arizona, is applicable to the entire piedmont, not just alluvial fans. The *PFHAM* methodology incorporates geomorphic methods into the flood hazard assessment of piedmont surfaces. According to the *FEMA Guidelines*, the geomorphic approach is considered an "approximate method" (p. 12, Table 1) because no base flood elevations are calculated in the geomorphic approach.

Additionally, a riverine reach of wash upstream of the hydrographic apex of the Site 36 alluvial fan was also delineated. In this stable reach, approximate normal-depth hydraulic calculations were performed to identify the limits of the flood hazard in this reach. The approximate normal-depth delineation of this reach was supplemented by interpretation of geomorphic information from maps, aerial photographs, and field observations.

1.4.1 Hydrology

The hydrologic information used in this study was the 100-year 24-hour HEC-1 analysis conducted by Alpha Engineering for the White Tanks Wash Floodplain Delineation Study (Alpha, 1994) for the watershed upstream of the hydrographic apex. This study computed a 100-year peak discharge of 3,600 cfs near the hydrographic apex. This value agrees well with the Region 13 regression equations (Thomas, et al., 1997). Paleoflood analyses by others (CH2M Hill, 1992) indicated a flood of about 2,000 to 5,000 cfs as the largest in the last 100 years or so. Therefore, the 3,600 cfs value was deemed reasonable for delineation of the 100-year flood hazard limits in this study. Additionally, it was assumed for the purposes of this approximate study that local inflows downstream of the hydrographic apex are approximately equal to the attenuation and transmission loss of the flow from the apex. This approach was part of the scope of work defined for this study. The hydrologic analyses are presented in Section 4 of the TDN.

1.4.2 Hydraulics

Hydraulic calculations for the riverine reach of this delineation study upstream of the hydrographic apex were limited to individual cross section Manning's equation calculations. The hydraulic analyses for the approximate floodplain delineation of this reach are presented in Section 5 of the TDN. The cross sections and normal-depth calculations are presented in Appendix E. The flood hazards in the remainder of the study area were evaluated using a geomorphic approach described in Section 6B.

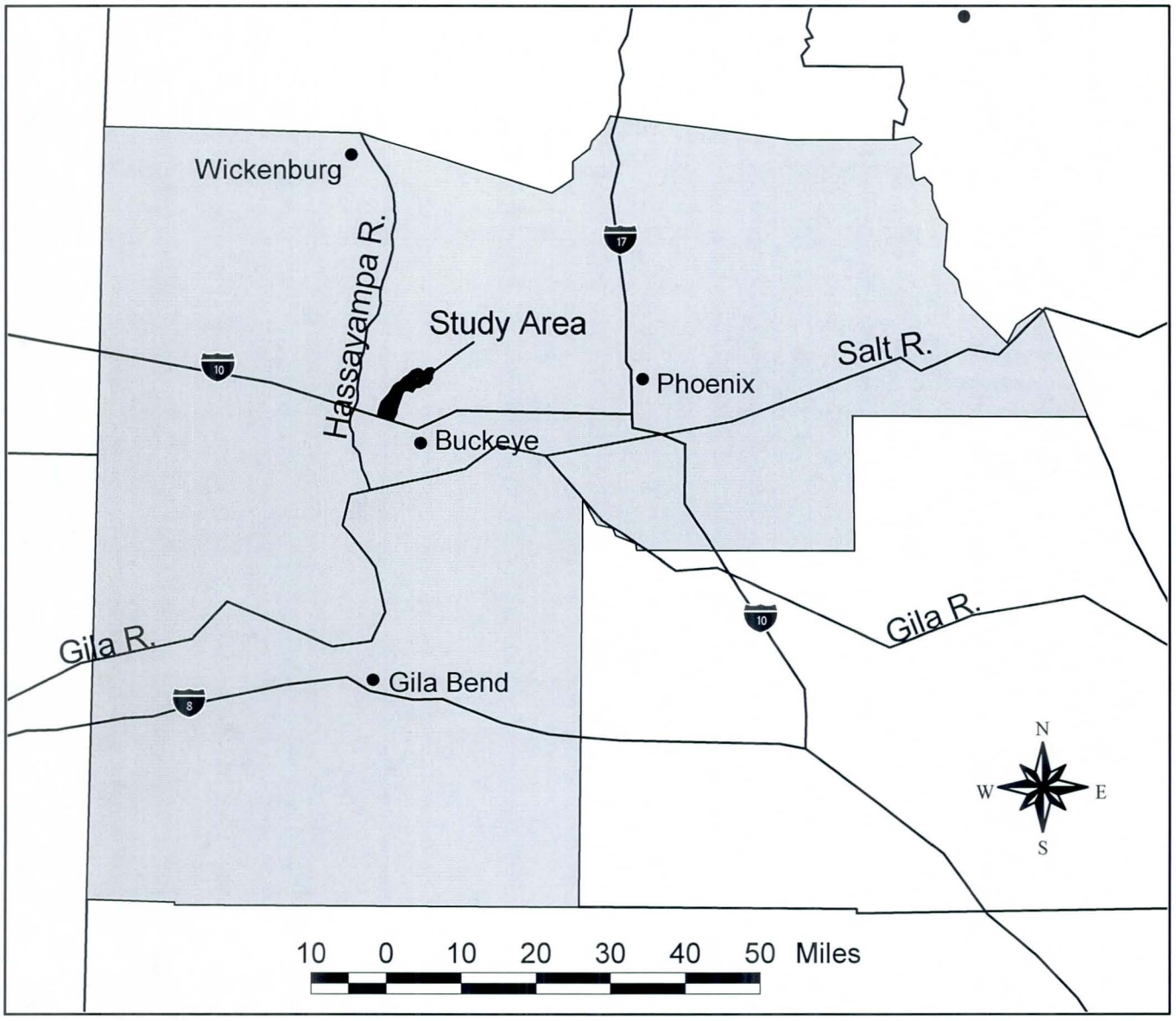
1.4.3 Geomorphic Analysis

The flood hazard assessment for this study was accomplished primarily through geomorphic methods used to identify the type and extent of the flood hazard within the study area. The procedures applied follow the three stage methods outlined in the *PFHAM* and the *FEMA*

Guidelines. Section 6B of the Technical Data Notebook discusses the geomorphic approach and results of the analyses. The approach relies on previous surficial geologic mapping (Field and Pearthree, 1991), NRCS soil mapping (Hartman, 1977; Camp, 1986), aerial photograph interpretation, field observations, and professional judgment. A description of the methods and results of these analyses is presented in Section 6B of the Technical Data Notebook (TDN). Section 6B has been added to the standard TDN format to accommodate the alternate methods and results.

1.5 Study Results

This study resulted in the new delineation of 5.8 square miles of approximate floodplain in the study area. The inundation areas for the newly delineated floodplains are shown on the maps in Section 6B and 7 and the Exhibit Maps at the end of this notebook. The floodplain mapping also includes administrative flood hazard zones defined by the Flood Control District of Maricopa County for the local management of flood hazards on the alluvial fan.



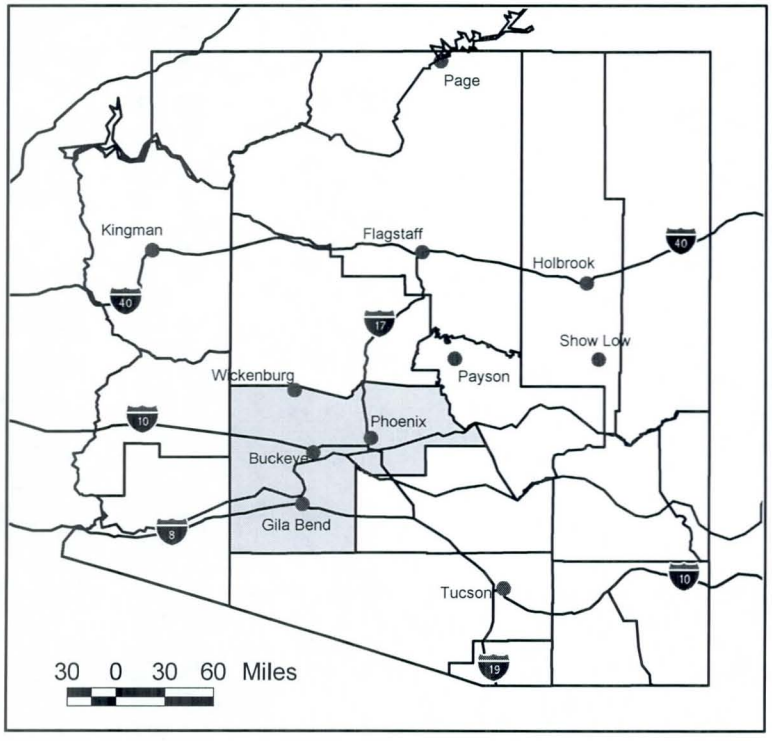


Figure 1.1
Location Map

White Tank Fan (Site 36) Approximate FDS
Wood, Patel & Associates
in association with
JE Fuller / Hydrology & Geomorphology, Inc.
July 2000

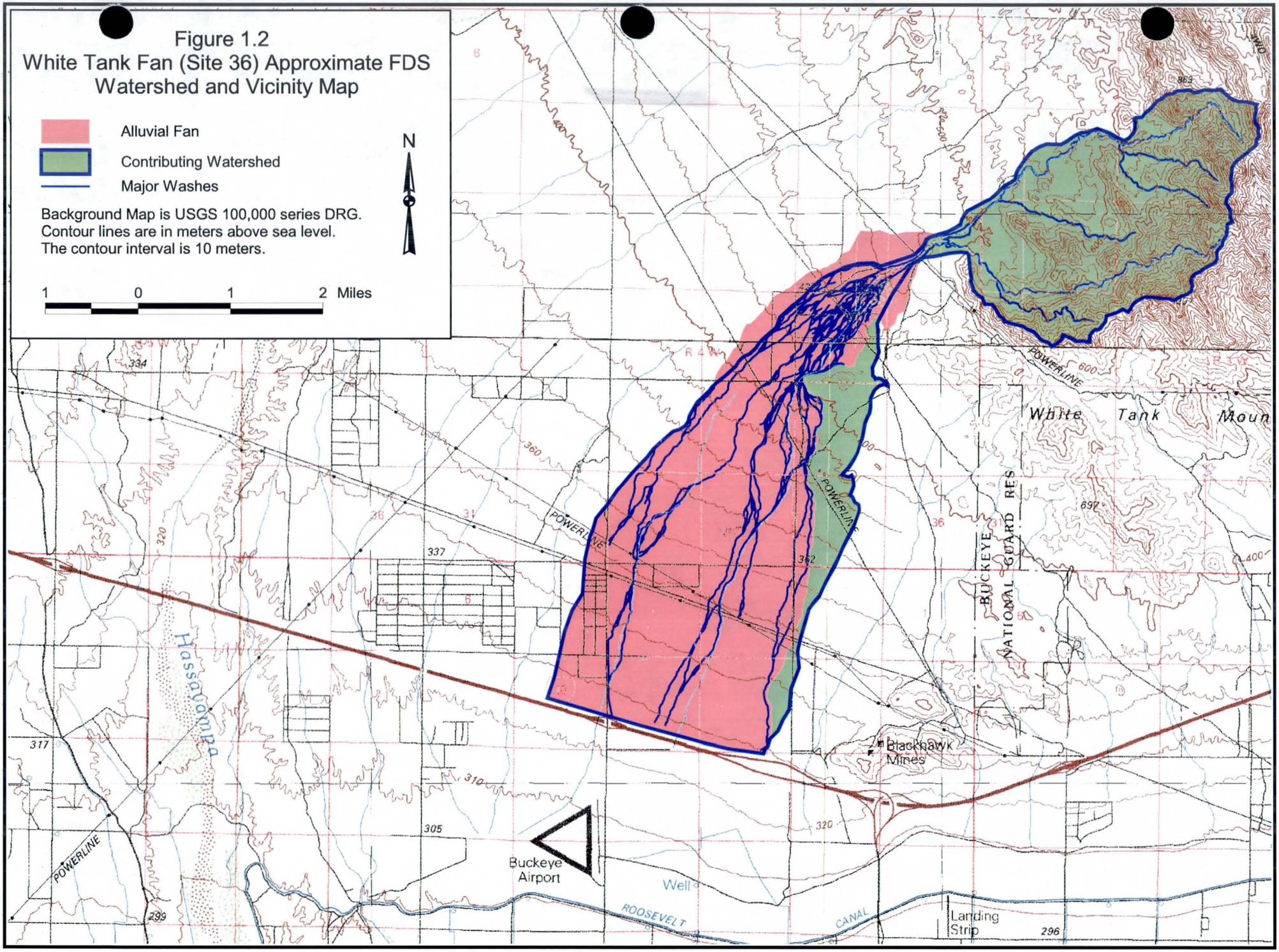


Figure 1.2
White Tank Fan (Site 36) Approximate FDS Watershed and Vicinity Map
Alluvial Fan
Contributing Watershed
Major Washes
N
Background Map is USGS 100,000 series DRG.
Contour lines are in meters above sea level.
The contour interval is 10 meters.
1 0 1 2 Miles
POWERLINE
White Tank Moun
BUCKEYE NATIONAL GUARD RES
Hassayampa
Blackhawk Mines
Buckeye Airport
Well
ROOSEVELT CANAL
Landing Strip
334
337
317
305
299
296
320
310
360
362
600
400
697

SECTION 2: ADWR/FEMA Forms and Local Government/ADWR Abstracts
2.1 Study Documentation Abstract for FEMA Submittals

Study Documentation Abstract For FEMA Submittals	Initial Study	X	Restudy	CLOMR	LOMR	X	Other

Section 2.1: Study Documentation Abstract for FEMA Submittals		
2.1.1	Date Study Accepted	
2.1.2	Study Contractors	Wood, Patel, and Associates JE Fuller / Hydrology & Geomorphology, Inc.
	Contact(s)	Ashok Patel, P.E., Wood/Patel Jonathan E. Fuller, P.E., JE Fuller, Inc.
	Address	Wood, Patel, and Associates 2051 W. Northern Ave., Suite 100 Phoenix, AZ 85021 JE Fuller / Hydrology & Geomorphology, Inc. 5235 S. Kyrene Road, Suite 205 Tempe, AZ 85283
	Phone	(602) 335-8500 (Wood/Patel) (480) 752-2124 (JE Fuller)
	Internal Reference Number	Wood/Patel Project #99958
2.1.3	FEMA Technical Review Contractor Contact(s) Address Phone Internal Reference Number	
2.1.4	FEMA Regional Reviewer	Michael Baker, Jr. Engineering
	Phone	(703) 960-8800
2.1.5	State Technical Reviewer	Arizona Department of Water Resources
	Phone	(602) 417-2445
2.1.6	Local Technical Reviewer	Flood Control District of Maricopa County
	Phone	(602) 506-1501
2.1.7	Reach Description	
2.1.8	USGS Quad Sheet(s) with original photo date & latest Photo revision date	Buckeye NW, AZ, photo date 1955, photo revised using 1978 photography Valencia, AZ, photo date 1954, photo revised using 1978 photography Wagner Wash Well, AZ, photo date 1984 White Tank Mtns NE, AZ, photo date 1954, photo revised 1971 White Tank Mtns SE, AZ, photo date 1954, photo revised 1971
2.1.9	Unique Conditions and Problems	Alluvial fan
2.1.10	Coordination of Peak Discharges (Agency, Date, Comments)	Alpha Engineering Group, 1994, White Tank Wash FIS obtained from Flood Control District of Maricopa County, September 1999, CP1M, 100-yr 24-hr HEC-1

2.2 FEMA Forms

FEDERAL EMERGENCY MANAGEMENT AGENCY REVISION REQUESTER AND COMMUNITY OFFICIAL FORM	O.M.B No. 3067-0148 Expires April 30, 2001

Public reporting burden for this form is estimated to average 2.13 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing and reviewing the form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, S.W., Washington DC 20472; and to the Office of Management and Budget, Paperwork Reduction Project (3067-0148), Washington, DC 20503.

You are not required to respond to this collection of information unless a valid OMB Control Number is displayed in the upper right corner of this form.

1. REQUESTED RESPONSE FROM FEMA

This request is for a:

☐ CLOMR A letter from FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision, or proposed hydrology changes (See 44 CFR Ch. 1, Parts 60,65 & 72).

☒ LOMR A letter from FEMA officially revising the current NFIP map to show the changes to floodplains, floodway or flood elevations. LOMRs typically decrease flood hazards. (See 44 CFR Ch. 1 Parts 60 & 65.)

☒ Other Describe: New Study

2. OVERVIEW

1. The basis for this revision request is (are): (check all that apply)

☐ Physical Change ☐ Improved Methodology/Data ☐ Floodway Revision

☒ Other Describe: New Flood Insurance Study

Note: A photograph is not required, but is very helpful during review.

2. Flooding Source: White Tank Fan, Site 36

3. Project Name/Identifier: White Tank Fan, Site 36, Approximate Floodplain Delineation Study FCD No. 99-02, Assignment No. 2

4. FEMA zone designations affected: D, X
(example: A, AH, AO, A1-A30, A99, AE, V, V1-V30, VE, B, C, D, X)

5. The NFIP map panel(s) affected for all impacted communities is (are):

Community No.	Community Name	State	Map No.	Panel No.	Effective Date
Ex: 480301 480287	Katy, City Harris County	TX TX	480301 48201C	0005D 0220G	02/08/83 09/28/90
040037	Unincorporated Maricopa County	AZ	04013C	1550F 1575E	12/03/93 Not printed
040037	Unincorporated Maricopa County	AZ	04013C	2020F 2025F	09/30/95 09/30/95

6. The area of revision encompasses the following types of flooding and structures. Check all that apply.

Types of Flooding	Structures
☒ Riverine	☐ Channelization
☐ Coastal	☐ Levee/Floodwall
☒ Alluvial fan	☐ Bridge/Culvert
☒ Shallow Flooding (e.g. Zones AO and AH)	☐ Dam
☐ Lakes	☐ Fill
☐ Other (describe)	☐ Other (describe)

PLEASE REFER TO THE INSTRUCTIONS FOR THE APPROPRIATE MAILING ADDRESS

Form 81-89, May 97 Revision Requester and Community Official Form MT-2 Form 1 Page 1 of 2

4. ENCROACHMENT INFORMATION

1. Does the State have jurisdiction over the floodway or its adoption by communities participating in the NFIP?
☐ Yes ☒ No

If Yes, attach a copy of a letter notifying the appropriate State agency of the floodway revision and documentation of the approval of the revised floodway by the appropriate State agency.

2. Does the development in the floodway cause the 1% annual chance (base) elevation to increase at any location by more than 0.000 feet? ☐ Yes ☐ No ☒ N/A

3. Does the cumulative effect of all development that has occurred since the effective SFHA was originally identified cause the base flood elevation to increase at any location by more than one foot (or other increase limit if community or state has adopted more stringent criteria - even if a floodway has not been delineated by FEMA)?
☐ Yes ☒ No

If the answer to either items is Yes, please attach documentation that all requirements of Section 65.12 of the NFIP regulations have been met, regarding evaluation of alternatives, notice to individual legal property owners, concurrence of CEO, and certification that no insurable structures are impacted.

5. MAINTENANCE RESPONSIBILITY

The community is willing to assume responsibility for ☐ performing ☐ overseeing compliance with the maintenance and operation plans of the ___ (Name)
flood control structure. If not performed promptly by an owner other than the community, the community will provide the necessary services without cost to the Federal government.
Operation and maintenance plans are attached. ☐ Yes ☐ No ☒ N/A

6. REVIEW FEE

The review fee for the appropriate request category has been included. ☒ Yes Fee amount: $

OR

This request is based on a federally sponsored flood-control project where 50 percent or more of the project's cost is federally sponsored, or the request is based on detailed hydrologic and hydraulic studies conducted by Federal, State, or local agencies to replace approximate studies conducted by FEMA and shown on the effective FIRM; thus the project is fee exempt.
☐ Yes
Please see Instructions for Fee Amounts

7. SIGNATURE

Note: I understand that my signature indicates that all information submitted in support of this request is correct Signature of Revision Requester Jonathan E. Fuller, P.E., P.H. Printed Name and Title of Revision Requester JE Fuller / Hydrology & Geomorphology, Inc. Company Name Telephone No.: (480)752-2124 Date:	*Note:* Signature indicates that the community understands, from the revision requester, the impacts of the revision on flooding conditions in the community. Signature of Community Official Michael S. Ellegood, Chief Engineer and General Manager Printed Name and Title of Community Official Flood Control District of Maricopa County Community Name Telephone No.: (602)506-1501 Date:

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR This certification is in accordance with 44 CFR Ch. 1, Sect 65.2 Signature Jonathan E. Fuller, P.E., P.H. Printed Name and Title of Revision Requester Registr No. 26846 Expires (Date) 3/31/02 State AZ Type of License/Expertise: Civil	Check which forms have been included with this request

Form Name and (Number)	Required if .....
☒ Hydrologic (3)	new or revised discharges
☒ Hydraulic (4)	new or revised water-surface elevations
☒ Mapping (5)	floodplain/floodway changes
☐ Channelization (6)	channel is modified
☐ Bridge/Culvert (7)	addition/revision of bridge/culvert
☐ Levee/Floodwall (8)	addition/revision of levee/floodwall
☐ Coastal (9)	new or revised coastal elevations
☐ Coastal Structures (10)	addition/revision of coastal structure
☐ Dam (11)	addition/revision of dam
☐ Alluvial Fan (12)	structures proposed on alluvial fan

Form 81-89, May 97 Revision Requester and Community Official Form MT-2 Form 1 Page 2 of 2

4. ENCROACHMENT INFORMATION

1. Does the State have jurisdiction over the floodway or its adoption by communities participating in the NFIP?
☐ Yes ☒ No

If Yes, attach a copy of a letter notifying the appropriate State agency of the floodway revision and documentation of the approval of the revised floodway by the appropriate State agency.

2. Does the development in the floodway cause the 1% annual chance (base) elevation to increase at any location by more than 0.000 feet? ☐ Yes ☐ No ☒ N/A

3. Does the cumulative effect of all development that has occurred since the effective SFHA was originally identified cause the base flood elevation to increase at any location by more than one foot (or other increase limit if community or state has adopted more stringent criteria - even if a floodway has not been delineated by FEMA)?
☐ Yes ☒ No

If the answer to either items is Yes, please attach documentation that all requirements of Section 65.12 of the NFIP regulations have been met, regarding evaluation of alternatives, notice to individual legal property owners, concurrence of CEO, and certification that no insurable structures are impacted.

5. MAINTENANCE RESPONSIBILITY

The community is willing to assume responsibility for ☐ performing ☐ overseeing compliance with the maintenance and operation plans of the ___ (Name)
flood control structure. If not performed promptly by an owner other than the community, the community will provide the necessary services without cost to the Federal government.
Operation and maintenance plans are attached. ☐ Yes ☐ No ☒ N/A

6. REVIEW FEE

The review fee for the appropriate request category has been included. ☒ Yes Fee amount: $

OR

This request is based on a federally sponsored flood-control project where 50 percent or more of the project's cost is federally sponsored, or the request is based on detailed hydrologic and hydraulic studies conducted by Federal, State, or local agencies to replace approximate studies conducted by FEMA and shown on the effective FIRM; thus the project is fee exempt.
☐ Yes
Please see Instructions for Fee Amounts

7. SIGNATURE

Note: I understand that my signature indicates that all information submitted in support of this request is correct

See Page 2-3

Signature of Revision Requester

Jonathan E. Fuller, P.E., P.H.
Printed Name and Title of Revision Requester

JE Fuller / Hydrology & Geomorphology, Inc.
Company Name

Telephone No.: (480)752-2124 Date:

Note: Signature indicates that the community understands, from the revision requester, the impacts of the revision on flooding conditions in the community

M Smith

Signature of Community Official

WOODRAW C. SCOUTTEN, TOWN ENGINEER
Printed Name and Title of Community Official

Town of Buckeye, Arizona
Community Name

Telephone No.: 602-993-5686 Date: 9-21-00

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR
This certification is in accordance with 44 CFR Ch. 1, Sect 65.2

Signature
Jonathan E. Fuller, P.E., P.H.
Printed Name and Title of Revision Requester

Registr No. 26846 Expires (Date) 3/31/02 State AZ

Type of License/Expertise: Civil

Check which forms have been included with this request

Form Name and (Number)	Required if .....
☒ Hydrologic (3)	new or revised discharges
☒ Hydraulic (4)	new or revised water-surface elevations
☒ Mapping (5)	floodplain/floodway changes
☐ Channelization (6)	channel is modified
☐ Bridge/Culvert (7)	addition/revision of bridge/culvert
☐ Levee/Floodwall (8)	addition/revision of levee/floodwall
☐ Coastal (9)	new or revised coastal elevations
☐ Coastal Structures (10)	addition/revision of coastal structure
☐ Dam (11)	addition/revision of dam
☐ Alluvial Fan (12)	structures proposed on alluvial fan

Form 81-89, May 97 Revision Requester and Community Official Form MT-2 Form 1 Page 2 of 2

FEDERAL EMERGENCY MANAGEMENT AGENCY RIVERINE HYDRAULIC ANALYSIS FORM	O.M.B No. 3067-0148 Expires April 30, 2001

Public reporting burden for this form is estimated to average 2.25 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing and reviewing the form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, S.W., Washington DC 20472; and to the Office of Management and Budget, Paperwork Reduction Project (3067-0148), Washington, DC 20503.

You are not required to respond to this collection of information unless a valid OMB Control Number is displayed in the upper right corner of this form.

Note: Fill out one form for each flooding source studied

Community Name: Unincorporated Maricopa County and Town of Buckeye, Arizona

Flooding Source: White Tank Alluvial Fan, Site 36 (Hjalmarson and Kemna, 1992)

Project Name/Identifier: White Tank Fan, Site 36, Approximate Floodplain Delineation Study FCD No. 99-02, Assignment No. 2

1. REACH TO BE REVISED

Describe the limits of the revision OR submit a copy of the FIRM with the revision area clearly highlighted.
Copy of FIRM(s) attached depicting area of the revision (highlighted, or circled)? ☒ Yes
Downstream Limit: Buckeye Flood Retarding Structure No. 1
Upstream Limit: White Tank Fan Site 36 source wash at the T2N, R4W, Sec. 8 eastern boundary

2. MODELS SUBMITTED

Requirements: for areas which have detailed flooding:	for areas which do not have detailed flooding:
Full input and output listings along with files on diskette for each of the models listed below (items 1-4) and a summary of the source of input parameters used in the models must be provided. The summary must include a description of any changes made from model to model (e.g., Duplicate Effective model to Corrected Effective model). At a minimum, the Duplicate Effective (item 1) and the Revised or Post-Project Conditions (item 4) models must be submitted. See instructions for directions on when other models may be required.	Only the 100-year (Base) flood profile is required. A hydraulic model is not required for areas which do not have detailed flooding; however, BFEs may not be added to the revised FIRM. If a hydraulic model is developed for the area, items 3 and 4 described below must be submitted.

If hydraulic models are not developed, hydraulic analyses (including all calculations) for existing or pre-project conditions and revised or post-project conditions must be submitted.

1. Duplicate Effective Model ☐ Natural File Name ___ ☐ Floodway File Name
Copies of the hydraulic analysis used in the effective FIS, referred to as the effective models (10-, 50-, 100-, and 500-year multi-profile runs and the floodway run) must be obtained and then reproduced on the requester's equipment to produce the Duplicate Effective model. This is required to assure that the effective models input data has been transferred correctly to the requester's equipment and to assure that the revised data will be integrated into the effective data to provide a continuous FIS model upstream and downstream of the revised reach.

2. Corrected Effective Model ☐ Natural File Name ___ ☐ Floodway File Name
The Corrected Effective model is the model that corrects any errors that occur in the Duplicate Effective model, adds any additional cross sections to the Duplicate Effective model, or incorporates more detailed topographic information than that used in the currently effective model. The Correctly Effective model must not reflect any man-made physical changes since the date of the effective model. An error could be a technical error in the modeling procedures, or any construction in the floodplain that occurred prior to the date of the effective model but was not incorporated into the effective model.

3. Existing or Pre-Project Conditions Model ☐ Natural File Name _____ ☐ Floodway File Name _____
The Duplicate Effective model or Corrective Effective model is modified to produce the Existing or Pre-Project Conditions model to reflect any modifications that have occurred within the floodplain since the date of the Effective model but prior to the construction of the project for which the revision is being requested. If no modification has occurred since the date of the effective model, then this model would be identical to the Corrected Effective model or Duplicate Effective model.

4. Revised or Post-Project Conditions Model ☐ Natural File Name ___ ☐ Floodway File Name
The Existing or Pre-Project Conditions model (or Duplicate Effective model or Corrected Effective model, as appropriate) is revised to reflect revised or post-project conditions. This model must incorporate any physical changes to the floodplain since the effective model was produced as well as the effects of the project. When the request is for the proposed project this model must reflect proposed conditions.

5. Other – Please attach a sheet describing all other models submitted along with the file names. ☐ Natural ☐ Floodway

PLEASE REFER TO THE INSTRUCTIONS FOR THE APPROPRIATE MAILING ADDRESS

Form 81-89C, May 97 Riverine Hydraulic Analysis Form MT-2 Form 4 Page 1 of 2

3. STARTING WATER-SURFACE ELEVATIONS

Explain how they were determined.
Explanation Attached? ☐ Yes ☐ No
NOTE: If the effective study is an approximate study, the slope/area method is recommended.
For detailed analysis studies, using a known water-surface elevation is recommended.

4. RESULTS (from the model used to revise the 100-year water surface elevations)

If the results indicate any of the following, attach an explanation - to this form, or to the hydraulic model printout- as to the reasonableness of the situation.

☐ Supercritial depth ☐ Critical Depth ☐ Drawdowns ☐ Negative Floodway Surcharges

☐ Floodway Surcharges Greater Than Maximum Allowed by Community/State

☐ Water surface elevations higher than the end points of cross sections.

☐ Floodway discharge is different than the Natural 100-year (base) flood discharge.

☐ Project causes 100-year floodplain or floodway elevations to increase (state if increases are located off the requester's property)

Explanation attached with Form ☐ Explanation provided on attached printout ☐
If Hydraulic model used is HEC-2, has it been checked with FEMA'S CHECK-2 computer program ☐ Yes ☐ No
(see instructions for information on how to obtain CHECK-2)

5. REVISED FIRM/FBFM AND FLOOD PROFILES

1. Profile Transition

a. 100-Year Water-Surface Elevations - indicate the difference in water surface elevations where the project 100-year elevations tie into the existing 100-year water surface elevations at each end of the project.

Downstream End: _____ within _____ (feet) Upstream End ___ within ___ (feet)

b. Floodway Elevations – indicate the difference in water surface elevations where the project floodway elevations tie into the existing floodway water surface elevations at each end of the project.

Downstream End: _____ within _____ (feet) Upstream End ___ within ___ (feet)

c. Floodway widths – indicate the difference in floodway widths where the project floodway widths tie into the existing floodway width at each end of the project.

Downstream End _____ within _____ (feet) Upstream End ___ within ___ (feet)
Cross-Section # *Cross-Section #*

2. Profile Checklist (check box if information has been provided on profile)

The following information (unless in parentheses) must be included at the same scale as the existing profiles for this project:

☐ Stream Name ☐ Community Name ☐ Corporate Limits labeled ☐ Study limits labeled

☐ Confluences labeled ☐ Channel Stationing ☐ Streambed profiled ☐ Cross Sections labeled

☐ Horizontal/Vertical Scales indicated ☐ 100-year elevs profiled*

☐ Road Crossings ☐ Labeled ☐ Low Chord Elevations ☐ Top of Road Elevations

*All recurrence intervals in the effective study must also be profiled.
Floodway Data Table
Attach a Floodway Data Table for each cross section listed in the published Floodway Data table in the FIS report.
Floodway Data Table Attached ☐ Yes ☐ Not Required

Form 81-89, May 97 Riverine Hydraulic Analysis Form MT-2 Form 4 Page 2 of 2

Explanation

3., 4., 5. No watersurface elevations or profiles were computed in this study. Only inundation limits are shown.

FEDERAL EMERGENCY MANAGEMENT AGENCY RIVERINE / COASTAL MAPPING FORM	O.M.B No. 3067-0148 Expires April 30, 2001

Public reporting burden for this form is estimated to average 1.5 hours per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing and reviewing the form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, S.W., Washington DC 20472; and to the Office of Management and Budget, Paperwork Reduction Project (3067-0148), Washington, DC 20503.

You are not required to respond to this collection of information unless a valid OMB Control Number is displayed in the upper right corner of this form.

Note: Fill out one form for each flooding source studied

Community Name: Unincorporated Maricopa County and Town of Buckeye, Arizona

Flooding Source: White Tank Fan, Site 36

Project Name/Identifier: White Tank Fan, Site 36, Approximate Floodplain Delineation Study FCD No. 99-02, Assignment No. 2

This is a ☒ Manual ☐ Digital submission. *Digital map submissions may be used to update digital FIRMs (DFIRMs). For updating DFIRMs, these submissions must be coordinated with FEMA Headquarters as far in advance as possible.*

1. MAPPING CHANGES

1. A topographic workmap must be submitted showing the following information (check N/A when not applicable):

a.	Revised approximate 100-year floodplain boundaries (Zone A)	☐ Yes	☒ No	☐ N/A
b.	Revised detailed 100- and 500-year floodplain boundaries.	☐ Yes	☒ No	☐ N/A
c.	Revised floodway boundaries	☐ Yes	☒ No	☐ N/A
d.	Location and alignment of all cross sections with stationing control indicated.	☐ Yes	☐ No	☒ N/A
e.	Stream alignments, road alignments and dam alignments.	☒ Yes	☐ No	☐ N/A
f.	Current community boundaries.	☒ Yes	☐ No	☐ N/A
g.	Effective 100- year floodplain and floodway boundaries from FIRM/FBFM reduced or enlarged to the scale of the topographic workmap	☒ Yes	☐ No	☐ N/A
h.	Tie-ins between the effective and revised 100-, 500-year and floodway boundaries	☒ Yes	☐ No	☐ N/A
i.	The requester's property boundaries and community easements	☐ Yes	☐ No	☒ N/A
j.	The signed certification of a registered professional engineer	☐ Yes	☐ No	☒ N/A
k.	Location and description of reference marks	☐ Yes	☐ No	☒ N/A
l.	Vertical datum (example: NGVD, NAVD)	☐ Yes	☐ No	☒ N/A
m.	Coastal zone designations tie into adjacent areas not being revised	☐ Yes	☐ No	☒ N/A
n.	Location and alignment of all coastal transects used to revise the coastal analyze	☐ Yes	☐ No	☒ N/A
o.	V-zone has been delineated to extend landward to the heel of the primary frontal dune	☐ Yes	☐ No	☒ N/A

If any items are marked No or N/A please attach an explanation.

2. What is the source and date of the updated topographic information (example: orthophoto maps, July 1985; filed survey, May 1979, beach profile, June 1987 etc.)? No detailed mapping performed

3. What is the scale and contour interval of the following workmaps?

Effective FIS Scale _____ Contour Interval _____

Revision Request Scale 1"=2000' Contour Interval 10', 20', and 40' depending on USGS quad

NOTE: Revised topographic information must be of equal or greater detail than effective.

4. Attach an annotated FIRM/FBFM at the scale of the effective FIRM/FBFM showing the revised 100- and 500-year floodplain and the floodway boundaries and how they tie into those shown on the effective FIRM/FBFM downstream and upstream of the revisions or adjacent to the area of revision for coastal studies. FIRM/FBFM attached? ☐ Yes ☒ No

PLEASE REFER TO THE INSTRUCTIONS FOR THE APPROPRIATE MAILING ADDRESS

2. EARTH FILL PLACEMENT

1. The fill is: ☐ Existing ☐ Proposed ☒ N/A

2. Has fill been/will be placed in the regulatory floodway? ☐ Yes ☐ No
   If Yes, please attach completed Riverine Hydraulic Analysis Form (Form 4).

3. Has fill been/will be placed in floodway fringe (*area between the floodway and 100-year floodplain boundaries*)? ☐ Yes ☐ No

   If Yes, then complete A, B, C, and D below.

   a. Are fill slopes for granular materials steeper than one vertical on one-and-one-half horizontal? ☐ Yes ☐ No

      If Yes, justify steeper slopes _____

   b. Is adequate erosion protection provided for fill slopes exposed to moving flood waters? (*Slopes exposed to flows with velocities of up to 5 feet per second (fps) during the 100-year flood must, at a minimum, be protected by a cover of grass, vines, weeds, or similar vegetation; slopes exposed to flows with velocities greater than 5 fps during the 100-year flood must, at a minimum, be protected by stone or rock riprap.)*

      ☐ Yes ☐ No

      If No, describe erosion protection provided _____

   c. Has all fill placed in revised 100-year floodplain been compacted to 95 percent of the maximum density obtainable with the Standard Proctor Test Method or acceptable equivalent method? ☐ Yes ☐ No

   d. Can structures conceivably be constructed on the fill at any time in the future? ☐ Yes ☐ No

If Yes, attach certification of fill compaction (item 3c. above) by the community's NFIP permit official, a registered professional engineer, or an accredited soils engineer in accordance with Subparagraph 65.5(a)(6) of the NFIP regulations.

Fill certification attached ☐ Yes ☐ No

4. Has fill been/will be placed in a V zone? ☐ Yes ☐ No

If Yes, is the fill protected from erosion by a flood control structure such as a revetment or seawall?

☐ Yes ☐ No

If Yes, attach the Coastal Structures Form (Form 10).

Riverine/Coastal Mapping Form MT-2 Form 5 Page 2 of 2

Explanations

1.a. The only existing hazard zones in the area are Zone A areas behind the Buckeye Flood Retarding Structure No. 1. Otherwise, no other areas have been previously mapped approximately or otherwise.
1.b. This is an approximate study. No detailed boundaries were mapped.
1.c. The floodways mapped are for local floodplain management jurisdiction. These are alluvial fan floodways, corridors reserved by the local community for the purpose of maintaining continuity of sediment and water discharges along the piedmont. These floodway boundaries were not determined by detailed hydraulic modeling nor a 1 foot rise criteria.
1.d. Not a detailed study.
1.h. No previous studies in area mapped.
1.i. Study for Flood Control District of Maricopa County.
1.j, k., and l. No detailed mapping performed or base flood elevations calculated as this is an approximate study.
1. m.,n., and o. No coastal or V- zones.
3. No previous flood hazard mapping with contours of any interval has been mapped in the area except the Zone A area behind Buckeye Flood Retarding Structure No. 1.

SECTION 3: SURVEY AND MAPPING INFORMATION

3.1 Field Survey Information

No detailed topographic mapping was performed for this approximate floodplain delineation study. Therefore, no field survey information is presented here.

3.2 Mapping

The primary topographic maps used for this project were the most recent USGS 7.5 minute quadrangles for the study area. Digital raster graphic versions of the quadrangles along with USGS digital orthographic quadrangles (DOQ) were used to compile and present the various types of data analyzed for this study. The data were assembled for display in ArcView GIS 3.2 and AutoCAD Map 2000.

SECTION 4: HYDROLOGY

4.1 Method Description

The hydrologic information used in this study included evaluation of previously published paleoflood surveys upstream of the hydrographic apex (CH2M Hill, 1992), and rainfall-runoff modeling performed for an earlier FIS for nearby White Tank Wash (Alpha, 1994). Regional regression equations were also compared to these previously published values.

The hydrologic data applied in this study were used most directly in the approximate riverine delineations upstream of the hydrographic apex. Downstream of the hydrographic apex, geomorphic methods were the primary basis of the flood hazard delineation.

4.2 Gage Data

There is no streamflow or rainfall gaging directly within the study area watershed. However, rainfall records for adjacent areas are available and are summarized below. Table 4.1 and 4.2 show a list of the nearby gages and significant rainfall events recorded by them.

Historical Flooding Information

Field (1994) describes significant channel changes resulting from a large tropical storm in 1951 as reported in Kangieser (1969). The National Weather Service (NWS) Buckeye station (#021026) recorded 1.00", 2.60", 0.75", and 0.80" of rainfall on August 27, 28, 29, and 30, 1951, respectively for a total of 5.15". This may be the rainfall event(s) responsible for the large channel changes reported by Field (1994). The largest daily total during the period of record for the NWS station is 4.90" recorded on September 2, 1894. The 2nd largest rainfall recorded since March 1893 occurred on September 8, 1916 when 3.29" of rainfall was recorded.

The SCS (1963) indicate that the August 1951 storm inundated 12,240 acres and was similar in magnitude to events in January 1916 and September 1939. In January 1916, 2.26" of rain was recorded over five consecutive days. During September 1939, 4.5" of precipitation was recorded between the 4th and 13th of the month. The highest single daily total during the period occurred on the 4th when 2.27" of rain were recorded at the NWS Buckeye station. It is unknown if the daily values recorded in August 1951 represent a single storm. If they do, it would be one of the highest storm totals in this long record.

CH2M Hill (1992) performed a paleoflood survey that indicated that a flood between 2,000 cfs and 5,000 cfs occurred at some time in the past 100 years. They also report a more recent event of 500 to 1,000 cfs. They suggest that the large flood attributed to a tropical storm in 1951, as reported in Field (1994), may be responsible for emplacing the slackwater deposits used in the 2,000 to 5,000 cfs estimate. The narrow chute of the channel above the apex may be preventing preservation of older paleoflood evidence. The more recent flood reported by CH2M Hill may have been the August 15, 1990 storm recorded by the FCD ALERT gage #5200 which is the largest and most intense rainfall recorded in the 16 years of operation of this station (3.15" in 24 hours and 2.20" in 3 hours).

No USGS or FCDMC streamflow or precipitation gages exist within the project limits. Nearby gages include the following:

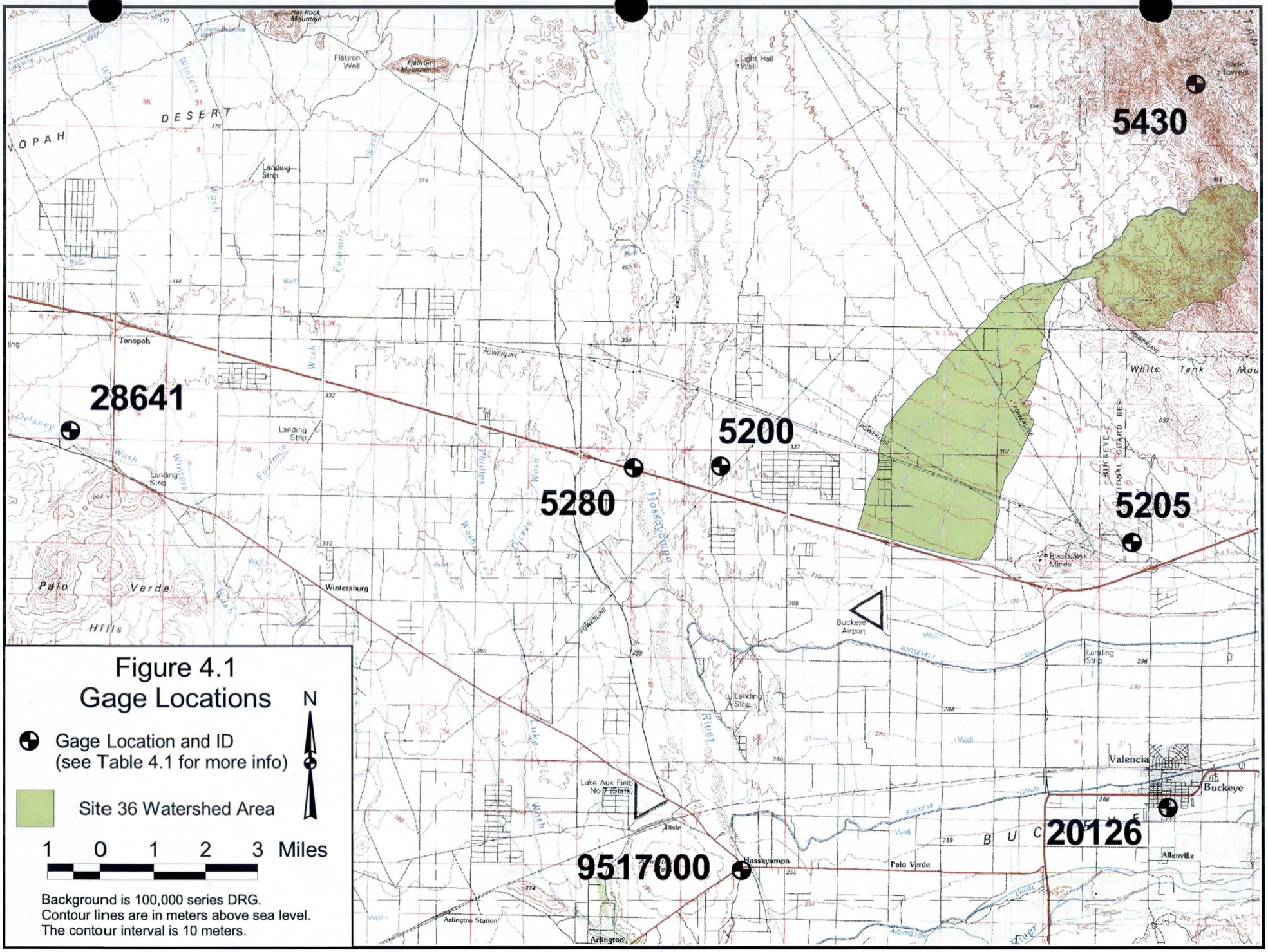
Table 4.1 Precipitation and Streamflow Gages Near the White Tank Fan Study Area

ID #	Gage Name	Type	Operator	Installation Date	Elevation (feet)
5200	Buckeye FRS #1	Rain & Stage	FCD	7-26-83	1,095
5205	Buckeye FRS #2	Rain & Stage	FCD	11-11-92	1,150
5280	Hassayampa @ I-10	Rain & Stage	FCD	11-9-94	1,035
5430	White Tanks East Peak	Rain	FCD	4-1-81	4,030
020126	Buckeye	Weather Station	NWS	3-1893	
028641	Tonopah	Weather Station	NWS	1951	
9517000	Hassayampa near Arlington	Stream-flow	USGS	1961	825

Locations of gages shown in Figure 4.1.

Table 4.2 Significant Rainfall Events Recorded by Nearby Gages

Station ID #	Years of Record	Max. 24-hr Rainfall		Max. 6-hr rainfall		Max. 3-hr rainfall	
		Depth	Date	Depth	Date	Depth	Date
FCDMC Stations							
5200	15	3.15"	8-14-90	2.44"	8-21-88	2.20"	8-14-90
5205	6	1.26"	11-15-93	1.10"	8-9-97	1.02"	8-8-97
5280	4	1.89	8-9-97	1.85"	8-9-97	1.77"	8-8-97
5430	17	Not Available		Not Available		2.32"	8-21-88
NWS Stations							
021026	102	4.90" (max. daily)	9-2-1894				
021026	102	1.00", 2.60", 0.75' , and 0.8" daily values for August 27-30 in 1951					
028941	20	3.05" (max. daily)	9-5-62				
028941	20	3.00" (daily)	9-1-84				


5430
28641
5200
5280
5205
20126
9517000
Figure 4.1
Gage Locations
Gage Location and ID
(see Table 4.1 for more info)
Site 36 Watershed Area
N
1 0 1 2 3 Miles
Background is 100,000 series DRG.
Contour lines are in meters above sea level.
The contour interval is 10 meters.
DESERT
Tonopah
Landing Strip
Wintersburg
Palo Verde
Hills
Buckeye Airport
Valencia
Buckeye
Hassayampa
Palo Verde
Arlington
Arlington Station
Luke Aux Field No 7 (Stats)
Blackhawk Mines
Allenville
White Tank
POWERLINE
CANAL
Wash
River

4.3 Flood Flow Frequency

White Tanks Wash FIS Hydrologic Analysis (Alpha, 1994 for FCD 90-64) will serve as the basis for the 100-year peak discharge for this study. Table 3 compares peak discharge estimates for a range of frequencies. The comparison shows the FCD 90-64 estimate to be reasonable.

Table 4.3 Comparison of discharge estimates for Site 36

Source	2-year	5-year	10-year	25-year	50-year	100-year
FCD 90-64 (Alpha, 1994) 100-yr 24-hr @ CP 1M						3,623
Waters, 1991, 24-hr logarithmic averaging, Clark Unit hydrograph	232	454	1,082	2,402	3,518	4,892
Waters, 1991, 24-hr logarithmic averaging, one basin S-graph	249	487	1,033	1,865	2,423	3,017
Hjalmarson, 1994	325		1,240			3,570
Thomas, et al., 1997 Region 13	325	790	1,245	2,001	2,681	3,575

The NOAA Atlas II 100-year 24-hour point rainfall values are shown in Figure 4.2.1.

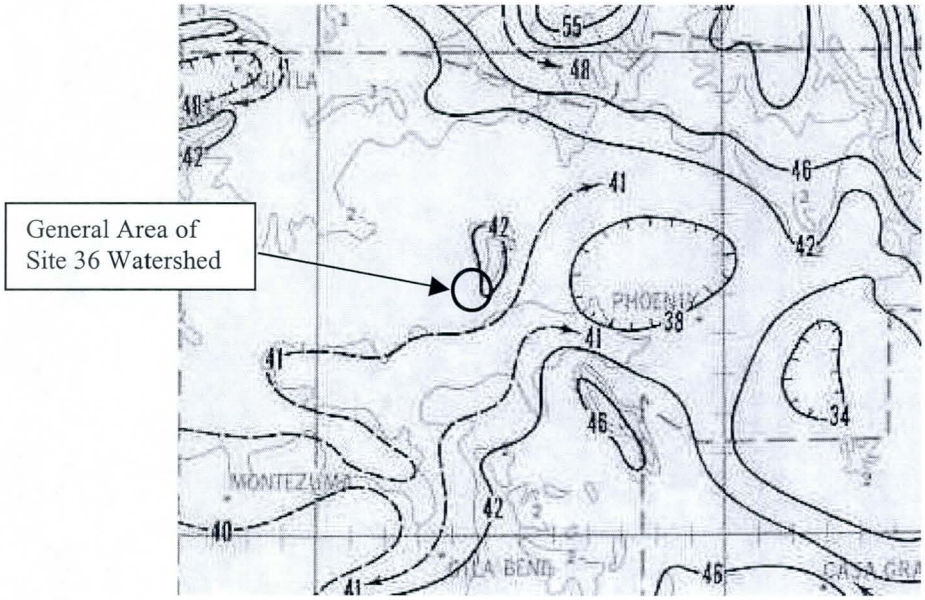


Figure 4.2 NOAA Atlas II 100-year 24-hour Rainfall

The NOAA Atlas II indicates a 100-year 24-hour point rainfall value of about 4.2 inches for the watershed upstream of the hydrographic apex.

4.4 Conclusions

The study watershed has no streamflow gage information. Therefore, synthetic rainfall-runoff estimates will be used for estimates of the 100-year discharge. Previous HEC-1 modeling results for the watershed are within the range of the results of regional regression equations. Therefore, the previous HEC-1 study results will be used in the current study for estimates of the 100-year discharge. Finally, the watershed has experienced significant flooding in the historic past and will continue to produce flooding in the future which could be a hazard to life and property.

4.5 References

Alpha Engineering Group, Inc., 1994, White Tanks Wash Flood Insurance Study, FCD No. 90-64: for FCDMC, Phoenix, Arizona.

CH2M Hill, 1992, Alluvial Fan Data Collection and Monitoring Study: Tempe, Arizona, CH2M Hill and R.H. French, Ph.D., P.E. Consulting Engineer for the Flood Control District of Maricopa County, 204 p.

Field, John J., 1994, Processes of Channel Migration on Fluvially Dominated Alluvial Fans in Arizona. Arizona Geological Survey OFR 94-13, 40 p.

Hjalmarson, H.W., 1994, Potential flood hazards and hydraulic characteristics of distributary-flow areas in Maricopa County, Arizona: U.S. Geological Survey Water Resources Investigations Report 93-4169, 56 p.

Hjalmarson, H.W., and Kemna, S.P., 1992, Flood hazards of distributary-flow areas in southwestern Arizona: U.S. Geological Survey Water Resources Investigations Report 91-4171, 68 p.

Kangieser, P.C., 1969, Major rainstorms and snowstorms in Arizona 1897-1969 [unpublished report]: Tempe, Arizona, Arizona Weather Bureau, 25 p.

National Archive, 1954, Black and white aerial photographs, scale 1:20,000.

National Archive, 1949, Black and white aerial photographs, scale 1:20,000.

Soil Conservation Service, 1963, Buckeye Watershed: Watershed Work Plan: USDA.

Thomas, Blakemore E, Hjalmarson, H.W., and Waltemeyer, S.D., 1997, Methods for Estimating Magnitude and Frequency of Floods in the Southwest United States: U.S. Geological Survey, Water Supply Paper 2433, 195 p.

U.S. Army Mapping Service, 1953, Large format black and white aerial photography. From FCDMC archives. Scale = approximately 1:14,400.

U.S. Geological Survey, 1988, Wagner Wash Well, Ariz. Quadrangle, 7.5 minute series, Provisional Edition, 1:24,000 (photo date 1984).

U.S. Geological Survey, 1982, Buckeye NW, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (photo date 1955, originally published 1958; photo revised in 1982 using 1978 photography).

U.S. Geological Survey, 1982, Valencia, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (original photo date 1954, originally published 1958; photo revised in 1982 using 1978 photography).

U.S. Geological Survey, 1978, White Tank Mtns NE, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (original photo date 1954, published 1957; photo revised 1971, and photo inspected with no changes made in 1978).

Waters, Stephen D., 1991, Hydrologic analysis for White Tanks Distributary Flow Area: Phoenix, Arizona, Flood Control District of Maricopa County, 29 p.

SECTION 5: HYDRAULIC ANALYSIS

5.1 Method Description

This study used approximate hydraulic methods. Normal depth computations for representative cross sections were used to estimate the depth and width of inundation from the 100-year flood. The resultant width was applied to the stream reach for each representative cross section. Adjustments to the computed width were made based on interpretation of aerial photographs and geomorphology. In all cases the final floodplain was at least as wide as the computed width for normal depth.

Description of Hydraulic Analysis of Riverine Reach Upstream of Hydrographic Apex

Upstream of the hydrographic apex of the Site 36 alluvial fan, a 3.1 mile stream reach was delineated using approximate methods for the 100-year floodplain. The data and procedure used are described as follows. The geometric data were obtained for 6 cross sections spaced evenly throughout the reach. The contour data were taken from existing 7.5 minute USGS topographic quadrangles. The contour interval for the quadrangles is 40 feet. Channel slope for computation of normal depth was also taken from the USGS quadrangles. Manning's n-values were estimated from examination of large scale aerial photographs and ground observations using procedures outlined in Thomsen and Hjalmarson (1991). The cross sections, slopes, and n-values were then used to compute normal depth of flow using the computed 100-year discharge at concentration point 1M (3,600 cfs) from the White Tanks Wash FIS (Alpha, 1994). Four of the six cross sections showed supercritical flow at normal depth, so the water surface elevation was raised to critical depth. The resultant top widths were then plotted onto a map. Adjustments to the computed width were made based on interpretation of the USGS digital orthographic quadrangle aerial photographs (DOQ) and recent aerial photographs (AMC, 1999). In all instances the resultant floodplain is at least as wide as the computed top width. The cross section locations, normal depth computations, and resulting floodplain are shown in Appendix E.

5.2 Work study maps

Appendix E contains maps of USGS topographic quadrangles over digital orthographic aerial photos (DOQ) with the location of cross sections and the resulting floodplains for reaches mapped using normal depth hydraulic methods. The maps are presented at various scales, but the original data from the USGS was produced at 1:24,000.

5.3 Parameter estimation

5.3.1 Roughness coefficients

Manning's n-values for representative reaches were computed using methods outlined in Thomsen and Hjalmarson (1991). The sources for evaluation of the roughness conditions in each reach included examination of reaches in the field and interpretation of aerial photographs. The n-values estimated for each representative cross section can be found in Appendix E.

5.3.2 Expansion and contraction coefficients

No step backwater modeling was performed for this study. Therefore, expansion and contraction coefficients were not considered.

5.4 Cross section description

Representative cross sections were taken from USGS 7.5 minute topographic quadrangles for the area. For the riverine reach upstream of the hydrographic apex, cross section locations were selected about every ½ mile and are intended to be reasonable representations of the reach halfway upstream and downstream to the next cross section. In all, six cross sections were used to represent the riverine reach upstream of the hydrographic apex.

5.5 Modeling considerations

Modeling was limited to normal depth computations of flow at individual cross sections. The computer program XSPRO (Grant, et al., 1992) was used to facilitate the normal depth computation. The program output is included in Appendix E.

5.6 Floodway modeling

No floodway was modeled as part of this approximate study using conventional hydraulic floodway analyses. Administrative floodways were delineated as part of the Stage 3 analysis of the 100-year floodplain downstream of the hydrographic apex. The identification and designation of the various alluvial fan administrative floodways are described in Section 6B.

5.7 Problems encountered during the study

No special problems were encountered in the approximate hydraulic analyses.

5.8 Calibration

No model calibration was performed due to a lack of data from which to calibrate.

5.9 Final Results

5.9.1 Hydraulic analysis results

The approximate method delineation of the 100-year floodplain upstream of the hydrographic apex resulted in 3.1 miles of new riverine floodplain. The floodplain limits are depicted in Figure 6B.13 and on Sheet 4 of 4 in Section 6B.

5.9.2 Verification of results

The results of the hydraulic analyses are considered reasonable based on engineering judgment, field observations, and results of previous modeling on similar watercourses. The estimates of the 100-year discharge as discussed in Section 4 compare well with regional regression equations. Also, the planimetric limits of the floodplain were evaluated in their geomorphic

context. That is, surfaces shown within the floodplain lie within areas whose geomorphology suggests that they have been and will continue to be prone to flooding. This is true of both the approximate hydraulic analyses presented in Section 5 as well as the geomorphic assessment described in Section 6B.

5.10 References

Aerial Mapping Company, 1999, Color stereographic aerial photographs of White Tank fan approximate delineation study area, flight date 9-25-99, scale 1:9,600 and flight date 10-6-99, scale 1:32,000, and miscellaneous oblique aerial photos also dated 10-6-99.

Alpha Engineering Group, Inc., 1994, White Tanks Wash Flood Insurance Study, FCD No. 90-64: for FCDMC, Phoenix, Arizona.

Grant, G., Duval, J., Koerper, G., and Fogg, J., 1992, XSPRO – Cross-section Professional Analyzer, Version 1.1, May 1992: DOS computer program by the USDA Forest Service and USDI Bureau of Land Management.

Thomsen, B.W. and Hjalmarson, H.W., 1991, Estimated Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona, USGS report prepared for the Flood Control District of Maricopa County, 126 p.

U.S. Geological Survey, 1988, Wagner Wash Well, Ariz. Quadrangle, 7.5 minute series, Provisional Edition, 1:24,000 (photo date 1984).

U.S. Geological Survey, 1982, Buckeye NW, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (photo date 1955, originally published 1958; photo revised in 1982 using 1978 photography).

U.S. Geological Survey, 1982, Valencia, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (original photo date 1954, originally published 1958; photo revised in 1982 using 1978 photography).

U.S. Geological Survey, 1978, White Tank Mtns NE, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (original photo date 1954, published 1957; photo revised 1971, and photo inspected with no changes made in 1978).

U.S. Geological Survey, 1997, White Tank Mountains, AZ, SW, Digital Orthographic Quarter Quadrangle, GeoTIFF format, 1 meter resolution, UTM, NAD83 projection.

U.S. Geological Survey, 1997, Wagner Wash Well, AZ, SE, Digital Orthographic Quarter Quadrangle, GeoTIFF format, 1 meter resolution, UTM, NAD83 projection.

U.S. Geological Survey, 1992, Buckeye NW, AZ, NE, Digital Orthographic Quarter Quadrangle, GeoTIFF format, 1 meter resolution, UTM, NAD83 projection.

SECTION 6A: EROSION AND SEDIMENT TRANSPORT

No specific erosion or sediment transport analyses were conducted as part of this study. However, implicit to the geomorphic assessment of the active alluvial fan areas were considerations of sedimentary processes on the Site 36 piedmont. Therefore, areas of erosion hazards associated with the active alluvial fan flooding have been included in the areas mapped on Sheet 4 of 4.

Modified Universal Soil Loss Equation (MUSLE) estimates of sediment yield for the watershed contributing to the alluvial fan hydrographic apex indicate average annual sediment yield rate of 0.14 ac-ft/mi^2/yr. The 100-year flood is estimated to deliver 6.23 acre-feet of sediment to the hydrographic apex. The calculations are provided in Appendix F.

SECTION 6B: GEOMORPHOLOGY

This section of the Technical Data Notebook is included to provide a separate place for a description of the geomorphic methods and results used in this study to identify the 100-year flood hazards on the Site 36 piedmont. The outline of the presentation generally follows the *Piedmont Flood Hazard Assessment Manual (PFHAM)* (Hjalmarson, 1998) and the FEMA *Guidelines for Determining Flood Hazards on Alluvial Fans (FEMA Guidelines)* (FEMA, 2000). Since parts of the geomorphic assessment require consideration of hydrologic and hydraulic characteristics of the piedmont, some of the information presented in Section 4 and 5 may be reiterated in Section 6B.

6B.1 Previous Studies

Several previous studies of the geomorphology and relative flood hazards have been conducted in and around the study area. These studies are: Hjalmarson and Kemna (1991), CH2M Hill (1992), Field & Pearthree (1991, 1992), Field (1994), and Hjalmarson (1994). All of these studies were conducted prior to the advent of the *PFHAM* or the *FEMA Guidelines*. Therefore, none of them presents their analyses or results according to the 3 stage process. Moreover, with the exception of Field & Pearthree (1992), the previous studies do not cover the entire extent of the current study. Therefore, the current study reviewed, reevaluated, refined, extended, and reformatted the information in the previous studies as well as incorporated additional data into the current flood hazard assessment.

6B.2 Method Description

The White Tank Fan, Site 36, Approximate Floodplain Delineation Study area is located in western Maricopa County, Arizona (Figure 6B.1). The watershed contributing to the hydrographic apex encompasses approximately 5.7 square miles. The piedmont surface downstream of the hydrographic apex covers about 9.7 square miles (8.9 within study area and 0.8 west of Sun Valley Parkway).

The flood hazard delineation for this study begins at the east boundary of Sec. 8, T2N, R4W about 3.1 miles upstream of the hydrographic apex. Downstream of the hydrographic apex, the delineation covers flood areas on the piedmont on both active and inactive alluvial fan surfaces for about 6 miles downstream to the Buckeye Flood Retarding Structure No. 1. The western boundary of the study area was taken at Sun Valley Parkway. Although the alluvial fan landform (see Stage 1) extends west of Sun Valley Parkway, the study contract limited the scope of the study to the area east of the Parkway. This study includes delineation of a total of about 8.9 square miles of floodplain on the Site 36 piedmont.

This section of Technical Data Notebook is dedicated to a description of the methods used to identify the type and extent of the flood hazard within the study area. The organization follows the general outline presented in the *PFHAM* and the *FEMA Guidelines*. Both of these documents describe a procedure that follows a three stage process: the first for piedmonts and the second for alluvial fans. In the *PFHAM,* which is applicable for use in Maricopa County, Arizona, the three stages are described as follows: 1) recognizing and characterizing piedmont landforms, 2)

identifying the active or unstable and inactive or stable areas of the piedmont, and 3) defining and characterizing the flood hazard.

The geomorphic analysis was the basis for the flood hazard delineation within the study area portions of the Site 36 piedmont downstream of the hydrographic apex. Upstream of the hydrographic apex, geomorphic methods were used to complement and refine conventional approximate normal-depth hydraulic methods which are described in Section 5 of the TDN.

6B.3 Work Study Maps

This study includes geomorphic mapping and floodplain delineation of parts of the Site 36 piedmont. The figures for Section 6B, including a cover sheet showing the project location and 11" x 17" versions of the Stage 1 Landform map, Stage 2 Stability map, and Stage 3 Floodplain map, are located at the end of Section 6B of the Technical Data Notebook. Large scale versions (1:12,000) of the Landform, Stability, and Floodplain study work maps are located in the map pockets at the back of the Notebook under the section labeled Exhibit Maps. The processes and rationale used to create these maps are described in the following sections.

6B.4 Description of Approach

The assessment of the 100-year flood hazard on the White Tank Fan, Site 36 piedmont generally follows the procedures outlined in the *PFHAM*. The *FEMA Guidelines* were also used to structure the analysis and presentation of results for this study. In particular, the geomorphic method for an approximate floodplain delineation discussed in the *FEMA Guidelines* served as the basis for identification of the 100-year flood hazard area in this study area.

The *PFHAM* method is founded on an approach to alluvial fan flood hazard assessment outlined in the National Research Council's 1996 *Alluvial Fan Flooding* report. Both documents describe a three stage method used to identify alluvial fan flood hazards. The *PFHAM* broadens the approach to application to the entire piedmont.

The first stage is the recognition and characterization of piedmont landforms. Data from published sources including topographic maps, NRCS soil surveys, geologic mapping, aerial photographs, and field observations are the basis for differentiating piedmont landforms which include mountains, inselbergs, alluvial fans, relict alluvial fans, pediments, and alluvial plains. Also identified for alluvial fan landforms are the location of the topographic and hydrographic apexes of the alluvial fan. The hydrographic apex is of particular interest because it is the location at which flow of water and sediment becomes unconfined and spreads out rapidly. Sudden expansion of flow causes deposition of sediment and uncertain flood flow paths and distribution below this point. The complex hydraulics associated with this flow expansion and sediment deposition create significant uncertainties (unpredictability) that "cannot be set aside in the realistic assessment of the flood hazard" (FEMA, 2000) near the hydrographic apex and for some distance downstream.

The second stage is the identification of active and inactive areas of the piedmont. Active areas are those locations where uncertainties about channel geometry and hydraulic conditions of water and sediment discharge cannot be set aside in the realistic assessment of flood hazard. The

second stage also shall identify the portions of the piedmont subject to various types of flooding such as stable riverine flooding, active alluvial fan flooding, inactive alluvial fan flooding, and broad sheet flooding.

The second stage may be applied using a geomorphic approach on alluvial fans with little or no urbanization (Table 1, FEMA, 2000). In the geomorphic approach, surface characteristics that indicate surface stability are assessed and compiled. Surface characteristics such as vegetation patterns, presence or absence of rock varnish and desert pavement, and degree of soil development provide important information. Surfaces with well developed soils, rock varnish, and desert pavement, for example, have developed these features because they have not experienced significant inundation or erosion for thousands of years. Hence, it can be inferred that they will continue to remain free from flooding in the future. Similarly, areas strongly dissected by drainage channels are less likely to unpredictably change their location than channels with little to no lateral relief relative to the neighboring land. Historical aerial photographs can also be examined to see if any movement of channel positions can be detected over the photographic record. In many instances, 50 to 60 years of record can be obtained from aerial photographs. All of these characteristics are used to produce a map of areas subject to flooding and those not subject to flooding. Further, the areas subject to flooding are evaluated and mapped to show whether the flooding occurs on stable surfaces or unstable ones.

The third and final stage of the *PFHAM* method is to identify the areas subject to flooding for the 100-year flood event. Methods available for the third stage range from conventional detailed or approximate hydraulic methods using fixed-bed hydraulic models, such as Manning's equation, to geomorphic interpretation based field observations and aerial photographs. Combining conventional engineering techniques and geomorphic methods is strongly advocated. This study will use such a combined approach. Stable reaches with reasonably predictable peak discharges will be evaluated using normal depth hydraulic modeling in combination with field observations and aerial photo interpretation. The delineation of flood hazards within unstable areas will rely solely on geomorphic interpretation of the piedmont surface characteristics. Additionally, flood hazards in stable areas subject to flooding sources with unpredictable flow distributions were also delineated based on geomorphic interpretation. These areas lie within stable areas downstream of unstable areas.

For each of the stages a number of maps will be presented to illustrate the various data and results. All of the maps for Section 6B are located at the end of the Section.

6B.5 Stage 1: Recognizing and Characterizing Piedmont Landforms

The first stage of the assessment of the flood hazard on the piedmont was to distinguish the types of landforms on the piedmont using a variety of characteristics shown on soils maps, surficial geology maps, topographic maps, aerial photographs, and observed in the field. These data also begin to reveal active and inactive areas of the piedmont which will be detailed in Stage 2. However, the focus of Stage 1 is to identify the landforms. Additionally, when alluvial fan landforms are identified, the location of the topographic and hydrographic apexes require identification. The topographic apex is the uppermost apex of the alluvial fan and may not be the location where sediment deposition begins at the present time. The hydrographic apex is the highest location on an active alluvial fan and the topographic apex is the highest point on the

alluvial fan landform. On alluvial fans with entrenched channels at their head, the topographic apex can be located some distance upstream from the beginning of active alluvial fan flooding. The hydrographic apex is the highest point on an alluvial fan where flow is last confined (Hjalmarson, 1998).

The Site 36 piedmont landform is an alluvial fan with a topographic apex in a well-entrenched channel near the east edge of Section 8, T2N, R3W. Relict fan deposits flank the entrenched channel downstream about three miles before the wash loses confinement and spreads out into an active alluvial fan. Site 36 was also identified as an alluvial fan in previous studies (Hjalmarson and Kemna (1991), CH2M Hill (1992), Field & Pearthree (1991, 1992), Field (1994), and Hjalmarson (1994)). In addition, the following description of the composition, morphology, location, and boundaries are presented in support of this assessment.

6B.5.1 Composition

NRCS soils maps (Figure 6B.2 and 6B.3 adapted from Camp, 1986; Hartman, 1977) and surficial geology maps (Figure 6B.4 adapted from Field and Pearthree, 1991) show that the western side of the White Tank Mountains is composed of alluvial sediments. Specifically, with the exception of a few inselbergs, the study area is entirely composed of alluvial sediments.

6B.5.1.1 Soils Data

Figure 6B.2 shows the NRCS soil map units on the USGS topographic quadrangles. Figure 6B.3 shows the NRCS soil map units on aerial photographs. The soil polygons are from the *Soil Survey of Aguila-Carefree Area* (Camp, 1986) and the *Soil Survey of Maricopa County, Central Part* (Hartman, 1977) for the Site 36 study area. Table 6B.1 gives a list and description of the soil units within the study area. In addition to showing the map unit boundaries and designations, Figure 6B.2 shows the setting or type of landforms generally associated with each of the various map units as distinguished by the NRCS. The three main categories of landforms distinguished by the NRCS are: 1) drainageways, floodplains, and alluvial fans, 2) alluvial fan terraces, and 3) mountains and hillslopes. Copies of the complete soil unit descriptions for the study area from Camp (1986) and Hartman (1977) are provided in Appendix G.1.

The NRCS soils maps show the smoother, gentler portion of the lower piedmont north of Interstate 10 as an area of soils formed on recent alluvial fans and valley plains of the Antho-Valencia association separated by an island of old alluvial fans of the Gunsight-Rillito complex and the Coolidge-Laveen association. The middle and upper piedmont upstream is shown as composed predominantly of fan terraces of the Gunsight-Rillito complex, and the Momoli-Carrizo and Denure-Momoli-Carrizo complexes.

Table 6B.1 also shows the relationship between the NRCS soil map units and the landforms of the Site 36 piedmont. As can be seen from the table, each soil map unit is actually comprised of several soil series. Each series has its own associated position or landform which is identified in the table. Characteristics important to the soil series age, stability, and flood history are also presented in Table 6B.1. These characteristics help identify the landform type, as well as the stability and the flood history and flood potential of the unit.

The Antho, Carrizo, Maripo, and Valencia soils series represent the areas subject to flooding on alluvial fans, drainageways, floodplains and low stream terraces. The Antho and Carrizo series in particular are identified as positioned on alluvial fans. However, the most active area of the Site 36 piedmont is mapped as unit 91 (Figure 6B.3). Unit 91 is composed of Momoli and Carrizo soils. The Momoli series is described as being located on stream terraces and fan terraces. The lower portions of the 91 polygon in Section 23 show numerous small narrow areas of older surfaces which appear to be in the process of being buried and eroded by water and sediment discharges from the Site 36 watershed. The NRCS reports that unit 91 is composed of 45% Momoli and 35% Carrizo soils along with 20% other soils including Mohall, Tremant, Gunsight, Chuckwalla, Denure, Gilman, and Maripo series. The Mohall, Tremant, Gunsight, and Chuckwalla soils are indicated as being located on higher terraces. The Denure soil is also associated with stream and fan terraces. The Gilman series is associated with floodplains and alluvial fans while the Maripo is found on floodplains and low terraces. Therefore, the area immediately downstream of the hydrographic apex mapped as unit 91 may transition from Carrizo, Gilman, and/or Maripo soils into the terrace soils of the other series found in unit 91. The older surfaces in the downstream portions of this area are being actively buried and eroded by floodwaters from the more active area upstream.

The soils of the Chuckwalla, Gunsight, Ebon, and Pinamt soil series are located on fan terraces. These soils are also more well developed and have characteristics of much older surfaces such as enriched clay and/or carbonate horizons. On the lower piedmont the Coolidge and Laveen soils are found on areas of old alluvial fans and valley plains. These soils also exhibit signs of geologic age based on the accumulation of calcium carbonate.

The above description of the soils of the Site 36 piedmont is consistent with the common soil types for alluvial fans shown in Table 2.1 of the *PFHAM*, which shows typical relict fan soils which are found adjacent to the alluvial fan soils in the upper piedmont and on the middle piedmont south of Spike Hill.

Table 6B.1 Soil Units and Characteristics on the White Tank Fan (Site 36) Piedmont

SCS soils map units	Component Soil Series	Position / Landform	Important Characteristics	Subgroup, Order
From Soil Survey, Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona (Camp, 1986)				
Antho gravelly sandy loams (2)	Antho - 80%	- on floodplains, alluvial fans, and drainageways	- 55% with non-calcareous surface layer & calcareous below, 25% calcareous throughout; main lin	-Typic Torrifluvents, Entisols
Antho-Carrizo-Maripo complex (3, 4)	Antho - 35% Carrizo - 30% Maripo - 20%	- on floodplains, alluvial fans, and drainageways - on floodplains, drainageways, alluvial fans, fan terraces, and stream terraces - on flooplains and low stream terraces	- see above - subject to occassional flooding; hazard due to water erosion is severe; channeling, deposition, and streambank erosion occur during flooding - subject to rare periods of flooding * Main limitation for urban development of entire units is that they are subject to flooding. See also unit AGB in Hartman (1977).	- Typic Torrifluvents, Entisols - Typic Torriorthents, Entisols - Typic Torrifluvents, Entisols
Chuckwalla-Gunsight complex (19)	Chuckwalla - 45% Gunsight - 35%	- on tops of fan terraces - on sides of fan terraces	- 85-95% of surface typically covered with varnished desert pavement - C horizon is strongly to violently effervescent and weakly cemented in some pedons ** These are old surfaces generally free from flooding.	- Typic Haplargids, Aridisols - Typic Calciorthids, Aridisols
Denure-Momoli-Carrizo complex (29)	Denure - 40% Momoli - 30% Carrizo - 20%	- on stream terraces and fan terraces - on stream terraces and fan terraces - on floodplains, drainageways, alluvial fans, fan terraces, and stream terraces	- calcareous below about 8 inches; B horizon development; buried calcic or argillic horizon present in some pedons - B horizon development; strongly effervescent at depth	- Typic Camborthids, Aridisols - Typic Camborthids, Aridisols - Typic Torriorthents, Entisols
Ebon-Gunsight-Cipriano association (47)	Ebon - 35% Gunsight - 20% Cipriano - 20%	- on fan terraces and stream terraces - on fan terraces - on fan terraces	- yellowish red color, common thin clay films, strongly effervescent B horizon - see above; also, high lime content and restricted available water capacity contribute to very low productivity on these soils - shallow soils, underlain by indurated duripan (caliche)	- Typic Haplargids, Aridisols - Typic Calciorthids, Aridisols - Typic Durorthids, Aridisols
Ebon-Pinamt complex (48, 49)	Ebon - 45% Pinamt - 35%	- on fan terraces and stream terraces - on fan terraces	- yellowish red color, high clay content, calcareous at depth - yellowish red B horizons which are strongly to violently effervescent	- Typic Haplargids, Aridisols - Typic Haplargids, Aridisols
Gunsight-Rillito complex (70)	Gunsight - 40% Rillito - 40%	- on fan terraces - on fan terraces	- see above - weakly cemented calcic horizon at 4 to 36 inches	- Typic Calciorthids, Aridisols - Typic Calciorthids, Aridisols
Momoli-Carrizo complex (91)	Momoli - 45% Carrizo - 35%	- on stream terraces and fan terraces - on floodplains, drainageways, alluvial fans, fan terraces, and stream terraces	- weakly developed, light brown - poorly developed, pinkish gray, brown moist	- Typic Camborthids, Aridisols - Typic Torriorthents, Entisols
Pinamt-Tremant complex (98)	Pinamt - 45% Tremant - 35%	- on fan terraces - on fan terraces and stream terraces	- yellowish red B horizons which are strongly to violently effervescent - light reddish brown B horizons, caclic horizon at 5 to 24 inches, strongly to violently effervescent at depth, clay accumulation at depth	- Typic Haplargids, Aridisols - Typic Haplargids, Aridisols
Quilotosa-Vaiva-Rock outcrop complex (100)	Quilotosa - 50% Vaiva - 20% Rock outcrop - 20%	- on hillslopes and mountain slopes - on hillslopes and mountain slopes	- mapped on surfaces with 20 to 65% slopes; basically thin hillslope soils in the mountains	- Lithic Torriorthents, Entisols - Lithic Haplargids, Aridisols

Table 6B.1 Soil Units and Characteristics on the White Tank Fan (Site 36) Piedmont

SCS soils map units	Component Soil Series	Position / Landform	Important Characteristics	Subgroup, Order
From Soil Survey, Maricopa Pinal County, Arizona, Central Part (Hartman, 1977)				
Antho-Carrizo complex (AGB)	Antho - 35% Carrizo - 30% Maripo - 20%	- on alluvial fans 1 to 3 miles from mountains and in some broader stream channels; similar to units 3 and 4 in Camp (1986)	- surface drainage provided by dendritic pattern of shallow stream channels spaced at 50- to 200-foot intervals; Carrizo soil is in or adjacent to old stream channels that form a braided pattern across larger bodies of Antho soils; Maripo is in transitional areas between Carrizo and Antho	- Typic Torrifluvents, Entisols - Typic Torriorthents, Entisols - Typic Torrifluvents, Entisols
Antho association (AL)	Antho - 85%	- on alluvial fans that radiate out from nearby mountains	- surface drainage provided by a dendritic pattern of shallow stream channels, 1 foot to 3 feet deep, spaced at 50- to 300 foot intervals; 55% Antho sandy loam at the lower ends of alluvail fans farthest from the mountains, 30% Antho gravelly sandy loam on the higher parts of the alluvial fans nearest the mountains	- Typic Torrifluvents, Entisols
Antho-Valencia association (AM)	Antho - 40% Valencia - 40%	- on long, smooth valley plains 1 to 3 miles from the base of the mountains	- surface drainage provided by a dendritic pattern of shallow stream channels, 1 foot to 3 feet deep, spaced at 50- to 200 foot intervals	- Typic Torrifluvents, Entisols - Typic Torrifluvents, Entisols
Coolidge-Laveen association (CV)	Coolidge - 40% Laveen - 40%	- on upper part of old alluvial fans and valley plains - on lower part of old alluvial fans and old valley plains	- dissected by stream channels at 50- to 300-ft intervals, strongly to violently effervescent - large cocentration of lime in lower part	- Typic Calciorthids, Aridisols - Typic Calciorthids, Aridisols
Gunsight-Rillito complex (GYD)	Gunsight - 40% Rillito - 40%	- on old alluvial fans - in circular spots near drainageways, and near the tops of fans; on old fans and stream terraces	- dissected by series of stream channels at 100- to 500-foot intervals; channels range from a few feet to as much as 30 feet deep; Gunsight soils mainly on the top of fans and are high in lime content	- Typic Calciorthids, Aridisols - Typic Calciorthids, Aridisols

6B.5.1.2 Surficial Geology

Figure 6B.4 shows the surficial geology of the Site 36 piedmont as mapped by the Arizona Geological Survey (AZGS) (adapted from Field and Pearthree, 1991). It shows the entire study area composed of alluvial fans of various ages as well as terraces and active stream channels. However, the AZGS maps (Appendix G.2) also show the edge of a pediment demarked near the limit of the bedrock inselbergs. While bedrock may be located at relatively shallow depth to warrant such a designation, no bedrock was observed in any of the channels on the piedmont. Moreover, discussions with Dr. Pearthree (personal communication, 1999) indicate that the pediment designation was identified solely on the basis of the inselbergs. He also said that no subsurface data were used in the delineation of the pediment boundary shown on the AZGS maps.

Table 6B.2 summarizes the significant distinguishing characteristics of each of the surficial geological units. Complete descriptions of the surficial geologic units from Field and Pearthree (1991) are included in Appendix G.2.

The Y units (Y1 and Y2) shown in Table 6B.2 are surfaces of Holocene age. That is, these surfaces have been experiencing active deposition and erosion during the last 10,000 years. The Y2 unit is the youngest unit. It is found on alluvial fans, low terraces, and active channels and covers a significant portion of the Site 36 piedmont downstream of the hydrographic apex. The M units are of Pleistocene age, that is, greater than 10,000 years old. The O units represent very old Pleistocene to Pliocene aged surfaces of relict alluvial fans greater than 1 million years old.

The surficial geology shows a general pattern of alluvial surfaces decreasing in age moving downslope from the White Tank Mountains. In addition to decreasing age, the extent of young alluvial deposits also increases. Field and Pearthree (1991) suggest that the location of active distributary flow areas on the alluvial fans has not shifted significantly since the Pleistocene. They also posit that the younger M2, Y1, and Y2 surfaces in the middle and lower piedmont are primarily the product of the erosion of M1 surfaces on the piedmont. In other words, the sediments being deposited on the lower piedmont are being eroded from older upstream piedmont surfaces, not the upper mountainous watersheds. The different sediment source areas may be responsible for the contrast in sediment size and surface texture between the most active areas of the alluvial fan in Section 23 downstream from the hydrographic apex, and the Y2 areas further downstream in T1N. The downstream Y2 areas are comprised of silts and sands and look more like overbank floodplain deposits compared with the much more gravelly deposits in the large Y2 area downstream of the hydrographic apex.

While the surficial geology provides greater detail than the NRCS soils maps, one can see the general agreement about the alluvial nature and origin of the Site 36 piedmont. The distinguishing characteristics of the landforms shown in Figure 6B.5 are described in Table 6B.2 and the following sections. The advantage of the surficial geology data is that areas are distinguished by characteristics related to their age and stability. Both are important to assessment of the flood hazard of the piedmont and will be elaborated upon further in Stage 2 and 3.

Table 6B.2
Landforms as Indicated by Surficial Geology

Landform	Unit	Name	Significant Distinguishing Characteristics	SCS soils units
Active alluvial fans, low terraces, and active channels	Y2	Late Holocene alluvial fans, low terraces, and active channels	composition: middle piedmont surfaces and active channels soil development: minimal to none age: < 3,000 years surficial features: typically undissected, smooth surfaces with a distribuary drainage network, some bar and swale topography in middle piedmont, no desert pavement or rock varnish soil great groups: Torrifluvents and Torriorthents flooding potential: subject to occasional to frequent flooding	Antho (2, AL), Antho-Carrizo-Maripo complex (3,4, AGB), Momoli-Carrizo complex (91), Antho-Valencia association (AM)
Active and inactive alluvial fans and alluvial plains	Y1	Late to early Holocene alluvial fans and terraces	composition: sheetflood areas, terraces, and limited overbank areas which are occasionally flooded soil development: minimal age: 1,000 to 10,000 years surficial features: fine grained, locally shallow channels (incision < 0.5 m), poorly developed desert pavement, light and incomple brownish black rock varnish along base of surface cobbles soil great groups: Torrifluvents, Torriorthents, and Camborthids flooding potential: most areas not flooded at present, but general lack of topographic relief to adjacent active channels suggests potential for flooding through minor shifts in the present depositional patterns	Denure-Momoli-Carrizo complex (29,30), Gunsight-Rillito (GYD, 70)
Active and inactive alluvial fans	Y	Undifferentiated Holocene alluvial surfaces	composition: intricately intermingled Y1 and Y2 surfaces age: isolated from depostion 0 to 10,000 years surficial features: see Y1 and Y2 units soil great groups: see Y1 and Y2 units flooding potential: occasional to frequent flooding	see Y1 and Y2

Table 6B.2
Landforms as Indicated by Surficial Geology

Landform	Unit	Name	Significant Distinguishing Characteristics	SCS soils units
Inactive alluvial fan	M2	Latest to late Pleistocene alluvial fans	composition: moderately old relict alluvial fan and terrace deposits soil development: weak to moderate, slight reddening, weak structure, and thin discontinuous carbonate coatings on clasts age: isolated from deposition for 10,000 to 150,000 years surfical features: moderately dissected by active channels which are incised <1-3 m, broad flat interfluves with moderately to well preserved orignal gravel bar and swale topography, poorly to moderately developed desert pavement, incompletely varnished to very dark brown with reddish brown to more commonly dull orange undersides soil great groups: Camborthids and Haplargids flooding potential: restricted to active incised channels except for areas of low relief	Chuckwalla-Gunsight (19), Denure-Momoli-Carrizo complex (29), Gunsight-Rillito (GYD, 70)
Inactive alluvial fan and relict fans	M1b	Middle to late Pleistocene alluvial fans	composition: old relict alluvial fan deposits soil development: moderate, reddened zones of clay accumulation, continuous carbonate coatings, locally weak carbonate cementation age: isolated from deposition for 150,000 to 300,000 years surficial features: strongly developed desert pavement with dark brown to black varnish with red coatings on undersides, well-developed tributary drainage networks, channels incised up to 3 m soil great groups: Haplargids and Calciorthids flooding potential: restricted to entrenched channels except for low relief areas on lower piedmont	Chuckwalla-Gunsight (19), Denure-Momoli-Carrizo complex (29), Ebon-Pinamt complex (48,49), Gunsight-Rillito (GYD, 70), Pinamt-Tremant complex (98), Coolidge-Laveen association (CV)
Inactive alluvial fan and relict alluvial fans	M1a	Middle to early Pleistocene alluvial fans	composition: old relict alluvial fan deposits soil development: moderate to very stongly developed reddened zones of clay accumulation (argillic horizons), commonly over stage IV calcic horizons (caliche) age: isolated from deposition for 300,000 to 1,000,000 years surficial features: well developed desert pavement with completely varnished black with reddish brown undersides on broat flat and smooth interfluves, bar and swale topography absent or poorly preserved, channels incised 1-6 m soil great groups: Haplargids flooding potential: restricted to entrenched channels	Chuckwalla-Gunsight (19), Gunsight-Rillito (GYD, 70), Pinamt-Tremant complex (98)

Table 6B.2
Landforms as Indicated by Surficial Geology

Landform	Unit	Name	Significant Distinguishing Characteristics	SCS soils units
Relict alluvial fan	O	Early Pleistocene to late Pliocene alluvial fans	composition: very old relict alluvial fan deposits of poorly sorted subangular gravels soil development:abundant fragments of pedogenic carbonate, exposed brecciated laminar petrocalcic horizons, exposed stage IV to VI petrocalcic horizons age: isolated from deposition for > 1,000,000 years surficial features: deeply dissected (10-15 m), well-rounded ridges, original surfaces rarely preserved soil great groups: Durorthids flooding potential: restricted to entrenched channels	Ebon-Gunsight-Cipriano association (47), Ebon-Pinamt complex (48,49), Gunsight-Rillito (70)
Bedrock	T, X	Bedrock	T : Tertiary volcanics X : Early Proterozoic gneiss and granite	Quilotosa-Vaiva-Rock outcrop complex (100)
Adapted from AZGS OFR 91-8 (Field and Pearthree, 1991) and AZGS OFR 91-10 (Field and Pearthree, 1992).				

6B.5.2 Morphology

According to the National Research Council definition (1996), "alluvial fans are landforms that have the shape of a fan, either partly or fully extended." The Site 36 study area shows the general form of a partially extended fan (Figure 6B.5). The picture is somewhat complicated by the coalescence on the north/west boundary with another alluvial fan (Site 37, Hjalmarson and Kemna, 1992) and with a few large inselbergs which redirect water and sediment discharges. The area of youngest sediments in Sections 13, 14, and 23 of T2N, R4W (shown as Y2 on the surficial geology mapping (Figure 6B.4) and as NRCS soil unit 91, Momoli-Carrizo complex (Figure 6B.3)) exhibits a more obvious partly extended fan shape. However, the entire landform also shows a partially extended fan shape distorted somewhat as it wraps around Spike Hill.

Topographic data also support the definition of a fan shaped landform. The USGS 7.5 minute quadrangles show mostly nearly straight or slightly concave downstream shape down the piedmont. Contour crenulations show channels ranging from 1 to 2 feet in depth across large areas. The mild transverse relief suggests bifurcating channels which are also evident in the aerial photographs of the piedmont. Locally areas of greater degree of incision are noted especially to the south of Spike Hill and along the northwest part of the middle piedmont. Areas upstream of the hydrographic apex also show much greater degree of entrenchment than downstream of the hydrographic apex. These are all characteristics of an alluvial fan.

Transverse cross sections of Site 36 (Figure 6B.6) downstream of the hydrographic apex look most similar to the active alluvial fan shown in Figure 2.2 of the *PFHAM*. Locally areas of greater degree of incision are noted especially to the south of Spike Hill and along the northwest part of the middle piedmont. Areas upstream of the hydrographic apex also show much greater degree of entrenchment. Transverse cross sections of these areas resemble the inactive alluvial fan shown in Figure 2.2 of the *PFHAM*.

6B.5.3 Location

The NRC definition also states that "alluvial fan landforms are located at a topographic break." The Site 36 alluvial fan begins as the main wash exits the mountains below about 2,000 feet elevation. Downstream of the topographic apex, the channel remains confined within a reach through very old alluvial fan deposits. The wash quickly widens and diverges into numerous channels as the wash becomes progressively less confined downstream of the 1560 foot contour. The 7.5' minute quadrangles show a stippled pattern indicating an area of deposition in this area. The longitudinal profile (Figure 6B.7) shows a slight hump or decrease in slope in the same area of widening stipples near the 1520 foot contour. This is the location of the hydrographic apex.

6B.5.4 Boundaries

The lateral and distal limits of the alluvial fan landform were determined from examination of the NRCS soil data, the AZGS surficial geology, and recent and historical aerial photographs.

The toe or distal terminus of the larger alluvial fan landform is defined by the intersection of the long sloping piedmont plain with the flood plains of the Hassayampa River on the west and the

Gila River on the south. The toe of the existing active areas of the alluvial fan will be addressed in Stage 2.

Pleistocene-aged surfaces bound the alluvial fan almost completely on both sides except at one location on the west where a small wash exits into a distributary channel of the Site 37 fan and on the southeast where younger sediments drain tributaries to the wash which makes up the east boundary of the Site 36 fan (Figure 6B.4).

The north/west lateral boundary is defined by a series of fan terraces. In Section 14, T2N, R4W a few small washes lose discharge to the Site 37 fan to the north. At a couple of locations the washes cross in 'X'-shaped patterns where some flows from the Site 36 fan and Site 37 fan to the north intermingle somewhat (Figure 6B.5). The similar sizes of these washes suggest that similar amounts of water and sediment are gained or lost from each fan. Elsewhere further down the fan in the SW¼ of Section 22, a neighboring wash splits returning some water and sediment from the adjacent drainages.

The upper part of the east lateral boundary is defined by a series of fan terraces and small hills. Downstream from Spike Hill at the boundary between Section 23 and 26, T2N, R4W, the fan begins to collect water and sediment discharges from a combination of local drainage and inflow from another alluvial fan to the east. If the local drainage from the fan terraces downstream of Spike Hill is considered part of the Site 36 landform, an eastern boundary can be defined with just a few inflows from the eastern fan (Figure 6B.5). These inflows enter at three locations in Section 26, three locations in Section 35, one in Section 2, T1N, R4W, and three locations in Section 11. At one location in Section 2, T1N, R4W discharge is lost to the east. With the exception of the most upstream inflow location in Section 26, most of these inflows appear fairly minor based on the size of the existing channels.

6B.5.5 Conclusion

The soil survey and surficial geology data clearly show the piedmont to be composed of sedimentary deposits. The USGS topographic maps also show that the landform is located at the base of a mountain front and has the shape of a partially extended fan. Therefore, it can be concluded that, with the exception of a few bedrock islands, the Site 36 piedmont in the study area is an alluvial fan.

The "Landform" column of Table 6B.2 shows how the NRCS data, the surficial geology, aerial photographs, topographic maps, and field observations fit together. Figure 6B.5, the Stage 1 - Landform map, shows the delineation of relict fan, alluvial fan, and bedrock areas on the Site 36 piedmont. The references to the active and inactive areas made in Table 6B.2 are incorporated into Stage 2 which results in the Stability map, described in the later Stage 2 and Stage 3 sections of this report. The areas identified as alluvial fan in Figure 6B.5 include both the active and inactive portions of the alluvial fan.

6B.6 Stage 2: Defining Active and Inactive Areas

In Stage 2, the objective is to define the active and inactive areas of the alluvial fan, and characterize the nature of flooding on different parts of the piedmont. Hjalmarson and Kemna (1991), CH2M Hill (1992), and Appendix A of *Alluvial Fan Flooding* (NRC, 1996) identify portions of the Site 36 fan as being active as indicated by recent channel movement observed in historical aerial photographs. The current study reevaluated and refined the specific limits of the active and inactive portions of the site identified in these studies. Moreover, the current study extended the assessment to the remainder of the piedmont downstream to Buckeye FRS #1.

Section 6B.5 will present an introduction of ideas important to the Stage 2 concepts and methods, followed by an overview of flooding on the Site 36 piedmont. Next, the identification of the active and inactive areas will be presented, followed by a description of the types of flooding and locations of flooding, and a summary.

6B.6.1 Introduction

The physical characteristics of a landform surface provide clues as to its depositional history, stability, and its flood potential. If an area of the landform ceases to receive new deposits, its surface will begin to age. As it ages, the surface begins to develop physical and chemical characteristics indicative of its age. In an arid environment like the Site 36 piedmont, soils begin to develop distinctive characteristics. As the soil develops, its structure, color and content changes. Clay and calcium carbonate accumulate in the soil. Soils tend to become reddish in color due to the accumulation and weathering of clay. Accumulation of carbonate cements the soils together eventually developing a highly resistant character referred to colloquially as caliche.

Surfaces may also develop an accumulation of pebbles and cobbles at the surface as they age. These gravel coverings are known as *desert pavement* which is believed to form by the accumulation of windblown silt and clay between the gravels. Repeated wetting by precipitation causes the fine-grained materials to swell, lifting the larger gravels to the surface. Repeated surface drying creates cracks into which more fine windblown material may accumulate. Over thousands of years these processes result in a mantle of closely packed gravels over a silt- and clay-rich soil layer (Dohrenwend, 1987; Vanden Dolder, 1992). The surface pebbles and cobbles, if they contain sufficient ferromagnesian minerals, will develop a dark black patina on their tops and an orange coating underneath known as *rock varnish*.

Surfaces free from new deposition will also begin to erode. As they erode, new tributary channel networks develop. These channels will also begin to entrench themselves into the surface creating a greater degree of relief between the channel bottoms and the ridges which separate them.

It takes thousands of years for many of these characteristics to develop. Therefore, surfaces that exhibit well developed soils, red color, significant carbonate development, desert pavements of strongly varnished gravels, and tributary drainage networks have been relatively free from flooding for thousands of years. As such, without external disturbance, it can be reasonably anticipated that the flood hazard potential in the future will remain low.

The NRCS soils survey data and surficial geology mapping differentiate surfaces based on the types of characteristics discussed above. Therefore, these data also inform on the surface's age, stablility, and flood potential. Young surfaces with little soil development are likely to continue to see water and sediment discharges. Older surfaces are much less likely to experience inundation by water and sediment in the future. Older surfaces with cemented soils and entrenched channels also tend to be stable. That is, the likelihood of the channel changing its location over time is greatly diminished. Conversely, areas with loose soil and little lateral relief are more susceptible to lateral changes in the channel's position.

Older surfaces may also be susceptible to flooding when lateral relief is low. Where local relief is great, the likelihood that higher areas will be flooded is lower than when an older surfaces lies relatively low compared to neighboring younger flood prone surfaces. In such a situation, the older surface may be susceptible to flooding from the adjacent area. An example of a flooded older surface adjacent to a younger surface with little lateral relief is found in Sec. 34, T2N, 4W along the right edge of soil unit 3 (Figures 6B.2 and 6B.3) will be shown in Section 6B.5.3.4.

6B.6.2 Overview of Flooding on Site 36 Piedmont

The approximately three mile long entrenched reach upstream of the hydrographic apex to the topographic apex is characterized by stable channel riverine flood hazards. Section 5 describes a normal depth approximate floodplain delineation of this reach.

Downstream of the hydrographic apex, flood waters become unconfined and spread out over a fan shaped area about one square mile in area. The 1954 aerial photograph (Figure 6B.9b) clearly shows the general area of unstable, very hazardous alluvial fan flooding. Downstream of a line perpendicular to the washes from near the end of Spike Hill near the 1320 foot contour, flood waters generally reorganize themselves into a series of parallel washes across more stable older surfaces. An exception to this trend is the area immediately adjacent to the west end of Spike Hill where flow expands and is collected in a number of smaller channels before crossing older, stable surfaces. Comparison of the 1942 and 1954 aerial photographs shows a large channel widening and a shortening of the channel flow length. The result was the deposition of sediment at the head of four washes just downstream of the area of most significant channel change.

Floodwaters flow across the middle piedmont through a number of stable channels across older surfaces before entering an area of younger late Holocene sediments. Much of the lower piedmont is characterized by broad areas of relatively stable shallow sheet flooding. Islands of older sediments are also located between these broad sheet flooding areas. Within these broad areas of relatively shallow sheet flooding are several more prominent washes. The more prominent washes connect to the throughflow channels coming from the upper and middle piedmont in a tributary manner. At the lowest end of the study area however, upstream of Buckeye FRS #1, the channels again distribute themselves into a larger number of small washes.

Field and Pearthree (1991) suggested that the younger sediments on the lower piedmont originate from the erosion of older surfaces in the middle piedmont. During more frequent runoff events, water and sediment both originate from areas of the middle and lower piedmont. Only the

largest runoff events translate significant flood water and sediment across the entire broad alluvial area immediately downstream of the hydrographic apex. The high infiltration rates of this broad area of young gravels transmits more frequent runoff into the subsurface before it can pass onto the lower piedmont. Evidence of significant transmission losses can be seen in the field by the lines of flotsam that stop within channels on the active fan. Moreover, the size of surface sediments generally decreases moving down piedmont. Smaller sediment sizes mean lower infiltration rates. For example, according to the Drainage Design Manual of Maricopa County (Sabol, et al., 1995), NRCS soil unit 91, located just downstream of the hydrographic apex, has a saturated hydraulic conductivity of 0.93 inches per hour, while units 2, AL, and AM, located on the lower piedmont have saturated hydraulic conductivity rates of 0.41, 0.40, and 0.39 inches per hour (see Figures 6B.2 and 6B.3 for location of soil units on the piedmont). Consequently, the lower piedmont is more effective at producing runoff during more frequent rainfalls.

6B.6.3 Identification of Active Areas

The Site 36 piedmont is mostly an eroding landform. Although significant aggradation occurs in several localized areas covering a limited area of the total landform, these aggradational areas represent an important part of the overall water and sediment discharge system of the Site 36 piedmont.

They are located:

1) at and immediately downstream of the hydrologic apex,
2) at the west end of Spike Hill
3) at an inset active fan area in the middle piedmont

Additionally, two locations on the lower piedmont were identified as having experienced new channel formation during the 50-year period of historic aerial photo coverage. These five locations are shown in the historical aerial photograph comparisons (Figures 6B.8-12) and discussed further in Section 6B.5.3.4.

The limits of the active areas of the Site 36 alluvial fan are shown in Figure 6B.13. These areas were identified through the use of NRCS soils surveys, AZGS surficial geology mapping, historical aerial photographs, interpretation of USGS 7.5 minute contour maps, and field observations. The relationship of each of these types of evidence to the limits of active and inactive areas is discussed below. Finally, a discussion of the relevance of the active areas and locations of various types of flooding to the Stage 3 evaluation of the 100-year flood hazard areas will be presented.

6B.6.3.1 NRCS Soil Surveys – Hartman (1977) and Camp (1986)

The NRCS soils maps (Figures 6B.2 and 6B.3) for the area show Antho and Carrizo soils series as major soils within the areas identified here as active or unstable areas. This designation is consistent with the information presented in the PFHAM. These soils are poorly developed and exhibit little sign of age such as clay or carbonate accumulation.

6B.6.3.2 AZGS Surficial Geology – Field and Pearthree (1991)

The AZGS surficial geology mapping of the White Tank piedmont differentiated areas based primarily on their relative age. The relative topographic position, surface characteristics such as desert pavement and rock varnish, and the degree of soil development were the primary criteria used to distinguish the relative ages of the surfaces. The AZGS delineated the youngest areas of the piedmont as Y2, Late Holocene alluvial fans, low terraces, and active stream channels. The Y2 areas shown in Figure 6B.4 include both the active alluvial fan areas identified in this study as well as the broad areas of sheet flooding which are considered stable areas in this study. Those areas are discussed in the identification of inactive areas below.

Field and Pearthree (1991) suggest that the overall morphology of the active area immediately downstream of the hydrographic apex has not changed significantly since the late Pleistocene. They suggest that the active areas further down the piedmont result from deposition of sediment eroded from Pleistocene surfaces on the piedmont.

6B.6.3.3 Interpretation of Topography

Contour crenulations are the wiggles in the contour lines which represents a location of common elevation. The more wiggly the contour line, the more incised the surface. Incision usually indicates stability. Hence, surfaces shown on the topographic map as highly crenulated tend to be stable surfaces. In contrast, smooth contour lines indicate very little incision. When smooth contour lines bow downstream, this is a good indication of an active area of deposition.

The USGS topographic quadrangle contours on the Site 36 piedmont show highly crenulated yet fan shaped contours just downstream of the topographic apex (Figure 6B.13). Downstream from there, between the topographic and hydrographic apexes, the contour lines remain quite crenulated indicating a continuing area of incised channels and an eroded landform. Immediately downstream of the hydrographic apex, an area of stippled pattern shows the expanding gravel bed of the wash. The stipple pattern actually splits into two paths for a short distance before ending within the most active area of the Site 36 piedmont. The area between the 1500 foot and 1420 foot contour shows relatively smooth slightly concave downstream contours. Following these contours north, one notes the rapid increase in the degree of crenulation. The piedmont generally increased in age and stability as one moves north onto the adjacent alluvial fans. This pattern is seen both in the surficial geology (Field and Pearthree, 1991) and in the degree of flood hazard evaluated for a series of distributary flow areas in Hjalmarson and Kemna (1992).

The 7.5 minute contours bow more but also show greater crenulation in the area passing around Spike Hill. From about the 1350 foot to the 1250 foot contour, the piedmont is more entrenched. The upper portion of this area is where the unstable, uncertain distribution of flood water and sediment begins to reorganize itself into a series of parallel channels moving down the piedmont. Downstream from this area the contours become much more parallel to one another and the degree of crenulation decreases. This is an area almost completely composed of Holocene sediments. The east half of the Site 36 piedmont is younger than the west half (Y2 vs. Y1 surfaces). Much of the lower piedmont is subject to widespread shallow sheet flooding.

However, a few more prominent channels can be seen and have been the predominant paths of flow on the lower piedmont during the period of historical aerial photos (i.e. 50 years).

6B.6.3.4 Historical Aerial Photography

Historical aerial photographic coverage of the study area will be an important component of the piedmont flood hazard assessment, especially the Stage 2 stability analysis. A number of different dates of aerial photography were identified for use in this study. Table 6B.3 summarizes these data.

The movement and formation of channels between 1949 and 1954 provides an excellent example of the nature and extent of alluvial fan flood hazards that have occurred on the Site 36 piedmont. It is inferred from Field (1994) and examination of rainfall records at Buckeye, that the flood responsible for the changes observed between the 1949 and 1954 photos occurred in August 1951, when, as discussed in Section 4.2, 5.15" of rain fell in Buckeye over a four day period from August 27-30. Subsequent adjustment of the piedmont drainage network following the 1951 flooding also suggest how the system rebounds from such extensive channel changes. The historical aerial photo record shows how over a 50 year period vegetation can reestablish itself and old channel positions can be filled in, masking the evidence of prior channel locations.

Table 6B.3 List of Historical Aerial Photographs of White Tank Fan Study Area

Source	Photo Date	Scale	Type	Digital
Field, 1994*	1942	1:15,000	Black and white	No
National Archives	1949	1:20,000	Black and white	No
FCDMC archives (US AMS, 1953)	1953	Approx. 1:14,400	Large format black and white	No
National Archives	1954	1:20,000	Black and white	No
SCS Soil Survey (Hartman, 1977; Camp, 1986)	1972 & 1973	1:24,000	Black and white orthophoto	No
MCDOT archives	1976	1:14,400	Black and white half townships	No
Collected by AZGS (BLM)	1979	1:24,000	Color 9x9s	No
FCDMC image database	1997 & 1998	1:7,200	Black and white	Part of FCD digital database
USGS Digital Orthographic Quadrangles (DOQ)	1992/1997	1:24,000	Black and white orthophotos	Yes. USGS supplied ¼ quads.
AMC/JEF	1999	1:9,600	Color	No
AMC/JEF	1999	1:32,000	Color orthophotos	Yes
* Photo only of area immediately downstream of hydrographic apex available.				

Figures 6B.9-12 show sequences of historical aerial photos at the active areas listed above. Note the changes in channel positions from 1949 to 1999. Also note the lack of change in position in

many of the neighboring stable areas. Figure 6B.8 shows the locations of each of the areas within the study area.

Figures 6B.9 a-d show the area downstream from the hydrographic apex and the west end of Spike Hill. The most dramatic differences occur between 1942 and 1954. The extensive development of new channels, widening of existing channels, and widespread sedimentation are clearly visible. A one mile long by 2000 foot wide area experienced the greatest changes. Additionally, the channel flowing around the west end of Spike Hill straightened and widened considerably. Between 1954 and 1999 one notices how the vegetation was reestablished and the extent of the flood scars was dramatically reduced. Also note how the tributary drainage at the southwest end of the photos remains stable throughout the period. These tributary channels collect the broad areas of flood water as they flow off the active area of the fan downstream of the hydrographic apex.

Figures 6B.10 a-d show the comparison of photographs from 1949 to 1999 for an area on the middle piedmont downstream of Spike Hill. Note the channel which approximately bisects the view frame from top to bottom. In the 1954 photo a new, lighter colored channel is visible. This new channel is more evident in the 1992 photo, but also present in 1954. Also evident are the divergent new channels in the lower half of the view frame. Overall, while many channel changes are evident in this series of photographs, one can see that the changes were largely limited to an area between older surfaces. Field and Pearthree (1991) indentify the adjacent surfaces as M1b, middle to late Pleistocene, 150,000 to 300,000 years in age. All of this corridor is designated here as unstable, though only the lower half is somewhat fan-shaped.

Figures 6B.11 a-d show an inset fan-shaped area of Y2, late Holocene surface, downstream of Tonopah-Salome Highway in W1/2 Sec. 4, T1N, R4W. The historical aerial photo comparison reveals a significant degree of channel changes over the 50 year period. While the channels are relatively small, the changes are not. Again in 1954 a new channel cuts itself along the east margin of the upper part of the area outlined in white just downstream of the highway. This new channel becomes the predominant channel by 1992 as the number of channels in the outlined area decreases. Many of the channels visible in 1949 and 1954 have been filled in by fine sediments by 1999. This area is designated as an inset active alluvial fan in this study.

Figures 6B.12 a-d show another area located in SW1/4 Sec. 3, T1N, R4W. Comparison of historical photographs from 1949 to 1999 indicate the formation of a new channel between 1949 and 1954 (presumably from the 1951 flooding) and subsequent disappearance of old channel locations from 1954 to 1999. Vegetation grew up, stabilizing the new channel and the old channel filled in over time. Note that the neighboring drainage channels remain largely in the same locations over time. Some small channels disappear while others gain in importance. Also note that the largest of the channels are about 15 feet in total width. The larger new channel formation occurs along one of the larger throughflow channels connected to the middle and upper piedmont. The neighboring smaller channels represent local drainage over the broad young surfaces of the lower piedmont. These areas are subject to broad, relatively shallow sheet flooding. While the significance of any particular small channel to the local drainage pattern varies over time, these small channels act primarily as conduits for more frequent local runoff. During larger floods, the area is broadly inundated by relatively shallow, relatively low velocity flows. In this area of the piedmont, slopes are about 0.01 ft/ft. For shallow flow depths, say 1.0

feet or less, average flow velocities would be in the range of 2.5 – 4.0 ft/sec based on normal depth. This lies within the range of velocities for stable erodible linings given by FHWA (Table 6.1 in Drainage Design Manual for Maricopa County, Volume II, 1996) for sandy loam to colloidal alluvial silts. While locally higher velocities are likely to occur, it is believed that it is reasonable to consider this surface stable.

6B.6.3.5 Vegetation

While saguaro cacti can be found in portions of the upper unstable area, the area exhibits a generally scattered appearance of vegetation downstream of the hydrographic apex. This is in contrast to the linearly aligned riparian vegetation seen in aerial photographs elsewhere on the piedmont. The riparian vegetation helps create as well as indicate the stability of large portions of the middle and lower piedmont within the study limits. However, as shown in the comparison of historical aerial photographs, flood waters do not always follow the washes which are lined by riparian trees such as palo verde, ironwood, and mesquite.

6B.6.3.6 Sediment Delivery Potential

Modified Universal Soil Loss Equation (MUSLE) computations (see Appendix F) of sediment yield from the watershed above the hydrographic apex predict about 6.2 acre-feet of sediment will be delivered to the hydrographic apex during the 100-year flood. Given the width of the channel at the hydrographic apex, 6.23 ac-ft would cover 2000 linear feet of channel if it were deposited 1 foot deep, 1000 linear feet if it were deposited 2 feet deep. Additionally, the active area upstream of Spike Hill is about 405 acres in area over which 6.23 ac-ft of sediment would be very thin if deposited uniformly. While this amount of sediment deposition is appreciable and capable of causing changes in the direction of floodwaters downstream of the hydrographic apex, it is not capable of covering very large areas in many feet of sediment delivered from the upper watershed. Field observations and aerial photo examination confirm that sediment within the channel upstream of the hydrographic apex is adequate to create a sedimentation hazard in the vicinity downstream of the apex.

6B.6.4 Identification of Inactive areas

Along with the active areas of the alluvial fan, Figure 6B.13 also shows the limits of the inactive areas of the alluvial fan. The discussions on the interpretation of topography, vegetation, and historical aerial photo comparisons in Section 6B.5.3 on the identification of active areas also suggests that large portions of the middle and lower piedmont have been and are likely to continue to be stable with respect to flooding in the future.

In particular, the inactive areas are on fan and/or stream terrace soils (series Chuckwalla, Gunsight, Momoli, Denure, Ebon, Tremant, Coolidge and Laveen), on units identified as Y1 or older on the surficial geology, and having a variety of characteristics associated with inactive (or stable) areas in the *PFHAM*. These characteristics include many of the same ones used by the NRCS and AZGS in the soils and geology mapping, such as, areas of desert pavement, desert varnish, tributary drainage patterns, reddened soils, carbonate accumulation in the soils, and incision of channels relative to the adjacent interfluve areas. Large tree vegetation, like palo verde, mesquite, and ironwood, within these areas are found predominantly along existing

washes. Field observations also identified donering of fine materials along channel banks. Donering is the plastering or coating of channel banks with fine alluvial sediments as floodwater soaks into the bank material, leaving some of its fine sediment load behind on the bank. This plastering increases the shear strength of the bank making it more resistant to erosion.

6B.6.5 Inactive areas still subject to flooding

The soils data, surficial geology, topographic contours, and historical aerial photographs indicate that large areas of the piedmont are subject to flooding, but that the nature of that flooding is within stable throughflow channels or broad sheet flooding across wide stable areas.

Within some of the throughflow channel corridors, some channel changes can be observed in the historical aerial photo record. However, these channel changes are confined within the corridors. These corridors are bounded by higher, generally older geomorphic surfaces. Channel changes occurring within these corridors may be considered analogous to changes in a braided riverine channel. That is, while channel changes do occur during floods, the limits of the flooding for large discharges are similar. Local velocities will vary between floods, but flood waters will be confined to the same overall channel. Additionally, the degree of flood hazard varies spatially within these corridors and between floods.

Within the broad sheet flooding areas small channels do exist. The distribution of flow in these very small channels (widths less than 10 feet, depths less than 2 feet) undoubtedly varies from flood to flood. The most important aspect of these small channels is that they are stable. That is, the channels are not moving from one location to another during floods. Another important consideration is that while these channels lie within broader areas of sheet flooding, the flood hazard within the channels themselves is greater, being more frequent, deeper, and having higher velocities than the overbank/interfluve areas subject to sheet flooding.

Downstream of the active area, floodwater recollects and enters stable throughflow channels which flow through the middle and through and onto the lower piedmont. The broad sheet flooding areas are located on the lower piedmont. Some of these sheet flooding areas are dominated by local runoff while others also experience distributary and overbank flow from the throughflow channels. For example, the large, prominent throughflow channel crossing the east half of Sec. 34, T2N, R4W has two locations where overbank flow exits into distributary washes at high stage. Between these two channels is a sheet flooding area where the flood hazard is dominated by local runoff.

In addition to the inactive areas still subject to local and throughflow flooding, the channel upstream of the hydrographic apex also represents a flood hazard. The flood hazard in the 3.1 mile reach between the topographic and hydrographic apex was evaluated using approximate normal depth methods and is described in Section 5 and Appendix E.

6B.6.6 Types of flooding and locations on the piedmont

Based on the evaluation of active and inactive areas on the Site 36 piedmont, the following locations and types of flood hazards were defined.

6B.6.6.1 Active alluvial fan areas

Active alluvial fan flooding on the Site 36 piedmont is limited to a large area downstream of the hydrographic apex, a small area at the west end of Spike Hill, and two inset fan areas; one on the middle piedmont in Section 34, T2N, R4W and the other in Section 4, T1N, R4W. These areas represent significant flood and sediment hazards.

6B.6.6.2 Flooding along stable channels

From the topographic to the hydrographic apexes, flooding occurs in a stable confined channel. Downstream of the active fan area flood waters concentrate into a series of parallel channels across older stable geomorphic surfaces. These channels have been stable over the past 50 years as indicated by the historical aerial photographs and possibly the past few thousand to tens of thousands of years as indicated by the surficial geology. Flood hazards along these corridors can be expected to be confined to the existing channel network. However, uncertainties in the discharges delivered to each channel make detailed quantitative evaluation of these hazards difficult. Until the discharge distribution uncertainty created by the active area upstream can be resolved, this study suggests that an approximate method relying on geomorphic surface interpretation can adequately and realistically evaluate the location and lateral extent of these hazards. The geomorphic analysis is supplemented by a normal-depth analysis of the total conveyance of the stable throughflow channels along the piedmont. These calculations are summarized in Section 6B.6.1.

6B.6.6.3 Sheetflow areas

Much of the lower piedmont is subject to broad areas of sheetflow. Broad areas of geologically young surfaces attest to their repeated inundation over the past few thousand years. Within these areas more prominent washes do exist, which can be expected to convey large portions of the flood discharge and which are likely to receive flood water much more frequently than other (non-channel) areas on the lower piedmont. Additionally, the fine-grained soils of the lower piedmont are capable of creating more frequent local runoff. Lower infiltration rates from the finer textured soils allow more frequent and localized storms to generate runoff. The local runoff facilitates the development of the tributary channel pattern. These small tributary channels may be exploited by broad overbank sheet flooding from upstream during larger general storms which generate runoff over the entire watershed. Small drainage features on the lower piedmont carry local runoff in identifiable channels that should be considered in any site specific construction project within the broader sheet flood hazard areas identified in this study. Moreover, these existing small local drainages will also help convey flood water from larger floods when broad areas of the lower piedmont are inundated.

6B.6.7 Summary of active and inactive areas

Figure 6B.13 shows the limits of the active and inactive areas of the Site 36 piedmont which form an important foundation in the evaluation of the 100-year flood hazard in Stage 3. The most active area of the Site 36 piedmont is an area about 1 square mile in extent downstream of the hydrographic apex. However, there are also a few other local inset active areas noted in this study. Upstream of the hydrographic apex flooding is limited to the entrenched channel. The middle piedmont is characterized by stable throughflow channels which recollect flood waters exiting the active area upstream. These throughflow channels spread out into broad areas of sheet flooding as the slope decreases on the lower piedmont. The surfaces on the lower piedmont, while broadly inundated, are considered stable except for an area on the west edge of the study area.

6B.7 Stage 3: Defining the Approximate 100-Year Floodplain

The 100-year flood hazard assessment is an outgrowth of the information and results identified and generated in Stages 1 and 2. The results of the 100-year floodplain are shown in Figure 6B.14 and the Stage 3 – 100-year Floodplain Map in the Exhibit Maps section of the TDN. The following is a more detailed description of the methods and rationale used in the identification and delineation of the various flood hazard zones shown in Figure 6B.14.

6B.7.1 Flood Hazard Zones

The following table (Table 6B.4) lists and describes the flood hazard zones identified and shown in Figure 6B.14 and the Stage 3 – 100-year Floodplain Map in the Exhibit Maps section of the TDN. These zones have been newly defined for use in the delineation of piedmont flood hazards in Maricopa County, Arizona by the Flood Control District of Maricopa County. These new regulations were approved the Maricopa County Board of Supervisors on November 1, 2000. The flood hazard zones shown on Figure 6B.14 are given in Table 6B.4. The resulting flood hazard map is similar in nature to the one shown in Example 4 in Appendix 1 of the *FEMA Guidelines* (2000).

The Arizona Geological Survey (AZGS) performed detailed mapping of the surficial geology of the White Tank piedmont in the early 1990s (Field and Pearthree, 1991). This mapping project was followed with an evaluation of flood hazards based on the surficial geology mapping (Figure 6B.15 adapted from Field and Pearthree, 1992). The current approximate floodplain delineation study builds from and incorporates many of the findings and evaluation of the AZGS work. The flood hazard areas shown in Figure 6B.14 were developed by elimination of small islands, interpretation of aerial photographs, and inclusions of areas adjacent to geologically young surfaces where uncertainties associated with alluvial fan flooding were incorporated. Finally, these interpretations were supplemented and finalized based on observations of ground conditions in the field. Island areas smaller than about 10 acres where not separated out from the surrounding zone. Additionally, approximate floodway corridors were identified to allow for conveyance of flood water and sediment down the piedmont.

Table 6B.4 Flood Hazard Zones Mapped in White Tank Fan (Site 36) Approximate FDS		
Zone Name	Local Community Zone Designation	Description
Zone A	Zone A	Approximate 100-year floodplain; riverine reaches upstream of hydrologic apex, and previously mapped ponding area behind Buckeye FRS #1
Zone A – Administrative Floodway Active Alluvial Fan	AFHH – Administrative Floodway	Alluvial Fan High Hazard, community to treat as a floodway district
Zone A – Administrative Floodway Active Alluvial Fan	AFUFD – Administrative Floodway	Alluvial Fan Uncertain Flow Distribution Area; transitional area downstream of AFHH zone characterized by channelized and sheet flooding generally becoming more stable and less uncertain with increasing downstream distance from the AFHH zone; community to treat as a floodway district
Zone A – Administrative Floodway Inactive Alluvial Fan	AAFF - Administrative Floodway	Approximate Alluvial Fan Floodway; corridors for conveyance of water and sediment on a stable alluvial fan surface downstream of the AFHH and AFUFD; community to treat as a floodway district
Zone A – Inactive Alluvial Fan	AFZA	Alluvial Fan Zone A; areas within the 100-year floodplain on an inactive alluvial fan characterized by shallow channelized flow and sheet flooding in stable channels; zone is considered approximate because no base flood elevations are provided; flood hazards within this zone are not necessarily equal throughout, that is, the frequency and magnitude of flooding with respect to depth and velocity of flow may vary within the AFZA zone; floodplain managers should consult available aerial photographs and topographic maps for more detailed evaluation of site specific flood hazard within this zone; development will be allowed in this zone given demonstration of adequacy of site and/or design which addresses safety from inundation and sedimentation hazards
X (shaded) – Inactive Alluvial Fan	X (shaded)	Areas flooded between 100-yr and 500-yr discharge; or areas of flooding with depth of 100-year flood less than 1 foot; or drainage area less than 1 square mile
X (unshaded)	X (unshaded)	Areas outside the 500-year floodplain; shown only on rocky hills
D	D	Area not studied

Specifically, the unstable areas from Stage 2 have been used to identify the location of the Zone A – Administrative Floodway Active Alluvial Fan (Local Community Zones AFHH and AFUFD). The AFHH (active alluvial fan) zone lies within the unstable area. The AFUFD (uncertain flow distribution) zone encompasses the remainder of the unstable area as well as an additional buffer area along the downstream edge of the unstable area identified in Stage 2. This buffer area was determined by use of the soils, surficial geology data, interpretation of recent and historical aerial photographs, and engineering judgment.

Emanating from the AFUFD zone are Zone A – Administrative Floodway Inactive Alluvial Fan (Local Community Zone AAFF) corridors which traverse the inactive (or stable) portions of the alluvial fan landform. These areas represent the primary throughflow channels that convey the majority of the sediment and water discharges from the Site 36 drainage basin as evidenced by the NRCS soils data, the AZGS surficial geology data, and by interpretation of geomorphic features as shown in color aerial photographs and field observations. These throughflow channel corridors can be considered similar to riverine floodways in that they are areas reserved for conveyance of the 100-year flood. Although these floodway corridors do not necessarily contain the entire limits of the 100-year flood across the middle and lower piedmont under the existing condition, they are adequate in size and continuity to convey floodwaters across the piedmont if flood water were restricted to them. Reservation of these corridors will allow for engineered flood protection and mitigation within other flood prone but stable areas of the inactive alluvial fan.

The approximate alluvial fan floodways (Local Community Zone AAFF) were determined by first identifying the most prominent, continuous channels which connect the active alluvial fan upstream to the lower piedmont. Next, since the discharge in any particular channel downstream of the active area is highly uncertain, it was decided to determine the width that would be required to convey the entire 100-year discharge (3,600 cfs) at 1 foot depth at the slope shown on the topographic map. These calculations are provided in Appendix E. The width required to convey 3,600 cfs at 1 foot depth ranges from about 500 feet to 1900 feet for slopes between 0.03 and 0.008 and Manning's n-values of 0.035 to 0.07. Table 6B.5 shows the width required to convey 3,600 cfs at particular locations along the piedmont starting at contour 1350 near the downstream limit of the largest active area. This approach is considered conservative in that the majority of throughflow channels have depths of two to three feet (see Figure 6B.6).

Table 6B.5 "Necessary" Widths for Site 36 Piedmont

Topographic Contour (feet)	Avg. Slope @ Contour (ft/ft)	Cumulative Width* (feet)	"Necessary" Width*** (feet)
1350	0.016	1672	670-1341
1300	0.014	3064	717-1433
1250	0.012	2215	774-1548
1200	0.011	2296	808-1617
1150	0.0094	1399**	875-1749
1100	0.010	2599	848-1696

* Cumulative widths exclude AFUFD and AFHH zones

** Does not include 550 ft westmost corridor that intersects study area boundary at Sun Valley Parkway.

*** Necessary width is the width required to convey 3600 cfs at 1 foot depth. Range represents Manning's n-values from 0.035 to 0.07.

Flood prone areas in inactive areas outside the alluvial fan floodways are identified in Figure 6B.14 as Zone A – Inactive Alluvial Fan (Local Community Zone AFZA). The throughflow channel corridors (Local Community Zone AAFF) would maintain major storm water and sediment conveyance. The areas designated as Local Community Zone AFZA would be subject

to overbank flow and local runoff. Engineering would be required to mitigate sheet flooding and overbank flow during major events in areas shown as zone AFZA. Development within these areas would be allowed given an adequately engineered site specific evaluation of the flood hazard and flood mitigation measures. The AFZA zone is generally characterized by sheet flooding and flooding within relatively small stable channels. These small channels may either represent small distributary drainages connected to the primary floodways, small local drainages, or various paths where broad sheet flooding recollects as it flows down the piedmont in an effort to reorganize itself. Consequently, the magnitude and frequency of flood hazards within the AFZA zone should not be considered equal at every location.

Local drainages and small channels periodically connected to the larger system by wide sheet flooding need to be identified and considered in any site specific design to mitigate flood hazards. The use of large scale aerial photographs, detailed topography, and the data from this study are highly recommended in the evaluation of site specific flood hazards within the AFZA zones identified in this study. Although the surfaces included in the AFZA areas are considered to be stable, they may be connected to and influenced by the larger distributary system on the Site 36 piedmont. As such, the structure of the existing distributary network ought to be considered when evaluating and designing mitigation of flood related hazards at any particular site.

Also included in the AFZA zone are larger islands of stable often older geomorphic surfaces. Islands smaller than 10 acres were not separated from the surrounding zone.

Between many of the AAFF and AFZA areas are large islands of old stable geomorphic surfaces. These areas have been given a flood hazard zone of Zone X (shaded). These zones include areas of possible flood hazards from local drainage areas smaller than one square mile as well as stable areas potentially flooded by events less frequent than the 100-year flood (e.g. the 500-year flood).

A few areas of bedrock hills are shown as unshaded Zone X. Again, while flood hazards from the piedmont drainage are absent from these hills, small hillsides may exhibit some level of flood risk that ought to be examined before development plans are approved.

6B.7.2 Verification of Results

Figure 6B.15 shows a comparison of the results of the Stage 3 analysis with the flood hazard evaluation by Field and Pearthree (1992). Figure 6B.16 shows the relationship of the Field and Pearthree surficial geology mapping to their flood hazard evaluation.

In general, everything shown by Field and Pearthree as H1 or H2 surfaces has been mapped as within one of the various 100-year flood hazard areas. H1 surfaces are characterized as "very high flood potential." H1 surfaces included areas with the "potential for localized, high-velocity, relatively deep, channelized flows and sheet flooding" with "some potential for drastic shifts in channel position." H2 surfaces were evaluated as having a "high flood potential" characterized by "predominantly shallow sheet flooding; channelized flow very limited in extent" with "broad areas probably inundated in large floods." The H1 areas largely correspond with the AFHH

zones mapped in this study. H1 zones are also shown within the AAFF zone administrative floodways.

The Field and Pearthree evaluation differs from the current study where approximate alluvial fan floodways (AAFF) cross I, L1, and L2 surfaces. The AAFF corridors follow stable channels or channels confined between older surfaces from the active fan upstream to the broad areas of sheet flooding downstream. The I surfaces are described as "intermediate flood potential; areas not flooded recently; near or within distributary drainage systems, and little topographic relief separates these areas from active alluvial fans or channels; could become floodprone with relatively modest changes in channel configurations." L1 surfaces are described as "relatively low flood potential; areas not flooded for at least 10,000 years, but near or within distributary drainage networks and typically with little topographic relief separating L1 from I, H1 or H2 surfaces." L2 surfaces are described as "very low flood potential; areas not flooded for at least 10,000 years or longer; spatially or topographically separate from distributary drainage networks."

Another difference between the current FDS and the Field and Pearthree evaluation is the exclusion of many small islands of L1 in the lower piedmont. As indicated above, islands smaller than about 10 acres were not separated out in the current study.

Another difference between the two studies shown in Figure 6B.15 is the inclusion of two islands of L1 in the AFUFD and AFZA zones along the southwest margin of the upstream active alluvial fan. These areas were evaluated as having a higher flood hazard potential based on their immediate proximity to the unstable area upstream.

Finally, a number of areas identified as I surfaces by Field and Pearthree have been given a Shaded X designation in this study. The authors of this study made the judgment that these areas, while having some geologic flood potential, lie outside the one percent chance limits. The Shaded X area reasonably represents the fact that while flood prone at some level, the frequency of flooding on those surfaces is less than one percent. Additionally, these areas receive floodwaters from local tributary drainage and as such are not completely flood free. Consequently, designation as Zone X (unshaded) is unwarranted.

Overall, the 100-year flood hazard assessment of the Site 36 piedmont and alluvial fan is believed to be reasonable, sound, and defensible based on the data presented in this Technical Data Notebook. However, revisions to the mapping presented here could be justified based on more detailed topographic mapping, hydrologic and hydraulic analyses in the future.

6B.7.3 Limitations

6B.7.3.1 Scale of mapping

The mapping for this study was compiled onto 1:24000 scale maps. The 1999 aerial photographs were taken at 1:9600 and thus served as the largest scale data used in this study. Additionally, the size of islands mapped in the floodplain was limited to areas larger than at least 10 acres. Therefore, areas smaller than 10 acres may be included within larger polygons for any given flood hazard area shown in Figure 6B.14.

6B.7.3.2 Accuracy of mapping

In addition to the limitations of scale, the accuracy is also limited to the ability to transfer the data to the USGS topographic quadrangles for construction of the final work map. The transfer of data was facilitated by use of the USGS digital orthographic quadrangles (DOQs). These orthographically rectified aerial photos are constructed to match with the topographic quadrangles. However, the topographic maps for this area are older than the DOQs. Therefore, some differences may exist between the two data sets. Additionally, in the process of transferring field and photo interpretations to the DOQs, the accuracy is limited to one's ability to identify precisely identical locations on each photograph. Through the use of landmarks, distinctive channel features and patterns, large trees, etc. it is believed that these errors have been minimized.

6B.7.3.3 Time period of historical photo record

Period of record for historical aerial photos spans 50 years. While this is a reasonably long period, it does not ensure that a 100-year event occurred during this time period. However, the 1951 flood was a very large flood and the impacts of this flood on the Site 36 piedmont are evident by comparison of the 1942/9 and 1954 photographs.

6B.8 References

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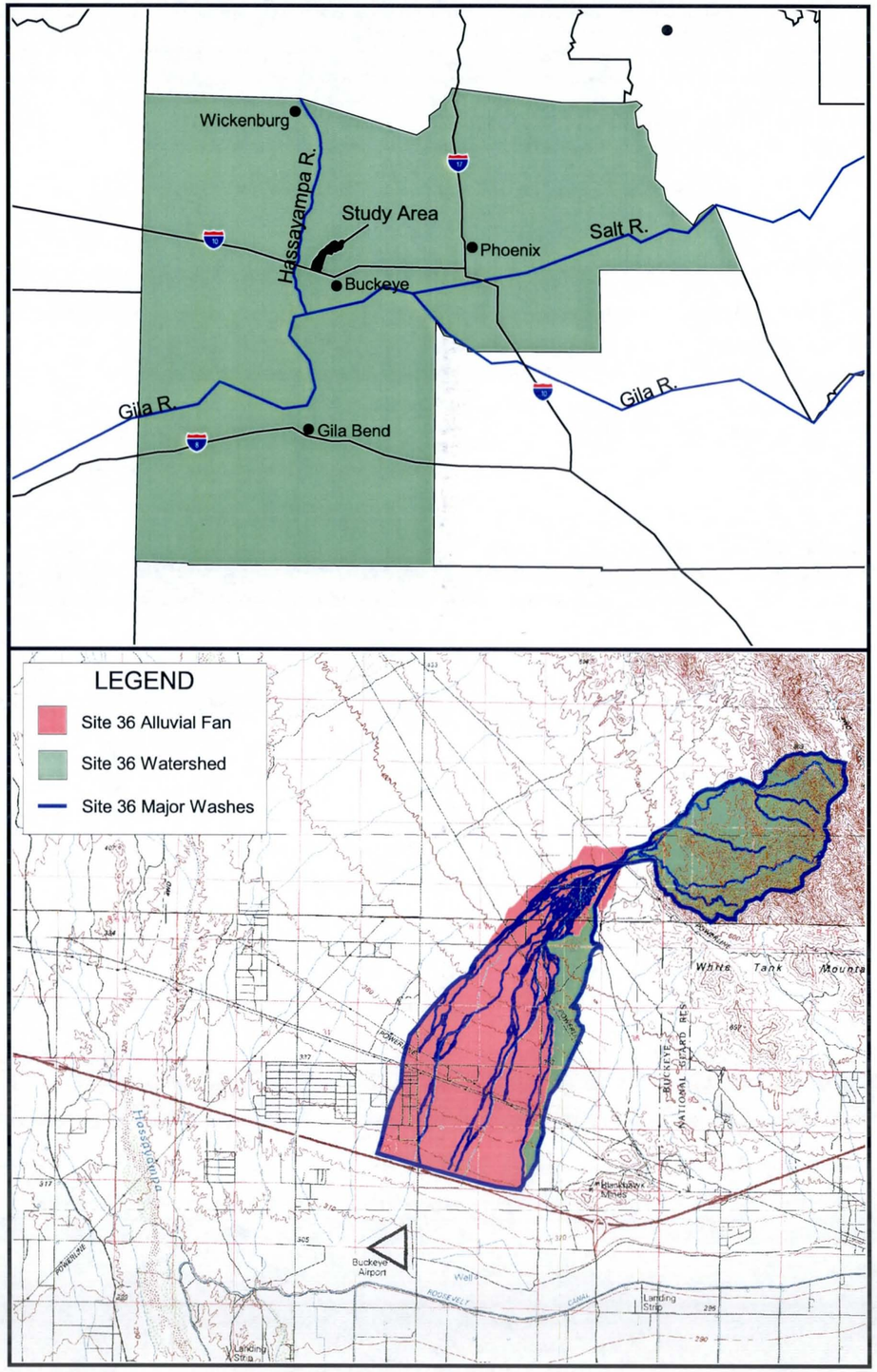


White Tank Fan (Site 36)
Approximate Floodplain Delineation Study
FCD 99-02
July 2000

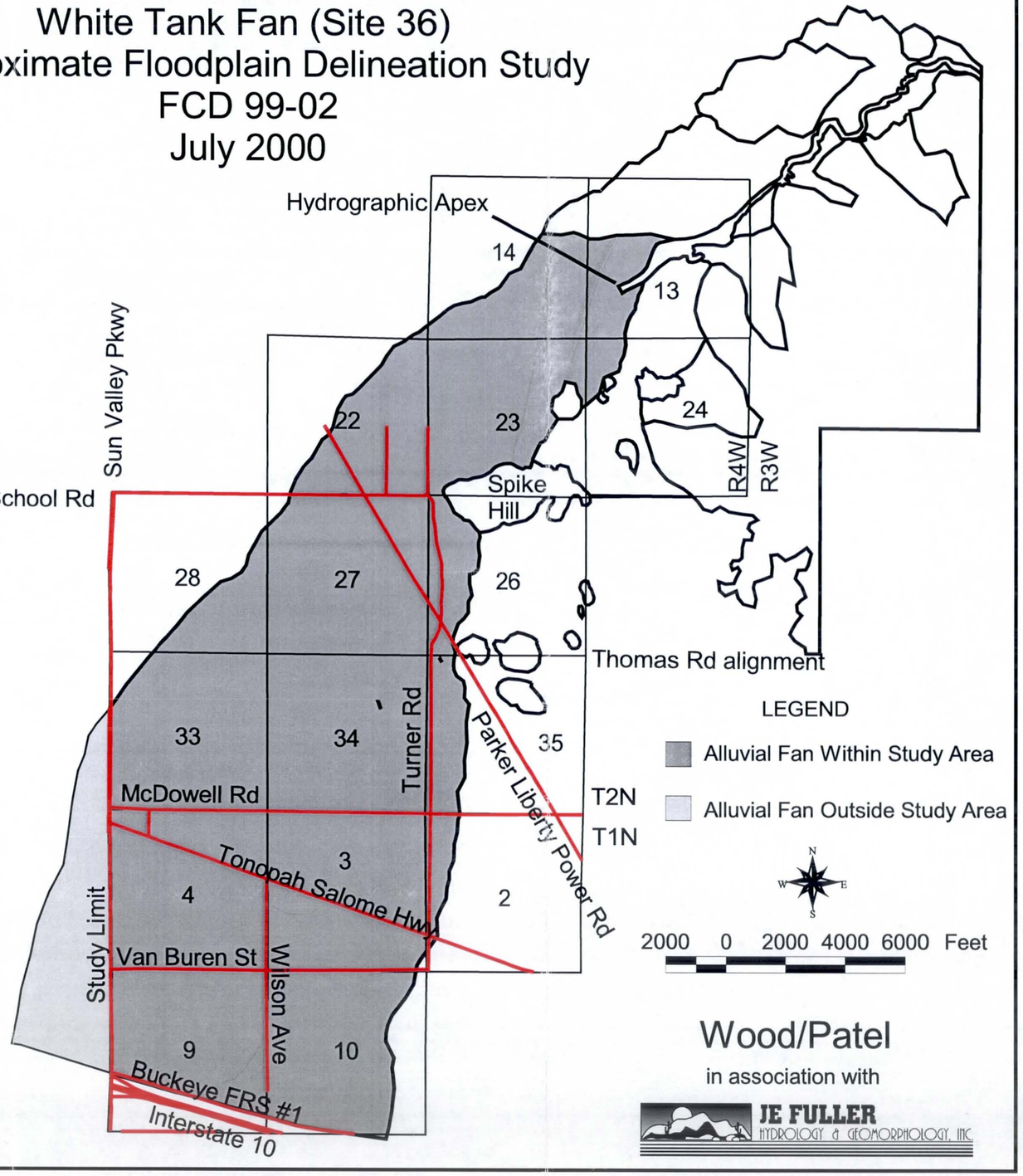


Figure 6B.1

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANK MTNS
SITE 36 ALLUVIAL FAN
APPROXIMATE FLOODPLAIN
DELINEATION STUDY

FCD 99-02, Assignment No. 2

LEGEND

- Alluvial fans, drainageways, and floodplains
- Valley plains
- Fan terraces
- Mountains and hillslopes
- 91 NRCS Soil Map Unit

Refer to Table 6B.1 for description of soil map units.

NOTES

1. Soils data from Camp (1986) and Hartman (1977)

INDEX MAP

Hydrographic Apex

Topographic Apex

1:36000
2000 0 2000 4000 6000 Feet

FIGURE 6B.2

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC

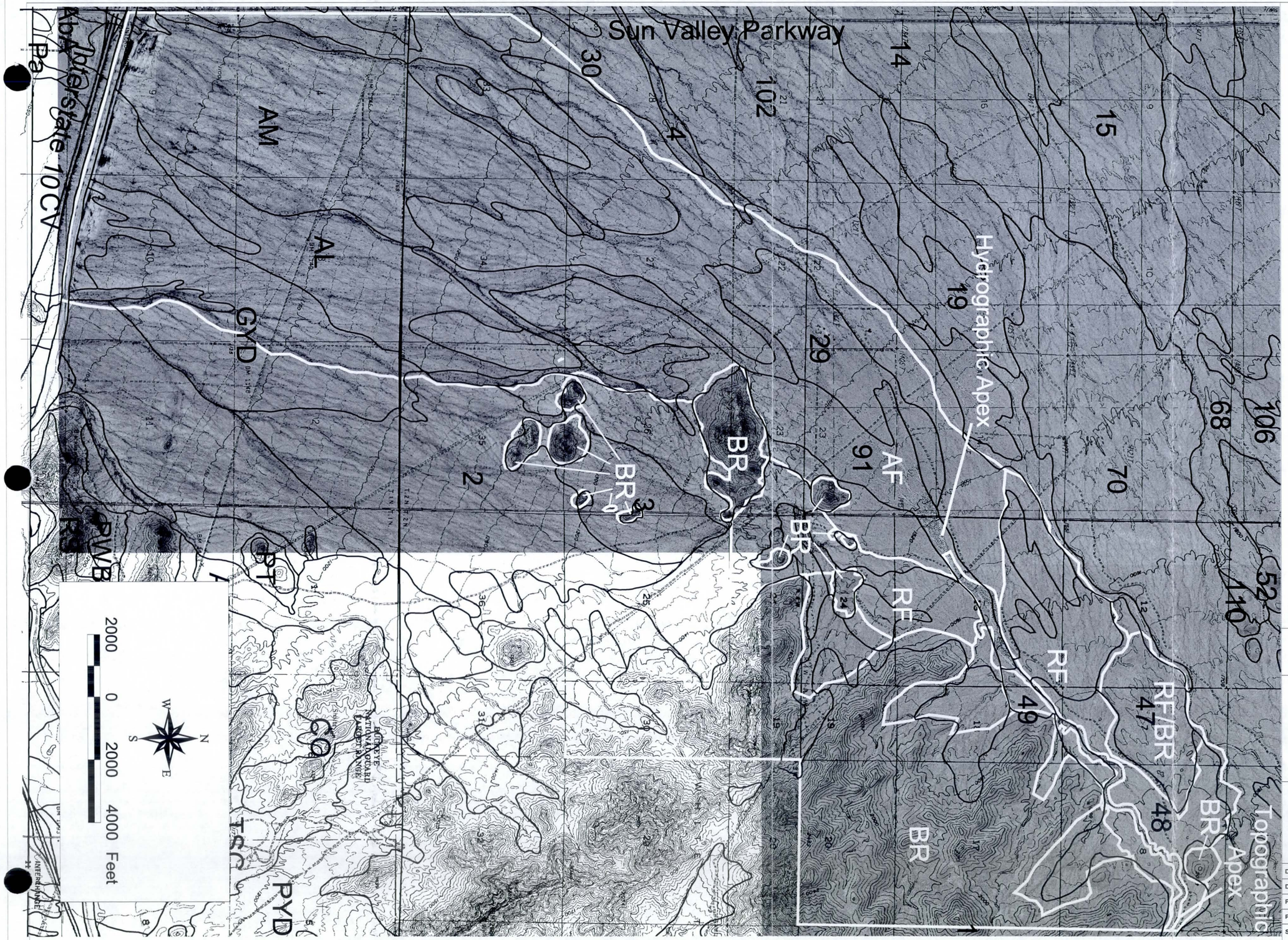
	BY	DATE
DESIGN		
DESIGN CHK.		
PLANS		
PLANS CHK.		
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER



FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

APPROXIMATE FLOODPLAIN
DELINEATION STUDY
FOR WHITE TANK FAN
(Site 36 - Hjalmarson and Kemna, 1992)

FCD 99-02, Assignment No. 2

NRCS Soil Units
and
Stage 1 Landforms

91 NRCS Soil Map Unit

See Table 6B.1 for description of NRCS map units.

See Figure 6B.5 for description of landform map units.

NOTES

NRCS Soil Data from
Hartman (1977) and Camp (1986)

INDEX MAP

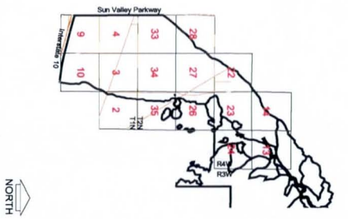


FIGURE 6B.3

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

	BY	DATE
DESIGN	TWL	
DESIGN CHK.	JEF	
PLANS	TWL	
PLANS CHK.	BRI	
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

WHITE TANK MTNS SITE 36 ALLUVIAL FAN APPROXIMATE FLOODPLAIN DELINEATION STUDY

FCD 99-02, Assignment No. 2

SURFICIAL GEOLOGY LEGEND

- Y2 – Y2 -- Late Holocene alluvial fans, low terraces, and active stream channels, < 3,000 years old
- Y1 -- Late to early Holocene alluvial fans and terraces, 1,000 - 10,000 years old
- Y -- Undifferentiated Holocene alluvial surface, 0 - 10,000 years old
- M2 -- Latest to late Pleistocene alluvial fans, 10,000 to 150,000 years old
- M1b -- Middle to late Pleistocene alluvial fans, 150,000 to 300,000 years old
- M1a -- Middle to early Pleistocene alluvial fans, 300,000 - 1,000,000 years old
- O – O -- Early Pleistocene to late Pliocene alluvial fans greater than 1,000,000 years old
- X and T – Bedrock

NOTES

1. Surficial geology data from Field and Pearthree (1991)

INDEX MAP

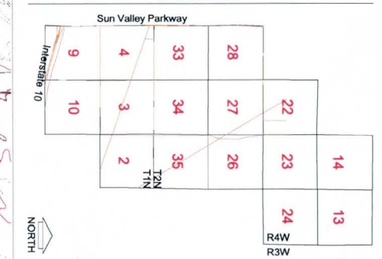


FIGURE 6B.4

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

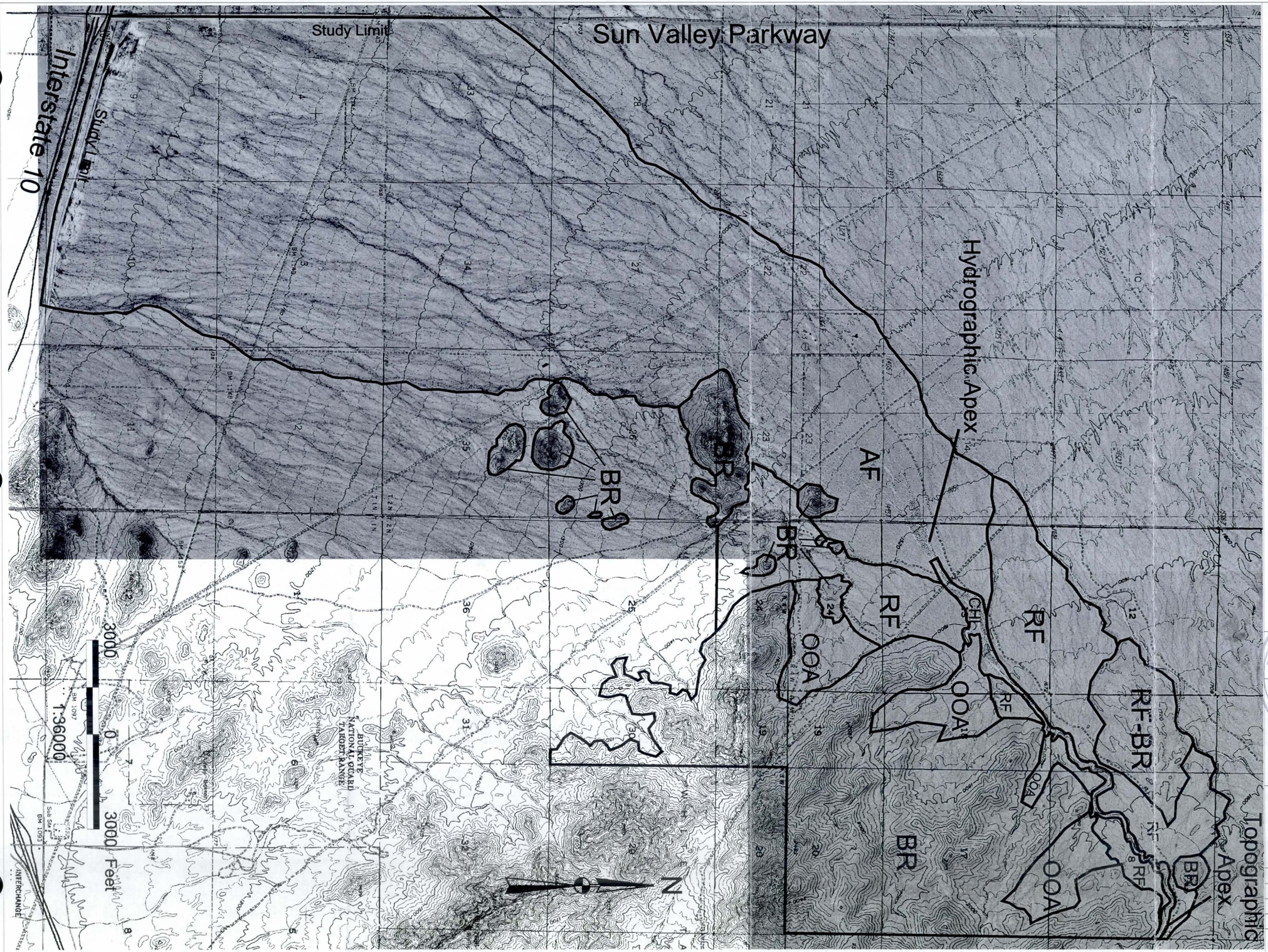
	BY	DATE
DESIGN		
DESIGN CHK.		
PLANS		
PLANS CHK.		
SUBMITTED BY: DATE:		

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER



FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

APPROXIMATE FLOODPLAIN
DELINEATION STUDY
FOR WHITE TANK FAN
(Site 36 - Hjalmarson and Kemna, 1992)

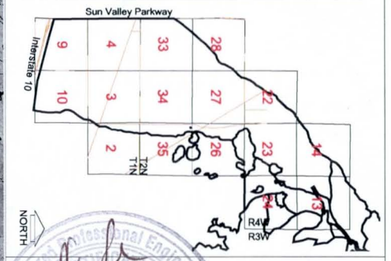
FCD 99-02, Assignment No. 2

STAGE 1
RECOGNITION OF LANDFORMS

LEGEND

AF = Alluvial fan
RF = Relict fan
OOA = Other old alluvium in embayed valleys and near toe of hillslopes in upper watershed
BR = Bedrock
RF-BR = Local thin relict fan deposits over eroded bedrock
CHL = Entrenched stable channel upstream of hydrographic apex

INDEX MAP



Registered Professional Engineer (Civil)
CERTIFICATE NO.
26846
JONATHAN E.
FULLER
Date Signed 7-18-00
ARIZONA, U. S. A.

FIGURE 6B.5

Wood, Patel & Associates, Inc.
in association with:
JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

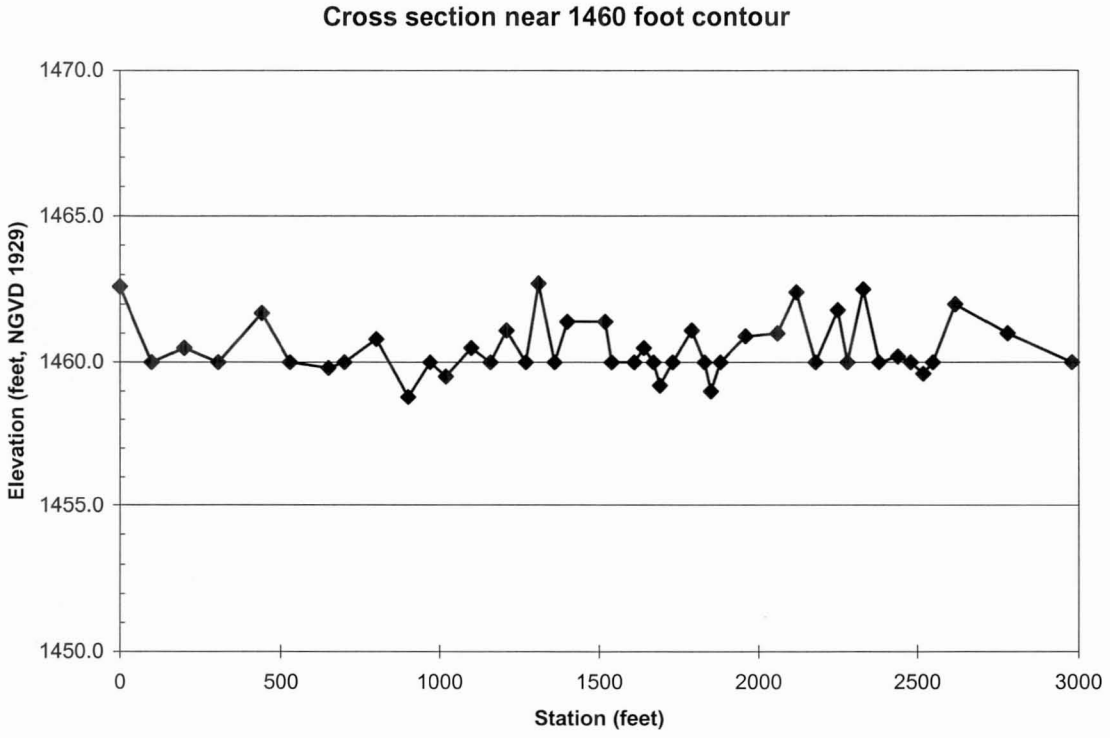
	BY	DATE
DESIGN	TWL	
DESIGN CHK.	JEF	
PLANS	TWL	
PLANS CHK.	BRI	
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER



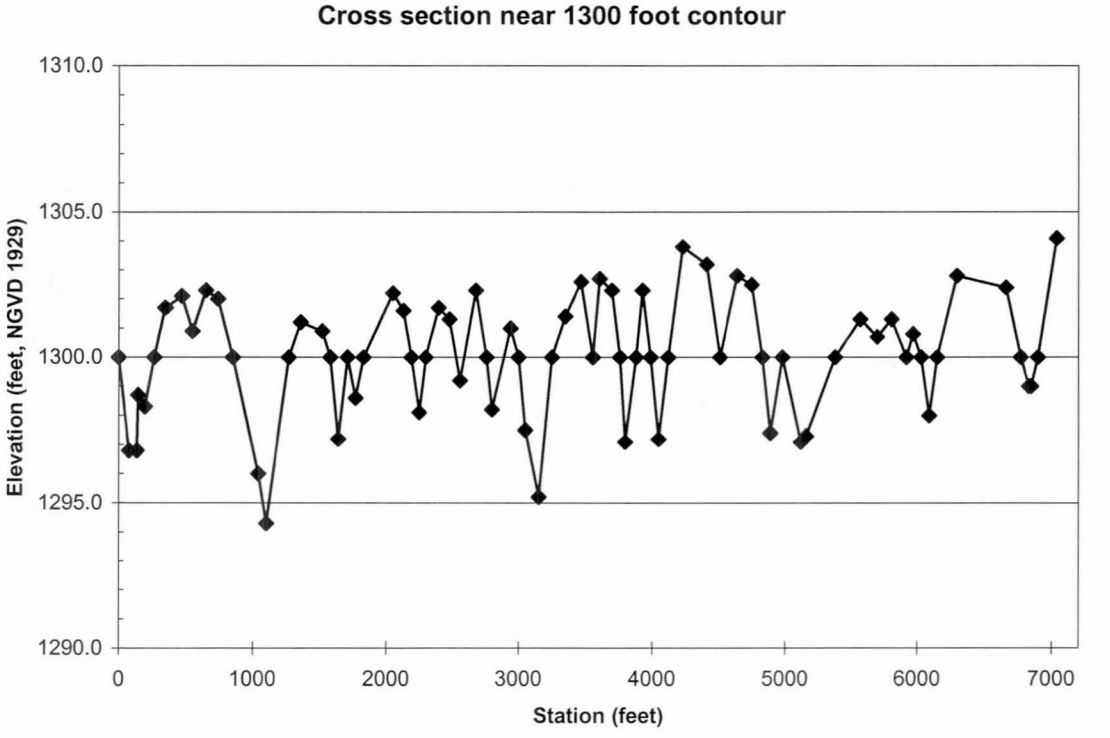
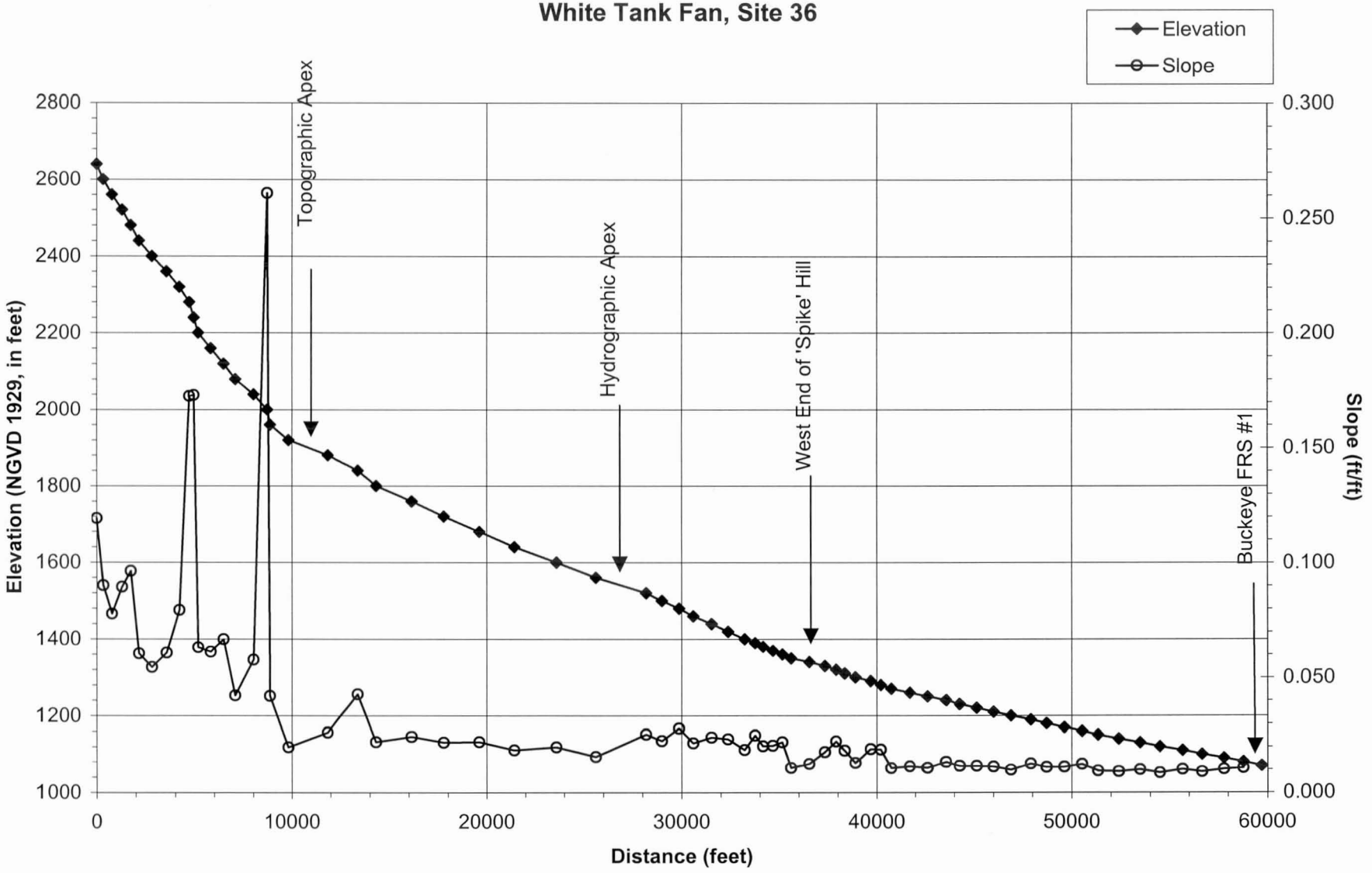


Figure 6B.6 Cross Sections of the Site 36 Piedmont

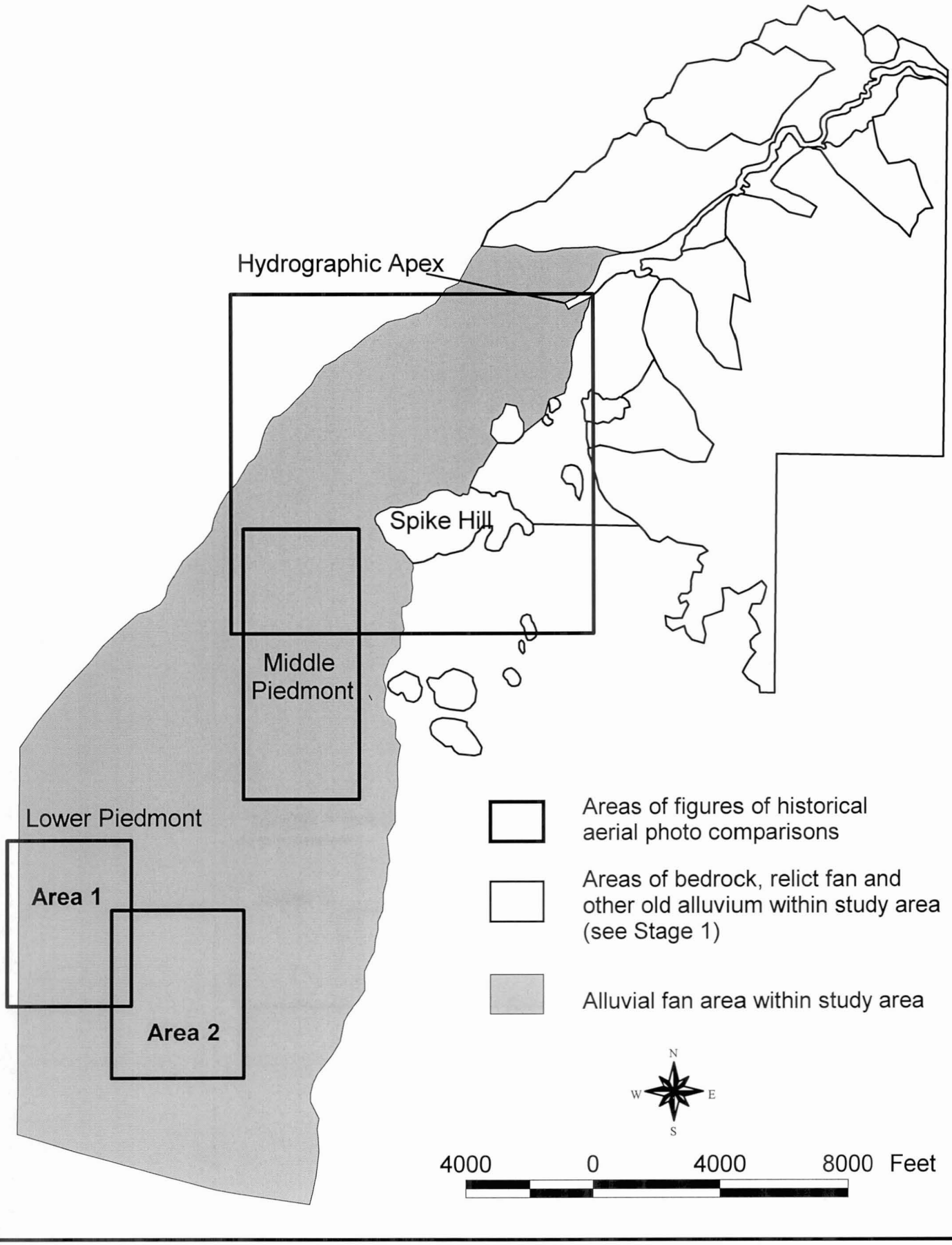
Figure 6B.7 Longitudinal Profile
White Tank Fan, Site 36

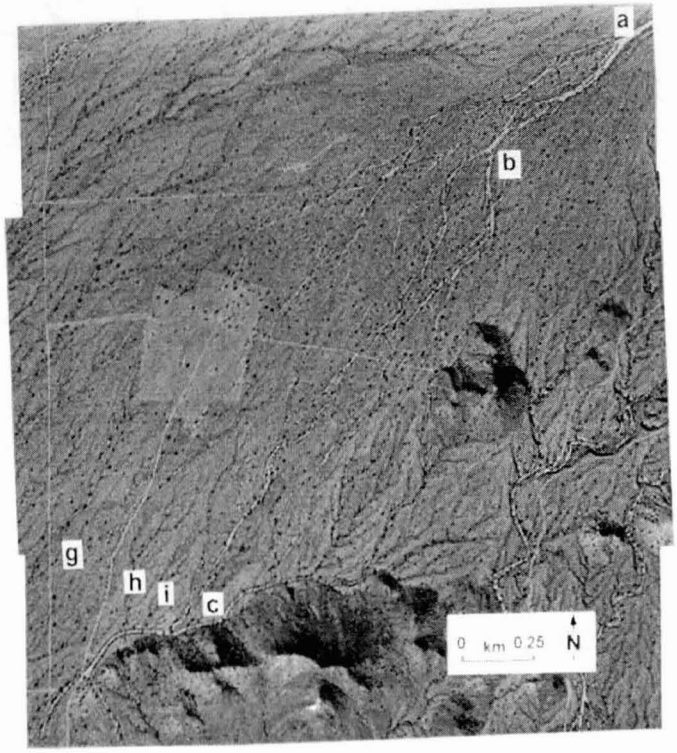


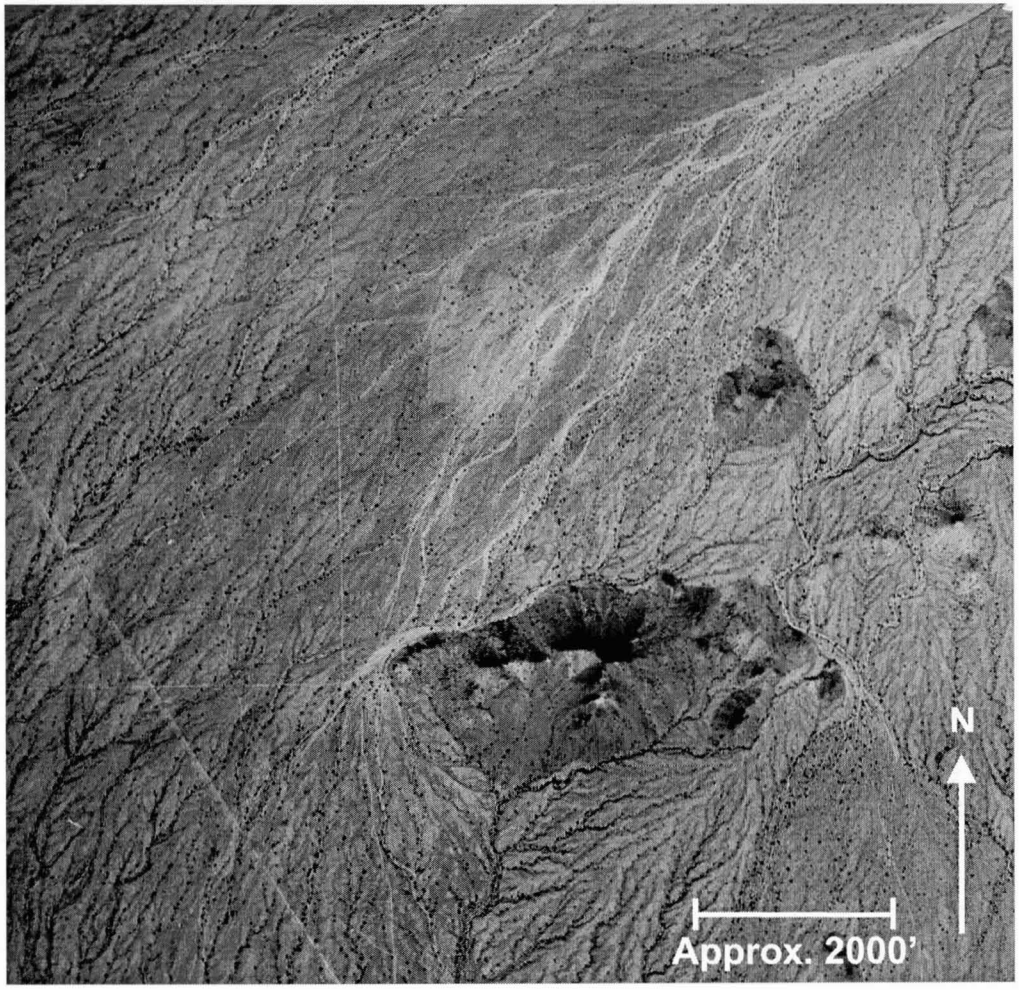
Wood, Patel, and Asssociates
in assocition with:
JE Fuller / Hydrology and Geomorphology, Inc.
July 2000

FCD No.99-02
Assignment No. 2

Figure 6B.8 Map of locations of aerial photo comparisons of channel changes



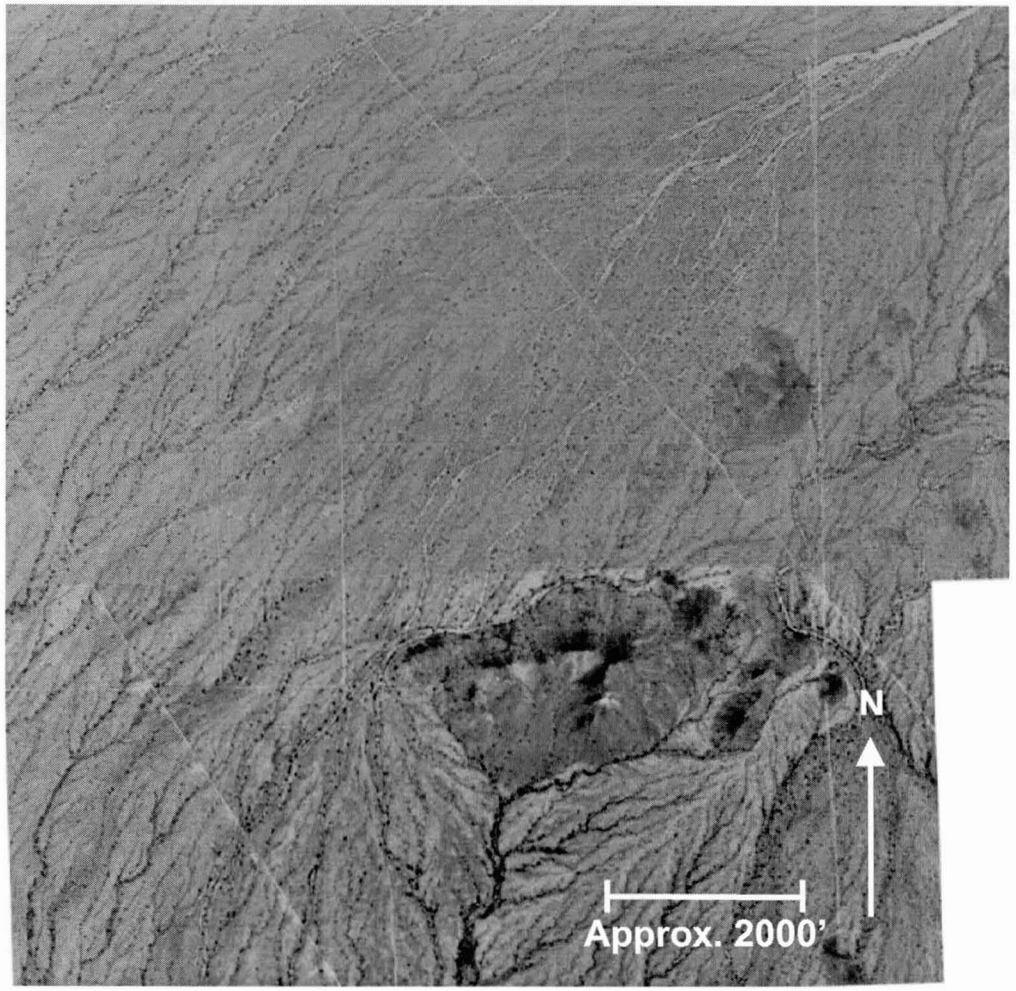




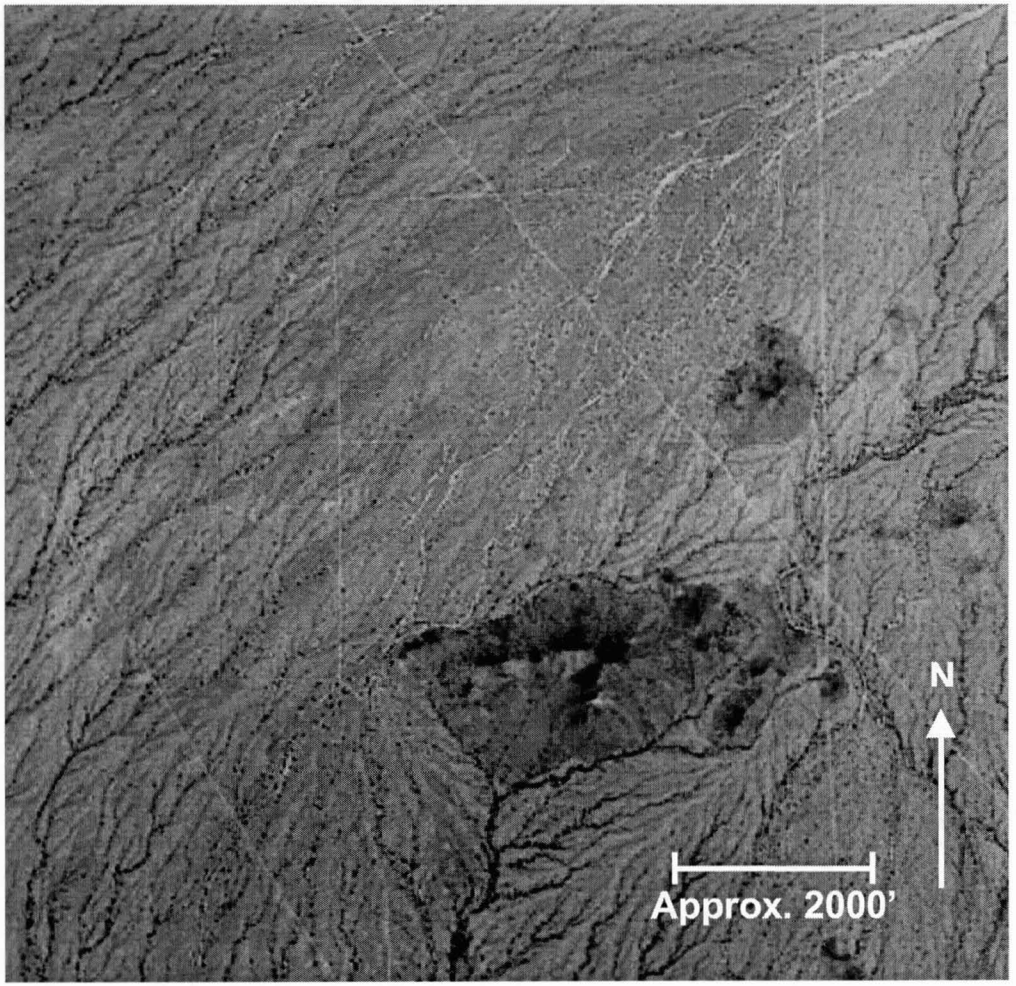
a) 1942

b) 1954

Figure 6B.9 Historical channel changes downstream of the hydrographic apex

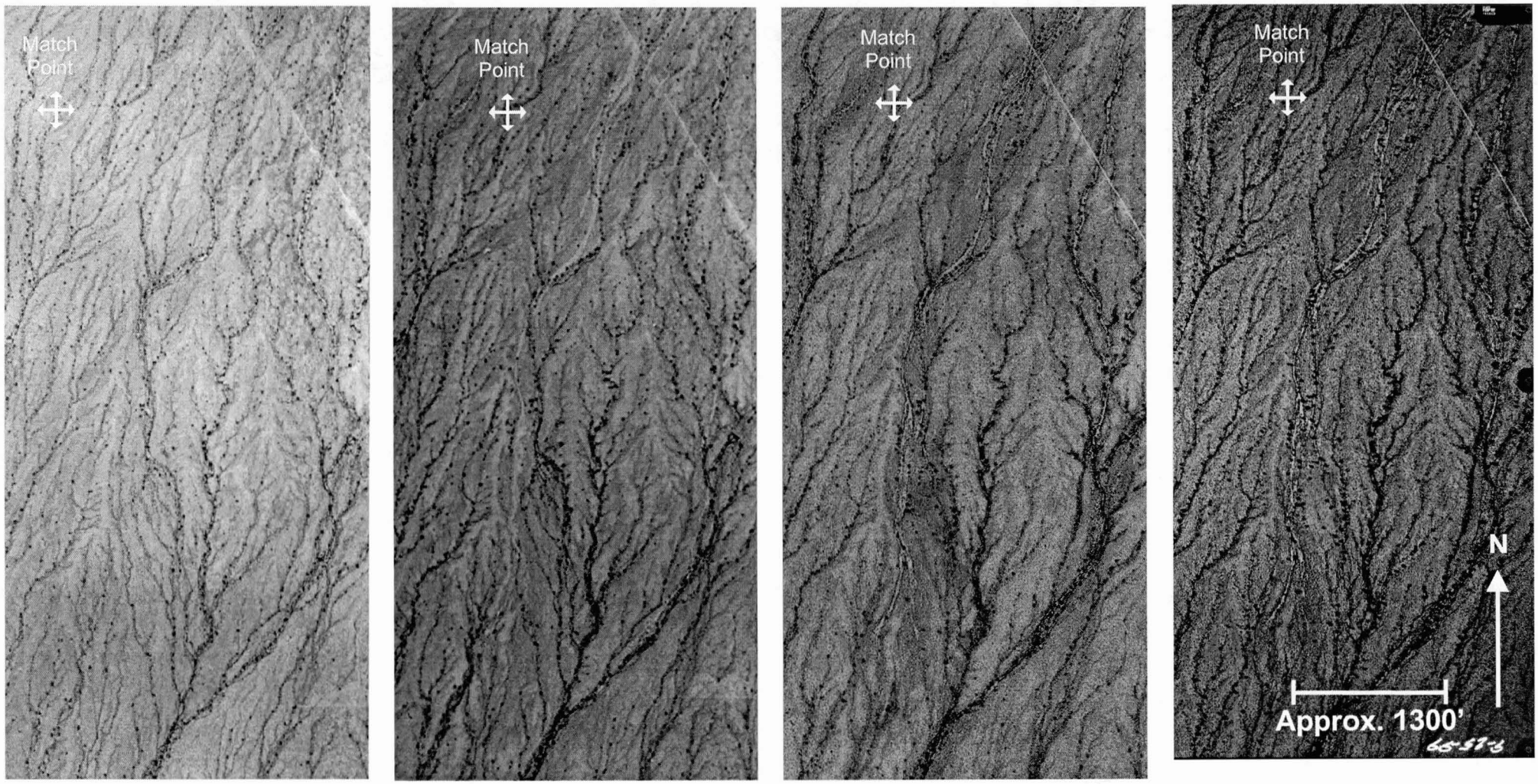


c) 1992/1997 (lower half 1992; upper half 1997)



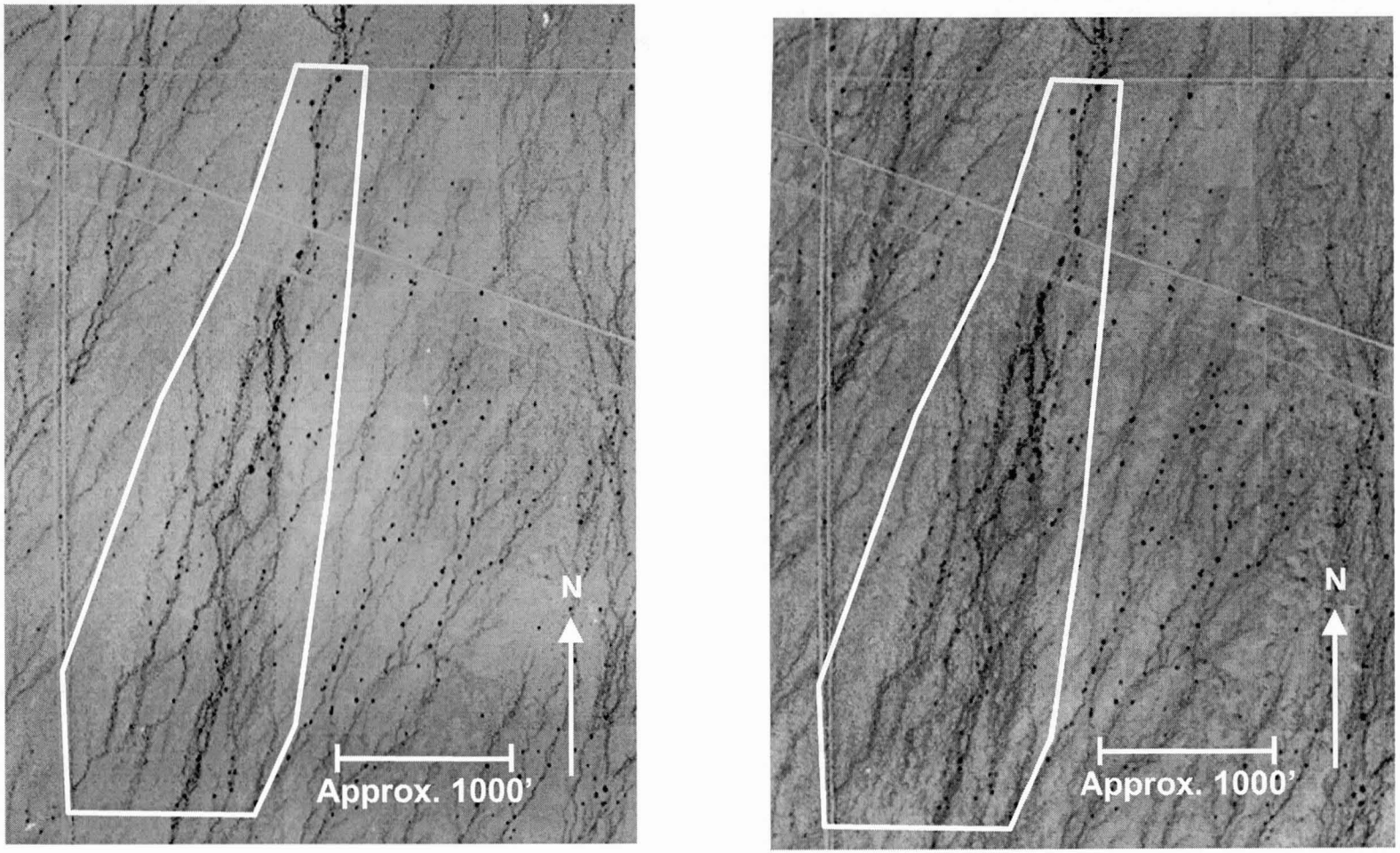
d) 1999

Figure 6B.9 (cont.) Historical channel changes downstream of the hydrographic apex



a) 1949 b) 1954 c) 1992 d) 1999

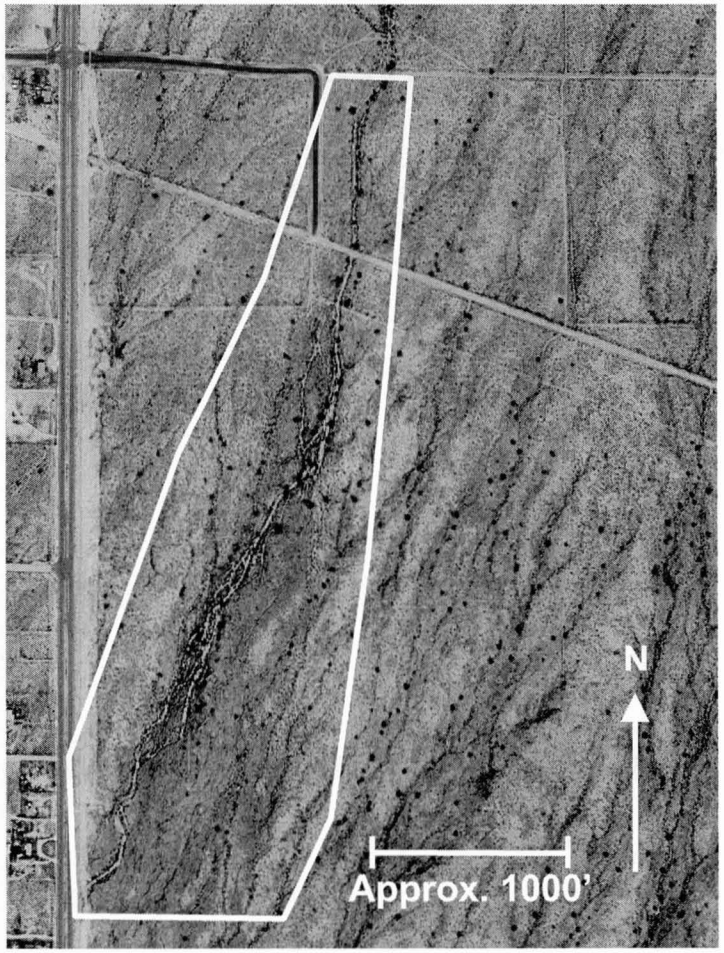
Figure 6B.10 Historical channel changes on the middle piedmont.



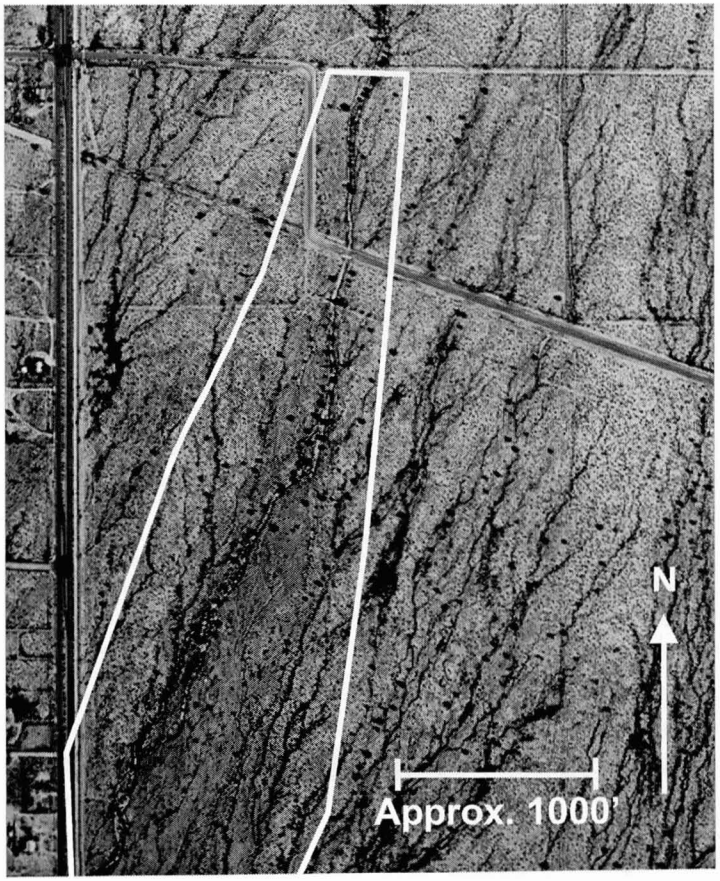
a) 1949

b) 1954

Figure 6B.11 Historical channel changes on the lower piedmont, Area 1.

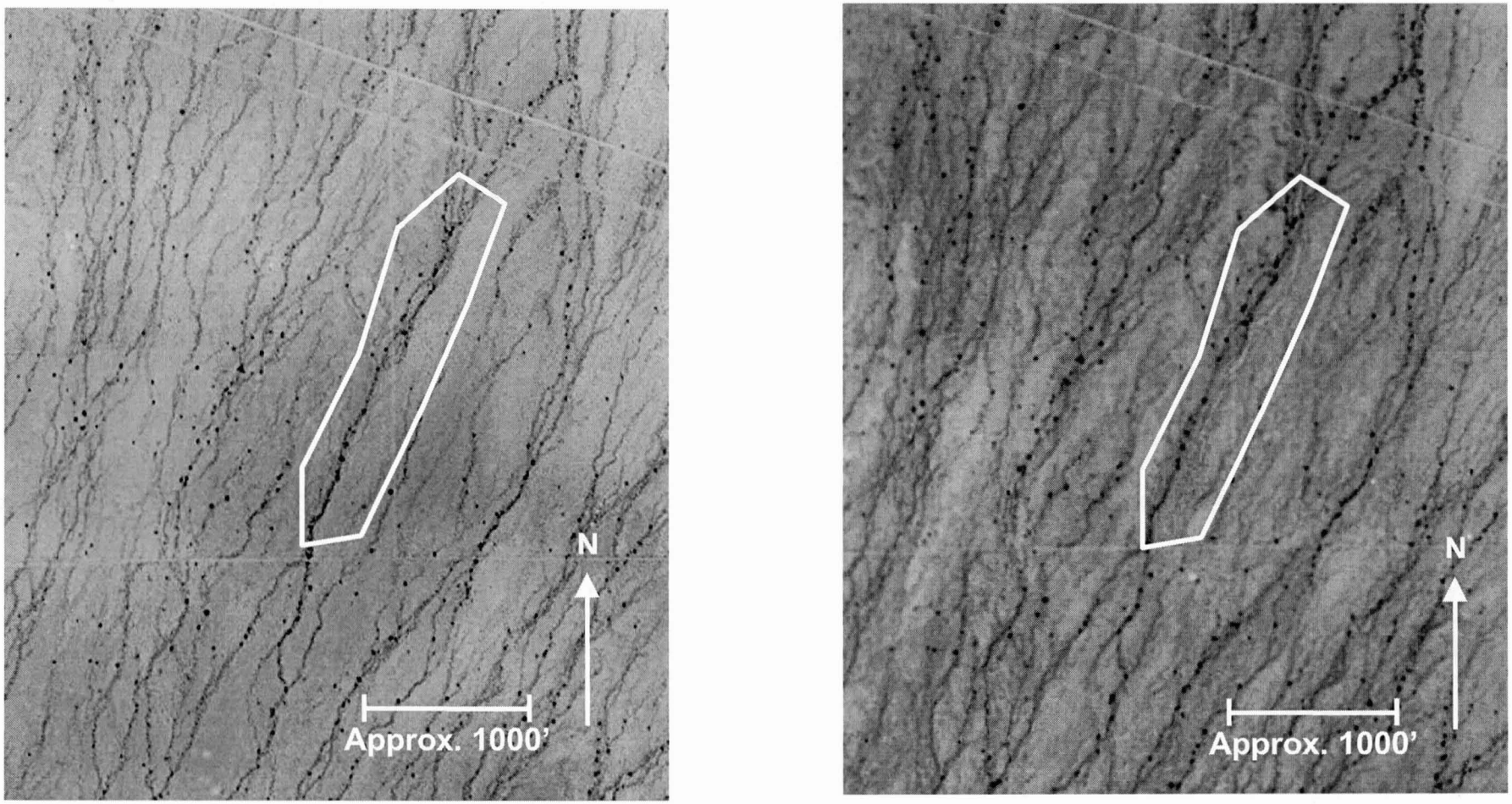


c) 1992



d) 1999

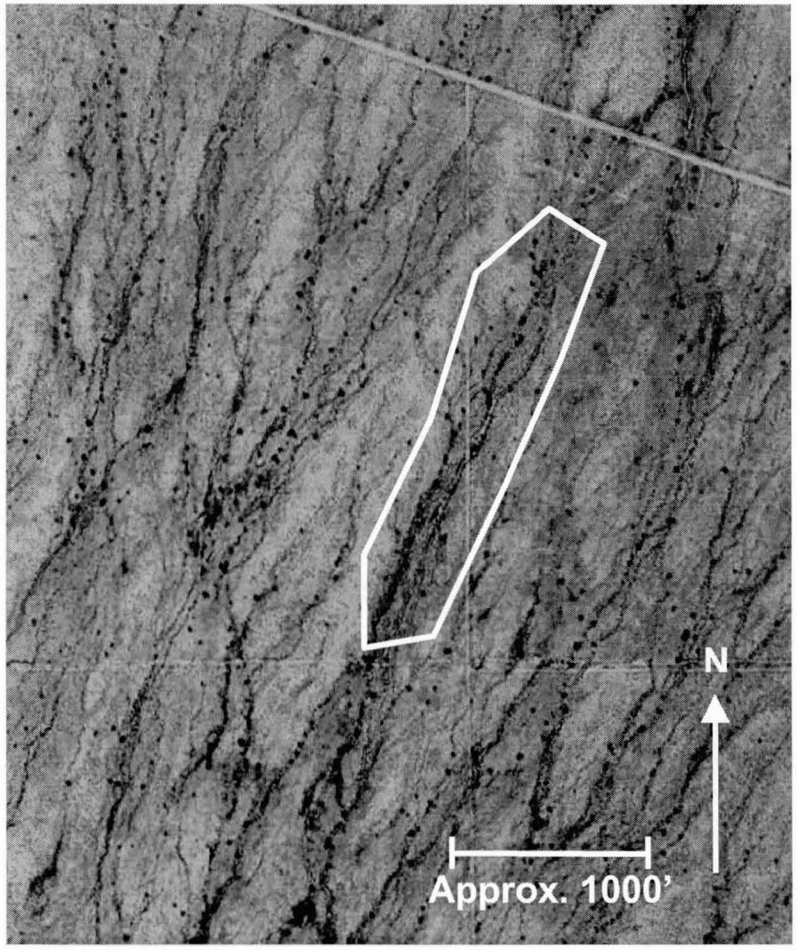
Figure 6B.11 (cont.) Historical channel changes on the lower piedmont, Area 1.



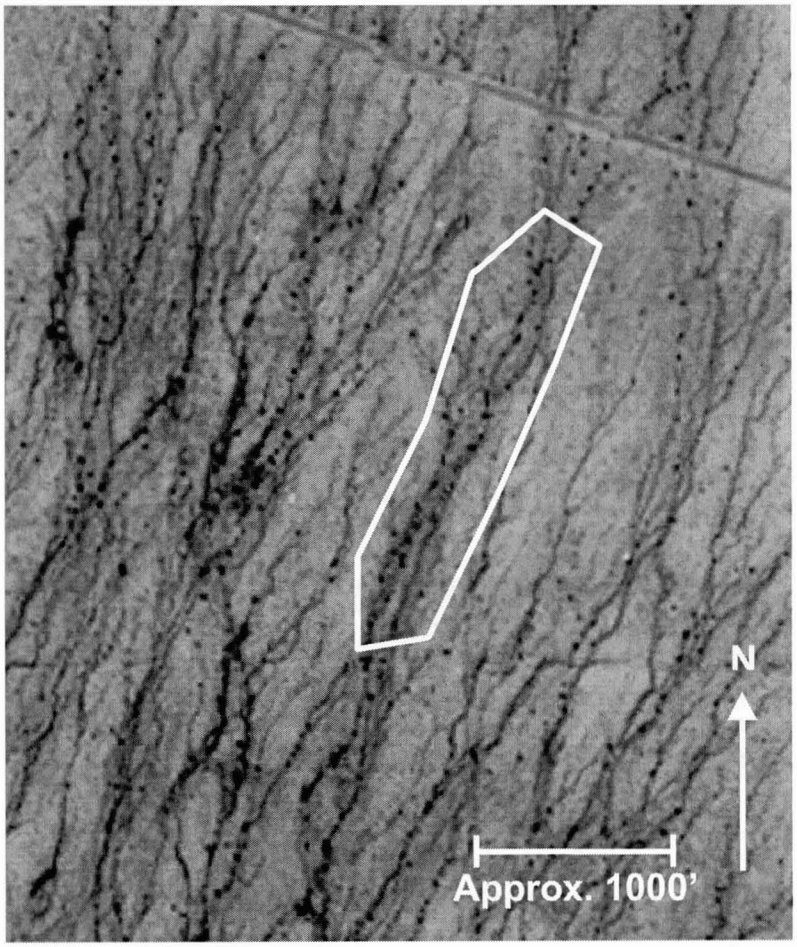
a) 1949

b) 1954

Figure 6B.12 Historical channel changes on the lower piedmont, Area 2.

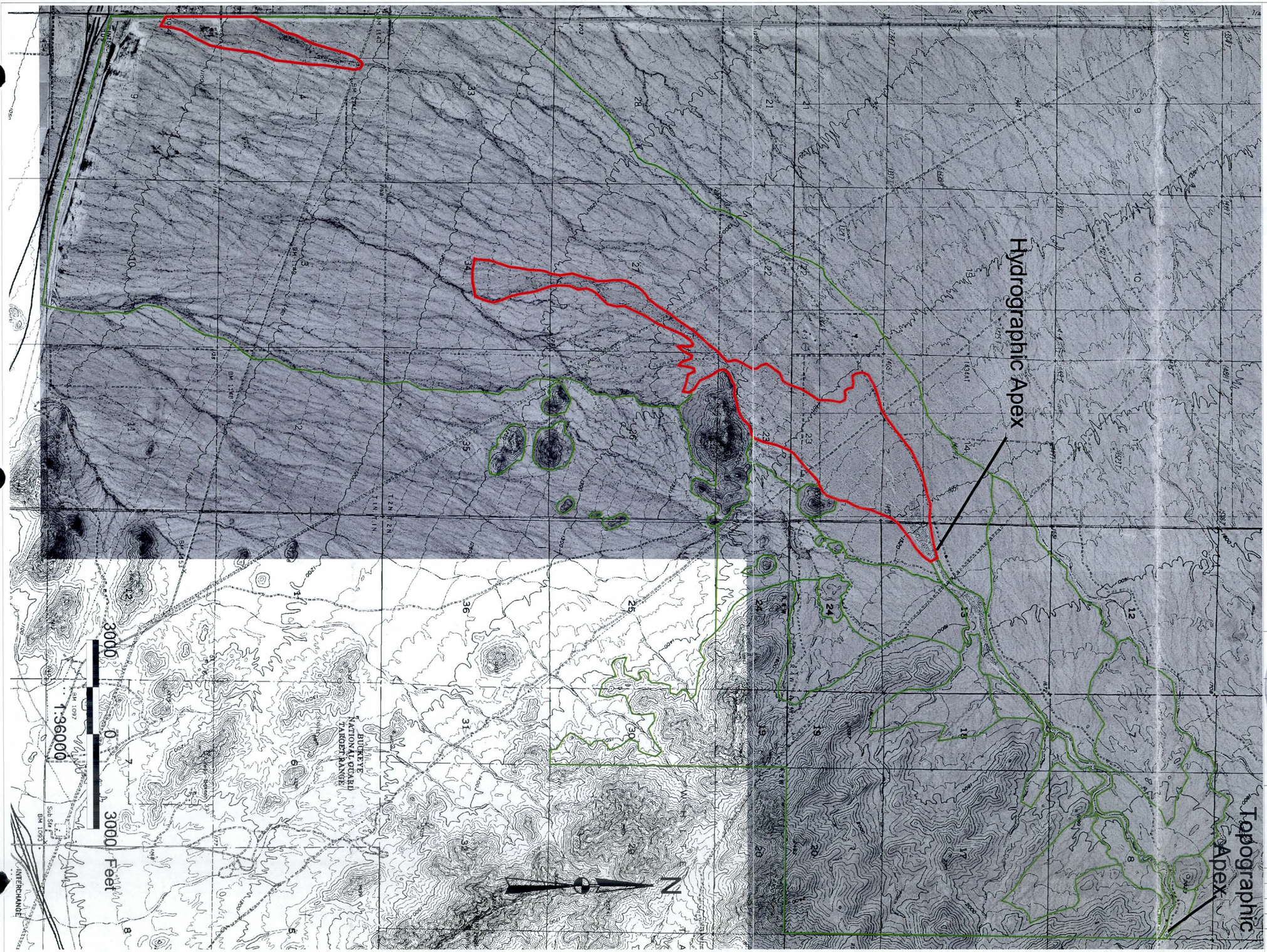


c) 1992



d) 1999

Figure 6B.12 (cont.) Historical channel changes on the lower piedmont, Area 2.



FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANK MTNS
SITE 36 ALLUVIAL FAN
APPROXIMATE FLOODPLAIN
DELINEATION STUDY

FCD 99-02, Assignment No. 2

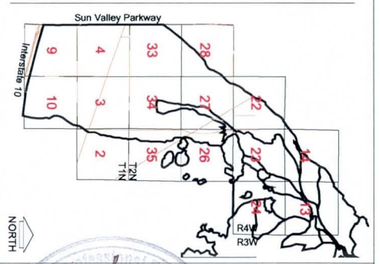
STAGE 2
IDENTIFICATION OF STABLE
AND UNSTABLE AREAS

LEGEND

- Unstable areas
- Stable areas

NOTES

INDEX MAP



Registered Professional Engineer (Civil)
CERTIFICATE NO.
26846
JONATHAN E.
FULLER
Date Signed 7-15-01
ARIZONA, U. S. A.

FIGURE 6B.13

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

	BY	DATE
DESIGN		
DESIGN CHK.		
PLANS		
PLANS CHK.		
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

WHITE TANK MTNS SITE 36 ALLUVIAL FAN APPROXIMATE FLOODPLAIN DELINEATION STUDY

FCD 99-02, Assignment No. 2

Comparison of 100-yr Flood Hazards with AZGS Flood Hazard Assessment

N

1:30000

2000 0 2000 4000 6000 Feet

LEGEND

H1 - Very high flood potential. Extensive young deposits; distributary channel system very evident. Potential for localized, high-velocity, relatively deep, channelized flows and sheetflooding; some potential for drastic shifts in channel position.

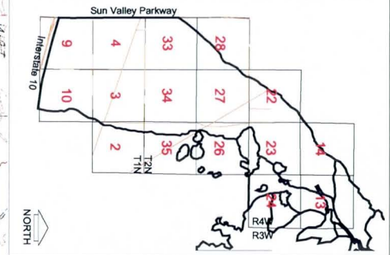
H2 - High flood potential. Extensive young deposits, but channels small to nonexistent. Predominantly shallow sheetflooding; channelized flow very limited in extent; broad areas probably inundated in large floods.

I - Intermediate flood potential. Areas not flooded recently. Near or within distributary drainage systems, and little topographic relief separates these areas from active alluvial fans or channels. Could become flood prone with relatively modest changes in channel configurations.

L1 - Relatively low flood potential. Areas not flooded for at least 10,000 years, but near or within distributary drainage networks and typically with little topographic relief separating L1 from I, H1, or H2 surfaces.

L2 - Very low flood potential. Areas not flooded for at least 10,000 years or much longer, spatially or topographically separate from distributary drainage networks.

INDEX MAP



NOTES

1. Digitized from Field and Pearthree, 1992.
2. Colored areas are Stage 3 flood hazard designations. See Figure 6B.14 for Stage 3 flood hazard legend.

FIGURE 6B.15

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC

	BY	DATE
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FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

Sun Valley Parkway

Interstate 10

T2N

T1N

R4W

R3W

N

1:30000

2000 0 2000 4000 6000 Feet

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

WHITE TANK MTNS SITE 36 ALLUVIAL FAN APPROXIMATE FLOODPLAIN DELINEATION STUDY

FCD 99-02, Assignment No. 2

Arizona Geological Survey
Flood Hazard Assessment

LEGEND

H1 - Very high flood potential. Extensive young deposits; distributary channel system very evident. Potential for localized, high-velocity, relatively deep, channelized flows and sheetflooding; some potential for drastic shifts in channel position.

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INDEX MAP

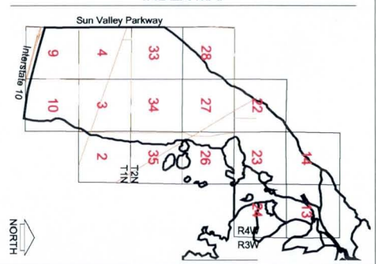

FIGURE 6B.16

NOTES

1. Digitized from Field and Pearthree, 1992.
2. Colored areas are surficial geology designations. See Figure 6B.4 for surficial geology legend.

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	BY	DATE
DESIGN		
DESIGN CHK.		
PLANS		
PLANS CHK.		
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SECTION 7: DRAFT FIS REPORT DATA

7.1 Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs)			
		10-Year	50-year	100-year	500-Year
White Tank Fan Site 36 Wash above hydrographic apex	5.7	--1	--1	3,600	--1
1 Not Computed					

The discharges listed above are taken from the previous FIS for nearby White Tanks Wash FIS by Alpha Engineering (1994).

7.2 Floodway Data

No typical floodway data are provided as this was not a detailed study. That is, floodways were not determined by detailed hydraulic modeling using a Method 4 or Method 1 one foot rise criteria. However, administrative floodways for use in management of the alluvial fan by the local community are presented. These floodways are intended to serve as corridors to maintain the continuity of the throughflow of water and sediment discharges along the alluvial fan landform. Management of these floodway corridors will be performed by the local community. The local community designation for these corridors is Approximate Alluvial Fan Floodways, Zone AAFF.

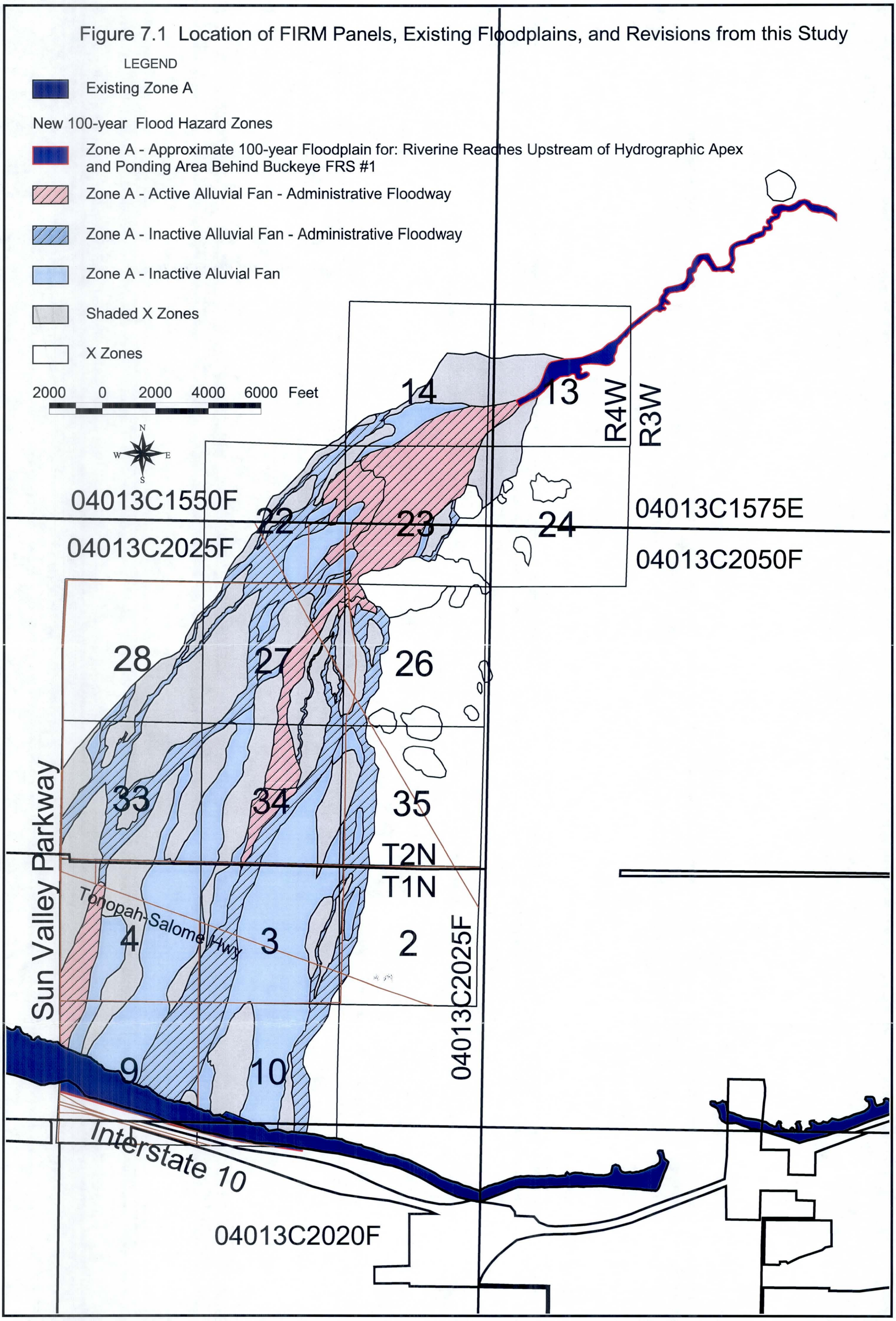
7.3 Annotated Flood Insurance Rate Maps

The area of flood hazard delineation includes portions of four FIRM panels in unincorporated Maricopa County, and Buckeye, Arizona. A map showing the new floodplain limits along with the existing floodplain limits and FIRM panel boundaries is included here.

7.4 Flood Profiles

No flood profiles were computed as this was not a detailed study.

Figure 7.1 Location of FIRM Panels, Existing Floodplains, and Revisions from this Study



APPENDIX A: REFERENCES

A.1 Data collection summary

APPROXIMATE
FLOODPLAIN DELINEATION STUDY
for
WHITE TANK FAN
(Site 36 - Hjalmarson and Kemna, 1992)

FCD CONTRACT NO. 99-02
Assignment No. 2

DATA COLLECTION REPORT

November 1999

Prepared for:

Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009
(602) 506-1501

By:

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In association with:

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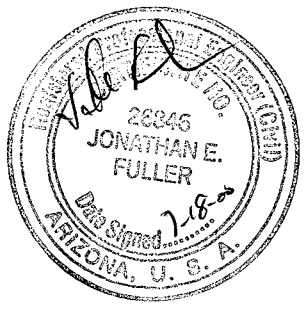

Introduction

JE Fuller / Hydrology and Geomorphology, Inc., (JEF) has collected and reviewed data which are pertinent to the flood hazard of the project study area. These data have come from the Flood Control District of Maricopa County and from outside sources. A large amount of literature on alluvial fan flood hazards exists but is not cited here. Refer to the *Piedmont Flood Hazard Assessment Manual* for a comprehensive listing of the pertinent literature on alluvial fans. This data collection effort limited its scope regarding general alluvial fan flooding issues to four documents: *Alluvial Fan Flooding* (NRC, 1996), *Piedmont Flood Hazard Assessment for Flood Plain Management, User's Manual, DRAFT* (Hjalmarson, 1998), *Guidelines for Determining Flood Hazards on Alluvial Fans* (FEMA, 1999), and *Alluvial Fan Data Collection and Monitoring Study* (CH2M Hill, 1992). The remaining sources investigated were limited to those sources pertinent to the western piedmont of the White Tank Mountains and the southwest portion of the piedmont in particular, especially two Arizona Geological Survey Open File Reports for the area (Field and Pearthree, 1991 and 1992). However, some of the sources which address the White Tank alluvial fans also discuss alluvial fan flooding more generally.

The following types of data were collected: historical flooding information, flood flow frequency data, as-built plans for structures, FEMA mapping, miscellaneous data, maps and aerial photographs, and field data.

Historical Flooding Information

Field (1994) describes significant channel changes resulting from a large tropical storm in 1951 as reported in Kangieser (1969). The National Weather Service (NWS) Buckeye station (#021026) recorded 1.00" and 2.60" of rainfall on August 27 and 28, 1951. This may be the rainfall event(s) responsible for the large channel changes reported by Field (1994). The SCS (1963) indicate that this storm inundated 12,240 acres and was similar in magnitude to events in January 1916 and September 1939.

CH2M Hill (1992) performed a paleoflood survey that indicated that a flood between 2,000 cfs and 5,000 cfs occurred at some time in the past 100 years. They also report a more recent event of 500 to 1,000 cfs. They suggest that the large flood attributed to a tropical storm in 1951 as reported in Field (1994) may be responsible for emplacing the slackwater deposits used in the 2,000 to 5,000 cfs estimate. The narrow chute of the channel above the apex may be preventing preservation of older paleoflood evidence. The more recent flood reported by CH2M Hill may have been the August 15, 1990 storm recorded by the FCD ALERT gage #5200. The August 15, 1990 storm is the largest and most intense rainfall recorded in the 16 years of operation of this station (3.15" in 24 hours and 2.20" in 3 hours).

No USGS or FCDMC streamflow or precipitation gages exist within the project limits. Nearby gages include:

Table 1. Precipitation and Streamflow Gages Near the White Tank Fan Study Area

Gage Name	Type	Operator /ID#	Installation Date	Elevation (feet)	TRS	Latitude	Longitude
Buckeye FRS #1	Rain & Stage	FCD/ 5200	7-26-83	1,095	T1N-R5W-Sec.3	33° 27' 36"	112° 44' 02"
Buckeye FRS #2	Rain & Stage	FCD/ 5205	11-11-92	1,150	T1N-R3W-Sec.7	33° 26' 26"	112° 35' 47"
Hassayampa @ I-10	Rain & Stage	FCD/ 5280	11-9-94	1,035	T1N-R5W-Sec.3	33° 27' 33"	112° 45' 46"
White Tanks East Peak	Rain	FCD/ 5430	4-1-81	4,030	T3N-R3W-Sec.27	33° 34' 08"	112° 45' 46"
Buckeye	Weather Station	NWS/ 020126	1893			33° 22'	112° 35'
Tonapah	Weather Station	NWS/ 028641	1951			33° 28'	112° 57'
Hassayampa near Arlington	Streamf low	USGS/ 09517000	1961	825	T1S-R5W-Sec.13	33° 20' 50"	112° 43' 30"

Table 2. Significant Rainfall Events Recorded by Nearby Gages

Station	Years of Record	Max. 24-hr rainfall	Date	Max. 6-hr rainfall	Date	Max. 3-hr rainfall	Date
5200	15	3.15"	8-14-90	2.44"	8-21-88	2.20"	8-14-90
5205	6	1.26"	11-15-93	1.10"	8-9-97	1.02"	8-8-97
5280	4	1.89	8-9-97	1.85"	8-9-97	1.77"	8-8-97
5430	17					2.32"	8-21-88
021026	102	4.90"(max. daily)	9-2-1894				
021026	102	1.00" and 2.60" maximum daily values for August 27 and 28 which occurred in 1951					
028941	20	3.05"(max. daily)	9-5-62				
028941	20	3.00"(daily)	9-1-84				

Flood Flow Frequency

White Tanks Wash FIS Hydrologic Analysis (Alpha, 1994 for FCD 90-64) will serve as the basis for the 100-year peak discharge for this analysis. Table 3 compares peak discharge estimates for a range of frequencies. The comparison shows the FCD 90-64 estimate to be reasonable. Note that the watershed sits very near the Region 12/13 boundary (Thomas, et al., 1997). Hence, both regional regression equation results are presented. The mean basin elevation also lies near the lowest portion of the cloud of common values for Region 12.

Table 3. Comparison of discharge estimates for Site 36

Source	2-year	5-year	10-year	25-year	50-year	100-year
FCD 90-64 (Alpha, 1994) 100-yr 24-hr @ CP 1M (see Figure 1)						3,623
Waters, 1991, 24-hr logarithmic averaging, Clark Unit hydrograph	232	454	1,082	2,402	3,518	4,892
Waters, 1991, 24-hr logarithmic averaging, one basin S-graph	249	487	1,033	1,865	2,423	3,017
Hjalmarson, 1994	325		1,240			3,570
Thomas, et al., 1997 Region 12	122	595	1,111	2,095	3,836	6,021
Thomas, et al., 1997 Region 13	325	790	1,245	2,001	2,681	3,575

As-Built Plans for Existing Structures:

The primary existing drainage structure in the study area is the Buckeye Flood Retarding Structure #1 located at the downstream limit of the study area. The flood hazard delineation will extend into the limits of the inundation area from the dam shown on the existing FIRMs (Panels 04013C2020F and 04013C2025F). Otherwise, the FRS will not be analyzed.

Some drainage structures also exist along and through the Sun Valley Parkway along the west boundary of subarea 6. Survey data in the FCD 90-64 TDN for these structures were collected in the event they will require analysis.

Tonapah-Salome Highway transverses the lower portion of the study area. The numerous small drainages that flow across the road are all conveyed by at-grade dip crossings.

No other significant drainage structures are currently present in the study area.

FEMA Flood Hazard Boundary Maps, LOMAs, LOMRs:

The only existing FEMA flood hazard areas mapped within the study area lie within the impoundment limits of the Buckeye FRS #1 along the north side of the dam. West of Sun Valley Parkway, White Tanks Wash and its Tributaries # 1-3 have been delineated by detailed methods. The White Tanks Wash delineations were performed as part of FCD 90-64. The 100-year peak discharges for FCD 99-02, Assignment No. 2 will be taken from FCD 90-64. That study indicates a 100-year peak discharge at the hydrologic apex in Sec. 13 of 3,623 cfs at concentration point 1M of the 100-year 24-hour HEC-1 model.

Historical Aerial Photography

Historical aerial photographic coverage of the study area will be an important component of the piedmont flood hazard assessment. A number of different dates of aerial photography were identified for use in this study. Table 4 summarizes these data.

Table 4. List of Historical Aerial Photographs of White Tank Fan Study Area

Source	Photo Date	Scale	Type	Digital
Field, 1994	1942		Black and white	
National Archives	1949	1:20,000	Black and white	No
FCDMC archives (US AMS, 1953)	1953	Approx. 1:14,400	Large format black and white	
National Archives	1954	1:20,000	Black and white	No
SCS Soil Survey (Hartman, 1977; Camp, 1986)	1972 & 1973	1:24,000	Black and white orthophoto	No
MCDOT archives	1976	1:14,400	Black and white half townships	
Collected by AZGS (BLM)	1979		Color 9x9s	No
FCDMC image database	1997 & 1998	1:7,200	Black and white	Part of FCD digital database
USGS Digital OrthographicQuadrangles (DOQ)	1992/1997	1:24,000	Black and white orthophotos	Yes. USGS supplied ¼ quads.
AMC/JEF	1999	1:9,600	Color	No
AMC/JEF	1999	1:32,000	Color orthophotos	Yes

Other Maps

Previously published maps have been collected and will be used extensively in this study. These include the following:

- the USGS 7.5 minute topographic quadrangles for the area (see Figure 2),
- the NRCS soil survey maps (Camp, 1986; Hartman, 1977) (see Figure 3),
- the surficial geology maps of Field and Pearthree (1991) (see Figure 4),
- and their flood hazard maps (Field and Pearthree, 1992) (see Figure 5).

Field Data

The complex nature of the flood hazard on the active portions of the alluvial fan was observed during a field trip conducted on September 14, 1999. Initial investigations indicate that flood waters do spill over to the north and west portion of the alluvial fan into subarea 6. Further investigations and a formal recommendation on inclusion of subarea 6 to the floodplain delineation study will be compiled in a separate report. The extensive area of relatively shallow flooding in the lower study area was also observed during the 9-14-99 field trip.

Other Pertinent Data:

Camp, 1986: This report describes the soil conditions for the area and provides soils maps and descriptions of the mapped soil units for the area. The mapping in this report shows most of the upper piedmont as fan terraces. Interestingly, the most active portions of the Site 36 alluvial fan are mapped as unit 91, Momoli-Carrizo complex on fan terraces. The older surfaces are mapped as unit 70, Gunsight-Rillito complex, 1-25 percent slopes, on fan terraces. Intermediately-aged surfaces in the mid-piedmont are identified as unit 29, Denure-Momoli-Carrizo complex on fan terraces. The lower portions of the piedmont which are dominated by younger, finer-grained sediments are shown as unit 2, Antho gravelly sandy loams on alluvial fans.

CH2M Hill, 1992: This is the best single source on the White Tank (Site 36) alluvial fan being examined in this study. It includes a discussion of flood flow frequency, a paleoflood analysis, and maps of the landform types and flood hazard area in general terms. This report will be used as a basis for the current study. However, this report limits its analyses to the area upstream of Spike Hill. That is, the CH2M Hill report is limited basically to the more active areas from the hydrologic apex in Sec. 13, T2N, R4W into parts of Sec. 14 and Sec. 23. The remaining lower portions of the piedmont are not addressed in this report.

Dames & Moore, 1990: This report was conducted for the FCDMC for the purpose of analyzing the Buckeye FRS's performance for dam safety. The hydrologic analyses included examination of the 100-year 6-hour and 24-hour events. Concentration point

CP1-3 in their model is approximately the same drainage basin examined by the current project except it also includes about 1.5 square miles west of Sun Valley Parkway. For a total area of 19.32 square miles, Dames & Moore computed a 100-year 6-hour peak inflow discharge of 3,810 cfs. Their 24-hour model yielded 6,930 cfs with a volume of 2.29" (approx. 2,360 ac-ft). The report also indicates that the SCS construction plans (SCS, 1971) called for 8,200 ac-ft of storage at the level of the emergency spillway (1079.8 feet) and a silt pool of 1,850 ac-ft (at 1071.5 feet).

Field, 1994: This report is another good resource on White Tank (Site 36) fan. The report describes changes observed on the fan as shown on historical aerial photos. The impacts of a large flood in 1951 are noted. Finally, the report discusses how the changes observed at this site along with four others support a conceptual model of channel changes on fluvially dominated alluvial fans. The author argues that overbank flow is the most important cause of channel migration on alluvial fans. Stream capture results from headward erosion caused by overbank flow. The author also concludes that large floods on these fans tend to follow previously existing drainage paths/patterns.

Field and Pearthree, 1992: This report presents maps depicting the distribution of relative flood hazards based on the age and character of the geomorphic surfaces surrounding the White Tank Mountains as identified in Field and Pearthree (1991). Degree of flood hazard is largely related to the age of the surface. If a surface is young, it has experienced recent deposition which had to have been brought in by a fluvial process, namely flowing water. The results of this analysis will be strongly considered in the identification of approximate 100-year floodplains in the current study.

Field and Pearthree, 1991: This report presents nine maps depicting the distribution and general ages of geomorphic surfaces surrounding the White Tank Mountains. The age of the surface estimates the timing of cessation of major deposition on these surfaces. The mapping performed in this study will form an important basis of the approximate floodplain delineation for Site 36.

Hartman, 1977: This earlier SCS soil survey covers the lower portions of the piedmont in Township 1N. This document shows the areas with pods of older surfaces as soil units GYD, Gunsight-Rillito complex on old alluvial fans, and CV, Coolidge-Laveen association on old alluvial fans. The finer grained areas are mapped as units AL, Antho association on alluvial fans, and AM, Antho-Valencia association on long smooth valley plains. These map designations generally agree with the Camp (1986) mapping.

Hjalmarson, 1994: This document describes hydraulic geometry coefficients and exponents, as well as channel competence, for the White Tank alluvial fan in this study for various frequencies of discharge. This site is referred to as Site 36 in the Hjalmarson report. It also discusses geomorphic and hydraulic characteristics influencing flood hazard potential for distributary flow areas (DFA) in general and provides detailed examples for a number of sites in Maricopa County including a DFA north of the Sec. 13

fan (Hjalmarson report Site 39). This report and Hjalmarson and Kemna (1992) indicate that the flood hazard degree of Site 36 is a 10, i.e. the most hazardous category defined in the Hjalmarson and Kemna (1992) report (see below).

Hjalmarson and Kemna, 1992: This report addresses flood hazard type and degree for the Site 36 alluvial fan in addition to numerous other distributary flow sites in southwestern Arizona. It examines geometric relationships of alluvial fans in the region and relates these to degree of flood hazard. Geometric information about Site 36 is provided. The flood hazard of the Site 36 alluvial fan is evaluated as a 10 on a scale of 10 where 1 is the least hazardous, and 10 is the most hazardous.

Waters, 1991: This reports describes an HEC-1 rainfall-runoff model that was constructed for the CH2M Hill (1992) report. Arithmetic versus logarithmic averaging of soil loss parameters was investigated. The report concludes that logarithmic averaging resulted in higher discharges as compared to arithmetic averaging.

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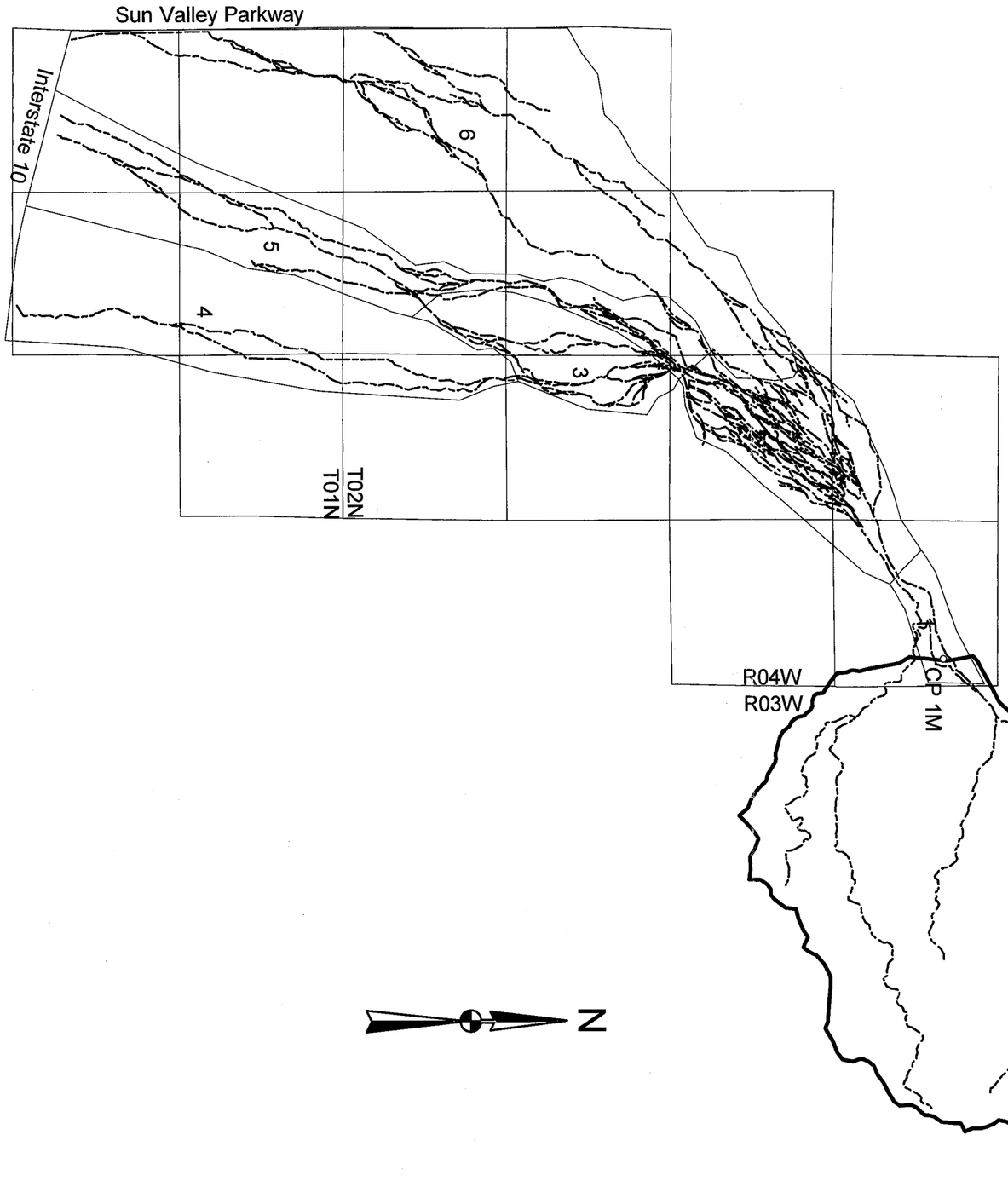
U.S. Geological Survey, 1971, White Tank Mtns SE, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (original photo date 1954, published 1957; photo revised 1971).

Waters, Stephen D., 1991, Hydrologic analysis for White Tanks Distributary Flow Area: Phoenix, Arizona, Flood Control District of Maricopa County, 29 p.



3000 0 3000 6000 9000 Feet

1:50000

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANK MTNS
SITE 36 ALLUVIAL FAN
APPROXIMATE FLOODPLAIN
DELINEATION STUDY

FCD 99-02, Assignment No. 2

LEGEND

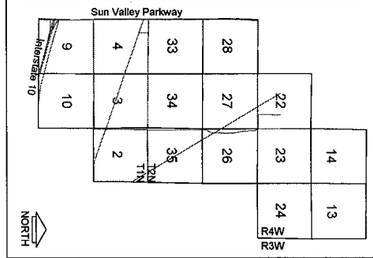
1 Study subarea number

Contributing Watershed to CP 1M (Alpha, 1994)

Washes

NOTES

INDEX MAP



JE FULLER
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	BY	DATE
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PLANS		
PLANS CHK.		

SUBMITTED BY: DATE:

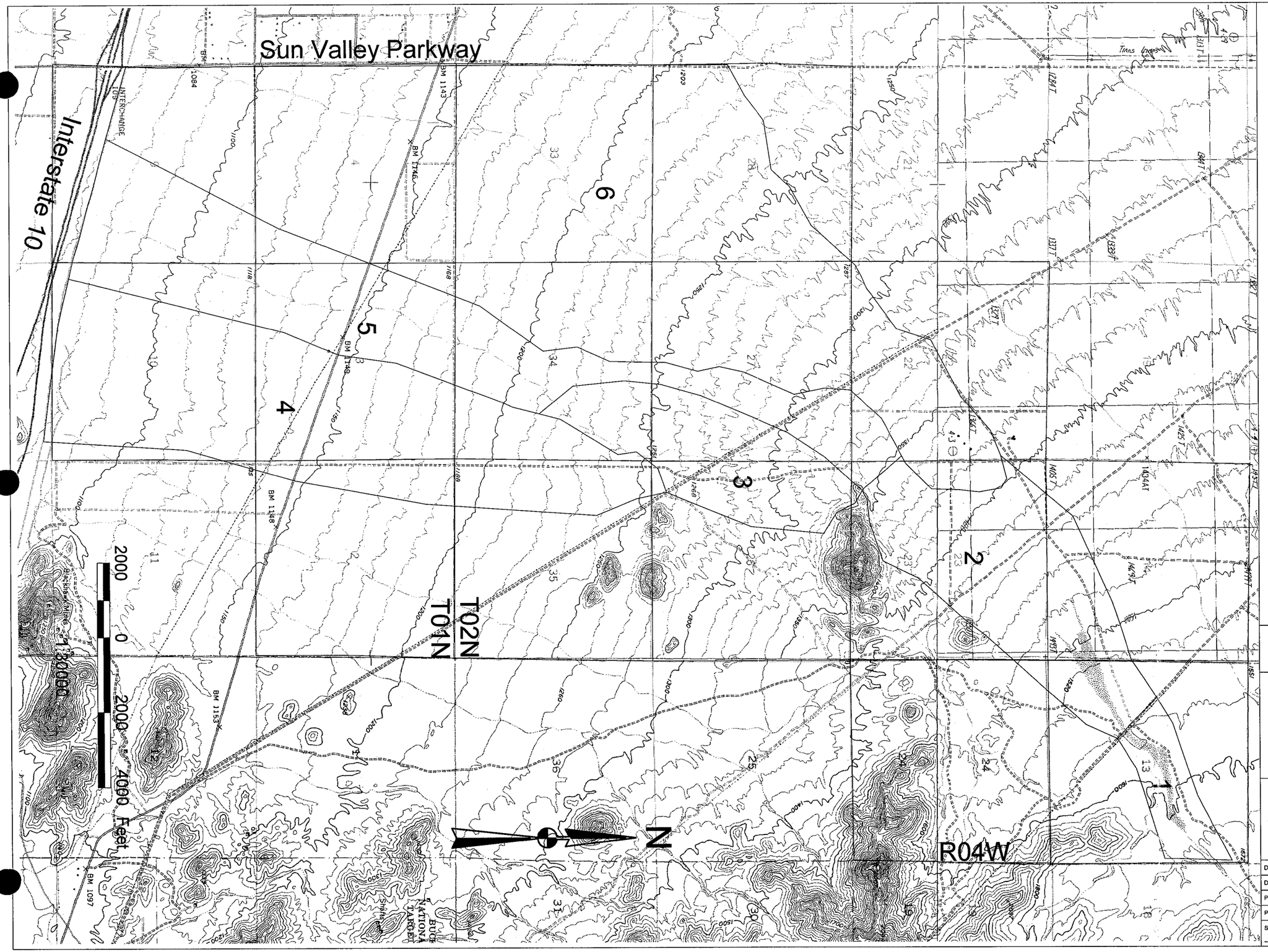
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

Figure 1



FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANK MTNS
SITE 36 ALLUVIAL FAN
APPROXIMATE FLOODPLAIN
DELINEATION STUDY

FCD 99-02, Assignment No. 2

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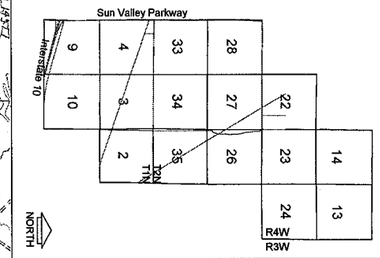
INDEX MAP



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CHIEF ENGINEER AND GENERAL MANAGER

Figure 2

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANK MTNS
SITE 36 ALLUVIAL FAN
APPROXIMATE FLOODPLAIN
DELINEATION STUDY

FCD 99-02, Assignment No. 2

LEGEND

91 NRCS Soil Map Unit

- Alluvial fans, drainageways, and floodplains
- Valley plains
- Fan terraces
- Bedrock

NOTES

1. Soils data from Camp (1986) and Hartman (1977)

INDEX MAP

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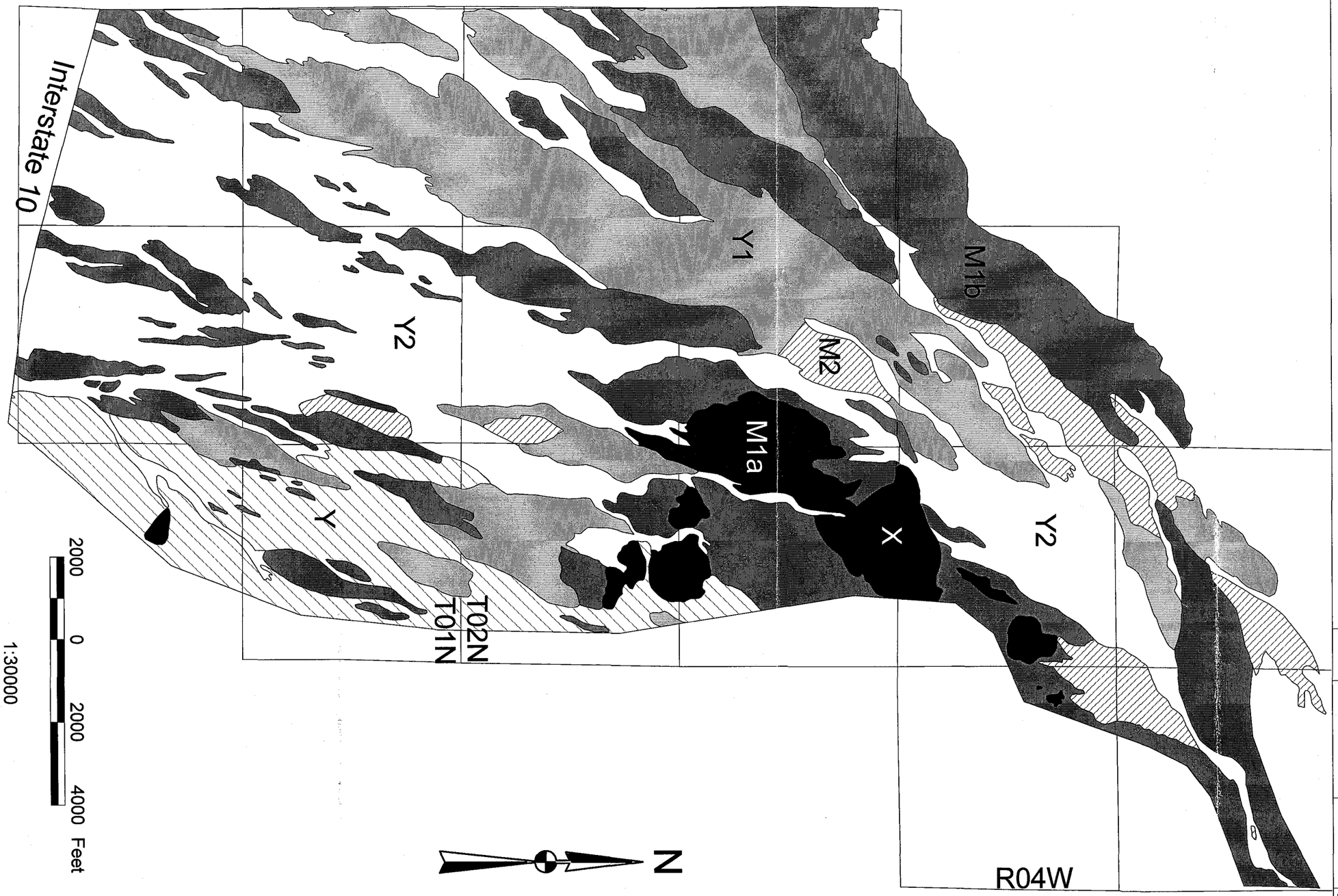
CHIEF ENGINEER AND GENERAL MANAGER

Figure 3



FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANK MTNS SITE 36 ALLUVIAL FAN APPROXIMATE FLOODPLAIN DELINEATION STUDY

FCD 99-02, Assignment No. 2

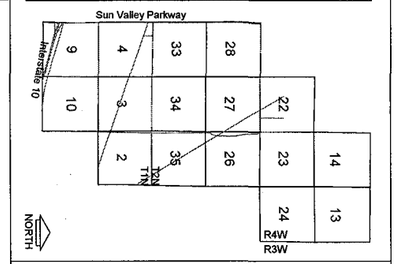
LEGEND

- Y2 - Late Holocene alluvial fans, low terraces, and active stream channels, < 3,000 years old
- Y1 - Late to early Holocene alluvial fans and terraces, 1,000 - 10,000 years old
- Y - Undifferentiated Holocene alluvial surfaces 0 - 10,000 years old
- M2 - Latest to late Pleistocene alluvial fans 10,000 to 150,000 years old
- M1a - Middle to late Pleistocene alluvial fans 150,000 to 300,000 years old
- M1b - Middle to early Pleistocene alluvial fans 300,000 to 1,000,000 years old
- X and T - Bedrock

NOTES

1. Surficial Geology data from Field and Pearthree (1991)

INDEX MAP



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PLANS CHK.		

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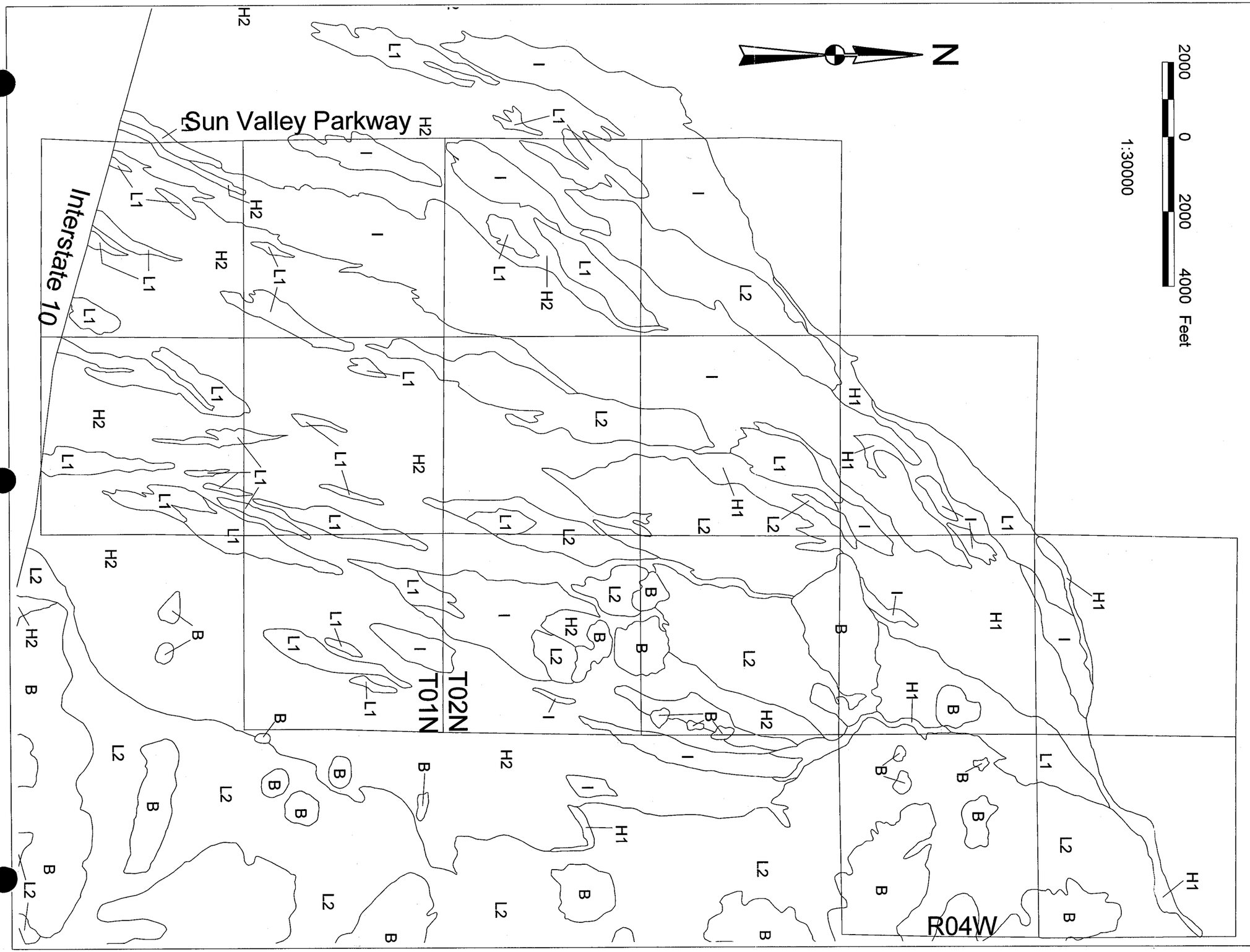
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

Figure 4



FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANK MTNS
SITE 36 ALLUVIAL FAN
APPROXIMATE FLOODPLAIN
DELINEATION STUDY

FCD 99-02, Assignment No. 2

Arizona Geological Survey
Flood Hazard Assessment

H1 - Very high flood potential. Extensive young deposits; distributary channel system very evident. Potential for localized, high velocity, relatively deep, channelized flows and sheetflooding; some potential for drastic shifts in channel position

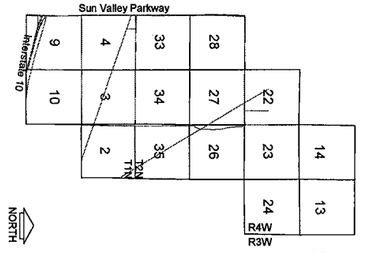
H2 - High flood potential. Extensive yound deposits, but channels small to nonexistent. Predominantly shallow sheetflooding; channelized flow very limited in extent; broad areas probably inundated in large floods.

I - Intermediate flood potential. Areas not flooded recently. Near or within distributary drainage systems, and little topographic relief separates these areas from active alluvial fans or channels. Could become flood prone with relatively modest changes in channel configurations.

L1 - Relatively low flood potential. Areas not flooded for at least 10,000 years, but near or within distributary drainage networks and typically with little topographic relief separating L1 from I, H1, or H2 surfaces.

L2 - Very low flood potential. Areas not flooded for at least 10,000 years or much longer, spatially or topographically separate from distributary drainage networks.

INDEX MAP



1. Digitized from Field and Pearthree (1992)

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DESIGN		
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SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

Figure 5

A.2 Referenced documents

APPENDIX B: GENERAL DOCUMENTATION AND CORRESPONDENCE

B.1 Special Problem Reports

B.2 Contact (telephone) Reports

Phone conversations of substance have been noted in memorandums contained in Appendix B.4. No other contact reports are recorded here.

B.3 Meeting Minutes or Reports

B.4 General Correspondence

JE Fuller/ Hydrology & Geomorphology, Inc.

Jonathan Fuller, P.E., P.H.	**Pat Deschamps, P.E., L.S.**	**6101 S. Rural Rd., Suite 110**
Brian Iserman, P.E.	**Michael Henze, M.A.**	**Tempe, Arizona 85283**
John Wallace, P.E.	**Brooks Dillard, B.A.**	**480-752-2124 (voice)**
Ted Lehman, P.E.	**Zack Washburn, M.S.**	**480-839-2193 (fax)**
W. Scott Ogden, P.E.	**Mike Kellogg, M.S.**	**www.jefuller.com**

September 11, 2001

Mr. Tim Murphy, P.E.
Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009

Re: review of TDN for White Tank Alluvial Fan, Site 36 by H.W. Hjalmarson, dated 2/14/01

Dear Mr. Murphy,

We have reviewed Mr. Hjalmarson's review comments. We appreciate the effort and thought he put into his review, and note that his comments indicate no technical concerns with the conclusions of the report. Therefore, we agree with your initial assessment that none of his comments materially change the outcome of the floodplain map produced by our study. However, we will address his comments individually below for your records. Also, most of his comments can be accommodated with relatively minor changes to the TDN, and will result in an improved product for FEMA submittal. Our responses and proposed actions are listed below. They are presented in the order they appear in his e-mail to Mr. Tram.

GENERAL:

1. The TDN is organized according to a modified version of State Standard 1-97. Joe Tram, Ed Raleigh, and I discussed how to address the delivery of an alluvial fan study. The conclusion was to adhere as much as possible to SS 1-97. The geomorphology section was added to Section 6 by dividing the existing SS1-97 Section 6 for Erosion and Sedimentation into two parts 6A and 6B. This may provide for a little confusion to the reader, but this was a decision jointly made at the time by the District and JEF. If the confusion experienced by Mr. Hjalmarson is evaluated by the District to be too great, we suggest the District explore alternate submittal formats for future alluvial fan studies. Perhaps a formally revised or additional state standard would be in order. If the organization of Section 6B is good as expressed by Mr. Hjalmarson, perhaps it could serve as a basis for such a new or revised standard.
2. We believe the report adequately addresses the site conditions as reflected in the various data sources used in the flood hazard assessment and described in the TDN.
3. We disagree with this comment.
4. Discussions characterized by Mr. Hjalmarson as generalizations and too Manual-like were included to facilitate (hopefully) easier comprehension and convincingness to the reader of the validity of our assessment. Undoubtedly, different investigators would have produced different reports. We believe our report presents adequate information to justify the flood hazard assessment.

5. Thank you.
6. The inclusion of reference to Site 36 in the NRC report was overlooked. It should be included for completeness. We will find a place to include this reference in the TDN.
7. We believe that the area Mr. Hjalmarson refers to is an inset active area within the larger alluvial fan landform. Whether this is a separate landform or part of the overall landform does not change the evaluation that the area is active as expressed by observed historical channel changes and the AZGS geomorphic mapping. As such the Stage 3 map is not affected. The general treatment of 'sub-landforms' may be an area for improvement in the PFHAM. The 3 stage method was applied and followed in its proscribed order. Mr. Hjalmarson's suggestions to the contrary are not accurate. Perhaps his difficulties with the SS1-97 organization led him to this conclusion.
8. Again, the comments would not result in a change to the flood hazard map.

DETAILED COMMENTS:

Title: The suggested title is not a bad one. We would be open to his suggested change or something similar. However, FCD would need to agree.

The use of "approximate" is perhaps not to Mr. Hjalmarson's liking, but conforms to the FEMA definitions of no BFE and as described in the characterization of the geomorphic method in the FEMA *Guidelines.* While we understand his discomfort with the terminology, we felt it would (will) facilitate successful approval by FEMA.

Again, this is a TDN per SS1-97 as modified by agreement with Mr. Tram and Mr. Raleigh.

Organization: see above.

Page 1-1: Perhaps the climate discussion is not needed, but it appears pretty standard in most TDNs for floodplain studies. We believe it should stay.

Section 1.1: Perhaps the confusion is semantic. It seems to us that "applying the FCDMC Manual method to Site 36" is reasonably equivalent to "this study incorporates the methods for assessment of piedmont flood hazards as outlined in PFHAM and FEMA Guidelines."

Sections 1.1, 1.4. 1.4.3, 6B, 6B.1, 6B.2, 6B.2: Repeated references are included only for clarity and to give credit to the authors and sources.

Section 1.4: The geomorphic method was applied below the hydrographic apex and riverine approximate methods complimented by geomorphic interpretations were applied upstream. This is clear in other portions of the report. Additional comments will be added to Sections 1.4 and 1.4.2 and possibly somewhere in Section 5.1 and 6B.6 for clarity.

We believe that work by others is clearly referenced. Section 1.4.3 lists the AZGS and SCS mapping. Full copies of the AZGS reports are included. Full copies of the SCS surveys and USGS reports could be included, but they contain significant additional information not pertinent to this report. Only pertinent portions were copied to facilitate FEMA review. Copy

reproduction quality is always a concern. We believe the copies adequately show the pertinent information needed for review. The full references to all materials are also included in the TDN so that the interested reader could obtain complete documents for themselves.

Section 1.4.1: We will add a reference to Section 4 to provide supporting data. Also, we will provide some more explicit discussion in Section 4 of its validity to this study. While it is true that the total area downstream of the hydrographic apex is large, the area contributing to any particular channel downstream is much smaller. Again, we do not believe that the flood hazard delineation is affected.

Figure 1.2 and 4.1: The green area on Figure 4.1 is the contributing area which is shown in Fig. 1.2 as the blue outline. The reason for the difference is that not all portions of the alluvial fan landform contribute runoff to the modern drainage system. It was felt appropriate to show only the contributing drainage area in the section on hydrology. The USGS maps are indeed metric, but FEMA and the District typically use English units. Therefore, the scale reflects the likely reviewer's normal system of units. Moreover, the large scale maps in the back of the report provide much better detail for anyone interested in the topography of the area. A statement as to the contour interval and units will be added to both Figures.

Section 1.4.2: Again, the organization is per SS1-97.

Section 1.4.3: The dual meaning of floodplain as a landform and a regulatory area remains fraught with potential misunderstanding. In this section floodplain is used in the context of the genre of study. We will change the phase here to "flood hazard assessment" for clarity.

SECTION 3: Again, the organization of the TDN reflects the requirements of SS1-97. Our understanding of what SS1-97 wants in Section 3 relates specifically to the topographic mapping which is described in Section 3. Mr. Hjalmarson's suggestion to include the other mapping for studies including geomorphic methods is a good one. Perhaps this should be included in a revised TDN standard. As for the current study, we do not believe any changes are required.

SECTION 4: Again, this comment reflects the SS1-97 format.

SECTION 5: 1) Again, this comment reflects the SS1-97 format. 2) We disagree that this section is unclear.

SECTION 6A: The reason we computed the sediment yield was to get a feel for the potential sediment volume. As for RUSLE vs. MUSLE, according to K.G. Renard's *Predicting Soil Erosion By Water: A Guide To Conservation Planning With The Revised Universal Soil Loss Equation (RUSLE)*(1997), "sediment yield should not be confused with erosion; the terms are not interchangeable." Also, "USLE and RUSLE do not estimate sediment yield." The Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975) was specifically "modified" to compute sediment yield (as opposed to soil loss).

SECTION 6B: Again, SS1-97 modified per agreement with Mr. Raleigh and Mr. Tram.

1st par.: It has been my experience that users of TDN's frequently do not read the entire document. Reiteration was included to help the impatient reader that turned just to Section 6B where the bulk of the pertinent portions of the flood hazard assessment for this study is described. It also allows Section 6B to (almost) stand alone from the remaining portions of the TDN.

Page 6b-1, par. 4, 3rd sentence: Both documents do describe a 3 stage process, one exclusively for fans, the second for piedmonts with a strong emphasis on fans. We will rewrite this to clarify.

There is no confusion about the Guidelines and the PFHAM. We are also aware of the chronological order of their publication. Mr. Hjalmarson needs to recognize that this document has to be approved by FEMA. We worked together with Mr. Tram to craft a presentation that would satisfy FCDMC needs and concerns and maximize the likelihood of expeditious FEMA approval. Therefore, the FEMA Guidelines and PFHAM are frequently referred to together. This is intended to demonstrate that both documents were considered and referred to during the flood hazard assessment and compilation of the TDN. A brief discussion of the relationship of the two documents will be added for clarification.

Sections 6B.1, 6B.3, and 1 par of 6B.4: These sections provide valuable background for the most readers of this report that are not as familiar with the PFHAM or the Guidelines as Mr. Hjalmarson. We strongly believe they belong in this document. Perhaps after the District and FEMA have reviewed dozens of similar studies such background material could be excluded.

6B.4.1, 1st par.: Actually, sediments could be aeolian or some other origin as opposed to alluvial. Perhaps in the context of this report it may be obvious, but we do not feel it materially detracts from the report or its conclusions.

FROM SECTION 6B.3...: Thank you.

6B.4, 2nd par.: This seems like a reversal of Mr. Hjalmarson's comments on our Tiger Wash report where we separated relict fans from alluvial fans. Here we lumped them a bit more given his earlier review comments. Either way, the active and inactive areas are delineated later and the relict portions of the alluvial fan are identified as inactive. The flood hazard assessment is not affected. Also, Section 6B.4 is Stage 1, not Stage 2. Discussion of active and inactive surfaces would be premature at this juncture in the report.

6B4.1.1 & Page 6B-4, last sentence of large par. near bottom: We do not totally disagree that some of this discussion relates to Stage 2. However, it is difficult to separate the presentation of the various data sources like the SCS soils data as they inform on all 3 stages. This will continue to be a challenge to authors of similar studies. Again, slightly misplaced or not, the delineations and conclusions of the report and the flood hazard assessment are not affected.

Section 6B.4.1.2: The surficial geology referenced here is from Field & Pearthree, not Bull. If they changed unit names from something Bull did previously, we are not familiar with their rationale. Regardless, the hazard assessment is not affected.

Page 6B-8, 4th par.: We believe the paragraph provides useful background information.

Section 6B.4.2, 1st par.: We believe the idea is conveyed adequately to the reader as currently written.

Section 6B.4.3: We selected the location of the topographic apex based on examination of the planimetric shape, the longitudinal profile, and discussions with geologists at ASU who have worked in the area. As Mr. Hjalmarson notes, regardless of the location selected, the flood hazard assessment is not affected.

Section 6B.5: This comment is inconsistent with Mr. Hjalmarson's comment for 6B.4.1.1 above. Again, the flood hazard assessment is not affected.

Section 6B.5.1: This section is labeled "introduction." As such, the concepts behind the evidence for active vs. inactive surfaces are presented for education of the reader.

Section 6B.5.2: Examination of aerial photos is explicitly discussed in this section already.

Page 6B-17, 3rd par., 2nd sentence: The conditions on Site 36 are described in the last two paragraphs in of this page.

Page 6B-18, 1st par. and Table 6B-3: We agree that the entire progression of photos is important. Most important is that something that looks relatively benign in a single photo can experience significant changes during a single event. Just because the 1951 event appears to be the only large significant channel change inducing event in the 50 year photographic record, does not mean it happens more or less frequently than once in 50 years. This is the same problem with all infrequent flood related phenomena in arid regions. Section 6B.5 presents evidence for the delineation of active and inactive areas. The single large channel change producing event in 50 years shows well what the limit and nature of a future large event is likely to be on Site 36.

A stereoscope was used for qualitative examination of channel changes as well as the computer. We agree that "there was a sudden change in 1951 followed by gradual filling." No quantitative measurements of vertical change were made. Again, we do not believe the resultant flood hazard delineation is affected.

Page 6B-18, last par.: Our copy looks fine. However, we can reprint copies for the District and FEMA copies if necessary.

Section 6B.6: We don't necessarily disagree. If the District would like to change the designation in this area, we could reprint the maps. We should discuss before deciding how to proceed.

Page 6B-24, last par., 2nd sentence: 1) Yes. 2) Yes. 3) Yes, it could. We believe the geologic history reflected in the surficial geology and the flood hazard zones delineated accommodate runoff generated downstream of the apex.

Page 6B-24, last par., 3nd sentence: The extra explanation may not be needed, but neither does it detract. We recommend no changes to this paragraph.

Page 6B-25, 1st par.: The 3,600 cfs is not arbitrarily picked. It is the Q100 at the hydrographic apex. Moreover, the delineations do heavily incorporate the geology and soils data. The hydrologic and hydraulic approach included was felt to provide some more conventional evidence for the non-geomorphologist reviewers. Also, it helped to provide confidence in the adequacy of the floodways. There is always a hydraulic component to geomorphic processes. Consideration of traditional methods is warranted.

Page 6B-27: Thank you. A discussion of field inspection is not required in this section.l

Thank you again for providing us with the comments from someone as thoughtful and experienced in this location and subject as Mr. Hjalmarson. Overall the incorporation of many of his comments as addressed above will result in a higher quality TDN. However, as we do not believe any of his comments, except possibly section 6B.6 which we need to discuss with you, change the delineation of the flood hazards shown on the Stage 3 map. However, Mr. Hjalmarson's concerns about the organization of the TDN warrant consideration for revision of the format of future submittals.

If you have any questions regarding our responses, please do not hesitate to call.

Sincerely,
JE Fuller / Hydrology & Geomorphology, Inc.

Ted Lehman, P.E.

FCD 99-01 Assignment No. 6, task 1

Review comments (colleague review) by Winn Hjalmarson, PE:

GENERAL:

1.Organization is confusing until section 6B which is great.

2.Report would be better if the basis of interpretations was given more frequently. What were the site conditions that formed the basis of the conclusions?

3. Report incorrectly relates to the Manual and to the FEMA method. This is discussed later.

4. Report should relate to a specific site (site 36) but generalizations are made throughout that make it read more like a manual. This over generalization is at the expense of interpretation of site characteristics mentioned in comment 2 above.

5.Parts of this report are excellent.

6. This site was one of several studied by the NRC committee and it is listed on p. 149 of the NRC report. This fact and its significance is ignored in the report. This report is the application of the Manual to a site that has a known active fan. It is an application of the Manual method and not a manual.

7. The small active area in section 4 poses an interesting situation because "active" applies to a portion of an alluvial fan typically located just below the apex. This small active area is fan like and I would need to see it before I could call it a fan. I believe section 4 is at or below the toe of the site 36 fan. Hjalmarson and Kemna had their toe near the 1250 contour but the toe appears to be a little below that location. The fan shape for site 36 clearly is lost near contour 1150 and there may be little distributary flow below—only sheet flow and flow in small channels that are kind of widely spaced. This location agrees with the "valley plain' designation for soil AM in the NRCS soil survey. I need a good aerial photo to examine the lower part of site 36.

The definition of the fan boundary should have been accomplished and reviewed before stage 2 was started. After the active and inactive areas are defined and reviewed, stage 3 can be started. This checking/review is an advantage of the three-stage method because each stage in independent of the following stage.

8. I have no doubt that the area below about 1150 ft is subject to sheetflow and a single flood hazard zone could be used. However, the conveyance corridor should be as shown. I feel the lower part of site 36 is an alluvial plain.

DETAILED COMMENTS:

Title: Misleading because it implies the site is a riverine site. Do active alluvial fans have flood plains? Also, later in the report you refer to it as site 36. How about a title something like "Assessment of flood hazards for White Tank Alluvial Fan-Site 36."?

Another problem with the title is the use of "approximate". In the traditional (riverine) sense of the word it has a specific meaning that is reflected with your assessment upstream of the hydrographic apex. It should not be used to describe the "geomorphic method" that applies to alluvial fans because it relegates the method to a low level that it does not deserve.

Unclear if this is a report or a "technical data notebook". Is this big white notebook the report (See last par. of Table 1.1 of the Manual) or what? In section 1.4.3 there is reference to "the TDN" but where is it or is this it?

Organization: Confusing and does not follow the Manual by Hjalmarson. For example, isn't it logical to identify the landforms before you do hydraulics? You may not need "hydraulics" for active fans. Chapter 5 of the Piedmont User's Manual shows three examples of how to perform and report the assessment. The assessment in the Manual logically builds and progresses from type of landform (Chapter 2) to stable/unstable areas (Chapter 3) and then to the definition of the 100-year flood hazards (Chapter 4). The method to accomplish this is based largely of geomorphology, soils, surface geology, vegetation, varnish, etc. Flood characteristics are also used. The Manual emphasizes the "geomorphology" because this is how landforms are systematically examined and identified and the manner in which they are produced is estimated. This method however is not necessarily the geomorphologic method for fans given in Table 1 of the FEMA report. For example, see the last sentence of paragraph 1 on p. 13 of the Manual that refers to the geomorphic method to define the extent of the 100-yr flood. See also stage 3 of Table 1.1. Thus, it would be much more logical to follow the examples in Chapter 5 of the Manual.

A major clue about what the 3-step procedure is accomplishing is given on p. 13, par. 1 of the Manual. See "The completion of stages 1 and 2.....". Thus, these steps should be described before the hydraulics is given.

Page 1-1, last paragraph: Discussion of climate not needed. Simply refer to something published.

Section 1.1: Seems like what you are really doing is applying the FCDMC Manual method to site 36. This three-step method was developed by the NRCS and applied by FEMA in their alluvial fan guidelines.

Sections 1.1, 1.4, 1.4.3, 6B, 6B.1, 6B.1, 6B.2, Why do you need to give reference to Hjalmarson 1998 and FEMA 1999 so often? I got tired of the repetition.

Section 1.4: Needs clarification to reflect what was really done. For example, how did you use Table 1 of the FEMA guidelines? Surely you made some decision to not use the FAN program and so forth. It seems to me that the approximate method for streams was used above the apex and the geomorphic method was used for much of the area below the hydrographic apex.

Suggest it be clear what previous work was used and what new work was performed as part of this contract. In this regard, the "**technical data notebook**" is confusing. It is difficult to determine what is old published info and what is actually information from this study. I feel that reference to available (reports the FCDMC will furnish) reports that are necessary to understand what you did is all that is needed. In my opinion, copies of entire reports are better than partial copies of reports such as the NRCS soil surveys and the USGS reports. Also, some copies of maps cannot be read.

Section 1.4.1: Great section except for the assumption about losses being equal to local inflows. There is contributing area (Figure 1.2) below the apex and the fan area is rather large relative to the drainage area. Seems like some rough quantitative estimates should backup this assumption (See last par. of Table 1.1 about substantiation of assumptions.) How about referring to Section 4 of your report where there is additional information?

Figure 1.2 and 4.1: Confusing because green areas are different. Is the explanation on Fig 4.1 for the green area correct? Also, the map seems to be metric but the scale is in miles. What is the contour interval?

Section 1.4.2: Unclear if this is the hydraulics or if section 5 is the hydraulics or if appendix E is the hydraulics?

Section 1.4.3: Very confusing section. The "floodplain" problem is here. See comments about title of this report or TDN or whatever this notebook contains. What is the standard TDN format? Is it something the FCDMC uses?

Please remember that where the earth has geometry that can be considered stable, we use traditional hydraulic methods to define the 100-year flood. These methods can yield approximate or detailed results (detailed where water surface elevations are defined). Where the earth does not have stable geometry we use geomorphology. FEMA says the limitation of this approach is that it is approximate but the method is the geomorphologic method as shown in Table 1 of the FEMA guidelines. Thus, where there

SECTION 3: So much more useful information could be given here such are aerial photos used, NRCS maps, etc.

SECTION 4 HYDROLOGY: Great section but don't you think presenting this section here presupposes knowledge of the landforms that you have not yet discussed? Is this logical to you? It confuses the reader.

SECTION 5 HYDRAULIC ANALYSIS: How does the reader know the landform where you are doing the hydraulics is stable? How was the hydrographic apex determined? I'm curious how the apex was defined.
The hydraulics are very crude. Cross sections of the channel rough guesses. Seems like the flood boundaries are at the steep cemented conglomerate banks and all the recent alluvium is shown as inundated. I suppose this is the same as evaluating planimetric limits of the floodplain in there geomorphic context. Why not use plain english?

SECTION 6A EROSION AND SEDIMENT TRANSPORT: No real reason to compute sediment yield other than to get a feel for the volume. Why was the modified universal soil loss equation (MUSLE) used? Isn't RUSLE more recent and better? I use RUSLE and have the software and so forth. MUSLE tends to over-predict sediment yields for small floods and under-predict sediment yields for large floods. Information published several years ago suggests that the MUSLE method gives too little yield for large floods and too much yield for small floods. Anyhow, it is a swag and the yield in tons for Q100 appears OK to my eyeball.

SECTION 6B GEOMORPHOLOGY: See prior comments about report outline and organization.

1st par.: the reiteration of information is a clue that the report is not organized logically.

Page 6b-1, par. 4, 3rd sentence: Sentence is incorrect. The FEMA guidelines are for alluvial fans and the FCDMC Manual is for piedmonts.

There is obvious confusion about the Manual and the Guidelines. The Guidelines are rather general and are for alluvial fans. The Manual is specifically for Maricopa Co. and shows considerably more detail than the Guidelines. This should be obvious upon reading both. However, the Manual was written before the Guidelines and therefore does not reference the Guidelines.

Sections 6B.1, 6B.3 and 1 par. of 6B.4 could be condensed because this reads like the Manual-it is too general. Report should be specifically for site 36 unless you wish to write another Manual.

6B.4.1, 1st par: Is there some other material than alluvial sediments? I always thought that alluvial or alluvium was sediment and so forth.

FROM SECTION 6B.3 TO THE END THIS IS AN EXCELLENT REPORT.

6B.4, 2nd par.: Seems important to mention that the relict fan deposits that flank the entrenched channel are classed as "relict fan" and not "alluvial fan" landforms because the fan shape has been lost by erosion over geologic time—or some such comment. Also, you might say that there is also a hydrographic apex above a small active fan but most of the alluvial fan below the hydrographic apex is inactive—or some such additional and important information that summarizes the site condition.

6B4.1.1: What is important about the fact that the NRCS shows a fan terrace below the hydrographic apex? This suggests that any active alluvial fan is small because the Carrizo component is too small to be mapped separately at the scale used.

Page 6B-4, last sentence of large par. near bottom: Unclear and not needed here. A lot of this alluvial fan is fan terrace and thus is cemented and rather stable or inactive but this discussion probably belongs in stage 2.

Section 6B412: Is there a valid reason to use different symbols for the surficial geologic units than Bull did in his earlier work?

Page 6B8 4th par.: This paragraph has information that is not needed for this report and this information is confusing. It is obvious that the mountains are a sediment source. It is also obvious that the older surfaces (relic fan and inactive fans) are eroding and also are a sediment source. Also, the 1st sentence about general decreasing age is confusing partly because it is not followed by an explanation of the Y2 sediment down most of the piedmont. There is continuous young sediment along the throughflow channel(or corridor) from the mountains to the base level. These are picky comments but the average reader may be confused.

Section 6B.4.2, 1st par.: The inselbergs restrict and do not really redirect. The landform appears as a partly extended fan that bends to the left or south around Spike Hill that is bedrock.

Section 6B43: I suppose the landform below the topo apex appears like an alluvial fan but there may be some argument about this. Seems like the area above the hydro apex could be classed as a relic fan and not an alluvial fan. It comes down to a shape thing as described on p. 4, 2nd par. of the Manual. However, of importance for the flood hazard assessment, it does not matter if it is relic or an actual fan.

Section 6B5: The 1st par. is a great place to mention the some of the references to active and inactive in the prior section.

Section 6B51: Excellent for a manual but this is an assessment of a specific site. Where is the desert pavement on site 36?

Section 6B52: Excellent for a manual but would be better if the basis for some of the statements was referenced. For example, is the basis for the floodflow paths evident on aerial photos?

Page 6B-17: 3rd par., 2nd sentence: Would one big wiggle(yucky word) also indicate an incised surface? Sounds like you are writing a manual and not interpreting site 36. This is a consultant type report and not a manual but it reads like a manual. What are the conditions of site 36? You might consider refering to the manual or to a source in regard to the crenulations if you really feel it is necessary.

Page 6B-18, 1st par. and Table 6B3: Don't you think the entire series of photos is more important than photos for only1949-54? I think the entire series of photos is important because the photos show that channel movement does not occur very often but it does occur. Photos also show that the flood processes can be " masked" by long periods of little flooding.

Are you relying on manual interpretation of single or stereo pair black and white aerial photographs for the detection of channel location changes? I understand that computer pattern-recognition capabilities still have very far to go before they can approach those of human interpreters. Consequently, land use classification of aerial photos has traditionally relied on visual interpretation. However, I'm becoming outdated and do not really know about computer methods. The Manual intentionally left this issue open because of changing technology.

Is it a laborious processes to produce accurate quantification of land cover modification? Aren't there two general types of land cover change: land cover conversion and land cover modification? This distinction seems to be important because it has significant implications for aerial photo analysis. Land cover conversion entails a shift in the relative proportions of land cover classes within a given area, such as urban expansion into formerly agricultural land. County assessors use this method. It is land cover conversion that has received most notice, as it tends to be more localized and immediate in impact and therefore draws greater attention. Land cover modification involves a shift within a particular land cover class, such as channel formation on a bush covered alluvial surface. Land cover modification can be sudden or can occur gradually and over a wider area, making it more difficult to detect. Apparently there was a sudden change in August 1951 followed by gradual filling of incised channels on the active alluvial fan.

Traditional landform mapping is based mostly on manual (visual) interpretation of aerial photographs and ground observation. Ground observations serve to define composition of distinctive landforms. Aerial photos are used to define the extent of landforms. In general, 1:20,000-scale or larger black and white photos permit precise boundary definition. Color and color infrared aerial photos are also used to define the type and extent of landforms. Photo-interpretation, backed by field observations, is a recommended means for delineating surficial materials and landforms for flood hazard assessment in Maricopa County. That said, how did you determine the channels filled for the past 50 years without using stereo pairs?

The ability to interpret terrain relief variations is greatly improved with stereoscopy. Is this how the channel filling was determined as mentioned in the **2nd par. on p. 6B-18?** Oblique aerial photos also provide extra information because of the relatively low angle of the image to the ground surface, thereby enhancing subtle and large-scale features that are either not evident or are only weakly expressed on vertical aerial photos. Hjalmarson and Kemna (1991) used 35mm slides taken from a small plane.

Page 6B-18, last par.: Copies of photos in Figures 6B. 9-12 are too dark to read. Some of the above comments are the result of this readability problem. I must admit that the poor quality of the photos is irritating.

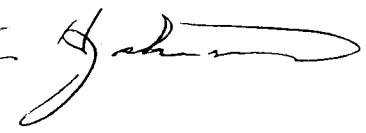
Section 6B6: Does it make sense to put an active alluvial fan area (from the stage 2) into a flood hazard zone other than AFHH as shown in **Figure 6B.14?** I don't think so. To the best of my recollection there is no shape criteria for active alluvial fan areas. There is a shape criteria for alluvial fans but not for the active area(s) within the fan. Therefore, simply because part of the active area resembles a channel and follows the throughflow channel, does not exclude it from zone AFHH and put it in another zone such as AAFF. (I've lost my table of flood hazard zones but the zones in Table 6B.4 seem OK.)

Page 6B-24, last par., 2nd sentence: Is this comment about the transport of sediment and water discharges in agreement with the last par. on page 6B-15? In regard to the lower inset fan in section 34, is it possible the sediment from the inactive fan surface is forming this little fan? A point I'm making is the inactive fan is large and a lot of flood discharge could be produced on it.

Page 6B-24, last par., 3rd sentence: These are defined in the table and it is not necessary to do so here. Picky comment.

Page 6B-25, 1st par.: The use of 3600 cfs for the difference channels (swales?) sounds arbitrary. Suggest the boundaries that are based mostly on the geomorph and geology and soils is the best way to go. Seems to be more logical to use information that means something rather that a wag at the peak Q. We need to keep the scientific method in mind at all times. The use of Q with conveyance might help with picking the boundaries but I would not talk about it very much.

Page 6B-27; I like the discussion of limitations. However, where is the field inspection mentioned?

E-mail
Winn 2/14/2001 

Subject: Site 36 review
Date: Thu, 01 Feb 2001 10:02:00 -0700
From: win hjalmarson <hjalmar@verdenet.com>
To: Joe Tram - FCDX <jjt@mail.maricopa.gov>

Joe,

I have a real elementary question. Is the report supposed to meet the requirements in the FCDMC Manual? For example, in the last para of Table 1.1 of the Manual a report is discussed.

If the Fuller report is supposed to conform to the manual then why

Public Notice

ANNOUNCEMENT OF INTENT TO PERFORM FLOODPLAIN DELINEATION STUDY OF SOUTHWESTERN WHITE TANK MOUNTAINS, PIEDMONT

The Flood Control District of Maricopa County (FCDMC) has contracted JE Fuller/Hydrology & Geomorphology, Inc. to perform an approximate floodplain delineation study for the wash on the southwest side of the White Tank Mountains which emanates from the NW¼ NW¼ of Sec. 18, T2N, R3W near the alignments of 259th Avenue and Bethany Home Road. The study will extend from this point south to the Buckeye Flood Retarding Structure #1. The study generally encompasses Sections 13, 14, 22, 23, 24, 26, 27, 28, 33, 34, and 35 of T2N, R4W, and Sections 2, 3, 4, 9 and 10 of T1N, R4W.

This study will examine and evaluate the flood hazard areas in the area. The results will then be published on the flood insurance rate map used by the Federal Emergency Management Agency (FEMA).

This announcement is intended to inform all interested persons and communities of the commencement of this study so that they may have an opportunity to bring any relevant technical information to the attention of the FCDMC/FEMA, to be considered during the course of this study. Your comments should be addressed to Mr. Joe Tram, P.E., Floodplain Delineation Branch Manager at the Flood Control District of Maricopa County, 2801 West Durango Street, Phoenix, AS 85009, (602) 506-1501.

Published in West Valley View and West Valley Business on September 15 and 22, 1999.

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Published in West Valley View and West Valley Business on September 15 and 22, 1999.

WEST VALLEY BUSINESS

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AFFIDAVIT OF PUBLICATION

State of Arizona

County of Maricopa

I, Elliott Freireich, publisher of West Valley View and West Valley Business, newspapers of general circulation in Avondale, Buckeye, Goodyear, Litchfield Park and Tolleson, Arizona, attest that the legal advertisement for

J.E. Fuller/Hydrology & Geomorphology, Inc.
Announcement of Intent

was published on September 15th, 22nd, 1999

E Freireich
Elliott Freireich

September 22nd, 1999
Date

Sworn and Subscribed to before me,

this 22nd Day of September, 1999

Elaine S. May
Notary Public

My Commission Expires

OFFICIAL SEAL
ELAINE S. MAY
Notary Public - State Of Arizona
MARICOPA COUNTY
My Comm. Expires March 31, 2003

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JEFuller / Hydrology & Geomorphology, Inc.

5235 South Kyrene, Suite 205
Tempe, AZ 85283
480-752-2124 (voice)
480-839-2193 (fax)
www.jefuller.com

October 20, 1999

TRANSMITTAL

Joe Tram, P.E.
Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009

Attached are the following materials provided by JE Fuller/ Hydrology & Geomorphology, Inc. for your use:

* 1 set of color stereo aerial photographs 1:9600 scale for Tiger Wash piedmont.

* 1 set of color stereo aerial photographs 1:9600 scale for White Tank fan, site 36 study area.

Joe:

I am sending your sets of the color stereo aerials for Tiger Wash and White Tank fan for your use and your files.

If you have any questions, please call Jon or myself.

FOR Jonathan Fuller, P.E.

10/20/99
Date

JEFuller / Hydrology & Geomorphology, Inc.

5235 South Kyrene, Suite 205
Tempe, AZ 85283
480-752-2124 (voice)
480-839-2193 (fax)
www.jefuller.com

October 20, 1999

TRANSMITTAL

Joe Tram, P.E.
Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009

Attached are the following materials provided by JE Fuller/ Hydrology & Geomorphology, Inc. for your review:

* Draft Data Collection Report for FCD 99-02, Assignment No. 2, Approximate Floodplain Delineation of White Tank fan and piedmont.

Joe:

I am sending you this Draft Data Collection Report for your review. I know you are very busy. So, please return your review comments to me at your earliest convenience.

If you have any questions, please call Jon or myself.

_____ _____

Jonathan Fuller, P.E. Date

Ted Lehman

From: Joe Tram - FCDX [jjt@mail.maricopa.gov]
Sent: Friday, October 22, 1999 5:24 PM
To: 'ted@jefuller.com'
Subject: Review of Data Collection

Looks pretty good to me....few minor problems....

Page 2 - need to insert a "be" in the last paragraph in the sentence ...This maybe the rainfall event(s)....

Page 6 - under other Pertinent Data - may want to reference the design hydrology from the NRCS which was used for the Buckeye Structures...

Page 7 - under Hartman - Gunsight Rillito comples - spelling (?)

References - NRCS - Buckeye Structures.

THANKS

FLOOD CONTROL DISTRICT
of
MARICOPA COUNTY
1959

FLOOD CONTROL DISTRICT
of
Maricopa County

2801 West Durango Street • Phoenix, Arizona 85009-6399
Telephone (602) 506-1501
Fax (602) 506-4601
TT (602) 506-5897

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January 18, 2000

JEFuller/Hydrology & Geomorphology, Inc.
5235 South Kyrene, Suite 205
Tempe, Arizona 85283

ATTN: Ted Lehman

Subject: FCD 99-02 - Assignment No. 2
Approximate Floodplain Delineation Study for White Tank Tan
Subarea 6, White Tanks Floodplain Delineation

Dear Mr. Lehman:

This is written confirmation to assess subarea 6 for Subtask 6.1, FCD 99-02, Assignment No. 2 as recommended in your *Evaluation of Subarea 6* report dated November 1999.

If you have any questions, please contact me at 602-506-4607.

Sincerely,

Joe Tram

Copy to: Ashok Patel, P.E.,
Wood, Patel & Associates, Inc.

Attachment D2-1 incorporates fee proposal from the following subconsultant on this phase:

- JE Fuller Hydrology & Geomorphology, Inc.

White Tank Wash - Alluvial Fan Study - Subarea 6 (Optional Item)

Phase 2 portion of Assignment 2 includes all work associated with Subarea 6. This work will be performed only after written authorization from your office. The lump sum fee is established for this phase at $22,589.00.

To accomplish this service, we have estimated project manhours required for this assignment. The manhours are summarized by tasks, subtasks, and staff categories in Attachment B2-2. These fees have been derived based on project manhours, subconsultant participation, and other pertinent costs as per Attachment C2-2.

Attachment D2-2 incorporates fee proposal from the following subconsultant on this phase:

- JE Fuller Hydrology & Geomorphology, Inc.

This proposal represents the entire understanding between the District and Wood/Patel in regard to the work set out herein and may only be modified in writing as agreed to by both parties.

We appreciate the opportunity to submit this proposal and look forward to working with you on this exciting project.

Sincerely,

WOOD, PATEL & ASSOCIATES, INC.

Ashok C. Patel, P.E., R.L.S.
Principal

ACP/tjd

Enclosures

Y:\WP\Proposals\99958-Fee Proposal.wpd

FLOOD CONTROL DISTRICT
of
Maricopa County

2801 West Durango Street • Phoenix, Arizona 85009-6399
Telephone (602) 506-1501
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Don Stapley
Mary Rose Garrido Wilcox

January 25, 2000

JEFuller/Hydrology & Geomorphology, Inc.
5235 South Kyrene, Suite 205
Tempe, Arizona 85283

ATTN: Ted Lehman

Subject: FCD 99-02 – Assignment No. 2
Approximate Floodplain Delineation Study for White Tank Fan
Subarea 6, White Tanks Floodplain Delineation

Dear Mr. Lehman:

In clarification of my letter of January 18, 2000, I offer the enclosed information. Assignment No. 2 was authorized not to exceed $66,825.01, which was the lump sum fee for both Phase 1 and Phase 2 of Assignment 2. Phase 2 was not to proceed without written authorization, which was my letter of January 18, 2000, confirming previous verbal notice to proceed.

Contractually, with respect to billing, one bill should be submitted for Assignment No. 2, with separate billings for each Phase of Assignment No. 2 not to exceed the lump sum fee negotiated for each Phase.

Thank you for bringing this to my attention. If you have any additional questions, please contact me at 602-506-4607.

Sincerely,

Joe Tram
Floodplain Branch Manger

WOOD/PATEL

CIVIL ENGINEERS • HYDROLOGISTS • LAND SURVEYORS

...rrel E. Wood, P.E., R.L.S.
...shok C. Patel, P.E., R.L.S.
James S. Campbell, P.E.
Gordon W. R. Wark, P.E.
Thomas R. Gettings, R.L.S.
Bruce Friedhoff, P.E.
Scott A. Nelson, R.L.S.
Richard L. Hiner, P.E.
Timothy A. Huval, P.E.
Michael J. Sexton, R.L.S.
Jack K. Moody, P.E.
Leslie J. Kland, P.E.
Curtis L. Brown, P.E.
R. Scott Rasmussen, P.E.
Paul M. Haas, P.E.
Shimin Zou, Ph.D., P.E.
Michael T. Young, P.E.
Shawn D. Gustafson, P.E.
John Bulka, P.E.
Robert J. Hedrick, P.E.

August 18, 1999

FLOOD CONTROL DISTRICT
RECEIVED
AUG 1 8 1999

	CHENG		P & PM
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	ADMIN		PWLMGT
	FINANCE		CONTRACT
	O & M		FILE
X	ENGR		

REMARKS

Mr. Joe Tram
Project Manager
Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, AZ 85009

Phone: (602) 506-1501
Fax: (602) 506-4601

Re: Approximate Zone "A"
Floodplain Delineation Studies
Contract FCD 99-02
WP #99958

Dear Mr. Tram:

Wood, Patel & Associates, Inc. (Wood/Patel) is pleased to submit this *Fee Proposal* in conjunction with the Assignments 1 and 2. These assignments will be performed for a combined fee of $249,485.82 as described below.

Assignment 1
Zone "A" Studies within Wickenburg ADMP Area

For a lump sum fee of $182,660.81, we will perform the services described in Assignment 1, Scope of Work. To accomplish these services, we have estimated project manhours required for this assignment. The manhours are summarized by tasks, subtasks, and staff categories in Attachment B1. These fees have been derived based on project manhours, subconsultant participation, and other pertinent costs as per Attachment C1.

Attachment D1 incorporates fee proposals from the following subconsultants on this Assignment:

- LTM Engineering, Inc.

Assignment 2
White Tank Wash - Alluvial Fan Study

For a lump sum fee of $66,825.01, we will perform the services described in Assignment 2, Scope of Work.

Assignment 2 will be performed in two separate phases. Phase 1 includes all work associated with Subareas 1 through 5. The lump sum fee is established for this phase at $44,236.01. To accomplish this Phase 1 service, we have estimated project manhours required for this assignment. The manhours are summarized by tasks, subtasks, and staff categories in Attachment B2-1. These fees have been derived based on project manhours, subconsultant participation, and other pertinent costs as per Attachment C2-1.

15 Year Anniversary

WOOD/PATEL

CIVIL ENGINEERS • HYDROLOGISTS • LAND SURVEYORS

arrel E. Wood, P.E., R.L.S.
Ashok C. Patel, P.E., R.L.S.
James S. Campbell, P.E.
Gordon W. R. Wark, P.E.
Thomas R. Gettings, R.L.S.
Bruce Friedhoff, P.E.
Scott A. Nelson, R.L.S.
Richard L. Hiner, P.E.
Timothy A. Huval, P.E.
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Leslie J. Kland, P.E.
Curtis L. Brown, P.E.
R. Scott Rasmussen, P.E.
Paul M. Haas, P.E.
Shimin Zou, Ph.D., P.E.
Michael T. Young, P.E.
Shawn D. Gustafson, P.E.
John Bulka, P.E.
Robert J. Hedrick, P.E.

August 26, 1999

Mr. Jonathan E. Fuller, P.E., P.H.
Principal
JE Fuller Hydrology & Geomorphology, Inc.
583 West Magdalena Street
Tempe, AZ 85283

Phone: *(602) 752-2124*
Fax: *(602) 839-2193*

Re: Zone A Floodplain Delineation for White Tank Wash
Contract No: FCD 99-02
Project No: WP #99958

Dear Jon:

Enclosed please find two (2) signed originals of our *"Subconsultant Agreement for Professional Services"* for the above referenced project. Please sign and return one (1) original to our office, keeping the other for your records.

If you have any questions, please feel free to call our office.

Sincerely,

WOOD, PATEL & ASSOCIATES, INC.

Tami Dale

Tami Dale
Administrative Assistant

Enclosures

15 Year Anniversary

JOB NAME: Approximate Zone "A" FPD

CONTRACT NO.: FCD 99-02

PROJECT NO.: WP #99958

SUBCONSULTANT AGREEMENT
FOR PROFESSIONAL SERVICES

THIS AGREEMENT, entered into this Aug 25th 1999, by and between **WOOD, PATEL & ASSOCIATES, INC.**, an Arizona Corporation located at 1550 East Missouri, Suite 203, Phoenix, Arizona 85014, hereinafter referred to as **"WOOD/PATEL"** and JE Fuller Hydrology and Geomorphology, Inc., a Geomorphology firm located at [redacted], Tempe, AZ 85283 hereinafter referred to as **"SUBCONSULTANT"**. 5235 South Kyrene Road Suite 205

WHEREAS, **WOOD/PATEL** has entered into a contract with the Flood Control District of Maricopa County (FCDMC) (OWNER) for the purposes of furnishing certain professional services in connection with Zone A Floodplain Delineation for White Tank Wash (PROJECT); and

WHEREAS, **WOOD/PATEL** desires **SUBCONSULTANT** to perform certain technical services in connection with the PROJECT and **SUBCONSULTANT** desires to perform such services.

NOW, THEREFORE, in consideration of the mutual covenants hereinafter contained, the parties hereto agree as follows:

I. SCOPE OF WORK

SUBCONSULTANT shall perform, in a proper manner satisfactory to **WOOD/PATEL**, the technical services as more fully described in Exhibit A - *"Scope of Work and Compensation & Payment"* which is attached hereto and incorporated herein by reference.

Additionally, this AGREEMENT is bound to the same terms of Agreement of Contract between FCDMC and **WOOD/PATEL** including any addendums to Contract FCD 99-02.

II. TIME OF PERFORMANCE

The services to be performed hereunder shall commence upon receipt by **SUBCONSULTANT** of a written *"Notice to Proceed"* from **WOOD/PATEL**.

III. COMPENSATION TERMS

For satisfactory performance of the services described above in "I. SCOPE OF WORK", **SUBCONSULTANT** will be paid per the compensation and payment terms provided for in Exhibit A - *"Scope of Work and Compensation & Payment"* which is attached hereto and incorporated herein by reference. This compensation request (invoice) will be processed in a timely manner, after receipt by **WOOD/PATEL**, and will be submitted to the OWNER. **WOOD/PATEL** shall retain ten percent (10%) of the net fee earned (as per FCDMC requirements) as shown on each **SUBCONSULTANT's** invoice until completion of the PROJECT to the satisfaction of **WOOD/PATEL** and OWNER and their acceptance of the work. **WOOD/PATEL** will include **SUBCONSULTANT's** invoice with **WOOD/PATEL's** regular billings to OWNER. **WOOD/PATEL** will make payment to the **SUBCONSULTANT** within thirty (30) days after receipt of payment from OWNER.

IT IS UNDERSTOOD AND AGREED TO BY THE **SUBCONSULTANT** THAT PAYMENT FROM OWNER TO **WOOD/PATEL** IS A CONDITION PRECEDENT FOR PAYMENT TO **SUBCONSULTANT** FROM **WOOD/PATEL.**

IV. COMPLIANCE WITH LAWS

SUBCONSULTANT shall observe and abide by all applicable laws, ordinances, and regulations of federal, state, and local governments in connection with the work performed hereunder.

V. SUBCONTRACT AND ASSIGNMENT

This AGREEMENT may not be assigned or subcontracted, in whole or part, without the prior written consent of **WOOD/PATEL.** Approval by **WOOD/PATEL** of any subcontractor shall not relieve the **SUBCONSULTANT** of any liability or responsibility for the proper performance of the work under this AGREEMENT.

VI. INSPECTIONS

All work performed by **SUBCONSULTANT** shall be subject to the quality inspection and approval by **WOOD/PATEL** at all times, but such approval shall not relieve **SUBCONSULTANT** of responsibility for the proper performance of the work. **SUBCONSULTANT** shall provide sufficient, safe, and proper facilities at all times for such inspection of the work and shall furnish all information concerning the work and grant **WOOD/PATEL's** duly authorized representatives free access at all reasonable times to **SUBCONSULTANT's** facilities where the work under this AGREEMENT is to be performed.

VII. CHANGES

WOOD/PATEL shall have the right, at any time prior to completion of the work to direct changes in this AGREEMENT, including but not limited to, changes in the Scope of Work. If the change causes an increase or decrease in the cost of, or the time required for the **SUBCONSULTANT's** performance under this AGREEMENT; the **SUBCONSULTANT** must submit to **WOOD/PATEL** within ten (10) days after receipt of the change notice of any request for adjustment. **WOOD/PATEL** will issue an addendum to this AGREEMENT for equitable adjustments.

VIII. TERMINATION FOR CONVENIENCE

a) **WOOD/PATEL** shall have the right at any time to terminate this AGREEMENT in whole, or in part, by written notice to **SUBCONSULTANT**. Upon receipt of this notice the **SUBCONSULTANT** shall immediately discontinue performance, will not place any further orders, and will promptly cancel all orders to subcontractors.

b) In the event of termination for convenience, **WOOD/PATEL** shall pay the **SUBCONSULTANT** for all work performed and accepted by **WOOD/PATEL** prior to termination, plus the profit due for the work performed. However, in no event shall **WOOD/PATEL** be obligated to pay more than the AGREEMENT value less any previously paid funds.

IX. DEFAULT

a) Should the **SUBCONSULTANT** breach any provisions of this AGREEMENT, **WOOD/PATEL** shall have the rights and remedies provided by law or under these terms and conditions.

b) **WOOD/PATEL** shall have the right at any time to terminate this AGREEMENT in whole, or in part, if the **SUBCONSULTANT** fails to perform any of its obligations or if the **SUBCONSULTANT** fails to give **WOOD/PATEL** assurance of adequate performance within ten (10) working days after written request by **WOOD/PATEL** for such assurances.

c) In the event of a breach of this AGREEMENT **WOOD/PATEL** may:
   1) declare the subconsultant to be in default;
   2) cancel this AGREEMENT in whole or in part;
   3) withhold payment of any further funds which may be due the **SUBCONSULTANT** until the default is corrected; and/or
   4) pursue any and all other remedies afforded by law.

X. INDEMNIFICATION AND INSURANCE

a) **SUBCONSULTANT** shall indemnify and hold harmless **WOOD/PATEL** and its officers, agents, and employees from and against all claims, demands, suits, loss, damage, injury, and liability including any and all costs and expenses, including attorney fees, incurred in connection therewith, resulting from or arising out of the **SUBCONSULTANT's** negligent acts, errors, or omissions in the performance of the services under this AGREEMENT.

WOOD/PATEL shall indemnify and hold harmless **SUBCONSULTANT**, its officers, agents, employees, and assigns from and against any and all liability, claims, suits, demands, loss, damage, judgments, costs , expenses, and fees arising out of or related to the PROJECT or this agreement caused in whole or part by any error, omission, or negligent act of **WOOD/PATEL** or **WOOD/PATEL's** agents, employees, or consultants.

b) Unless otherwise required in this AGREEMENT, the **SUBCONSULTANT** shall, during the performance of the work, maintain the following insurance in the types and amounts, and with insurers satisfactory to **WOOD/PATEL.**

Workers Compensation	Statutory requirements at the locations of work and in accordance with **SUBCONSULTANT's** established program for employees.
Employer's Liability	One Hundred Thousand Dollars ($100,000)
General Bodily Injury	One Million Dollars ($1,000,000) each occurrence
General Property Damage	One Million Dollars ($1,000,000) each occurrence
Automobile Bodily Injury	One Million Dollars ($1,000,000) per injury and $1,000,000 each occurrence
Automobile Property Damage	One Million Dollars ($1,000,000) each occurrence
Professional Liability	One Million Dollars ($1,000,000)

Prior to commencing performance of the work, the **SUBCONSULTANT** shall furnish **WOOD/PATEL** with a Certificate of Insurance as evidence of the required insurance and such Certificate shall provide for ten (10) days written notice to **WOOD/PATEL** prior to cancellation thereof.

WOOD/PATEL shall be named as an additional insured on coverages furnished under General Bodily Injury; General Property Damage; Automobile Bodily Injury; and Automobile Property Damage.

XI. INDEPENDENT CONTRACTOR

The **SUBCONSULTANT** is an independent contractor and shall not be regarded as an employee or agent of **WOOD/PATEL**.

XII. CONFIDENTIALITY

No publicity releases (including news releases and advertising) relating to this AGREEMENT or the work hereunder shall be issued by the **SUBCONSULTANT** without the prior written approval of **WOOD/PATEL**.

XIII. EXAMINATION OF RECORDS

The **SUBCONSULTANT** agrees that **WOOD/PATEL** will have access to and the right to examine any books, documents, papers, and records of any and all the transactions relating to this AGREEMENT.

XIV. RETENTION OF RECORDS

The **SUBCONSULTANT** shall keep and maintain all books, papers, records, accounting records, files, accounts, reports, cost proposals (with backup data), and all other material relating to the PROJECT, and shall make all such materials available at any reasonable time during the term of work on the PROJECT and for five (5) years from the date of final payment to the **SUBCONSULTANT** for auditing, inspection, and copying upon **WOOD/PATEL's** or the OWNER's request and delivered to **WOOD/PATEL**. The **SUBCONSULTANT** shall insert in each of its subcontracts the above requirement and also a clause requiring its subconsultants to include the above requirement in any lower-tier subcontracts or purchase orders.

XV. OWNERSHIP OF DOCUMENTS

Tracings, plans, specifications, and maps prepared or obtained by the **SUBCONSULTANT** under the terms of this AGREEMENT shall be delivered to and become the property of the OWNER.

Basic survey notes and sketches, charts, computations, and other data prepared or obtained under this contract shall be retained by **SUBCONSULTANT** for no less than five (5) years and shall be made available, upon request, to **WOOD/PATEL** or the OWNER without restriction or limitation on their use. Basic survey notes shall, if deemed desirable by the OWNER, become and remain the property of the OWNER.

XVI. PARTIAL INVALIDITY

If any term, covenant, condition, or provision of this AGREEMENT is found by a court of competent jurisdiction to be invalid, void, or unenforceable, the remainder of the provisions hereof shall remain in full force and effect, and shall in no way be affected, impaired, or invalidated thereby.

XVII. HEADINGS

Headings in this AGREEMENT are for convenience only and are not intended to be used in interpreting or construing the terms, covenants, and conditions of this AGREEMENT.

XVIII. GOVERNING LAWS

The validity or construction of this AGREEMENT, as well as the rights and duties of the parties hereinunder, shall be governed by the laws of the State of Arizona.

XIX. CIVIL RIGHTS

The **SUBCONSULTANT** is required to comply with Executive Order 75-5, *"Non-Discrimination in Employment by Government Contractors and Subcontractors"*, and City of Phoenix Ordinances G-1372 and G-1901, which are hereby included in their entirety by reference and considered a part of this AGREEMENT.

The **SUBCONSULTANT** is required to comply with Title VI of the Civil Rights Act of 1964, as amended. Accordingly, Title 49, Code of Federal Regulations, Part 21 through Appendix H and Title 23, CFR 710.405(b) are made applicable by reference and are hereinafter considered a part of this AGREEMENT.

The **SUBCONSULTANT** is required to comply with the provisions of Executive Order 11246, entitled *"Equal Employment Opportunity"*, as amended by Executive Order 11374, and as supplemented in Department of Labor Regulations (41 CFR Part 60). Said provisions are made applicable by reference and are hereinafter considered a part of this AGREEMENT.

XX. EMPLOYMENT OFFER

Neither party to this agreement shall hire nor make an offer of employment to an employee of the other party, without prior written consent of the other party, during this agreement and for one (1) year following completion of this agreement.

XXI. SUPPLEMENTS TO AGREEMENT

The following exhibits, supplements or addenda form an integral part of this AGREEMENT:

1) Exhibit A *"Scope of Work and Compensation & Payment"*.

XXII. ENTIRE AGREEMENT

This AGREEMENT constitutes the whole agreement between the parties with respect to the subject matter contained herein and there are no terms other than those contained herein. No modification or amendment of this AGREEMENT shall be valid unless in writing and signed by the parties hereto.

WOOD, PATEL & ASSOCIATES, INC.

Notice to Proceed Authorized 9/23/99

NAME

President

TITLE

SUBCONSULTANT

NAME

President

TITLE

Y:\WP\CONTRACT\GENCONTR-99958-JE Fuller.wpd

JOB NAME: Approx. Zone "A" FPD
CONTRACT NO: FCD 99-02
PROJECT NO: WP #99958

SUBCONSULTANT AGREEMENT FOR PROFESSIONAL SERVICES

EXHIBIT "A"

Scope of Work and Compensation and Payment

Scope of Work

Attached

Cost Proposal Summary

Attached

Compensation & Payment Terms

This Agreement is based on a lump sum fee. The Subconsultant is to be paid in accordance with the tasks/project completed during the billing period and accounting for appropriate retainage. A progress report indicating the status of the project (by each major task) including the work completed during the previous billing period, will be required with each invoice.

NTP 8/23/99

ASSIGNMENT 2

White Tank Wash - Alluvial Fan Study

Scope of Work

SCOPE OF WORK
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
ZONE A FLOODPLAIN DELINEATION
ON-CALL CONTRACT
FCD 99-02

Assignment Number 2

GENERAL

The study area for Assignment Number 2 is the White Tanks Wash Alluvial Fan piedmont surface upstream and downstream of its' hydraulic apex to the toe of the Buckeye FRS #1 dam. The limits of the project are shown on attached Exhibit A. The study area is generally located in sections 13, 14, 22, 23, 24, 26, 27, 28, 33, 34, and 35 of T2N, R4W and sections 2, 3, 4, 9, and 10 of T1N, R4W. Approximate floodplain delineations will be performed for subareas 1-5 shown in Exhibit A. An evaluation of the impact of the alluvial fan in subarea 2 on subarea 6 will also be performed. A recommendation regarding whether subarea 6 should be delineated with consideration for the alluvial fan impacts upstream will be made. No delineations will be performed west of Sun Valley Parkway. For this study the consultant will use USGS topography as the base mapping. For those areas upstream of the hydraulic apex and downstream of the alluvial fan that exhibit stable channel characteristics, normal riverine Zone A, approximate method delineations will be conducted. For the alluvial fan piedmont, the three-stage method identified in the draft Piedmont Assessment Manual for Maricopa County will be used to develop the floodplain delineation. This method progressively focuses on defining flood hazard zones by first recognizing and characterizing the kind and extent of piedmont landforms, and showing these landforms on a map. The second stage is the definition of the nature of the piedmont landform, identifying unstable and stable components of the piedmont, and showing these areas subject to various flood hazards on a map. The third stage identifies and applies methods for defining and characterizing areas affected by the 100-year flood, and showing these areas on a map.

All work must meet Arizona Department of Water Resources (ADWR) and Federal Emergency Management Agency (FEMA) requirements for approximate method **Zone A** floodplain delineations. Prior to the finalization of this contract, FEMA and the District must review and accept the results of this study, and all items called for in this Scope of Work must be delivered to the District.

The consultant and the District will discuss, coordinate and finalize the areas of study.

For this assignment the FEMA submittal package must be completed and ready for submittal to FEMA within 270 days of notice to proceed on this assignment. The 270-day time limit includes a minimum of 60 days for District review. All work under this contract, including FEMA review, must be completed within the 730 days of the notice to proceed on this contract.

TASK 1 - COORDINATION

1.1 Within fourteen days of Notice to Proceed, the consultant will submit a project schedule to the District's Project Manager showing coordination meetings and completion dates for each task identified in the scope of work. The consultant will update this project schedule when appropriate.

1.2 The consultant will participate in regular coordination meetings (at least every 4 weeks) with the District's Project Manager, and in milestone coordination meetings in the development of the maps. The consultant is responsible for the minutes of any meetings. Whenever possible, coordination and milestone meetings will be combined. The consultant will participate in a maximum of eight coordination and other project meetings.

1.3 The consultant will submit an estimate of the monthly billing within 14 days of Notice to Proceed. Thereafter, this estimate will be updated and submitted to the District's project manager at least 10 days before the end of each quarter.

1.4 The consultant will submit monthly progress reports at least 5 days before submittal of monthly invoices. The report shall be brief and should be no longer than two typed pages. At a minimum, the monthly report shall contain the following:

a. A description of the work accomplished by task during the reporting month.

b. Percent (%) completed for the month and percent (%) cumulative completed for each task.

c. A brief description of the work to be accomplished in the upcoming month.

d. A description of any problems encountered.

1.5 The consultant is responsible for placing the legal advertising at the beginning of the study, notifying the public of the study. The ad will be run in a widely circulated local newspaper twice, with approximately one week between runs. The ad must also be run twice in a local newspaper that serves the area being studied. After the newspapers run the ad, the consultant will supply the District with the original affidavit of publication from each newspaper for each day that the ad ran.

1.6 The District will notify all property owners and obtain any necessary Rights of Entry for the study area.

1.7 The consultant will meet with officials from the District and the communities within the study areas impacted by the new floodplain delineations.

1.8 The District may plan and conduct one public meeting in conjunction with this study or notify property owners by letter. The meeting will be to inform the public about the study, and obtain public comment on the study results, and shall take place prior to the submittal of the final report to FEMA. The consultant will be responsible for the preparation of the graphic displays for these meetings. At least one representative from the consultant will

attend each of the meetings. The consultant will respond to the public's comments and make revisions to the study as necessary.

1.9 Consultant/District Performance Evaluations will be performed. An informal evaluation will be performed at the completion of the study. A formal evaluation will be performed at the completion of the project upon receipt of all deliverables.

TASK 2 - DATA COLLECTION

2.1 The consultant will collect and review pertinent data from the District and other outside sources. The CH2M HILL and Arizona Geological Survey reports will be the baseline from which other data will be collected. The District will provide the Consultant with copies of the latest digital aerial photography and contact prints of the study area, as well as copies of any other aerial photographs and topography of the study area. The District will also provide copies of the USGS topographic quadrangle maps in digital format, if readily available from the District.

2.2 A written report summarizing the data collected will be submitted to the District for information purposes. A preliminary draft of this report is due within 90 days of Notice to Proceed.

TASK 3- TOPOGRAPHIC MAPPING

3.1 The consultant will use USGS 7.5-minute topographic maps as the base mapping for displaying the results of this study. For each exhibit developed the District's Project Manager will determine the scale, and sheet size to use. The District will provide additional topographic mapping to the consultant for the study site if available. The District will also provide the USGS DEM and DRGs to the consultant for use in the study.

TASK 4 - FIELD SURVEY

4.1 Where additional monuments are needed, survey monuments identifying cross section locations, shall be placed 2" +/- above grade, and topped with a brass cap. Elevation Reference Marks will be labeled on available maps and described so that they can be readily located in the field. Surveyed cross section data required for this project may be referenced to a relative datum, and do not need to be tied to previously established elevation reference marks, except at the discretion of the Consultant.

4.2 Copies of the survey field books and office calculations, if any, must be included in the Technical Data Notebooks. If District approval is obtained, this information can be submitted separately.

TASK 5 - HYDROLOGY

5.1 The Consultant will make use of the hydrology generated for the existing Flood Insurance Study, FCD No. 90-64. The peak discharge of 3,623 cfs from concentration point 1M of the 100-year 24-hour HEC-1 model will be used as the discharge for delineation of riverine

reaches upstream and downstream of the alluvial fan. Contributions from downstream drainage area will be assumed offset by transmission losses and attenuation losses along the piedmont. No additional hydrologic analyses will be performed.

5.2 The Hydrologic Report The basis of the hydrologic data used in this study will be presented in Section 3 of the Technical Data Notebook and will be prepared in accordance with ADWR State Standards Attachment 1-97 (SSA 1-97). The report will be organized as specified by the District, following SSA 1-97 format. Specific deviations from this hydrologic scope shall not be undertaken without the specific written concurrence from the Flood Control District.

TASK 6 - FLOODPLAIN DELINEATION

6.1 The first task to be accomplished will be an evaluation of the capacity of cross section A-A'-A" shown in Exhibit A for the 100-year discharge of 3,623 cfs. A recommendation will be made from this evaluation if subarea 6 is affected by floodwaters from the alluvial fan in subarea 2. The recommendation report will be submitted to the District for its use.

6.2 The first stage of the floodplain delineation will use the procedures in the draft Piedmont Assessment Manual for Maricopa County to determine the kind and extend of the piedmont landforms. The results of this analysis will be displayed on a map. Digitial aerial photographs of the mapping area will provided by the District to cover all of the White Tank Wash distributary system north of Buckeye FRS #1. The Consultant will obtain 9"x 9" contact prints at a photo scale of ~1:9600 (1"=800') of subareas 1-5 as shown in Exhibit A and subarea 6 depending on the outcome of Task 6.1. USGS 7.5-minute topographic quadrangle maps for the study area shall be used as the base map for this task

6.3 The second stage will use the procedures in the draft Piedmont Assessment Manual for Maricopa County to identify the unstable and stable components of the piedmont. A map will be generated showing the results of this analysis, and it will also show those areas subject to various types of flood hazards.

6.4 The third stage will identify and apply methods for defining and characterizing areas affected by the 100-year flood, and the results of this analysis will be shown on a map. Those areas that are subject to active alluvial fan movement will be classified as "Zone A High Hazard." Those areas classified as stable may be assessed using normal depth calculations and approximate method Zone A areas will be identified. Delineation of floodplains by detailed methods are not part of this scope of service.

6.5 The delineation work shall meet requirements for approximate floodplain delineations as prescribed by FEMA and the Arizona Department of Water Resources.

6.5 The consultant must obtain District approval at each of the following steps:

a. Map developed under 6.1.

b. Map developed under 6.2.

c. Map developed under 6.3.

d. Final report describing the analysis and procedures used to develop maps 6.1 – 6.3.

e. Field reconnaissance report and estimation of Manning's "n" values.

f. Proposed location and alignment of the cross sections and channel centerline.

g. Methodology being used for the riverine delineation.

h. Floodplain (natural) delineation.

i. Final Hydraulics Report.

6.6 Field Reconnaissance

6.6.1 The consultant will conduct a field reconnaissance of the full study reach. This will include observation and documentation of channel and floodplain conditions, vegetation and surficial geology, soils and vegetation.

6.6.2 A draft report on the field reconnaissance will be submitted to the District for review and approval. The report will discuss floodplain conditions affecting the delineation, describe structures and obstructions, and provide color photos or photocopies of major hydraulic structures. Photo locations, structures, and important points will be displayed on reduced scale mapping developed from the USGS 7.5-minute topographic maps and included in the Final Report.

6.7 Cross Sections

6.7.1 The location and alignment of cross sections and channel centerline will be submitted for the District's review and approval before digitizing the cross section data. The Consultant must coordinate with the District on the methodology being used to generate the cross sections, such as BOSS RMS, WMS, GPS surveyed sections in the field, or cross sections from USGS or ADMS topography. In the majority of instances, the channel centerline will be the USGS line indicated on the current Flood Insurance Rate Map for the study area.

6.7.2 The cross section plots will show at a minimum the water surface elevation, cross section identification number, and "n" values. All plots are to be accompanied by a legend and should be available at all reviews.

6.8 The hydraulics of bridges and culverts identified in FCD No. 90-64 should be incorporated into assessing the floodplain around such structures, especially in areas where ponding will occur. Zone A's must be determined according to FEMA criteria, and clearly labeled on the final drawings.

6.9 The findings of the floodplain delineation study will be presented in Section 4 of the Technical Data Notebook, and will be prepared in accordance with ADWR State Standards

Attachment 1-97 (SSA 1-97). The report will be organized as specified by the District standards, following SSA 1-97 format.

6.10 The Consultant shall fill out all the forms required by FEMA for the submittal of a Floodplain Delineation Study.

6.11 The consultant will provide the delineations on work maps using the base topographic mapping supplied by the District. The preferred size of these drawings is 24" X 36". However, the sheets will usually match the sheet size of the supplied topographic mapping. The District's Project Manager must approve the sheet size being used. A cover sheet will be part of the work study drawings and shall have on it the project title, date of topographic mapping, and a location map showing geographic range covered by each specific mapping sheet. Each drawing will include the floodplain delineations, and a minimum of a north arrow, scale, section corners and quarter corners, current and proposed streets and highway names, State Plane Coordinate System, major drainage features, corporate boundaries, cross section lines, channel station center line, index map, the floodplain boundaries, and a description and elevation of each elevation reference mark (ERMs).

6.12 Approximate method Zone A's must be determined according to FEMA criteria and clearly labeled on the final drawings.

TASK 7 - HIS DATA

7.1 Digital data in either a CADD or GIS format will be prepared in conformance with the District's Hydrologic Information System Data Delivery Specifications, Revision 3.1. The following themes are the ones generally used for the data developed for Floodplain Delineation Studies. However, for this study there may not be data for every theme identified here, or the consultant might develop data for themes not listed here. Therefore, only those themes for which there are data need to be completed. If the consultant has data that don't fit one of the themes listed here, the District's Project Manager shall be contacted to determine the appropriate theme for those data.

a.	NDXPRJ (FCD Project Map Index)	b.	PRJ (Project Boundaries)
c.	CARTO (Cartographic Features)	d.	CORNERS (if any)
e.	CTRL (Miscellaneous Control Survey Points)	f.	STRCT (Structure)
g.	FPZNFCD (Floodplain FCD Zone)	h.	ELV (contour)
i.	FPCTLFCD (FCD Reference Marks)	j.	DQ (Data Quality)
k.	FPBLN (Floodplain Baseline Route System)	l.	ELV (contour)
m.	FPXFCD (Cross Section)	n.	DTM

7.2 If the hydrologic and delineation maps were not derived directly from the digital data delivered to the District, then the consultant will develop check plots and certify that they have been examined, and that the check plots represent the data and maps used in the report and /or work maps. For data submitted in a GIS format, separate check plots will be produced from either Arc-Info or Arc-CAD from the digital database(s) of each theme in 7.1. The check plots will be prepared with a minimum of annotation and will serve only to verify the information in the database

TASK 8 - DELIVERABLES

8.1 Prior to FEMA Submittal: The consultant will deliver the following items to the District before delivering the FEMA submittal package:

8.1.1 Original Affidavits of Publication of the legal advertisements. Additional copies are to be included in the Technical Data Notebook.

8.1.2 All-topographic and related data developed by the consultant for the District's Hydrologic Information System that isn't subject to change during FEMA's review should be submitted at this time.

8.1.3 If bound separately from the Technical Data Notebook, two (2) copies of the field survey notes and office calculations.

8.1.4 Red-lined FIRM panels indicating the new delineations.

8.2 FEMA Submittal: The consultant will submit the following items to the District for review by FEMA and any other appropriate governmental agency. All of the following products are considered deliverables for the FEMA submittal:

8.2.1 Two (2) complete sets of blackline topographic base maps with the floodplain delineations shown. All drawings will be signed and sealed by persons of appropriate professional registration(s). Each registrant will provide a specific statement as to what service they performed.

8.2.2 Two (2) complete copies of the Technical Data Notebook. The Technical Data Notebook will be prepared in accordance with ADWR State Standards Attachment 1-97 (SSA 1-97). The notebook will be organized as specified by the District, following SSA 1-97 format. These copies will be updated if necessary based upon FEMA's review comments. Completed FEMA forms will be included in the notebook, along with copies of any public announcements about the study results.

8.3 Final Submittal: The following products are considered deliverables for the final submittal to the District after FEMA approval is issued:

8.3.1 One (1) complete set of non-erasable topographic/orthophoto mylars of the floodplain delineations. These mylars will reflect all the revisions made to the floodplain delineations during the FEMA review process. The preferred size of

these mylars is 24" X 36", the District's Project Manager must authorize the use of any other size. All drawings will be signed and sealed by persons of appropriate professional registration(s). Each registrant will provide a specific statement as to what service they performed.

8.3.2 All remaining hydrologic and floodplain delineation data in conformance with the District's HIS Specifications.

8.3.3 Two (2) additional copies of the Technical Data Notebooks. The Technical Data Notebook will be prepared in accordance with ADWR State Standards Attachment 1-97 (SSA 1-97). The notebook will be organized as specified by the District, following SSA 1-97 format. This submittal of the Technical Data Notebook shall include any correspondence and/or meeting minutes with the reviewing agencies, and shall reflect any revisions required by those reviewing agencies.

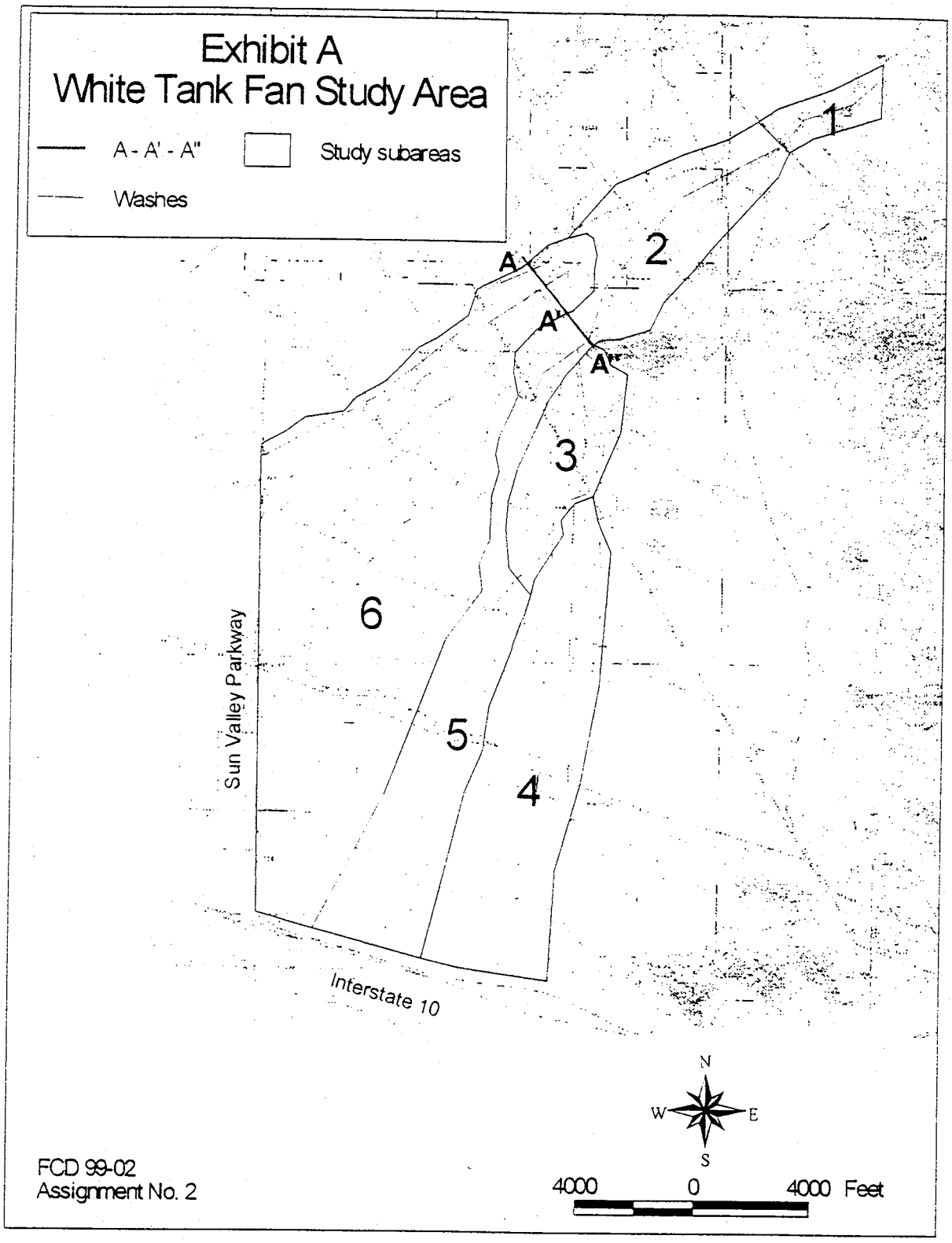


Exhibit A
White Tank Fan Study Area
A - A' - A"
Study subareas
Washes
A
A'
A"
1
2
3
4
5
6
Sun Valley Parkway
Interstate 10
N
W
E
S
4000
0
4000 Feet
FCD 99-02
Assignment No. 2

APPENDIX C: SURVEY FIELD NOTES

C.1 Survey Field Notes for aerial mapping control

No aerial mapping for topography was performed for this study. New color aerial photographs were flown, but no ground control network was surveyed. The photos facilitated the geomorphic and field investigations for the assessment of the flood hazards.

C.2 Survey Field Notes for hydrologic modeling

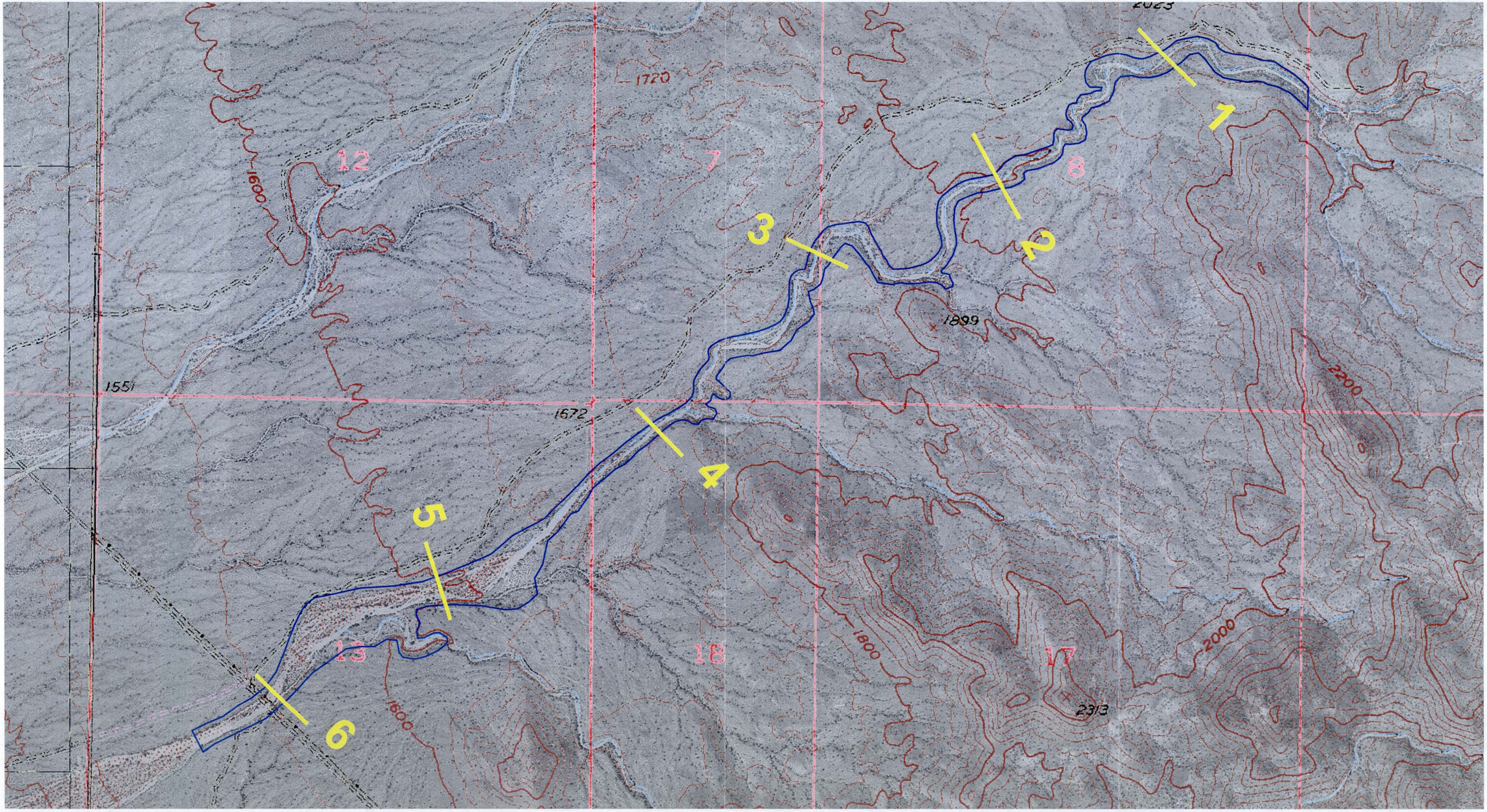
No topographic surveying for hydrologic modeling was performed for this study.

C.3 Survey Field Notes for Hydraulic Modeling

No topographic surveying for hydraulic modeling was performed for this study. Cross sections for normal depth analyses were taken from USGS 7.5 minute contour maps.

APPENDIX D: HYDROLOGIC ANALYSIS SUPPORTING DOCUMENTATION

APPENDIX E: HYDRAULICS
SUPPORTING DOCUMENTATION



WORK MAP
Riverine Reach Upstream from Hydrographic Apex
Normal Depth Cross Section Layout
and Approximate Floodplain

LEGEND

Yellow lines and numbers are Cross section location and ID.

Blue outline is approximate 100-year floodplain limit.

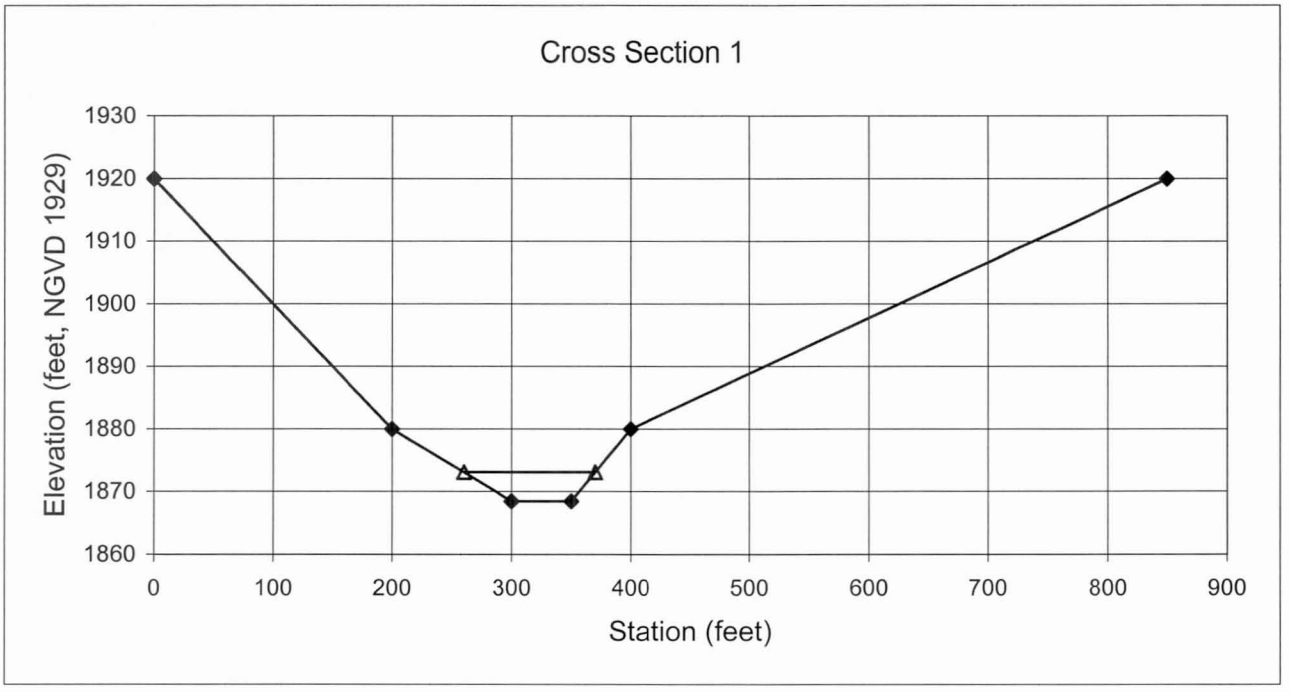
1000 0 1000 2000 Feet

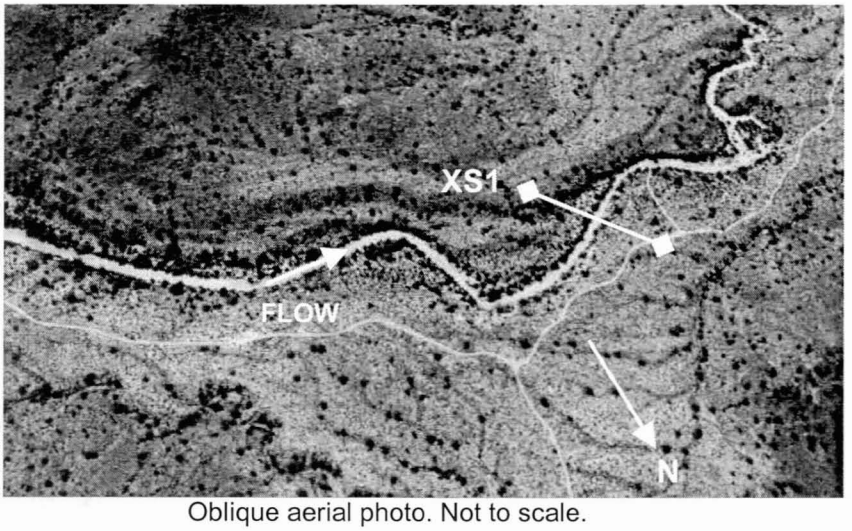
N

JE Fuller, Inc.
April 2000

CROSS SECTION 1						
Station (feet)	Elevation (feet, MSL)		Slope = (1920 - 1840) / 3300 =		0.0242	
0	1920		Manning's n value =	nb	0.03	base
200	1880			n1	0.002	irregularities
300	1868.5	Left Toe		n2	0	obstructions
350	1868.5	Right Toe		n3	0.008	vegetation
400	1880			n4	0.002	variations in XSs
850	1920			n5	1.05	meandering
				ntotal	0.044	

Normal Depth								Find Critical Depth		
Q (cfs)	A (sq. ft.)	V (ft/s)	D (ft)	WSE (ft, MSL)	Top Width (ft)	Bot.Wid (ft)	Fr	A (sq.ft.)	V (ft/s)	Fr
3600	324.9	11.2	4.2	1872.7	104.8	50	1.12	325.08	11.07	1.11
3600	346.1		4.4	1872.9	107.4	50		346.28	10.40	1.02
3600	367.9		4.6	1873.1	110	50		368	9.78	0.94





Oblique aerial photo. Not to scale.

Elevation data from USGS 7.5 minute quadrangle.
N-values estimated using Thomsen & Hjalmarson (1991).
Hydraulic calculations from XSPRO (Grant & others, ver. 1.1, May 1992).

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS1.TXT
CROSS-SECTION NUMBER 1

CHANNEL SLOPE RANGE: 0.0242 to 0.0242

VELOCITY FORMULA: User Supplied Mannings n

cross-section treated as one section

XS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.20	1	10.3	52.6	52.6	0.2	0.2	0.0242	0.044	1.8	18.16
0.40	1	21.0	55.3	55.2	0.4	0.4	0.0242	0.044	2.8	58.20
0.60	1	32.3	57.9	57.8	0.6	0.6	0.0242	0.044	3.6	115.51
0.80	1	44.2	60.6	60.4	0.7	0.7	0.0242	0.044	4.3	188.46
1.00	1	56.5	63.2	63.0	0.9	0.9	0.0242	0.044	4.9	276.23
1.20	1	69.4	65.9	65.6	1.1	1.1	0.0242	0.044	5.5	378.35
1.40	1	82.8	68.5	68.3	1.2	1.2	0.0242	0.044	6.0	494.57
1.60	1	96.7	71.1	70.9	1.4	1.4	0.0242	0.044	6.5	624.76
1.80	1	111.1	73.8	73.5	1.5	1.5	0.0242	0.044	6.9	768.88
2.00	1	126.0	76.4	76.1	1.6	1.7	0.0242	0.044	7.4	926.97
2.20	1	141.5	79.1	78.7	1.8	1.8	0.0242	0.044	7.8	1099.09
2.40	1	157.5	81.7	81.3	1.9	1.9	0.0242	0.044	8.2	1285.34
2.60	1	174.0	84.3	83.9	2.1	2.1	0.0242	0.044	8.5	1485.86
2.80	1	191.1	87.0	86.5	2.2	2.2	0.0242	0.044	8.9	1700.79
3.00	1	208.6	89.6	89.1	2.3	2.3	0.0242	0.044	9.3	1930.30
3.20	1	226.7	92.3	91.7	2.5	2.5	0.0242	0.044	9.6	2174.56
3.40	1	245.3	94.9	94.3	2.6	2.6	0.0242	0.044	9.9	2433.76
3.60	1	264.4	97.6	96.9	2.7	2.7	0.0242	0.044	10.2	2708.09
3.80	1	284.1	100.2	99.6	2.8	2.9	0.0242	0.044	10.6	2997.75
4.00	1	304.2	102.8	102.2	3.0	3.0	0.0242	0.044	10.9	3302.94
4.20	1	324.9	105.5	104.8	3.1	3.1	0.0242	0.044	11.2	3623.88
4.40	1	346.1	108.1	107.4	3.2	3.2	0.0242	0.044	11.4	3960.76
4.60	1	367.9	110.8	110.0	3.3	3.3	0.0242	0.044	11.7	4313.81
4.80	1	390.1	113.4	112.6	3.4	3.5	0.0242	0.044	12.0	4683.24
5.00	1	412.9	116.1	115.2	3.6	3.6	0.0242	0.044	12.3	5069.26

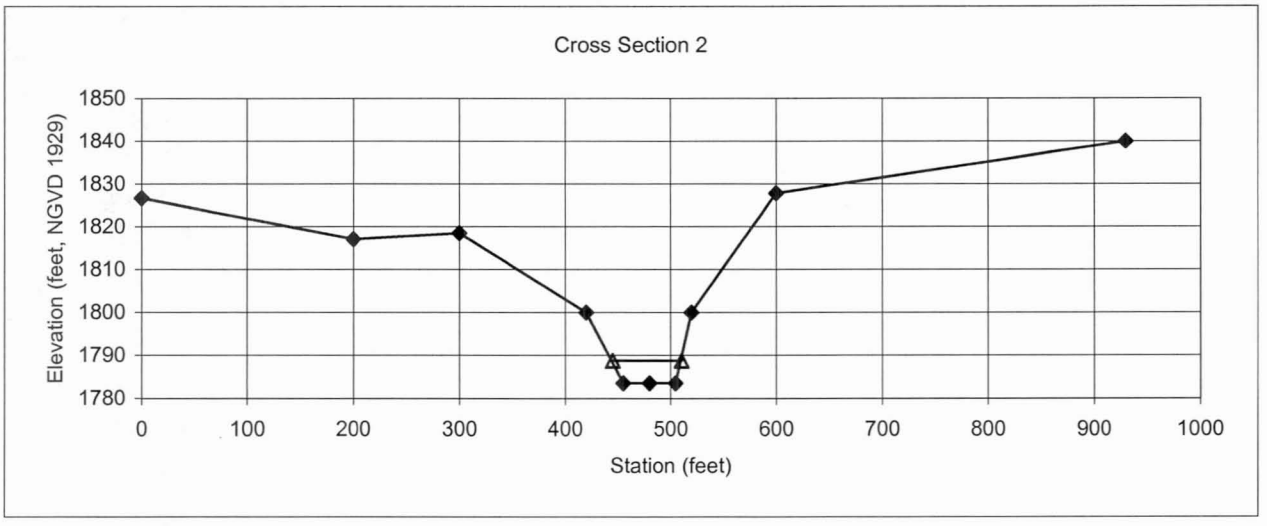
CROSS SECTION 2

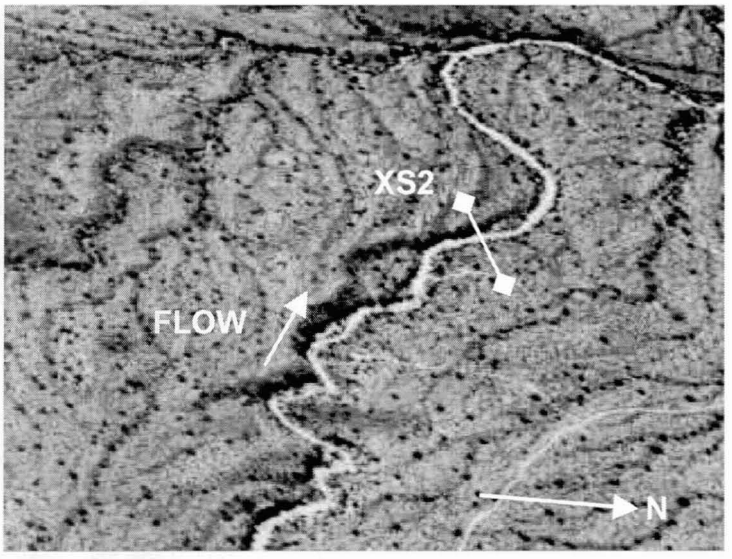
Station (feet)	Elevation (feet, MSL)	
0	1826.7	
200	1817.1	
300	1818.5	
420	1800	
455	1783.5	Left Toe
480	1783.5	
505	1783.5	Right Toe
520	1800	
600	1827.8	
930	1840	

Slope = (1840 - 1760) / 2800 = 0.0286

Manning's n value =			
nb	0.03	base
n1	0.002	irregularities
n2	0.002	obstructions
n3	0.004	vegetation
n4	0.002	variations in XSs
n5	1.05	meandering
ntotal	0.042	

Normal Depth								Find Critical Depth		
Q (cfs)	A (sq. ft.)	V (ft/s)	D (ft)	WSE (ft, MSL)	Top Width (ft)	Bot.Wid (ft)	Fr	A (sq.ft.)	V (ft/s)	Fr
3600	249.3	14.5	4.4	1787.9	63.3	50	1.29	249.3	14.44	1.28
3600	274.8		4.8	1788.3	64.5	50		274.8	13.10	1.12
3600	300.9		5.2	1788.7	65.8	50		301.1	11.96	0.99





Oblique aerial photo. Not to scale.

Elevation data from USGS 7.5 minute quadrangle.

N-values estimated using Thomsen & Hjalmarson (1991).

Hydraulic calculations from XSPRO
(Grant & others, ver. 1.1, May 1992)

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS2.TXT
CROSS-SECTION NUMBER 2

CHANNEL SLOPE RANGE: 0.0286 to 0.0286

VELOCITY FORMULA: User Supplied Mannings n

cross-section treated as one section

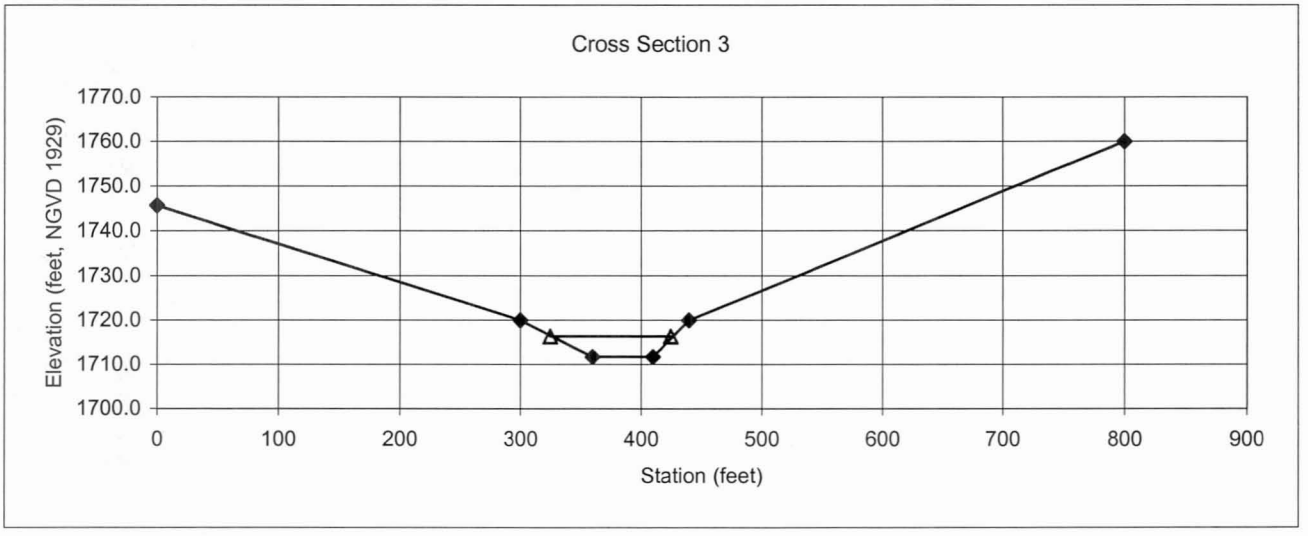
XS from 7.5' quadrangles

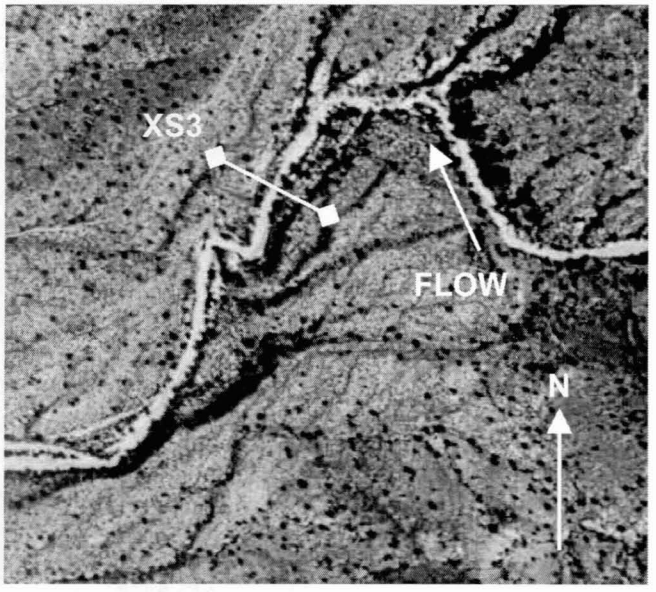
STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.20	1	10.1	50.7	50.6	0.2	0.2	0.0286	0.042	2.0	20.52
0.40	1	20.2	51.5	51.2	0.4	0.4	0.0286	0.042	3.2	65.16
0.60	1	30.5	52.2	51.8	0.6	0.6	0.0286	0.042	4.2	128.13
0.80	1	41.0	53.0	52.4	0.8	0.8	0.0286	0.042	5.1	207.06
1.00	1	51.5	53.7	53.0	1.0	1.0	0.0286	0.042	5.8	300.52
1.20	1	62.2	54.4	53.6	1.1	1.2	0.0286	0.042	6.6	407.50
1.40	1	73.0	55.2	54.2	1.3	1.3	0.0286	0.042	7.2	527.25
1.60	1	83.9	55.9	54.8	1.5	1.5	0.0286	0.042	7.9	659.19
1.80	1	94.9	56.7	55.5	1.7	1.7	0.0286	0.042	8.5	802.85
2.00	1	106.0	57.4	56.1	1.8	1.9	0.0286	0.042	9.0	957.84
2.20	1	117.3	58.1	56.7	2.0	2.1	0.0286	0.042	9.6	1123.82
2.40	1	128.7	58.9	57.3	2.2	2.2	0.0286	0.042	10.1	1300.53
2.60	1	140.2	59.6	57.9	2.4	2.4	0.0286	0.042	10.6	1487.72
2.80	1	151.8	60.3	58.5	2.5	2.6	0.0286	0.042	11.1	1685.19
3.00	1	163.6	61.1	59.1	2.7	2.8	0.0286	0.042	11.6	1892.75
3.20	1	175.5	61.8	59.7	2.8	2.9	0.0286	0.042	12.0	2110.26
3.40	1	187.5	62.6	60.3	3.0	3.1	0.0286	0.042	12.5	2337.56
3.60	1	199.6	63.3	60.9	3.2	3.3	0.0286	0.042	12.9	2574.55
3.80	1	211.8	64.0	61.5	3.3	3.4	0.0286	0.042	13.3	2821.10
4.00	1	224.2	64.8	62.1	3.5	3.6	0.0286	0.042	13.7	3077.13
4.20	1	236.7	65.5	62.7	3.6	3.8	0.0286	0.042	14.1	3342.55
4.40	1	249.3	66.3	63.3	3.8	3.9	0.0286	0.042	14.5	3617.28
4.60	1	262.0	67.0	63.9	3.9	4.1	0.0286	0.042	14.9	3901.26
4.80	1	274.8	67.7	64.5	4.1	4.3	0.0286	0.042	15.3	4194.43
5.00	1	287.8	68.5	65.1	4.2	4.4	0.0286	0.042	15.6	4496.74

CROSS SECTION 3

Station (feet)	Elevation (feet, MSL)		Slope = (1760 - 1680) / 3250 =	0.0246	
0	1745.7		Manning's n value = nb	0.03	base
300	1720.0		n1	0.002	irregularities
360	1711.7	Left Toe	n2	0.005	obstructions
410	1711.7	Right Toe	n3	0.004	vegetation
440	1720.0		n4	0.004	variations in XSs
800	1760.0		n5	1.05	meandering
			ntotal	0.047	

Normal Depth								Find Critical Depth		
Q (cfs)	A (sq. ft.)	V (ft/s)	D (ft)	WSE (ft, MSL)	Top Width (ft)	Bot.Wid (ft)	Fr	A (sq.ft.)	V (ft/s)	Fr
3600	324.9	11	4.4	1716.1	97.7	50	1.06	324.94	11.08	1.07
3600	344.6		4.6	1716.3	99.9	50		344.77	10.44	0.99





Aerial photo approximate scale = 1:8,000.

Elevation data from USGS 7.5 minute quad.
N-values estimated using
Thomsen & Hjalmarson (1991).
Hydraulic calculations from XSPRO
(Grant & others, ver. 1.1, May 1992).

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS3.TXT
CROSS-SECTION NUMBER 3

CHANNEL SLOPE RANGE: 0.0246 to 0.0246

VELOCITY FORMULA: User Supplied Mannings n

cross-section treated as one section

XS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.20	1	10.2	52.2	52.2	0.2	0.2	0.0246	0.047	1.7	17.12
0.40	1	20.9	54.4	54.3	0.4	0.4	0.0246	0.047	2.6	54.74
0.60	1	31.9	56.6	56.5	0.6	0.6	0.0246	0.047	3.4	108.44
0.80	1	43.5	58.8	58.7	0.7	0.7	0.0246	0.047	4.1	176.57
1.00	1	55.4	61.0	60.8	0.9	0.9	0.0246	0.047	4.7	258.26
1.20	1	67.8	63.3	63.0	1.1	1.1	0.0246	0.047	5.2	352.99
1.40	1	80.6	65.5	65.2	1.2	1.2	0.0246	0.047	5.7	460.42
1.60	1	93.9	67.7	67.3	1.4	1.4	0.0246	0.047	6.2	580.36
1.80	1	107.5	69.9	69.5	1.5	1.5	0.0246	0.047	6.6	712.69
2.00	1	121.7	72.1	71.7	1.7	1.7	0.0246	0.047	7.0	857.37
2.20	1	136.2	74.3	73.8	1.8	1.8	0.0246	0.047	7.4	1014.38
2.40	1	151.2	76.5	76.0	2.0	2.0	0.0246	0.047	7.8	1183.75
2.60	1	166.6	78.7	78.2	2.1	2.1	0.0246	0.047	8.2	1365.54
2.80	1	182.5	80.9	80.4	2.3	2.3	0.0246	0.047	8.5	1559.81
3.00	1	198.7	83.1	82.5	2.4	2.4	0.0246	0.047	8.9	1766.67
3.20	1	215.5	85.3	84.7	2.5	2.5	0.0246	0.047	9.2	1986.20
3.40	1	232.6	87.6	86.9	2.7	2.7	0.0246	0.047	9.5	2218.52
3.60	1	250.2	89.8	89.0	2.8	2.8	0.0246	0.047	9.8	2463.76
3.80	1	268.2	92.0	91.2	2.9	2.9	0.0246	0.047	10.1	2722.05
4.00	1	286.7	94.2	93.4	3.0	3.1	0.0246	0.047	10.4	2993.52
4.20	1	305.5	96.4	95.5	3.2	3.2	0.0246	0.047	10.7	3278.31
4.40	1	324.9	98.6	97.7	3.3	3.3	0.0246	0.047	11.0	3576.56
4.60	1	344.6	100.8	99.9	3.4	3.5	0.0246	0.047	11.3	3888.43
4.80	1	364.8	103.0	102.0	3.5	3.6	0.0246	0.047	11.6	4214.05
5.00	1	385.4	105.2	104.2	3.7	3.7	0.0246	0.047	11.8	4553.60

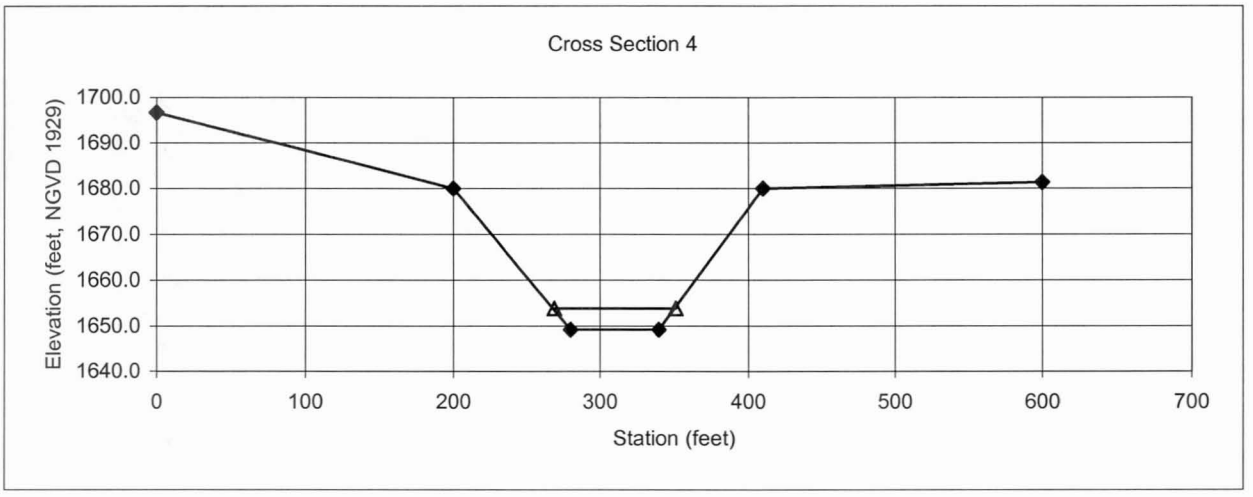
CROSS SECTION 4

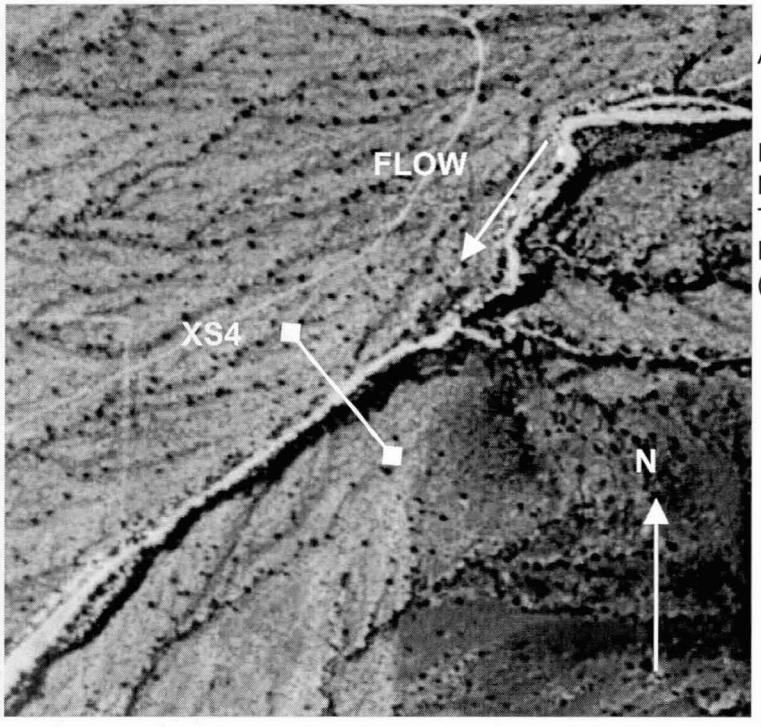
Station (feet)	Elevation (feet, MSL)	
0	1696.7	
200	1680.0	
280	1649.2	Left Toe
340	1649.2	Right Toe
410	1680.0	
600	1681.3	

Slope = (1680 - 1640) / 1820 = 0.0220

Manning's n value =			
	nb	0.03	base
	n1	0.002	irregularities
	n2	0.002	obstructions
	n3	0.005	vegetation
	n4	0.002	variations in XSs
	n5	1	meandering
	ntotal	0.041	

Normal Depth								Find Critical Depth		
Q (cfs)	A (sq. ft.)	V (ft/s)	D (ft)	WSE (ft, MSL)	Top Width (ft)	Bot.Wid (ft)	Fr	A (sq.ft.)	V (ft/s)	Fr
3600	287	12.5	4.1	1653.3	80.2	60	1.16	287.41	12.53	1.17
3600	303.1		4.3	1653.5	80.7	60		302.51	11.90	1.08
3600	319.4		4.5	1653.7	81.9	60		319.28	11.28	1.01
3600	327.7		4.6	1653.8	82.4	60		327.52	10.99	0.97





Aerial photo approximate scale = 1:8,000.

Elevation data from USGS 7.5 minute quad.
N-values estimated using
Thomsen & Hjalmarson (1991).
Hydraulic calculations from XSPRO
(Grant & others, ver. 1.1, May 1992).

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS4.TXT
CROSS-SECTION NUMBER 4

CHANNEL SLOPE RANGE: 0.0220 to 0.0220

VELOCITY FORMULA: User Supplied Mannings n

cross-section treated as one section

XS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
3.00	1	201.9	75.8	74.6	2.7	2.7	0.0220	0.041	10.4	2091.49
3.05	1	205.7	76.1	74.9	2.7	2.7	0.0220	0.041	10.5	2151.47
3.10	1	209.4	76.3	75.1	2.7	2.8	0.0220	0.041	10.6	2212.19
3.15	1	213.2	76.6	75.3	2.8	2.8	0.0220	0.041	10.7	2273.64
3.20	1	216.9	76.9	75.6	2.8	2.9	0.0220	0.041	10.8	2335.82
3.25	1	220.7	77.1	75.8	2.9	2.9	0.0220	0.041	10.9	2398.72
3.30	1	224.5	77.4	76.1	2.9	3.0	0.0220	0.041	11.0	2462.36
3.35	1	228.4	77.6	76.3	2.9	3.0	0.0220	0.041	11.1	2526.71
3.40	1	232.2	77.9	76.6	3.0	3.0	0.0220	0.041	11.2	2591.80
3.45	1	236.0	78.2	76.8	3.0	3.1	0.0220	0.041	11.3	2657.60
3.50	1	239.9	78.4	77.0	3.1	3.1	0.0220	0.041	11.4	2724.13
3.55	1	243.7	78.7	77.3	3.1	3.2	0.0220	0.041	11.5	2791.37
3.60	1	247.6	79.0	77.5	3.1	3.2	0.0220	0.041	11.5	2859.34
3.65	1	251.5	79.2	77.8	3.2	3.2	0.0220	0.041	11.6	2928.02
3.70	1	255.4	79.5	78.0	3.2	3.3	0.0220	0.041	11.7	2997.43
3.75	1	259.3	79.8	78.3	3.3	3.3	0.0220	0.041	11.8	3067.54
3.80	1	263.2	80.0	78.5	3.3	3.4	0.0220	0.041	11.9	3138.38
3.85	1	267.2	80.3	78.8	3.3	3.4	0.0220	0.041	12.0	3209.92
3.90	1	271.1	80.5	79.0	3.4	3.4	0.0220	0.041	12.1	3282.18
3.95	1	275.1	80.8	79.2	3.4	3.5	0.0220	0.041	12.2	3355.16
4.00	1	279.0	81.1	79.5	3.4	3.5	0.0220	0.041	12.3	3428.84
4.05	1	283.0	81.3	79.7	3.5	3.5	0.0220	0.041	12.4	3503.24
4.10	1	287.0	81.6	80.0	3.5	3.6	0.0220	0.041	12.5	3578.35
4.15	1	291.0	81.9	80.2	3.6	3.6	0.0220	0.041	12.6	3654.16
4.20	1	295.0	82.1	80.5	3.6	3.7	0.0220	0.041	12.6	3730.69
4.25	1	299.1	82.4	80.7	3.6	3.7	0.0220	0.041	12.7	3807.92
4.30	1	303.1	82.7	80.9	3.7	3.7	0.0220	0.041	12.8	3885.87

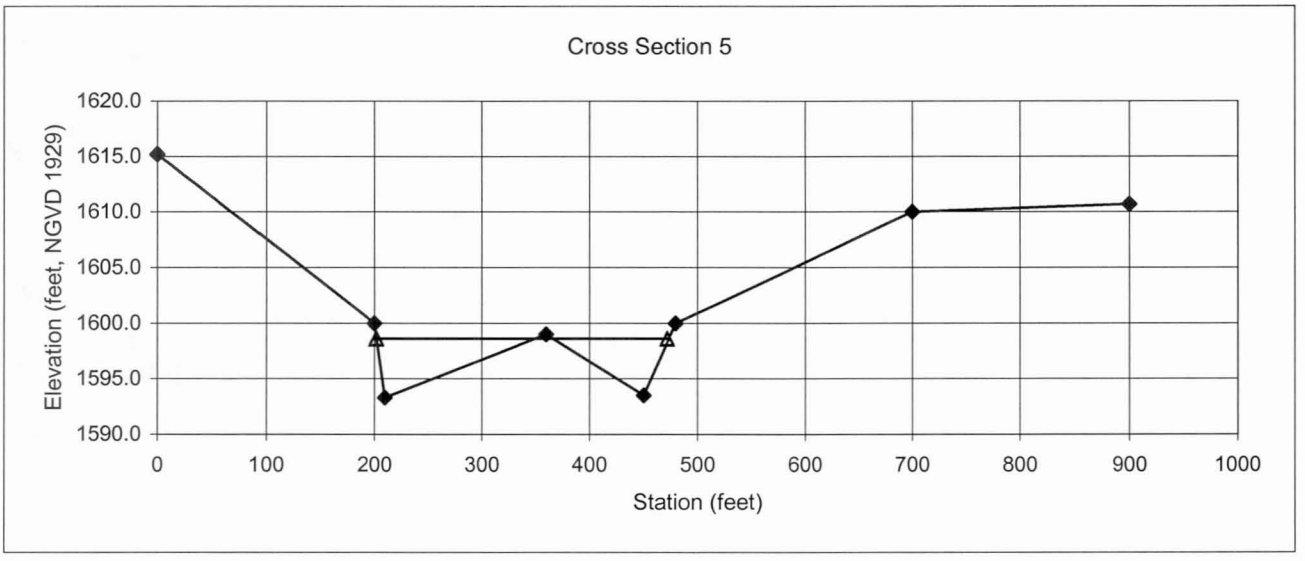
4.35	1	307.2	82.9	81.2	3.7	3.8	0.0220	0.041	12.9	3964.52
4.40	1	311.3	83.2	81.4	3.7	3.8	0.0220	0.041	13.0	4043.88
4.45	1	315.3	83.4	81.7	3.8	3.9	0.0220	0.041	13.1	4123.94
4.50	1	319.4	83.7	81.9	3.8	3.9	0.0220	0.041	13.2	4204.71
4.55	1	323.5	84.0	82.2	3.9	3.9	0.0220	0.041	13.2	4286.19
4.60	1	327.7	84.2	82.4	3.9	4.0	0.0220	0.041	13.3	4368.38
4.65	1	331.8	84.5	82.7	3.9	4.0	0.0220	0.041	13.4	4451.26
4.70	1	335.9	84.8	82.9	4.0	4.1	0.0220	0.041	13.5	4534.86
4.75	1	340.1	85.0	83.1	4.0	4.1	0.0220	0.041	13.6	4619.16
4.80	1	344.3	85.3	83.4	4.0	4.1	0.0220	0.041	13.7	4704.16
4.85	1	348.4	85.6	83.6	4.1	4.2	0.0220	0.041	13.7	4789.87
4.90	1	352.6	85.8	83.9	4.1	4.2	0.0220	0.041	13.8	4876.28
4.95	1	356.8	86.1	84.1	4.1	4.2	0.0220	0.041	13.9	4963.39
5.00	1	360.9	86.3	84.4	4.2	4.3	0.0220	0.041	14.0	5047.77

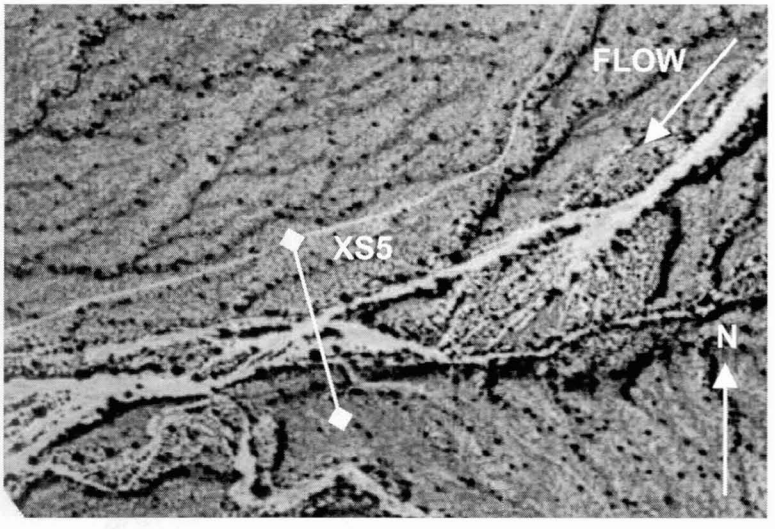
CROSS SECTION 5

Station (feet)	Elevation (feet, MSL)		Slope = (1640 - 1560) / 4200 =		0.0190	
0	1615.2		Manning's n value =	nb	0.03	base
200	1600.0			n1	0.005	irregularities
210	1593.3	Left Toe		n2	0.005	obstructions
360	1599.0			n3	0.02	vegetation
450	1593.5	Right Toe		n4	0.01	variations in XSs
480	1600.0			n5	1	meandering
700	1610.0	Road		ntotal	0.07	
900	1610.7					

Normal Depth

Q (cfs)	A (sq. ft.)	V (ft/s)	D (ft)	WSE (ft, MSL)	Top Width (ft)	Bot.Wid (ft)	Fr	
3600	663.5	5.5	5.3	1598.6	254.4	240	0.60	Subcritical = OK





Aerial photo approximate scale = 1:8,000.

Elevation data from USGS 7.5 minute quad.
N-values estimated using
Thomsen & Hjalmarson (1991).
Hydraulic calculations from XSPRO
(Grant & others, ver. 1.1, May 1992).

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS5.TXT
CROSS-SECTION NUMBER 5

CHANNEL SLOPE RANGE: 0.0190 to 0.0190

VELOCITY FORMULA: User Supplied Mannings n

cross-section treated as one section

XS from 7.5' quadrangles

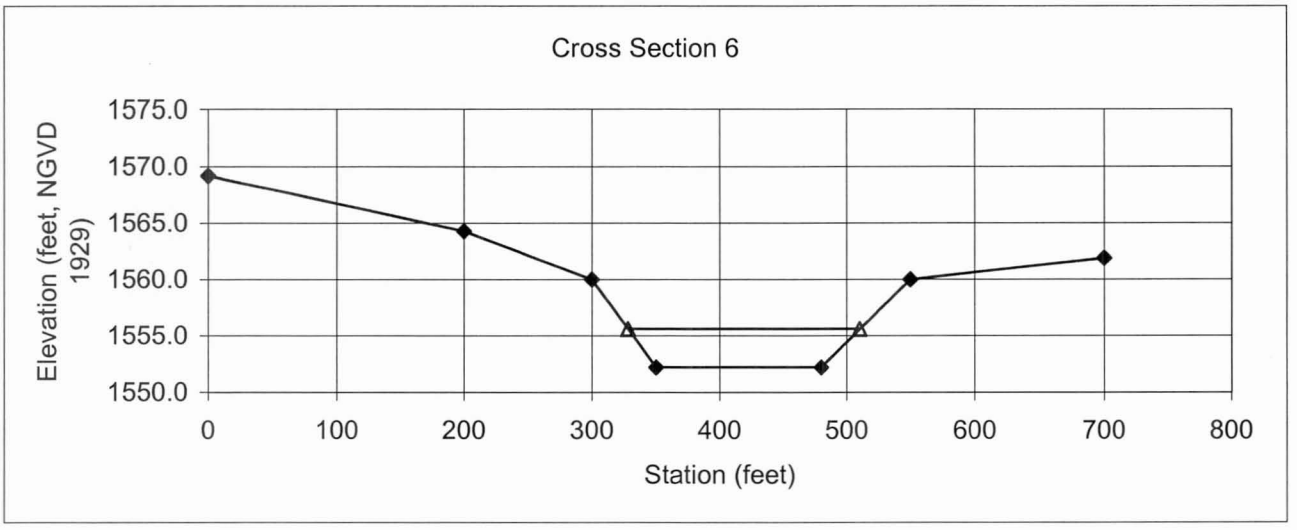
STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
5.00	1	589.3	242.0	239.7	2.4	2.5	0.0190	0.070	5.3	3129.30
5.05	1	601.4	244.5	242.2	2.5	2.5	0.0190	0.070	5.3	3214.98
5.10	1	613.5	246.9	244.6	2.5	2.5	0.0190	0.070	5.4	3302.10
5.15	1	625.8	249.4	247.1	2.5	2.5	0.0190	0.070	5.4	3390.68
5.20	1	638.3	251.9	249.5	2.5	2.6	0.0190	0.070	5.5	3480.74
5.25	1	650.8	254.3	252.0	2.6	2.6	0.0190	0.070	5.5	3572.27
5.30	1	663.5	256.8	254.4	2.6	2.6	0.0190	0.070	5.5	3665.30
5.35	1	676.3	259.3	256.8	2.6	2.6	0.0190	0.070	5.6	3759.82
5.40	1	689.2	261.7	259.3	2.6	2.7	0.0190	0.070	5.6	3855.86
5.45	1	702.2	264.2	261.7	2.7	2.7	0.0190	0.070	5.6	3953.41
5.50	1	715.4	266.7	264.2	2.7	2.7	0.0190	0.070	5.7	4052.50
5.55	1	728.7	269.1	266.6	2.7	2.7	0.0190	0.070	5.7	4153.12
5.60	1	742.1	271.6	269.0	2.7	2.8	0.0190	0.070	5.7	4255.29
5.65	1	755.6	274.1	271.5	2.8	2.8	0.0190	0.070	5.8	4359.01
5.70	1	769.3	276.5	273.9	2.8	2.8	0.0190	0.070	5.8	4464.64
5.75	1	783.0	276.8	274.2	2.8	2.9	0.0190	0.070	5.9	4594.49
5.80	1	796.7	277.1	274.5	2.9	2.9	0.0190	0.070	5.9	4725.85
5.85	1	810.4	277.5	274.8	2.9	2.9	0.0190	0.070	6.0	4858.72
5.90	1	824.2	277.8	275.1	3.0	3.0	0.0190	0.070	6.1	4993.09
5.95	1	838.0	278.1	275.4	3.0	3.0	0.0190	0.070	6.1	5128.95
6.00	1	851.5	278.4	275.7	3.1	3.1	0.0190	0.070	6.2	5263.61

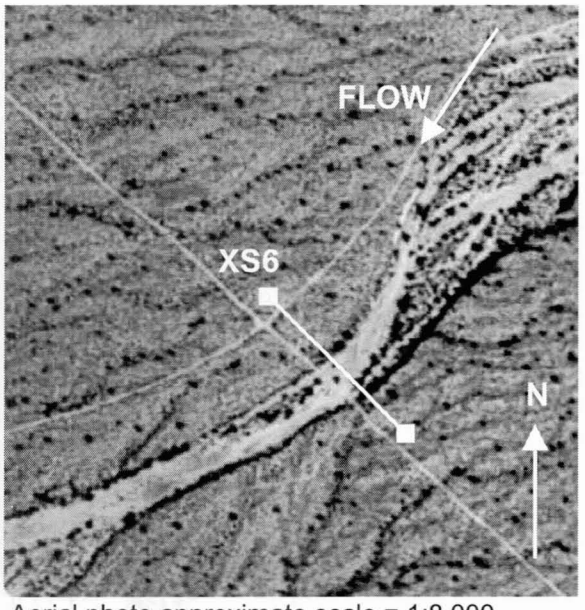
CROSS SECTION 6

Station (feet)	Elevation (feet, MSL)		Slope = (1560 - 1520) / 2500 =		0.0160	
0	1569.2		Manning's n value =	nb	0.03	base
200	1564.3			n1	0.005	irregularities
300	1560.0			n2	0.005	obstructions
350	1552.2	Left Toe		n3	0.01	vegetation
480	1552.2	Right Toe		n4	0.005	variations in XSs
550	1560.0			n5	1	meandering
700	1561.9			ntotal	0.055	

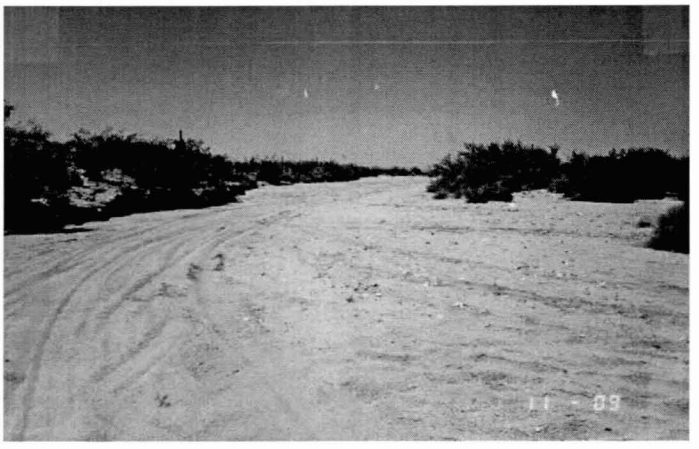
Normal Depth

Q (cfs)	A (sq. ft.)	V (ft/s)	D (ft)	WSE (ft, MSL)	Top Width (ft)	Bot.Wid (ft)	Fr	
3600	530.9	7	3.4	1555.6	182.3	130	0.72	Subcritical = OK





Aerial photo approximate scale = 1:8,000.



View downstream near XS 6.

Elevation data from USGS 7.5 minute quad.
N-values estimated using
Thomsen & Hjalmarson (1991).
Hydraulic calculations from XSPRO
(Grant & others, ver. 1.1, May 1992).

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS6.TXT
CROSS-SECTION NUMBER 6

CHANNEL SLOPE RANGE: 0.0160 to 0.0160

VELOCITY FORMULA: User Supplied Mannings n

cross-section treated as one section

XS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
3.00	1	459.2	176.6	176.2	2.6	2.6	0.0160	0.055	6.5	2976.36
3.10	1	476.9	178.1	177.7	2.7	2.7	0.0160	0.055	6.6	3151.43
3.20	1	494.8	179.7	179.2	2.8	2.8	0.0160	0.055	6.7	3331.05
3.30	1	512.8	181.2	180.8	2.8	2.8	0.0160	0.055	6.9	3515.21
3.40	1	530.9	182.8	182.3	2.9	2.9	0.0160	0.055	7.0	3703.90
3.50	1	549.2	184.3	183.8	3.0	3.0	0.0160	0.055	7.1	3897.14
3.60	1	567.7	185.9	185.4	3.1	3.1	0.0160	0.055	7.2	4094.91
3.70	1	586.3	187.4	186.9	3.1	3.1	0.0160	0.055	7.3	4297.21
3.80	1	605.0	189.0	188.5	3.2	3.2	0.0160	0.055	7.4	4504.06
3.90	1	624.0	190.5	190.0	3.3	3.3	0.0160	0.055	7.6	4715.44
4.00	1	643.0	192.1	191.5	3.3	3.4	0.0160	0.055	7.7	4931.36
4.10	1	662.3	193.6	193.1	3.4	3.4	0.0160	0.055	7.8	5151.84
4.20	1	681.6	195.2	194.6	3.5	3.5	0.0160	0.055	7.9	5376.86
4.30	1	701.2	196.7	196.1	3.6	3.6	0.0160	0.055	8.0	5606.43
4.40	1	720.9	198.3	197.7	3.6	3.6	0.0160	0.055	8.1	5840.57
4.50	1	740.7	199.8	199.2	3.7	3.7	0.0160	0.055	8.2	6079.28
4.60	1	760.7	201.4	200.8	3.8	3.8	0.0160	0.055	8.3	6322.56
4.70	1	780.8	202.9	202.3	3.8	3.9	0.0160	0.055	8.4	6570.42
4.80	1	801.1	204.5	203.8	3.9	3.9	0.0160	0.055	8.5	6822.87
4.90	1	821.6	206.0	205.4	4.0	4.0	0.0160	0.055	8.6	7079.92
5.00	1	842.2	207.6	206.9	4.1	4.1	0.0160	0.055	8.7	7341.58

Sta - Elev. Data

Riverine Reach U/s of Hydrographic Apex

	Sta	Elev	
XS ②	0	1826.7	
	200	1817.1	
	300	1818.5	
	420	1800.0	
	480	1783.5	] 50' wide from photo (aerial DOQ)
	520	1800.0	
	600	1827.8	
	930	1840.0	

$S = (80)/2800 = 0.0286$
[1840 - 1760]

XS ①	0	1920.0	
	200	1880.0	
	300	1868.5	L. Toe
	350	1868.5	R. Toe
	400	1880.0	
	850	1920.0	

$= 1920 - 1840$

$S = 80/3300 = 0.02424$

XS ③	0	1745.7	
	300	1720.0	
	360	1711.7	LT
	410	1711.7	RT
	440	1720.0	
	800	1760.0	

$S = (1760 - 1680)/3250 = 0.02462$

XS ④	0	1696.7	
	200	1680.0	
	280	1649.2	LT
	340	1649.2	RT
	410	1680.0	
	600	1681.3	

$S = [1680 - 1640]/1820 = 0.0220$

XS ⑤	0	1615.2	
	200	1600.0	~~LT~~
	480	1600.0	~~RT~~
	700	1610.0	Road
	900	1610.7	
	210	1593.3	LT
	360	1599.0	
	450	1593.5	RT

$S = [1640 - 1560]/4200 = 0.0190$

XS (E)

Sta	Elev	
0	1569.2	
200	1564.3	
300	1560.0	@ 1552.2 LT
350 → 480	1552.2	RT
550	1560.0	
700	1561.9	

$S = [1560 - 1520] / 2500 = 0.01($

Assuming D = 1.0'

Q	n	1.486	S	S^1/2	W
(cfs)			(ft/ft)		(feet)
3600	0.07	1.486	0.03	0.173205	979
3600	0.06	1.486	0.03	0.173205	839
3600	0.05	1.486	0.03	0.173205	699
3600	0.045	1.486	0.03	0.173205	629
3600	0.04	1.486	0.03	0.173205	559
3600	0.035	1.486	0.03	0.173205	490
3600	0.07	1.486	0.025	0.158114	1073
3600	0.06	1.486	0.025	0.158114	919
3600	0.05	1.486	0.025	0.158114	766
3600	0.045	1.486	0.025	0.158114	689
3600	0.04	1.486	0.025	0.158114	613
3600	0.035	1.486	0.025	0.158114	536
3600	0.07	1.486	0.02	0.141421	1199
3600	0.06	1.486	0.02	0.141421	1028
3600	0.05	1.486	0.02	0.141421	857
3600	0.045	1.486	0.02	0.141421	771
3600	0.04	1.486	0.02	0.141421	685
3600	0.035	1.486	0.02	0.141421	600
3600	0.03	1.486	0.02	0.141421	514
3600	0.07	1.486	0.015	0.122474	1385
3600	0.06	1.486	0.015	0.122474	1187
3600	0.05	1.486	0.015	0.122474	989
3600	0.045	1.486	0.015	0.122474	890
3600	0.04	1.486	0.015	0.122474	791
3600	0.035	1.486	0.015	0.122474	692
3600	0.03	1.486	0.015	0.122474	593
3600	0.07	1.486	0.01	0.1	1696
3600	0.06	1.486	0.01	0.1	1454
3600	0.05	1.486	0.01	0.1	1211
3600	0.045	1.486	0.01	0.1	1090
3600	0.04	1.486	0.01	0.1	969
3600	0.035	1.486	0.01	0.1	848
3600	0.03	1.486	0.01	0.1	727
3600	0.07	1.486	0.008	0.089443	1896
3600	0.06	1.486	0.008	0.089443	1625
3600	0.05	1.486	0.008	0.089443	1354
3600	0.045	1.486	0.008	0.089443	1219
3600	0.04	1.486	0.008	0.089443	1083
3600	0.035	1.486	0.008	0.089443	948
3600	0.03	1.486	0.008	0.089443	813

APPENDIX F: EROSION AND SEDIMENT TRANSPORT ANALYSIS SUPPORTING DOCUMENTATION

F.1 Sediment Yield

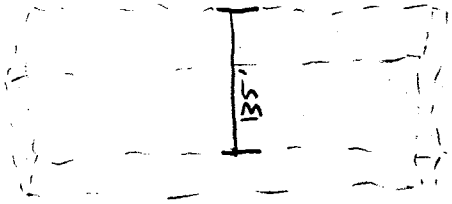
White Tank Fan

4-10-00
Page 1

Sediment Yield using MUSLE predicts
$Q_{s\ 100\text{-}yr} = 6.23$ ac-ft

The channel near the hydrographic apex is
≈ 135 feet wide

$6.23 \text{ac-ft} = 271{,}380 \text{ ft}^3 / 135 \text{ ft} = 2010 \text{ ft}^2$



Assume 4ft Depth of deposition

Then deposit would cover ≈ 500 ft linearly of channel

If 2ft Deep then deposit covers $\times 1000$ ft of channel

If $V = 7$ ft/s, & $W = 135'$

Then $Q = W \cdot D \cdot V \Rightarrow 3600 = 135 \cdot D \cdot 7$

or $D = 3.8$ ft

So $D_w + D_s = 2 + 3.8 = 5.8$ ft @ 3600 cfs
or $D_w + D_s = 4 + 3.8 = 7.8$ ft

If we assume V is critical, $n = 0.04$, & $W = 135'$
and $Q = 3600$ cfs &, slope $= S_o \leq 0.025$,
then, $D_c \approx 2.5'$ & $V_c = \sqrt{32.2 \cdot 2.5} \cong 9$ ft/s

So $D_c + D_s = 2.5 + 2 = 4.5'$
or $2.5 + 4 = 6.5'$

Watershed to Site 36 alluvial fan - Sediment Yield

Sediment Yield Computation
MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE), Ys = Rw * K * LS * C * P

A. Rw, STORM ENERGY RUNOFF FACTOR; Rw = a(V*q)^b

Hydrographs based on Alpha Engineering HEC-1 & Region 13 Q Eq'ns (USGS WSP 2433)

Drainage Area at CP1M = 5.67 sq. mi.
Area Contributing Sediment = 5.67 sq. mi.

Recurrence Interval	Volume, V (ac-ft)	Flow Peak (cfs)	a	b	Rw
Q-2	34	297	95	0.56	16694
Q-5	67	581	95	0.56	35388
Q-10	142	1233	95	0.56	82151
Q-25	257	2225	95	0.56	159214
Q-50	334	2891	95	0.56	213450
Q-100	416	3600	95	0.56	272863

B. K, SOIL ERODIBILITY FACTOR: Figure 3, SCS Ag. Handbook #537

Soil Group	% Silt & v.f.sand	% Sand	% Organic Material	Soil Structure	Permeability	K	% of Basin
48						0.08	7.03
49						0.08	1.85
70						0.24	4.30
91						0.08	1.08
98						0.17	1.66
100						0.02	84.08
					Weighted K Factor:		0.04

Above data and K-Factors from: "Soil Survey of Maricopa County, Central Part" (Hartman, 1974), and "Soil Survey of Aguila Carefree Area, Parts of Maricopa and Pinal Counties, Arizona, (Camp, 1986). Data also from Figure B.1 in "Design Manual for Engineering Analysis of Fluvial Systems", ADWR, 1985. Also see the project file for more details.

C. C, COVER AND MANAGEMENT FACTOR; Figures 5-7, SCS Ag. Handbook #537

Cover Type	% of Basin	Canopy Factor	Mulch Factor	Root Factor	Composite C Factor	Weighted C Factor
Sonoran desert	100	0.85	0.90	0.42	0.32	0.32

Composite Weighted C Factor= 0.321

D. LS, TOPOGRAPHIC FACTOR; LS = ((L/72.6)^n)*(0.65+0.0454*S+0.0065*S^2)

Slope Lengths: 300 ft (Basin Average)
Slope Angles: 15 % (Basin Average)
n = 0.5
Eq'n 8.4 ADWR Manual, Appendix B

LS = 4.49

E. P, EROSION CONTROL FACTOR

No Practice, Natural or Regulated
Weighted P for Contributing Watershed = 1

F. RESULTS:

Recurrence Interval	Rw	K	LS	C	P	Ys (tons)	Unit Ys (AF/sq.mi)	Ys (AF)
Q-2	16694	0.04	4.49	0.32	1.00	913	0.07	0.38
Q-5	35388	0.04	4.49	0.32	1.00	1936	0.14	0.81
Q-10	82151	0.04	4.49	0.32	1.00	4495	0.33	1.88
Q-25	159214	0.04	4.49	0.32	1.00	8712	0.64	3.64
Q-50	213450	0.04	4.49	0.32	1.00	11680	0.86	4.88
Q-100	272863	0.04	4.49	0.32	1.00	14931	1.10	6.23
WEIGHTED AVERAGE ANNUAL SEDIMENT YIELD:						**1860**	**0.14**	

APPENDIX G: GEOMORPHOLOGY SUPPORTING DOCUMENTATION

G.1 NRCS Soil Map Unit Descriptions

Photocopies from *Soil Survey, Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona* (Camp, 1986) and *Soil Survey of Central Part, Arizona, Central Part* (Hartman, 1977).

Table G.1 Soil Units and Characteristics on the White Tank Fan (Site 36) Piedmont

SCS soils map units	Component Soil Series	Position / Landform	Important Characteristics	Subgroup, Order
From Soil Survey, Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona (Camp, 1986)				
Antho gravelly sandy loams (2)	Antho - 80%	- on floodplains, alluvial fans, and drainageways	- 55% with non-calcareous surface layer & calcareous below, 25% calcareous throughout; main lin	-Typic Torrifluvents, Entisols
Antho-Carrizo-Maripo complex (3, 4)	Antho - 35% Carrizo - 30% Maripo - 20%	- on floodplains, alluvial fans, and drainageways - on floodplains, drainageways, alluvial fans, fan terraces, and stream terraces - on flooplains and low stream terraces	- see above - subject to occassional flooding; hazard due to water erosion is severe; channeling, deposition, and streambank erosion occur during flooding - subject to rare periods of flooding * Main limitation for urban development of entire units is that they are subject to flooding. See also unit AGB in Hartman (1977).	- Typic Torrifluvents, Entisols - Typic Torriorthents, Entisols - Typic Torrifluvents, Entisols
Chuckwalla-Gunsight complex (19)	Chuckwalla - 45% Gunsight - 35%	- on tops of fan terraces - on sides of fan terraces	- 85-95% of surface typically covered with varnished desert pavement - C horizon is strongly to violently effervescent and weakly cemented in some pedons ** These are old surfaces generally free from flooding.	- Typic Haplargids, Aridisols - Typic Calciorthids, Aridisols
Denure-Momoli-Carrizo complex (29)	Denure - 40% Momoli - 30% Carrizo - 20%	- on stream terraces and fan terraces - on stream terraces and fan terraces - on floodplains, drainageways, alluvial fans, fan terraces, and stream terraces	- calcareous below about 8 inches; B horizon development; buried calcic or argillic horizon present in some pedons - B horizon development; strongly effervescent at depth	- Typic Camborthids, Aridisols - Typic Camborthids, Aridisols - Typic Torriorthents, Entisols
Ebon-Gunsight-Cipriano association (47)	Ebon - 35% Gunsight - 20% Cipriano - 20%	- on fan terraces and stream terraces - on fan terraces - on fan terraces	- yellowish red color, common thin clay films, strongly effervescent B horizon - see above; also, high lime content and restricted available water capacity contribute to very low productivity on these soils - shallow soils, underlain by indurated duripan (caliche)	- Typic Haplargids, Aridisols - Typic Calciorthids, Aridisols - Typic Durorthids, Aridisols
Ebon-Pinamt complex (48, 49)	Ebon - 45% Pinamt - 35%	- on fan terraces and stream terraces - on fan terraces	- yellowish red color, high clay content, calcareous at depth - yellowish red B horizons which are strongly to violently effervescent	- Typic Haplargids, Aridisols - Typic Haplargids, Aridisols
Gunsight-Rillito complex (70)	Gunsight - 40% Rillito - 40%	- on fan terraces - on fan terraces	- see above - weakly cemented calcic horizon at 4 to 36 inches	- Typic Calciorthids, Aridisols - Typic Calciorthids, Aridisols
Momoli-Carrizo complex (91)	Momoli - 45% Carrizo - 35%	- on stream terraces and fan terraces - on floodplains, drainageways, alluvial fans, fan terraces, and stream terraces	- weakly developed, light brown - poorly developed, pinkish gray, brown moist	- Typic Camborthids, Aridisols - Typic Torriorthents, Entisols
Pinamt-Tremant complex (98)	Pinamt - 45% Tremant - 35%	- on fan terraces - on fan terraces and stream terraces	- yellowish red B horizons which are strongly to violently effervescent - light reddish brown B horizons, caclic horizon at 5 to 24 inches, strongly to violently effervescent at depth, clay accumulation at depth	- Typic Haplargids, Aridisols - Typic Haplargids, Aridisols
Quilotosa-Vaiva-Rock outcrop complex (100)	Quilotosa - 50% Vaiva - 20% Rock outcrop - 20%	- on hillslopes and mountain slopes - on hillslopes and mountain slopes	- mapped on surfaces with 20 to 65% slopes; basically thin hillslope soils in the mountains	- Lithic Torriorthents, Entisols - Lithic Haplargids, Aridisols

Table G.1 Soil Units and Characteristics on the White Tank Fan (Site 36) Piedmont

SCS soils map units	Component Soil Series	Position / Landform	Important Characteristics	Subgroup, Order
From Soil Survey, Maricopa Pinal County, Arizona, Central Part (Hartman, 1977)				
Antho-Carrizo complex (AGB)	Antho - 35% Carrizo - 30% Maripo - 20%	- on alluvial fans 1 to 3 miles from mountains and in some broader stream channels; similar to units 3 and 4 in Camp (1986)	- surface drainage provided by dendritic pattern of shallow stream channels spaced at 50- to 200-foot intervals; Carrizo soil is in or adjacent to old stream channels that form a braided pattern across larger bodies of Antho soils; Maripo is in transitional areas between Carrizo and Antho	- Typic Torrifluvents, Entisols - Typic Torriorthents, Entisols - Typic Torrifluvents, Entisols
Antho association (AL)	Antho - 85%	- on alluvial fans that radiate out from nearby mountains	- surface drainage provided by a dendritic pattern of shallow stream channels, 1 foot to 3 feet deep, spaced at 50- to 300 foot intervals; 55% Antho sandy loam at the lower ends of alluvail fans farthest from the mountains, 30% Antho gravelly sandy loam on the higher parts of the alluvial fans nearest the mountains	- Typic Torrifluvents, Entisols
Antho-Valencia association (AM)	Antho - 40% Valencia - 40%	- on long, smooth valley plains 1 to 3 miles from the base of the mountains	- surface drainage provided by a dendritic pattern of shallow stream channels, 1 foot to 3 feet deep, spaced at 50- to 200 foot intervals	- Typic Torrifluvents, Entisols - Typic Torrifluvents, Entisols
Coolidge-Laveen association (CV)	Coolidge - 40% Laveen - 40%	- on upper part of old alluvial fans and valley plains - on lower part of old alluvial fans and old valley plains	- dissected by stream channels at 50- to 300-ft intervals, strongly to violently effervescent - large cocentration of lime in lower part	- Typic Calciorthids, Aridisols - Typic Calciorthids, Aridisols
Gunsight-Rillito complex (GYD)	Gunsight - 40% Rillito - 40%	- on old alluvial fans - in circular spots near drainageways, and near the tops of fans; on old fans and stream terraces	- dissected by series of stream channels at 100- to 500-foot intervals; channels range from a few feet to as much as 30 feet deep; Gunsight soils mainly on the top of fans and are high in lime content	- Typic Calciorthids, Aridisols - Typic Calciorthids, Aridisols

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United States Department of Agriculture

Soil Conservation Service

In Cooperation with United States Department of the Interior, Bureau of Indian Affairs and Bureau of Land Management, and the Arizona Agricultural Experiment Station

Soil Survey of Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona

miscellaneous areas are somewhat similar. Luke-Cipriano association, 1 to 15 percent slopes, is an example.

This survey includes *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Table 4 gives the acreage and proportionate extent of each map unit. Other tables (see "Summary of Tables") give properties of the soils and the limitations, capabilities, and potentials for many uses. The Glossary defines many of the terms used in describing the soils or miscellaneous areas.

Map Unit Descriptions

1—Antho sandy loams. These deep and well drained soils are on alluvial fans. They formed in alluvium derived dominantly from acid and basic igneous rock. Slope is 0 to 3 percent. Elevation is 1,100 to 1,700 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

About 55 percent in this unit is Antho sandy loam that is noncalcareous in the surface layer and is calcareous below, and 25 percent is Antho sandy loam that is calcareous throughout. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Carrizo, Gilman, and Maripo soils on flood plains and Denure and Momoli soils on fan terraces. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

Typically, the surface layer of these Antho soils is brown sandy loam about 3 inches thick. The underlying material to a depth of 60 inches or more is light brown sandy loam. In some areas these soils are affected by salts and sodium.

Permeability of these Antho soils is moderately rapid. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight. Where unprotected, these soils are subject to rare periods of flooding.

Most areas of this unit are used as rangeland or wildlife habitat. A few areas are used for urban development.

In areas where the soils in this unit are noncalcareous in the surface layer, they have high potential for producing forage and respond well to rangeland management. Where the range is in good or excellant condition, it produces forage year round. It is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing. To control erosion, extra care must be taken to maintain a good plant cover.

In areas where these soils are calcareous throughout, they have moderate potential for producing forage and respond slowly to rangeland management. Most of the vegetation is produced following rainfall in winter and spring. In favorable winters, the production of annual grasses and forbs can support grazing for about 2 to 3 months. Little forage is available during the rest of the year.

A few small areas in the Hassayampa Plain area receive less precipitation than is typical for the unit. These areas are somewhat less productive than most other areas of the unit.

If the soils in this unit are used as sites for buildings o roads, the main limitation is the hazard of flooding. These soils are subject to localized flooding from overland flow, particularly during high intensity thunderstorms of short duration. Foundations built on this unit should be placed on elevated fill material, and yards should be graded away from the foundations so that surface water will flow away from the buildings.

If the soils in this unit are used for septic tank absorption fields, the main limitation is the hazard of flooding. In areas that are subject to flooding, sewerlines should be connected to a community sewage system to minimize the possibility of contaminating ground water and creating a hazard to health.

Onsite investigation is needed to determine the most suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, nonirrigated. The Antho sandy loam that is noncalcareous in the surface layer is in the Sandy Loam Upland, 7- to 10-inch p.z., range site, and the Antho sandy loam that is calcareous throughout is in the Limy Fan, 7- to 10-inch p.z., range site.

2—Antho gravelly sandy loams. These deep and well drained soils are on alluvial fans. They formed in alluvium derived dominantly from acid and basic igneous rock. Slope is 0 to 3 percent. Elevation is 1,100 to 1,700 feet. The average annual precipitation is 7 to 10 inches and the average annual air temperature is 70 to 73 degrees F.

About 55 percent of the soil in this unit is Antho gravelly sandy loam that is noncalcareous in the surface layer and is calcareous below the surface layer, and 25 percent is Antho gravelly sandy loam that is calcareous throughout. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Carrizo soils in drainageways, Gilman and Maripo soils on flood plains, and Denure and Momoli soils on fan terraces. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

Typically, the surface layer of these Antho soils is brown gravelly sandy loam about 3 inches thick. The underlying material to a depth of 60 inches or more is

ratified, light brown sandy loam and gravelly sandy oam.

Permeability of these Antho soils is moderately rapid. vailable water capacity is low to moderate. Effective ooting depth is 60 inches or more. Runoff is slow, and ie hazard of water erosion is slight. Where unprotected, iese soils are subject to rare periods of flooding.

Most areas of this unit are used as rangeland and ildlife habitat. A few areas are used for urban evelopment.

In areas where these soils are noncalcareous in the urface layer, they have high potential for producing orage and respond well to rangeland management. Vhere the range is in good or excellent condition, it roduces forage year round. It is easily traversed by vestock. Resting pastures during alternate growing easons helps to maintain or improve the vegetation. encing and developing watering facilities help to control razing. To control erosion, extra care must be taken to iaintain a good plant cover.

In areas where these soils are calcareous throughout, iey have moderate potential for producing forage and espond slowly to rangeland management. Most of the egetation is produced following rainfall in winter and pring. In favorable winters, the production of annual ses and forbs can support grazing for about 2 to 3 ..ths. Little forage is available during the rest of the ear.

A few small areas in the Hassayampa Plain area eceive less precipitation than is typical for the unit. hese areas are somewhat less productive than most ther areas of the unit.

If the soils in this unit are used as sites for buildings or oads, the main limitation is the hazard of flooding. This nit is subject to localized flooding from overland flow, articularly during high intensity thunderstorms of short uration. Foundations built on this unit should be placed n elevated fill material, and yards should be graded way from the foundations so that surface water will flow way from the buildings.

If the soils in this unit are used for septic tank bsorption fields, the main limitation is the hazard of ooding. In areas that are subject to flooding, sewerlines hould be connected to a community sewage system to iinimize the possibility of contaminating ground water nd creating a hazard to health.

Onsite investigation is needed to determine the most uitable alternatives and the best design of buildings, oads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, onirrigated. The Antho gravelly sandy loam that is oncalcareous in the surface layer is in the Sandy Loam nd, 7- to 10-inch p.z., range site, and the Antho ..elly sandy loam that is calcareous throughout is in ie Limy Fan, 7- to 10-inch p.z., range site.

3—Antho-Carrizo-Maripo complex. This map unit is on flood plains and in drainageways. Slope is 0 to 3 percent. Elevation is 1,100 to 2,100 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 35 percent Antho sandy loam, 30 percent Carrizo very gravelly sand, and 20 percent Maripo sandy loam. The Antho and Maripo soils are on flood plains, and the Carrizo soil is in narrow, meandering drainageways. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Brios soils in drainageways, Gilman and Vint soils on flood plains, and Denure, Momoli, and Carrizo soils on stream terraces. The included areas make up about 15 percent of the total acreage. The percentage varies from one area to another.

The Antho soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is brown sandy loam about 3 inches thick. The underlying material to a depth of 60 inches or more is light brown, slightly calcareous sandy loam. In some areas the soil is gravelly throughout.

Permeability of the Antho soil is moderately rapid. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is moderate. Where unprotected, this soil is subject to rare periods of flooding.

The Carrizo soil is deep and excessively drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the soil is pinkish gray, calcareous very gravelly sand and very gravelly coarse sand to a depth of 60 inches or more.

Permeability of the Carrizo soil is very rapid. Available water capacity is very low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is severe. Where unprotected, this soil is subject to occasional periods of flooding. Channeling, deposition, and streambank erosion occur during periods of flooding.

The Maripo soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown sandy loam about 18 inches thick. The upper 11 inches of the underlying material is light brown, calcareous sandy loam, and the lower part to a depth of 60 inches or more is light brown, calcareous very gravelly loamy sand. Depth to very gravelly loamy sand ranges from 20 to 36 inches.

Permeability of this Maripo soil is moderately rapid. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is moderate. Where unprotected, this soil is subject to rare periods of flooding.

This unit is used mainly as rangeland and wildlife habitat. A few areas are used for urban development.

The Antho and Maripo soils have moderate potential for producing forage. They respond well to rangeland management. Where the range is in good or excellent condition, the soils produce forage year round. They are easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing. To control erosion, extra care must be taken to maintain a good plant cover. In a few areas these soils are calcareous in the surface layer and are therefore less productive than in most other areas of the unit.

The Carrizo soil is one of the most productive rangeland soils in the survey area. It receives extra moisture from runoff, which increases production. The soil responds well to rangeland management. Extra care in management is needed to protect the soil from gullying and channeling. This soil can produce forage year round, and it is easily traversed by cattle. Because of the availability of water, ease of access, and abundance of feed, some areas of this soil are overgrazed.

The riparian habitat in some areas of the Carrizo soil is extremely important to wildlife.

The soils in this unit are severely limited for urban use because they are in drainageways and on flood plains that are subject to flooding.

This map unit is in capability subclass VIIw, nonirrigated. The Antho and Maripo soils are in the Sandy Loam Upland, 7- to 10-inch p.z., range site, and the Carrizo soil is in the Sandy Bottom, 7- to 10-inch p.z., range site.

4—Antho-Carrizo-Maripo complex, low precipitation. This map unit is on flood plains and in drainageways. Slope is 0 to 3 percent. Elevation is 1,100 to 2,100 feet. The average annual precipitation is 2 to 7 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 35 percent Antho sandy loam, 30 percent Carrizo very gravelly sand, and 20 percent Maripo sandy loam. The Antho and Maripo soils are on flood plains, and the Carrizo soil is in narrow, meandering drainageways. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Brios soils in drainageways, Gilman and Vint soils on flood plains, and Denure, Momoli, and Carrizo soils on stream terraces. The included areas make up about 15 percent of the total acreage. The percentage varies from one area to another.

The Antho soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is brown sandy loam about 3 inches thick. The underlying material to a depth of 60 inches or more is light brown, slightly calcareous sandy loam. In some areas the soil is calcareous throughout.

Permeability of the Antho soil is moderately rapid. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is moderate. Where unprotected, this soil is subject to rare periods of flooding.

The Carrizo soil is deep and excessively drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the soil is pinkish gray, calcareous very gravelly sand and very gravelly coarse sand to a depth of 60 inches or more.

Permeability of the Carrizo soil is very rapid. Available water capacity is very low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is severe. Where unprotected, this soil is subject to occasional periods of flooding. Channeling, deposition, and streambank erosion occur during periods of flooding.

The Maripo soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown sandy loam about 18 inches thick. The upper 11 inches of the underlying material is light brown, calcareous sandy loam, and the lower part to a depth of 60 inches or more is light brown, calcareous very gravelly loamy sand. Depth to very gravelly loamy sand ranges from 20 to 36 inches.

Permeability of the Maripo soil is moderately rapid. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is moderate. Where unprotected, this soil is subject to rare periods of flooding.

This unit is used as rangeland and wildlife habitat.

The Antho and Maripo soils have low potential for producing forage. They respond well to rangeland management. Where the range is in good or excellent condition, the soils produce forage year round. They are easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing. To control erosion, extra care must be taken to maintain a good plant cover. In a few areas these soils are calcareous in the surface layer and are therefore less productive than in most other areas of the unit.

The Carrizo soil is one of the most productive rangeland soils in the survey area. It receives extra moisture from runoff, which increases production. The soil responds well to rangeland management. Extra care in management is needed to protect the soil from gullying and channeling. This soil can produce forage year round, and it is easily traversed by cattle. Because of the availability of water, ease of access, and abundance of feed, some areas of this soil are overgrazed.

The riparian habitat in some areas of the Carrizo soil is extremely important to wildlife.

content of large stones. The cuts needed to provide nearly level building sites or roadbeds can expose the hardpan and bedrock, which are difficult to excavate. Ripping or blasting, or both, may be necessary. Because of the steepness of slope, extensive cutting and filling are necessary to create a level building site. Fill areas should be compacted to the same density as cut areas. Cuts and fills are highly susceptible to erosion. Erosion can be controlled by using diversions or terraces to reduce the length of slopes or by revegetating to slow runoff.

If the soil in this unit is used for septic tank absorption fields, the main limitations are the depth to the cemented hardpan and to bedrock, the slope, and the content of large stones. Septic tank absorption fields may not operate properly in some areas of this unit. The depth to the hardpan and to bedrock restricts the movement of effluent. Effluent is likely to flow through cracks in the rock, resulting in little filtration. Steepness of slope makes it difficult to control the distribution of effluent. Effluent can move along the surface of the bedrock and seep to the surface downslope, creating a hazard to health. Alternatives include locating absorption fields in more suitable soils in adjacent areas and transporting the effluent to them by pipeline or installing community sewage systems.

Onsite investigation is needed to determine the most suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIe, nonirrigated. It is in the Basalt Hills, 7- to 10-inch p.z., range site.

19—Chuckawalla-Gunsight complex, 1 to 8 percent slopes. This map unit is on fan terraces. The Chuckawalla soil has slopes of 1 to 3 percent, and the Gunsight soil has slopes of 1 to 8 percent. Elevation is 1,200 to 1,600 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Chuckawalla extremely gravelly loam and 35 percent Gunsight very gravelly loam. The Chuckawalla soil is on the tops of fan terraces, and the Gunsight soil is on the sides of fan terraces. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Sal, Pinamt, and Tremant soils in areas of fan terraces that do not have a desert pavement; Rillito soils on side slopes; and Antho, Gilman, and Maripo soils on flood plains. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

The Chuckawalla soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, 85 to 95 percent of the surface is covered with varnished desert pavement. The surface layer is light brown extremely gravelly loam about 2 inches thick. The upper 4 inches of the subsoil is light brown, calcareous very gravelly sandy clay loam and the lower 8 inches is yellowish red, saline extremely gravelly sandy clay loam. The substratum to a depth of 60 inches or more is white, calcareous extremely gravelly sandy loam.

Permeability of the Chuckawalla soil is moderate. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is rapid, and the hazard of water erosion is slight.

The Gunsight soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown, calcareous very gravelly loam about 3 inches thick. The underlying material to a depth of 60 inches or more is light brown, calcareous very gravelly loam and pinkish gray very gravelly sandy loam.

Permeability of the Gunsight soil is moderate. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is medium, and the hazard of water erosion is slight.

This unit is used mainly as rangeland and wildlife habitat.

The soils in this unit are among the least productive rangeland soils in the survey area. They respond very slowly to rangeland management. The high content of lime and the low available water capacity contribute to the low productivity of this unit. The included Antho, Gilman, and Maripo soils on flood plains are much more productive than the other soils in the unit. Management of this unit should therefore be concentrated on these included soils because they produce nearly all the available forage.

This map unit is in capability subclass VIIs, nonirrigated. The Chuckawalla soil is in the Saline Upland (Loamy), 7- to 10-inch p.z., range site, and the Gunsight soil is in the Limy Upland, 7- to 10-inch p.z., range site.

20—Chuckawalla-Gunsight complex, low precipitation, 1 to 8 percent slopes. This map unit is on fan terraces. The Chuckawalla soil has slopes of 1 to 3 percent, and the Gunsight soil has slopes of 1 to 8 percent. Elevation is 1,200 to 1,600 feet. The average annual precipitation is 2 to 7 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Chuckawalla extremely gravelly loam and 35 percent Gunsight very gravelly loam (fig. 4). The Chuckawalla soil is on the tops of fan terraces, and the Gunsight soil is on the sides of fan terraces. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

and, in the Ohaco soil, the depth to the hardpan. The effects of shrinking and swelling can be reduced by maintaining a constant moisture content in the soil. Runoff should be diverted away from buildings. Landscaping plants that require little water should be used near building foundations, and overwatering should be avoided. A sealer can be used under roads to prevent shrinking and swelling of the material below. The effects of shrinking and swelling on building foundations can be minimized by using an appropriate engineering design and by backfilling with material that has low shrink-swell potential. In addition, more reinforcement can be provided. The limited depth to the hardpan interferes with excavation. Ripping the pan may be necessary.

If the soils in this unit are used for septic tank absorption fields, the main limitations are the slow permeability and, in the Ohaco soil, the depth to the hardpan. The limitation of slow permeability can be minimized by increasing the size of the absorption field and by backfilling excavations with gravelly or sandy material.

In the Ohaco soil, the hardpan restricts the movement of effluent. Where the hardpan is thin and is underlain by more permeable material, the pan can be ripped and the absorption lines placed below it. In some areas the size of the absorption field needed may exceed the lot size. Alternatives include locating absorption fields in more suitable soils in adjacent areas or installing community sewage systems. Poor design of septic tank absorption fields can seriously compound shrink-swell problems when foundations are installed close to the absorption fields.

Onsite investigation is needed to determine the most suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, nonirrigated. It is in the Clayey Upland, 10- to 12-inch p.z., range site.

29—Denure-Momoli-Carrizo complex. This map unit is on fan terraces. Slope is 0 to 3 percent. Elevation is 1,400 to 2,200 feet. The average annual precipitation is 7 to 10 inches, the average annual air temperature is 70 to 73 degrees F.

This unit is about 40 percent Denure fine sandy loam, 30 percent Momoli gravelly sandy loam, and 20 percent Carrizo gravelly sandy loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Gilman, Maripo, and Carrizo soils on flood plains. The included areas make up about 10 percent of the total acreage. The percentage varies from one area to another.

The Denure soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown fine sandy loam about 2 inches thick. The underlying material to a depth of 60 inches or more is light brown sandy loam and gravelly sandy loam. This soil is calcareous below a depth of about 8 inches. In some areas the surface layer is gravelly sandy loam.

Permeability of the Denure soil is moderately rapid. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

The Momoli soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown gravelly sandy loam about 10 inches thick. The next layer is light brown, calcareous very gravelly and extremely gravelly sandy loam about 22 inches thick. The substratum to a depth of 60 inches or more is brown extremely gravelly sandy loam. In some areas the surface layer is sandy loam or very gravelly sandy loam.

Permeability of the Momoli soil is moderately rapid. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

The Carrizo soil is deep and excessively drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is brown gravelly sandy loam about 10 inches thick. The upper 13 inches of the underlying material is light brown very gravelly loamy sand, and the lower part to a depth of 60 inches or more is light brown, calcareous extremely gravelly sand.

Permeability of the Carrizo soil is very rapid. Available water capacity is very low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

The soils in this unit have moderate potential for producing forage. They respond well to rangeland management. Where the range is in good or excellent condition, the soils produce forage year round. They are easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing. To control erosion, extra care must be taken to maintain a good plant cover. In a few areas these soils are calcareous in the surface layer and are therefore less productive than in most other areas of the unit.

This map unit is in capability subclass VIIs, nonirrigated. It is in the Sandy Loam Upland, 7- to 10-inch p.z., range site.

30—Denure-Momoli-Carrizo complex, low precipitation. This map unit is on fan terraces. Slope is 0 to 3 percent. Elevation i s 1,400 to 2,200 feet. The average annual precipitation is 2 to 7 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 40 percent Denure fine sandy loam, 30 percent Momoli gravelly sandy loam, and 20 percent

and the average annual air temperature is 70 to 73 degrees F.

Typically, the surface layer is light brown very gravelly loam about 1 inch thick. The upper 10 inches of the subsoil is yellowish red very gravelly clay, and the lower 32 inches is yellowish red, calcareous very gravelly sandy clay. The substratum to a depth of 60 inches or more is white, calcareous gravelly loamy sand.

Included in this unit are small areas of Contine, Luke, Beardsley, Pinamt, Mohall, Cipriano, and Gunsight soils on fan terraces. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

Permeability of this Ebon soil is slow. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is medium, and the hazard of water erosion is slight.

This unit is used mainly as rangeland and wildlife habitat. A few areas are used for urban development.

This unit has moderate potential for producing forage. It responds moderately well to rangeland management. The unit can produce forage year round. It is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing.

If the soil in this unit is used as sites for buildings or roads, the main limitation is the slope. In the steeper areas, extensive cutting and filling may be required to create a level building pad. Fill areas should be compacted to the same density as cut areas. Cuts and fills are highly susceptible to erosion. Erosion can be controlled by using diversions or terraces to reduce the length of slopes or by revegetating to slow runoff.

If the soil in this unit is used for septic tank absorption fields, the main limitations are the slow permeability and the slope. The limitation of slow permeability can be minimized by increasing the size of the absorption field and by backfilling excavations with gravelly or sandy material. It is difficult to control the distribution of effluent in the steeper areas of the unit. Absorption lines should be placed on the contour in these areas to slow the flow of effluent to achieve a more nearly even distribution.

Onsite investigation is needed to determine the most suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, nonirrigated. It is in the Clay Loam Upland, 7- to 10-inch p.z., range site.

46—Ebon-Contine complex, 1 to 8 percent slopes. This map unit is on fan terraces. Elevation is 1,200 to 2,200 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Ebon very gravelly loam and 35 percent Contine clay loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Beardsley, Luke, Pinamt, Suncity, and Tremant soils on fan terrac and Carrizo soils in drainageways. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

The Ebon soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneo rock. Typically, the surface layer is light brown very gravelly loam about 1 inch thick. The upper 10 inches the subsoil is yellowish red very gravelly clay, and the lower 32 inches is yellowish red, calcareous very grav sandy clay. The substratum to a depth of 60 inches or more is white, calcareous gravelly loamy sand.

Permeability of the Ebon soil is slow. Available wate capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow to medium, and the hazard of we erosion is slight.

The Contine soil is deep and well drained. It formed alluvium derived dominantly from acid and basic igneo rock. Typically, the surface layer is brown clay loam about 2 inches thick. The subsoil is reddish brown, calcareous clay loam and clay 28 inches thick. The substratum to a depth of 60 inches or more is light reddish brown, calcareous sandy loam.

Permeability of the Contine soil is slow. Available water capacity is high. Effective rooting depth is 60 inches or more. Runoff is slow to medium, and the hazard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

This unit has moderate potential for producing forag It responds moderately well to rangeland managemen The unit can produce forage year round. It is easily traversed by livestock. Resting pastures during alterna growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing.

This map unit is in capability subclass VIIs, nonirrigated. It is in the Clay Loam Upland, 7- to 10-in p.z., range site.

47—Ebon-Gunsight-Cipriano association, 3 to 25 percent slopes. This map unit is on fan terraces. The Ebon soil has slopes of 3 to 8 percent, and the Gunsi and Cipriano soils have slopes of 3 to 25 percent. Elevation is 1,600 to 2,200 feet. The average annual precipitation is 7 to 10 inches, and the average annua air temperature is 70 to 73 degrees F.

This unit is about 35 percent Ebon very gravelly cla loam, 20 percent Gunsight very gravelly sandy loam, 20 percent Cipriano very gravelly loam. The Ebon soil dominantly on the tops of terraces, the Gunsight soil i on the side slopes, and the Cipriano soil is on the sid slopes and tops.

Included in this unit are small areas of Carrizo soils drainageways and Beardsley, Contine, and Luke soils

ıan terraces. The included areas make up about 25 percent of the total acreage. The percentage varies from one area to another.

The Ebon soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown very gravelly clay loam about 3 inches thick. The upper 10 inches of the subsoil is yellowish red very gravelly clay, and the lower 32 inches is yellowish red, calcareous very gravelly sandy clay. The substratum to a depth of 60 inches or more is white, calcareous very gravelly loamy sand.

Permeability of the Ebon soil is slow. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow to medium, and the hazard of water erosion is slight.

The Gunsight soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown, calcareous very gravelly sandy loam about 3 inches thick. The underlying material to a depth of 60 inches or more is light brown, calcareous very gravelly loam and pinkish gray very gravelly sandy loam.

Permeability of the Gunsight soil is moderate. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow to medium, and the ızard of water erosion is slight.

The Cipriano soil is very shallow and shallow and is well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light reddish brown, calcareous very gravelly loam about 1 inch thick. The underlying material is yellowish brown, calcareous very gravelly loam about 7 inches thick over a silica- and lime-cemented hardpan. Depth to the hardpan ranges from 4 to 20 inches.

Permeability of the Cipriano soil is moderate. Available water capacity is very low. Effective rooting depth is 4 to 20 inches. Runoff is medium, and the hazard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

The Ebon soil has moderate potential for producing forage. It responds moderately well to rangeland management. Where the range is in good or excellent condition, it produces forage year round. The soil is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing.

The Gunsight and Cipriano soils are among the least productive rangeland soils in the survey area. They respond very slowly to rangeland management. The high content of lime and the restricted available water capacity contribute to the low productivity of these soils.

This map unit is in capability subclass VIIs, ınirrigated. The Ebon soil is in the Clay Loam Upland, 7- to 10-inch p.z., range site, and the Gunsight and Cipriano soils are in the Limy Upland, 7- to 10-inch p.z., range site.

48—Ebon-Pinamt complex, 3 to 20 percent slopes. This map unit is on fan terraces. Elevation is 1,200 to 2,200 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Ebon very gravelly loam and 35 percent Pinamt extremely gravelly sandy loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Carrizo and Antho soils in drainageways and Contine, Luke, Cipriano, Gunsight, Momoli, and Tremant soils on fan terraces. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

The Ebon soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown very gravelly loam about 1 inch thick. The upper 10 inches of the subsoil is yellowish red very gravelly clay, and the lower 32 inches is yellowish red, calcareous very gravelly sandy clay. The substratum to a depth of 60 inches or more is white, calcareous gravelly loamy sand.

Permeability of the Ebon soil is slow. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is medium, and the hazard of water erosion is slight.

The Pinamt soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the upper 1 inch of the surface layer is brown extremely gravelly sandy loam and the lower 2 inches is light brown very gravelly loam. The upper 12 inches of the subsoil is yellowish red very gravelly sandy clay loam, and the lower 13 inches is light brown, calcareous extremely gravelly sandy clay loam. The substratum to a depth of 60 inches or more is light brown, calcareous extremely gravelly sandy loam.

Permeability of the Pinamt soil is moderately slow. Available water capacity is low to moderate. Effective rooting depth is 60 inches or more. Runoff is slow to medium, and the hazard of water erosion is slight.

This unit is used as rangeland, as wildlife habitat, and for urban development.

This unit has moderate potential for producing forage. It responds moderately well to rangeland management. The unit produces forage year round. It is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Proper placement of fences and watering facilities helps to control the distribution of grazing.

A few small areas of this unit in the Hassayampa Plain area receive less precipitation than is typical for the unit.

These areas are somewhat less productive than most other areas of the unit.

If the soils in this unit are used as sites for buildings or roads, the main limitation is the slope. In the steeper areas, extensive cutting and filling may be required to create a level building pad. Fill areas should be compacted to the same density as cut areas. Cuts and fills are highly susceptible to erosion. Erosion can be controlled by using diversions or terraces to reduce the length of slopes or by revegetating to slow runoff.

If the soils in this unit are used for septic tank absorption fields, the main limitations are the slow permeability of the Ebon soil and slope. The Pinamt soil is better suited to use for septic tank absorption fields than is the Ebon soil; therefore, absorption fields should be located in areas of the Pinamt soil if feasible. If absorption fields are located in areas of the Ebon soil, the limitation of slow permeability can be minimized by increasing the size of the absorption field and by backfilling excavations with gravelly or sandy material.

It is difficult to control the distribution of effluent in the steeper areas of the unit. Absorption lines should be placed on the contour in these areas to slow the flow of effluent and to achieve a more nearly even distribution.

Onsite investigation is needed to determine the most suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, nonirrigated. The Ebon soil is in the Clay Loam Upland, 7- to 10-inch p.z., range site, and the Pinamt soil is in the Loamy Upland, 7- to 10-inch p.z., range site.

49—Ebon-Pinamt complex, 20 to 40 percent slopes. This map unit is on fan terraces. Elevation is 1,200 to 2,200 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Ebon very gravelly loam and 35 percent Pinamt extremely gravelly sandy loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Luke and Tremant soils scattered throughout the unit and Antho and Carrizo soils in drainageways. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

The Ebon soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown very gravelly loam about 1 inch thick. The upper 10 inches of the subsoil is yellowish red very gravelly clay, and the lower 32 inches is yellowish red, calcareous very gravelly sandy clay. The substratum to a depth of 60 inches or more is white, calcareous gravelly loamy sand.

Permeability of the Ebon soil is slow. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is medium to rapid, and the hazard of water erosion is moderate.

The Pinamt soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the upper 1 inch of the surface layer is brown extremely gravelly sandy loam and the lower 2 inches is light brown very gravelly loam. The upper 12 inches of the subsoil is yellowish red very gravelly sandy clay loam, and the lower 13 inches is light brown, calcareous extremely gravelly sandy clay loam. The substratum to a depth of 60 inches or more is light brown, calcareous extremely gravelly sandy loam.

Permeability of the Pinamt soil is moderately slow. Available water capacity is low to moderate. Effective rooting depth is 60 inches or more. Runoff is medium, and the hazard of water erosion is moderate.

This unit is used as rangeland, as wildlife habitat, and for urban development.

This unit has moderate potential for producing forage. It responds moderately well to rangeland management. It can produce forage year round. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing.

A few small areas of this unit adjacent to the Hassayampa River receive less precipitation than is typical for the unit. These areas are somewhat less productive than most other areas of the unit.

If the soils in this unit are used as sites for buildings or roads, the main limitation is the slope. Because of the steepness of slope, extensive cutting and filling are necessary to create a level building pad. Fill areas should be compacted to the same density as cut areas. Cuts and fills are highly susceptible to erosion. Erosion can be controlled by using diversions or terraces to reduce the length of slopes or by revegetating to slow runoff.

If the soils in this unit are used for septic tank absorption fields, the main limitations are the slow permeability of the Ebon soil and slope. The Pinamt soil is better suited to use for septic tank absorption fields than is the Ebon soil; therefore, absorption fields should be located in areas of the Pinamt soil if feasible. If absorption fields are located in areas of the Ebon soil, the limitation of slow permeability can be minimized by increasing the size of the absorption field and by backfilling excavations with gravelly or sandy material.

It is difficult to control the distribution of effluent because of the steepness of slope. Effluent can seep to the surface downslope, creating a hazard to health. Absorption lines should be placed on the contour to slow the flow of effluent and produce more uniform distribution. To achieve the deepest possible infiltration and minimize downslope seepage, absorption lines should be placed at a greater depth.

69—Gunsight-Cipriano complex, low precipitation, 1 to 7 percent slopes. This map unit is on fan terraces. Slopes mainly are 1 to 2 percent, but in some areas they are as much as 30 percent. Elevation is 1,400 to 2,200 feet. The average annual precipitation is 2 to 7 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Gunsight very gravelly sandy loam and 40 percent Cipriano very gravelly loam. The Gunsight soil is on side slopes, and the Cipriano soil is on the tops of terraces. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Gilman soils on flood plains, Carrizo soils in drainageways, and Pinamt, Rillito, and Tremant soils on fan terraces. The included areas make up about 15 percent of the total acreage. The percentage varies from one area to another.

The Gunsight soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown, calcareous very gravelly sandy loam about 1 inch thick. The underlying material to a depth of 60 inches or more is light brown, calcareous very gravelly sandy loam.

Permeability of the Gunsight soil is moderate. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

The Cipriano soil is very shallow and shallow and is well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown, calcareous very gravelly loam about 1 inch thick. The underlying material is light brown, calcareous very gravelly loam about 5 inches thick over a light brown and pinkish gray, silica-cemented hardpan. Depth to the hardpan ranges from 4 to 20 inches. In a few areas this soil has slightly less gravel than is typical.

Permeability of the Cipriano soil is moderate. Available water capacity is very low. Effective rooting depth is 4 to 20 inches. Runoff is slow to medium, and the hazard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

The Gunsight and Cipriano soils are among the least productive rangeland soils in the survey area. They respond very slowly to rangeland management. The high content of lime and the low available water capacity contribute to the low productivity of these soils. The included soils on flood plains are much more productive than the other soils in the unit. Management of the soils in this unit should therefore be concentrated on these included soils, because they produce nearly all the available forage.

This map unit is in capability subclass VIIs, nonirrigated. It is in the Limy Upland, 2- to 7-inch p.z., range site.

70—Gunsight-Rillito complex, 1 to 25 percent slopes. This map unit is on fan terraces. Elevation is 1,100 to 2,100 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 40 percent Gunsight very gravelly loam and 40 percent Rillito gravelly loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Chuckawalla, Ebon, Mohall, Pinamt, and Tremant soils on the tops of terraces; Cipriano soils scattered throughout the unit; and Antho, Carrizo, and Gilman soils on flood plains. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

The Gunsight soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is light brown, calcareous very gravelly loam about 11 inches thick. The underlying material to a depth of 60 inches or more is light brown and pinkish white, calcareous extremely gravelly loam. In some areas the surface layer is gravelly loam.

Permeability of the Gunsight soil is moderate. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow to medium, and the hazard of water erosion is slight.

The Rillito soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the upper layer of this soil is pinkish gray and very pale brown, calcareous gravelly loam about 12 inches thick. The next 24 inches is very pale brown, calcareous gravelly sandy loam. Below this to a depth of 60 inches or more is very pale brown, calcareous very gravelly sandy loam. In some areas the surface layer is loam or very gravelly loam.

Permeability of the Rillito soil is moderate. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is medium, and the hazard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

The Gunsight and Rillito soils are among the least productive rangeland soils in the survey area. They respond very slowly to rangeland management. The high content of lime and the low available water capacity contribute to the low productivity of these soils.

The included soils on flood plains are much more productive than the other soils in this unit. Management of the soils in this unit should therefore be concentrated on these included soils, because they produce nearly all the available forage.

This map unit is in capability subclass VIIs, nonirrigated. It is in the Limy Upland, 7- to 10-inch p.z., range site.

90—Momoli gravelly sandy loam, 1 to 5 percent slopes. This deep and well drained soil is on fan terraces. It formed in alluvium derived dominantly from acid and basic igneous rock. Elevation is 1,400 to 2,200 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

Typically, the surface layer is strong brown gravelly sandy loam about 3 inches thick. The subsoil is strong brown very gravelly sandy loam about 23 inches thick. The substratum to a depth of 60 inches or more is brown, calcareous very gravelly sandy loam.

Included in this unit are small areas of Carrizo and Maripo soils on flood plains and Pinamt and Denure soils on fan terraces. The included areas make up about 30 percent of the total acreage. The percentage varies from one area to another.

Permeability of this Momoli soil is moderately rapid. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

Most areas of this unit are used as rangeland and wildlife habitat. A few areas are used for urban development.

The soil in this unit has moderate potential for producing forage. It responds moderately well to rangeland management. Where the range is in good or excellent condition, it produces forage year round. The soil is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing. To control erosion, extra care must be taken to maintain a good plant cover.

If this unit is used as sites for buildings, roads, or septic tank absorption fields, it has few limitations. Onsite investigation is needed to determine the most suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, nonirrigated. It is in the Sandy Loam Upland, 7- to 10-inch p.z., range site.

91—Momoli-Carrizo complex. This map unit is on fan terraces. Slope is 0 to 3 percent. Elevation is 1,400 to 2,200 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Momoli very gravelly sandy loam and 35 percent Carrizo very gravelly sandy loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Mohall, Remant, Gunsight, and Chuckawalla soils on slightly lower terraces, Denure soils scattered throughout the unit, and Gilman, Maripo, and Carrizo soils on flood plains and in drainageways. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

The soils in some areas of this unit south of Pinnacle Peak and west of the McDowell Mountains are noncalcareous to a depth of 20 inches or more. The soils in these areas typically are extremely cobbly or extremely gravelly.

The Momoli soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is pinkish gray, calcareous very gravelly sandy loam about 1 inch thick. Below this to a depth of 60 inches or more is light brown, calcareous very gravelly sandy loam. In some areas this soil is noncalcareous to a depth of 15 inches or more.

Permeability of the Momoli soil is moderately rapid. Available water capacity is low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

The Carrizo soil is deep and excessively drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is pinkish gray, calcareous very gravelly sandy loam about 2 inches thick. The upper 9 inches of the underlying material is light brown, calcareous very gravelly sandy loam, and the lower part to a depth of 60 inches or more is brown, calcareous extremely gravelly loamy sand. In some areas this soil is noncalcareous to a depth of 15 inches or more.

Permeability of the Carrizo soil is very rapid. Available water capacity is very low. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

The soils in this unit have moderate potential for producing forage. They respond slowly to rangeland management. Most of the vegetation is produced following rainfall in winter and spring. In favorable winters, the production of annual grasses and forbs can support grazing for about 2 to 3 months. Little forage is available during the rest of the year. In some areas of this unit, west of the McDowell Mountains and south of the Vulture Mountains, the soils are noncalcareous in the surface layer and are therefore more productive than they are in most other areas of the unit.

This map unit is in capability subclass VIIs, nonirrigated. It is in Limy Fan, 7- to 10-inch p.z., range site.

92—Momoli-Carrizo complex, low precipitation. This map unit is on fan terraces. Slope is 0 to 3 percent. Elevation is 1,400 to 2,200 feet. The average annual precipitation is 2 to 7 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Momoli very gravelly sandy loam and 35 percent Carrizo very gravelly sandy loam. The components of this unit are so intricately

he soils in this unit have moderate potential for ducing forage. They respond well to rangeland nagement. The unit can produce forage year round. It asily traversed by livestock. Resting pastures during rnate growing seasons helps to maintain or improve vegetation. Proper placement of fences and watering lities helps to control the distribution of grazing. In ne areas of this unit, the soils are calcareous in the face layer and are therefore less productive than in st other areas of the unit.

the Pinaleno soil is used as sites for buildings or ds, it has few limitations. If the Tres Hermanos soil is d as sites for buildings or roads, the main limitation is shrink-swell potential. The effects of shrinking and elling can be reduced by maintaining a constant isture content in the soil. Runoff should be diverted ay from buildings. Landscaping plants that require e water should be used near building foundations, and erwatering should be avoided. A sealer can be used der roads to prevent shrinking and swelling of the terial below. The Pinaleno soil is better suited to use sites for buildings and roads than is the Tres rmanos soil; therefore, buildings and roads should be ated in areas of the Pinaleno soil if feasible.

f the soils in this unit are used for septic tank rption fields, they have few limitations. In a few the substratum is somewhat finer in texture than is ical, and in other areas the substratum is weakly mented. The reduced permeability in these areas may quire the use of larger absorption fields.

Onsite investigation is needed to determine the most itable alternatives and th e best design of buildings, ads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, nirrigated. The Pinaleno soil is in the Loamy Upland, - to 12-inch p.z., range site, and the Tres Hermanos il is in the Sandy Loam Upland, 10- to 12-inch p.z., nge site.

97—Pinaleno-Tres Hermanos complex, low ecipitation, 1 to 10 percent slopes. This map unit is n fan terraces. Elevation is 2,000 to 2,500 feet. The erage annual precipitation is 8 to 10 inches, and the erage annual air temperature is 66 to 70 degrees F.

This unit is about 45 percent Pinaleno very gravelly ay loam and 40 percent Tres Hermanos gravelly loam. ne components of this unit are so intricately termingled that it was not practical to map them eparately at the scale used.

Included in this unit are small areas of Arizo soils in rainageways; Mohave, Greyeagle, Eba, Vado, and ickel soils on fan terraces; and soils that have less vel throughout the profile. Also included are small s of soils that are stratified sandy loam, are in and djacent to drainageways, and receive runoff from urrounding areas. The included areas make up about 15 percent of the total acreage. The percentage varies from one area to another.

The Pinaleno soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is yellowish red very gravelly clay loam about 1 inch thick. The upper 11 inches of the subsoil is yellowish red, calcareous gravelly clay loam and very gravelly clay loam, and the lower 12 inches is light brown, calcareous gravelly loam. The substratum to a depth of 60 inches or more is light brown, calcareous loam. In some areas the surface layer is gravelly sandy loam. In some areas a buried soil is below the substratum.

Permeability of the Pinaleno soil is moderately slow. Available water capacity is low to moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

The Tres Hermanos soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is reddish yellow gravelly loam about 2 inches thick. The upper 2 inches of the subsoil is reddish yellow, calcareous clay loam, and the lower 16 inches is yellowish red and pink, calcareous gravelly clay loam and very gravelly clay loam. The substratum to a depth of 60 inches or more is white, weakly lime-cemented or strongly lime-cemented very gravelly loam. In some areas the surface layer is gravelly sandy loam.

Permeability of the Tres Hermanos soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

This unit has moderate potential for producing forage. It responds well to rangeland management. The unit can produce forage year round. It is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Proper placement of fences and watering facilities helps to control the distribution of grazing. In some areas of this unit, the soil is calcareous in the surface layer and is therefore less productive than in most other areas of the unit.

This map unit is in capability subclass VIIs, nonirrigated. The Pinaleno soil is in the Loamy Upland, 8- to 10-inch p.z., range site, and the Tres Hermanos soil is in the Sandy Loam Upland, 8- to 10-inch p.z., range site.

98—Pinamt-Tremant complex, 1 to 10 percent slopes. This map unit is on fan terraces. Elevation is 1,200 to 2,200 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 45 percent Pinamt extremely gravelly sandy loam and 35 percent Tremant gravelly loam. The components of this unit are so intricately intermingled

that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Carrizo soils in drainageways and Chuckawalla, Ebon, Gunsight, and Rillito soils on fan terraces. The included areas make up about 20 percent of the total acreage. The percentage varies from one area to another.

The Pinamt soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the upper 1 inch of the surface layer is brown, calcareous extremely gravelly sandy loam and the lower 2 inches is light brown, calcareous very gravelly loam. The upper 12 inches of the subsoil is yellowish red, calcareous very gravelly sandy clay loam, and the lower 13 inches is light brown, calcareous extremely gravelly sandy clay loam. The substratum to a depth of 60 inches or more is light brown, calcareous extremely gravelly sandy loam. In some areas this soil is noncalcareous to a depth of 60 inches or more.

Permeability of the Pinamt soil is moderately slow. Available water capacity is low to moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

The Tremant soil is deep and well drained. It formed in alluvium derived dominantly from acid and basic igneous rock. Typically, the surface layer is reddish yellow gravelly loam 5 inches thick. The subsoil is reddish yellow and yellowish red, calcareous sandy clay loam and gravelly clay loam about 24 inches thick. The substratum to a depth of 60 inches or more is white, calcareous gravelly sand. In some areas this soil is noncalcareous to a depth of 60 inches or more, and in some areas it is calcareous throughout.

Permeability of the Tremant soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

This unit is used mainly as rangeland and wildlife habitat. A few areas are used for urban development.

The Pinamt soil has low potential for producing forage. It responds slowly to rangeland management. Most of the vegetation is produced following rainfall in winter and spring. In favorable winters, the production of annual grasses and forbs can support grazing for about 2 to 3 months. Little forage is available during the rest of the year. In some areas this soil is noncalcareous in the surface layer and is therefore more productive than in most other areas of the soil.

The Tremant soil has moderate potential for producing forage. It responds moderately well to rangeland management. Where the range is in good or excellent condition, it produces forage year round. It is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing. In some areas this soil is calcareous in the surface layer and is therefore less productive than in most other areas of the soil.

If the Pinamt soil is used as sites for buildings or roads, it has few limitations. If the Tremant soil is used as sites for buildings or roads, the main limitation is the shrink-swell potential. The effects of shrinking and swelling can be reduced by maintaining a constant moisture content in the soil. Runoff should be diverted away from buildings. Landscaping plants that require little water should be used near building foundations, ar overwatering should be avoided. A sealer can be used under roads to prevent shrinking and swelling of the material below. The Pinamt soil is better suited to use a sites for buildings and roads than is the Tremant soil; therefore, buildings and roads should be located in are of the Pinamt soil if feasible.

If the soils in this unit are used for septic tank absorption fields, they have few limitations. In a few areas the substratum is somewhat finer in texture than typical for the soils, and in other areas the substratum weakly cemented. The reduced permeability in these areas may require the use of larger absorption fields.

Onsite investigation is needed to determine the mos suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIs, nonirrigated. The Pinamt soil is in the Limy Fan, 7- to inch p.z., range site, and the Tremant soil is in the Loamy Upland, 7- to 10-inch p.z., range site.

99—Pinamt-Tremant complex, low precipitation, to 10 percent slopes. This map unit is on fan terrace Elevation is 1,200 to 2,200 feet. The average annual precipitation is 2 to 7 inches, and the average annual temperature is 70 to 73 degrees F.

This unit is about 45 percent Pinamt extremely grav sandy loam and 35 percent Tremant gravelly loam. Th components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Carrizo soils drainageways and Chuckawalla, Ebon, Gunsight, and Rillito soils on fan terraces. The included areas make about 20 percent of the total acreage. The percentag varies from one area to another.

The Pinamt soil is deep and well drained. It formed alluvium derived dominantly from acid and basic igne rock. Typically, the upper 1 inch of the surface layer i brown, calcareous extremely gravelly sandy loam and the lower 2 inches is light brown, calcareous very gravelly loam. The upper 12 inches of the subsoil is yellowish red, calcareous very gravelly sandy clay loa and the lower 13 inches is light brown, calcareous extremely gravelly sandy clay loam. The substratum t depth of 60 inches or more is light brown, calcareous extremely gravelly sandy loam. In some areas this so noncalcareous to a depth of 20 inches or more.

Permeability of the Pinamt soil is moderately slow. vailable water capacity is low to moderate. Effective oting depth is 60 inches or more. Runoff is slow, and e hazard of water erosion is slight.

The Tremant soil is deep and well drained. It formed in luvium derived dominantly from acid and basic igneous ck. Typically, the surface layer is reddish yellow avelly loam 5 inches thick. The subsoil is reddish llow and yellowish red, calcareous sandy clay loam nd gravelly clay loam about 24 inches thick. The ubstratum to a depth of 60 inches or more is white, alcareous gravelly sandy loam. In some areas the soil is alcareous throughout.

Permeability of the Tremant soil is moderately slow. vailable water capacity is moderate. Effective rooting epth is 60 inches or more. Runoff is slow, and the azard of water erosion is slight.

This unit is used as rangeland and wildlife habitat.

The Pinamt soil has low potential for producing forage. responds slowly to rangeland management. Most of ne vegetation is produced following rainfall in winter and pring. In favorable winters, the production of annual rasses and forbs can support grazing for about 2 to 3 nonths. Little forage is available during the rest of the ear. In some areas this soil is noncalcareous in the rface layer and is therefore more productive than in t other areas of the soil.

The Tremant soil has moderate potential for producing orage. It responds moderately well to rangeland nanagement. Where the range is in good or excellent condition, it produces forage year round. The soil is easily traversed by livestock. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation. Fencing and developing watering facilities help to control grazing. In some areas this soil is calcareous in the surface layer and is therefore less productive than in most other areas of the soil.

This map unit is in capability subclass VIIs, nonirrigated. The Pinamt soil is in the Limy Fan, 2- to 7-inch p.z., range site, and the Tremant soil is in the Loamy Upland, 2- to 7-inch p.z., range site.

100—Quilotosa-Vaiva-Rock outcrop complex, 20 to 65 percent slopes. This map unit is on mountain slopes and hill slopes. Elevation is 1,200 to 3,000 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

This unit is about 50 percent Quilotosa extremely gravelly sandy loam, 20 percent Vaiva extremely gravelly sandy loam, and 20 percent Rock outcrop. The Quilotosa soil is dominantly on mountain slopes, the Vaiva soil is on hill slopes that have slopes of less than 25 percent, and the Rock outcrop is scattered oughout the unit. The components of this unit are so icately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Schenco soils on mountain slopes. The included areas make up about 10 percent of the total acreage. The percentage varies from one area to another.

The Quilotosa soil is very shallow and shallow and is well drained. It formed in alluvium and colluvium derived dominantly from granite and gneiss. Typically, the surface is covered with gravel, cobbles, and stones. The surface layer is light brown extremely gravelly sandy loam about 2 inches thick. The upper 12 inches of the underlying material is light brown, calcareous extremely gravelly loam, and the lower part to a depth of 18 inches is calcareous, highly fractured granite overlying unweathered granite.

Permeability of the Quilotosa soil is moderately rapid. Available water capacity is very low. Effective rooting depth is less than 20 inches. Runoff is medium to rapid, and the hazard of water erosion is moderate.

The Vaiva soil is very shallow and shallow and is well drained. It formed in alluvium and colluvium derived dominantly from granite and gneiss. Typically, the surface layer is brown very gravelly loam about 1 inch thick. The upper 2 inches of the subsoil is yellowish red very gravelly sandy loam, and the lower 8 inches is red, calcareous very gravelly sandy clay loam. Below the subsoil to a depth of 17 inches is highly fractured granite overlying unweathered granite.

Permeability of the Vaiva soil is moderate. Available water capacity is very low. Effective rooting depth is less than 20 inches. Runoff is medium to rapid, and the hazard of water erosion is moderate.

Rock outcrop consists of exposed areas of granite and gneiss.

This unit is used as rangeland and wildlife habitat.

The Quilotosa and Vaiva soils have moderate potential for producing forage. They respond moderately well to rangeland mangement. They can produce forage year round. Steepness of slope, the areas of Rock outcrop, and cobbles and stones on the surface limit use. Fencing and developing watering facilities help to improve distribution of livestock. Permitting a large number of livestock to graze for short periods of time promotes an efficient distribution of livestock and use of available forage. Resting pastures during alternate growing seasons helps to maintain or improve the vegetation.

If the soils in this unit are used as sites for buildings or roads, the main limitations are the depth to rock and slope. The cuts needed to provide nearly level building sites or roadbeds can expose bedrock that is difficult to excavate. Ripping or blasting, or both, may be necessary to remove bedrock to the desired depth. The very shallow and shallow depth to bedrock also interferes with excavation for installing utilities. Because of the steepness of slope, extensive cutting and filling are necessary to create a level building pad. Fill areas should be compacted to the same density as cut areas.

Cuts and fills are highly susceptible to erosion. The risk of erosion can be reduced by using diversions or terraces to reduce the length of slopes or by revegetating to slow runoff.

If the soils in this unit are used for septic tank absorption fields, the main limitations are the depth to rock and slope. Septic tank absorption fields may not operate properly in some areas of this unit.The limited depth to bedrock restricts the movement of effluent. Effluent is likely to flow through cracks in the rock, resulting in little filtration. Steepness of slope makes it difficult to control the distribution of effluent. Effluent can move along the surface of the bedrock and seep to the surface in downslope areas, creating a hazard to health. Alternatives include locating absorption fields in more suitable soils in adjacent areas and transporting the effluent to them by pipeline or installing community sewage systems. The use of septic tank absorption fields can create serious hazards in areas of the Vaiva soil. If the soil becomes saturated with water, slippage can occur in downslope areas.

Onsite investigation is needed to determine the most suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclass VIIe, nonirrigated. It is in the Granitic Hills, 7- to 10-inch p.z., range site.

101—Rillito loam, 0 to 3 percent slopes. This deep and well drained soil is on fan terraces. It formed in alluvium derived dominantly from acid and basic igneous rock. Most of the areas used as cropland have slopes of less than 1 percent. Elevation is 1,200 to 1,600 feet. The average annual precipitation is 7 to 10 inches, and the average annual air temperature is 70 to 73 degrees F.

Typically, the upper layer is light brown, calcareous loam about 11 inches thick. The next 13 inches is light brown, calcareous loam. The next 15 inches is light brown, calcareous, weakly lime- and silica-cemented gravelly loam. Below this to a depth of 60 inches or more is light brown, calcareous, weakly cemented extremely gravelly loam. In some areas the surface layer is gravelly loam. In a few areas the profile has slightly less gravel than is typical for this soil. Depth to the weakly cemented substratum ranges from 20 to 40 inches. Many of the pebbles in the soil are lime- and silica-cemented.

Included in this unit are small areas of Cipriano, Gunsight, Mohall, and Tremant soils on fan terraces and Gilman soils on flood plains. The included areas make up about 15 percent of the total acreage. The percentage varies from one area to another.

Permeability of this Rillito soil is moderate. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight.

This unit is used as irrigated cropland, as wildlife habitat, as rangeland, and for urban development.

If this unit is used as irrigated cropland, the main limitation is the depth to the weakly lime- and silica-cemented, gravelly substratum. Leveling cuts of 20 to inches generally will expose the substratum. Applicatio of manure or cotton gin trash are beneficial in leveled areas where cuts have exposed concentrations of lime Phosphorus should be applied in split applications in such areas because it is readily tied up in the soil. Citr trees, sorghum, and sudangrass in these limy areas ar subject to chlorosis. Lining irrigation ditches with concrete reduces loss of water by seepage. Applying manure or cotton gin trash or plowing under crop resic or green manure crops improves tilth and increases th water intake rate. Keeping tillage to a minimum also helps to maintain soil tilth.

The Rillito soil is one of the poorest forage-producin soils in the survey area. It responds very slowly to rangeland management. The high content of lime and the low available water capacity contribute to the low productivity of this soil. The included Gilman soils on flood plains are much more productive than are the ot soils in the unit. Management of the soils in this unit should therefore be concentrated on these included soils, because they produce nearly all the available forage.

If the soil in this unit is used as sites for buildings, roads, or septic tank absorption fields, it has few limitations. In a few areas the substratum is more strongly cemented than is typical for the soil. In these areas excavations may be limited and permeability ma be a concern.

Onsite investigation is needed to determine the mos suitable alternatives and the best design of buildings, roads, and septic tank absorption fields.

This map unit is in capability subclasses IIs, irrigatec and VIIs, nonirrigated. It is in the Limy Upland, 7- to 1 inch p.z., range site.

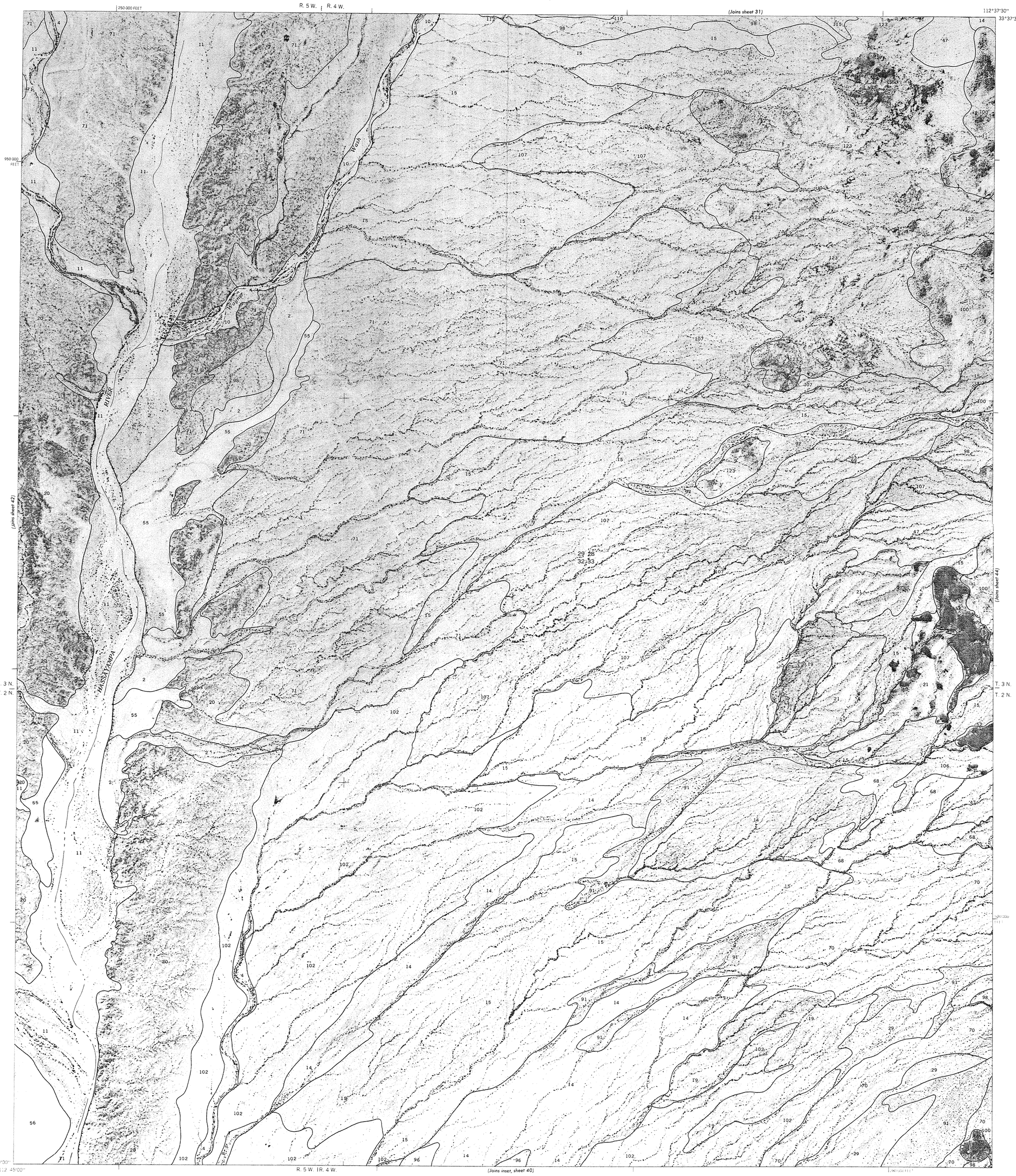
102—Rillito gravelly loam, 1 to 8 percent slopes. This deep and well drained soil is on fan terraces. It formed in alluvium derived dominantly from acid and basic igneous rock. Elevation is 1,100 to 1,800 feet. T average annual precipitation is 2 to 7 inches, and the average annual air temperature is 70 to 73 degrees F

Typically, the upper layer of this soil is pinkish gray, calcareous gravelly loam about 14 inches thick. Belov this to a depth of 60 inches or more is pinkish white, calcareous gravelly loam. In some areas the upper la is loam or very gravelly loam. In a few areas the profi has slightly less gravel than is typical for this soil.

Included in this unit are small areas of Mohall, Pina and Tremant soils on the tops of terraces; Gunsight a Cipriano soils scattered throughout the unit; Gilman, Antho, and Maripo soils on flood plains; and Carrizo s in drainageways. The included areas make up about

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SHEET NO. 43
AGUILA-CAREFREE AREA, PARTS OF
MARICOPA AND PINAL COUNTIES, ARIZONA



This soil survey was compiled in 1978 by the U. S. Department of Agriculture, Soil Conservation Service and cooperating agencies

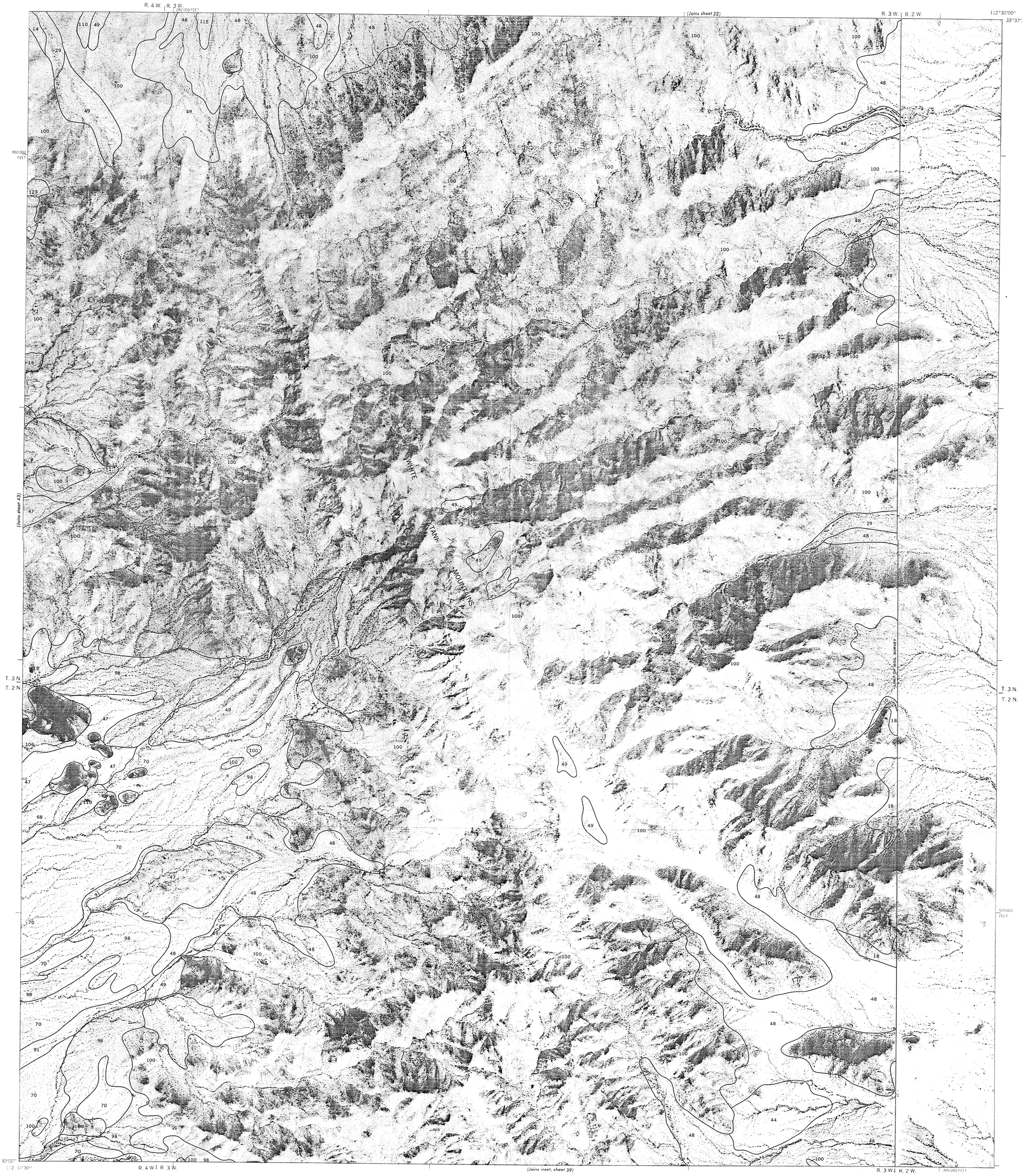
1 ¾ ½ ¼ 0 1 2 Miles
5000 4000 3000 2000 1000 0 5000 10000 Feet
Scale 1:24000

Orthophotobase compiled from 1972 and 1973 aerial photography by the U.S. Department of The Interior, Geological Survey. Planimetric detail obtained from 7½ minute series maps. 10,000-foot grid based on state coordinate system.

AGUILA — CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA NO. 43

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SHEET NO. 44
AGUILA-CAREFREE AREA, PARTS OF
MARICOPA AND PINAL COUNTIES, ARIZONA



This soil survey was compiled in 1978 by the U.S. Department of Agriculture, Soil Conservation Service and cooperating agencies

1 ¾ ½ ¼ 0 1 2 Miles
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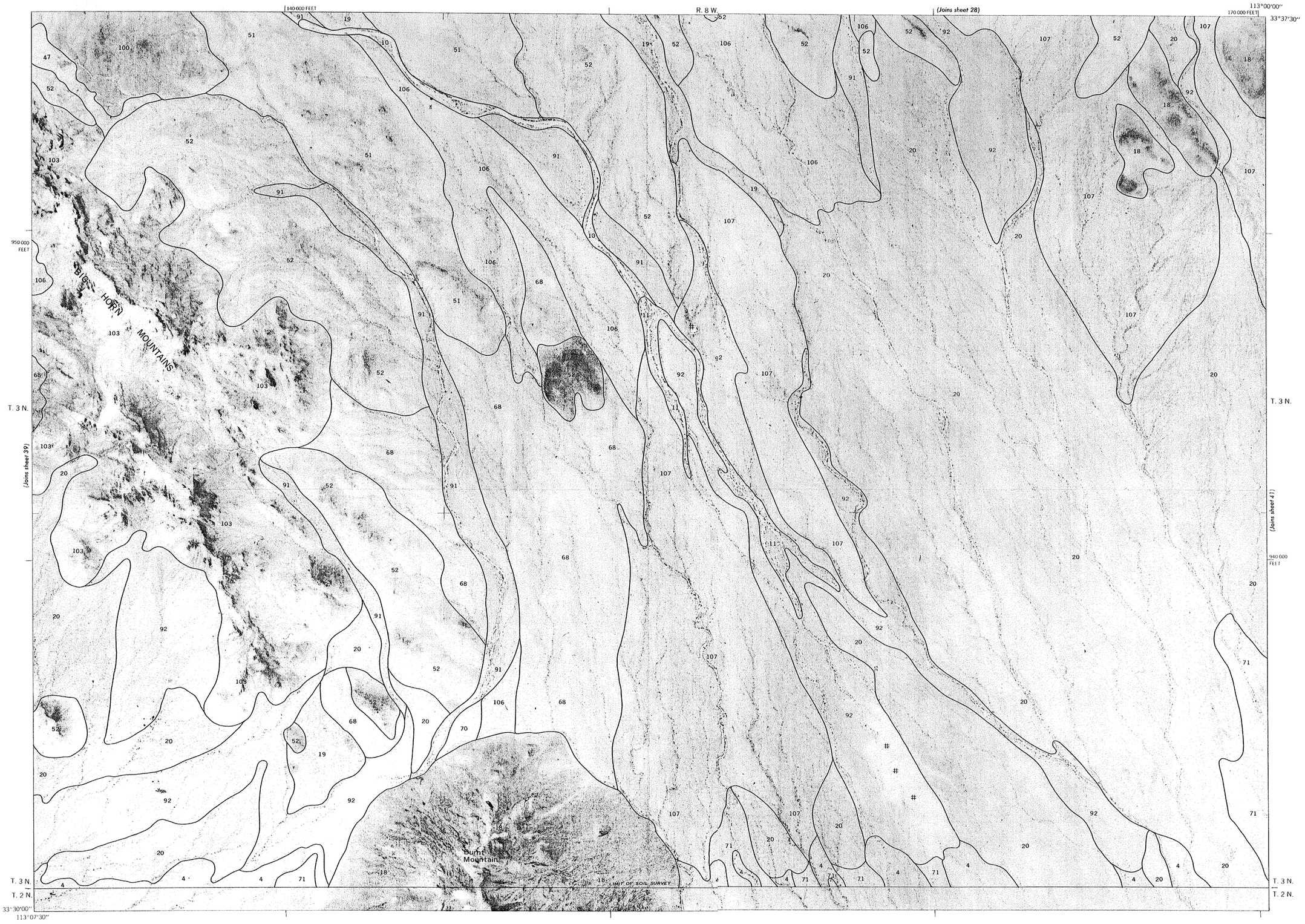
Scale 1:24 000

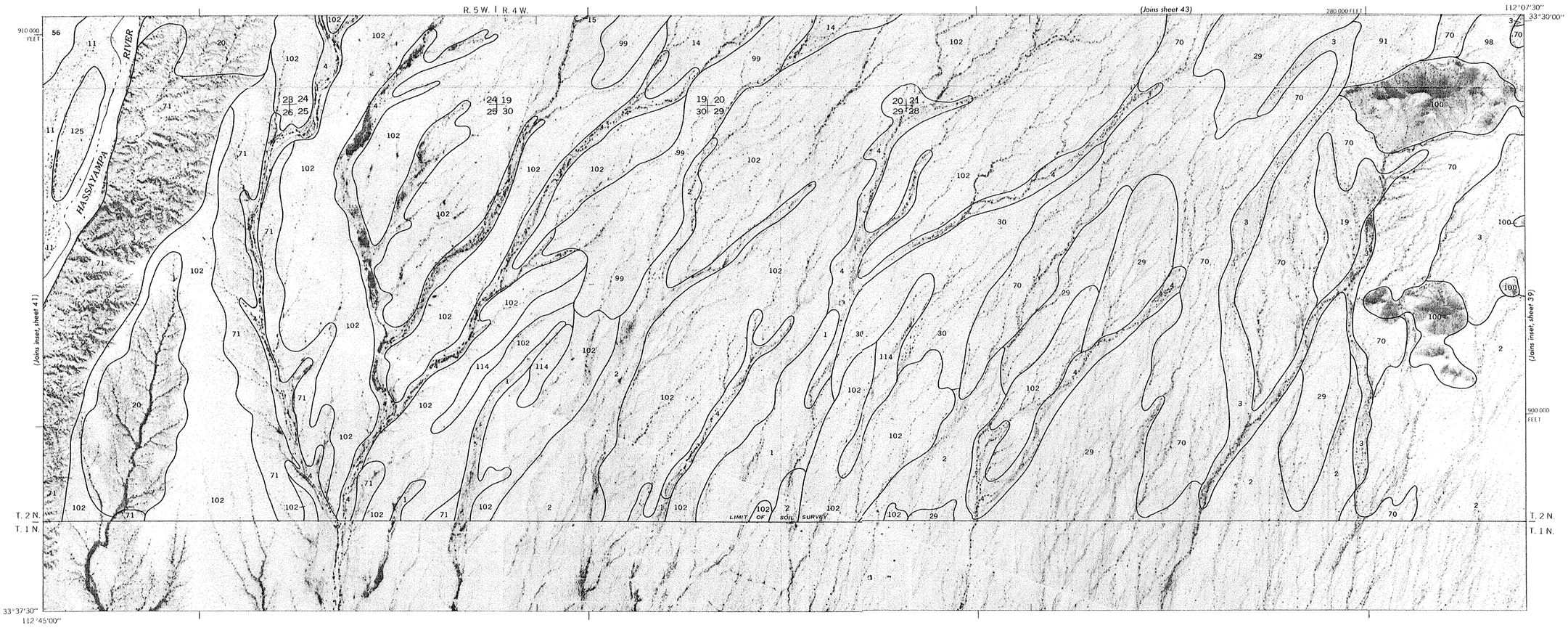
Orthophotobase compiled from 1972 and 1973 aerial photography by the U.S. Department of The Interior, Geological Survey. Planimetric detail obtained from 7½ minute series maps. 10,000-foot grid based on state coordinate system.

AGUILA — CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA NO. 44

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SHEET NO. 40
AGUILA-CAREFREE AREA, PARTS OF
MARICOPA AND PINAL COUNTIES, ARIZONA





1 ¾ ½ ¼ 0 1 2 Miles
5000 4000 3000 2000 1000 0 5000 10000 Feet
Scale 1:24000

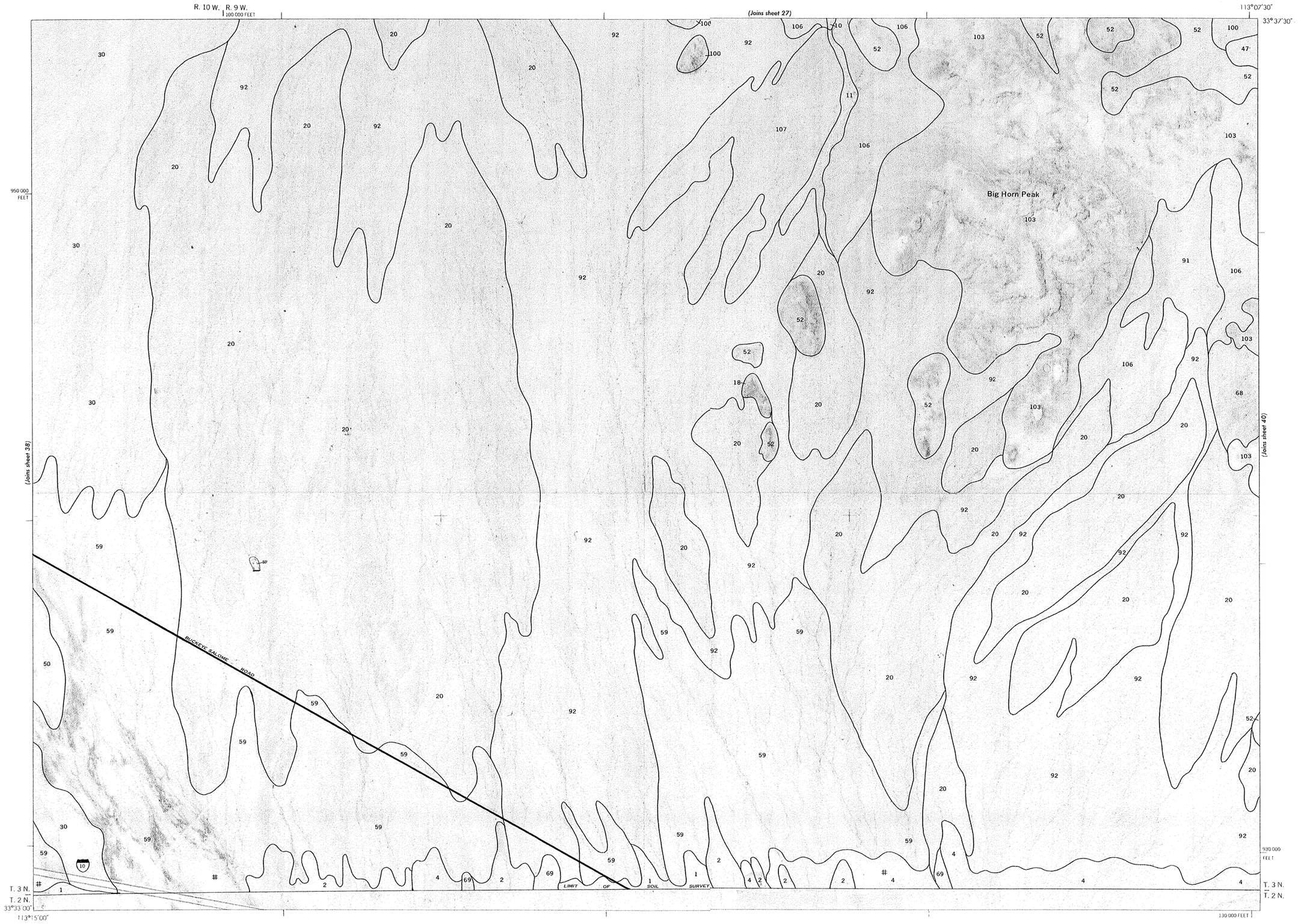
This soil survey was compiled in 1978 by the U.S. Department of Agriculture, Soil Conservation Service and cooperating agencies

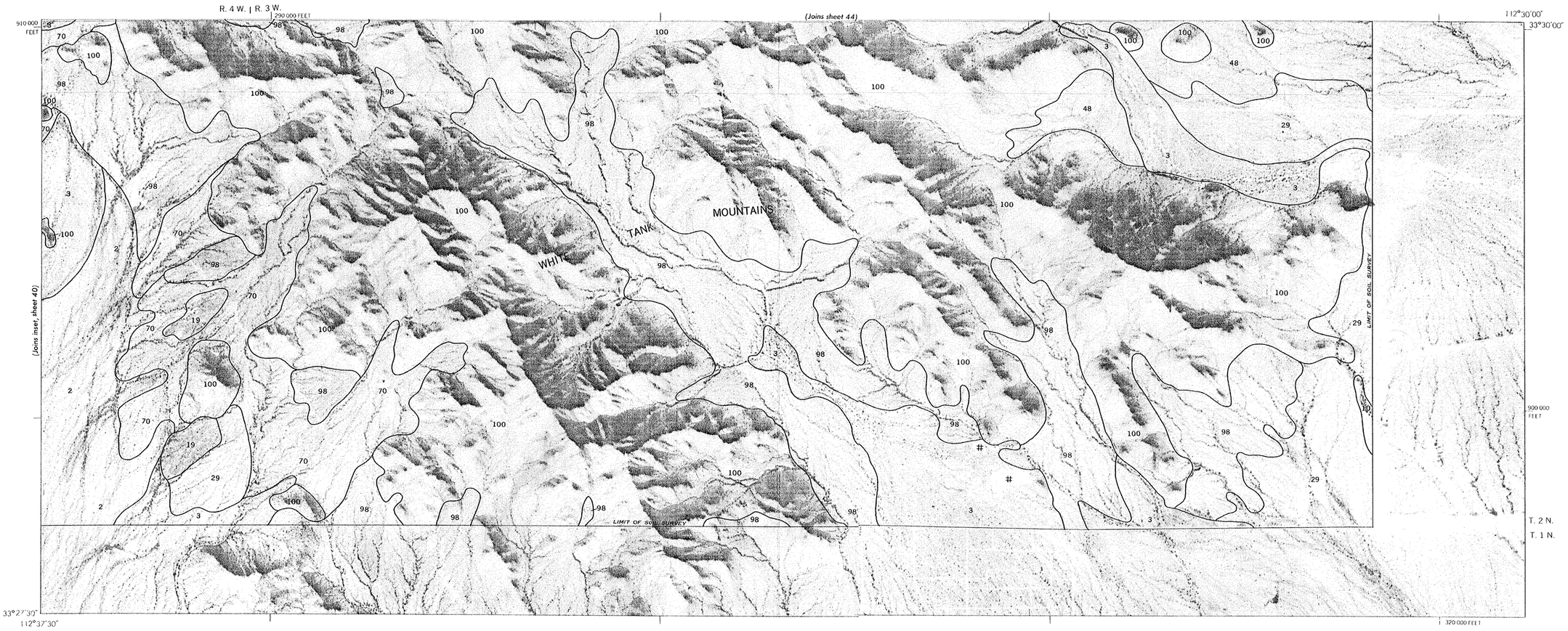
Orthophotobase compiled from 1972 and 1973 aerial photography by the U.S. Department of The Interior, Geological Survey. Planimetric detail obtained from 7½ minute series maps. 10,000-foot grid based on state coordinate system.

AGUILA — CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA NO. 40

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SHEET NO. 39
AGUILA-CAREFREE AREA, PARTS OF
MARICOPA AND PINAL COUNTIES, ARIZONA





This soil survey was compiled in 1978 by the U.S. Department of Agriculture, Soil Conservation Service and cooperating agencies

1 ¾ ½ ¼ 0 1 2 Miles
5000 4000 3000 2000 1000 0 5000 10000 Feet
Scale 1:24000

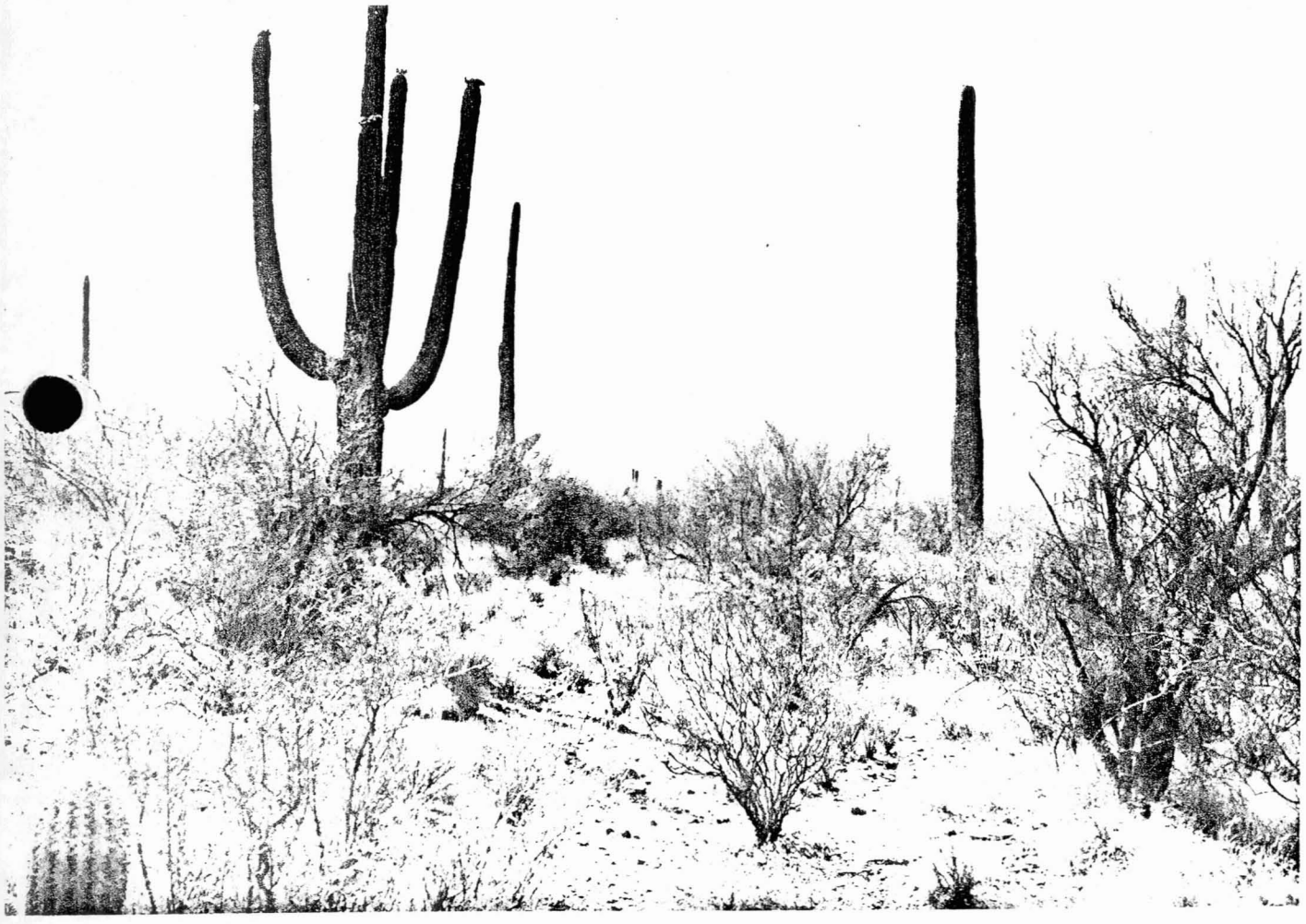
Orthophotobase compiled from 1972 and 1973 aerial photography by the U.S. Department of The Interior, Geological Survey. Planimetric detail obtained from 7½ minute series maps. 10,000-foot grid based on state coordinate system.

AGUILA — CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA NO. 39

SOIL SURVEY OF

Maricopa County, Arizona

Central Part



United States Department of Agriculture
Soil Conservation Service
in cooperation with
University of Arizona
Agricultural Experiment Station

TABLE 1.—*Approximate acreage and proportionate extent of the soils*—Continued

Soil	Acres	Percent [1]	Soil	Acres	Percent [1]
Valencia sandy loam, saline-alkali	1, 499	0. 14	Wintersburg complex	1, 378	0. 13
Valencia gravelly sandy loam	355	. 03	Borrow pits	655	. 06
Vecont loam	901	. 08	Dumps	149	. 01
Vecont clay	4, 691	. 44	Gravel pits	1, 261	. 11
Vint loamy fine sand	4, 107	. 38	Surveyed at High Intensity	651, 106	
Vint fine sandy loam	5, 141	. 48	Surveyed at Low Intensity	424, 523	
Vint loam	996	. 09	Lakes and all other water	701	. 06
Vint clay loam	396	. 04			
Vint-Carrizo complex	686	. 06	Total	[2] 1, 076, 330	100. 00

[1] Figures were rounded to nearest hundredth.

[2] Acreage includes water.

describing soils can be found in the Glossary at the end of this survey, and more detailed information about the terminology and methods of soil mapping can be obtained from the Soil Survey Manual (*5*).[2]

Agualt Series

The Agualt series consists of deep, well-drained soils. These soils formed in recent alluvium that was deposited on flood plains, low terraces, and alluvial fans. The alluvium was derived from a wide mixture of rock, including granite, granite-gneiss, andesite, and basalt. Slopes are 0 to 3 percent. Elevations are 800 to 1,500 feet. In areas not irrigated, the vegetation is creosotebush, cactus, annual weeds and grasses, and scattered mesquite and paloverde trees. The average annual rainfall is about 6 to 8 inches, the mean annual air temperature is 69° to 74° F, and the frost-free season is 250 to 300 days.

In a representative profile the soil is brown loam to a depth of about 27 inches and pale-brown sand to a depth of 60 inches. The soil is moderately alkaline throughout and in most places is calcareous throughout.

Premeability is moderate in the loamy upper part of the soil and very rapid in the sandy lower part. Runoff is slow, and the hazard of erosion is slight. The available water capacity is 5 to 7 inches. Roots penetrate to a depth of about 60 inches.

Agualt soils are used for irrigated crops, range, recreation, and wildlife. Irrigated crops are cotton, alfalfa, barley, safflower, sugar beets, sorghum, citrus, and vegetables.

Representative profile of Agualt loam, 200 feet east and 75 feet north of southwest corner of cultivated field SW¼SE¼SW¼ sec. 18, T. 2 N., R. 1 E.

Ap—0 to 11 inches, brown (10YR 5/3) loam, dark brown (10YR 3/3) when moist; massive; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; common fine and very fine roots; common very fine interstitial and tubular pores; common very fine mica flakes; strongly effervescent; moderately alkaline; abrupt, smooth boundary.

C1—11 to 27 inches, brown (10YR 5/3) loam, dark brown (10YR 3/3) when moist; massive; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; common fine and very fine roots; many very fine interstitial and tubular pores; common very fine mica flakes; strongly effervescent; few, fine, faint, light-gray (10YR 7/2) filaments of lime; moderately alkaline; abrupt, wavy boundary.

IIC2—27 to 60 inches, pale-brown (10YR 6/3) sand, brown (10YR 5/3) when moist; single grained; loose when dry, nonsticky and nonplastic when wet; few fine roots in upper part; many fine interstitial pores; many fine and very fine mica flakes; 5 percent fine waterworn gravel; slightly effervescent; moderately alkaline.

The soil is typically dry, but is sometimes moist in the upper part during July, August, and September. The Ap and C1 horizons have hue of 7.5YR and 10YR, value of 5 to 6 dry and 3 to 5 moist, and chroma of 2 through 4 dry and moist. They are very fine sandy loam or loam and have a few thin strata of finer and coarser material. The content of gravel ranges from 0 to about 10 percent. Lime filaments are few to common in the lower part of the C1 horizon. The IIC2 horizon is at a depth ranging from 20 to 39 inches, but is most commonly at 26 to 30 inches. It ranges from loamy sand to sand. In places this horizon is as much as 35 percent gravel. Thin strata of finer material are also common.

Agualt loam (Aa).—Areas of this soil are long and narrow and about 10 acres in size. Slopes are generally less than 1 percent, but range to 3 percent. Included in mapping are small areas of Gilman loam, 0 to 1 percent slopes; Maripo sandy loam; Antho sandy loam, 0 to 1 percent slopes; Carrizo gravelly sandy loam; and Laveen loam, 0 to 1 percent slopes. The total extent of all included soils does not exceed 15 percent.

This Agualt soil is used for grazing. Capability unit IIs–7 irrigated, subclass VIIs dryland; Loam Upland range site; horticultural group 4; wildlife habitat group 2 irrigated, 10 dryland.

Antho Series

The Antho series consists of deep, well-drained soils. These soils formed in recent alluvium deposited on alluvial fans and stream terraces. The alluvium was derived from a wide variety of rock, but was dominantly from granite. Slopes are generally less than 1 percent, but range to 3 percent. Elevations are 850 to 1,400 feet. In areas not cultivated, the vegetation is creosotebush, bursage, cactus, and scattered mesquite and paloverde trees. The precipitation is 6 to 8 inches, the mean annual air temperature is 69° to 74° F, and the frost-free season is 250 to 300 days.

In a representative profile the soil is light yellowish-brown and light-brown sandy loam to a depth of 47 inches and reddish-brown light sandy clay loam to a depth of 60 inches. The soil is slightly to strongly calcareous and moderately alkaline throughout. In places it is gravelly throughout.

[2] Italic numbers in parentheses refer to Literature Cited, p. 115.

Permeability is moderately rapid. Runoff is slow to medium, and the erosion hazard is slight to moderate. Roots penetrate to a depth of 60 inches.

Antho soils are used for irrigated crops, range, recreation, wildlife, and homesites. Irrigated crops are cotton, alfalfa, barley, sugar beets, sorghum, citrus, truck crops, and safflower.

Representative profile of Antho sandy loam, 0 to 1 percent slopes, 200 feet west and 110 feet north of southeast corner SW¼ sec. 16, T. 2 N., R. 1 W. in desert shrub area near Litchfield Park:

A1—0 to 1 inch, brown (10YR 5/3) light sandy loam, dark brown (10YR 5/3) when moist; weak, coarse, platy structure; slightly hard when dry, very friable when moist, nonsticky and nonplastic when wet; few very fine roots; common very fine tubular pores; slightly effervescent; moderately alkaline; abrupt, smooth boundary.

C1—1 to 13 inches, light yellowish-brown (10YR 6/4) light sandy loam, brown (10YR 4/3) when moist; massive; slightly hard when dry, very friable when moist, nonsticky and nonplastic when wet; many fine roots; common very fine tubular pores; slightly effervescent to noneffervescent; moderately alkaline; clear, smooth boundary.

C2—13 to 23 inches, light yellowish-brown (10YR 6/4) sandy loam, brown (10YR 4/3) when moist; massive; slightly hard when dry, very friable when moist, slightly sticky and nonplastic when wet; common very fine roots; common fine tubular pores; strongly effervescent; moderately alkaline; clear, smooth boundary.

C3—23 to 36 inches, light-brown (7.5YR 6/4) sandy loam, brown (7.5YR 5/4) when moist; massive; slightly hard when dry, very friable when moist, slightly sticky and nonplastic when wet; few very fine roots; common fine tubular pores; strongly effervescent; few fine faint filaments of lime; moderately alkaline; clear, smooth boundary.

C4—36 to 47 inches, light-brown (7.5YR 6/4) loamy sand, brown (7.5YR 5/4) when moist; massive; soft when dry, very friable when moist, slightly sticky and nonplastic when wet; few very fine roots; few interstitial pores; strongly effervescent; few fine faint filaments of lime; moderately alkaline; clear, wavy boundary.

IIB2tb—47 to 60 inches, reddish-brown (5YR 4/4) light sandy clay loam, reddish brown (5YR 4/4) when moist; massive; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few very fine roots; common very fine and few fine tubular and many interstitial pores; few thin clay films in tubular pores; strongly effervescent; few fine faint filaments of lime; moderately alkaline.

The A and C horizons have hue of 10YR and 7.5YR, value of 5 to 7 dry and 4 to 5 moist, and chroma of 2 to 4 dry and moist. These horizons are sandy loam or gravelly sandy loam and are 0 to 35 percent gravel. Strata of finer and coarser material are common. In places the A1 horizon is noneffervescent. Lime filaments are few to common in the C3 and C4 horizons. In places the soil has no IIB2tb horizon.

Antho sandy loam, 0 to 1 percent slopes (AbA).—This level to nearly level soil is on broad alluvial fans and low stream terraces. Slopes are less than 1 percent. Runoff is slow, and the hazard of erosion is slight. Except in cultivated areas, surface drainage is provided by a dendritic pattern of shallow stream channels spaced at 100- to 300-foot intervals. Areas are long and narrow and about 25 acres in size.

This soil has the profile described as representative of the series. Included in mapping are small areas of Maripo sandy loam; Agualt loam; Valencia sandy loam; Estrella loam; Gilman loam, 0 to 1 percent slopes; Coolidge sandy loam; and a soil that is similar to the Antho soil but has an 8- to 10-inch loam surface layer. The total extent of all included soils seldom exceeds 15 percent.

This Antho soil holds 5 to 7 inches of water available to plants. It is used for irrigated crops, range, recreation, wildlife, and homesites. Irrigated crops are cotton, alfalfa, barley, sugar beets, sorghum, safflower, citrus (fig. 5), and truck crops. Capability unit IIs–4 irrigated, subclass VIIs dryland; Loam Upland range site; horticultural group 1; wildlife habitat group 2 irrigated, 11 dryland.

Antho sandy loam, 1 to 3 percent slopes (AbB).—This gently sloping soil is on broad alluvial fans. Slopes are 1 to 3 percent, but a few are short and are as much as 5 percent. Runoff is medium, and the erosion hazard is moderate. Except in cultivated areas, surface drainage is provided by a dendritic pattern of shallow stream channels spaced at 100- to 300-foot intervals. Areas are long and narrow and about 10 acres in size.

Included with this soil in mapping are small areas of Gilman loam, 0 to 1 percent slopes; Maripo sandy loam; Coolidge sandy loam; and Antho gravelly sandy loam, 1 to 3 percent slopes. The total extent of all included soils seldom exceeds 15 percent.

This Antho soil holds 5 to 7 inches of water available to plants. About half the acreage is cultivated and is used for cotton, alfalfa, safflower, small grain, and citrus. The rest is grazed. A small part of the city of Phoenix is on this soil. Capability unit IIe–4 irrigated, subclass VIIe dryland; Loam Upland range site; horticultural group 1; wildlife habitat group 2 irrigated, 11 dryland.

Antho sandy loam, saline-alkali (Ac).—This nearly level soil is on valley plains in the Harquahala Valley and in the area near Wintersburg. Slopes are less than 1 percent and are slightly convex. Unless cultivated, areas are somewhat hummocky and are drained by a dendritic pattern of shallow stream channels spaced at 100- to 300-foot intervals. Areas are long and narrow and about 20 acres in size.

This soil has a profile similar to the one described as representative of the series, but is strongly alkaline at a depth of about 14 inches.

Included with this soil in mapping are small areas of Valencia sandy loam, saline-alkali; Gilman loam, saline-alkali; Laveen loam, saline-alkali; Antho sandy loam, 0 to 1 percent slopes; and Coolidge sandy loam. The total extent of all included soils seldom exceeds 20 percent.

The available water capacity is about 4 to 6 inches. Runoff is slow, and the hazard of erosion is slight.

Most of the acreage of this Antho soil is used for grazing. Irrigated crops are cotton, alfalfa, sorghum, and barley. Capability unit IIs–9 irrigated, subclass VIIs dryland; Saline Upland range site; horticultural group 5; wildlife habitat group 2 irrigated, 13 dryland.

Antho gravelly sandy loam, 0 to 1 percent slopes (AdA).—This level to nearly level soil is on the upper parts of alluvial fans and in overwash areas adjacent to stream channels. Slopes are less than 1 percent and are slightly convex. Unless cultivated, areas are drained by

dendritic pattern of shallow stream channels spaced at 50- to 200-foot intervals.

This soil has a profile similar to the one described as representative of the series, but it is 15 to 55 percent gravel.

Included with this soil in mapping are small areas of Antho sandy loam, 0 to 1 percent slopes; Maripo sandy loam; Brios sandy loam; and Valencia gravelly sandy loam. The total extent of all included soils does not exceed 15 percent.

Runoff is slow, and the erosion hazard is slight. The available water capacity is 5 to 7 inches.

About half the acreage of this Antho soil is cultivated. Cotton, alfalfa, sorghum, barley, and citrus are the chief crops. The rest of the acreage is grazed. Capability unit IIs–4 irrigated, subclass VIIs dryland; Loam Upland range site; horticultural group 1; wildlife habitat group 2 irrigated, 11 dryland.

Antho gravelly sandy loam, 1 to 3 percent slopes (AdB).—This gently sloping soil is on the upper part of alluvial fans. Slopes are 1 to 3 percent and convex. Runoff is medium, and the erosion hazard is moderate. Surface drainage is provided by a dendritic pattern of shallow stream channels spaced at 50- to 150-foot intervals. Areas are long and narrow and about 10 acres in size. They parallel stream channels.

This soil has a profile similar to the one described as representative of the series, but it is 15 to 35 percent gravel.

Included with this soil in mapping are small areas of alencia gravelly sandy loam; Rillito sandy loam, 1 to 3 percent slopes; Carrizo gravelly sandy loam; and Coolidge gravelly sandy loam, 1 to 3 percent slopes. The total extent of all included soils seldom exceeds 15 percent.

None of the acreage of this Antho soil is cultivated. It provides some grazing. Capability unit IIe–4 irrigated, subclass VIIe dryland; Loam Upland range site; horticultural group 1; wildlife habitat group 2 irrigated, 11 dryland.

Antho-Brios sandy loams (Ae).—This nearly level mapping unit is on broad alluvial fans and in the bottoms of broad intermittent stream channels. Slopes are less than 1 percent. Runoff is slow, and the erosion hazard is slight. Surface drainage is provided by a dendritic pattern of shallow stream channels spaced at 20- to 100-foot intervals. Areas are long and narrow and about 30 acres in size.

This mapping unit is about 45 percent Antho sandy loam, 0 to 1 percent slopes; 25 percent Brios sandy loam; and 20 percent Maripo sandy loam. The Brios soil occurs as long strips, 10 to 50 feet wide, that meander through larger areas of Antho soils. These strips form a braided pattern. The Maripo soil is in transitional areas between Brios and Antho soils. Included in mapping are a few small areas of Carrizo gravelly sandy loam, Gilman fine sandy loam, Agualt loam, and Valencia sandy loam. These included soils make up about 10 percent of the mapping unit.

Only about half the acreage is cultivated, and this acreage is within fields of better soils. The rest is grazed. Irrigated crops are cotton, alfalfa, sorghum, and grapes. Capability unit IIIs–7 irrigated, subclass VIIs dryland. Antho soil in Loam Upland range site; horticultural group 1; wildlife habitat group 2 irrigated, 11 dryland. Brios soil in Sandy Bottom range site; horticultural group 1; wildlife habitat group 4 irrigated, 11 dryland.

Antho-Carrizo complex, 0 to 1 percent slopes (AfA).—This nearly level mapping unit is on long, narrow stream terraces that parallel stream channels, and it is cut by one or more meandering channels. Slopes are generally less than 1 percent. Runoff is slow, and the erosion hazard is slight. About 30 to 40 percent of the surface area is covered with gravel. Areas range from 10 to 50 acres in size.

This mapping unit is about 50 percent Antho sandy loam, 0 to 1 percent slopes, and 30 percent Carrizo gravelly sandy loam. The Carrizo soil is in old stream channels that meander through larger areas of Antho soils. These channels are 2 to 5 feet above the present stream channel and ½ foot to 2 feet above the rest of the area. They form a braided pattern.

Included with this unit in mapping are small areas of Maripo sandy loam, Valencia sandy loam, Vint fine sandy loam, and Gilman fine sandy loam. The total extent of all included soils seldom exceeds 20 percent.

This mapping unit is sometimes used as range following seasonal rains. Few areas are cultivated. Irrigated crops are cotton, alfalfa, and citrus. Capability unit IVs–7 irrigated, subclass VIIs dryland. Antho soil in Loam Upland range site; horticultural group 1; wildlife habitat group 2 irrigated, 11 dryland. Carrizo soil in Sandy Bottom range site; horticultural group 4; wildlife habitat group 6 irrigated, 12 dryland.

Antho-Carrizo complex, 1 to 3 percent slopes (AfB).—This gently sloping mapping unit is on broad alluvial fans near the base of mountains. The largest area is in the Harquahala Valley near the base of the Big Horn Mountains. Slopes range from 1 to 3 percent but are dominantly 1½ to 2 percent. Runoff is medium, and the erosion hazard is moderate. About 30 to 40 percent of the surface area is covered with gravel and cobbles. Areas are oval in shape and range from 10 to 200 acres in size.

This mapping unit is about 40 percent Antho sandy loam, 1 to 3 percent slopes; 25 percent a Carrizo gravelly sandy loam that has 1 to 3 percent slopes; and 20 percent Maripo sandy loam that has 1 to 3 percent slopes. These soils have profiles similar to the ones described as representative of their respective series, but in some areas the Antho soil has a gravelly and cobbly stratum below a depth of 40 inches and the Maripo soil is gravelly throughout. The Carrizo soil occurs as long, narrow strips in old stream channels that meander through larger areas of Antho soils. These strips form a braided pattern. The Maripo soil is in transitional areas between Antho and Carrizo soils.

Included with this unit in mapping are small areas of Valencia gravelly sandy loam and Rillito sandy loam, 1 to 3 percent slopes. The total extent of all included soils seldom exceeds 15 percent.

This mapping unit is grazed. None of the acreage is cultivated. Capability subclass VIIe dryland; Antho soil in Loam Upland range site; horticultural group 1; wildlife habitat group 11 dryland. Carrizo soil in Sandy Bottom range site; horticultural group 4; wildlife habitat group 12 dryland.

Antho-Carrizo complex, 0 to 3 percent slopes (AGB).—This nearly level to gently sloping mapping unit is on alluvial fans that are 1 to 3 miles from the mountains and in some of the broader stream channels. Slopes are

mostly less than 1 percent, but a few convex ridges are more than 2 percent. In the more sloping parts, runoff is medium and the erosion hazard is moderate. Surface drainage is provided by a dendritic pattern of shallow stream channels spaced at 50- to 200-foot intervals. About 20 to 40 percent of the surface area is covered with gravel.

This mapping unit is about 35 percent an Antho sandy loam and an Antho gravelly sandy loam, 30 percent a Carrizo gravelly sandy loam, and 20 percent a Maripo sandy loam. The Carrizo soil is in or adjacent to old stream channels that form a braided pattern across larger bodies of Antho soils. The Maripo soil is in transitional areas between Carrizo and Antho soils.

Included with this unit in mapping are small areas of Brios sandy loam, Harqua gravelly loam, and Valencia sandy loam. The total extent of all inclusions seldom exceeds 15 percent.

This mapping unit provides grazing. Capability subclass VIIe dryland. Antho soils in Loam Upland range site; horticultural group 1; wildlife habitat group 11 dryland. Carrizo soil in Sandy Bottom range site; horticultural group 4; wildlife habitat group 12 dryland.

Antho-Tremant complex, 1 to 5 percent slopes (AHC).—This undulating mapping unit is on the upper part of alluvial fans that are ½ mile to 2 miles from the mountains. The largest area is on the east side of the White Tank Mountains. Slopes range from 1 to 5 percent. Runoff is medium, and the erosion hazard is moderate. Surface drainage is provided by a dentritic pattern of V-shaped stream channels spaced at 50- to 300-foot intervals. Areas range from 200 to 500 acres in size.

This mapping unit is about 40 percent an Antho gravelly sandy loam that has 1 to 5 percent slopes, and 30 percent a Tremant gravelly loam that has 1 to 3 percent slopes. The Antho soil has a profile similar to the one described as representative of the series, but it is 15 to 35 percent gravel. The Tremant soil has a profile similar to the one described as representative of the series, but the surface layer is gravelly loam 6 to 10 inches thick. The Antho soil is in slightly concave positions between stream channels and fan crests. The Tremant soil is on fan crests that are covered with a varnished desert pavement.

Included with this unit in mapping are small areas of Gunsight, Maripo, Rillito, Laveen, Carrizo, Mohall, Gilman, Valencia, and Estrella soils. The total extent of included soils does not exceed 30 percent of the unit.

This unit is not cultivated because slopes are complex. It provides grazing. Capability subclass VIIe dryland. Antho soil in Loam Upland range site; horticultural group 1; wildlife habitat group 11 dryland. Tremant soil in Loam Upland range site; horticultural group 2; wildlife habitat group 11 dryland.

Antho-Tremant-Mohall complex, 1 to 5 percent slopes (AkB).—This gently sloping to sloping mapping unit is on the upper parts of alluvial fans that are 1 mile to 3 miles from the base of the White Tank Mountains and other mountains. Elevation is generally more than 1,300 feet. Local relief is undulating, and slopes range from 1 to 5 percent. Runoff is medium, and the erosion hazard is moderate. A few slopes near stream channels are nearly 15 percent. On these, runoff is rapid. Surface drainage is provided by a dendritic pattern of V-shaped stream channels that are entrenched 5 to 25 feet. Areas are 200 to 400 acres in size.

This mapping unit is about 35 percent an Antho gravelly sandy loam that has 1 to 5 percent slopes; 15 percent Antho sandy loam, 1 to 3 percent slopes; 20 percent Tremant gravelly clay loam, 1 to 5 percent slopes, and 15 percent a Mohall gravelly sandy loam that has 0 to 1 percent slopes. These soils have profiles similar to the ones described as representative of their respective series, but the Antho gravelly sandy loam is 15 to 35 percent gravel and contains numerous thin strata of gravelly loamy sand and gravelly sand and the Mohall soil has a surface layer of gravelly sandy loam 5 to 10 inches thick. The Antho sandy loam and the Mohall and Tremant soils are on long, narrow convex ridges. From 40 to 90 percent of this surface area is covered with gravel and cobbles. The Antho sandy loam is in slightly concave depressional areas near stream channels.

Included with this unit in mapping are areas of Calciorthids and Torriorthents, eroded, along the margins of stream channels, where slopes range from 10 to 40 percent. Also included are a few small areas of Carrizo gravelly sandy loam and Gilman fine sandy loam. Included soils make up about 15 percent of this mapping unit.

This mapping unit provides grazing. None of the acreage is cultivated. Capability subclass VIIe dryland. Antho soils in Loam Upland range site; horticultural group 1; wildlife habitat group 11 dryland. Tremant soil in Loam Upland range site; horticultural group 2; wildlife habitat group 11 dryland. Mohall soil in Loam Upland range site; horticultural group 2; wildlife habitat group 11 dryland.

Antho association (AL).—This nearly level to gently sloping mapping unit is on alluvial fans that radiate out from nearby mountains. It occurs throughout the uncultivated part of the survey area, but is most extensive at the base of the Estrella Mountains in the Rainbow Valley. Slopes are generally less than 1 percent. Runoff is slow, and the erosion hazard is slight. A few slopes near stream channels are nearly 3 percent. On these, runoff is medium and the erosion hazard is moderate. Surface drainage is provided by a dendritic pattern of shallow stream channels, 1 foot to 3 feet deep, spaced at 50- to 300-foot intervals. Areas are somewhat pear shaped and range from 100 to 900 acres in size.

This mapping unit is about 55 percent an Antho sandy loam and 30 percent an Antho gravelly sandy loam. Antho gravelly sandy loam has a profile similar to the one described as representative of the series, but it is 15 to 35 percent gravel. Antho sandy loam is at the lower ends of alluvial fans farthest from the mountains. Antho gravelly sandy loam is on the higher parts of the alluvial fans nearest the mountains. Many of the more sloping areas have a few cobbles on the surface and in the profile.

Included with this unit in mapping are small areas of Coolidge sandy loam, Laveen sandy loam, Valencia sandy loam, Carrizo gravelly sandy loam, Maripo sandy loam, and Rock outcrop. The total extent of included soils seldom exceeds 15 percent of the unit.

This unit is grazed. None of the acreage is cultivated. Capability subclass VIIs dryland; Loam Upland range site; horticultural group 1; wildlife habitat group 11 dryland.

Antho-Valencia association (AM).—This mapping unit is on long, smooth valley plains that are 1 mile to 3 miles

from the base of the mountains. Slopes are 0 to 1 percent. Runoff is slow, and the erosion hazard is slight. Surface drainage is provided by a dendritic pattern of shallow stream channels, 1 foot to 3 feet deep, spaced at 50- to 200-foot intervals. Areas range from 200 to 2,000 acres in size.

This mapping unit is about 40 percent Antho sandy loam, 0 to 1 percent slopes, and 40 percent Valencia sandy loam.

Included with this unit in mapping are small areas of Coolidge sandy loam, Mohall sandy loam, and Gilman fine sandy loam. These included soils make up about 20 percent of the unit.

This mapping unit is grazed. None of the acreage is cultivated. Antho soil in capability subclass VIIs dryland; Valencia soil in capability subclass VIIc dryland. Both soils in Loam Upland range site; horticultural group 1; wildlife habitat group 11 dryland.

Avonda Series

The Avonda series consists of deep, well-drained soils on stream terraces and valley plains. These soils formed in recent mixed alluvium derived from acid and basic rocks, limestone, quartzite, and schist. They are mostly along the Gilea, Salt, and Agua Fria Rivers. Slopes are less than 1 percent. Elevations are 750 to 1,200 feet. The vegetation is creosotebush, mesquite, saltcedar, and annual weeds and grasses. The precipitation is 6 to 8 inches, the mean annual air temperature is 69° to 74° F, and the frost-free season is 250 to 290 days.

In a representative profile the surface layer is grayish-brown clay loam about 13 inches thick. The underlying material is light-brown loam to a depth of 27 inches and pinkish-gray and light-brown loam to a depth of 60 inches. The soil is moderately alkaline throughout and is weakly effervescent.

Permeability is moderately slow. Runoff is medium to slow, and the erosion hazard is slight. The available water capacity is 6 to 7 inches. Roots penetrate to a depth of about 60 inches.

Avonda soils are used for irrigated crops, range, recreation, and wildlife. Irrigated crops are cotton, alfalfa, barley, safflower, sorghum, and sugar beets.

Representative profile of Avonda clay loam, 2,730 feet south and 530 feet west of northeast corner sec. 4, T. 1 S., R. 3 W., in a cultivated field east of Buckeye:

Ap—0 to 13 inches, grayish-brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) when moist; weak, fine and medium, granular structure; slightly hard when dry, friable when moist, sticky and plastic when wet; common fine and very fine roots; few fine and very fine tubular and few medium interstitial pores; slightly effervescent; moderately alkaline; abrupt, smooth boundary.

C1—13 to 27 inches, light-brown (7.5YR 6/4) loam or very fine sandy loam, dark brown (7.5YR 4/4) when moist; massive; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; common very fine and fine roots; common very fine and fine tubular and common very fine interstitial pores; common mica flakes; strongly effervescent; moderately alkaline; clear, smooth boundary.

IIC2—27 to 60 inches, pinkish-gray (7.5YR 6/2) and light-brown (7.5YR 6/4) loamy coarse sand, brown (7.5YR 5/4) when moist; single grained; loose when dry and moist, nonsticky and nonplastic when wet; few very fine roots; many fine and coarse interstitial pores; few fine gravel; strongly effervescent; moderately alkaline.

Hue is 7.5YR and 10YR. The Ap horizon has value of 4 to 5 dry and 3 moist and chroma of 2 to 3 dry and moist. The A horizon is clay loam or silty clay loam. The C1 horizon has value of 5 to 6 dry and 3 to 5 moist and chroma of 3 to 4 dry and moist. The C2 horizon is loam or very fine sandy loam. In places filaments or threads of lime are common in the lower part of the C2 horizon. The IIC2 horizon has value of 6 or 7 dry and 4 or 5 moist and chroma of 3 or 4 dry and moist. The IIC2 horizon is loamy fine sand or coarser textured. Some soils are gravelly, but the gravel content is less than 15 percent. Some commonly are thinly stratified with finer textured material.

Avonda clay loam (An).—This soil is in long, narrow areas about ¼ to 1 mile from, and parallel to, major stream channels. Slopes are less than 1 percent. Areas range from 5 to 100 acres in size. Included in mapping are small areas of Avondale clay loam, Glenbar clay loam, Agualt loam, and Gilman loam, 0 to 1 percent slopes. The total extent of included soils seldom exceeds 2 percent.

This soil is used for range. Capability unit IIs–7 irrigated, subclass VIIs dryland; Sandy Bottom range site, horticultural group 4; wildlife habitat group 1 irrigated, 11 dryland.

Avondale Series

The Avondale series consists of deep, well-drained soils on stream terraces and alluvial plains. These soils formed in recent alluvium derived from basic and acid igneous rocks, quartzite, schist, and limestone. They are in the Buckeye and Salt River Valleys. Slopes are less than 1 percent. Elevations are 750 to 1,350 feet. In areas not cultivated the vegetation is creosotebush, saltcedar, mesquite, annual weeds, and grasses. The precipitation is 6 to 8 inches, the mean annual air temperature is 69° to 74° F, and the frost-free season is 250 to 300 days.

In a representative profile the surface layer is brown clay loam about 12 inches thick. The underlying material is pale brown to a depth of 60 inches. The soil is moderately alkaline and strongly effervescent throughout. In a few areas it is saline and very strongly alkaline.

Permeability is moderate or moderately slow. Runoff is slow, and the erosion hazard is slight. Roots penetrate to a depth of 60 inches.

Avondale soils are used for irrigated crops, range, recreation, and wildlife. Irrigated crops are cotton, alfalfa, barley, safflower, sorghum, sugar beets, grapes, citrus, and truck crops. Some areas are used as homesites.

Representative profile of Avondale clay loam, northwest corner SE¼NW¼ sec. 34, T. 1 N., R. 2 W., in a cultivated field:

Ap—0 to 12 inches, brown (10YR 5/3) clay loam, dark brown (10YR 3/3) when moist; weak, fine, subangular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many very fine roots; common fine and very fine interstitial pores; strongly effervescent; moderately alkaline; abrupt, smooth boundary.

C1—12 to 37 inches, pale-brown (10YR 6/3) loam, brown (10YR 4/3) when moist; massive; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; common very fine roots; many very fine and common fine tubular pores; common mica flakes; strongly effervescent; few fine filaments of lime; moderately alkaline; clear, smooth boundary.

run parallel to and are one-eighth to one-fourth mile from the main stream channels.

Calciorthids and Torriorthents, eroded, is highly variable remnants of old soils that were derived from mixed acid and basic igneous and some sedimentary rocks. It ranges from loamy sand to clay loam, is 35 to 85 percent gravel and cobbles, and is mainly very calcareous. Stones are on the surface in some areas. Included in mapping in some more gently sloping areas are small areas of Gunsight or Pinal soils. They make up less than 10 percent of the mapping unit.

Calciorthids and Torriorthents, eroded, provide a source of gravel and road fill, and some are used for grazing. Capability subclass VIIe dryland; Loam Upland range site; horticultural group 6; wildlife habitat group 12 dryland.

Carrizo Series

The Carrizo series consists of deep, excessively drained soils. These soils formed in recent alluvium deposited on flood plains along the major streams and along stream channels in alluvial fans. The alluvium was derived from a wide mixture of rock, including granite, granite-gneiss, andesite, and basalt. Slopes are mainly less than 5 percent, but range from 0 to 12 percent. Elevations are 750 to 1,400 feet. In areas not cultivated the vegetation is creosotebush, Indian ricegrass, six-weeks fescue, and scattered mesquite, paloverde, ironwood, and tamarix trees. The climate is arid continental. The average annual rainfall is 6 to 8 inches, the mean annual air temperature is 69° to 74° F, and the frost-free season is 250 to 300 days.

In a representative profile the surface layer is yellowish-brown gravelly sandy loam about 5 inches thick. The underlying material is pale-brown very gravelly loamy coarse sand and very gravelly coarse sand to a depth of 60 inches. The profile is moderately alkaline throughout and is weakly to moderately calcareous.

Permeability is rapid. Runoff is slow, and the erosion hazard is slight. The available water capacity is 2 to 4 inches. Roots penetrate to a depth of 60 inches. The soils are subject to occasional flooding.

Carrizo soils are seldom cultivated, but are used for range and wildlife and as a source of sand and gravel.

Representative profile of Carrizo gravelly sandy loam, 138 feet west and 200 feet south of the northeast corner of the SW¼ sec. 23, T. 4 N., R. 1 E. in a citrus grove north of Peoria:

Ap—0 to 5 inches, yellowish-brown (10YR 5/4) gravelly sandy loam, brown (10YR 4/3) when moist; massive; slightly hard when dry, very friable when moist, nonsticky and nonplastic when wet; few fine tubular and interstitial pores; 15 percent gravel and 3 percent cobbles; strongly effervescent; moderately alkaline; abrupt, smooth boundary.

C1—5 to 17 inches, pale-brown (10YR 6/3) very gravelly loamy coarse sand, brown (10YR 5/3) when moist; single grained; loose when dry; many fine interstitial pores; 38 percent gravel and 15 percent cobbles; strongly effervescent; moderately alkaline; clear, wavy boundary.

C2—17 to 25 inches, pale-brown (10YR 6/3) very gravelly coarse sand, brown (10YR 5/3) when moist; single grained; loose when dry; many fine interstitial pores; 38 percent gravel and 20 percent cobbles; slightly effervescent; moderately alkaline; clear, wavy boundary.

C3—25 to 60 inches, pale-brown (10YR 6/3) very gravelly coarse sand, dark yellowish brown (10YR 4/4) when moist; single grained; loose when dry; many fine interstitial pores; 35 percent gravel and 10 to 15 percent cobbles; slightly effervescent; moderately alkaline.

The soil is slightly to strongly effervescent. Hue of the Ap and C horizons is 10YR to 7.5YR, value is 5 to 7 dry and 4 or 5 moist, and chroma is 3 or 4 dry and moist. The A horizon is gravelly fine sandy loam, gravelly sandy loam, gravelly loamy sand, or gravelly sand. The content of coarse fragments ranges from slightly less than 15 to slightly more than 35 percent. The C horizon ranges from very gravelly coarse loamy sand to very gravelly coarse sand or sand. It is more than 35 percent coarse fragments. The coarse fragments are dominantly well-rounded pebbles and a few cobbles. Strata of finer textured material, ½ inch to 2 inches thick, are common in the C horizon.

Carrizo gravelly sandy loam (Cb).—This soil is in stream channels, on low terraces near stream channels, and on alluvial fans. It occurs throughout the survey area. Slopes are generally less than 1 percent, but in some undulating areas they are nearly 3 percent. Areas are long and narrow and are about 13 acres in size.

This soil has the profile described as representative of the series. Included in mapping are small areas of Maripo sandy loam; Brios loamy sand; Antho sandy loam, 0 to 1 percent slopes; Vint fine sandy loam; and Agualt loam. Also included are areas of other Carrizo soils that have a surface layer of loam, sand, or gravelly loam; and areas where a buried limy soil is below a depth of 30 inches. The total extent of all included soils seldom exceeds 15 percent.

This soil provides grazing and a source of sand and gravel for construction. It is used for irrigated crops only where it occurs within fields of better soils. Capability unit IVs–7 irrigated, subclass VIIs dryland; Sandy Bottom range site; horticultural group 4; wildlife habitat group 6 irrigated, 12 dryland.

Carrizo-Ebon complex, 3 to 12 percent slopes (CeD).—This gently sloping to moderately steep mapping unit is on alluvial fans, mainly at the base of the Salt River Mountains. Slopes range from 3 to 12 percent and are 400 to 2,000 feet long. The steeper slopes are mostly the short sides of deep drainageways that dissect the area at 50- to 300-foot intervals. The poorly sorted, very gravelly and cobbly underlying material is mainly derived from the granite-gneiss mountains.

This mapping unit is about 60 percent a Carrizo gravelly sandy loam that has 3 to 5 percent slopes and 30 percent an Ebon gravelly loam that has 3 to 12 percent slopes. Ebon soils are on long, narrow, slightly convex ridges that parallel long, narrow, slightly concave areas of Carrizo soils. Carrizo soils are in or near meandering stream channels, many of which are old and cut off and are now 1 foot to 5 feet above the present channel. Ebon soils are more prevalent at the lower and upper ends of the alluvial fans.

Included with this unit in mapping are a few small areas of Tremant gravelly clay loam, 3 to 5 percent slopes; areas of Rock outcrop; and some areas of soils, near the base of the South Mountains, that are shallow to moderately deep over a weakly to strongly lime cemented pan. Included soils make up about 10 percent of this mapping unit.

This mapping unit provides grazing. None of the acreage is cultivated. Capability subclass VIIe dryland. Carrizo

C2sicam—6 to 12 inches, pinkish-white (7.5YR 8/2) and light-brown (7.5YR 6/4) extremely hard duripan, light brown (7.5YR 6/4) and pink (7.5YR 7/4) when moist; massive; ⅛-inch laminar layer on surface of pan; pan is 60 percent gravel; violently effervescent; moderately alkaline; abrupt, wavy boundary.

R—12 inches, extremely hard andesite bedrock that is fractured in places. Surface is coated with lime.

Depth to the indurated duripan ranges from 5 to 12 inches. Depth to bedrock ranges from 6 to 20 inches, but is dominantly 9 to 16 inches. These soils are generally dry, but are moist in places in summer, mainly in July, August, and September. The mean annual soil temperature ranges from 72° to 76° F. The duripan ranges from 1 to 8 inches in thickness.

The A1 and C1 horizons have hue of 10YR and 7.5YR and value of 6 or 7 dry and 3 to 5 moist. These horizons are loam, fine sandy loam, and very fine sandy loam. They range from 35 to 80 percent coarse fragments; the average content of coarse fragments is about 50 percent. About 5 to 30 percent of the coarse fragments are angular pieces of the duripan. In places a Cca horizon is just above the pan.

Cherioni-Rock outcrop complex (CO).—This mapping unit is on low hills and the lower slopes of mountains. It is dissected by low stream channels that have cut 3 to 20 feet below the surface. These channels are 50 to 200 feet apart. Gravel, cobbles, and stones cover 50 to 90 percent of the surface. Slopes are complex and range from 3 to 25 percent.

This mapping unit is about 50 percent a Cherioni very gravelly loam that has slopes of 3 to 25 percent and about 20 percent Rock outcrop. The Cherioni soil is on the lower slopes of mountains and low hills, and Rock outcrop is on the upper slopes.

Included with this unit in mapping are some areas of a very gravelly loam that has an accumulation of lime just above the bedrock. This soil is in similar positions to those of the Cherioni soil. Also included are areas of Gachado very gravelly clay loam, Pinal soils, Gunsight soils, and Rillito soils. These included soils seldom make up more than 30 percent of the mapping unit.

This mapping unit provides grazing. It is not cultivated. A few areas in the city of Phoenix are used as homesites. Capability subclass VIIe dryland. Loam Hills range site; horticultural group 7; wildlife habitat group 12 dryland.

Coolidge Series

The Coolidge series consists of deep, well-drained soils. These soils formed in alluvium deposited on old alluvial fans and valley plains. The alluvium was derived from granite, granite-gneiss, schist, limestone, andesite, rhyolite, tuff, and basalt. Slopes are 0 to 3 percent. Elevations are 800 to 1,400 feet. In areas not cultivated, the vegetation is creosotebush, annual weeds and grasses, bursage, cactus, and scattered mesquite and paloverde trees. The average annual rainfall is 6 to 8 inches, the mean annual air temperature is 69° to 74° F, and the frost-free season is 250 to 300 days.

In a representative profile the soil is light yellowish-brown sandy loam to a depth of about 24 inches and pale-brown sandy loam to a depth of 63 inches. The lower part contains filaments and nodules of lime. The soil is moderately alkaline throughout and is strongly to violently effervescent.

Permeability is moderately rapid. Runoff is medium to slow, and the erosion hazard is light to moderate. The available water capacity is 6 to 7 inches. Roots penetrate to a depth of 60 inches or more.

Coolidge soils are used for irrigated crops, range, recreation, and wildlife. Irrigated crops are cotton, alfalfa, barley, safflower, sorghum, sugar beets, citrus, and grapes. Parts of the cities of Phoenix and Buckeye are on these soils.

Representative profile of Coolidge sandy loam, 600 feet west and 207 feet north of the southeast corner NE¼ NE¼ sec. 8, T. 1 N., R. 2 W., in a cultivated field northwest of Perryville:

Ap—0 to 13 inches, light yellowish-brown (10YR 6/4) sandy loam, brown (10YR 4/3) when moist; massive; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; violently effervescent; moderately alkaline; abrupt, smooth boundary.

C1—13 to 24 inches, light yellowish-brown (10YR 6/4) sandy loam, dark yellowish brown (10YR 4/4) when moist; massive; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few fine tubular pores; violently effervescent; many fine filaments of lime; moderately alkaline; abrupt, smooth boundary.

C2ca—24 to 42 inches, pale-brown (10YR 6/3) sandy loam, yellowish brown (10YR 5/4) when moist; massive; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many fine tubular pores; violently effervescent; many white (10YR 8/2) filaments of lime and medium lime nodules; moderately alkaline; abrupt, wavy boundary.

C3ca—42 to 63 inches, pale-brown (10YR 6/3) sandy loam, brown (10YR 5/3) when moist; massive; very hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few medium tubular pores; few pebbles; strongly to violently effervescent; many fine white filaments of lime and many medium lime nodules; moderately alkaline.

Depth to the calcic horizon ranges from 14 to 30 inches. The soil between depths of 10 and 40 inches averages sandy loam or fine sandy loam. The content of gravel averages less than 15 percent, but in any one strata it can be as much as 35 percent.

The soil has hue of 7.5YR and 10YR. The A horizon and C1 horizons have value of 5 or 6 dry and 4 or 5 moist and chroma of 3 or 4 dry and moist. The soil generally is sandy loam or fine sandy loam, but in places has a few ¼- to 1-inch strata of finer or coarser material in the C1 horizon. The Cca horizon has value of 5 to 7 dry and 3 to 5 moist and chroma of 2 to 4 dry and moist. It is dominantly sandy loam, but in places contains strata of loam or loamy sand. It contains soft powdery lime or is 5 to 10 percent lime nodules ¼ to ¾ inch in diameter, or both. It is more than 15 percent calcium carbonate. In places it is weakly cemented with lime.

Coolidge sandy loam (Cp).—This nearly level soil is on valley plains and alluvial fans. It occurs throughout the survey area, but is most extensive in the northern part of Buckeye Valley. Slopes are slightly convex and generally less than 1 percent, but in a few areas they are nearly 2 percent. Unless cultivated, areas are dissected by shallow stream channels at 50- to 300-foot intervals. They are long and narrow and about 55 acres in size.

This soil has the profile described as representative of the series. Included in mapping are small areas of Laveen sandy loam; Antho sandy loam, 0 to 1 percent slopes; Rillito sandy loam, 0 to 1 percent slopes; Perryville sandy loam; and Valencia sandy loam. Also included in the Harquahala Valley and near Tonopah and Wintersburg are a few areas where the soil is strongly alkaline. The total extent of all included soils seldom exceeds 20 percent.

This soil is used for cultivated crops and grazing. Irrigated crops are cotton, alfalfa, barley, safflower, sugar

ts, sorghum, citrus, and grapes. Capability unit IIs–7 gated, subclass VIIs dryland; Loam Upland range site; horticultural group 2; wildlife habitat group 2 irrigated, 11 dryland.

Coolidge gravelly sandy loam, 1 to 3 percent slopes (CrB).—This gently sloping soil is on old alluvial fans and low ridges. It occurs throughout the survey area. Slopes are slightly convex and generally about 2 percent, but some short slopes are as much as 3 percent. The erosion hazard is moderate. Areas are long and narrow and about 35 acres in size.

This soil has a profile similar to the one described as representative of the series, but the surface layer is gravelly sandy loam 6 to 14 inches thick.

Included with this soil in mapping are a few small areas of Rillito sandy loam, 1 to 3 percent slopes; Perryville sandy loam, 1 to 3 percent slopes; and Antho gravelly sandy loam, 1 to 3 percent slopes. Also included are a few areas of soils that are very strongly saline and alkaline in the lower part.

This Coolidge soil is grazed, but is seldom cultivated. Capability unit IIe–7 irrigated, subclass VIIe dryland; Loam Upland range site; horticultural group 2; wildlife habitat group 2 irrigated, 11 dryland.

Coolidge-Tremant complex (Cs).—This nearly level mapping unit is on old alluvial fans and valley plains in Rainbow Valley and in the northwestern part of Salt River Valley. Slopes are generally less than 1 percent, but in a few small areas are 2 percent or more. Most areas are long and narrow and about 40 acres in size.

This mapping unit is about 50 percent Coolidge gravelly dy loam and about 30 percent Tremant gravelly loam. The Tremant soil is in small circular areas that are covered with a varnish desert pavement and are surrounded by Coolidge soils. The Coolidge soil has a profile similar to the one described as representative of the series, but the surface layer is gravelly sandy loam 6 to 12 inches thick.

Included with this unit in mapping are small areas of Laveen loam, 0 to 1 percent slopes; Perryville gravelly loam, 0 to 1 percent slopes; Antho sandy loam, 0 to 1 percent slopes; and Rillito loam, 0 to 1 percent slopes. Also included are a few areas of Tremant soils that are slightly saline in the lower part. Included soils make up about 20 percent of unit.

This mapping unit provides grazing, recreational sites, and wildlife habitat. It is not cultivated, but several areas have been cleared and cultivated. Capability unit IIs–6 irrigated, subclass VIIs dryland; Loam Upland range site; horticultural group 2; wildlife habitat group 2 irrigated, 11 dryland.

Coolidge-Laveen association, 0 to 3 percent slopes (CV).—This nearly level to gently sloping mapping unit is on old alluvial fans in Rainbow Valley and in the area north of Buckeye. It is about ½ mile to 4 miles from granitic, granite-gneiss, and quartzitic mountains. It is dissected by stream channels at 50- to 300-foot intervals. Slopes are generally less than 1 percent, but a few short slopes are more than 2 percent. Areas range from 100 to 1,000 acres in size and are somewhat pear shaped.

This mapping unit is about 40 percent Coolidge sandy loam and 40 percent Laveen sandy loam. The Laveen soil has a profile similar to the one described as representative of the series, but the surface layer is sandy loam. The Coolidge soil is on the upper part of alluvial fans, and the Laveen soil is on the lower part.

Included with this unit in mapping are small areas of Antho sandy loam, 0 to 1 percent slopes; Perryville gravelly loam, 0 to 1 percent slopes; and Rillito loam, 0 to 1 percent slopes. Included soils make up about 20 percent of the unit.

This mapping unit is grazed. None of the acreage is cultivated. Coolidge soil in capability subclass VIIs dryland, Laveen soil in subclass VIIc dryland. Both soils in Loam Upland range site; horticultural group 2; wildlife habitat group 11 dryland.

Dune Land

Dune land (Dn) consists of ridges of very fine, fine, and medium sand that is drifted and deposited by wind. The dunes are 4 to 30 feet high, 100 to 500 feet wide, and ⅛ to ½ mile long. They are oriented to the north or northeast. In most places they are fairly stable and support some vegetation. The sand is dominantly light brown or pale brown and noncalcareous to weakly calcareous. Older material that is strongly calcareous and very strongly alkaline underlies the dunes.

Dune land is in the Harquahala Valley and in an area near Wintersburg. It provides grazing and wildlife habitat. Capability subclass VIIs dryland; Loam Upland range site; horticultural group 4; wildlife habitat group 12 dryland.

Ebon Series

The Ebon series consists of deep, well-drained soils. These soils formed on old alluvial fans that radiate out from the base of the White Tank, Salt River, and Estrella Mountains. The underlying material is very gravelly alluvium derived from granite and granite-gneiss. Slopes range from 0 to 10 percent. Elevations are 1,100 to 1,400 feet. In areas not cultivated the vegetation is bursage, creosotebush, ocotillo, cholla cactus, and scattered mesquite, paloverde, and ironwood trees. The average annual rainfall is 6 to 8 inches, the mean annual air temperature is 69° to 73° F, and the frost-free season is 260 to 300 days.

In a representative profile the surface layer is brown gravelly loam about 2 inches thick. The subsoil extends to a depth of 60 inches. The upper 11 inches is reddish-brown very cobbly clay loam, the next 25 inches is yellowish-red and reddish-brown very cobbly clay, and the lower 22 inches is light reddish-brown very cobbly sandy clay loam. The lower part contains a few filaments and soft spots of lime. The soil is moderately alkaline throughout. It is noneffervescent in the upper 23 inches.

Permeability is slow. Runoff is medium, and the erosion hazard is slight to moderate. The available water capacity is 4 to 6 inches. Roots penetrate to a depth of 60 inches or more.

Ebon soils are used mainly for recreation, wildlife, and range. They are not cultivated. A few areas are used as homesites.

Representative profile of Ebon gravelly loam, 0 to 8 percent slopes, 2,300 feet south and 1,450 feet west of northeast corner of sec. 31, T. 3 N., R. 2 W. in an uncultivated area at the base of the White Tank Mountains:

A1—0 to 2 inches, brown (7.5YR 5/4) gravelly loam, reddish brown (5YR 4/4) when moist; weak, thick, platy structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet;

lored than the one described in the representative profile.

This Glenbar soil holds 11 to 13 inches of water available to plants. It is used for irrigated crops, range, recreation, and wildlife. Irrigated crops are cotton, alfalfa, wheat, barley, sorghum, safflower, sugar beets, citrus, grapes, and vegetables. Also, the soil is used as material for bricks. The town of Tolleson and parts of the cities of Phoenix and Glendale are on this soil. Capability unit I-1 irrigated, subclass VIIc dryland; Loam Upland range site; horticultural group 1; wildlife habitat group 1 irrigated, 11 dryland.

Glenbar clay loam, saline-alkali (Gu).—This level to nearly level soil is on flood plains and low alluvial terraces along the Gila and Salt Rivers. Slopes are less than 1 percent. Areas are smooth, are oblong in shape, and range from 3 to 100 acres in size.

This soil has a profile similar to the one described as representative of the series, but it is slightly saline to strongly saline. In areas not cultivated, the surface is generally covered with a thin white crust of salt. In irrigated areas, the soil is commonly nonsaline in the upper 20 inches.

This soil is mainly well drained, but is moderately well drained to somewhat poorly drained in a few areas below canals. The available water capacity is 7 to 8 inches.

Included with this soil in mapping are small areas of Avondale clay loam, saline-alkali; Cashion clay, saline-alkali; Gadsden clay, saline-alkali; and Gilman loam, saline-alkali.

This Glenbar soil is cultivated and used as range. Irrigated crops are cotton, alfalfa, barley, sorghums, safflower, and bermudagrass pasture. Capability unit IIs-9 irrigated, subclass VIIs dryland; Saline Upland range site; horticultural group 5; wildlife habitat group 1 irrigated, 13 dryland.

Glenbar clay (Gv).—This nearly level soil is on low stream terraces and valley plains, mainly in the southern half of the Salt River and Buckeye Valleys. Areas range from 5 to 100 acres in size, but are generally 20 to 30 acres.

This soil has a profile similar to the one described as representative of the series, but the surface layer is clay and ranges from 8 to 20 inches in thickness. In dry areas it generally has cracks that are one-half inch wide and 8 to 15 inches deep.

Included with this soil in mapping are small areas of Cashion clay, saline-alkali; Gadsden clay; and Avondale clay loam; and a few areas that are darker colored than described as representative of the series.

This Glenbar soil holds 10 to 12 inches of water available for plants. It is used for cotton, alfalfa, sugar beets, barley, sorghums, and safflower. It is also used for range. Capability unit IIIs-3 irrigated, subclass VIIs dryland; Loam Upland range site; horticultural group 1; wildlife habitat group 3 irrigated, 11 dryland.

Gunsight Series

The Gunsight series consists of deep, well-drained soils. These soils formed in mixed alluvium on old alluvial fans. Slopes range from 0 to 10 percent.

In areas not cultivated, the vegetation is creosotebush, annual weeds and grasses, and scattered mesquite and paloverde trees. Elevations are 800 to 1,400 feet. The climate is arid continental. The average annual rainfall ranges from about 6 to 8 inches, the mean annual air temperature is about 68° to 72° F, and the frost-free season is 250 to 300 days.

In a representative profile the surface layer is very pale brown and yellowish-brown gravelly loam about 1 inch thick. Below this is about 2 inches of light-brown loam, 4 inches of light-brown gravelly fine sandy loam, 39 inches of light-brown very gravelly loam, and 14 inches of yellowish-red and reddish-brown very gravelly sandy clay loam. The underlying material contains many soft lime masses and semirounded lime concretions (fig. 7) and in places is weakly cemented. The soil is moderately alkaline.

Permeability is moderate. Runoff is slow to medium, and the erosion hazard is slight to moderate. The available water capacity is 3 to 4 inches. Roots penetrate to a depth of 60 inches or more.

Gunsight soils are used for irrigated crops, range, recreation, and wildlife. Irrigated crops are cotton, alfalfa, citrus, and small grain. Some areas provide a source of gravel. A few areas are used as homesites.

Representative profile of Gunsight gravelly loam in an area of Gunsight-Rillito complex, 0 to 1 percent slopes, 500 feet north and 1,870 feet east of southwest corner of sec. 9, T. 1 S., R. 6 W. in an uncultivated area south of Wintersburg:

A1—0 to 1 inch, very pale brown (10YR 7/3) and yellowish-brown (10YR 5/4) gravelly loam, light yellowish brown (10YR 6/4) and dark yellowish brown (10YR 4/4) when moist; weak, thin, platy structure; slightly hard when dry, friable when moist, slightly sticky and

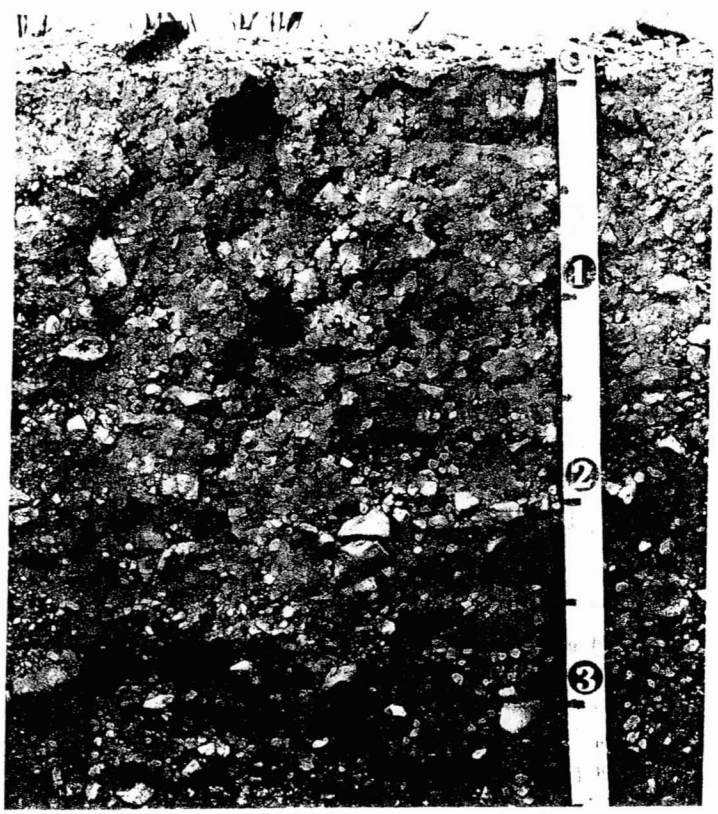


Figure 7.—**Profile of Gunsight gravelly loam. Soil is shallow over concentrations of lime.**

slightly plastic when wet; few fine roots; many fine and medium vesicular pores; 35 percent fine, medium, and coarse subangular gravel; strongly effervescent; very strongly alkaline; abrupt, smooth boundary.

C1—1 to 3 inches, light-brown (7.5YR 6/4) loam, brown (7.5YR 5/4) when moist; massive; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; few fine roots; few fine tubular and common fine interstitial pores; 10 percent fine, medium, and coarse subangular gravel; strongly effervescent; many, fine, distinct, pinkish-white (7.5YR 8/2) filaments of lime and few, fine, faint, soft lime masses; moderately alkaline; abrupt, smooth boundary.

C2ca—3 to 7 inches, light-brown (7.5YR 6/4) gravelly fine sandy loam, brown (7.5YR 5/4) when moist; massive; slightly hard when dry, very friable when moist, nonsticky and slightly plastic; common fine roots; common fine tubular pores; 25 percent fine, medium, and coarse subangular gravel; violently effervescent; common, fine, distinct, pinkish-white (7.5YR 8/2), soft lime masses and many, fine, distinct filaments of lime; moderately alkaline; clear, wavy boundary.

C3ca—7 to 33 inches, light-brown (7.5YR 6/4) very gravelly loam, brown (7.5YR 5/4) when moist; massive; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; few fine roots; common fine tubular and many fine interstitial pores; 50 percent fine, medium, and coarse subangular gravel; violently effervescent; common, fine and medium, distinct, pinkish-white (7.5YR 8/2), soft lime masses and common, fine, extremely hard, semi-rounded lime concretions; moderately alkaline; clear, wavy boundary.

C4ca—33 to 46 inches, light-brown (7.5YR 6/4) very gravelly loam, brown (7.5YR 5/4) when moist; massive; slightly hard when dry, very friable when moist; slightly sticky and slightly plastic when wet; common fine tubular pores; 50 percent fine, medium, and coarse subangular gravel; violently effervescent; common, fine and medium, distinct, pinkish-white (7.5YR 8/2), soft lime masses and extremely hard semi-rounded lime concretions; moderately alkaline; abrupt, wavy boundary.

IIB2b—46 to 67 inches, yellowish-red (5YR 5/6) and reddish-brown (5YR 5/4) very gravelly sandy clay loam, yellowish red (5YR 5/6) and reddish brown (5YR 5/4) when moist; massive; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many fine and medium interstitial pores; 55 percent fine, medium, and coarse subangular gravel; noneffervescent in matrix, strongly effervescent in common, medium, distinct, pinkish-white (7.5YR 8/2) masses of lime or volcanic ash; few, fine, pinkish-white, soft masses of salt; moderately alkaline.

Depth to the Cca horizon ranges from 3 to 20 inches, but averages about 9 inches. The soil is commonly sandy loam or loam that is 35 to 70 percent semirounded, generally lime-coated gravel at a depth of 10 to 40 inches. In some areas about 5 to 25 percent of the coarse fragments are extremely hard, semirounded lime concretions.

In areas not cultivated, 50 to 90 percent of the surface is covered with gravel. In cultivated areas the A1 horizon is mixed with the C1 horizon and the resulting Ap horizon is 15 to 40 percent gravel. The A horizon has hue of 7.5YR and 10YR, value of 6 and 7 dry and 4 or 5 moist, and chroma of 3 or 4 dry and moist.

The C horizon has hue of 7.5YR to 10YR, value of 5 to 8 dry and 4 to 7 moist, and chroma of 2 to 4 dry and moist. In places the Cca horizon is weakly cemented and contains a few pockets of strongly cemented material.

Gunsight-Pinal complex, 1 to 10 percent slopes (GWD).—This gently sloping to moderately steep mapping unit is on old alluvial fans in the western part of the survey area. It is dissected by drainageways, 2 to 15 feet deep, at 50- to 300-foot intervals. About 30 to 70 percent of the surface area is covered with angular cobbles and gravel and a few stones. Slopes are mainly about 3 percent, but some of the larger alluvial fan tops are nea 1 percent and some short slopes along drainageways nearly 10 percent.

This mapping unit is about 40 percent a Gunsi cobbly loam, 30 percent a Pinal gravelly loam, and 12 p cent a Pinamt cobbly loam. The Gunsight soil is on sides and on some tops of alluvial fans. It has a pro similar to the one described as representative of the ser but the surface layer is cobbly and slopes range from 1 10 percent. The Pinal soil is on the tops of alluvial f and in a few drainageways. The profile of this soil is sim to the one described as representative of the series, slopes range from 1 to 3 percent. The Pinamt soil is on tops and shoulders of some fans.

Included with this unit in mapping are a few area Rillito gravelly loam, 1 to 3 percent slopes; Antho grav sandy loam, 1 to 3 percent slopes; and Carrizo very gr elly sand. These included soils make up about 18 perc of the mapping unit.

This mapping unit provides grazing. Capability subc VIIe dryland; Gunsight soil in Loam Upland range s horticultural group 6; wildlife habitat group 11 dryl Pinal soil in Loam Upland range site; horticultural gr 7; wildlife habitat group 11 dryland.

Gunsight-Rillito complex, 0 to 1 percent slopes (GxA This deep, well-drained mapping unit is on old allu fans throughout the survey area. It is dissected by sha stream channels spaced at 200- to 500-foot inter About 40 to 90 percent of the surface area is covered gravel. Slopes range from 0 to 1 percent. Areas range f 5 to 250 acres in size, but most are less than 20 acres.

This mapping unit is about 45 percent a Gunsight g elly loam and 45 percent a Rillito gravelly loam that 0 to 1 percent slopes. The Gunsight soil has the pr described as representative of the series. The Ri soil has a profile similar to the one described as represe tive of the series, but the surface layer is gravelly lo The Gunsight soil is in small, oval-shaped areas near center of alluvial fans. It is surrounded by the Ri soil, which is in slightly lower positions.

Included with this unit in mapping are small are Laveen loam, 0 to 1 percent slopes, and Harqua gra clay loam, 0 to 1 percent slopes. Also included are a areas of Rillito and Gunsight soils that are slightly s to moderately saline in the lower part. The total exte all included soils is about 10 percent.

Only a small acreage of this mapping unit is cultiv Cotton, alfalfa, barley, and citrus are grown. The u also used as range. Capability unit IVs–7 irrigated, class VIIs dryland; Loam Upland range site; horticul group 6; wildlife habitat group 7 irrigated, 11 dryland.

Gunsight-Rillito complex, 1 to 3 percent slopes (GxE This gently sloping mapping unit is on old alluvial It is dissected by shallow stream channels that ro parallel the alluvial fans. About 40 to 90 percent o surface area is covered with gravel and a few co Slopes are convex and mainly range from 1 to 3 per but a few short slopes are nearly 5 percent. Areas are and narrow and range from 3 to 40 acres in size.

This mapping unit is about 45 percent a Gun gravelly loam and 45 percent a Rillito gravelly loa to 3 percent slopes. Except for texture of the surface l the Rillito soil has a profile similar to the one desc as representative of the series.

ıded with this unit in mapping are a few small areas veen loam, 0 to 1 percent slopes; Pinal loam, 1 to 3 cent slopes; Coolidge gravelly sandy loam, 1 to 3 cent slopes; and Harqua gravelly clay loam, 0 to 1 cent slopes. Also included are a few areas of Rillito and nsight soils that are moderately saline to strongly ine in the lower part. The total extent of all included ls is about 10 percent.

This mapping unit is used for range. It is not cultivated. pability subclass VIIe dryland; Loam Upland range e; horticultural group 6; wildlife habitat group 11 yland.

Gunsight-Rillito complex, 0 to 10 percent slopes ;YD).—This nearly level to moderately steep mapping it is on old alluvial fans. It is dissected by a series of ream channels at about 100- to 500-foot intervals. The ream channels range from a few feet to as much as 30 et deep. Slopes on the tops of fans are seldom more than percent, but short slopes along stream channels range to) percent. Areas are long and narrow and range from 50) 1,000 acres in size.

This mapping unit is about 40 percent Gunsight soils nd 40 percent Rillito soils. The Gunsight soils have a rofile similar to the one described as representative of he series, but the surface layer is gravelly loam, cobbly oam, and gravelly sandy loam and the soils are slightly aline below a depth of 30 inches. Gunsight soils are nainly on the top of fans. Rillito soils have a profile similar to the one described as representative of the series, ut the surface layer is loam, gravelly loam, gravelly sandy n, and sandy loam and in places the soils are slightly ine below a depth of 30 inches. The Rillito soils are in circular spots near drainageways and near the tops of fans.

Included with this unit in mapping are small areas of Perryville gravelly loam, 0 to 3 percent slopes; Laveen loam, 0 to 3 percent slopes; Pinal loam, 0 to 3 percent slopes; Gilman loam, 0 to 1 percent slopes; Antho gravelly sandy loam; 0 to 3 percent slopes; and Carrizo gravelly sandy loam, 0 to 1 percent slopes. These included soils make up about 20 percent of the mapping unit.

The mapping unit is used for range. Capability subclass VIIe dryland; Loam Upland range site; horticultural group 6; wildlife habitat group 11 dryland.

Harqua Series

The Harqua series consists of deep, well-drained soils on old alluvial fans. These soils are strongly saline and have distinct accumulations of calcium carbonate at a depth of about 12 inches. They formed in alluvium derived from granite, schist, gneiss, and rhyolite. Slopes are mostly 0 to 4 percent but range to as much as 8 percent. Elevations are 800 to 1,350 feet. The native vegetation is saltbush, creosotebush, mesquite, paloverde, and annual weeds and grasses. The average annual rainfall is 6 to 8 inches, the mean annual air temperature is 69° to 74° F, and the frost-free season is 250 to 300 days.

In a representative profile the surface layer is pinkish-gray and light reddish-brown gravelly clay loam and loam about 3 inches thick. The subsoil is reddish-brown, light reddish-brown, and pink gravelly clay loam about 25 inches thick. The underlying material is light-brown clay loam and gravelly clay loam to a depth of 60 inches. The underlying material and lower part of the subsoil contain segregations, filaments, and soft masses of lime. The soil is strongly saline and moderately alkaline.

Permeability is moderately slow. Runoff is slow to medium, and the erosion hazard is slight. The available water capacity is about 6 to 8 inches. Roots penetrate to a depth of 60 inches or more.

Harqua soils provide grazing. They are not cultivated.

Representative profile of Harqua gravelly clay loam in an area of Harqua complex, 0 to 3 percent slopes, 150 feet north and 1,550 feet south of northeast corner of sec. 13, T. 1 S., R. 9 W. in an uncultivated area at the south end of the Harquahala Valley:

A2—0 to 1 inch, pinkish-gray (7.5YR 7/2) gravelly clay loam, strong brown (7.5YR 5/6) when moist; weak, thick, platy structure; slightly hard when dry, firm when moist, sticky and plastic when wet; common vesicular pores; strongly effervescent; strongly alkaline; abrupt, smooth boundary.

A&Bsa—1 to 3 inches, pinkish-gray (7.5YR 7/2) and light reddish-brown loam, strong brown (7.5YR 5/6) and brown (7.5YR 5/4) when moist; weak, fine and medium, subangular blocky structure; slightly hard when dry, firm when moist, slightly sticky and plastic when wet; few tubular pores; strongly effervescent; moderately alkaline; abrupt, smooth boundary.

B21tsa—3 to 9 inches, reddish-brown (5YR 5/4) gravelly clay loam, yellowish red (5YR 4/6) when moist; weak, very fine, subangular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many very fine interstitial pores; few thin clay films in pores; slightly effervescent; moderately alkaline; clear, smooth boundary.

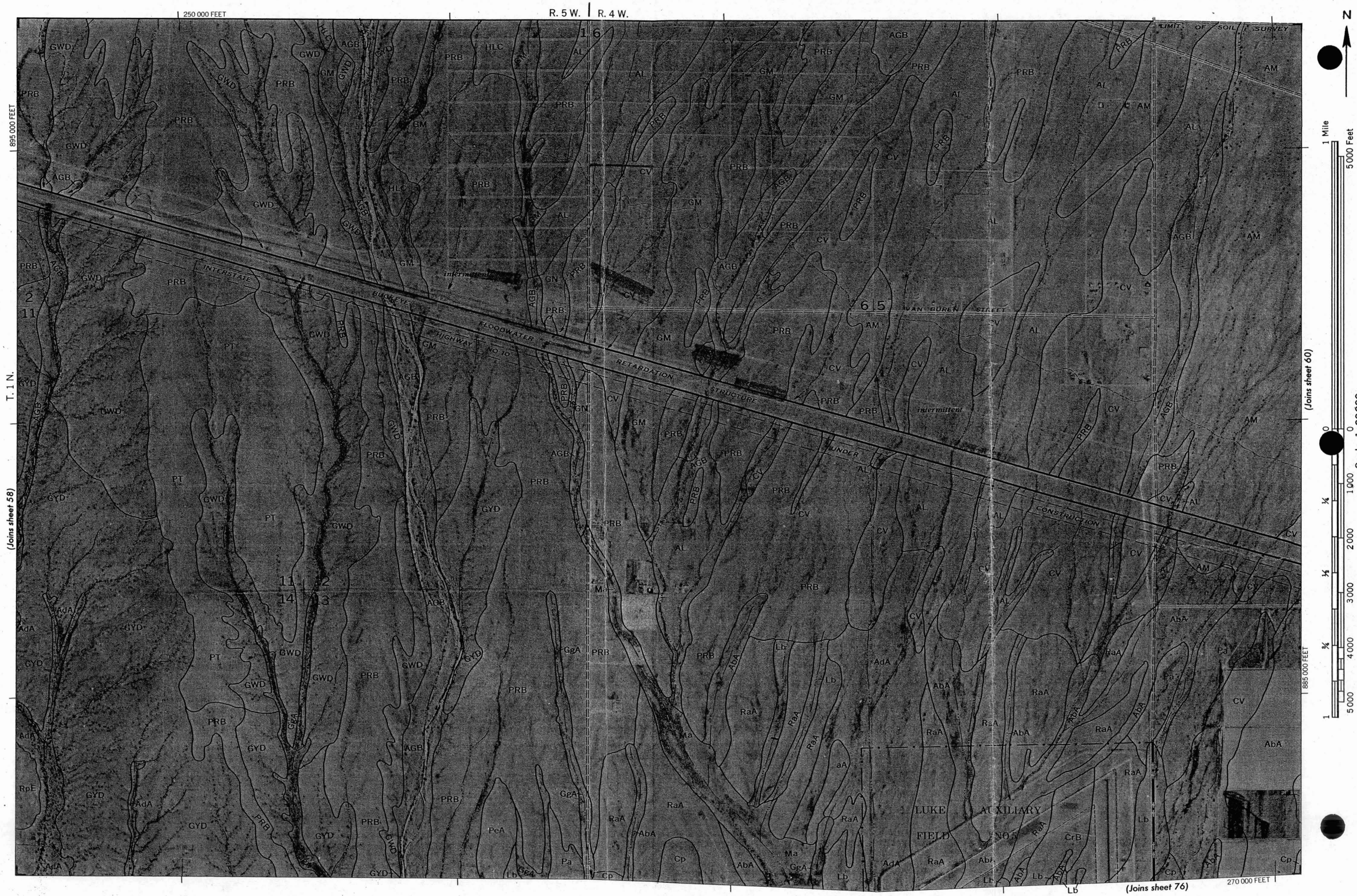
B22tsa—9 to 12 inches, light reddish-brown (5YR 6/4) gravelly clay loam, reddish brown (5YR 4/4) when moist; weak, fine, subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common fine tubular and many fine interstitial pores; common thin clay films on peds and in pores and as bridges between sand grains; slightly effervescent; common, fine, pink (5YR 8/3), soft lime masses and salt crystals; moderately alkaline; clear, smooth boundary.

B31tcasa—12 to 20 inches, light reddish-brown (5YR 6/4) gravelly clay loam, reddish brown (5YR 4/4 and 5/4) when moist; massive; hard when dry, friable when moist, sticky and plastic when wet; common fine and very fine tubular pores; few thin clay films in pores and as bridges between sand grains; violently effervescent; many, coarse, pink (5YR 7/3) lime segregations and soft lime masses; moderately alkaline; abrupt, smooth boundary.

B32casa—20 to 28 inches, pink (7.5YR 7/4) gravelly clay loam, brown (7.5YR 5/4) when moist; massive; hard when dry, friable when moist, sticky and plastic when wet; many fine and very fine discontinuous tubular and common fine interstitial pores; few thin clay films in pores; strongly to violently effervescent; many, coarse, pinkish-white (7.5YR 8/2) filaments of lime and common, fine, pinkish-white (7.5YR 8/2), soft lime masses; moderately alkaline; abrupt, smooth boundary.

C1casa—28 to 33 inches, light-brown (7.5 YR6/4) clay loam, brown (7.5YR 5/4) when moist; massive; very hard when dry, firm when moist, slightly sticky and plastic when wet; many very fine tubular pores; very few thin clay films in pores; slightly effervescent; common, fine, pinkish-white (7.5YR 8/2), soft lime masses; moderately alkaline; abrupt, smooth boundary.

C2casa—33 to 37 inches, light-brown (7.5YR 6/4) gravelly clay loam, dark brown (7.5YR 4/4) when moist; massive; very hard when dry, firm when moist, slightly sticky and plastic when wet; many fine and very fine tubular and interstitial pores; very few clay films in pores; slightly to strongly effervescent; common, medium, pinkish-white (7.5YR 8/2), soft


250 000 FEET
R. 5 W.
R. 4 W.
895 000 FEET
T. 1 N.
(Joins sheet 58)
(Joins sheet 60)
(Joins sheet 76)
270 000 FEET
885 000 FEET
LIMIT OF SOIL SURVEY
INTERSTATE HIGHWAY NO 10
BUCKEYE FLOODWATER RETARDATION STRUCTURE
UNDER CONSTRUCTION
VAN BUREN STREET
Intermittent
LUKE AUXILIARY FIELD NO 5
N
1 Mile
5000 Feet

N

Scale 1:20000

5000 Feet

0 1000 2000 3000 4000 5000

R. 4 W. | R. 3 W.

290 000 FEET

895 000 FEET

885 000 FEET

275 000 FEET

T. 1 N.

LIMIT OF SOIL SURVEY

4 3

9 10 16 15

10 11 15 14

7 18

INTERSTATE BUCKEYE HIGHWAY

FLOODWATER RETARDATION STRUCTURE

CONSTRUCTION UNDER

intermittent

AM AL GYD AGB CO PT PYD TSC GWD HLC RS CV RYD NO 10 PWB AbA Cp Ae Lb

(Joins sheet 59)

(Joins sheet 61)

(Joins sheet 77)

This map is compiled on 1972 aerial photography by the U.S. Department of Agriculture, Soil Conservation Service and cooperating agencies.
Soil lines and symbols conform to National standards and are correctly positioned.

G.2 AZGS Surficial Geology and Flood Hazard Assessment

Photocopies from *Surficial Geology Around the White Tank Mountains, Central Arizona* (Field and Pearthree, 1991) and *Geologic Mapping of Flood Hazards in Arizona: An Example From the White Tank Mountains Area, Maricopa County* (Field and Pearthree, 1992).

Approximate FDS for White Tank Fan
FCD Contract No. 99-02, Assignment No. 2
July 2000
Technical Data Notebook
Appendix G.2 AZGS Open File Reports

Open-File REPORT

Surficial Geology Around the White Tank Mountains, Central Arizona

by

John J. Field and Philip A. Pearthree

Arizona Geological Survey

Open-File Report 91-8

November, 1991

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the U.S. Geological Survey COGEOMAP Program,
the Flood Control District of Maricopa County,
and the Arizona Department of Water Resources

This report is preliminary and has not been edited
or reviewed for conformity with Arizona Geological Survey standards

Introduction

These nine maps depict the distribution and general ages of Quaternary geomorphic surfaces and associated alluvial deposits surrounding the White Tank Mountains, on the western margin of the Phoenix metropolitan area. The White Tank Mountains are one of many mountain ranges in the Basin and Range physiographic province of Arizona. The Basin and Range province in the vicinity of the study area is characterized by relatively small mountain ranges of modest topographic relief separated by wide, gently sloping piedmonts and basin bottom river drainages. The study area is drained by the Gila River. By indicating the age of alluvial surfaces and deposits, these maps provide a basis for evaluating the Quaternary geologic history of the area and assessing potential geologic hazards.

Alluvial surfaces and deposits differentiated for this map are assigned to Quaternary and Upper Tertiary geologic units primarily on the basis of the estimated timing of cessation of major deposition on each geomorphic surface. Relative topographic positions of each surface, surface characteristics, and degree of soil development in underlying deposits are the principal criteria used to assess surface age. The geomorphic surfaces and associated deposits were formed during discrete time intervals ranging from the Late Tertiary to the late Holocene. Six categories of alluvial surfaces are differentiated and mapped on the basis of surface age. Alluvial surfaces are further subdivided into piedmont and basin axis units. The characteristics of each map unit are described in detail below. The estimated ages of the units are inferred by correlation with similar surfaces and soils radiometrically dated elsewhere in the southwestern United States (Gile and others, 1981; Bull, 1991; Menges and McFadden, 1981).

The mapping is based primarily on interpretation of natural-color (1:24,000 scale) aerial photographs. Initial unit designations were later field checked throughout the map area. In extensive agricultural tracts where natural surface characteristics are altered, published soil surveys (Soil Conservation Service, 1977; 1986) were used to evaluate soil development and to delineate boundaries between surfaces of different ages. The nine 1:24,000 scale maps of this series represent a more detailed survey over a small portion of regions mapped on a reconnaissance basis (1:100,000 scale) by Demsey (1988, 1989).

This project was supported by the Arizona Geological Survey, U.S. Geological Survey Cooperative Geologic Mapping (COGEOMAP) Program, the Maricopa County Flood Control District, and the Arizona Department of Water Resources. Aerial photographs were provided by the U.S. Bureau of Land Management.

Description of Map Units

Piedmont Units

Y2 - Late Holocene alluvial fans, low terraces, and active stream channels, < 3 ka.

Alluvial fan deposits on the lower piedmont are fine silts and sands. Middle piedmont surfaces and active channels extending into the White Tank Mountains are very gravelly sands and

silts. Surfaces are typically undissected and display distributary drainage patterns, although 1.5 m arroyo cuts occur locally on the lower piedmont. Surfaces are typically smooth, but bar and swale topography is present on the middle piedmont. Desert pavement and desert varnish are absent. Minimal to no soil development has occurred. Soil great groups are Torrifluvents and Torriorthents. These areas are subject to occasional to frequent flooding.

Y1 - Late to early Holocene alluvial fans and terraces, 1 to 10 ka.

Deposits on the middle piedmont are a coarse poorly sorted, angular to subangular admixture of silt, sand, and gravel. On the lower piedmont, deposits are typically fine silt and sand. Surface relief is typically less than 0.5 m above active channels. Lower piedmont surfaces are smooth and flat with an incipient dendritic drainage pattern. Middle piedmont surfaces have well preserved bar and swale topography with very little tributary drainage development. A poorly developed pebble to granule desert pavement (cobble to granule on middle piedmont) exists over 50 to 85 percent of the surface. Surface cobbles, when present, are lightly and incompletely varnished along the base of the cobble to brownish black (10 YR 2/2). An orange (7.5 YR 7/6) to dull yellowish brown (10 YR 5/4) color is rarely observed on cobble undersides. Minimal soil development has occurred in the underlying deposits -- the most strongly developed profiles contain cambic horizons (hue 7.5 YR) above stage I to II calcic horizons. Soil great groups are Torrifluvents, Torriorthents, and Camborthids. Most Y1 areas are not subject to flooding at present. However, because typically there is little topographic relief between active channels and Y1 surfaces, they could potentially become subject to flooding through minor shifts in the present depositional patterns.

Y - Undifferentiated Holocene alluvial surfaces, 0 to 10 ka.

In some places this designation is used where the Y1 and Y2 surfaces are too intricately intermingled to map separately at this scale. In other areas on the lower piedmont the designation is used where surface characteristics are not distinctive of either Y1 or Y2 surfaces but are clearly of Holocene age. These areas may be subject to occasional to frequent flooding.

M2 - Latest to late Pleistocene alluvial fans, 10 to 150 ka.

Deposits are a poorly sorted, angular to subangular admixture of silt, sand, and gravel. The surfaces are moderately dissected with typically < 1 m to 3 m relief above active channels. Interfluve areas are broad and flat with original gravel bar and swale topography typically moderately to well preserved. A poorly to moderately developed cobble to granule desert pavement is found over 50 to 80 percent of the surface. Surface cobbles are incompletely varnished to very dark brown (7.5 YR 2/3) on top and reddish brown (2.5 YR 4/6) to more commonly dull orange (5 YR 6/4) on undersides. M2 surfaces are not widespread and are predominantly restricted to the middle piedmont. Underlying soils typically contain cambic horizons (hue 7.5 YR), above a stage I to II calcic horizon. Soil great groups are Camborthids and Haplargids. Most areas are free from flooding, although those areas of low relief could become susceptible to flooding with relatively minor shifts in depositional patterns.

M1b - Middle to late Pleistocene alluvial fans, 150 to 300 ka.

Deposits are a poorly sorted, angular to subangular admixture of silt, sand, and gravel. The surfaces are moderately dissected on the upper piedmont with 1-6 m of relief above active channels.

On the lower and middle piedmont relief may be less than 1 m. Interfluve areas are broad and flat with original gravel bar and swale topography poorly preserved. A moderately to well developed cobble to pebble desert pavement is found over 50 to 75 percent of the surface. Surface cobbles are incompletely varnished to black (5 YR 1.7/1) on top and reddish brown (2.5 YR 4/6) to less commonly dull orange (7.5 YR 7/4) on undersides. Underlying soils are characterized by weakly developed argillic horizons (hue 5 YR), typically above a stage II calcic horizon. Soil great groups are Haplargids and Calciorthids. Most areas are isolated from flooding except in entrenched channels, but areas of low relief on the middle and lower piedmont could become susceptible to flooding with relatively minor shifts in depositional patterns.

M12 - Middle or late Pleistocene distal alluvial fans, 10 to 300 ka.

Undifferentiated M1b and M2 surfaces. This designation is used mostly in agricultural areas where surface characteristics are destroyed and available soil descriptions do not enable differentiation of the two surfaces. This designation is locally used elsewhere in areas not field checked. Only areas of low relief may be susceptible to flooding.

M1a - Middle to early Pleistocene alluvial fans, 300 to 1,000 ka.

Deposits are a poorly sorted, angular to subangular admixture of silt, sand and gravel. The surfaces are moderately dissected with typically 1-6 m of relief above active channels but less than 0.5 m of relief above Unit M1b. Interfluve areas are broad, flat, and smooth; bar and swale topography is typically absent or poorly preserved. A well developed cobble to pebble desert pavement is found over the entire surface. Surface cobbles are completely varnished black (5 YR 1.7/1) on top and reddish brown (2.5 YR 4/8) on undersides. Surfaces are typically well preserved and are the darkest surfaces on the White Tank Mountains piedmont. Underlying soils are characterized by moderately to very strongly developed argillic horizons (hue 5 to 2.5 YR), commonly overlying a stage IV calcic horizon. (May locally be composed of river terraces west of the Hassayampa River). Soil great groups are Haplargids. These areas are isolated from active fluvial processes, and only entrenched channels are subject to flooding.

M1 - Middle Pleistocene alluvial fans, 150 to 1,000 ka.

Undifferentiated M1b and M1a surfaces. (May locally be composed of river terraces of the same age immediately north of and adjacent to Wagner Wash and Trilby Wash). On the middle piedmont this designation is used where the two surfaces are too intricately intermingled to map separately at this scale. In other areas this designation is used where surface characteristics are destroyed (agricultural areas) or where extensive field checking was not conducted (north of Wagner Wash and Trilby Wash). Only entrenched channels dissected into the surface are subject to flooding in undisturbed areas.

O - Early Pleistocene to late Pliocene alluvial fans, > 1,000 ka.

Alluvial fan surfaces and deposits of inferred early Pleistocene to late Pliocene age. This unit occupies the highest topographic positions on the White Tank Mountains piedmont and occurs only on the upper piedmont. The deposits are characteristically poorly sorted subangular gravels containing minor amounts of finer material. Deposits range in thickness from greater than 15 m to only a thin veneer (<2 m) over bedrock pediments. The surfaces are deeply dissected (10-15 m). Interfluve

areas are well-rounded ridges with intervening swales or ravines; original depositional surfaces are rarely preserved. Degraded surfaces are typically covered with abundant fragments of pedogenic carbonate derived from exposed brecciated laminar petrocalcic horizons. The petrocalcic fragments commonly impart a light colored appearance to these surface remnants as observed on aerial photographs. Soils are generally stripped by erosion down to exposed remnants of stage IV to VI petrocalcic horizons. Soil great groups are Durorthids. Flooding is restricted to entrenched channels, although hillside slope wash is probable.

Axial Drainage Units

Y2r - Active channels and low terraces along axial drainages, < 3 ka.

Basin axis river channels and deposits of the Gila River, Hassayampa River, Wagner Wash, and Trilby Wash. Active channels on the present river bottoms were not separately mapped as channel positions frequently shift across the entire surface. Deposits range from silt to coarse sands but well rounded cobble bars are common along the Gila River and Hassayampa River. Flooding occurs frequently in basin axis channels.

Y1rt - Late to early Holocene terraces along axial drainages, 1 to 10 ka.

Deposits are typically fine silt and sand with common gravel lenses of well rounded cobbles. Terrace surfaces are smooth and typically less than 1.5 m above the active basin axis drainages (Y2r). These areas could potentially be flooded during very large flow events or after an extended period of aggradation in the active basin axis channels (Y2r).

M1bt - Middle to late Pleistocene river terraces, 150 to 300 ka.

High terrace of the Hassayampa River. This surface is mapped in only one area along the eastern edge of the Hassayampa River at the northern end of the Daggs Tank quadrangle. The terrace surface is flat and dissected up to 30 m by small tributaries flowing into the Hassayampa. The surface is inset 10 m below the adjacent Org deposits. Flooding may occur in entrenched channels and locally along the margin with the topographically higher Org deposits.

Ort - Early Pleistocene to late Pliocene river terraces, > 1,000 ka.

Highest terrace along the Hassayampa River. The well rounded gravel found at the surface is typically darkly varnished. In small localized areas, much of the surface is covered by petrocalcic fragments derived from underlying petrocalcic horizons. The terrace surfaces are dissected up to 30 m by small tributaries flowing into the Hassayampa River. Elsewhere the surface is very flat with a wide spacing between broad shallowly dissected (<2 m) drainages developed on the surface. Flooding restricted to entrenched channels.

Org - Early Pleistocene to late Pliocene river deposits, > 1,000 ka.

Deposits of well-rounded, well-sorted gravel and cross-stratified sand representing bedload material of major axial drainages. This unit is currently exposed along the margins of the

Hassayampa River. The deposits exhibit zones (> 1 m) strongly indurated with carbonate cement. The original depositional surface (Ort) is completely eroded in these areas exposing the underlying deposits (Org). Flooding restricted to entrenched channels, although hillside slope wash is probable.

Bedrock Units* -

T - Tertiary volcanics

TK - Tertiary or Cretaceous intrusive and volcanic rocks

X - Early Proterozoic gneiss and granite

* - Bedrock units are generalized to show lithologies and ages. Detailed lithologic contacts and structures are not shown. Rock ages from Reynolds (1988).

Key to Map Symbols

Surficial geologic contact (dashed where inferred)

Basinward pediment boundary

Upslope edge of agricultural fields

Distribution of Surficial Deposits and the Quaternary Evolution of the White Tanks Piedmonts

In general, relatively young alluvial surfaces become increasingly extensive downslope on the piedmonts of the White Tank Mountains. The oldest surfaces (O and M1a) are found along the mountain front while the youngest surfaces (Y) are dominant adjacent to the basin axis drainages. This distribution suggests a general tendency toward erosion throughout the Quaternary punctuated by periods of equilibrium or aggradation.

Thick alluvial-fan deposits associated with the early Pleistocene to late Tertiary (O) surfaces probably represent the final stage of basin-filling sedimentation associated with the Basin and Range disturbance. All of the younger surfaces are associated with thin veneers of sediment, typically several meters thick or less, overlying older deposits. As a result of erosion throughout the Quaternary, only small, deeply dissected remnants of the early Pleistocene to late Tertiary surfaces are exposed along the mountain front. The change from an aggradational to a primarily erosional phase is most likely related to the cessation of tectonic activity in the region, although integration of the major basin axis drainages and climate changes probably played a minor role.

Middle to late Pleistocene surfaces (M1a and M1b) extend from the upper to lower piedmont and cover much of the White Tank Mountains piedmonts. These relatively thin but areally extensive deposits represent pulses of deposition that punctuated the long-term tendency toward downcutting and erosion on the piedmonts. Distinct differences in surface characteristics and soil development between M1a and M1b indicate that the interval between deposition of these units was probably hundreds of thousands of years long. However, the amount of relief between M1a and M1b typically is negligible, so the net downcutting in the middle Pleistocene was minimal. As a result, distinguishing between these two surfaces is sometimes difficult and they remain undifferentiated in some areas (M1).

The younger surfaces (M2, Y1, and Y2) are found predominantly in the lower and middle piedmont areas. Associated deposits indicate these surfaces are largely the product of erosion of M1 surfaces. Most drainages supplying sediment to the younger surfaces on the lower piedmont head on M1 surfaces and do not extend into the mountains. Sediment thickness on the young surfaces is extremely thin and it is common to see small pods of older units poking through the younger surfaces.

The presence of relatively small, active distributary flow areas on the middle piedmont suggest that loci of deposition has not shifted significantly since the latest Pleistocene. Active distributary flow areas are alluvial fans that become reconfined between older deposits at their downstream ends. They are characterized by distributary channel networks and extensive, young (Y2 and Y1) deposits. Late Pleistocene surfaces (M2) are restricted for the most part to the middle piedmont, where they usually flank younger distributary flow areas.

Deep entrenchment of the Hassayampa River has occurred during the Quaternary, as the present river bottom (Y2r) is over 30 m below the early Pleistocene to Late Tertiary river terrace (Ort). Entrenchment evidently has preceded relatively continuously throughout the Quaternary as no major terraces of intermediate height are observed except for a small middle Pleistocene terrace (M1bt) in the northern portion of the study area. The piedmont surfaces appear largely unaffected by the entrenchment of the Hassayampa River as even the youngest surfaces are graded to the high river

terrace (Org). Only minor dissection has occurred along the downslope edges of the piedmont units as newly formed drainages graded to the present river bottom erode headward.

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Surficial Geology Around the White Tank Mountains, Central Arizona: Daggs Tank Quadrangle

ARIZONA GEOLOGICAL SURVEY

Open File Report OFR 91-8, sheet 1 of 9

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET

NORTH

INDEX MAP OF ARIZONA
Showing Location of Maricopa County

MAP AREA

Surficial Geology Around the White Tank Mountains, Central Arizona: White Tank Mts. NE Quadrangle

ARIZONA GEOLOGICAL SURVEY

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SCALE 1:24,000

1 .5 0 1 MILE

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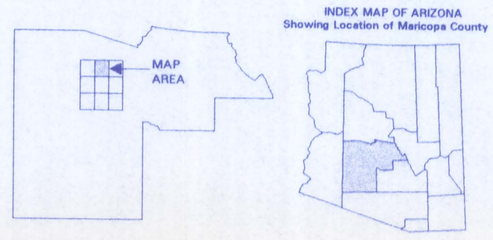
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

NORTH

INDEX MAP OF ARIZONA
Showing Location of Maricopa County



Surficial Geology Around the White Tank Mountains, Central Arizona: McMicken Dam Quadrangle

ARIZONA GEOLOGICAL SURVEY

Open File Report OFR 91-8, sheet 3 of 9

SCALE 1:24,000

CONTOUR INTERVAL 10 FEET

NORTH

INDEX MAP OF ARIZONA
Showing Location of Maricopa County

MAP AREA

Surficial Geology Around the White Tank Mountains, Central Arizona: Wagner Wash Well Quadrangle

ARIZONA GEOLOGICAL SURVEY

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NORTH

SCALE 1:24,000

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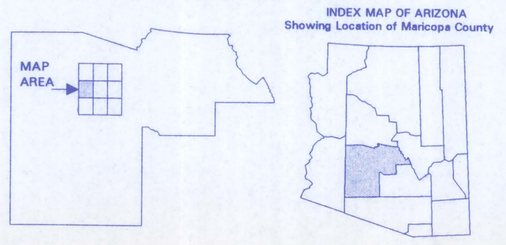
CONTOUR INTERVAL 20 FEET

INDEX MAP OF ARIZONA
Showing Location of Maricopa County



Surficial Geology Around the White Tank Mountains, Central Arizona: White Tank Mts. SE Quadrangle

ARIZONA GEOLOGICAL SURVEY

Open File Report OFR 91-8, sheet 5 of 9

SCALE 1:24,000

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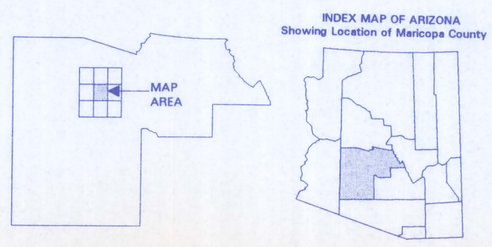
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET

NORTH

INDEX MAP OF ARIZONA
Showing Location of Maricopa County



Surficial Geology Around the White Tank Mountains, Central Arizona: Waddell Quadrangle

ARIZONA GEOLOGICAL SURVEY

Open File Report OFR 91-8, sheet 6 of 9

NORTH

SCALE 1:24,000

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1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

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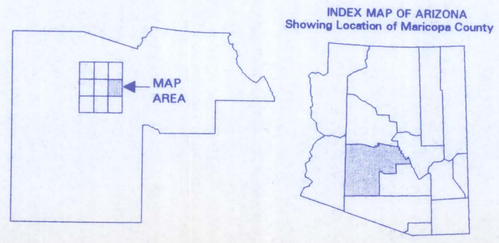
Showing Location of Maricopa County



Surficial Geology Around the White Tank Mountains, Central Arizona: Buckeye NW Quadrangle

ARIZONA GEOLOGICAL SURVEY

Open File Report OFR 91-8, sheet 7 of 9

SCALE 1:24,000

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1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

NORTH

INDEX MAP OF ARIZONA
Showing Location of Maricopa County

MAP AREA

Surficial Geology Around the White Tank Mountains, Central Arizona: Valencia Quadrangle

ARIZONA GEOLOGICAL SURVEY

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NORTH

SCALE 1:24,000

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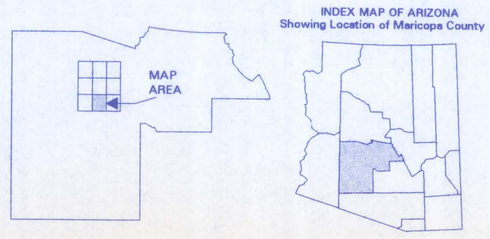
CONTOUR INTERVAL 20 FEET

INDEX MAP OF ARIZONA
Showing Location of Maricopa County



Surficial Geology Around the White Tank Mountains, Central Arizona: Perryville Quadrangle

ARIZONA GEOLOGICAL SURVEY

Open File Report OFR 91-8, sheet 9 of 9

SCALE 1:24,000

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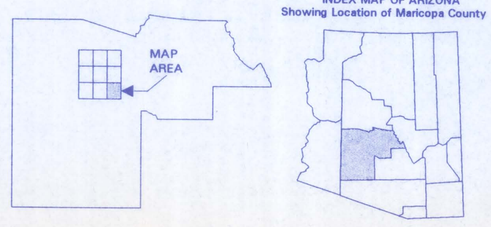
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 5 FEET

NORTH

INDEX MAP OF ARIZONA
Showing Location of Maricopa County



Approximate FDS for White Tank Fan
FCD Contract No. 99-02, Assignment No. 2
July 2000
Technical Data Notebook
Appendix G.2 AZGS Open File Reports

Open-File REPORT

Geologic Mapping of Flood Hazards in Arizona: An Example From the White Tank Mountains Area, Maricopa County

by

John J. Field and Philip A. Pearthree

Arizona Geological Survey
Open-File Report 91-10

March, 1992

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Geologic Mapping of Flood Hazards in Arizona: An Example From the White Tank Mountains Area, Maricopa County

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Open-File Report 91-10

March, 1992

Arizona Geological Survey
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Prepared in cooperation with
the Flood Control District of Maricopa County
and the Arizona Department of Water Resources

This report is preliminary and has not been edited
or reviewed for conformity with Arizona Geological Survey standards

Introduction

Assessment of the character of flood hazards and the extent of flood-prone areas on the piedmonts of Arizona is an increasingly important concern to floodplain managers as urban areas continue to expand. Piedmonts are the low-relief, gently sloping plains between mountain ranges and the streams or playas that occupy the lowest portions of the valleys. Proper management of flood hazards on piedmonts is important because much of southern, central, and western Arizona is composed of piedmonts; they comprise most of the developable land around Phoenix and other rapidly expanding population centers of the State.

Management of flood hazards in Arizona and elsewhere in the western United States is complicated because portions of many piedmonts are composed of active alluvial fans. During floods, these fans are subject to widespread inundation and local high-velocity flow, and substantial changes in channel patterns may occur. Development that proceeds on piedmonts without regard to the locations of active alluvial fans is likely to place people and property at risk during large floods.

Geomorphic analyses and geologic mapping of piedmonts provide the best data for determining if active alluvial fans exist on a given piedmont and which portions of that piedmont may be subject to alluvial-fan flooding. Active alluvial fans have distinctive physical characteristics, including distributary drainage networks and laterally extensive, geologically young alluvial surfaces (Pearthree, 1989; Pearthree and Pearthree, 1989). Typically, large portions of piedmonts in Arizona have not been subject to flooding for many thousands of years and thus are not active alluvial fans. These areas can be distinguished from active alluvial fans by examining differences in drainage patterns, topographic relief, soil development, and surface characteristics (Christenson and others, 1978; Pearthree, 1991; Pearthree and others, in prep).

The principal objective of this study was to use geomorphic analyses and geologic mapping to delineate different flood-hazard zones on the piedmonts around the White Tank Mountains. Flood hazard designations on piedmonts obtained through geomorphic analyses and mapping are more reliable than those generated by hydrologic and hydraulic models currently available. These models, by necessity, make assumptions about rainfall intensity and duration, runoff characteristics, and flow behavior during floods. The validity of flood-hazard assessments derived through hydrologic modeling thus depends on the validity of the underlying assumptions and input parameters (Baker and others, 1990). In contrast, geologic mapping of flood hazards is based on analysis of surface characteristics and drainage patterns that actually exist on piedmonts. Geomorphic studies typically cannot resolve the details of individual floods, but they document which areas have actually been subject to significant flooding over thousands of years. Detailed geologic maps derived from these studies thus provide a long-term perspective on the distribution of flood-prone areas.

This report outlines the methods used to map and characterize flood hazard zones

on the piedmonts around the White Tank Mountains. Studies of this kind could be used to delineate flood hazards on any undeveloped or sparsely developed piedmont in Arizona. Because of their wide applicability, the procedures used to map alluvial surfaces of different ages and to develop flood-hazard maps are described in some detail. The distribution of flood-prone areas around the White Tank Mountains is representative of many piedmonts in Maricopa County and elsewhere in Arizona. The report, therefore, also describes typical differences in the character and distribution of flood hazards in the upper, middle, and lower piedmont areas.

Methods Used to Map Alluvial Surfaces of Different Ages

The distribution of alluvial surfaces of different ages was the fundamental data set used to develop flood-hazard maps for this study. Interpretation of aerial photographs and field surveys provide much of the data used in our analyses, because surface characteristics evident on photographs and on the ground are related to the age of the surface. (See Table 1 for sources of data.) Aerial photographs depict surface color, dissection, vegetation density, and drainage patterns over large areas, some of which are inaccessible to motor vehicles. Subsequent ground surveys more thoroughly define the surface characteristics identified on aerial photographs and supply additional information on desert pavement, rock varnish, soil development, depositional topography, and vegetation.

Interpretation of Aerial Photographs

For this study, we interpreted 1:24,000-scale stereo-paired color aerial photographs provided by the U.S. Bureau of Land Management. Many surface characteristics are also evident on high-quality black-and-white photographs. Widely available, 1:24,000-scale, black-and-white orthophotoquads offer less resolution of surface characteristics, but they serve as an excellent base map for transferring information to 7.5' USGS topographic maps. Three characteristics that are visible on aerial photographs reflect surface age: surface color, drainage patterns, and depth of dissection and surface relief.

Surface Color. The color of alluvial surfaces depicted on aerial photographs is primarily controlled by soil color, and to a lesser extent, rock varnish. Significant soil development begins on an alluvial surface after it becomes isolated from active flooding and depositional processes (Gile and others, 1981, Birkeland, 1984; Birkeland and others, 1991). Over thousands of years, distinct soil horizons develop. Two typical soil horizons in old (> 10,000 years) alluvial sediments of Arizona are reddish brown argillic horizons and white calcic horizons. (See further description of soil formation below.) As a result, on color aerial photographs older alluvial surfaces characteristically appear redder or whiter (on more eroded surfaces) than younger surfaces.

Older surfaces have a dark brown color where darkly varnished desert pavements are well preserved. This colors is present in only small areas on the White Tank Mountain

Topographic Maps
Drainage patterns
Drainage spacing
Depth of dissection
Relief between surfaces

Aerial Photographs
Surface Color
Drainage patterns
Drainage spacing
Depth of dissection
Relief between surfaces

SCS Soil Maps
Soil development

Ground Survey
Surface color
Drainage spacing
Depth of dissection
Relief between surfaces
Desert pavement
Rock varnish
Soil development
Depositional topography
Vegetation types and distributions

Vegetation Maps
Vegetation distributions

Table 1. Data sources for geomorphic analyses and mapping of alluvial surfaces on piedmonts of Arizona. Note that there are sometimes multiple sources of information for a single characteristic (i.e. depth of dissection).

piedmonts, probably because desert pavements have been disturbed by animal burrowing and uprooting of large vegetation. These activities expose the underlying white and red soils.

Drainage Patterns. Differences in the drainage patterns between surfaces provide clues to surface age and potential flood hazards. Young alluvial surfaces that are subject to flooding commonly display a distributary (branching downstream) or braided channel pattern; young surfaces may have very little developed drainage if unconfined shallow flooding predominates. Dendritic tributary (branching upstream) drainage patterns are characteristic of older surfaces that are not subject to extensive flooding. (See Plates 1a through 1d for examples of drainage patterns on young and old alluvial surfaces.) Tributary drainage networks typically extend headward with time, and the spacing between drainages tends to decrease with time as the drainage network becomes better developed.

Depth of Dissection and Surface Relief. Relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be determined using stereo-paired aerial photographs and topographic maps. Young flood-prone surfaces appear nearly flat on aerial photographs and are less than 1 m (3 ft) above channel bottoms. On these young surfaces, channel infilling or bank erosion might redirect floodwaters anywhere on the surface. Active channels are typically entrenched 1 to 10 m (3 to 30 ft) below older surfaces. In these areas, floodwaters are conveyed in the entrenched channels and have not affected the adjacent old surfaces for 10,000 years or more.

Younger surfaces are commonly inset into and topographically lower than older surfaces in upper piedmont areas (Figure 1a). Long-term climatic, tectonic, and base-level changes have resulted in lower surface gradients on younger surfaces, so the depth of dissection on older surfaces generally decreases away from the mountain front. In some middle and lower piedmont areas, relief between surfaces of different ages is minimal (figure 1c), so other surface characteristics are needed to estimate surface ages.

Field Investigations

Field investigations provide additional information on surface characteristics and topographic relationships between surfaces of different ages. Characteristics that are best observed on the ground are used to refine map units and to further describe surfaces already identified through interpretation of aerial photographs. These characteristics include development of desert pavements, rock varnish, and soils; preservation of small-scale depositional topography; and vegetation types.

Desert Pavement. Desert pavement is a concentration of pebbles and cobbles at the surface, which forms as windblown silt and clay accumulates between pebbles and cobbles. Repeated wetting of the surface by rain causes the silt and clay to swell, thereby lifting and pushing more cobbles and pebbles towards the surface. Repeated drying of the surface causes the formation of cracks in which more silt and clay can accumulate. Over thousands of years a surface mantling of closely packed pebbles and cobbles develops over

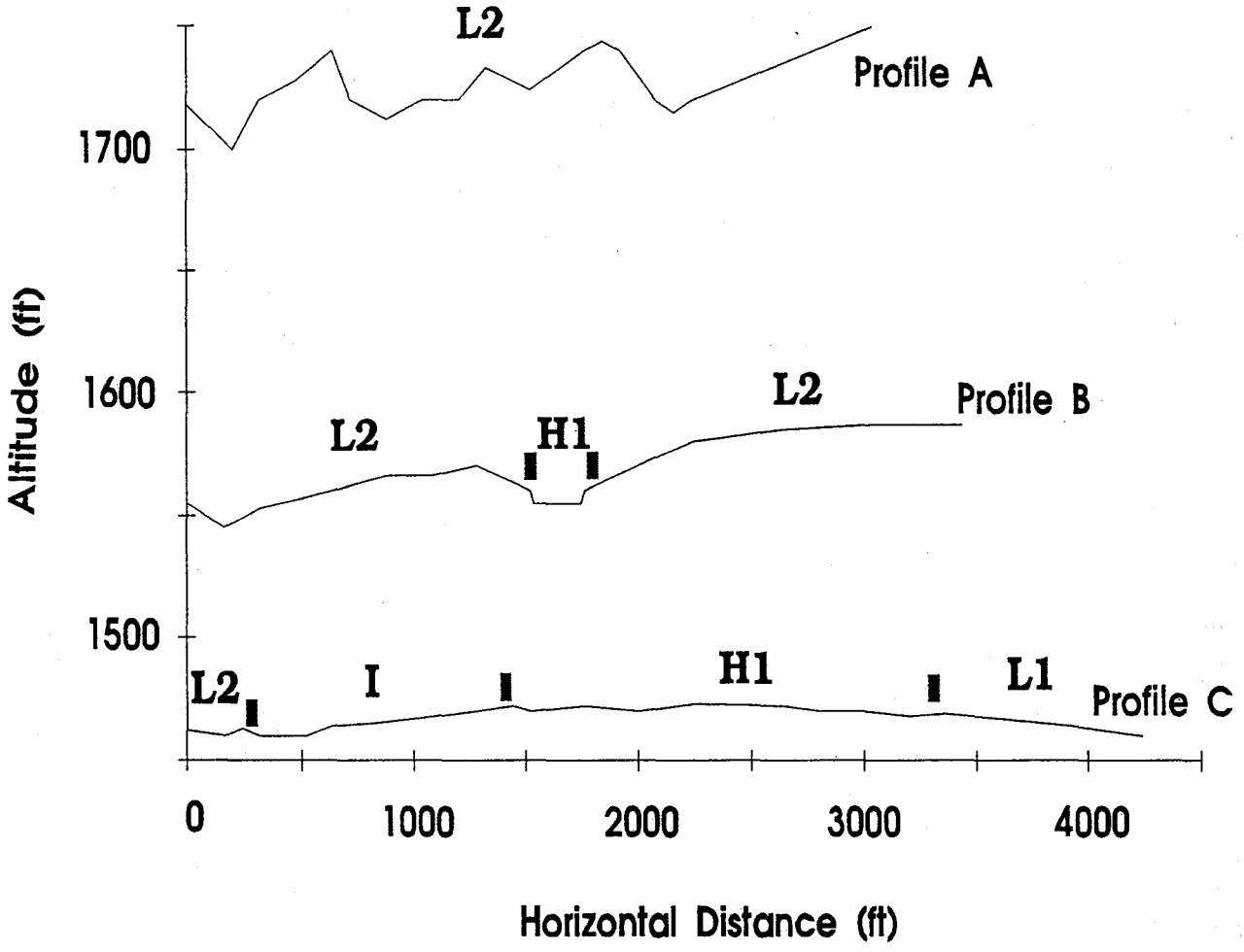


Figure 1. Topographic profiles showing changes in the extent of flood-prone areas downstream and away from the mountains. Profiles were constructed perpendicular to a large stream draining the western side of the White Tank Mountains. Flood-hazard zones are discussed in the text.

a) Upper piedmont area, where channels are deeply entrenched and flood-prone areas are very limited.

b) Transition to the middle piedmont, where flood-prone areas are still of limited extent but topographic confinement of channels is much less.

c) Middle piedmont area, where flood-prone areas are extensive, there is minimal topography on active alluvial fans, and there is little relief between areas that have been flooded recently and those that have not been flooded for 10,000+ years.

a silt- and clay-rich soil layer (Dohrenwend, 1987; Vanden Dolder, 1992). Desert pavements are generally most closely packed on relatively old alluvial surfaces; they are more open and poorly developed on intermediate aged surfaces. Young alluvial surfaces that have been flooded within the past few thousand years do not have desert pavements because surface sediments have been recently reworked by floodwaters. As noted above, desert pavements can be disrupted by animal activity or vegetation. The best developed desert pavements in Arizona are in relatively arid areas, where little vegetation grows on the alluvial surfaces.

Rock Varnish. Rock varnish forms on pebbles and cobbles at the land surface; these pebbles and cobbles are often incorporated into a desert pavement. Rock varnish that forms on rock surfaces exposed to the atmosphere is a brown to black patina composed of manganese oxides and clay minerals precipitated on the rock surface by microbial organisms (Dorn and Oberlander, 1982; Vanden Dolder, 1992). As the surface exposed to the atmosphere darkens, the undersides of the pebbles and cobbles are simultaneously reddened by the accumulation of iron oxides and clay minerals. The varnishing process is very slow in arid regions and only occurs on gravel that is continuously exposed at the surface and has not been moved for thousands of years. Rocks with weakly developed varnish indicate that a surface has not been subject to significant flooding for thousands of years; rocks with well-developed varnish have not been disturbed by flooding for tens to hundreds of thousands of years. Young surfaces that have been flooded in the past few thousand years are unvarnished because the rocks have not been in place long enough to develop varnish.

Soil Development. Soil development generally increases with the age of an alluvial surface. When the accumulation of stream deposits on a land surface ceases, the sediment beneath the surface begins to be altered into distinct horizons by soil-forming processes. The most important process that leads to the development of soils on the piedmonts of Arizona is the accumulation of material from the atmosphere (windblown dust and calcium carbonate dissolved in rainwater) in the first 1 to 2 m (3 to 6 ft) below the land surface. The ages of these soils can be roughly estimated from the amount of silt, clay, and calcium carbonate that has accumulated in them (Table 2).

Because of accumulation of windblown dust, the first 1 to 10 cm (1 to 4 in.) of sediment beneath alluvial surfaces is typically silt-rich even if the parent material (the original stream deposit) is sand and gravel. Beneath this surface horizon, rainwater percolates into the sediment and alters the parent material, producing a weak fabric in the soil (soil structure) or slight soil reddening or both; this horizon is called a cambic horizon. Suspended clay is also carried from the surface and concentrated in this portion of the soil. As the amount of clay increases with time, the cambic horizon develops into an orange to reddish brown, clay-rich argillic horizon. The strength of cambic or argillic horizon development depends on the age of the surface and climate. Cambic horizons probably form in a few thousand years to 10,000 years in Arizona. Weak argillic horizons probably forme in 10,000 years or more in most areas, and strongly developed argillic horizons have developed over hundreds of thousands of years (Gile and others, 1981; Pearthree and

Estimated Age	Soil Development Color	Texture	Calcic Horizon	Drainage Patterns	Surface Dissection	Surface Topography	Rock Varnish
Late Holocene (< 3 ka)	brown	sand	thin, discontinuous rock coatings	distributary	< 1 m	bars and swales channels	none
Mid- to early Holocene (3-10 ka)	brown to orange	sand to sandy loam	discontinuous to continuous rock coatings	distributary or tributary	< 1 m	bars and swales obvious	minimal brown/ orange
Late Pleistocene (10-150 ka)	brown to orange	loamy sand sandy loam	continuous coatings whitened matrix	tributary	< 3 m	bars and swales well preserved	moderate dark brown/ orange
Late to Middle Pleistocene (150-300 ka)	orange to reddish brown	sandy loam loam	continuous coatings whitened matrix	tributary	< 6 m	bars and swales moderately to poorly preserved	moderate black/ reddish brown
Middle Pleistocene (300-800 ka)	reddish brown	clay	thick coatings locally cemented matrix	tributary	< 6 m	smooth, bars and swales poorly preserved	strong black/ reddish brown
Early Pleistocene (> 800 ka)	orange to white	loam	cemented very thick coatings	tributary	10 to 15 m	erosionally rounded ridges	variable poorly preserved

Table 2. Selected surface properties that change with increasing alluvial surface age around the White Tank Mountains. Estimated ages are in thousands of years old (ka); soil colors and soil textures reported are from the zone of silt and clay accumulation; rock varnish colors are from exposed surfaces/undersides of cobbles.

Calvo, 1987; Bull, 1991). The presence of reddened, clay-rich argillic horizons thus indicate that surfaces have not been subject to significant flooding for at least 10,000 years, and commonly much longer than that.

Comparisons of calcic horizon development on the White Tank Mountains piedmont with other soil sequences in the western United States provide one of the few methods of estimating the ages of the different alluvial surfaces. Calcium carbonate from dust and rainwater gradually precipitates in soils, forming a whitish calcic horizon. Geomorphologists and soil scientists recognize six morphologic stages of calcic-horizon development and have linked these states to soil ages in several areas in the southwestern United States (Machette, 1985; Birkeland and others, 1991). Calcic horizon development varies from fine white filaments of calcium carbonate in young soils to soil horizons completely plugged with calcium carbonate (caliche) in very old soils.

Soil horizons lie beneath the surface and thus must be examined in natural stream cuts, hand-dug soil pits, or backhoe trenches. Although soil development is a very useful characteristic in producing a geologic flood-hazard map, care must be exercised when interpreting soil- and surface-age relationships. A soil exposed beneath a surface may be a buried soil and unrelated to the surface that it is presently beneath. Young deposits on the lower piedmont are commonly only a thin veneer (<30 cm, or 1 ft) over much older soils. As a result, the presence of a well developed calcic horizon on the lower piedmont does not necessarily indicate that the overlying surface has not been flooded for a long time, unless other surface characteristics confirm that the surface is old.

Depositional Topography. The degree of preservation of original depositional surface features is another key to determining the age of an alluvial surface. One such feature, bar-and-swale topography, is common on alluvial surfaces of Arizona. Gravel bars deposited during large floods are separated by intervening sand-filled channel swales or troughs. After a surface is isolated from major flood events,it is gradually smoothed as bars are eroded and swales are filled in by windblown dust and sediment derived from adjacent bars. Bar-and-swale topography is readily apparent on alluvial surfaces that have been deposited within the past 10,000 years, but is more subdued on increasingly older alluvial surfaces; very old surfaces typically are quite smooth. It is important to note, however, that development of bar-and-swale topography also depends on the size of bedload particles conveyed by a stream. Streams that convey coarse bedloads (cobbles and boulders) typically have obvious, well-developed bars and swales. This topography is not evident on young, flood-prone surfaces on the lower piedmont because very little coarse-grained bedload is present far from the mountains.

Vegetation. The distribution of plant types is commonly associated with the age of alluvial surfaces. Vegetation is also controlled by elevation and rock type, however, so vegetation patterns are not as clear an indicator of surface ages as are some of the aforementioned characteristics. On the White Tank Mountains piedmonts, creosote and brittle bush are pervasive on all surfaces; thus their distributions cannot be used as an indicator of surface age. Saguaro, palo verde, ironwood, cane cholla, and barrel cactus are not as pervasive,

but do not correlate definitively with alluvial surfaces of different ages. Jumping cholla, however, is abundant only on old flood-free surfaces; its distribution probably correlates with clay-rich soils.

Alluvial-Surface Characteristics -- Indicators of Recency of Flooding

The surficial characteristics discussed above impart a distinctive appearance to alluvial surfaces of a given age. In general, alluvial surfaces that have been flooded within the past 10,000 years are dominated by characteristics related to primary depositional processes. These characteristics include (1) distributary drainage patterns, (2) minimal entrenchment of stream channels below the surface, (3) brown surface colors, (4) little or no soil development, (5) obvious bar and swale topography; and (6) no desert pavement or rock varnish; . Old alluvial surfaces that have not been subject to substantial flooding for hundreds of thousands of years are typically characterized by (1) well-developed, moderately to deeply entrenched, dendritic tributary drainages, (2) reddish, whitish, or dark brown surface colors, (3) strongly developed soil profiles, (4) subdued, smoothed bar-and-swale topography, and (5) dark-brown to black varnish on exposed rock surfaces and orange to red varnish on the undersides of rocks. If local conditions are conducive, old alluvial surfaces may also have well-developed desert pavements. Characteristics of surfaces of intermediate age, which have not been flooded for tens of thousands of years, fall within the two extremes.

We estimated the ages of alluvial surfaces around the White Tank Mountains by comparing their characteristics, especially soil development (Table 2), with those of dated surfaces in similar climatic regions. Other means of directly dating surfaces include radiocarbon dating when carbon fragments are found and archaeological remains when present.

A single surface characteristic is insufficient to conclusively estimate surface age, because some of the characteristics mentioned above as distinctive of young surfaces may be attributes of old surfaces and vice versa. Not all the characteristics distinctive of surfaces of a certain age need be present to assign a surface that age designation, however. For example, deep dissection of a surface clearly indicates that it is not flood prone, but the absence of dissection does not necessarily mean the surface is young and flood prone. Large areas on the lower and middle piedmonts of the White Tank Mountains have not been disturbed by flooding for more than 10,000 years, even though the surfaces are less than 1 meter (3 ft) above the channel bottoms. In these areas, well-developed pavement, varnish, and soils are better indicators of surface age. In general, certain characteristics are only present on a surface of a given age, and are reliable indicators of the time since a surface was last flooded. Other characteristics are not always present or are attributes of surfaces of different ages (Table 3). A final surface-age designation is based on all of the surface characteristics outlined above.

Alluvial surfaces on the piedmonts of the White Tank Mountains range in age from

Flood Hazard	Surface Age	Characteristic Category*	Surface Characteristic
Low	10,000+	1	Mod. to well developed pavement Mod. to well developed varnish Mod. to strong soil development
		2	Deep dissection (>4 ft.)
		3	Abundant jumping cholla Reddish or whitish surface Mod. to closely spaced drainage Dendritic tributary drainage Absent or subtle bar and swale
Intermediate	1,000-10,000	1	Weak to mod. soil development Weakly developed pavement
		2	Incipient desert varnish Obvious bar and swale
		3	Dendritic tributary drainage Shallow dissection (<3 ft.) Mod. to widely spaced drainage
High	0-3,000	1	Incipient soil development No desert pavement
		2	Distributary drainage Fresh bar and swale
		3	Shallow dissection (<3 ft.) No desert varnish

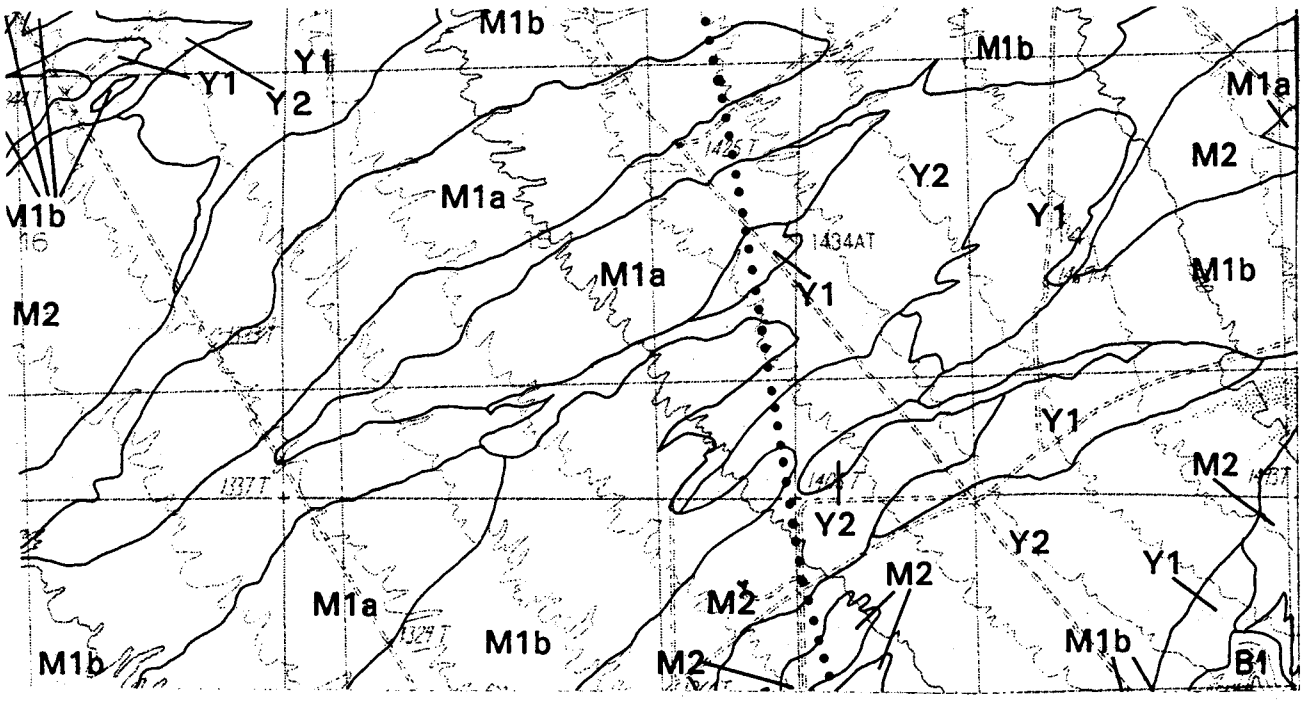
* Characteristic Category 1 - These characteristics are indicative of surface age and are almost always present on the surfaces of given age. If the characteristic is absent, the surface is most likely of a different age.

Characteristic Category 2 - These characteristics are indicative of surface age but are not always present. Absence of these characteristics from the surface does not imply the surface is of another age (as in Category 1).

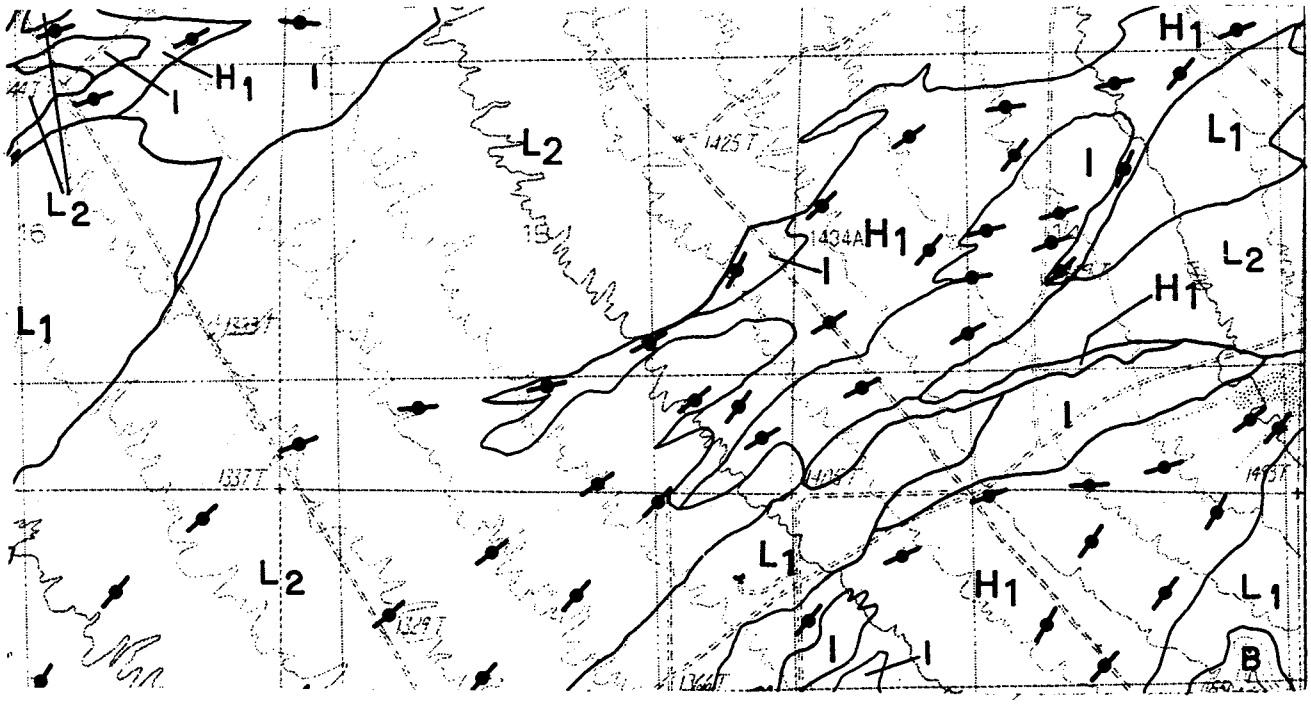
Characteristic Category 3 - These characteristics are almost always present on the surface but are not indicative of surface age, because they are found on other surfaces as well. However, if the characteristic is absent the surface is most likely of another age.

Table 3. Characteristics used to delineate three flood hazard zones on alluvial piedmonts around the White Tank Mountains. Note that the opposite of a characteristic does not necessarily imply the opposite flood hazard (i.e. shallow dissection does not always imply the surface is flood prone).

Figure 2. Development of a flood-hazard map using geologic and geomorphic data.



a) Map of alluvial surfaces covering part of the western piedmont of the White Tank Mountains. Surfaces ages (in years) are as follows: Y2, <3,000; Y1, 1,000 to 10,000; M2, 10,000 to 150,000; M1b, 150,000 to 300,000; M1a, 300,000 to 800,000.



b) Geologic flood-hazard map of the same area. Heavy dots with lines show approximate locations of channels of major drainages that head in adjacent mountains. Surface age, proximity to major drainages, local topographic relief, and evidence of channelized flow were used to delineate flood-hazard zones. See text for description of flood-hazard categories.

modern to 1,000,000 years old or more (Table 2; see Field and Pearthree, 1991, for a more complete discussion of surface characteristics and surface-age estimates). We differentiated and mapped the following alluvial surfaces: late Holocene, < 3,000 years old; late to early Holocene, 1,000 to 10,000 years old; late Pleistocene, 10,000 to 150,000 years old; late middle Pleistocene, 150,000 to 300,000 years old; early middle Pleistocene, 300,000 to 800,000 years old, and early Pleistocene, > 800,000 years old.

Development of Flood-Hazard Zones

We integrated maps of alluvial surfaces of different ages (Field and Pearthree, 1991) with other geomorphic information to delineate flood-hazard zones around the White Tank Mountains (Figure 2; Plate 1). Assessments of flood hazards were based on (1) the age of the alluvial surface; (2) local topographic relief between the surface and active channels; (3) proximity to active channels, especially channels of major distributary flow systems; and (4) the size, number, and character of active channels in the area.

The most important data we used to develop the flood hazard maps was the distribution of surfaces of different ages. The critical assumption of our analysis is that areas that have been subject to flooding over the past few thousand years are the areas that are likely to be flood prone. The potential for flooding in areas that have not been flooded for at least 10,000 years is considered to be very low, unless local circumstances suggest flow patterns have changed very recently. Areas composed of surfaces of 1,000 to 10,000 years old are considered to have intermediate or high flood potential, depending on their proximity to active channels or active alluvial fans.

Our delineation of flood-hazard zones was also based on drainage patterns, local topography, and the character of active channels. We considered areas that are within or near distributary drainage networks of the larger washes to be relatively more flood prone than areas that are spatially separated from these networks. We also incorporated local topographic relief between active channels and adjacent alluvial surfaces into our assessments. The flood potential on old surfaces that are several meters or more (5 to 10+ ft) higher than adjacent active channels is considered to be very low. In contrast, if little relief separates old surfaces and active channels, the flood potential on the old surfaces is considered to be higher because of the possibility that flooding patterns might change and affect the old surface. We subdivided flood potential in areas of extensive young alluvial surfaces based on the size and abundance of channels. Large or abundant channels indicate that relatively deep, high velocity flows are an important element of flooding. Furthermore, the positions of these channels may shift occasionally during large floods (CH2MHill, 1991), subjecting the areas covered by young deposits between the existing channels to sheet flooding or channelized flooding. Areas of extensive young deposits where channels are not evident are subject primarily to shallow sheetflooding. These areas are clearly flood prone, but the character of the flooding is far less threatening.

The characteristics of the five flood-hazard zones are summarized below.

H1 - Very high flood potential. Extensive young deposits; distributary channel system very evident. Potential for localized, high-velocity, relatively deep, channelized flows and sheetflooding; some potential for drastic shifts in channel positions.

H2 - High flood potential. Extensive young deposits, but channels are small or nonexistent. Predominantly shallow sheetflooding; channelized flow very limited in extent; broad areas probably inundated in large floods.

I - Intermediate flood potential. Areas have not been flooded recently. Near or within distributary drainage systems, and little topographic relief separates these areas from active alluvial fans or channels. Could become flood prone with relatively modest changes in channel configurations.

L1 - Relatively low flood potential. Areas have not been flooded for at least 10,000 years. Flooding has been confined to channels and immediately adjacent terraces for that long. However, these areas are near or within distributary drainage networks, and typically little topographic relief separates L1, I, H2, and H1 areas. L1 areas should be carefully evaluated to determine if potential for shifts in channel configurations or depositional patterns could result in these areas becoming flood prone.

L2 - Very low flood potential. Areas have not been flooded for at least 10,000 years, and typically for much longer. Drained by tributary streams that head on the piedmont. Streams entrenched 1 to 10 m (3 to 30 ft) below inactive alluvial surfaces; spatially separate from or topographically isolated from distributary drainage networks. Flood-prone areas limited to channels and adjacent low terraces.

Distribution of Flood Hazards on the Piedmonts of the White Tank Mountains

The distribution of flood hazards varies widely across the piedmonts of the White Tank Mountains. On upper piedmonts, flood-prone surfaces are restricted to channel bottoms and low terraces set well below older flood free surfaces (Figure 1a, 1b; Plate 1). Only the largest channel bottoms are mappable at this scale (1:24,000), but smaller, unmapped channel bottoms are also subject to high-velocity channelized flow (H1 flood hazard).

The largest areas with the highest flood potential (H1) are associated with active alluvial fans on the middle piedmont west and south of the White Tank Mountains (Figure 1c; Plate 1). These are areas where entrenched large drainages become unconfined downstream, distributing floodwaters into several smaller channels and sheetfloods. Extensive very young deposits (<3,000 years old) and distributary channel networks indicate that these areas are active alluvial fans. Some areas within the distributary-flow

networks have not been subject to significant flooding for at least 1,000 years and are somewhat isolated from the distributary channels; the potential for flooding in these areas is less (intermediate flood potential; category I). Downstream from the active alluvial fans, distributary channels typically become reconfined into fairly narrow passages between older surfaces that have not been flooded significantly for at least 10,000 years. We have assigned a low flood hazard potential (L1) to areas where the relief between the reconfined channels and adjacent old alluvial surfaces is less than one meter (3 ft); we assigned the lowest flood potential (L2) to areas where the relief is more than one meter (3 ft). Widespread zones of fairly high flood hazards (H2) are present on the middle piedmont north of the White Tank Mountains (Plate 1a and 1b). In this area several large drainages become unconfined and floodwaters spread out into low-velocity sheetfloods.

On the lower piedmont, many of the major drainages again become unconfined and floodwaters spread out into sheetflows (Plate 1). High-velocity, channelized flood hazards (H1) are restricted to very small portions of the lower piedmont, but areas prone to shallow flooding (H2) are ubiquitous. A single large flood probably will not inundate the entire lower piedmont, but the absence of substantial relief across the lower piedmont makes it difficult to predict where the next sheetflow will occur.

Conclusions

The White Tank Mountains flood hazard map demonstrates the value of using geomorphic analyses and mapping to delineate flood potential on desert piedmonts. A single geomorphic characteristic, by itself, cannot conclusively establish the age of a piedmont surface. Suites of characteristics identifiable on aerial photographs and in the field, however, are diagnostic of surface age. Alluvial surfaces of different ages on desert piedmonts can be readily mapped using these diagnostic suites of characteristics. By integrating surface age information with topographic data and the character of drainage networks, geologists can reliably delineate flood potential zones across the entire piedmont. Similar detail and reliability is not possible with current numerical hydraulic models. Geologic and geomorphic studies, therefore, should be an integral part of any flood hazard management project on desert piedmonts.

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White Tank Mountains
Flood Hazard Map - NW Section

by
John J. Field and Philip A. Pearthree
1991

E X P L A N A T I O N

Map Unit Description

H_1 **Flood Hazard:** Highest; high-velocity channelized flow and sheetflow

Distribution: Entrenched reaches of major drainages and distributary flow areas on middle and upper piedmont

Soil Group*: Torrifluvents

Channel Pattern: Braided (anastomosing) or distributary

Surface Relief: Less than 2 ft; bar and swale topography

Surface Texture: Silt to very gravelly sand

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation:** Brittle bush, rabbit bush, bunch grass, creosote

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

H_2 **Flood Hazard:** Moderately high; dominantly sheetflow with minor channel flows

Distribution: Restricted to lower piedmont and small drainages heading on the piedmont

Soil Group: Torrifluvents

Channel Pattern: Distributary; incipient dendritic drainage in less active areas

Surface Relief: Less than 2 ft with uncommon, 4-ft arroyo cuts; smooth surface

Surface Texture: Sandy silt with 10% scattered gravel; less active areas have granule to pebble lag

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation: Creosote, brittle bush

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

I **Flood Hazard:** Intermediate; has not been subject to significant flooding for more than 1,000 yrs, but lack of topographic relief between these surfaces and active surfaces (H_1 and H_2) suggests that they could become flood prone with channel filling, avulsion, or human disturbance

Distribution: Adjacent to H_1 and H_2 in distributary flow areas and on lower piedmont

Soil Groups: Torrifluvents and Camborthids

Channel Pattern: Widely spaced, dendritic tributary drainages

Surface Relief: Less than 4 ft in distributary flow areas and less than 3 ft on lower piedmont; bar and swale topography well preserved in distributary flow areas

Surface Texture: Open desert pavement consisting of granules and small cobbles

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished to weakly developed over 10% of the surface - brownish black (7.5YR 3/1) on top and orange (7.5YR 7/6) on undersides

Vegetation: Brittle bush, creosote, palo verde

Estimated Surface Age: Late Holocene to latest Pleistocene (1,000 to 15,000 yrs old)

L_1 **Flood Hazard:** Low; localized sheetflooding possible; flooding might occur if channels are altered by human disturbance because of low relief downslope from major distributary flow areas

Distribution: Downslope from and adjacent to distributary flow areas on middle and lower piedmont

Soil Groups: Camborthids and Haplargids

Channel Pattern: Moderately spaced, dendritic tributary drainages

Surface Relief: 1 to 10 ft; fairly smooth subdued bar and swale topography

Surface Texture: Open to closed desert pavement consisting of granules and cobbles

Surface Color: Bright brown (7.5YR 5/6) to orange (7.5YR 6/6)

Desert Varnish: Weakly to moderately developed over 50% of surface - brownish black (7.5YR 2/2) to grayish brown (7.5YR 4/2) on top and dull orange (5YR 6/4) to reddish brown (2.5YR 4/6) on undersides

Vegetation: Brittle bush, creosote, cane cholla

Estimated Surface Age: Latest Pleistocene to middle Pleistocene (15,000 to 250,000 yrs old)

L_2 **Flood Hazard:** Lowest; restricted to small channels and localized sheetflooding

Distribution: Upper and middle piedmont and adjacent to Hassayampa River

Soil Groups: Haplargids and Durorthids

Channel Pattern: Closely to widely spaced, dendritic tributary drainages; rounded interfluves in areas of highest relief

Surface Relief: 5 to 40 ft; fairly smooth surface; uncommon bar and swale topography

Surface Texture: Closed desert pavement consisting of cobbles and pebbles; uncommon salt-shattered cobbles; in places, surface is denuded and covered by petrocalcic fragments

Surface Color: Dull orange (7.5YR 6/4 to 5YR 6/3)

Desert Varnish: Well developed over 50 to 100% of undenuded surfaces - black (5YR 1.7/1) on top and dark red (10R 3/6) to dull orange (7.5YR 7/4) on undersides

Vegetation: Jumping cholla, brittle bush, creosote

Estimated Surface Age: Late Pleistocene to Pliocene (50,000 to 1,000,000+ yrs old)

M **Flood Hazard:** Mechanized disturbance; flood hazard unknown

B **Flood Hazard:** Bedrock outcrops; flood hazard low, but localized slope wash and debris flows possible in steepest areas

* Soil groups are taken from the Soil Conservation Service survey of the Aguila-Carefree area

** Only dominant plant types are listed

Channel bottoms of larger drainages heading in the White Tank Mountains

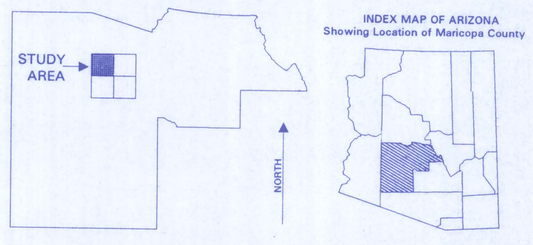
SCALE 1:24,000

1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

TOPOGRAPHIC CONTOUR INTERVAL 5, 10, 20, 40 FEET



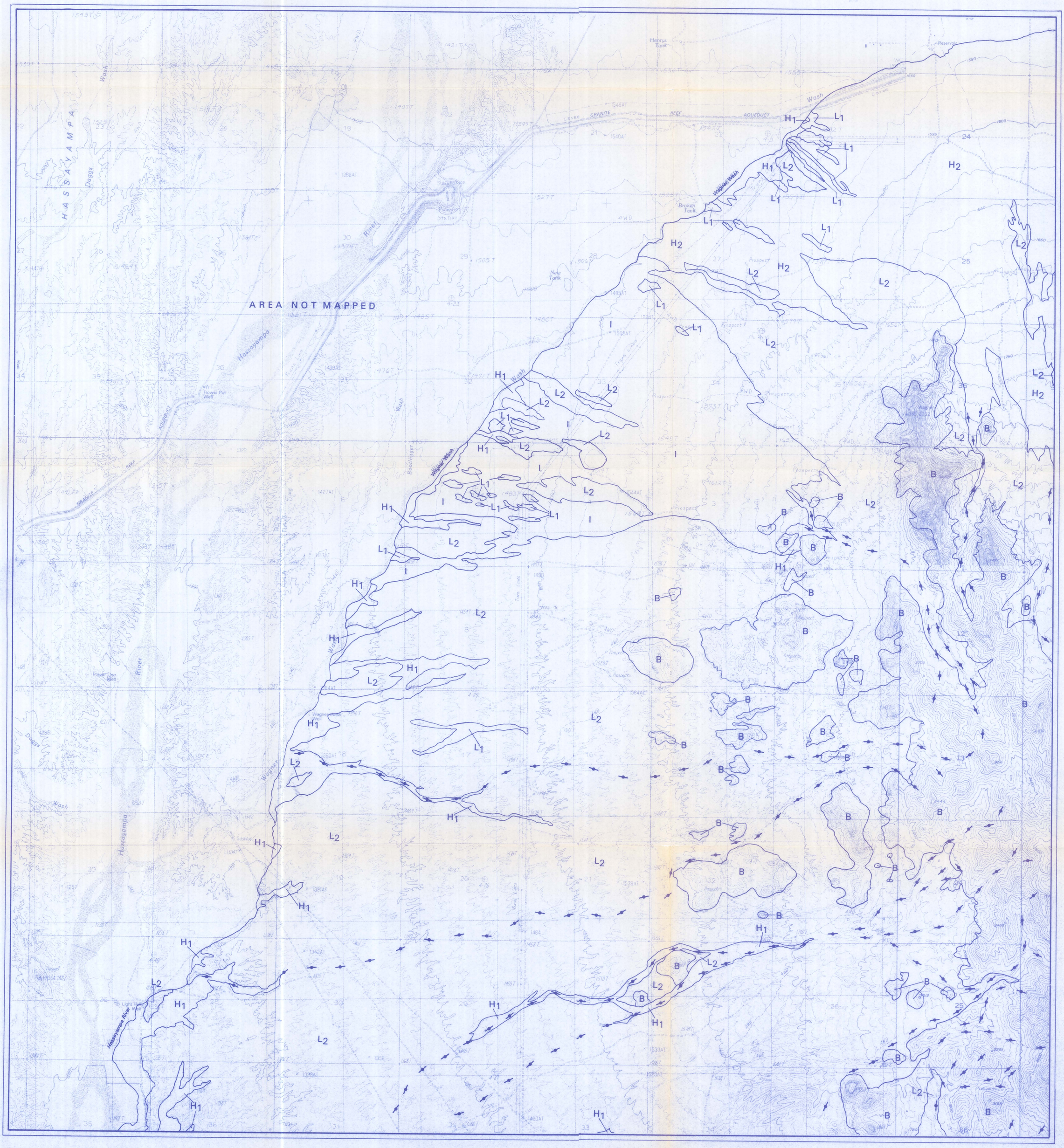


Plate Ia

White Tank Mountains
Flood Hazard Map - NE Section

by
John J. Field and Philip A. Pearthree
1991

E X P L A N A T I O N

Map Unit Description

H_1 **Flood Hazard:** Highest; high-velocity channelized flow and sheetflow

Distribution: Entrenched reaches of major drainages and distributary flow areas on middle and upper piedmont

Soil Group*: Torrifluvents

Channel Pattern: Braided (anastomosing) or distributary

Surface Relief: Less than 2 ft; bar and swale topography

Surface Texture: Silt to very gravelly sand

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation:** Brittle bush, rabbit bush, bunch grass, creosote

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

H_2 **Flood Hazard:** Moderately high; dominantly sheetflow with minor channel flows

Distribution: Restricted to lower piedmont and small drainages heading on the piedmont

Soil Group: Torrifluvents

Channel Pattern: Distributary; incipient dendritic drainage in less active areas

Surface Relief: Less than 2 ft with uncommon, 4-ft arroyo cuts; smooth surface

Surface Texture: Sandy silt with 10% scattered gravel; less active areas have granule to pebble lag

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation: Creosote, brittle bush

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

I **Flood Hazard:** Intermediate; has not been subject to significant flooding for more than 1,000 yrs, but lack of topographic relief between these surfaces and active surfaces (H_1 and H_2) suggests that they could become flood prone with channel filling, avulsion, or human disturbance

Distribution: Adjacent to H_1 and H_2 in distributary flow areas and on lower piedmont

Soil Groups: Torrifluvents and Camborthids

Channel Pattern: Widely spaced, dendritic tributary drainages

Surface Relief: Less than 4 ft in distributary flow areas and less than 3 ft on lower piedmont; bar and swale topography well preserved in distributary flow areas

Surface Texture: Open desert pavement consisting of granules and small cobbles

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished to weakly developed over 10% of the surface - brownish black (7.5YR 3/1) on top and orange (7.5YR 7/6) on undersides

Vegetation: Brittle bush, creosote, palo verde

Estimated Surface Age: Late Holocene to latest Pleistocene (1,000 to 15,000 yrs old)

L_1 **Flood Hazard:** Low; localized sheetflooding possible; flooding might occur if channels are altered by human disturbance because of low relief downslope from major distributary flow areas

Distribution: Downslope from and adjacent to distributary flow areas on middle and lower piedmont

Soil Groups: Camborthids and Haplargids

Channel Pattern: Moderately spaced, dendritic tributary drainages

Surface Relief: 1 to 10 ft; fairly smooth subdued bar and swale topography

Surface Texture: Open to closed desert pavement consisting of granules and cobbles

Surface Color: Bright brown (7.5YR 5/6) to orange (7.5YR 6/6)

Desert Varnish: Weakly to moderately developed over 50% of surface - brownish black (7.5YR 2/2) to grayish brown (7.5YR 4/2) on top and dull orange (5YR 6/4) to reddish brown (2.5YR 4/6) on undersides

Vegetation: Brittle bush, creosote, cane cholla

Estimated Surface Age: Latest Pleistocene to middle Pleistocene (15,000 to 250,000 yrs old)

L_2 **Flood Hazard:** Lowest; restricted to small channels and localized sheetflooding

Distribution: Upper and middle piedmont and adjacent to Hassayampa River

Soil Groups: Haplargids and Durorthids

Channel Pattern: Closely to widely spaced, dendritic tributary drainages; rounded interfluves in areas of highest relief

Surface Relief: 5 to 40 ft; fairly smooth surface; uncommon bar and swale topography

Surface Texture: Closed desert pavement consisting of cobbles and pebbles; uncommon salt-shattered cobbles; in places, surface is denuded and covered by petrocalcic fragments

Surface Color: Dull orange (7.5YR 6/4 to 5YR 6/3)

Desert Varnish: Well developed over 50 to 100% of undenuded surfaces - black (5YR 1.7/1) on top and dark red (10R 3/6) to dull orange (7.5YR 7/4) on undersides

Vegetation: Jumping cholla, brittle bush, creosote

Estimated Surface Age: Late Pleistocene to Pliocene (50,000 to 1,000,000+ yrs old)

M **Flood Hazard:** Mechanized disturbance; flood hazard unknown

B **Flood Hazard:** Bedrock outcrops; flood hazard low, but localized slope wash and debris flows possible in steepest areas

* Soil groups are taken from the Soil Conservation Service survey of the Aguila-Carefree area

** Only dominant plant types are listed

Channel bottoms of larger drainages heading in the White Tank Mountains

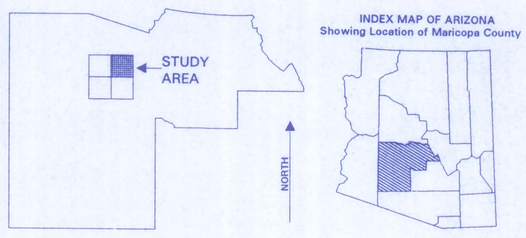
SCALE 1:24,000

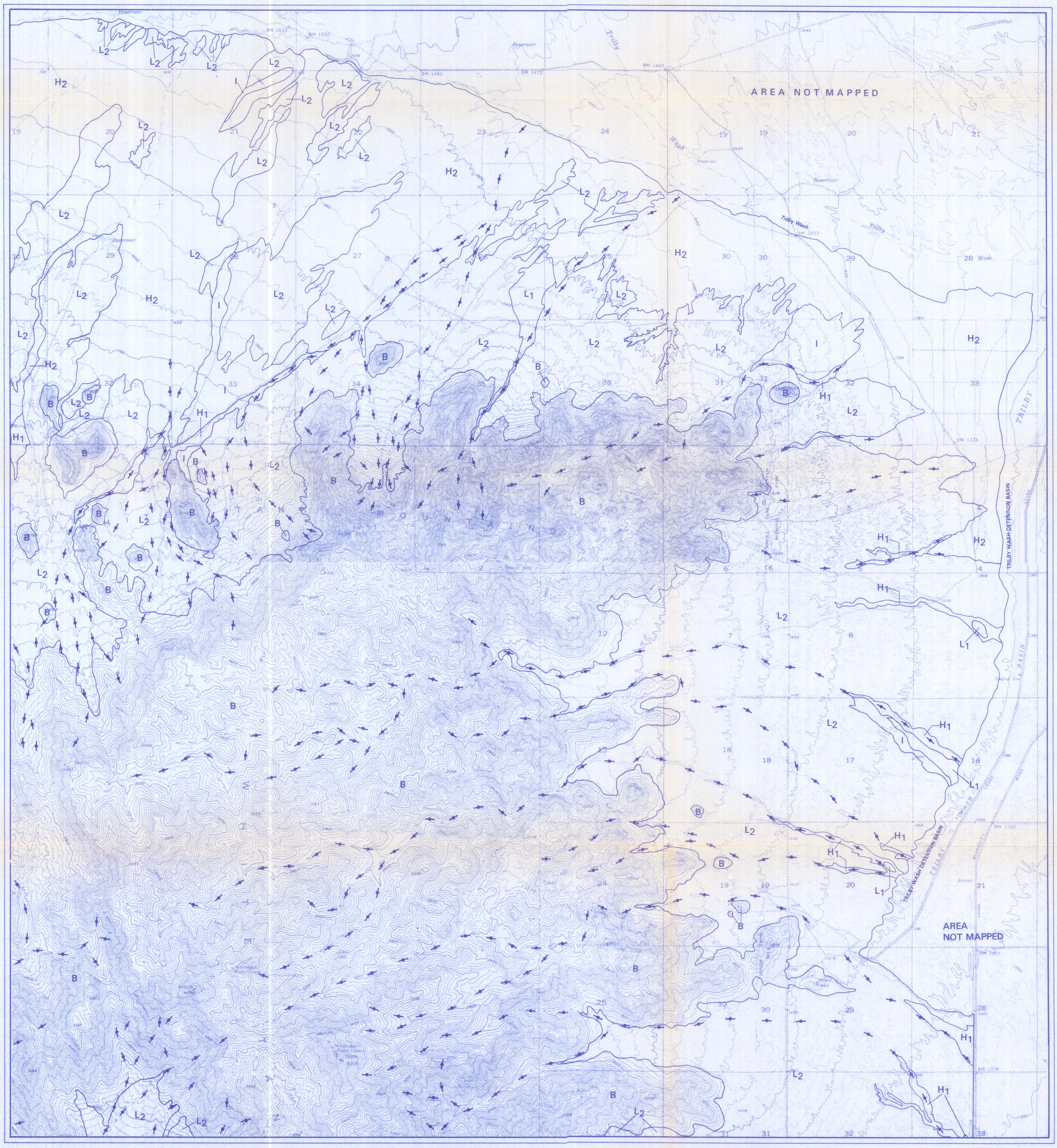
1 .5 0 1 MILE

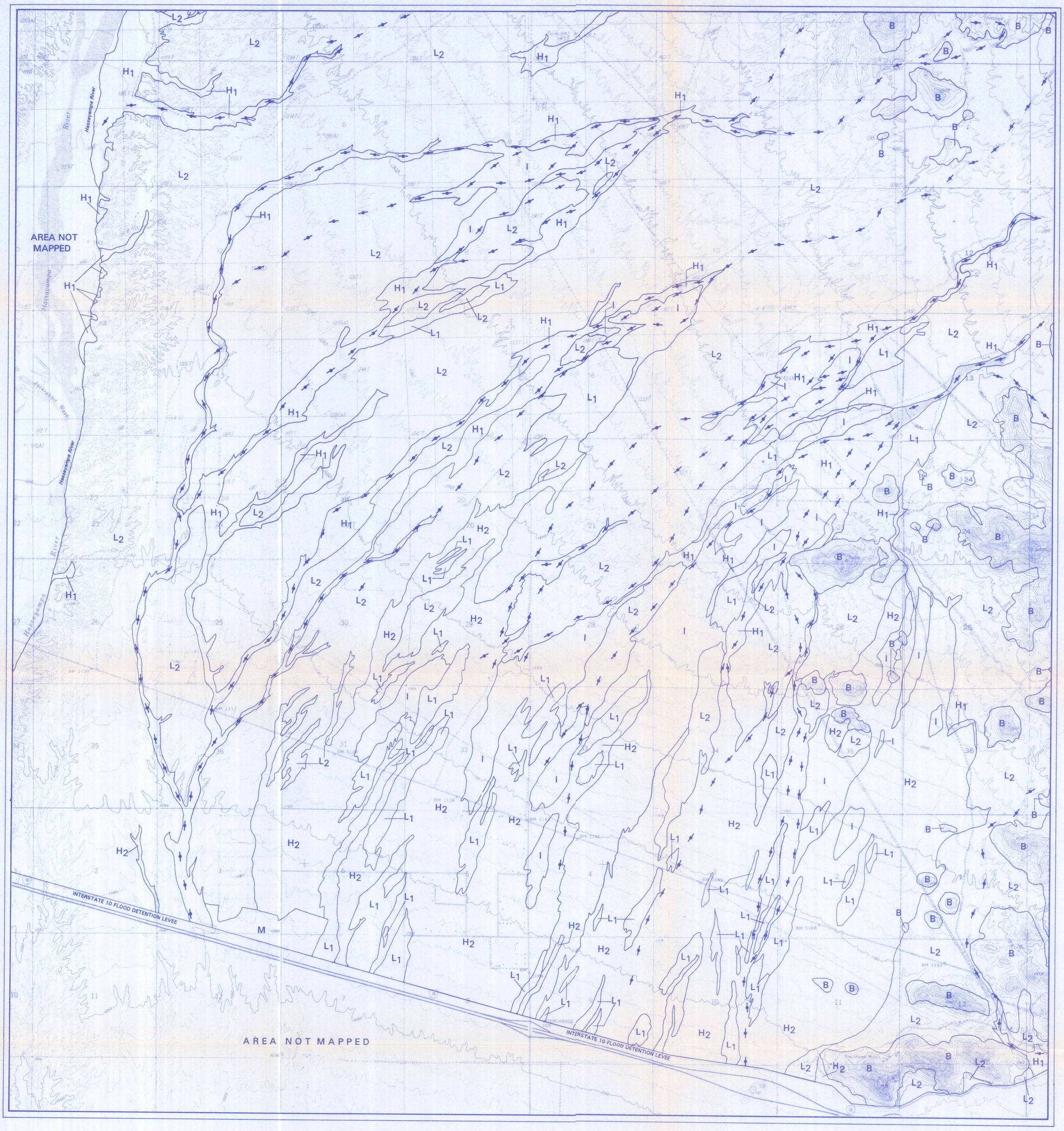
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

TOPOGRAPHIC CONTOUR INTERVAL 5, 10, 20, 40 FEET







White Tank Mountains
Flood Hazard Map - SW Section

by
John J. Field and Philip A. Pearthree
1991

E X P L A N A T I O N

Map Unit Description

H_1 **Flood Hazard:** Highest; high-velocity channelized flow and sheetflow

Distribution: Entrenched reaches of major drainages and distributary flow areas on middle and upper piedmont

Soil Group*: Torrifluvents

Channel Pattern: Braided (anastomosing) or distributary

Surface Relief: Less than 2 ft; bar and swale topography

Surface Texture: Silt to very gravelly sand

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation:** Brittle bush, rabbit bush, bunch grass, creosote

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

H_2 **Flood Hazard:** Moderately high; dominantly sheetflow with minor channel flows

Distribution: Restricted to lower piedmont and small drainages heading on the piedmont

Soil Group: Torrifluvents

Channel Pattern: Distributary; incipient dendritic drainage in less active areas

Surface Relief: Less than 2 ft with uncommon, 4-ft arroyo cuts; smooth surface

Surface Texture: Sandy silt with 10% scattered gravel; less active areas have granule to pebble lag

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation: Creosote, brittle bush

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

I **Flood Hazard:** Intermediate; has not been subject to significant flooding for more than 1,000 yrs, but lack of topographic relief between these surfaces and active surfaces (H_1 and H_2) suggests that they could become flood prone with channel filling, avulsion, or human disturbance

Distribution: Adjacent to H_1 and H_2 in distributary flow areas and on lower piedmont

Soil Groups: Torrifluvents and Camborthids

Channel Pattern: Widely spaced, dendritic tributary drainages

Surface Relief: Less than 4 ft in distributary flow areas and less than 3 ft on lower piedmont; bar and swale topography well preserved in distributary flow areas

Surface Texture: Open desert pavement consisting of granules and small cobbles

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished to weakly developed over 10% of the surface - brownish black (7.5YR 3/1) on top and orange (7.5YR 7/6) on undersides

Vegetation: Brittle bush, creosote, palo verde

Estimated Surface Age: Late Holocene to latest Pleistocene (1,000 to 15,000 yrs old)

L_1 **Flood Hazard:** Low; localized sheetflooding possible; flooding might occur if channels are altered by human disturbance because of low relief downslope from major distributary flow areas

Distribution: Downslope from and adjacent to distributary flow areas on middle and lower piedmont

Soil Groups: Camborthids and Haplargids

Channel Pattern: Moderately spaced, dendritic tributary drainages

Surface Relief: 1 to 10 ft; fairly smooth subdued bar and swale topography

Surface Texture: Open to closed desert pavement consisting of granules and cobbles

Surface Color: Bright brown (7.5YR 5/6) to orange (7.5YR 6/6)

Desert Varnish: Weakly to moderately developed over 50% of surface - brownish black (7.5YR 2/2) to grayish brown (7.5YR 4/2) on top and dull orange (5YR 6/4) to reddish brown (2.5YR 4/6) on undersides

Vegetation: Brittle bush, creosote, cane cholla

Estimated Surface Age: Latest Pleistocene to middle Pleistocene (15,000 to 250,000 yrs old)

L_2 **Flood Hazard:** Lowest; restricted to small channels and localized sheetflooding

Distribution: Upper and middle piedmont and adjacent to Hassayampa River

Soil Groups: Haplargids and Durorthids

Channel Pattern: Closely to widely spaced, dendritic tributary drainages; rounded interfluves in areas of highest relief

Surface Relief: 5 to 40 ft; fairly smooth surface; uncommon bar and swale topography

Surface Texture: Closed desert pavement consisting of cobbles and pebbles; uncommon salt-shattered cobbles; in places, surface is denuded and covered by petrocalcic fragments

Surface Color: Dull orange (7.5YR 6/4 to 5YR 6/3)

Desert Varnish: Well developed over 50 to 100% of undenuded surfaces - black (5YR 1.7/1) on top and dark red (10R 3/6) to dull orange (7.5YR 7/4) on undersides

Vegetation: Jumping cholla, brittle bush, creosote

Estimated Surface Age: Late Pleistocene to Pliocene (50,000 to 1,000,000+ yrs old)

M **Flood Hazard:** Mechanized disturbance; flood hazard unknown

B **Flood Hazard:** Bedrock outcrops; flood hazard low, but localized slope wash and debris flows possible in steepest areas

* Soil groups are taken from the Soil Conservation Service survey of the Aguila-Carefree area

** Only dominant plant types are listed

Channel bottoms of larger drainages heading in the White Tank Mountains

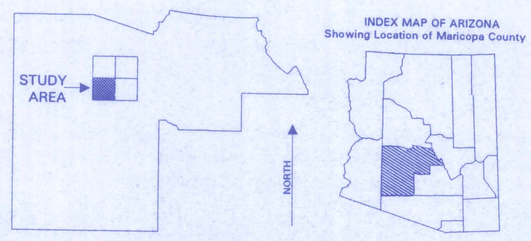
SCALE 1:24,000

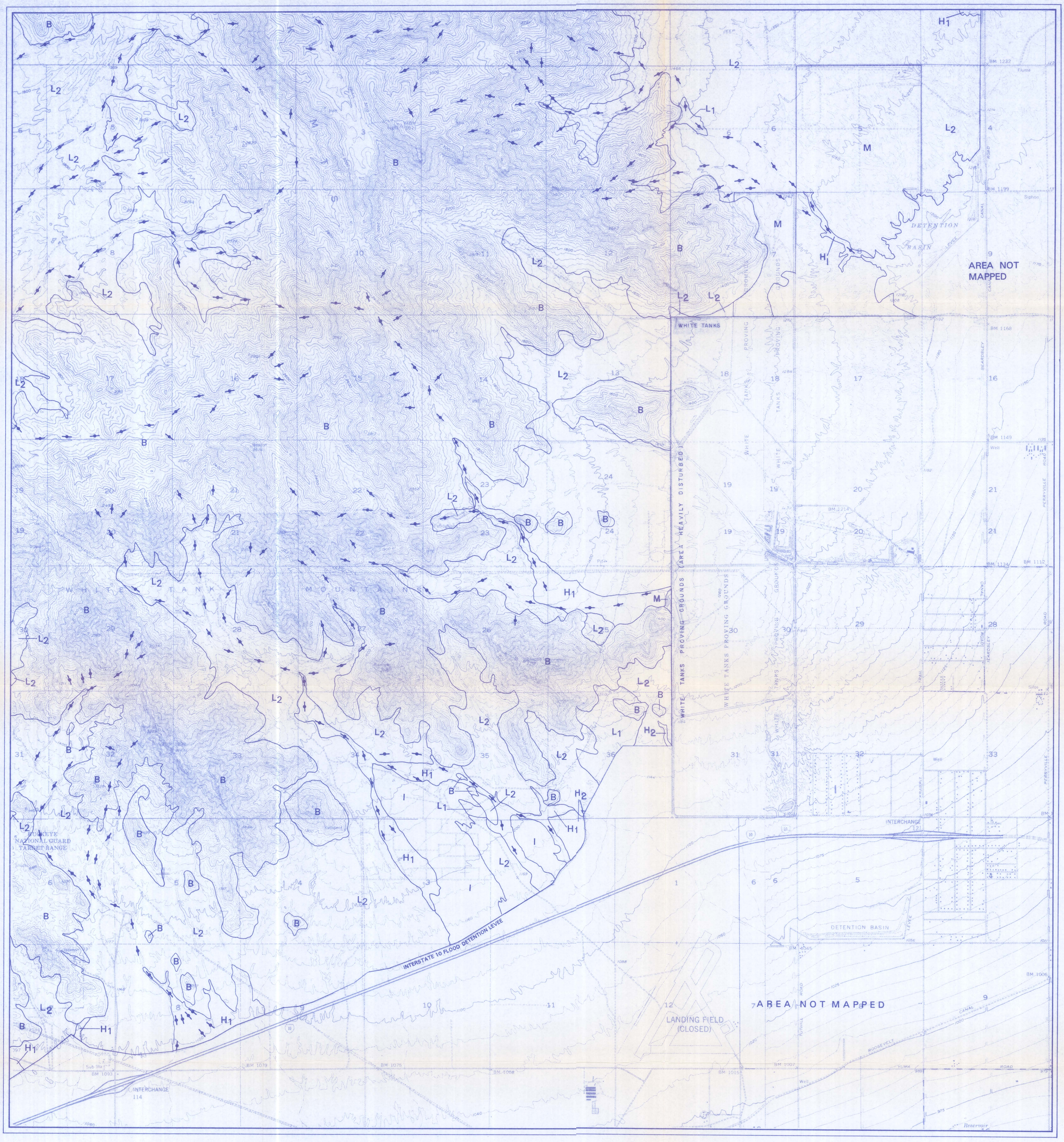
1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

TOPOGRAPHIC CONTOUR INTERVAL 5, 10, 20, 40 FEET





White Tank Mountains
Flood Hazard Map - SE Section

by
John J. Field and Philip A. Pearthree
1991

E X P L A N A T I O N

Map Unit Description

H_1 **Flood Hazard:** Highest; high-velocity channelized flow and sheetflow

Distribution: Entrenched reaches of major drainages and distributary flow areas on middle and upper piedmont

Soil Group*: Torrifluvents

Channel Pattern: Braided (anastomosing) or distributary

Surface Relief: Less than 2 ft; bar and swale topography

Surface Texture: Silt to very gravelly sand

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation:** Brittle bush, rabbit bush, bunch grass, creosote

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

H_2 **Flood Hazard:** Moderately high; dominantly sheetflow with minor channel flows

Distribution: Restricted to lower piedmont and small drainages heading on the piedmont

Soil Group: Torrifluvents

Channel Pattern: Distributary; incipient dendritic drainage in less active areas

Surface Relief: Less than 2 ft with uncommon, 4-ft arroyo cuts; smooth surface

Surface Texture: Sandy silt with 10% scattered gravel; less active areas have granule to pebble lag

Surface Color: Dull yellow-orange (10YR 6/4)

Desert Varnish: Unvarnished gravel

Vegetation: Creosote, brittle bush

Estimated Surface Age: Historical to late Holocene (0 to 2,000 yrs old)

I **Flood Hazard:** Intermediate; has not been subject to significant flooding for more than 1,000 yrs, but lack of topographic relief between these surfaces and active surfaces (H_1 and H_2) suggests that they could become flood prone with channel filling, avulsion, or human disturbance

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Soil Groups: Torrifluvents and Camborthids

Channel Pattern: Widely spaced, dendritic tributary drainages

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Surface Texture: Open desert pavement consisting of granules and small cobbles

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Vegetation: Brittle bush, creosote, palo verde

Estimated Surface Age: Late Holocene to latest Pleistocene (1,000 to 15,000 yrs old)

L_1 **Flood Hazard:** Low; localized sheetflooding possible; flooding might occur if channels are altered by human disturbance because of low relief downslope from major distributary flow areas

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Soil Groups: Camborthids and Haplargids

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Surface Relief: 1 to 10 ft; fairly smooth subdued bar and swale topography

Surface Texture: Open to closed desert pavement consisting of granules and cobbles

Surface Color: Bright brown (7.5YR 5/6) to orange (7.5YR 6/6)

Desert Varnish: Weakly to moderately developed over 50% of surface - brownish black (7.5YR 2/2) to grayish brown (7.5YR 4/2) on top and dull orange (5YR 6/4) to reddish brown (2.5YR 4/6) on undersides

Vegetation: Brittle bush, creosote, cane cholla

Estimated Surface Age: Latest Pleistocene to middle Pleistocene (15,000 to 250,000 yrs old)

L_2 **Flood Hazard:** Lowest; restricted to small channels and localized sheetflooding

Distribution: Upper and middle piedmont and adjacent to Hassayampa River

Soil Groups: Haplargids and Durorthids

Channel Pattern: Closely to widely spaced, dendritic tributary drainages; rounded interfluves in areas of highest relief

Surface Relief: 5 to 40 ft; fairly smooth surface; uncommon bar and swale topography

Surface Texture: Closed desert pavement consisting of cobbles and pebbles; uncommon salt-shattered cobbles; in places, surface is denuded and covered by petrocalcic fragments

Surface Color: Dull orange (7.5YR 6/4 to 5YR 6/3)

Desert Varnish: Well developed over 50 to 100% of undenuded surfaces - black (5YR 1.7/1) on top and dark red (10R 3/6) to dull orange (7.5YR 7/4) on undersides

Vegetation: Jumping cholla, brittle bush, creosote

Estimated Surface Age: Late Pleistocene to Pliocene (50,000 to 1,000,000+ yrs old)

M **Flood Hazard:** Mechanized disturbance; flood hazard unknown

B **Flood Hazard:** Bedrock outcrops; flood hazard low, but localized slope wash and debris flows possible in steepest areas

* Soil groups are taken from the Soil Conservation Service survey of the Aguila-Carefree area

** Only dominant plant types are listed

Channel bottoms of larger drainages heading in the White Tank Mountains

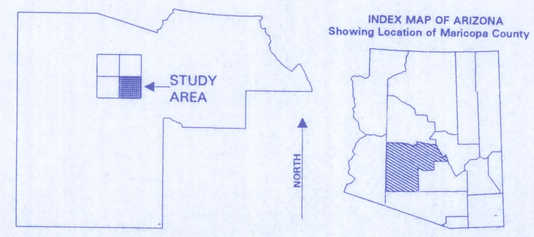
SCALE 1:24,000

1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

TOPOGRAPHIC CONTOUR INTERVAL 5, 10, 20, 40 FEET



G.3 Aerial Photographs

See separate binder for Appendix G.3.

G.4 Other Documentation

JEFuller / Hydrology & Geomorphology, Inc.

5235 South Kyrene, Suite 205
Tempe, AZ 85283
480-752-2124 (voice)
480-839-2193 (fax)
www.jefuller.com

November 19, 1999

TRANSMITTAL

Joe Tram, P.E.
Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009

Attached are the following materials provided by JE Fuller/ Hydrology & Geomorphology, Inc. for your review:

* Evaluation of Subarea 6 Report for Subtask 6.1, FCD 99-02, Assignment No. 2, Approximate Floodplain Delineation of White Tank fan and piedmont.

Joe:

As indicated in the attached report and as we have discussed previously, we are recommending inclusion of subarea 6 in the flood hazard evaluation of the Site 36 piedmont. If you concur, please contact us regarding formalizing the extension of our floodplain delineation study to subarea 6. You should have a copy of our original fee proposal for subarea 6. However, I can supply you with another copy at your request.

If you have any questions, please call Jon or myself.

For Jonathan Fuller, P.E.

11/19/99
Date

APPROXIMATE
FLOODPLAIN DELINEATION STUDY
for
WHITE TANK FAN
(Site 36 (Hjalmarson and Kemna, 1992))

FCD CONTRACT NO. 99-02
Assignment No. 2

Subtask 6.1

Evaluation of Subarea 6

November 1999

Prepared for:

Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009
(602) 506-1501

By:

WOOD, PATEL, & ASSOCIATES, INC.

In association with:

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

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Introduction

JE Fuller / Hydrology and Geomorphology, Inc., (JEF) has collected and reviewed data which are pertinent to the impact of the flood hazard from the alluvial fan called Site 36 (Hjalmarson and Kemna, 1992) on subarea 6 of the project study area (Figure 1). Based on our review of these data, we believe that floodwaters from the alluvial fan Site 36 do impact subarea 6. Therefore, subarea 6 should be considered in a complete evaluation of the flood hazards impacting the piedmont downstream of Site 36.

Data

A variety of data are already available that shed light on the impact of the Site 36 alluvial fan on subarea 6.

Surficial Geology

Field and Pearthree (1991 and 1992) show connected young surfaces along the northwest portion of the fan (Figure 2, lower map). Continuous ribbons of young surfaces (unit Y2) extend into subarea 6 from the main portion of the active alluvial fan upstream. The Y2 surface of Field and Pearthree (1991) are described as late Holocene alluvial fans, low terraces, and active stream channels less than 3,000 years old. These surfaces indicate that floodwaters and sediments have flowed into and been deposited within subarea 6 from the Site 36 alluvial fan in the recent geologic past.

Historical Aerial Photographs

Examination of historical aerial photos shows that flood waters and sediment have entered into subarea 6 in the period since 1942. The most dramatic changes occurred between 1942 and 1953. These channel changes were most likely the result of a large flood in August 1951. Figure 3 shows the 1997 channel position tracings over the 1942 aerial photograph. Figures 4a and 4b shows the 1942 photo side by side with the 1997 photograph. Both Figure 3 and 4 show the expansion of channels and the extension of the main channel more directly west toward subarea 6.

Cross Sections

Figure 2 shows the location of three cross sections across the more active portion of the Site 36 alluvial fan. Elevations measured from the 7.5 minute USGS topographic quadrangles indicate that all three cross sections show sufficient capacity to convey the 100-year discharge of 3,600 cfs (Alpha, 1994). Cross section 2, near the 1480 foot contour, shows that the northern portion (subsection 3) has more than enough capacity alone. This estimate assumes a fixed channel bed geometry and hydraulic independence from the south portion of the cross section. Nevertheless, it demonstrates that a significant portion of the 100-year discharge could be conveyed toward subarea 6 from the north half of the upper active alluvial fan. The downstream cross section (3), near the

1350 foot contour (approximately at section A to A' to A" referred to in the Scope of Work), shows sufficient capacity to convey the 100-year discharge within its southern most portion near the west end of 'spike' hill. However, as noted at the 1480 foot contour and shown by the channel locations in Figures 2, 3, and 4, not all of the floodwaters make the southerly turn and flow around the west end of 'spike' hill.

Field Observations

Evidence from field visits by JEF, Inc. also indicate modern flood debris, such as tin fuel containers and lumber, entering subarea 6 from the Site 36 fan.

Previous Investigators

Site 36 was investigated by Hjalmarson and Kemna (1992). They identified the flood hazard degree for Site 36 as a 10 in a rating from 1 to 10 where 10 is the most hazardous. Figure 14 from Hjalmarson (1994) (reproduced below) shows an oblique photograph of Site 36 from just upstream of the hydrographic apex (labeled as the 'primary diffluence' in Figure 14). Hjalmarson (1994) also reports that on Site 36 "floodwater of the 100-year flood can inundated any part of the DFA" (distributary flow area). Figure 14 shows the boundary of the distributary flow area extending north (to the right in Figure 14) and west in the direction of subarea 6.

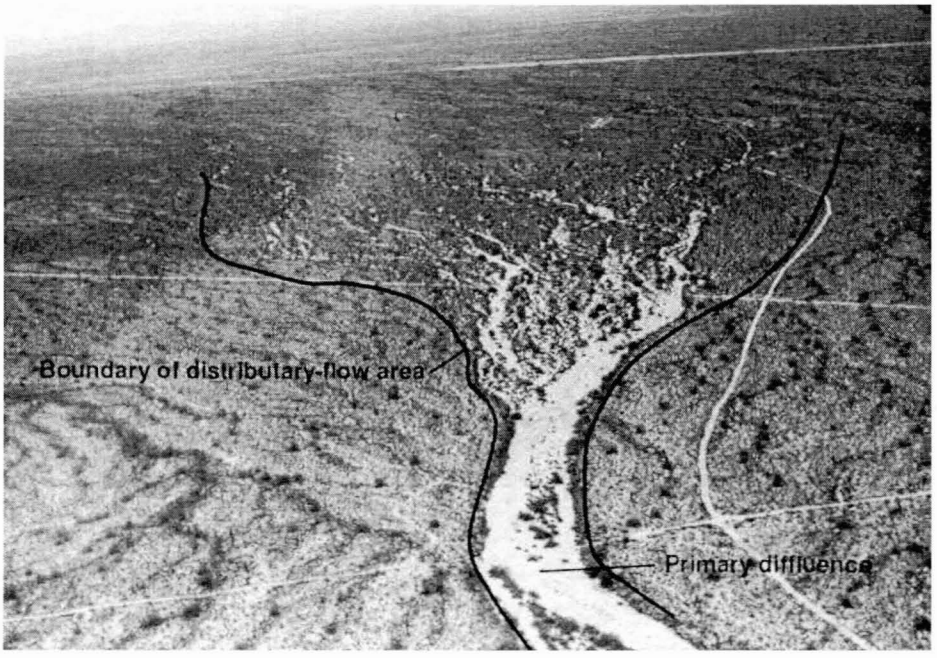

Figure 14 (from Hjalmarson (1994)). Looking downstream and southwest at the primary diffluence and distributary-flow area at Site 36. The bushes and trees in the middle part of the distributary-flow area are larger that those outside the distributary-flow area. The soils are light colored, and most of the area has the appearance of being inundated during a single large flood.

Evaluation

Subarea 6 does receive water and sediment from the Site 36 alluvial fan. This was especially evidenced by the flood of August 1951. The fact that the upstream area is an alluvial fan creates uncertainty that cannot be set aside in the evaluation of how much sediment and floodwater enters subarea 6. Therefore, a realistic evaluation of the flood hazards of the Site 36 piedmont must acknowledge the possibility of floodwaters entering subarea 6.

Recommendation

The surficial geology, historical aerial photos, cross section geometry, and field observations indicate that subarea 6 is impacted by floodwaters from the Site 36 alluvial fan. **It is, therefore, recommended that subarea 6 should be included in an assessment of flood hazards resulting from the site 36 alluvial fan.**

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U.S. Geological Survey, 1982, Valencia, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (original photo date 1954, originally published 1958; photo revised in 1982 using 1978 photography).

U.S. Geological Survey, 1978, White Tank Mtns NE, Ariz. Quadrangle, 7.5 minute series, 1:24,000 (original photo date 1954, published 1957; photo revised 1971, and photo inspected with no changes made in 1978).

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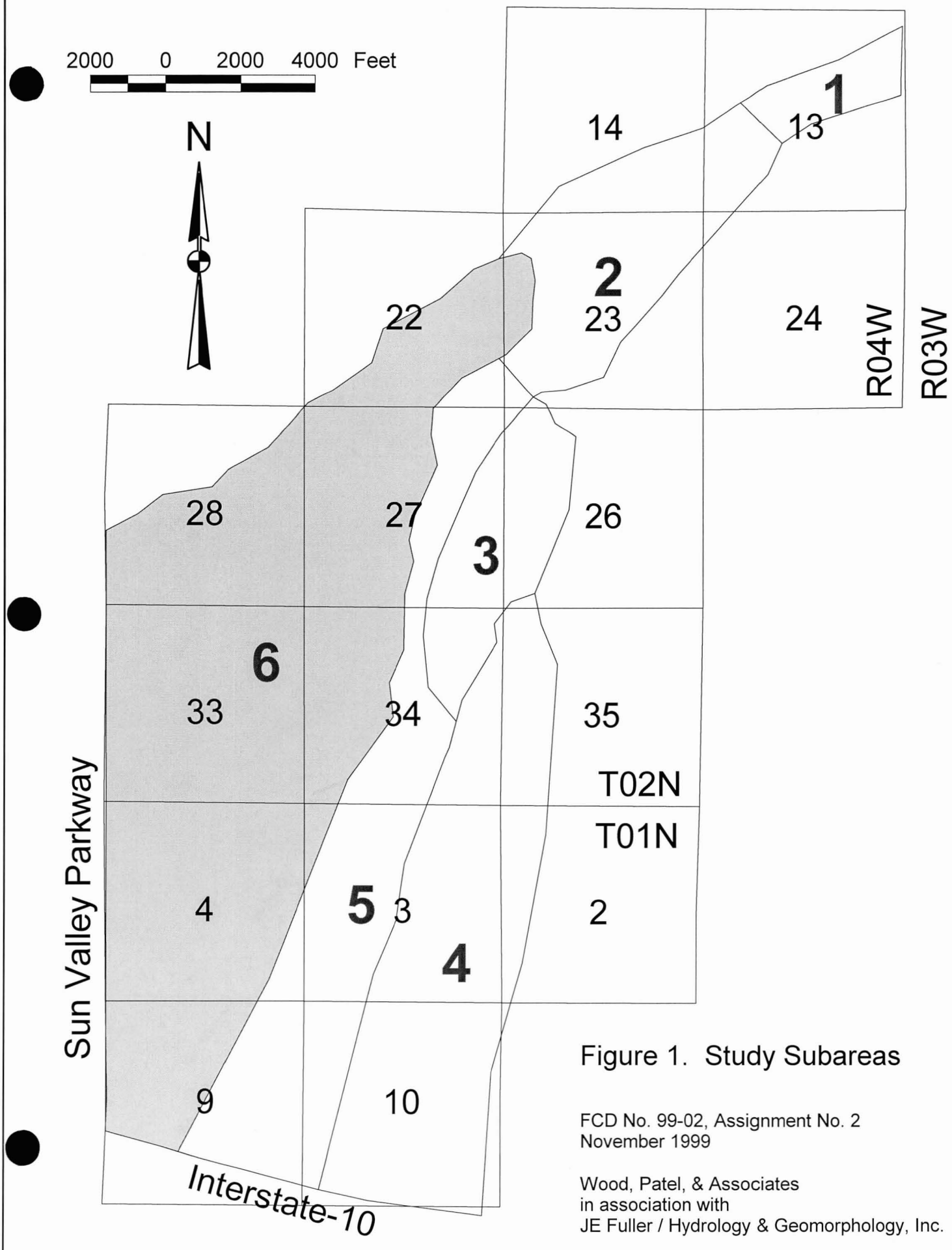


Figure 1. Study Subareas

FCD No. 99-02, Assignment No. 2
November 1999

Wood, Patel, & Associates
in association with
JE Fuller / Hydrology & Geomorphology, Inc.

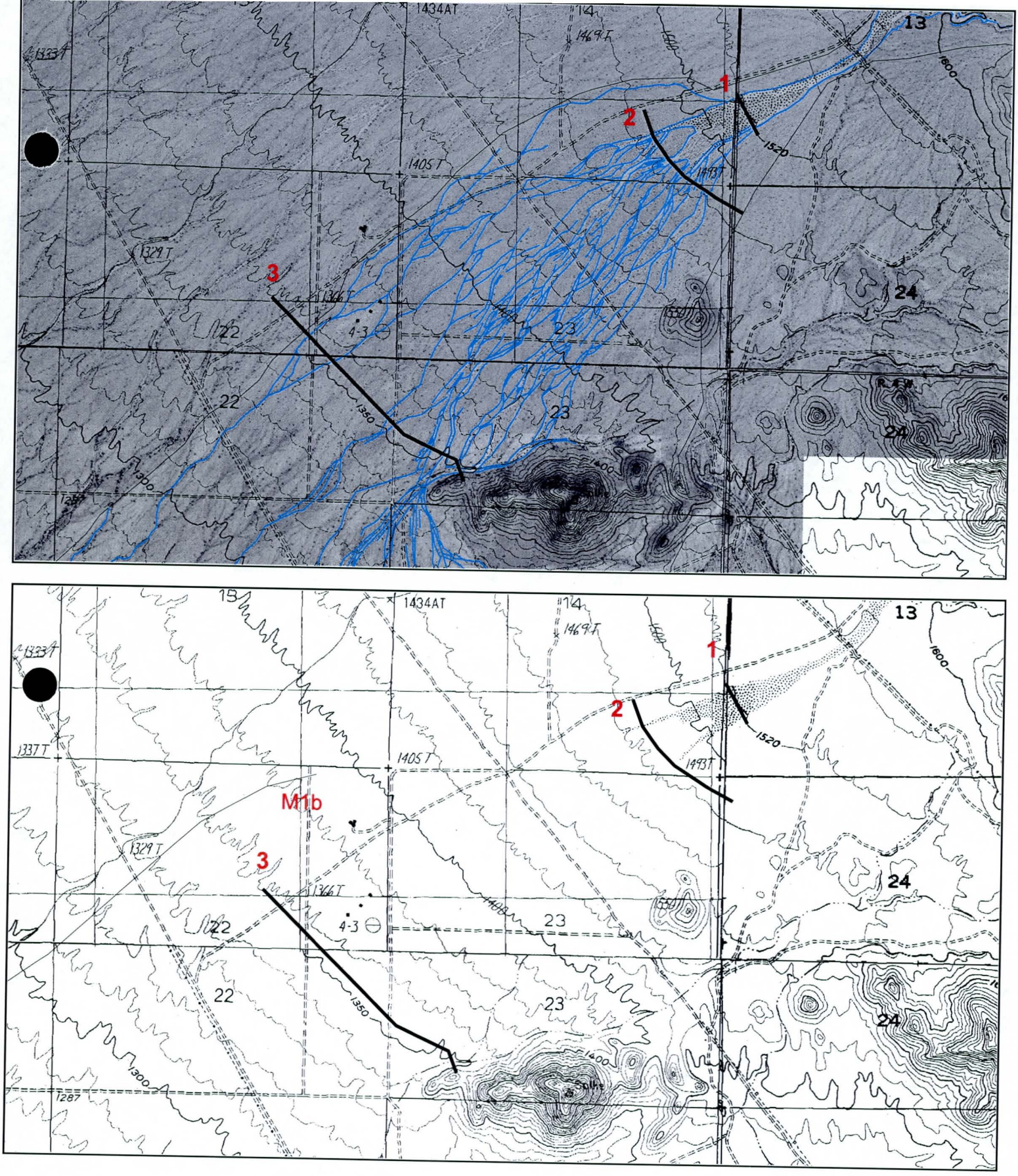


Figure 2. Cross-section Locations for Subarea 6 Evaluation.

99-02
Assignment No. 2
Subtask 6.1

1000 0 1000 2000 Feet

N

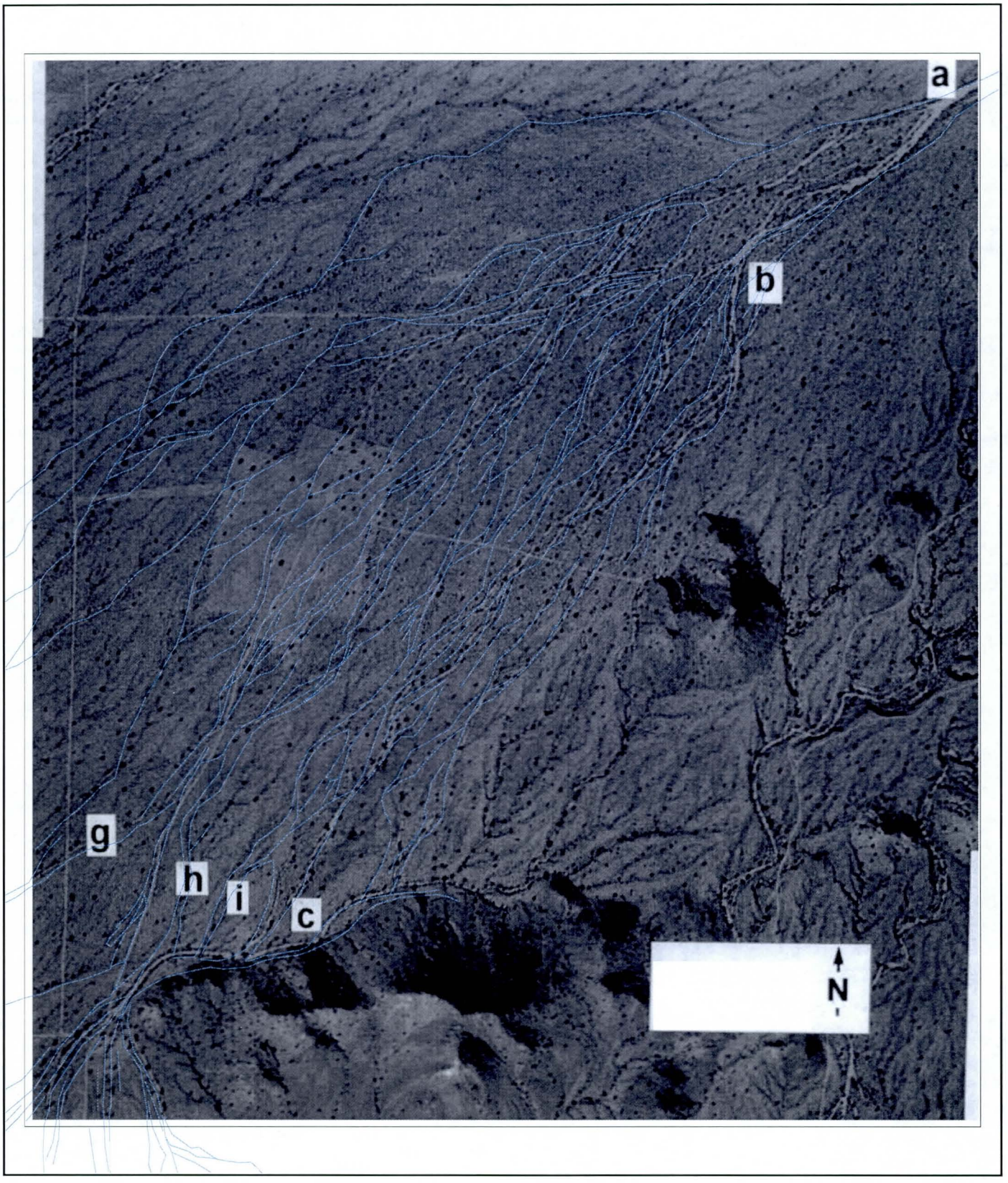


Figure 3. 1942 aerial photograph with tracings of 1997 washes superimposed. Scale 1:12,000.

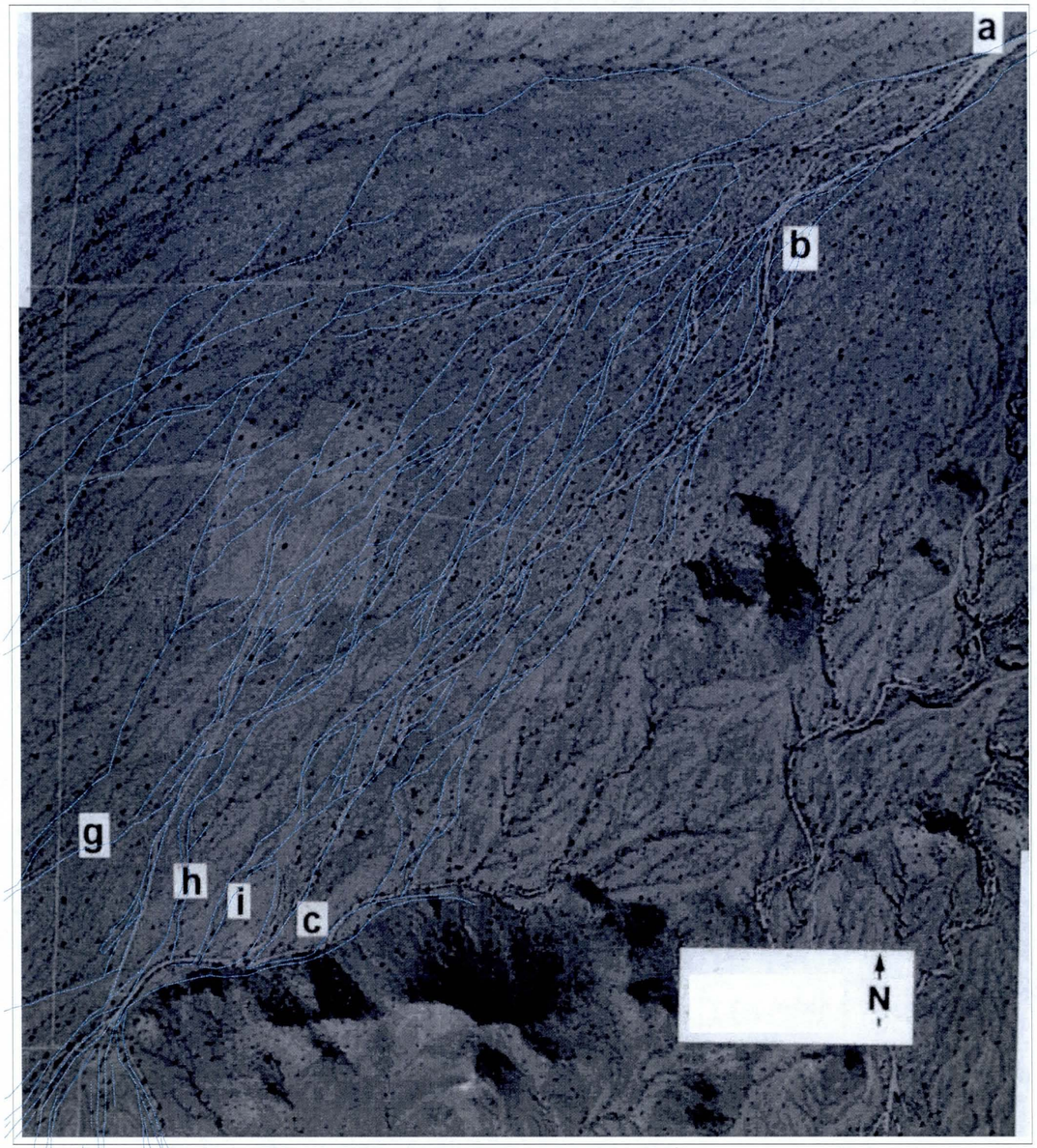


Figure 4a. 1942 aerial photograph of Site 36 alluvial fan.
Letters from Field, 1994. Letter 'a' is the location of the hydrographic apex.
This photo is NOT orthographic, hence local differences between photos.
Scale approximately 1:12,000.

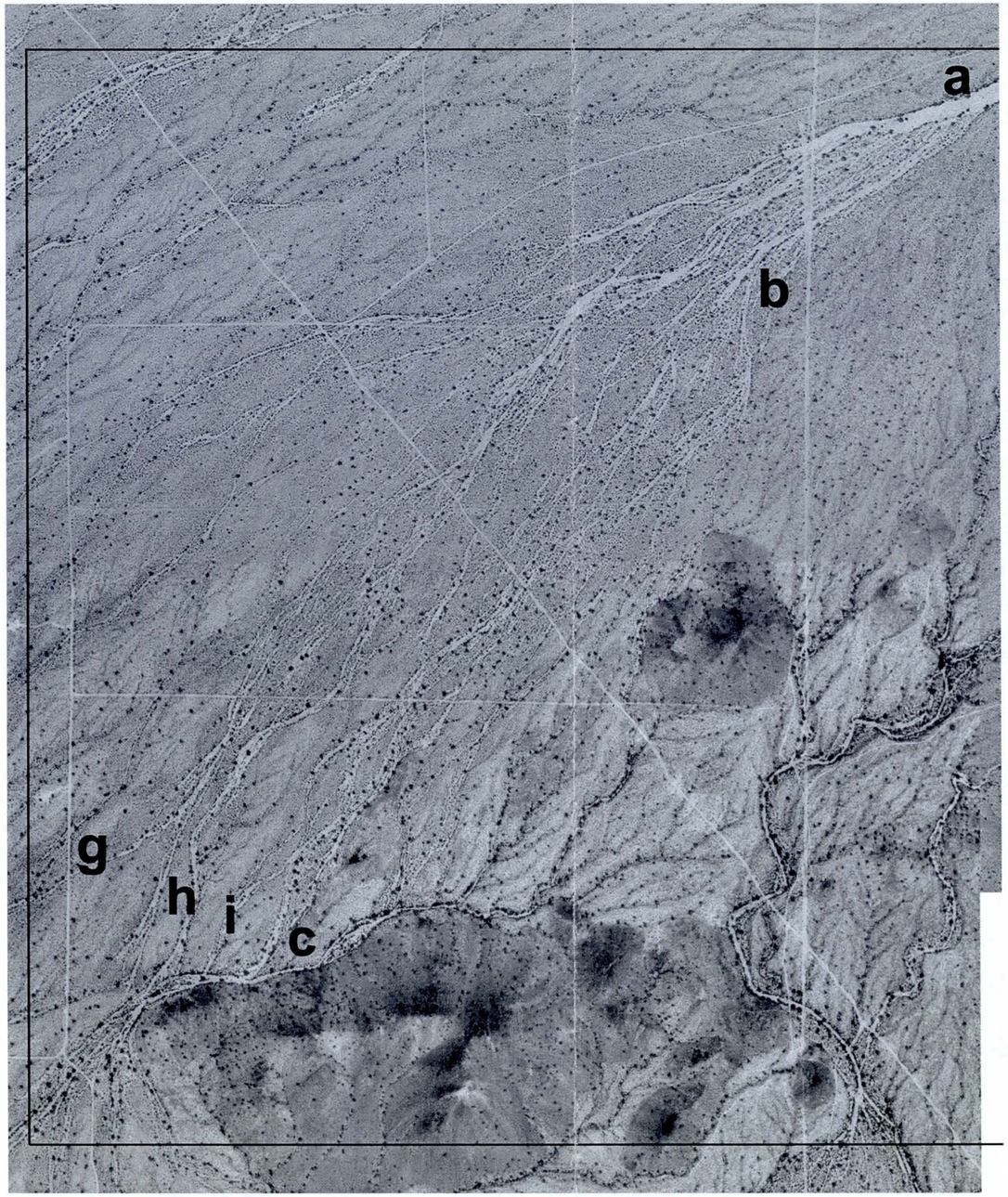


Figure 4b. 1997 aerial ortho photograph of Site 36 alluvial fan.
Letters approximately match 1942 locations.
Scale 1:12,000.

Cross section data and calculations

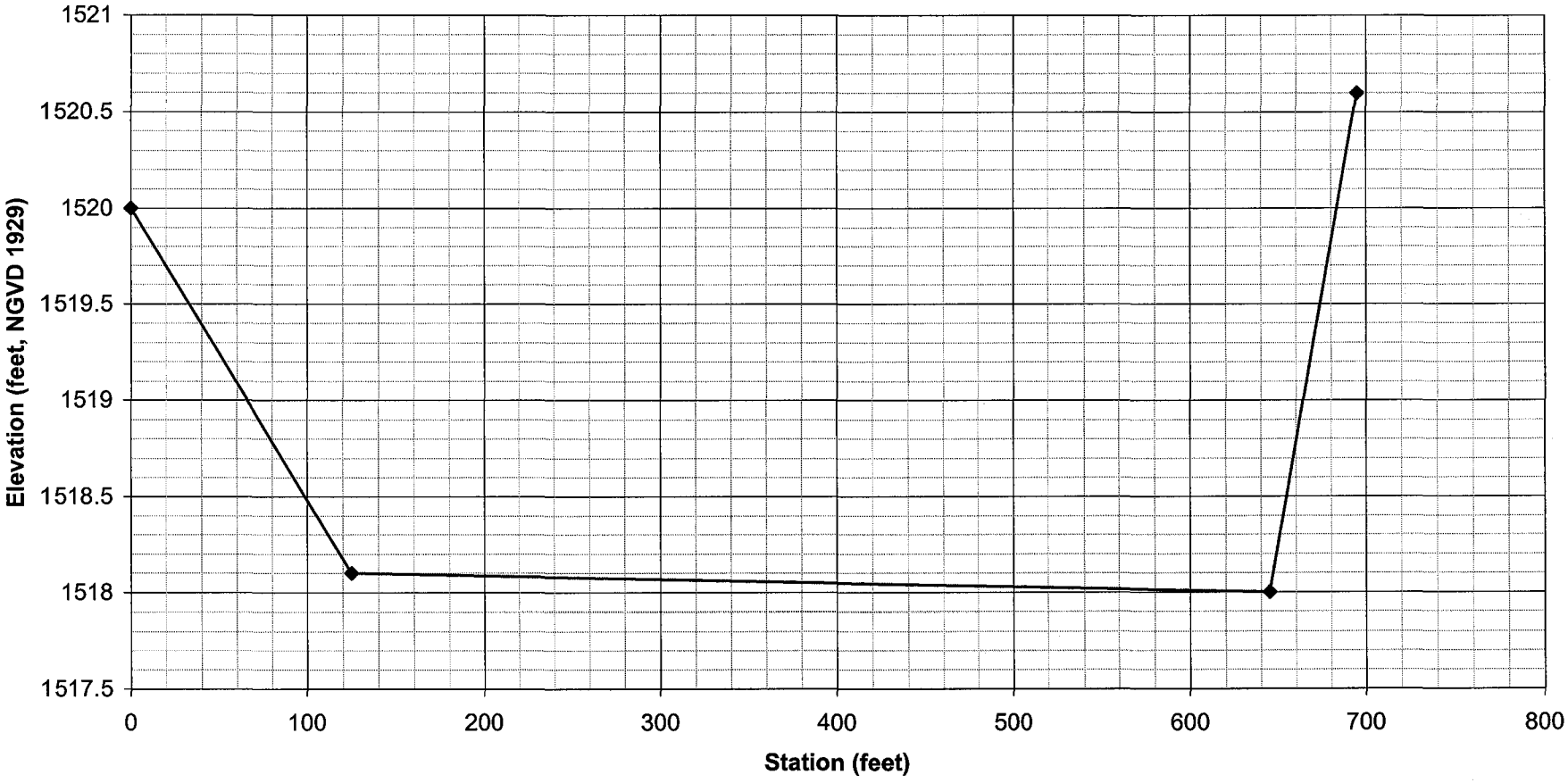
Cross section 1 near the 1520 ft contour shown on the USGS 7.5 minute quadrangles

Station (ft)	Elevation (ft)
0	1520
125	1518.1
645	1518
695	1520.6

S1 = 0.019 from 1560 ft to 1460 ft
S2 = 0.025 - 0.031 from 1520 ft to 1500 ft

Q1 = 5,030 cfs @ 1.5 ft
Q2 = 6,105 cfs @ 1.5 ft

White Tank Fan, Site 36
Cross-section 1 near the 1520 ft contour
just upstream of first breakout toward the north
at Section line between Sec 13 and 14, T2N, R4W
from USGS 7.5 Quadrangles



STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS4.DAT
CROSS-SECTION NUMBER 1
DATE OF CROSS-SECTION MEASUREMENT: 991109

CHANNEL SLOPE RANGE: 0.0190 to 0.0190

VELOCITY FORMULA: User Supplied Mannings n
D84 = 1.000 (ft)

cross-section treated as one sectionXS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.50	1	242.4	558.8	558.8	0.4	0.4	0.0190	0.044	2.7	652.04
1.00	1	533.2	604.2	604.2	0.9	0.9	0.0190	0.043	4.4	2370.21
1.50	1	846.6	649.6	649.6	1.3	1.3	0.0190	0.041	5.9	5029.10
2.00	1	1182.8	695.1	695.0	1.7	1.7	0.0190	0.040	7.3	8655.99

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS4_2.DAT
CROSS-SECTION NUMBER 1
DATE OF CROSS-SECTION MEASUREMENT: 991109

CHANNEL SLOPE RANGE: 0.0280 to 0.0280

VELOCITY FORMULA: User Supplied Mannings n
D84 = 1.000 (ft)

cross-section treated as one sectionXS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.50	1	242.4	558.8	558.8	0.4	0.4	0.0280	0.044	3.3	791.54
1.00	1	533.2	604.2	604.2	0.9	0.9	0.0280	0.043	5.4	2877.33
1.50	1	846.6	649.6	649.6	1.3	1.3	0.0280	0.041	7.2	6105.10
2.00	1	1182.8	695.1	695.0	1.7	1.7	0.0280	0.040	8.9	10507.98

Cross section 2 near the 1480 ft contour
shown on the USGS 7.5 minute quadrangles

Station (ft)	Elevation (ft)	Stage (ft)
0	1487.4	5.5
500	1484.7	2.8
650	1482.9	1.0
730	1484.7	2.8
800	1485.8	3.9
880	1485.5	3.6
990	1487.1	5.2
1120	1485.6	3.7
1190	1486.7	4.8
1220	1485.1	3.2
1300	1486.6	4.7
1330	1484.3	2.4
1420	1487.0	5.1
1520	1486.3	4.4
1560	1482.4	0.5
1660	1484.4	2.5
1740	1481.9	0.0
1840	1485.3	3.4
1870	1485.3	3.4
1950	1483.4	1.5
2030	1487.5	5.6
2230	1486.5	4.6
2360	1484.7	2.8

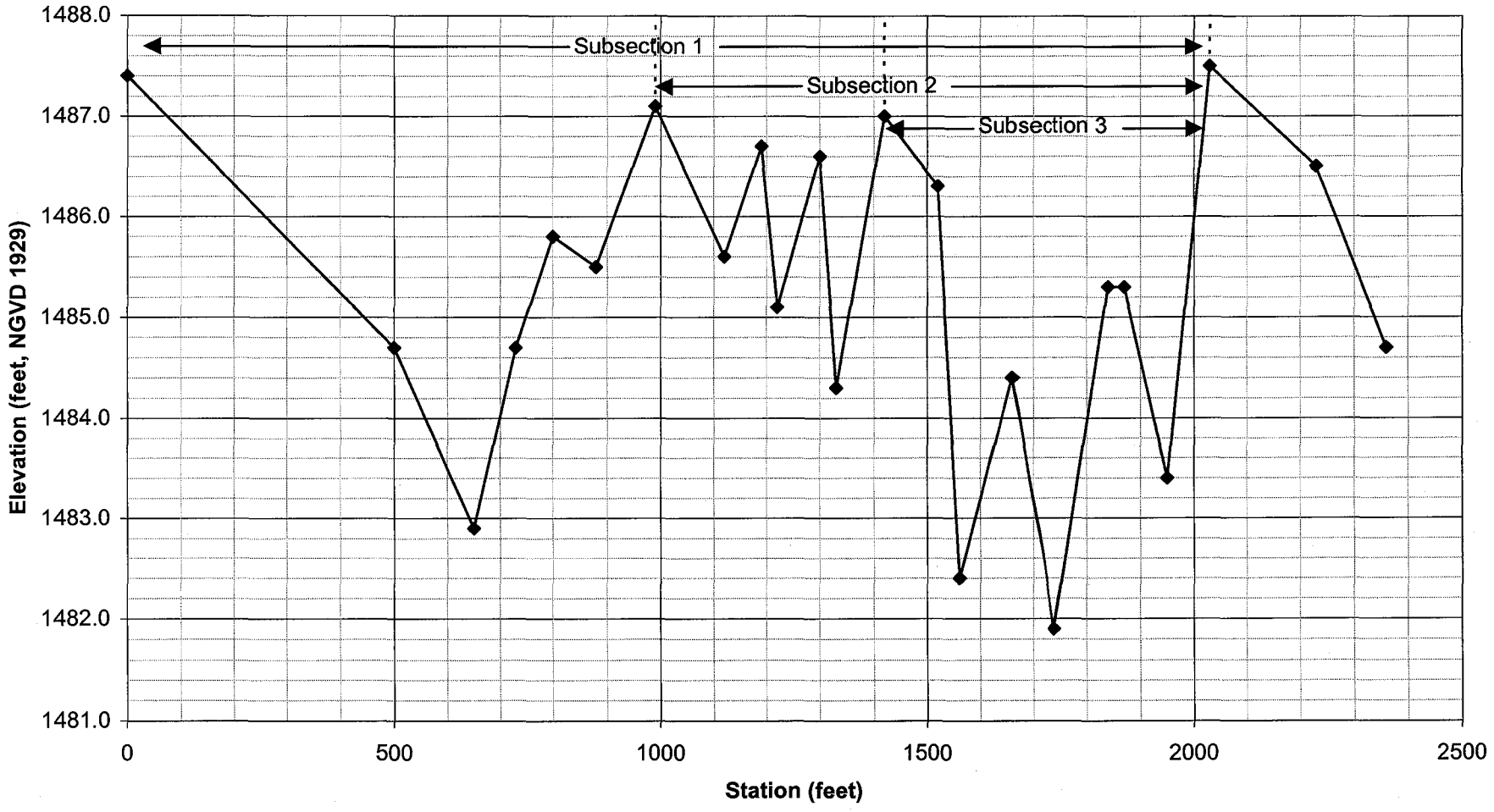
S = 0.020

Q3 @ 3.0 ft = 3,070 cfs
Q3 @ 4.0 ft = 7,780 cfs

Q2 @ 3.0 ft = 3,010 cfs
Q2 @ 4.0 ft = 7,290 cfs

Q1 @ 3.0 ft = 4,120 cfs
Q1 @ 4.0 ft = 10,730 cfs

White Tank Fan, Site 36
Cross-section 2 just upstream of 1480 contour
from USGS 7.5 Quadrangles



STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS1480_1.DAT
CROSS-SECTION NUMBER 1
DATE OF CROSS-SECTION MEASUREMENT: 991111

CHANNEL SLOPE RANGE: 0.0200 to 0.0200

VELOCITY FORMULA: User Supplied Mannings n
D84 = 1.000 (ft)

cross-section treated as one sectionXS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.50	1	7.7	30.7	30.7	0.2	0.2	0.0200	0.049	1.7	13.10
1.00	1	38.2	91.6	91.5	0.4	0.4	0.0200	0.048	2.5	93.76
1.50	1	115.2	216.4	216.3	0.5	0.5	0.0200	0.047	2.9	339.22
2.00	1	262.2	372.0	371.8	0.7	0.7	0.0200	0.046	3.6	951.32
2.50	1	487.2	532.2	532.0	0.9	0.9	0.0200	0.045	4.4	2150.94
3.00	1	790.1	694.3	693.9	1.1	1.1	0.0200	0.044	5.2	4124.13
3.50	1	1192.5	937.1	936.6	1.3	1.3	0.0200	0.043	5.8	6862.10
4.00	1	1742.3	1281.9	1281.4	1.4	1.4	0.0200	0.042	6.2	10725.96
4.50	1	2452.8	1571.5	1570.9	1.6	1.6	0.0200	0.041	6.9	16961.57
5.00	1	3319.2	1877.7	1877.0	1.8	1.8	0.0200	0.040	7.7	25563.09

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS1480_2.DAT
CROSS-SECTION NUMBER 1
DATE OF CROSS-SECTION MEASUREMENT: 991111

CHANNEL SLOPE RANGE: 0.0200 to 0.0200

VELOCITY FORMULA: User Supplied Mannings n
D84 = 1.000 (ft)

cross-section treated as one sectionXS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.50	1	7.7	30.7	30.7	0.2	0.2	0.0200	0.049	1.7	13.10
1.00	1	38.2	91.6	91.5	0.4	0.4	0.0200	0.048	2.5	93.76
1.50	1	99.2	152.5	152.4	0.7	0.7	0.0200	0.047	3.4	334.01
2.00	1	198.3	244.2	244.0	0.8	0.8	0.0200	0.046	4.0	790.77
2.50	1	343.5	340.5	340.3	1.0	1.0	0.0200	0.045	4.7	1617.52
3.00	1	532.1	414.4	414.1	1.3	1.3	0.0200	0.044	5.7	3009.89
3.50	1	763.5	532.8	532.4	1.4	1.4	0.0200	0.043	6.2	4755.11
4.00	1	1055.0	652.1	651.7	1.6	1.6	0.0200	0.042	6.9	7294.10
4.50	1	1418.8	814.8	814.2	1.7	1.7	0.0200	0.041	7.4	10554.41
5.00	1	1875.1	994.0	993.3	1.9	1.9	0.0200	0.040	8.0	15081.65

STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE XS1480_3.DAT
CROSS-SECTION NUMBER 1
DATE OF CROSS-SECTION MEASUREMENT: 991111

CHANNEL SLOPE RANGE: 0.0200 to 0.0200

VELOCITY FORMULA: User Supplied Mannings n
D84 = 1.000 (ft)

cross-section treated as one sectionXS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
0.50	1	7.7	30.7	30.7	0.2	0.2	0.0200	0.049	1.7	13.10
1.00	1	38.2	91.6	91.5	0.4	0.4	0.0200	0.048	2.5	93.76
1.50	1	99.2	152.5	152.4	0.7	0.7	0.0200	0.047	3.4	334.01
2.00	1	198.3	244.2	244.0	0.8	0.8	0.0200	0.046	4.0	790.77
2.50	1	343.2	335.9	335.7	1.0	1.0	0.0200	0.045	4.8	1630.55
3.00	1	523.7	386.6	386.3	1.4	1.4	0.0200	0.044	5.9	3070.80
3.50	1	732.2	460.1	459.8	1.6	1.6	0.0200	0.043	6.7	4890.33
4.00	1	965.8	475.1	474.7	2.0	2.0	0.0200	0.042	8.1	7776.16
4.50	1	1207.5	503.2	502.8	2.4	2.4	0.0200	0.041	9.2	11123.21
5.00	1	1479.2	584.4	584.0	2.5	2.5	0.0200	0.040	9.8	14472.46

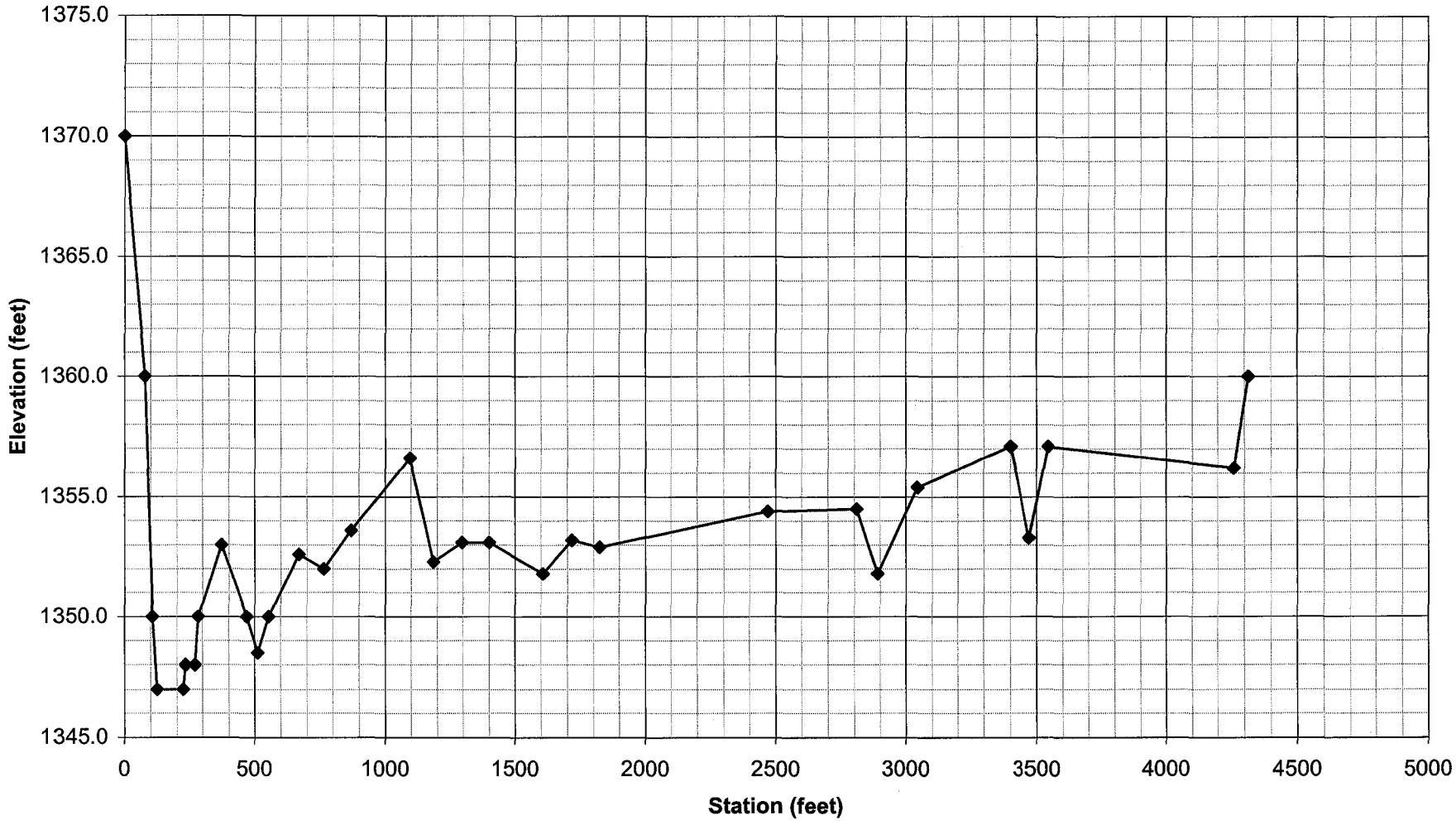
Cross section 3 near the 1350 ft contour
shown on the USGS 7.5 minute quadrangles

Station (feet)	Elevation (feet)	Stage (ft)
0	1370.0	23.0
78	1360.0	13.0
108	1350.0	3.0
125	1347.0	0.0
225	1347.0	0.0
235	1348.0	1.0
270	1348.0	1.0
283	1350.0	3.0
373	1353.0	6.0
470	1350.0	3.0
512	1348.5	1.5
554	1350.0	3.0
669	1352.6	5.6
765	1352.0	5.0
870	1353.6	6.6
1095	1356.6	9.6
1185	1352.3	5.3
1296	1353.1	6.1
1400	1353.1	6.1
1606	1351.8	4.8
1718	1353.2	6.2
1825	1352.9	5.9
2470	1354.4	7.4
2810	1354.5	7.5
2890	1351.8	4.8
3045	1355.4	8.4
3400	1357.1	10.1
3472	1353.3	6.3
3545	1357.1	10.1
4260	1356.2	9.2
4316	1360.0	13.0

S = 0.0169

Q @ 3.0 ft = 3,100 cfs
Q @ 4.0 ft = 5,650 cfs

White Tank Fan, Site 36
Cross Section 3 (A-A') - just upstream of 1350' contour
(Data from USGS 7.5 minute quadrangles)



STAGE-DISCHARGE DATA FOR CROSS-SECTION FILE A2A.DAT
CROSS-SECTION NUMBER 1
DATE OF CROSS-SECTION MEASUREMENT: 991108

CHANNEL SLOPE RANGE: 0.0169 to 0.0169

VELOCITY FORMULA: User Supplied Mannings n
D84 = 1.000 (ft)

cross-section treated as one sectionXS from 7.5' quadrangles

STAGE ft	#SEC	AREA ft^2	PERIM ft	WIDTH ft	R ft	DAVG ft	SLOPE	n	VAVG ft/s	Q cfs
1.00	1	107.8	115.8	115.7	0.9	0.9	0.0169	0.049	3.8	404.57
2.00	1	271.6	191.2	190.8	1.4	1.4	0.0169	0.048	5.1	1371.88
3.00	1	496.5	259.5	259.0	1.9	1.9	0.0169	0.048	6.3	3107.66
4.00	1	810.3	369.3	368.6	2.2	2.2	0.0169	0.047	7.0	5647.97
5.00	1	1235.1	493.6	492.7	2.5	2.5	0.0169	0.046	7.7	9553.56
6.00	1	1958.4	1010.5	1009.3	1.9	1.9	0.0169	0.045	6.6	12992.88
7.00	1	3458.6	1854.4	1852.9	1.9	1.9	0.0169	0.045	6.6	22751.72
8.00	1	5755.7	2598.4	2596.6	2.2	2.2	0.0169	0.044	7.5	43207.03
9.00	1	8490.5	2915.0	2912.9	2.9	2.9	0.0169	0.043	9.2	77866.00
10.00	1	11846.0	3907.0	3904.5	3.0	3.0	0.0169	0.042	9.6	113615.73
11.00	1	15876.7	4065.8	4063.1	3.9	3.9	0.0169	0.042	11.6	183589.84
12.00	1	19966.9	4120.5	4117.5	4.8	4.8	0.0169	0.041	13.6	271655.31
13.00	1	24111.7	4175.2	4171.9	5.8	5.8	0.0169	0.040	15.6	375836.41

XS near 1300 ft contour

Station (ft)	Elevation (ft)
0	1300.0
80	1296.8
140	1296.8
150	1298.7
200	1298.3
270	1300.0
350	1301.7
470	1302.1
550	1306.9
650	1302.3
740	1302.0
850	1300.0
1040	1296.0
1100	1294.3
1270	1300.0
1360	1301.2
1520	1300.9
1580	1300.0
1640	1297.2
1710	1300.0
1770	1298.6
1830	1300.0
2050	1302.2
2130	1301.6
2190	1300.0
2250	1298.1
2300	1300.0
2400	1301.7
2480	1301.3
2560	1299.2
2680	1302.3
2760	1300.0
2800	1298.2
2940	1301.0
3000	1300.0
3050	1297.5
3150	1295.2
3250	1300.0
3350	1301.4
3470	1302.6
3560	1300.0
3610	1302.7
3700	1302.3
3760	1300.0
3800	1297.1
3880	1300.0
3930	1302.3
3990	1300.0
4050	1297.2
4120	1300.0
4230	1303.8
4410	1303.2
4510	1300.0
4640	1302.8
4750	1302.5
4830	1300.0
4890	1297.4
4980	1300.0
5120	1297.1
5160	1297.3
5380	1300.0
5570	1301.3
5700	1300.7
5810	1301.3
5920	1300.0
5970	1300.8
6030	1300.0
6090	1298.0
6150	1300.0
6300	1302.8
6660	1302.4
6770	1300.0
6830	1299.0
6850	1299.0
6900	1300.0
7040	1304.1

XS near 1460' contour - active area

Station (ft)	Elevation (ft)
0	1462.6
100	1460.0
200	1460.5
305	1460.0
440	1461.7
530	1460.0
650	1459.8
700	1460.0
800	1460.8
900	1458.8
970	1460.0
1020	1459.5
1100	1460.5
1160	1460.0
1210	1461.1
1270	1460.0
1310	1462.7
1360	1460.0
1400	1461.4
1520	1461.4
1540	1460.0
1610	1460.0
1640	1460.5
1670	1460.0
1690	1459.2
1730	1460.0
1790	1461.1
1830	1460.0
1850	1459.0
1880	1460.0
1960	1460.9
2060	1461.0
2120	1462.4
2180	1460.0
2250	1461.8
2280	1460.0
2330	1462.5
2380	1460.0
2440	1460.2
2480	1460.0
2520	1459.6
2550	1460.0
2620	1462.0
2780	1461.0
2980	1460.0

data from USGS 7.5' Quad

potential cummulative width of all corridors for Q_{100}

use average slope on lower piedmont of ≈ 1%

$\therefore \quad Q = AV$

Q_{100} @ apex $\cong$ 3600 cfs

$A = D \cdot W$ for broad shallow rectangular channel

Assume $\bar{D} \cong 1$ ft for Q_{100}

$\therefore \quad A = 1 \cdot W$

Also, $V = \frac{1.486}{n}\left(\frac{A}{WP}\right)^{2/3} S^{1/2}$

$= \frac{1.486}{n}\left(\frac{1 \cdot W}{2 \cdot 1 + W}\right)^{2/3} (0.01)^{1/2}$

Assume $n = 0.045$

$\therefore \quad V = \frac{1.486}{0.045}(0.01)^{1/2}\left(\frac{W}{W+2}\right)^{2/3}$

$= 3.3 \cdot \left(\frac{W}{W+2}\right)^{2/3}$

$\therefore Q = AV$

$\Rightarrow 3600 = W \cdot 3.3 \left(\frac{W}{w+2}\right)^{2/3}$

Solve for w:

$$1090 = w^{5/3} \cdot \left(\frac{1}{w+2}\right)^{2/3}$$

$$1090 = \frac{w^{5/3}}{(w+2)^{2/3}}$$

$$1090 (w+2)^{2/3} = w^{5/3}$$

$$1090 \left(\frac{w+2}{w}\right)^{2/3} = w$$

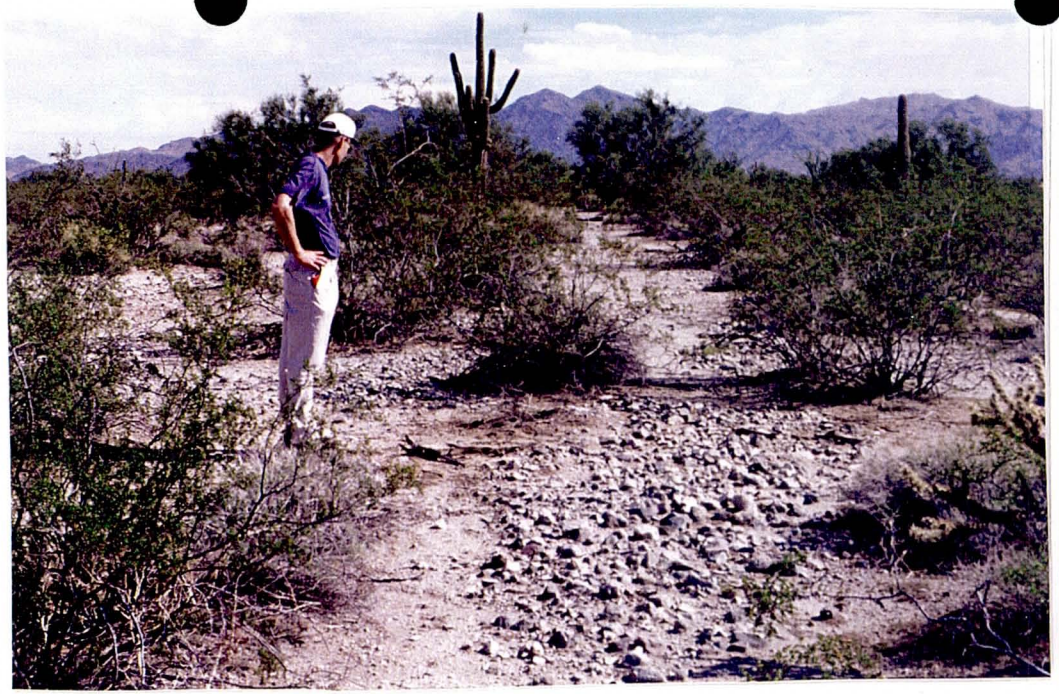
since we know w is large
($Q = D \cdot W \cdot V = 1 \cdot W \cdot V$)
$w+2 \approx w$ so $\left(\frac{w+2}{w}\right) \approx 1$

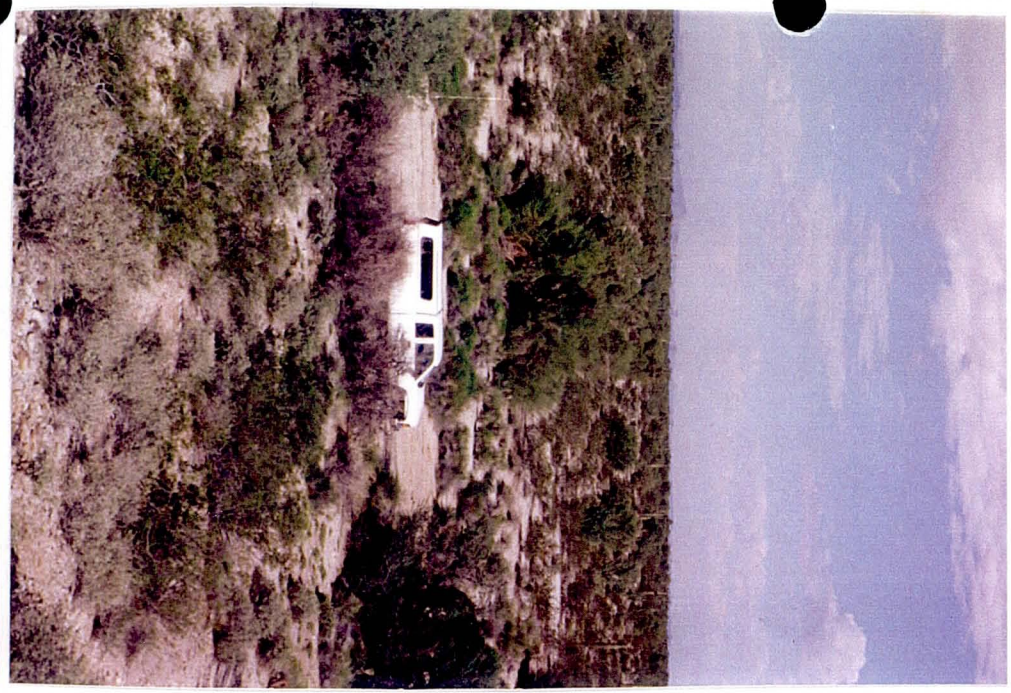
and $1^{2/3} = 1$ so,

$w \approx 1090$ ft

Check, $3600 \overset{?}{=} 1 \cdot 1090 \cdot 3.3 \left(\frac{1090}{1092}\right)^{2/3}$
$= 3592.6$

Good enough





White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View U/S on fan N of large inselberg in the SW1/4 of Sec. 23, T2N, 4W
Note coarse deposit w/ fluvial transport, saguargo in background and biological soil crusts in channel

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View S from W end of large inselberg in the SW1/4 of Sec. 23, T2N, 4W
Note gopher holes bringing up red material from below desert pavement surface.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View of scour of about ½ ft at base of ocotillo
In Sec. 23.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View NW from W end of large inselberg in the SW1/4 of Sec. 23, T2N, 4W
Across section A"-A'-A

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View D/S of diffluence with HWM from recent low flow.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

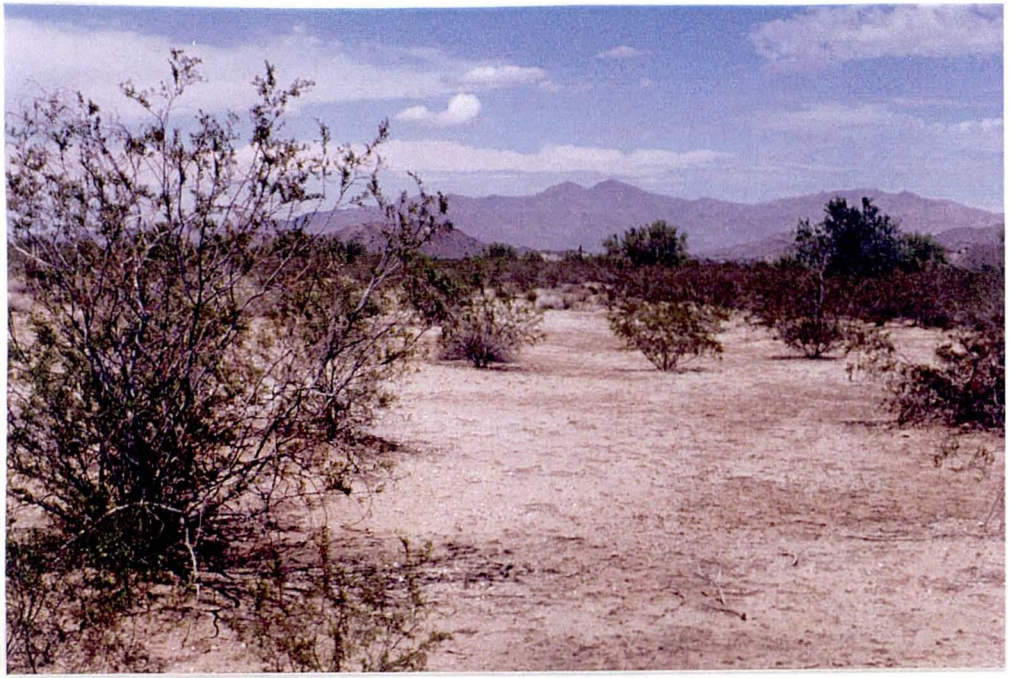
View S from just W of Sec 13-14 N-S line on SW trending road
Note lack of lateral relief.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View of buried tree in Sec. 23

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View down road/channel from just W of Sec 13-14 N-S line on SW trending road



White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View N from rightmost fan channel in S ½ SE ¼ Sec 14, T 2N, R4W. Note degree of lateral relief.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
September 14, 1999

View N across Y2 surface on dirt road near mid section between T2N, R4W, Sec. 34 and T1N, R4W, Sec. 3.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999
SW1/4 SW1/4 Sec. 26, T2N, R4W
View downstream of split just upstream of road on photo 3-7 near center; note how 2 big palo verdes "force" split
Channels about 10' wide by 2' deep on outer banks with about 0.75' high interior banks

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

SW1/4 SW1/4 Sec. 26, T2N, R4W

View downstream on left channel of split

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

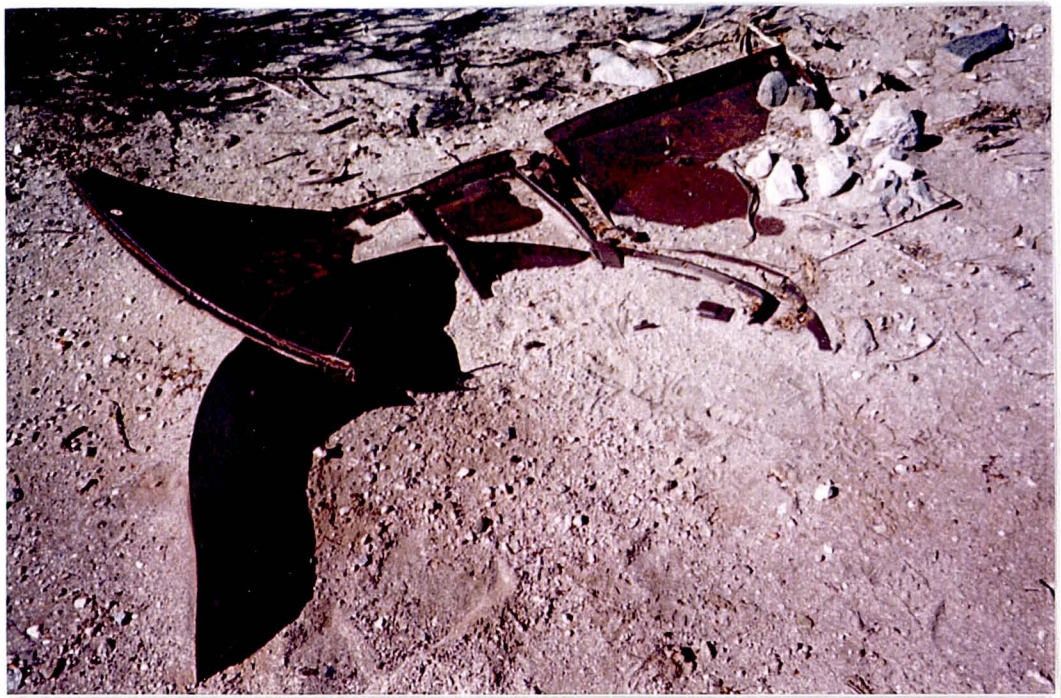
SW1/4 SW1/4 Sec. 26, T2N, R4W

View downstream on right channel of split.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

NW1/4 NW1/4 Sec. 35, T2N, R4W

View of old brakeline setting in desert pavement. Note how it was slightly sunken into pavement.



White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

NW1/4 NW1/4 Sec. 26, T2N, R4W

View D/S of on left of big diffluence at the west nose of spike hill.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

NW1/4 Sec. 26, T2N, R4W

View D/S at split on east edge of flows over old (M1a) surface D/S of spike hill. (2 of 2)

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

NW1/4 Sec. 26, T2N, R4W

View D/S at split on east edge of flows over old (M1a) surface D/S of spike hill. (1 of 2)

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

NW1/4 of Sec. 26, T2N, R4W

Photo of old (1920s?) car parts in wash.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

View D/S (south) on one of leftmost channels on photo 4-3 just north of little inselbergs in NE1/4 Sec. 23, T2N, R4W
Note abandoned look and gravel mounds from road cut not moved.

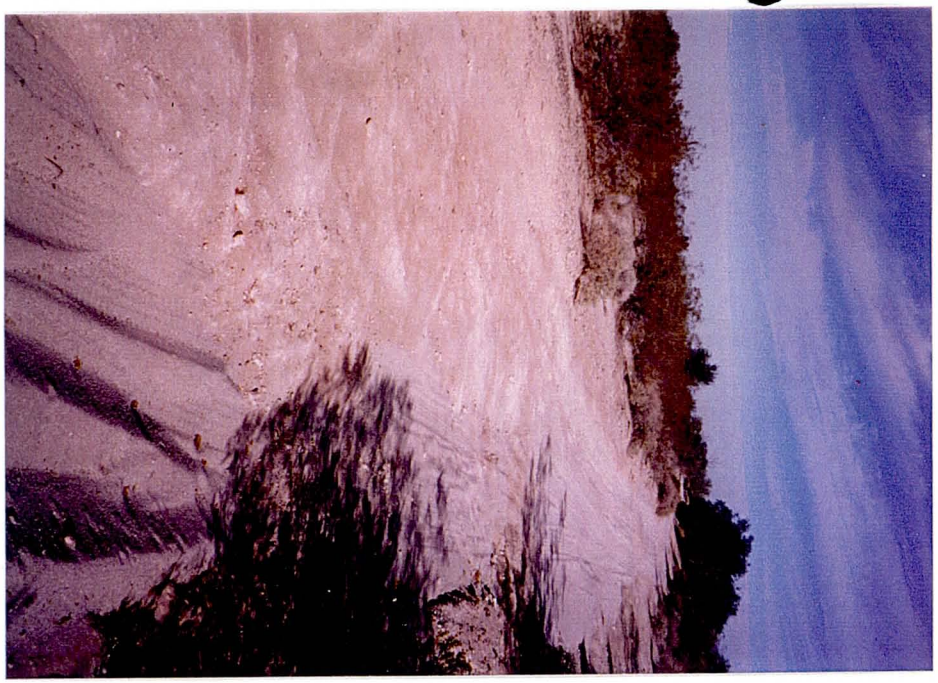
White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

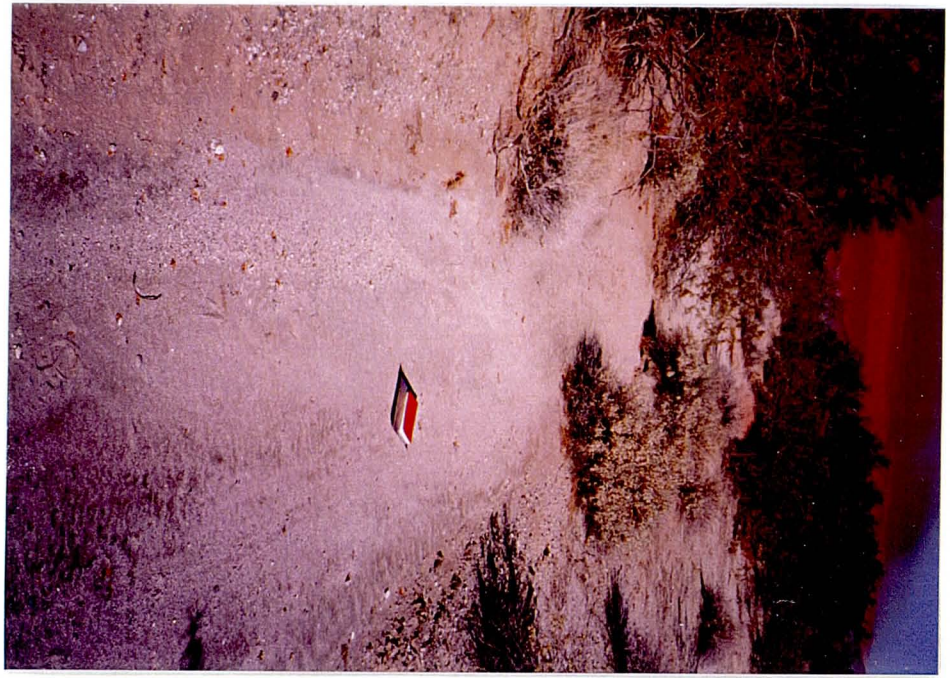
View D/S of small headcut in NE1/4 Sec.23, T2N, R4W.
Note general area steeper and passing over larger caliber materials; recollection of clear(er) water from U/S?

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
November 17, 1999

View D/S of leftmost split in photo 4-3 N of inselberg in the NE1/4 of Sec. 23, T2N, 4W

Note LB about 4 ft higher than channel.





White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P1. View U/S from Tonapah-Salome Hwy up the Sec. 2-3 road (T1N, R4W).
Note caliche and new sand in road.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P2. View of pavement on M1b near wash/road rejoin along Section 2-3 road (T1N, R4W).
(in NW1/4 NW1/4 Sec. 2, T1N, R4W)

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P3. View of typical small channel split flow in aerial 3-5, east of Sec. 34-35 line near U/S road-wash split (T2N, R4W)

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P4. View of 'typical' channel on photo 3-5 near P3.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P5. view N near road on (older) inactive surface on photo 3-5 just U/S of road captured wash along Section line 34-35 (T2N, R4W).

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P6. View D/S of road captured wash.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P7. View of surface on photo 2-5.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P8. View of smooth surface in center of SE1/4 of photo 2-5.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P9,10,11. View of (abandoning?) small flow split.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

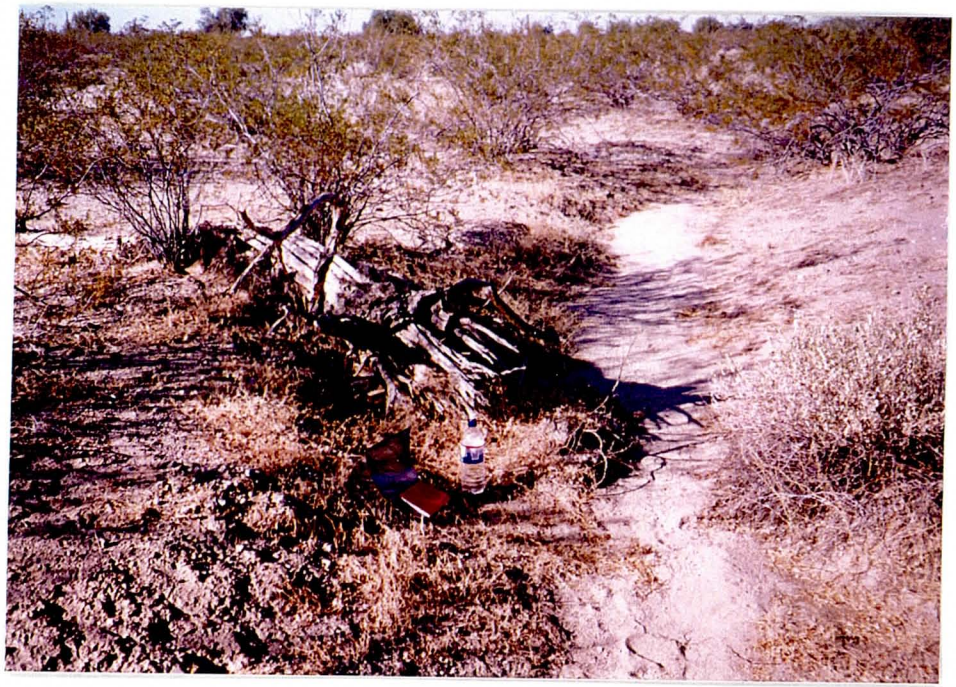
P9,10,11. View of (abandoning?) small flow split.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P9,10,11. View of (abandoning?) small flow split.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P14,15,16. Donnering on LB of channel U/S of P12,13.
Indicator of stability.



White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P17. Eroding / flooded old surface near D/S limit of active inset fan in E1/2 of photo 2-5.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P18. View NW of ctively aggrading area on inset fan in NE1/4 Sec. 34, T2N, R4W.
Note lack of relief over to heavily varnished desert pavement in upper left of photo.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P19. View U/S of headcut in fine-grained soils in area of overflows in area U/S of P18 fan.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P20,21. Eroded and fallen saguaro in LB overflow recollection area, NE1/4 Sec. 34, T2N, R4W.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P12,13. Diffluence on 'big' channel in N1/2 SE1/4 of photo 2-5.
Note flotsam with HWM's about 2.5 ft deep.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P12,13. Diffluence on 'big' channel in N1/2 SE1/4 of photo 2-5.
Note flotsam with HWM's about 2.5 ft deep.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P14,15,16. Donnering on LB of channel U/S of P12,13.
Indicator of stability.

White Tank Fan, Site 36, FCD No. 99-02, Assignment No. 2
December 6, 1999

P14,15,16. Donnering on LB of channel U/S of P12,13.
Indicator of stability.

WHITE TANKS FAN

RIPON TRIP 9.14.99

T: L JF

PHOTO LOG:

P1 - look A-A' section @ lower inselberg

P2 - look S from knob

~~P3~~

- NOTE: Gopher holes bring up red material from below pavement surface

P3 Look W/S on fan N of knob - contrast of fluvial transport - Say in background & cryptogamic crust in ctrl

P4 scour of ½' @ base of Ceotillo

P5 split w/ Hw marks on R bank

P6 Buried tree

P7 view S. from just west of Sec 13/14 N/S line on SW trending road Note lack of lateral relief

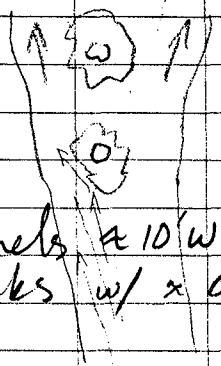
P8 view down road/channel from same spot as P7

P9 look N back to Xn line Rd & track from fan dist (E-most)

P10 - look x^{yz} surface on dirt Rd - mid section Township boundary $\frac{34}{3}$ (look N)

Nov. 17, 1999 1 of 3
White Tank Flow

P1-10 - view D/s of spl.7 just U/s of road on photo 3-7 near center note how 2 big PV's 'force' split



channels ± 10'W x 2'H on outer banks w/ x 0.75'H interior bank

P1-11 - view D/s on Right Ch1
P1-12 - view D/s on Left Ch1
P1-13 - view of brake line in desert pavement
P1-14 view D/s on L. at big difference at the west nose of spike hill
P1-15 & 16 view D/s at split on east edge of flows overdd surface D/s of spike hill

Pl-17 photo of old car parts in wash (1920's)

Pl-1B view D/S - S. on one of leftmost chls on photo 4-3 just north of little hill
Note abandoned looking + gravel mounds from road cut (date?)

Pl-19 view D/S of leftmost split in photo 4-3

Note: ~~as~~ LB ≈ 4' higher than chl

Pl-20 - view D/S of small headcut general area steeper over longer materials - recollection of clearer from U/S?

General

TWI: • west area, SA 6 & west much different, chls more clearly incised
• confusion of sagebrush "all over"
• abandoned looking materials

of many channels, esp. in "active" fan
• yellow browns (tones)? in many of bank & near surface deposits in active fan area, esp. on areas apparently less active - vulnerable in 1942 photos through all w/ 42
• contrast of "disappearance" of evidence from trench near apex to road cuts elsewhere on 'active' fan

Dec 6, 1995 White Tank Fan

Photo 1 - view u/s from Tank pickup Sa lane thru
up 2-3 sec line
note caliche & new sand in road

P2 - view of pavement on
MB near wash/road rejoin
along section line road

P3 - view of typical small ch1
split flow in photo 3-5
east of 2-3 Sec line
near u/s Road split

P4 - view u/s of "typical" ch1
on photo 3-5 near 2-3
Sec line (see P3)

P5 - view N near road on
(older) inactive surface on 13-5
just u/s of road capture of wash

P6 - view d/s at road capture

P7 - view of surface on p 2-5

P8 - view of smooth surface in center
of SE¼ P2-5

P9,10,11 - view of abandonment? small
difference

P12,13 difference on 'big' ch1
in N½ SE¼ P 2-5
note flotsam
HWM's ± 2-2.5'

P14,15,16 Doming on LB u/s of
P 12,13

P17 - working / flooded old
surface not d/s limit
of active fan
road in E½ of p2-5

P19 - treatment on sandy area of
d/s part of
over flows u/s of channel
difference

P 20,21 - eroded & fallen segments in
LB overflow recollection area

Referenced Literature
That the Reviewer May Not
Have Easily at Their Disposal

FLOOD HAZARDS OF DISTRIBUTARY-FLOW AREAS IN SOUTHWESTERN ARIZONA

By H.W. Hjalmarson and S.P. Kemna

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 91 – 4171

Prepared in cooperation with the
ARIZONA DEPARTMENT OF WATER RESOURCES
and the FLOOD CONTROL DISTRICT OF
MARICOPA COUNTY

Tucson, Arizona
December 1991

[redacted] = White Tank Fan

Table 1.--Location and selected characteristics of sample sites--Continued

Site name	Site number (fig. 1)	Location of primary diffluence	Selected characteristics
Tyson Wash tributary at the front of the Plomosa Mountains--Continued	33	Lat 33°33'58", long 114°08'33", in sec. 32, T. 3 N., R. 18 W., Yuma County, 8 miles southeast of Quartzite, tributary to Tyson Wash--Continued.	soils. Extensive desert varnish occurs on old-fan remnants with a distinct boundary along the active channels. Scattered trees and bushes are along the active channels, and some vegetation is on the ridges. The channel profile is slightly concave with two segments of uniform slope. The end of the first segment occurs at a diffluence. Tyson Wash acts as a base-level stream.
Alamo Wash at Ranegras Plain	34	Lat 33°30'57", long 113°47'27", in sec. 15, T. 2 N., R. 15 W., Yuma County, 28 miles southeast of Quartzite, tributary to Bouse Wash.	The PD is at a mountain pass. The channel at the PD is entrenched in old alluvium and is bounded by a mountain on the left bank. In the upper DFA, two distinct channels are separated by a high flat ridge. In the middle and lower DFA, many channels are separated by low ridges. Large areas in the DFA have light-colored soils. There are scattered large areas of darker soil. A large area of desert varnish occurs along the entire length of the DFA that separates two active regions of the DFA. Vegetation is sparse except along the larger channels where there are scattered trees and brush. The channel profile is slightly concave with two segments of uniform slope. Ranegras Plain acts as a base-level area.
Tiger Wash near Big Horn Mountains	35	Lat 33°43'48", long 113°17'28", in sec. 34, T. 5 N., R. 10 W., Maricopa County, 12 miles south of Gladden, tributary to Centennial Wash.	The PD is at a mountain pass. The right bank of the channel is composed of old-fan deposits, and the left bank is a mountain. In the upper DFA, many deeply incised channels are separated by high ridges. In the middle and lower DFA, many small channels are separated by low ridges. In the DFA, the soils along active channels are light in color. The density of bushes increases in the DFA, and scattered trees are along the active channels. The channel profile is concave. In the middle and lower DFA, floodwater will be unconfined, and there probably will be large areas of sheetflow during major flooding.
Hassayampa River tributary no. 1 near the southern end of the White Tank Mountains	[redacted] 36	Lat 33°30'52", long 112°37'07", in sec. 13, T. 2 N., R. 4 W., Maricopa County, 10 miles north of Buckeye, tributary to the Hassayampa River.	The PD is at the lower edge of the pediment. Two distinct channels about 3,000 feet downstream from the PD are separated by a low ridge. In the middle and lower DFA's, many small channels are separated by low ridges. The soils in the DFA are lighter in color than the surrounding areas. A slight increase occurs in the density of bushes in the DFA. The channel profile has a hump at a depositional lobe below the PD. Downslope from the hump, the profile generally is concave. The Hassayampa River acts as a base-level stream and is a few miles downstream from the toe of the DFA.
Hassayampa River tributary no. 2 near the southern end of the White Tank Mountains	37	Lat 33°31'23", long 112°37'19", in sec. 12, T. 2 N., R. 4 W., Maricopa County, 11 miles north of Buckeye, tributary to the Hassayampa River.	The PD is at the lower edge of the pediment. Several small channels generally are separated by low ridges and a couple of high ridges. The soil is lighter in color in the active channels of the DFA. In the DFA, there is a slight increase in the density of the bushes. The channel profile is slightly concave with a constant slope downstream from a small depositional lobe. The Hassayampa River acts as a base-level stream and is a few miles downstream from the toe of the DFA.

Table 1.--Location and selected characteristics of sample sites--Continued

Site name	Site number (fig. 1)	Location of primary diffluence	Selected characteristics
Hassayampa River tributary no. 3 near the southern end of the White Tank Mountains	38	Lat 33°31'35", long 112°39'13", in sec. 10, T. 2 N., R. 4 W., Maricopa County, 12 miles north of Buckeye, tributary to the Hassayampa River.	The PD is on apparent old-fan deposits about 1 mile downstream from the lower edge of the pediment. In the DFA, several small channels generally are separated by low ridges and a few high ridges. The soil in the DFA is lighter in color along the active channels. In the DFA, there is a slight increase in the density of bushes. The channel profile is slightly concave. The Hassayampa River acts as a base-level stream a few miles downstream from the toe of the DFA.
Hassayampa River tributary no.4 near the southern end of the White Tank Mountains	39	Lat 33°32'38", long 112°38'35", in sec. 3, T. 2 N., R. 4 W., Maricopa County, 13 miles north of Buckeye, tributary to the Hassayampa River.	The PD is at the lower edge of the pediment. The channels in the DFA are deeply incised and are separated by high ridges. Soils in the DFA are lighter in color than soils in the surrounding areas. A slight increase occurs in the density of bushes in the DFA. The channel profile is slightly concave with a fairly constant slope below a small depositional mound. The Hassayampa River acts as a base-level stream a few miles downstream from the toe of the DFA.

Table 2.--*Summary of channel characteristics, estimated discharge, and Froude number of the 100-year flood for the primary diffluences*

[≤, Less than or equal to, >, greater than, ≥, greater than or equal to, <, less than]

Site number	Estimated Manning's *n*, in feet$^{1/6}$	Slope, in foot per foot	100-year flood discharge, in cubic feet per second	Top width, in feet	Area, in square feet	Average velocity, in feet per second	Estimated Froude number in main channel
1	0.035	0.0210	4,400	302	512	8.6	≤1
2	.041	.0222	5,400	410	324	7.5	1
3	.035	.0166	3,500	664	655	5.3	1
4	.040	.0243	890	57	110	8.1	1
5	.035	.0287	3,600	461	459	7.8	>1
6	.042	.0329	6,150	249	567	10.8	>1
7	.040	.0108	8,200	110	556	14.7	>1
8	.035	.0133	3,300	647	649	5.1	1
9	.025	.0108	7,600	201	597	12.7	>1
10	.028	.0140	1,400	71	143	9.8	>1
11	.030	.0080	3,100	261	353	8.8	>1
12	.035	.0232	2,100	118	218	9.6	>1
13	.040	.0231	2,600	355	402	6.5	≥1
14	.044	.0356	2,200	208	254	8.7	>1
15	.030	.0296	1,200	76	116	10.3	>1
16	.035	.0270	1,500	171	213	7.0	≥1
17	.045	.0156	2,200	69	247	8.9	≤1
18	.030	.0126	1,700	271	318	5.3	≤1
19	.040	.0150	1,100	98	172	6.4	≤1
20	.025	.0275	3,800	239	328	11.6	>1
21	.031	.0112	2,000	195	293	6.8	1
22	.035	.0116	4,400	353	725	6.1	<1
23	.045	.0288	3,500	114	325	10.8	1
24	.040	.0170	2,200	278	371	5.9	1
25	.031	.0110	5,100	1,123	1,016	5.0	≤1
26	.040	.0208	1,600	106	196	8.2	1
27	.040	.0134	3,000	200	428	7.0	≤1
28	.025	.0126	2,500	179	291	8.6	>1
29	.025	.0241	1,600	90	135	11.9	>1
30	.040	.0206	3,700	157	384	9.6	>1
31	.040	.0406	1,000	47	91	11.0	>1
32	.040	.0375	1,200	203	191	6.3	>1
33	.040	.0099	3,400	539	746	4.5	<1
34	.045	.0080	10,300	340	1,371	7.5	<1
35	.039	.0093	10,700	937	1,865	5.7	<1
36	.030	.0178	2,600	203	310	8.4	>1
37	.025	.0159	2,300	136	231	10.0	>1
38	.025	.0148	2,000	149	209	9.6	>1
39	.025	.0134	2,000	97	190	10.5	>1

Table 4.--*Discharge intensities for sites that have random and nonrandom channel links and that have high and low degrees of flood hazard*

Site number	Degree of flood hazard	Discharge intensity of distributary-flow areas, in cubic feet per second per square mile			
		Random links	Degree of flood hazard 9-10	Nonrandom links	Degree of flood hazard 1-8
1	5	-----	-----	680	680
2	6	-----	-----	-----	540
3	7	-----	-----	380	380
4	10	-----	2,100	-----	-----
5	10	-----	2,100	-----	-----
6	9	3,600	3,600	-----	-----
7	8	-----	-----	400	400
8	5	-----	-----	400	400
9	9	-----	210	210	-----
10	2	1,000	-----	-----	1,000
11	9	-----	5,600	-----	-----
12	2	-----	-----	-----	3,100
13	8	-----	-----	-----	1,700
14	9	-----	970	970	-----
15	9	-----	1,300	-----	-----
16	5	-----	-----	-----	400
17	10	-----	3,500	-----	-----
18	9	-----	510	510	-----
19	9	-----	3,400	-----	-----
20	9	-----	640	-----	-----
21	9	-----	390	-----	-----
22	10	-----	810	-----	-----
23	10	-----	5,800	-----	-----
24	3	-----	-----	-----	440
25	9	-----	190	190	-----
26	9	-----	800	-----	-----
27	9	-----	1,100	-----	-----
28	10	-----	940	-----	-----
29	9	4,100	1,100	-----	-----
30	2	-----	-----	1,400	1,400
31	8	-----	-----	-----	350
32	8	-----	-----	460	460
33	7	-----	-----	990	990
34	9	-----	410	-----	-----
35	10	280	280	-----	-----
36	10	1,200	1,200	-----	-----
37	9	2,200	2,200	-----	-----
38	9	-----	2,900	2,900	-----
39	8	-----	-----	-----	850
Average	--	1,560	1,750	790	880

Table 7.--Physiographic and hydrologic characteristics of sample sites

[B, degree of flood hazard; RN, ruggedness number of drainage basin; MRDA, mean-relief ratio of drainage basin; MRDFA, mean-relief ratio of distributary-flow area; H, average contour sinuosity of distributary-flow area; K, average contour-band width of drainage basin, in inches; L, average contour-band width of distributary-flow area, in inches; DA, drainage-basin area, in square miles; DFA, area of distributary-flow area, in square miles; MBE, mean-basin elevation, in feet; P, 10-year 24-hour precipitation, in tenths of inches; MAF, mountain-area factor; V, location factor of primary diffluence; W, 100-year flood at primary diffluence, in cubic feet per second; CC, contour-band width just downstream from primary diffluence, in inches]

Site number	B	RN	MRDA	MRDFA	H	K	L	DA	DFA	MBE	P	MAF	V	W	CC
1	5	0.085	0.0292	0.0198	1.49	0.47	0.31	3.89	6.46	2,590	30	1	5	4,380	0.20
2	6	.0721	.0273	.0183	1.45	.49	.30	6.10	10.0	2,710	30	1	5	5,440	.24
3	7	.0997	.0256	.0173	1.46	.49	.24	2.79	9.11	2,660	30	1	6	3,450	.24
4	10	.247	.138	.0193	1.18	.33	.55	.479	.429	2,030	28	4	8	885	.08
5	10	.189	.0812	.0247	1.34	.92	.13	10.8	1.68	4,660	26	1	2	3,560	.04
6	9	.119	.110	.0312	1.18	.38	.09	8.04	1.71	2,670	30	4	8	6,150	.05
7	8	.0546	.0359	.0108	2.26	1.5	.65	56.0	20.7	2,060	27	4	5	8,200	1.0
8	5	.0905	.0685	.0121	1.54	.18	.20	9.24	8.17	1,240	25	1	5	3,340	.32
9	9	.0775	.0434	.0115	1.36	1.2	.56	58.4	35.9	3,310	29	2	5	7,580	.22
10	2	.0996	.0779	.0126	1.71	.40	.26	1.37	1.38	2,240	34	7	7	1,420	.25
11	9	.0543	.0348	.0107	1.99	.76	.27	7.65	.549	2,140	30	3	2	3,050	.26
12	2	.0968	.0526	.0261	1.85	.80	.15	3.17	.682	3,960	28	6	3	2,060	1.1
13	8	.164	.0636	.0289	1.11	.78	.11	5.46	1.52	3,150	27	6	6	2,630	.10
14	9	.169	.0767	.0322	1.14	.98	.08	3.77	2.26	3,440	30	7	8	2,230	.08
15	9	.217	.0930	.0318	1.30	.31	.15	.989	.916	3,100	30	6	7	1,220	.06
16	5	.221	.0556	.0312	1.38	.33	.18	1.65	3.72	3,950	32	3	7	1,540	.14
17	10	.0609	.0251	.0192	1.63	1.1	.20	3.60	.631	4,090	26	1	3	2,180	.14
18	9	.121	.0707	.00980	1.29	1.0	.15	2.40	3.32	1,870	29	6	10	1,700	.22
19	9	.199	.141	.0161	1.29	.36	.15	.922	.320	1,820	29	5	4	1,060	.08
20	9	.155	.0924	.0202	1.39	1.2	.31	12.7	5.89	5,670	30	9	10	3,830	.12
21	9	.115	.0967	.00912	1.94	.46	.46	3.41	5.18	1,470	27	2	9	2,030	.46
22	10	.151	.0898	.00577	1.26	.33	.26	2.33	5.46	1,740	28	3	7	4,400	.18
23	10	.245	.143	.0270	1.32	.44	.12	2.81	.600	2,260	28	7	8	3,500	.04
24	3	.235	.105	.0165	3.75	1.4	.80	4.05	4.98	1,600	22	8	9	2,210	.25
25	9	.0551	.0394	.0127	1.32	1.2	.30	21.6	26.4	2,160	26	1	6	5,100	.12
26	9	.173	.128	.0214	1.37	1.2	.16	1.99	1.99	2,170	26	9	9	1,550	.46
27	9	.101	.0562	.0130	1.30	1.1	.22	7.54	2.77	1,790	26	5	8	3,010	.21
28	10	.103	.0548	.00972	1.09	1.3	.18	5.25	2.65	1,870	25	4	5	2,520	.18
29	9	.253	.130	.0165	1.78	1.2	.26	2.07	1.44	2,420	26	3	9	1,580	.17
30	2	.208	.124	.0197	2.52	1.2	.44	11.1	2.62	3,110	28	9	9	3,660	.47
31	8	.243	.174	.0260	2.05	.48	.35	.847	2.84	1,770	26	8	10	1,010	.52
32	8	.184	.154	.0287	2.21	.90	.43	1.28	2.62	1,990	26	9	10	1,240	.20
33	7	.126	.0694	.0114	3.09	1.1	.44	9.73	3.45	1,720	27	4	6	3,420	.14
34	9	.0482	.0341	.00706	2.03	.94	.58	88.8	25.2	2,070	27	4	6	10,300	.77
35	10	.0747	.0708	.0073	1.75	2.5	.51	95.9	38.8	2,600	26	4	9	10,700	.56
36	10	.131	.0837	.0192	1.36	.94	.14	5.63	2.15	2,130	26	6	7	2,610	.12
37	9	.188	.0946	.0175	1.47	.73	.15	4.30	1.03	2,150	26	4	8	2,280	.18
38	9	.271	.0948	.0152	1.75	.71	.19	3.47	.700	2,160	26	4	6	2,050	.24
39	8	.191	.110	.0137	2.37	.81	.41	3.26	1.25	1,860	26	3	8	1,980	.42

Potential Flood Hazards and Hydraulic Characteristics of Distributary-Flow Areas in Maricopa County, Arizona

By H.W. HJALMARSON

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4. Soils of much of the DFA are yellow and tan on and near the surface.

5. Most of the interfluves in the upper DFA are below the expected level of the 100-year flood.

6. There is little or no desert varnish on stones in the DFA.

Site 30 represents the simplest degree of flood hazard in which the channel divides into two channels that remain separated. The middle of the range of flood-hazard degree is represented by site 2 that has a degree of 6. The flood hazard of site 2 is discussed in detail because it represents typical conditions of DFA's with stable paths of flow in southern and central Arizona. Site 39 has a degree of 8, and stable ridges separate the distributary channels. Site 6 has a degree of 9 where flow paths can change in the upper DFA and most of the ridges will be overtopped by the 100-year flood. Site 23 has the highest degree of flood hazard (10), with a perched main channel and banks in the upper DFA that are the result of recent debris deposition. The DFA's are in two main categories: (1) unstable DFA's that have an aggrading surface and unpredictable paths of flow and (2) stable DFA's that are characterized by a laterally stable network of incised channels. Sites 6 and 23 with respective degrees of flood hazard of 9 and 10 are unstable DFA's, and sites 2 and 30 with respective degrees of flood hazard of 6 and 2 are stable DFA's. Site 39 that has a degree of flood hazard of 8 appears to be a stable DFA because the paths of flow appear to be eroded into old-fan remnants of the Pleistocene Epoch; however, it has a relatively high degree of flood hazard because it appears that most of the interfluvial areas can be overtopped by the 100-year flood.

Contrasting degrees of flood hazard at nearby sites are shown by sites 3 and 36 (fig. 1). Site 3 is adjacent and to the south of site 2. Site 3 has a flood-hazard degree of 7 where two channels are separated by a large island of old-fan remnants in the upper DFA. Site 36 is near and to the south of site 39 on the western slopes of the White Tank Mountains and is an inset alluvial fan that has a flood-hazard degree of 10. An inset fan or DFA is formed during the Holocene Epoch on the surface of an old fan (old-fan remnants) of the Pleistocene Epoch. The paths of flow for site ~~39~~ 36 appear to be much more unstable than the paths of flow of site ~~36~~ 39, which is a short distance to the north.

Site 30

Site 30 is near the western edge of Maricopa County on the southern slopes of the Harquahala Mountains. This site is an example of the simplest type of distributary flow (flood-hazard degree of 2) with a single diffluence and two distributary channels (fig. 2). A few hundred feet above the PD, tributary inflow occurs with a small amount of flow from a small channel to the west of the main channel (fig. 3A). The subtle hump in the stream profile (fig. 4) shown by the smaller slope (fig. 4B) reflects sedimentation at the confluence of the channels. The slope of the main channel steepens above the PD and then flattens. Just downstream from the PD, floodwater of large floods can overtop the left side of the main channel and enter a deeply incised distributary channel on the east through an overflow area (figs. 3A, 3B, and 3D). At the PD, the 100-year flood is confined on the left by a high, erosion-resistant vertical bank (fig. 5A). The channel bed at the PD is composed of sand, gravel, and scattered boulders (fig. 3E). At the overflow area, the capacity of the channel is about equal to the peak discharge of the 10-year flood (fig. 5B). Floodflows less than about the 10-year flood remain in a single channel, whereas larger floods overtop the 4-foot-high left bank from the PD to about 600 ft downstream and spill into a well-defined distributary channel to the east (figs. 5C and 3A–D).

The two distributary channels are separated by a high ridge downstream from the overflow reach (figs. 3C and 5C). About 1,300 ft downstream from the PD, the ridge is 500 ft wide and 15–20 ft above the two stream channels. The high separating ridge is covered with desert varnish (fig. 3B). The varnished interfluve is about 3 mi long and about 2 mi wide (maximum) with a tributary network of channels for local drainage (fig. 2). The soils of the interfluve area are well developed.

Both of the distributary channels contain reaches of branching channels. Where channel branches occur, the number of forks in the channels equals the number of joins. Also, the channel branches do not have terraces and appear to be part of a single, large channel that includes all the branches.

see errata attached

ERRATA

The following changes should be noted for the report entitled "Potential flood hazards and hydraulic characteristics of distributary-flow areas in Maricopa County, Arizona," by H.W. Hjalmarson. U.S. Geological Survey Water-Resources Investigations Report 93-4169.

Page 4—Last sentence on left column should read:
DFA's are not considered landforms as such, rather areas characterized by a distributary-drainage pattern as opposed to the more common nonradiating tributary-drainage pattern.

Page 8—Last sentence on left column should read:
The paths of flow for site 36 appear to be much more unstable than the paths of flow of site 39, which is a short distance to the north.

Figure 3A—Photograph. Cross section 5.A should be cross section 5.B

with reasonable computational simplicity and accuracy, the above conveyance-slope method is considered a satisfactory solution to this complex problem.

Site 39

Site 39 is on the western slopes of the White Tank Mountains in central Maricopa County. Site 39 was assigned a flood-hazard degree of 8. The location of most of the sand channels appears stable, but most of the interfluvial areas can be overtopped by the 100-year flood. The width of the DFA increases gradually to the toe (fig. 10), and the slope of the DFA is fairly uniform (fig. 11). Only a small depositional mound is downstream from the PD. The DFA is inset in old-fan deposits (fig. 12A); boundaries are defined by distinct differences in vegetation density, soil color, and drainage texture (fig. 12B). The level of the 100-year flood is about 5 ft below the top of the left bank at the PD (fig. 13A), the banks at the PD are cemented old-fan remnants, and the surface rocks are covered with iron oxide (fig. 12C). A light coating of desert varnish is on some of the stones at the top of the banks at the PD. The channel bed is composed of sand and gravel with scattered cobbles and boulders (fig. 12D). About 500 ft downstream from the PD, the channel widens abruptly, and distributary flow occurs downstream (fig. 12E). About 1,700 ft downstream from the PD, floodflow is in four distinct distributary channels separated by three ridges that are from 4 to 10 ft above the channel beds (fig. 13B). Small high ridges like those shown in figure 13B are not defined in figure 12A.

Two large ridge areas that are above the level of the 100-year flood (1) are undissected by stream channels, (2) have distinctly less vegetation than the surrounding DFA, and (3) have slightly darker soils. A few other high-ridge areas are above the level of the 100-year flood; however, some of the ridges can be overtopped.

The difference between stable and unstable paths of flow can be observed by comparison of the upper DFA's of sites 36 and 39. Site 36 is also on the western slopes of the White Tank Mountains and is about 2.5 mi to the southeast of site 39. The flow paths in the upper part of the DFA of site 36 are rather uniformly distributed across the DFA (fig. 14). Few interfluvial ridges are in the upper DFA of site 36. The flood-hazard degree of site 36 is 10, and flood water of the 100-year flood can inundate any part of the DFA.

Site 6

The DFA of site 6, which is on the western slopes of the McDowell Mountains, has four distinct areas of flood hazard. The largest area includes the western one-half of the total DFA where floodflow from the PD fills many channels that divide and combine (fig. 15) and includes most of the DFA that was defined by Hjalmarson and Kemna (1991). The second area is along the east side of the DFA where some flow that passes the PD overtops the left bank of the main channel and becomes separated (figs. 15, 16A, and 16B). Approximately 0.75 mi downstream, the separated flow to the east is constricted at the toe of the mountain along the left bank where there is tributary inflow from a small mountainous basin. Downstream, the floodflow is confined except near the center of section 20 (fig. 15) where there are several small unstable channels. Tributary inflow occurs along the separated channel from the mountainous basins to the east. At the north side of section 29, most of the potential flood hazard appears to be related to the tributary flow. Between the areas inundated by the main and overflow channels is a small third area of old-fan remnants (figs. 15 and 16B) above the level of the 100-year flood in the DFA. The fourth area is in a "shadow" downslope from the old-fan remnants (fig. 16C). This area is mostly tributary channels with a few small distributary channels, which may carry floodflow that emanates from the PD. Most upslope floodflow that passed the PD is diverted to the right and left of the "shadow" area by the old-fan remnants.

The potential flood hazard of the four areas downstream from the PD of site 6 are markedly different. The large DFA on the west has a flood-hazard degree of 9 or 10 because most of the ridges will be overtopped, some of the flow paths may be stable, and several of the flow paths can change. A few of the flow paths appear stable

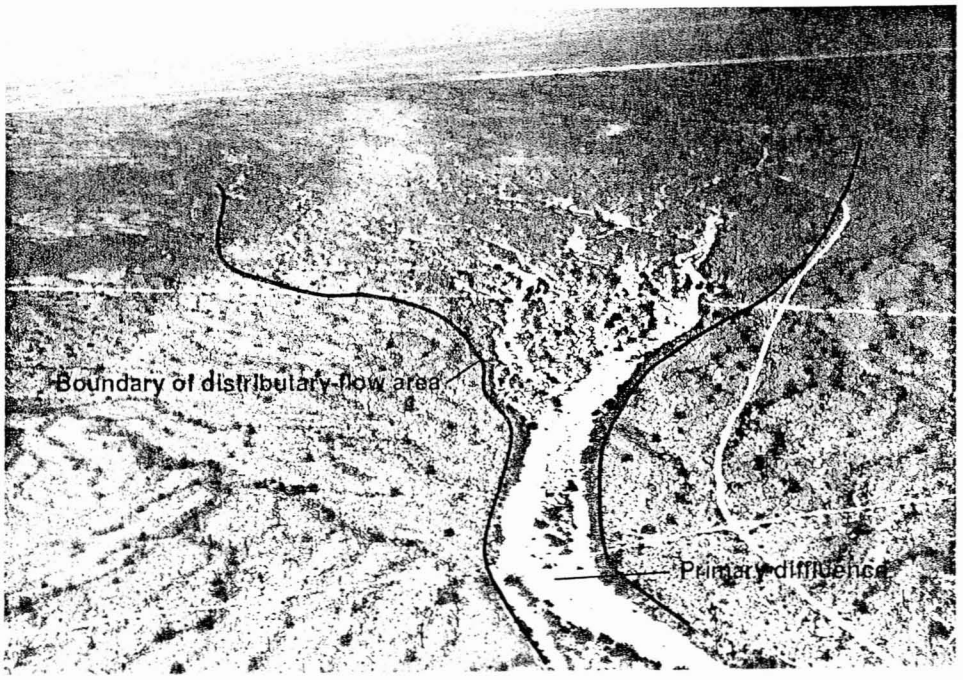

Figure 14. Looking downstream and southwest at the primary diffluence and distributary-flow area at site 36. The bushes and trees in the middle part of the distributary-flow area are larger than those outside the distributary-flow area. The soils are light colored, and most of the area has the appearance of being inundated during a single large flood.

Υ_g = specific weight of the bed sediment, in pounds per cubic foot.

Floodflows appear to be competent to move most of the bed material of the defined channels that emanate from the PD of the sample of sites. The channel competence of the 2-year flood was several times more than the grain size of the bed material at the PD (table 3). At several sites, the competent size that could be moved by the 10-year flood is an order of magnitude greater than the median grain size of the sample of the channel bed. Also, the channel competence along the incised channels in the DFA's appears considerably larger than the grain size of the channel beds (Camp, 1986, table 13). The channel competence of incised channels of DFA's commonly is not much less than the competence at the PD's because the flow is confined and the channel slopes are about the same. Also, because the channels in the drainage basin above the PD's commonly are confined and steep, floodflows appear competent to move the sand-and-gravel material of the drainage basin.

Sediment Yield

The large channel competence indicates that the amount of sediment transported to the DFA's

Table 3. Peak discharge and competence at the 2-, 10-, and 100-year recurrence intervals and grain sizes of the channel bed (D50, D75, D84, and D90) at the primary diffluences for sites in and near Maricopa County, Arizona

Site	Site discharge, at indicated recurrence interval, in cubic feet per second[1]			Channel competence, in millimeters, at indicated recurrence interval			Grain size, in millimeters, at indicated amount, in percent of bed material finer than the size given[2]			
	2	10	100	2	10	100	D50	D75	D84	D90
1	97	805	4,290	19	50	94	1.82	4.5	6.30	8.0
2	128	1,060	5,690	38	63	130	1.32	2.9	4.00	5.3
3	78	639	3,350	25	38	63	[3,4]1.5	([3])	([3])	([3])
6	152	1,290	6,850	44	130	300	2.98	5.8	7.90	10.0
22	70	672	3,570	25	44	110	5.59	16.0	([5])	([5])
23	79	685	3,630	25	110	230	2.33	5.0	6.80	8.2
25	649	2,450	7,020	82	130	230	([3])	([3])	([3])	([3])
26	183	694	1,960	31	76	130	2.99	5.3	6.80	8.1
27	380	1,450	4,180	57	88	110	5.48	11.1	14.10	([5])
29	188	710	2,010	25	82	140	([6])	([6])	([6])	([6])
30	464	1,770	5,090	57	110	150	([3])	([3])	([3])	([3])
35	1,310	4,760	13,200	19	50	82	1.30	3.9	7.60	11.4
36	325	1,240	3,570	25	76	130	1.24	2.5	3.30	4.2
37	282	1,080	3,080	31	69	110	.87	2.0	2.95	4.0
38	250	955	2,730	31	69	120	1.72	7.3	([5])	([5])
39	242	922	2,630	38	69	130	1.84	4.0	5.40	7.1

[1]From Hjalmarson and Kemna (1991).

[2]Representative grain size determined at each site from a relation between the grain size and the cumulative percentage of grains smaller than the particular sieve size.

[3]Sample not taken.

[4]Estimated from visual comparison with sites 1 and 2.

[5]Sample amount not sufficient to compute.

[6]Sample not taken because channel bed is well-cemented rocks that are resistant to erosion. Deposits of mostly sand and gravel were sparsely scattered along the channel bed.

Table 5. Coefficients and exponents for width, depth, and velocity for the 2-, 10-, and 100-year floods at the primary diffluence of sites in Maricopa County, Arizona

Site	Width		Depth		Velocity	
	Coefficient	Exponent	Coefficient	Exponent	Coefficient	Exponent
			A. 2-year flood			
6	15	0.38	0.07	0.38	0.97	0.24
22	3.4	.80	.21	.12	1.4	.08
23	2.8	.58	.21	.25	1.7	.17
25	.21	.20	.05	.50	.88	.30
26	23	.25	.06	.45	.71	.30
27	15	.23	.08	.46	.82	.31
29	27	.09	.05	.55	.75	.36
30	35	.20	.04	.48	.63	.32
35	13	.37	.11	.38	.67	.25
36	3.4	.58	.14	.25	2.2	.17
37	55	.12	.04	.53	.49	.35
38	32	.13	.05	.52	.63	.35
39	31	.19	.05	.48	.62	.33
Mean		.32		.41		.27
Standard deviation		.22		.13		.09
			B. 10-year flood			
6	41	.23	.04	.45	.61	.32
22	320	.01	.02	.59	.21	.40
23	3.4	.41	.18	.36	1.6	.23
25	7.2	.38	.09	.40	1.6	.22
26	27	.21	.05	.47	.67	.32
27	.12	.94	1.5	.04	5.6	.02
29	18	.16	.06	.50	.90	.34
30	23	.27	.06	.44	.75	.29
35	42	.23	.06	.46	.42	.31
36	120	.03	.01	.59	.50	.38
37	34	.19	.05	.49	.60	.32
38	9.3	.33	.11	.40	1.0	.27
39	83	.04	.03	.58	.42	.38
Mean		.27		.44		.29
Standard deviation		.24		.14		.10
			C. 100-year flood			
6	107	.09	.03	.51	.35	.40
22	300	.02	.02	.55	.17	.43
23	30.2	.14	.05	.52	.67	.34
25	170	.002	.01	.66	.52	.338
26	83.2	.04	.03	.58	.43	.38
27	74.1	.12	.03	.53	.43	.35
29	15.5	.19	.07	.49	.96	.32
30	36.3	.20	.04	.48	.63	.32
35	33.9	.25	.06	.45	.46	.30
36	98.0	.06	.02	.56	.56	.38
37	74.1	.08	.03	.55	.44	.37
38	22.9	.19	.06	.49	.73	.32
39	77.6	.05	.03	.57	.43	.38
Mean		.11		.53		.36
Standard deviation		.08		.05		.04

Quaternary mapping of a desert piedmont using NS001 and TIMS remote sensing datasets

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Quaternary mapping of a desert piedmont using NS001 and TIMS remote sensing datasets

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Introduction

Quaternary deposits are often in the part of the landscape which experiences the most human development and modification, for it is on the flood plains, piedmonts, lake shores and coasts that we tend to build, farm, and live. Understanding the landforms and processes associated with Quaternary deposits is necessary in order to meet civilization's needs efficiently, safely, and with minimal environmental degradation. This study uses remote sensing and field mapping to aid in the understanding the development of a Quaternary piedmont, the apron of eroded material surrounding a mountain range.

Quaternary mapping is traditionally accomplished using a combination of field studies and aerial photographs. This study explores how the addition of other remote sensing datasets to Quaternary mapping can enhance the detail and information in the resulting product. The focus of this effort is the Quaternary geology on the western side of the White Tank Mountains, west of Phoenix, AZ. These mountains are surrounded by a desert piedmont consisting of a series of coalescing alluvial fans of multiple ages.

The White Tank Mountains are an appropriate choice for this exploration for several reasons. First, detailed maps exist of the area's Quaternary geology (Field and Pearthree 1991); these were produced by Field and Pearthree using aerial photographs and field investigations. Their product provides a standard result of traditional methods against which this study's map and images can be compared. Second, the Quaternary geology consists of map units that are characterized by their unique surface characteristics, such as surface-clast composition, rock varnish development, and desert pavement development. Having a variety of mapping units tests the range of applicability of these datasets in the differentiation of geologic units. Finally, the White Tank Mountains are relatively undisturbed, removing the need to account for and explain changes in the surfaces and deposits due to human impact. As alluvial fans and piedmonts are the target of much human development, large unaltered and easily accessible areas, such as the White Tank Mountains, are becoming increasingly rare and should be studied while they remain intact. This environment provides a natural laboratory to investigate the geologic history, material, and surficial processes in a setting analogous to many rapidly developing areas in the desert southwestern United States.

Physiographic Province and Location

The White Tank Mountains are located west of Phoenix, AZ. They are one of a series of small ranges that encircle the Valley of the Sun, in which Phoenix is located. This mountain range, part of the Basin and Range province, has been identified as a metamorphic core complex (Reynolds and DeWitt, 1991). A

metamorphic core complex is produced by kilometers of slip along a low-angle, normal fault. As the lower plate rocks are pulled from below, the decrease in overburden causes them and the faults to bow upwards. This range is rare in that the upper plate rocks are preserved along with the lower plate rocks of the core complex. The upper plate rocks are Tertiary Volcanic rocks (T); the lower plate rocks consist of Precambrian and Cretaceous plutons, dikes and gneisses (Wood, 1997). This range is also noteworthy for the complex Quaternary geology preserved in the surrounding piedmont.

Quaternary Geology

A piedmont environment, like that surrounding the White Tank Mountains, is an area of accumulation of detritus eroded from the adjacent mountain front producing alluvial fans, channels and terraces. The sediment is typically deposited by braided streams and debris flows (National Research Council 1996, Cooke 1973). This sediment is deposited and eroded in cycles of aggradation and incision. During periods of aggradation, the sediment accumulates in growing alluvial fans; periods of incision are characterized by streams that erode and transport sediment from the alluvial fans out of the piedmont. Fortunately, the periods of erosion do not completely remove the previously deposited material, preserving pockets of deposits from different intervals of deposition (Bull 1991, Cooke 1973). Thus, the contacts between units are discontinuities apparently developed during times of incision. The subsequent changes in the soil and surface of these deposits are generally attributed to be a function of exposure time. Therefore, we can group together deposits with similar degrees of surface and subsurface modification and construct a chronology of their development (Bull 1991, National Research Council 1996, McFadden et al. 1989.)

Based on this post-depositional modification, the Quaternary deposits in the White Tank Mountains can be divided into three groups representing large sections of Quaternary time: an older O deposit (>1000 ka), a mid to late Pleistocene M age category, and a younger Holocene Y age group. These ages are taken from Field and Pearthree's work on the Quaternary geology in the White Tank Mountains (Field and Pearthree 1991) and are consistent with the timeline outlined by Bull (1991) for piedmont surfaces of the lower Colorado River region. These ages are determined from ^{14}C dating, degree of rock varnish, $^{230}Th/^{234}$ Ub dating of carbonate, and K/Ar dates of associated volcanic units (Bull 1991.)

Each of the O, M, and Y groups have distinctive characteristics related to their age. The O surfaces are hummocky and are being actively incised; the surface is littered with clasts of caliche, pedogenic soil carbonate, being exposed by the incision indicating the presence of a well developed zone of soil carbonate. These surfaces are also the topographically highest of the Quaternary deposits. The M surfaces have low relief. They typically are only incised 1-2 meters, except for the active channels where incision can exceed five meters. The individual M surfaces are characterized by varying degrees of desert pavement, rock varnish and caliche development. These surfaces are typically 5-10 meters below the peak of the O surfaces. The Y deposits are the most recent, consisting of active channels, associated terraces, and abandoned channels.

Within each of these broad sections of M and Y time there are subgroups that represent distinct pulses of activity. Four M surfaces are differentiated primarily on their desert pavement development, soil profile and height above active channels. The older M1a surface has the most well developed desert pavement, darkest rock varnish and thickest caliche layer; the surface can be up to six meters above active channels. M1ab and M1b, the next oldest surfaces respectively, are defined by lesser degrees development of these characteristics. M2, the youngest M surface, has poor desert pavement development, little to no rock varnish, and only incipient soil carbonate development. The three Y surfaces can be divided based on the age of the most recent episode of flooding experienced. Y2 surfaces are active channels with unconsolidated sandy beds with some boulders and clasts. Y1 surfaces have not been flooded for over 1000 years and have less sand, more clasts, and the beginning of a consolidated soil profile. The Y surfaces include all the areas in which Y1 and Y2 cannot yet be differentiated.

Methods

We used a combination of airborne remote sensing data and field studies to produce the final Quaternary Geologic map (see Plate I). Plates II-IV are examples of the remote sensing datasets used to produce this Quaternary map. Remote sensing datasets span the electromagnetic spectrum from visible to microwave wavelengths. The sensors that produce these datasets measure the energy reflected or emitted by the surface in a particular wavelength region. The result is a spectrum of the surface that represents the materials present (i.e. vegetation, rocks, soil, etc.) Some surfaces and materials look similar in one part of the spectrum, but completely different in another. Thus, the broader the region of the electromagnetic spectrum covered and the greater the number of wavelengths at which information is recorded, the more confident one can identify what the materials at the surface may be.

Traditional studies are limited by using datasets, specifically aerial photographs, that only record information in the visible wavelengths (0.4 to 0.7 microns) in a single band. This study used NS001 data (7 bands, 0.458 to 2.38 microns) which covers the visible and near-infrared sections of the spectrum and TIMS data (6 bands, 8.2 to 12.2 microns) which gathers information in the infrared (JPL 1995.) Both of these datasets were collected by sensors flown on a C130 aircraft on June 18, 1995; airborne acquisition reduces the amount of atmospheric scattering of the ground signal and increases the pixel resolution relative to satellite platforms. The ground resolution for both the NS001 and TIMS data was approximately 5 meters per pixel.

The NS001 and TIMS datasets were processed with several algorithms using both the Vicar and ErMapper computer programs. TIMS data were processed by Vicar programs with the following steps (specific vicar programs seen in quotes): 1) DN converted to calibrated radiance using "timscal", 2) atmospheric correction performed using "timscal2", 3) emissivity was separated from temperature using "et", and 4) initially rectified using "c130rect." NS001 data were processed by Vicar programs with the following steps: 1) DN converted to calibrated radiance using "nscal", 2) converted radiance to byte format using "c", and 3) initially rectified using "c130rect." The subsequent six bands of TIMS emissivity data and the seven bands

of NS001 radiance data were imported into the remote sensing data processing program ErMapper in band sequential format. These were subsequently georeferenced using topographic maps and projected into UTM coordinate space with a geodetic datum of NAD27.

These datasets were then processed with algorithms representing different band combinations, band ratios, principal component analyses and decorrelations. Each algorithm produced a unique image, the goal being to produce images that would allow the user to discriminate between the various Quaternary units. Working with more than one algorithm is important. For example, one algorithm may produce an image that differentiates between unit a and b, but not between unit b and c; however, another image may distinguish unit b from c, but sees unit a and b as the same thing. No one processing algorithm differentiated all the units, thus only by using several algorithms can all units be separated.

The utility of multiple processing algorithms for Quaternary mapping is demonstrated with three algorithms that were used in this study: two band combination algorithms applied to the NS001 data and a (531) decorrelation algorithm applied to the TIMS data. Each of these algorithms was used because of its ability to discriminate between two or more units. Gillespie et al. (1984) used TIMS data to differentiate alluvial fans in Death Valley showing that TIMS was able to detect differences in clast composition and could be used to ascertain relative ages and degrees of desert pavement development. The use of visible data in determining alluvial fan characteristics was explored by Farr and Chadwick (1996) using SPOT multispectral imagery. For a detailed introduction to properties, strengths and applications of both visible/near-infrared and thermal/infrared datasets refer to chapters 3-5 in Pieters and Englert (1993). For this study of the White Tank Mountains piedmont, the NS001 data were more informative about the Quaternary geology, while the TIMS data were better at separating the different bedrock units (e.g. Wood 1997).

The (742) processing algorithm applied to NS001 airborne scanner data combines information from the mid-infrared, near-infrared, and visible regions of the electromagnetic spectrum (see Plate II). This combination is commonly used to detect varying moisture contents in vegetation and soils (Sabins 1987). In this study, this algorithm discriminated between the four Mid to Late-Pleistocene M surfaces; these appear as varying shades of red and pink in the image (see Plate II upper inset). The continuum from greyish-pink of the younger surfaces to the darker red of the older surfaces may be the result of corresponding increases in the amount of rock varnish. This is a probable result of the strong absorption features of iron oxide (an important component of rock varnish) in the visible and near infrared region (Gaffy 1993). With increasing age, the clay content at and near the surface also increases; this algorithm may also be detecting this variation due to the sensitivity of band seven to hydroxyl ions in mineral structures (Sabins 1987). While this (742) algorithm effectively differentiated between the M surfaces, it displayed units Y1 and M1b in similar shades of pink, although they are different units based on age and surface characteristics. There was also little contrast among the three bedrock units and the Y surfaces.

The second band combination of NS001 data uses two band ratios and a single band (see Plate III). An iron ratio (6*3/4*4) was placed in the red band to detect varying amounts of rock varnish; this ratio exploits the distinctive shape imparted to a spectrum between bands 3 and 6 when iron-oxides are present (Gaffy 1993 and Sabins 1987). The (7*6/5*5) ratio, displayed in the green band, combines the three NS001 bands that contain information about rock composition; consequently, this band could constrain surface-clast distribution by distinguishing between rock types and/or between rock clasts and surface soil (Sabins 1987). Ratios are useful because they emphasize color differences and spectral similarities without being affected by changes in illumination caused by slope, shading, etc. (Gillespie 1980). Because topographic shadowing is minimized when bands are ratioed, the expression of topography is muted in the red and green bands of this algorithm (Sabins 1987). To preserve topographic shading in the resulting image, band 1, instead of a ratio, was placed in the blue band.

This (6*3/4*4, 7*6/5*5,1) combination was one of the few that could discriminate among the Holocene Y2 and Y1 deposits and surfaces (see upper inset of Plate III.) Both deposits consist of channel sediment, yet Y1 surfaces have not been flooded in over 1000 years, while Y2 surfaces are currently actively flooded. Thus, the older Y1 surfaces are less sandy, more clast rich, more compacted, and have begun development of a soil profile.

This algorithm also did an adequate job of differentiating the four M surfaces, though not as well as the (742) algorithm in Plate II. An explanation is that the iron and rock ratios in the red and green bands may be sensitive to rock varnish and clast amounts on the surface. The older surfaces have a well developed desert pavement with large amounts of varnished clasts, while a younger surface has a less developed pavement. Thus, in this algorithm, the M surfaces become a darker green as they progress in age. Like the (742), this algorithm also had difficulty discriminating between the three bedrock units.

The TIMS image was processed using a decorrelation stretch of bands 5, 3, and 1 (See Plate IV). A decorrelation algorithm enhances the contrast due to compositional differences by converting the image to principle components, stretching these bands, and finally converting these stretched data back to the original band axes (Gillespie 1984). In the (531) decorrelation algorithm, red is associated with silicic composition, blue associated with mafic, and purple represents an intermediate composition (Kahle 1983).

This algorithm easily differentiates the bedrock types and active channels, while having difficulty with the majority of the Quaternary units. Thermal datasets, such as TIMS, are very successful in distinguishing different rock types. This is due to the strong spectral features, known as absorption bands, that are associated with the different silicate structures. The color differences between the Tertiary volcanic unit (T), which appears as light blue, and the early Proterozoic gneiss and granite (X), which appear as dark blue or blue make it easy to distinguish the two (see Plate IV upper inset). The active channels (Y2), displayed in bright red due to the high quartz content, lack of varnish, and lack of clay of the coarse sediment on the channel floors, are also easily distinguished by this algorithm.

The (531) decorrelation algorithm of TIMS data, however, does not readily distinguish among the Quaternary units. The M and Y units (other than Y2) are reddish purple with no consistent shade change by which to differentiate them. While the O units are different shades than the M units, it is the drainage density that clearly distinguishes the two, not the color on the image.

As the discussion of these three algorithms demonstrates, no one processing algorithm can distinguish between and effectively differentiate all the units. ErMapper allows more than one algorithm to be displayed at the same time; by using all three simultaneously, we could most effectively and accurately delineate unit boundaries. From information in these multiple algorithms, we created a preliminary map by grouping similar areas, based on their image characteristics, together into image classes. These processing algorithms are site specific; a particular algorithm may not display highly varnished older M_1 surfaces in two different mountain ranges in the same shades. In addition, individual areas may have other factors such as more vegetation or different rock types that mask the iron-oxide contribution to the spectrum, thus displaying a similarly varnished area in a different color from those in the White Tank Mountains.

The next step involved attaching ground characteristics to these image classes. Grouping areas that look similar on an image is not enough to produce a map. Often, characteristics other than those in the spectral data, are determining factors, such as morphology and landform associations. The (742) NS001 algorithm displayed the Y1 and M1b surfaces in similar colors. However, field observations of the area and landforms indicated that Y1 is clearly associated with an active channel while M1b is not. It is this landform association, not the image colors that is the basis for the discrimination. Furthermore, an algorithm may execute a discrimination based on characteristics that are not mapping criteria, thus separating two areas that should be mapped as the same geologic or geomorphic unit. Once ground characteristics have been determined, one can group the image classes into units that have geologic significance. In this study, the preliminary map, based on image classes, was taken into the field and subjected to numerous field checks and observations. Ground truthing was used to assure that areas mapped as the same unit were similar and that each map unit indeed represented a unique deposit.

Results

The resulting map from this study (Plate I) is similar to that created by Field and Pearthree (Arizona Geological Survey OFR 91-8) with some specific additions and differences. We differentiated the M units into four by adding M1ab, which is easily distinguished on the images and differentiated M1a and M1b deposits in some areas that had previously been unclear with aerial photographs. The M1ab unit has a stronger degree of desert pavement formation and less developed bar and swale topography than M1b, but is not the same as M1a, which has the most development pavement and almost no bar and swale topography. The map boundaries and geologic distinctions between units were easier to tell apart on the NS001 and TIMS images than standard color aerial photographs. Interestingly, the most useful algorithms for the Quaternary units, specifically NS001 (742) and NS001 (6*3/4*4, 7*6/5*5,1), used bands that were not just in the visible, but also in the near-infrared.

This implies useful information beyond the visible such as the iron-oxide absorptions and absorption bands of hydroxyl-ions in minerals found in near-infrared bands 4 (0.767-.910 microns) through 7 (2.10-2.38 microns). As aerial photographs only record in the visible, this type of information is lost in traditional Quaternary mapping. Aerial photographs are also limited by having all their information in only one band, thus they cannot be subjected to the same type of image processing such as ratios, principle component analysis, and stretching of individual bands as the multi-band NS001 and TIMS data.

In summary, the use of remote sensing datasets spanning not only the visible, but also near-infrared and infrared, enhanced the mapping of a Quaternary piedmont. The use of multiple algorithms and datasets can increase the number of units that can be differentiated with confidence, as no one algorithm can distinguish between all the units. However, mapping is still based on interpretation; using digital remote sensing data sets does not create an automated system for making geologic maps. As shown above, merely grouping similarly colored areas on an image does not create an accurate map. Field checking and ground truthing of the preliminary image class map is necessary to assign ground characteristics to the units and to assure that units are indeed based on mapping criteria and not solely on spectral characteristics.

The next level in this process is to gather quantitative characteristics of the units from the remote sensing data, such as clast percentage, presence and type of clay, etc. To do this more datasets and techniques must be used and integrated such as radar, DEMs, field spectroscopy measurements, and linear unmixing. While mapping can be done by field work alone, field work used in conjunction with these datasets can enhance the efficiency, accuracy and detail of a geologic map.

Applications of Quaternary Mapping

A Quaternary deposit or landform is typically defined by its age and formation process. In the White Tank mountains, the deposits were formed from detritus being eroded from the adjacent mountain front to produce alluvial fans, channels, and terraces. Thus, because the process of formation is similar, the primary discerning factor of units in this area is age.

As deposits age in the arid Southwest, they typically develop a desert pavement on the surface, form caliche in the subsurface, and exhibit surface clasts covered with rock varnish. Desert pavement is the armoring of the surface with an increasingly interconnected layer of clasts, one to two clasts deep, overlying a clay-rich, clast-poor horizon. (Dixon 1994, McFadden 1997). The formation process of desert pavement is still a source of controversy. Three prominent theories are: 1) deflation involving the removal of fines and concentration of clasts as the surface lowers, 2) "born at the surface" where the pavement is developed during deposition, and 3) upward migration of clasts in which subsurface stones move up through the column of overlying soil (Bull 1991, Birkeland 1990, Cooke 1973.) Dixon (1994) provides a concise overview of these three and two additional possible methods of formation and associated references. Typically, the development of pavement is associated with increasing amounts of rock varnish, an iron-magnesium oxide layer that coats the clasts (Dorn 1991, Bull 1991, Cooke 1973.)

As increasing amounts of rock varnish and desert pavement are surface indicators of increasing age, caliche and clay accumulation in the subsurface can also be used to estimate age. Caliche is calcium carbonate that has precipitated in the subsurface from percolating rainwater or ground water. Its development begins as thin coatings on individual pebbles and progresses until the entire column of sediment is cemented and plugged. In its more advanced stages it forms laminar sheets at the top of the column (Vincent 1994, Mayer et. al 1988).

These surface and subsurface characteristics are influential in determining the hydraulic characteristics of the surface. As desert pavement develops, more of the surface becomes armored with clasts reducing the access to permeable soil by precipitation. The caliche, in turn, determines the permeability of this soil, causing permeability to decrease as the amount of caliche increases. The compelling relationship between age and these parameters could allow for the inference of a map of areas with similar hydraulic characteristics from a geomorphic map based on age. This relationship is especially useful as relative age can be determined from characteristics easily detected with remote sensing data. Using a map that indicates the hydraulic characteristics of the natural surface in planning for these developments would aide in mitigating and gauging the flood risk and hazard on these piedmonts.

Acknowledgments

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Plate I. Geologic map of the Western White Tank Mountains' Quaternary Geology

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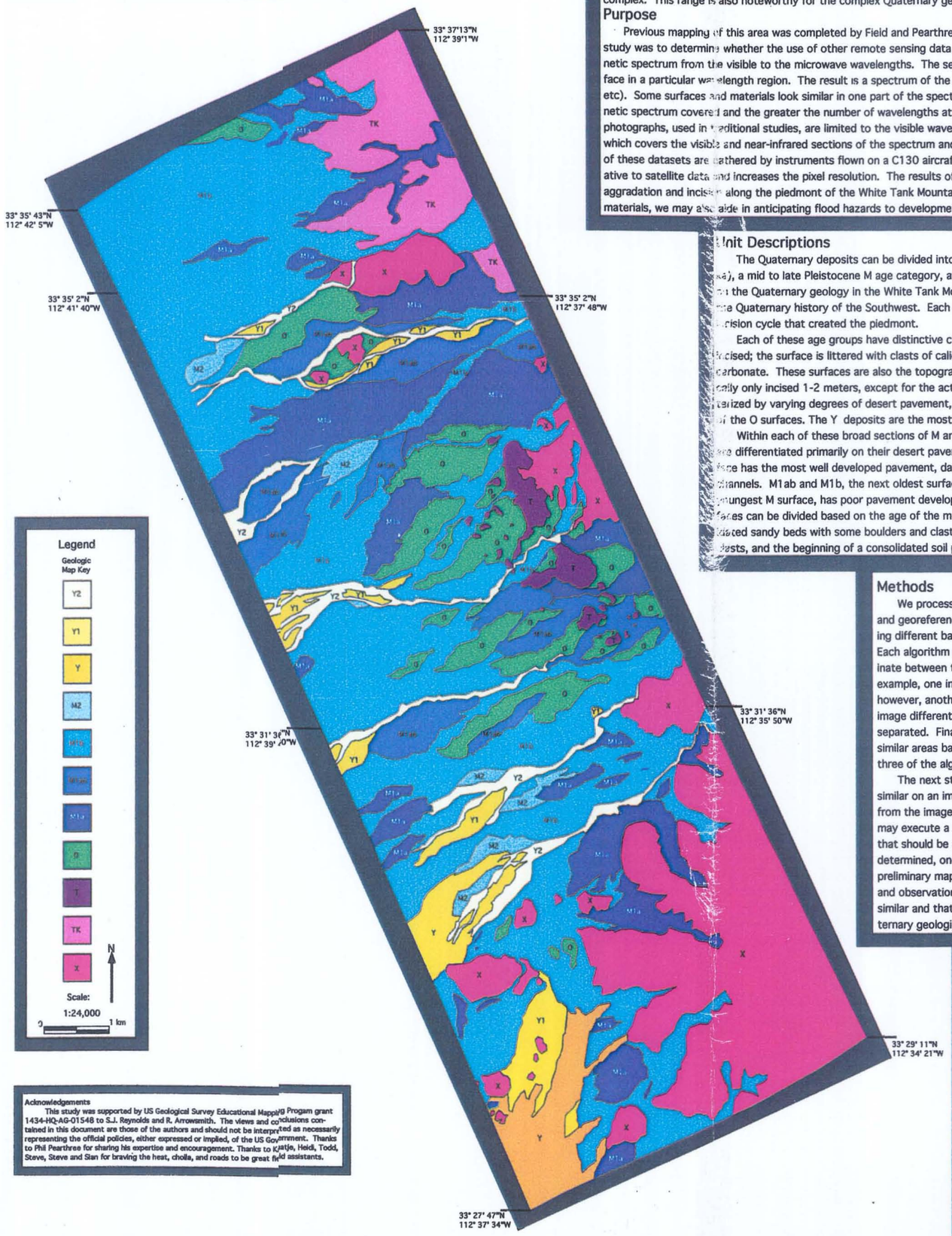
Physiographic Province and Location

The White Tank Mountains are located west of Phoenix, AZ. They are one of a series of small ranges that encircle the Valley of the Sun, in which Phoenix is located. This mountain range, part of the Basin and Range province, has been identified as a metamorphic core complex, which is produced by kilometers of slip alonga low angle normal fault (Reynolds and DeWitt 1991). As the lower plate rocks (X and TK on the map) are pulled up from below, the decrease in overburden causes them to bow upwards. This range is rare in that the upper plate (T on the map) rocks are preserved along with the lower plate rocks of the core complex. This range is also noteworthy for the complex Quaternary geology that is preserved in the surrounding piedmont.

Purpose

Previous mapping of this area was completed by Field and Pearthree (Arizona Geological Survey OFR 91-8) using aerial photographs. The purpose of our study was to determine whether the use of other remote sensing data could provide more detailed information. Remote sensing datasets span the electromagnetic spectrum from the visible to the microwave wavelengths. The sensors that produce these datasets measure the energy reflected or emitted by the surface in a particular wavelength region. The result is a spectrum of the surface which represents the combination of materials present (i.e. vegetation, rocks, soil, etc). Some surfaces and materials look similar in one part of the spectrum, but completely different in another. Thus, the broader the region of the electromagnetic spectrum covered and the greater the number of wavelengths at which information is recorded, the easier it is to identify material(s) at the surface. Aerial photographs, used in traditional studies, are limited to the visible wavelengths (.4 to .7 microns). This study used NS001 data (7 bands, .458 to 2.38 microns) which covers the visible and near-infrared sections of the spectrum and TIMS data (6 bands, 8.2 to 12.2 microns) which gathers information in the infrared. Both of these datasets are gathered by instruments flown on a C130 aircraft; using an airplane reduces the amount of atmospheric scattering of the ground signal relative to satellite data and increases the pixel resolution. The results of this mapping indicate that these remote sensing data provide a record of the Quaternary aggradation and incision along the piedmont of the White Tank Mountains. By correlating this surficial geologic mapping with hydraulic properties of the materials, we may also aide in anticipating flood hazards to developments on similar piedmonts.



Unit Descriptions

The Quaternary deposits can be divided into three groups representing large sections of Quaternary time: an older O surface (>1000 ka), a mid to late Pleistocene M age category, and a younger Holocene Y surface. These ages are taken from Field and Pearthree's work on the Quaternary geology in the White Tank Mountains (Arizona Geological Survey OFR 91-8) and are consistent with other studies of the Quaternary history of the Southwest. Each of these units represents a preserved deposit from a past period in the aggradation and incision cycle that created the piedmont.

Each of these age groups have distinctive characteristics related to their age. The O surfaces are hummocky and are being actively incised; the surface is littered with clasts of caliche being exposed by the incision indicating the presence of a well developed zone of soil carbonate. These surfaces are also the topograhically highest of the Quaternary deposits. The M surfaces have low relief. They are typically only incised 1-2 meters, except for the active channels where incision can exceed five meters. The individual M surfaces are characterized by varying degrees of desert pavement, varnish and caliche development. These surfaces typically lay 5-10 meters below the peak of the O surfaces. The Y deposits are the most recent, consisting of active channels, associated terraces and abandoned channels.

Within each of these broad sections of M and Y time there are subgroups that represent distinct pulses of activity. Four M surfaces are differentiated primarily on their desert pavement development, soil profile and also height above active channels. The older M1a surface has the most well developed pavement, darkest varnish and thickest caliche layer; the surface can be up to six meters above active channels. M1ab and M1b, the next oldest surfaces respectively, are defined by the lesser development of these characteristics. M2, the youngest M surface, has poor pavement development, little to no varnish, and only incipient soil carbonate development. The three Y surfaces can be divided based on the age of the most recent episode of flooding experienced. Y2 surfaces are active channels with unconsolidated sandy beds with some boulders and clasts. Y1 surfaces have not been flooded for over 1000 years and have less sand, more clasts, and the beginning of a consolidated soil profile. The Y surfaces include all the areas in which Y1 and Y2 cannot be differentiated.

Methods

We processed NS001 and TIMS data to produce a Quaternary geologic map. Datasets were collected and georeferenced to topographic maps. These datasets were then analyzed using algorithms representing different band combinations, band ratios, principal component analysis and decorrelation stretches. Each algorithm produced a unique image, the goal being to produce images that could identify and discriminate between the various Quaternary units. Working with more than one algorithm is important. For example, one image may be able to differentiate between unit a and b, but not between unit b and c; however, another image may be able to tell unit b from c, but sees unit a and b as the same thing. No one image differentiates all the units, thus only with combinations of several algorithms can all units be separated. Finally, the most informative algorithms were used to create a preliminary map by grouping similar areas based on their image characteristics together into image classes. Plates II, III, IV represent three of the algorithms used to produce the geologic map to the left.

The next step was to attach ground characteristics to these image classes. Grouping areas that look similar on an image is not enough to produce a map. Often, it is characteristics that are not self-evident from the images that are determining factors, such as landform associations. Further-more, an algorithm may execute a discrimination on characteristics that are not mapping criteria, thus separating two areas that should be mapped as the same geologic or geomorphic unit. Once ground characteristics have been determined, one can group the image classes into units that have geologic significance. In this study, the preliminary map, based on image classes, was taken into the field and subjected to numerous field checks and observations. Ground truthing was used to assure that areas mapped as the same unit were indeed similar and that each map unit did indeed represent a unique deposit. The result of this study is the Quaternary geologic map to the left.

Applications of Quaternary Mapping

A Quaternary deposit or landform is typically defined by its age and formation process. In this area the deposits were formed from detrital material eroded from the adjacent mountain front producing alluvial fans, channels, and terraces. Thus, because the process of formation is similar, the primary discerning factor of units in this area is age. As deposits age in the arid Southwestern United States, they typically develop a desert pavement, form caliche, and become covered with desert varnish. These surface and subsurface characteristics are influential in determining the hydraulic characteristics of the deposit. As desert pavement develops more of the surface becomes armored with clasts reducing the access to permeable soil by precipitation. The caliche in turn affects the permeability of this soil, decreasing it as the amount of caliche increases. The compelling relationship between age and these parameters could allow for the inference of a map of areas with similar hydraulic characteristics from a geomorphic map based on deposit age. This relationship is especially useful as relative age can be determined from charactersitics easily detected with remote sensing data. Understanding the hydraulic characteristics of the natural geomorphic units would aide in mitigating and gauging flooding in these piedmonts, which are being rapidly developed.

Acknowledgements

This study was supported by US Geological Survey Educational Mapping Progam grant 1434-HQ-AG-01548 to S.J. Reynolds and R. Arrowsmith. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the US Government. Thanks to Phil Pearthree for sharing his expertise and encouragement. Thanks to Kathie, Heidi, Todd, Steve, Steve and Stan for braving the heat, cholla, and roads to be great field assistants.

Plate II. (742) (RGB) Image of the Western White Tank Quaternary Geology

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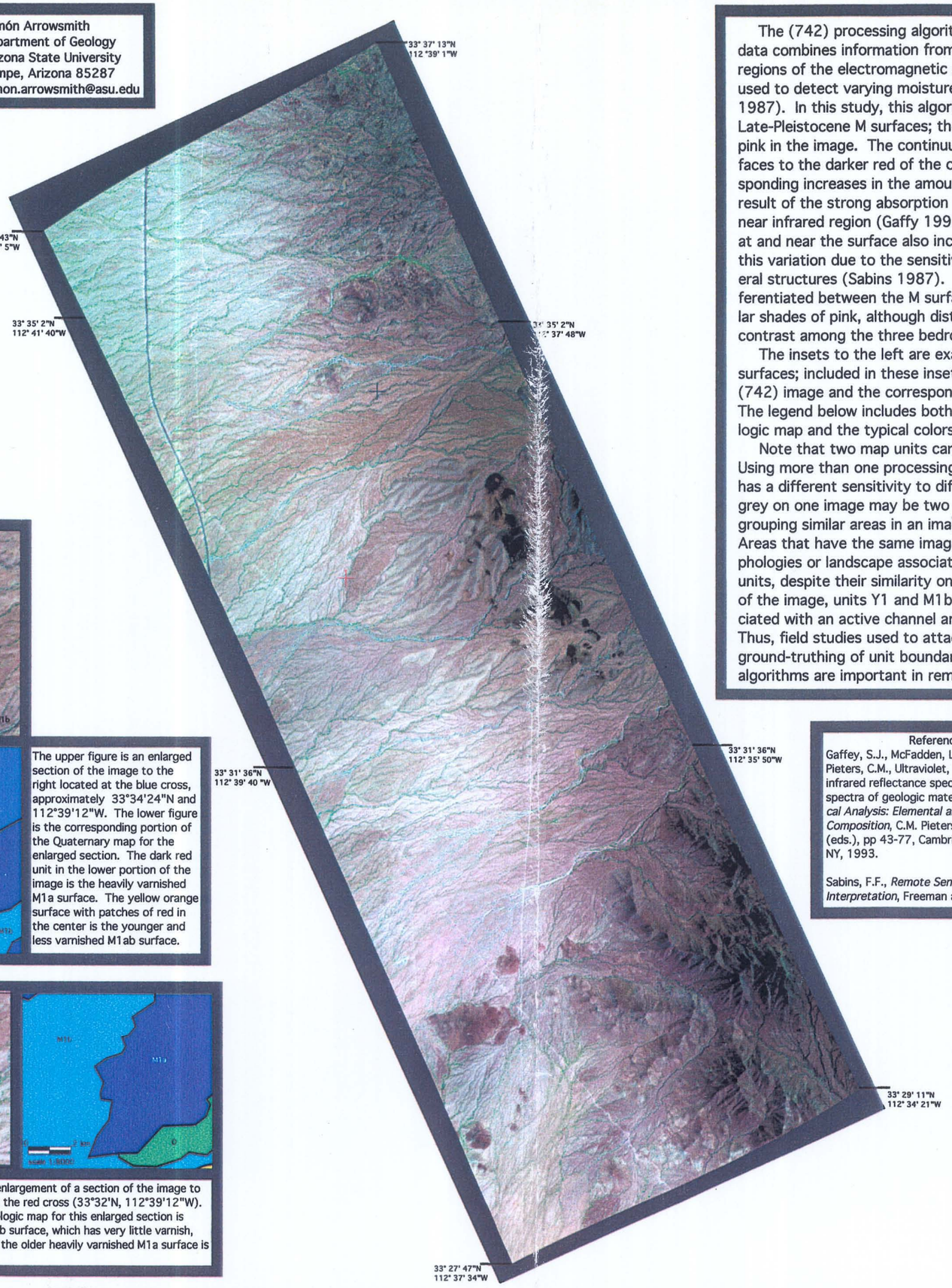
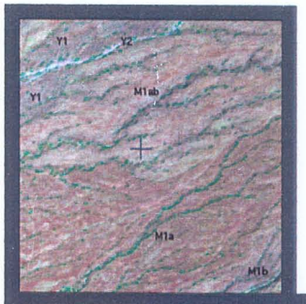
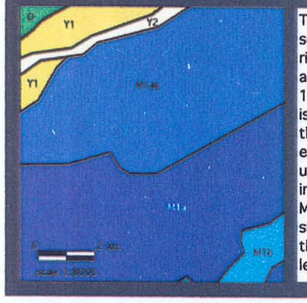


The (742) processing algorithm applied to NS001 airborne scanner data combines information from the mid-infrared, near-infrared, and visible regions of the electromagnetic spectrum. This combination is commonly used to detect varying moisture contents in vegetation and soils (Sabins 1987). In this study, this algorithm discriminated between the four Mid to Late-Pleistocene M surfaces; these appear as varying shades of red and pink in the image. The continuum from greyish-pink of the younger surfaces to the darker red of the older surfaces may be the result of corresponding increases in the amount of desert varnish. This is a probable result of the strong absorption features of iron oxide in the visible and near infrared region (Gaffy 1993). With increasing age, the clay content at and near the surface also increases; this algorithm may be detecting this variation due to the sensitivity of band seven to hydroxyl ions in mineral structures (Sabins 1987). While this (742) algorithm effectively differentiated between the M surfaces, it displayed units Y1 and M1b in similar shades of pink, although distinctly different units. There was also little contrast among the three bedrock units and the Y surfaces.

The insets to the left are examples of the clear discrimination of M surfaces; included in these insets are enlargements of sections on the (742) image and the corresponding sections of the geologic map (Plate I). The legend below includes both the unit color and symbols from the geologic map and the typical colors these units appear on the image.

Note that two map units can have the same colors on the image. Using more than one processing algorithm is essential as each algorithm has a different sensitivity to different units. Thus, two units that are both grey on one image may be two different colors on another. Second, grouping similar areas in an image is not sufficient to produce a map. Areas that have the same image color, may have distinctly different morphologies or landscape associations that would place them in separate units, despite their similarity on the image. For example, in the left center of the image, units Y1 and M1b have similar colors, but Y1 is clearly associated with an active channel and therefore a different unit than M1b. Thus, field studies used to attach ground observations to the units, ground-truthing of unit boundaries, and the use of multiple processing algorithms are important in remote sensing mapping studies.





The upper figure is an enlarged section of the image to the right located at the blue cross, approximately 33°34'24"N and 112°39'12"W. The lower figure is the corresponding portion of the Quaternary map for the enlarged section. The dark red unit in the lower portion of the image is the heavily varnished M1a surface. The yellow orange surface with patches of red in the center is the younger and less varnished M1ab surface.

The figure above to the left is an enlargement of a section of the image to the right with its center located at the red cross (33°32'N, 112°39'12"W). The corresponding Quaternary Geologic map for this enlarged section is shown above to the right. The M1b surface, which has very little varnish, appears in light grey to pink, while the older heavily varnished M1a surface is a dark red.

References Cited

Gaffey, S.J., McFadden, L.A., Nash, D. and Pieters, C.M., Ultraviolet, Visible, and near-infrared reflectance spectroscopy: laboratory spectra of geologic materials, in *Remote Chemical Analysis: Elemental and Mineralogical Composition*, C.M. Pieters and P.A.J. Englebert (eds.), pp 43-77, Cambridge University Press, NY, 1993.

Sabins, F.F., *Remote Sensing Principles and Interpretation*, Freeman and Co., New York 1987.

Legend

Geologic Map Key	Typical colors on 742 image
Y2	Yellow, pink
Y1	grey to pinkish grey
Y	white and light blue
M2	grey to pinkish grey
M1b	light grey to pink
M1ab	yellow-orange with patches of dark red
M1a	orange red to dark red
Q	grey and yellow
T	black
TK	red to purple
X	blue to purple

N

Scale: 1:24,000

0 1 km

Plate III. (6*3/4*4,7*6/5*5,1) (RGB) Image of the Western White Tank Quaternary Geology

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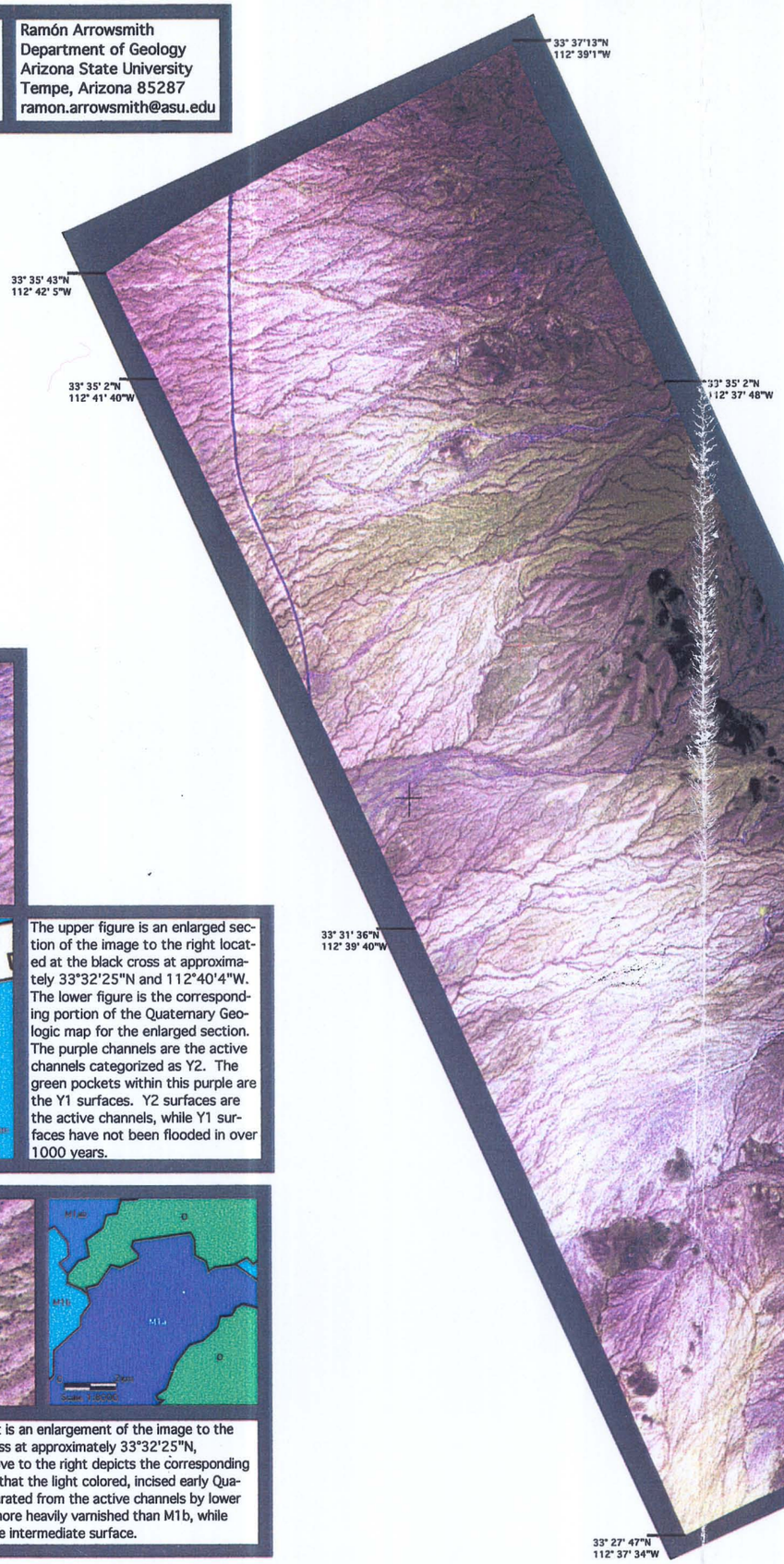
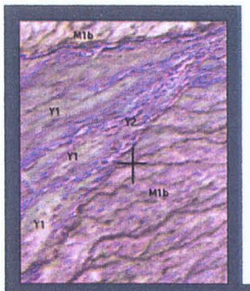
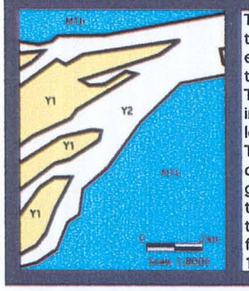


This processing algorithm uses two band ratios and a single band to analyze NS001 airborne scanner imagery. The red band is an iron ratio (6*3/4*4) used to detect varying amounts of desert varnish. The (7*6/5*5) ratio, displayed in the green band, combines the three bands that contain information about rock composition (Sabins 1987). Ratios are useful because they emphasize color differences and spectral similarities without being affected by changes in illumination (Gillespie 1980). Because topographic shadowing is minimized when bands are ratioed, the expression of topography is muted in the red and green bands of this algorithm (Sabins 1987). To preserve topographic shading in the resulting image, band 1, instead of a ratio, was placed in the blue band.

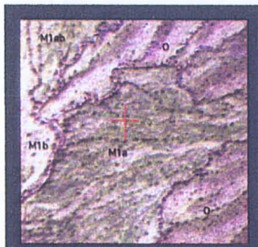
This (6*3/4*4, 7*6/5*5,1) combination was one of the few that could discriminate between the Holocene Y2 and Y1 deposits and surfaces. Both deposits consist of channel sediment, yet Y1 surfaces have not been flooded in over 1000 years, while Y2 surfaces are actively flooded. Thus, the older Y1 surfaces are less sandy, more clast rich and compacted, and have begun development of a soil profile. This algorithm also did an adequate job of differentiating the four M surfaces, though not as well as the (742) algorithm (See Plate II). An explanation is that the iron and rock ratios in the red and green bands are sensitive to varnish and clast amounts on the surface. The older surfaces have a well developed desert pavement with large amounts of varnish and clasts, while a younger surface has a less developed pavement. Thus, in this algorithm, the M surfaces become a darker green as they progress in age.

The insets to the left are examples of the clear discrimination of Y1 and Y2 and of M1a and M1b; included in these insets are enlargements of sections on the image and the corresponding sections of the geologic map (Plate I). The legend below includes both the unit color and symbols from the geologic map (Plate I) and the typical colors of these units on the image.





The upper figure is an enlarged section of the image to the right located at the black cross at approximately 33°32'25"N and 112°40'4"W. The lower figure is the corresponding portion of the Quaternary Geologic map for the enlarged section. The purple channels are the active channels categorized as Y2. The green pockets within this purple are the Y1 surfaces. Y2 surfaces are the active channels, while Y1 surfaces have not been flooded in over 1000 years.



The figure above to the left is an enlargement of the image to the right located at the red cross at approximately 33°32'25"N, 112°40'4"W. The map above to the right depicts the corresponding Quaternary Geology. Note that the light colored, incised early Quaternary O surfaces are separated from the active channels by lower relief M surfaces. M1a is more heavily varnished than M1b, while M1b is a distinctly mappable intermediate surface.

References Cited

Gillespie, A.R., Digital techniques of image enhancement, *in Remote Sensing in Geology*, (Siegal, B.S. and Gillespie, A.R. eds.), 139-227, New York, John Wiley & Sons, 1980.

Sabins, F.F., *Remote Sensing Principles and Interpretation*, Freeman and Co., New York 1987.

Legend

Geologic Map Key	Typical colors on (6*3/4*4, 7*6/5*5, 1) image
Y2	Yellow, white
Y1	green
Y	purple
M2	white with some patches of green
M1b	white to lavendar
M1ab	light to medium green
M1a	dark green
O	grey and yellow-white
T	black
TK	brown to black
X	brown to black

Scale: 1:24,000

0 1 km

N

Plate IV. TIMS Image of the Western White Tank Quaternary Geology

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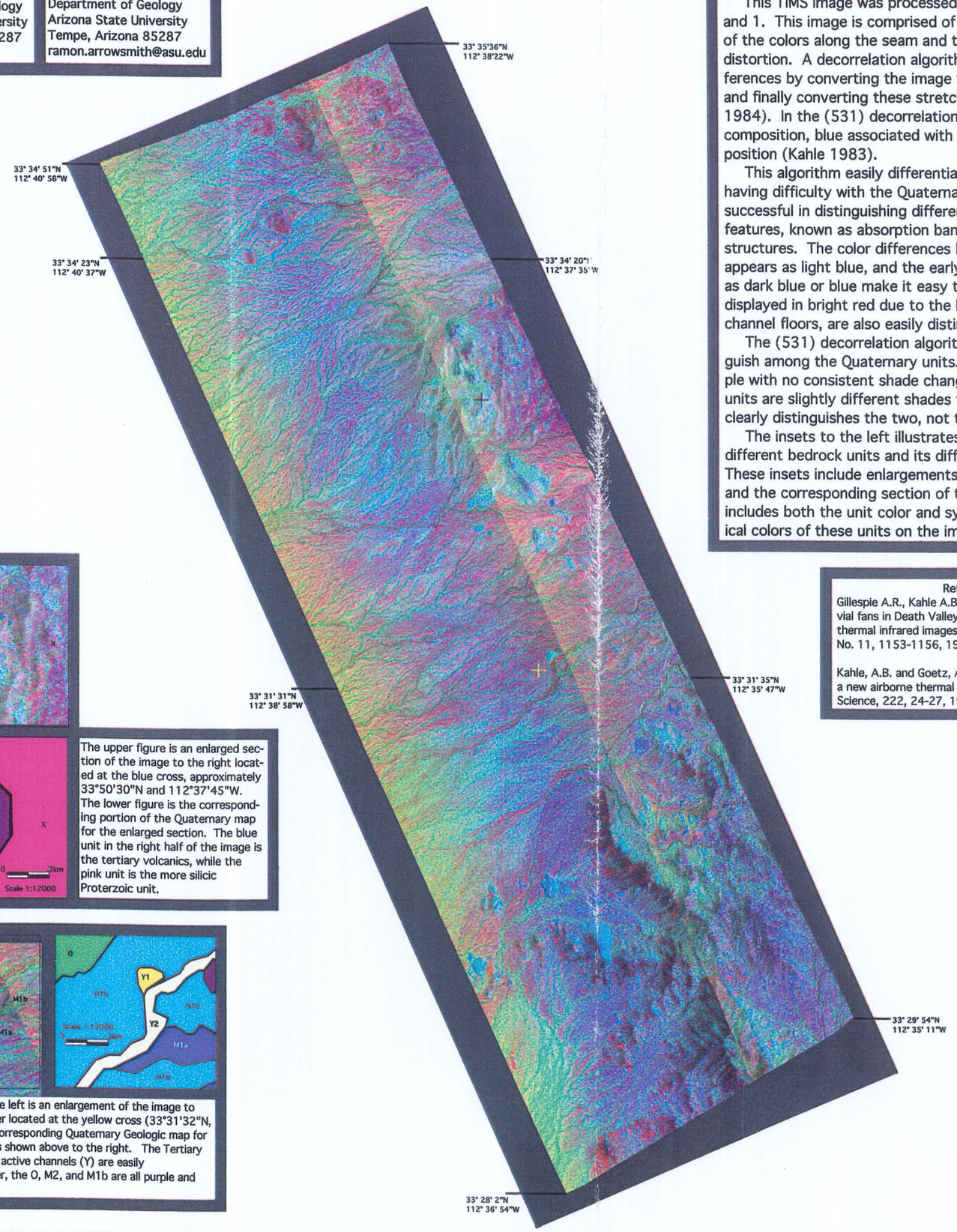
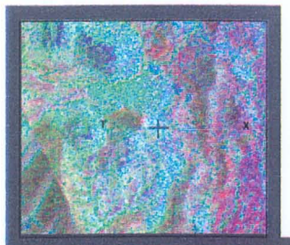


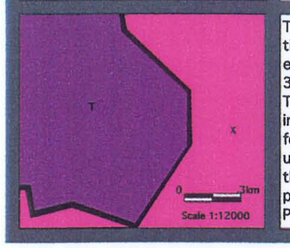
This TIMS image was processed using a decorrelation algorithm of bands 5, 3, and 1. This image is comprised of two TIMS lines mosaicked together. The yellowing of the colors along the seam and the left edge of the image is due to atmospheric distortion. A decorrelation algorithm enhances the contrast due to compositional differences by converting the image to principle components, stretching these bands, and finally converting these stretched data back to the original band axes (Gillespie 1984). In the (531) decorrelation algorithm red is associated with silicic composition, blue associated with mafic, and purple represents an intermediate composition (Kahle 1983).

This algorithm easily differentiates the bedrock types and active channels, while having difficulty with the Quaternary units. Thermal datasets, such as TIMS, are very successful in distinguishing different rock types. This is due to the strong spectral features, known as absorption bands, that are associated with the different silicate structures. The color differences between the Tertiary volcanic unit (T), which appears as light blue, and the early Proterozoic gneiss and granite (X), which appear as dark blue or blue make it easy to distinguish the two. The active channels (Y2), displayed in bright red due to the high quartz content of the loose sediment on the channel floors, are also easily distinguished by this algorithm.

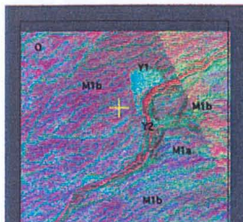
The (531) decorrelation algorithm of TIMS data, however, does not readily distinguish among the Quaternary units. The M and Y units (other than Y2) are reddish purple with no consistent shade change by which to differentiate them. While the O units are slightly different shades than the M units, it is the drainage density that clearly distinguishes the two, not the color on the image.

The insets to the left illustrates this algorithm's ability at distinguishing between different bedrock units and its difficulty in differentiating the Quaternary units. These insets include enlargements of sections of the image, denoted by the crosses, and the corresponding section of the geologic map (Plate I). The legend below includes both the unit color and symbols from the geologic map (Plate I) and the typical colors of these units on the image.





The upper figure is an enlarged section of the image to the right located at the blue cross, approximately 33°50'30"N and 112°37'45"W. The lower figure is the corresponding portion of the Quaternary map for the enlarged section. The blue unit in the right half of the image is the tertiary volcanics, while the pink unit is the more silicic Proterzoic unit.

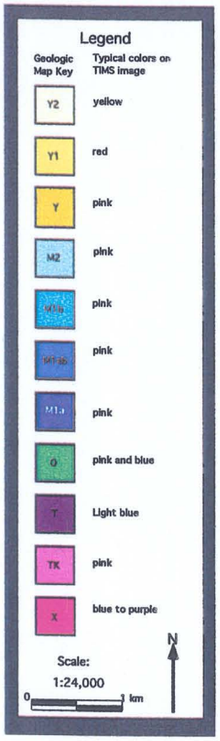


The figure above to the left is an enlargement of the image to the right with its center located at the yellow cross (33°31'32"N, 112°36'55"W). The corresponding Quaternary Geologic map for this enlarged section is shown above to the right. The Tertiary Volcanics (T) and the active channels (Y) are easily distinguished. However, the O, M2, and M1b are all purple and hard to differentiate.

References Cited

Gillespie A.R., Kahle A.B., and Palluconi, F.D., Mapping alluvial fans in Death Valley, California, using multichannel thermal infrared images, *Geophysical Research Letters*, 11, No. 11, 1153-1156, 1984.

Kahle, A.B. and Goetz, A.F.H., Mineralogic information from a new airborne thermal infrared multispectral scanner, Science, 222, 24-27, 1983.



Topographic Apex

Hydrographic Apex

Sun Valley Parkway

Study Limit

Interstate 10

RF-BR

RF

BR

OOA

CHL

AF

Stage 1 - Recognizing and Characterizing Piedmont Landforms

Wood, Patel & Associates
in association with

JE Fuller / Hydrology & Geomorphology, Inc.

July 2000

AF = Alluvial fan
RF = Relict alluvial fan
BR = Bedrock
RF-BR = Area of thin relict fan deposits over eroded bedrock
CHL = Channel upstream of hydrographic apex
OOA = Other old alluvium in embayed valleys or near toe of hillslopes

N
W E
S

2000 0 2000 4000 6000 Feet

1:12000

Topographic Apex

Hydrographic Apex

Stage 2 - Identification of Active and Inactive Areas

Wood, Patel & Associates
in association with

JE Fuller / Hydrology & Geomorphology, Inc.

July 2000

Inactive (stable) areas

Active (unstable) areas

N
W E
S

2000 0 2000 4000 6000 Feet

1:12000

Stage 3 - 100-year Floodplain Map
Flood Hazard Zones on USGS DOQ and DRG

Wood, Patel, and Associates
in association with
JE Fuller / Hydrology & Geomorphology, Inc

Description of Flood Hazard Zones

A - Approximate 100-year floodplain; riverine reaches upstream of hydrologic apex, and previously mapped ponding area behind Buckeye FRS #1

AFHH - Alluvial fan high hazard; community to treat as a floodway district

AFUFD - Alluvial fan uncertain flow distribution area; transitional area downstream of AFHH zone characterized by channelized and sheet flooding generally becoming more stable and less uncertain with increasing distance from the AFHH zone; community to treat as a floodway district

AAFF - Approximate Alluvial Fan Floodway; corridors for conveyance of water and sediment on a stable alluvial fan surface downstream of the AFHH and AFUFD zones; community to treat as a floodway district

AFZA - Alluvial fan zone A; areas within the 100-year floodplain on an inactive alluvial fan characterizedby shallow channelized flow and sheet flooding in stable channels; zone is considered approximate because no base flood elevations are provided; flood hazards within this zone are not necessarily equal throughout

X (shaded) - Areas flooded between the 100-year and 500-year discharge; or areas of floodign with depth of 100-year flood less than 1 foot; or drainage areas less than 1 square mile

X (unshaded) - Areas outside the 500-year floodplain; shown only on rocky hills

N

800 0 800 1600 2400 3200 4000 4800 5600 Feet