GEOMORPHOLOGICAL DESCRIPTION & HYDRAULIC ANALYSES

for

FEMA DESIGNATED WASHES 5, 6A, 6B & 6C

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TABLE OF CONTENTS

Page

1.0 Introduction 1
- 1.1 Scope 1
- 1.2 Washes 5 & 6: Upper Watershed Description 1
- 1.3 Geomorphological Characteristics of Washes 5 & 6 2

2.0 Flood Hazard Investigation 3
- 2.1 Background 3
- 2.2 Debris Flows, Mudflows & Avulsions 4
- 2.3 Depth and Velocity Hazards 15

3.0 FEMA Alluvial Fan Methodology 18
- 3.1 Explicit and Implicit Assumptions 18
- 3.2 Applicability to Washes 5 & 6 19
- 3.3 Evaluation of FEMA's Analysis of Washes 5 & 6 21

4.0 Wash Corridor Delineations 27
- 4.1 Geomorphological Basis 28
- 4.2 Delineation of the Wash Corridors 31

5.0 Conclusions and Recommendations 39

6.0 References 41

APPENDICES

Appendix A: LACFCD Debris Flow Methodology
Appendix B: Uniform Flow Calculations & Supporting Data
Appendix C: Referenced Correspondence

LIST OF PLATES & FIGURES

Plate 1	Drainage Boundary Map	Pocket
Plate 2:	Typical Surface Soil	8
Plates 3a&b:	Geologic Mapping by Doorn & Péwé	9-10
Plate 4:	Vegetation Condition	13
Plate 5	FEMA Designated Floodplains	Pocket
Plate 6	Cross Section Location Map	Pocket
Plate 7:	Exposed Caliche Along Water Courses	17
Plates 8&9:	Geologic Mapping by Cella Barr et. al. (1988)	Pocket
Figure 1	Comparison of Longitudinal Profiles	11
Figure 2	Typical Wash Cross Section	33

1.0 Introduction

1.1 Scope

Coe & Van Loo Consultants, Inc., (CVL) has been contracted to evaluate the flood plains for Washes 5, 6A, 6B, and 6C designated on the preliminary Flood Insurance Rate Maps (FIRM) dated July 9, 1991. In this report Washes 5, 6A, 6B, & 6C will collectively be referenced to as Washes 5 & 6. CVL's scope of work includes the evaluation of these maps on a hydrological, geomorphological, hydraulic, and flood protection basis. However, this report only addresses the geomorphologic and hydraulic aspects of Washes 5 & 6 indicated on the preliminary FIRM maps. More specifically, this report addresses:

a) the special flood hazards associated with alluvial fan flooding and the potential for these special flood hazards to occur along Washes 5 & 6;

b) the applicability of FEMA's Alluvial Fan model to Washes 5 & 6;

c) FEMA/MBJ's application of the Alluvial Fan model to Washes 5 & 6; and

d) the recommended methodology for delineating flood hazards along Washes 5 & 6.

It is important to note that the watershed and geomorphological characteristics for Washes 5 & 6 may differ significantly from those for Washes 1 through 4. Therefore, the findings presented in this report may not apply to Washes 1 through 4.

1.2 Washes 5 & 6: Upper Watershed Description

Washes 5 & 6 are located on a gently sloping alluvial plain, with maximum slopes of approximately two percent to the southwest. A recent geologic investigation of the area, documented in a 1991 report published by the Arizona Geological Survey, indicates that the washes are primarily located on deep alluvial deposits with old igneous rock formations located at the upper and lower limits of the drainage area (Doorn & Péwé, 1991).

The watersheds for Washes 5 & 6 are primarily comprised of an intricate system of shallow sand/gravel bed washes that drain small ridges (Plate 1). Review of aerial photographs, topography, and field investigation reveals that channel bifurcations and channel braiding occurs with the study area. Though the processes of watershed and fluvial sediment transport do occur in this area, the landforms and slopes are not those required to generate debris flows, mudflows nor avulsions normally associated with active alluvial fans.

Within the watershed, younger alluvium forms a thin veneer, over older more consolidated alluvium. In the upper layers of this older alluvium a more resistant layer, known as caliche, has formed (Doorn & Péwé, 1991). Caliche is formed from the precipitation of calcium carbonate within the soil matrix. Caliche can be very erosion resistant and can effectively reduce or prevent bank and channel erosion on an engineering time scale.

1.3 Geomorphological Characteristics of Washes 5 & 6

Washes 5 & 6, currently and for the past several hundred thousand years, flow across two geologic basins named the Carefree and the Paradise Valley Basins (Doorn & Péwé, 1991) (CBA et. al., 1988). These geologic basins are the result of basin and range tectonic disturbances. Regional block faulting along steeply-inclined normal faults have produced closed basins into which alluvium or clastic sediments have accumulated for millions of years. The Carefree and Paradise Valley Basins are separated by Precambrian granites and scattered Tertiary igneous formations (see Plate 1). The Carefree Basin is located in the northeast portion of the study area; whereas, the Paradise Valley Basin is located in the southwest portion of the study area.

The Precambrian granites and the Tertiary igneous formations are highly erosion resistant formations that have the effect of concentrating the runoff from the Carefree Basin into the well defined channels of Washes 5 & 6A. However, upstream and downstream of these erosion

resistant formations, Washes 5 & 6 flow across sediment filled basins at moderate slopes between 1 to 2 percent as both riverine and shallow sheet flow.

The geomorphological characteristics of Washes 5 & 6 are primarily a result of the soil structure of the alluvium, landform slopes, and the hydraulic characteristics of the surface runoff events. Within the Paradise Valley Basin, Washes 5 & 6 exhibit the following characteristics:

a) The main channels of Washes 5 & 6 have formed over a long period of time and have relatively stable banks that are stabilized by caliche and vegetation.

b) The main channels of Washes 5 & 6 may have capacity for only frequent runoff events.

c) Washes 5 & 6 lack the hydraulic characteristics required to erode a channel that has capacity for infrequent or high magnitude events.

d) The main channel may bifurcate into multiple main channels that may or may not recombine downstream.

e) During infrequent events, the flow overtops the banks of the main channel(s) and disperses as shallow sheet flow or shallow flow in small local drainage swales.

f) Local runoff flowing in shallow swales is collected by the main channel(s) of Washes 5 & 6 that extend further up into the watershed; that is, the washes exhibit tributary flow characteristics unlike alluvial fans.

g) Washes 5 & 6 exhibit complex, but not random or unpredictable, flow paths.

2.0 Flood Hazard Investigation

2.1 Background

Alluvial fans are recognized by the Federal Emergency Management Agency's (FEMA's) National Flood Insurance Program (NFIP) to pose special flood hazards. To regulate

development on alluvial fans, the NFIP regulations indicate that FEMA will credit or acknowledge only major flood control measures whose design and construction effectively eliminate alluvial fan flood hazards. To evaluate the alluvial fan flood hazards, the NFIP requires "engineering analyses that quantify the discharges and volumes of water, debris, and sediment movement associated with the flood that has a one-percent probability . . ." (FEMA: NFIP - Sect. 65.13, 1990).

As recognized by FEMA (1989), special flood hazards that may be encountered on alluvial fans include:

- debris flows & mudflows, producing impact forces and the deposition of sediment and debris (depths of 15 - 20 feet have been observed)
- high-velocity flow (as high as 15 - 30 feet per second), producing significant hydrodynamic forces
- erosion/scour (to depths of several feet)
- inundation, producing hydrostatic/buoyant forces
- flash flooding

2.2 Debris Flows, Mudflows & Avulsions

Debris flows, mudflows, and avulsions are special flood hazards and are also believed to be the primary hydraulic processes responsible for the formation and modification of alluvial fans. Dr. Richard French, of the Desert Research Institute in Nevada, is a noted expert in the field of alluvial fan hydraulics. Dr. French has the following definitions for these processes (French, 1987):

Debris flow: Moving rampart or wall of boulders and mud a few meters in height without visible water that moves forward in a series of surges or waves along an alluvial fan. Also, a

debris flow is a flowage of a mixture of all sizes of sediment. Boulders accumulate at the front of the debris wave and form a lobe behind which follows the finer-grained more fluidic debris.

Mudflow: Debris laden water originating on steep slopes so charged with mud and sand that it forms a fluid far denser than water and is capable of transporting huge blocks and boulders which are buoyed up by the viscous mass.

Avulsion: An avulsion refers to the sudden abandonment of one flow channel and the formation of a new channel. An avulsion may occur when material deposited by a debris or mud flow obstructs the active channel.

Researchers have identified several factors believed to be conducive to the formation of debris and mud flows. The main factors identified by various researchers and documented by French (1987) include:

Precipitation Factors

- Large Volumes of High Intensity Rainfall: Croft (1967) found that 1 to 2 inches of rainfall with intensities of 4 to 8 inches per hour and a duration of at least 0.08 hours are required for debris flow formation.
- Areal Extent and Frequency of Rainfall Events: If major rainfall events are too frequent, then weathered material required for the formation of the debris and mud flows may not have sufficient time to accumulate in the watershed (French, 1987).

Geologic/Lithologic Factors

- Availability of Clay, Silt, and Fine Material: Hooke (1965) indicated that substantial amounts of clay, silt and fine material produced by weathering or derived from alluvial material is conducive, if not required, for the formation of debris and mud flows. French (1987) indicates that several investigators have noted that the availability of clay is also very important in the formation of debris flows. Desert

pavement and caliche can limit the exposure, of fine material present in soils, to erosion and sediment transport processes.

Topographic Factor

- Watershed and Channel Slopes: French (1987) states that "the slopes of the drainage basin must be sufficiently steep to support very viscous flows and produce high flow velocities necessary to entrain the weathered material into the flow, yet the watershed must not be so steep that debris cannot accumulate."

Land-Use/Vegetation Cover Factor

- Vegetation Cover: The condition and type of vegetation cover affects both the runoff and soil erosion processes. Therefore, a well established vegetation cover upstream and downstream of the apex is not conducive to the formation of debris or mudflows.

With respect to these factors, the watersheds for Washes 5 & 6 can be characterized as follows:

Precipitation

- Based on an average annual rainfall of approximately 12 inches, the watersheds for Washes 5 & 6 are in a semi-arid region. Rainy seasons occur in both late summer and winter months. In late summer, there are typically frequent localized thunderstorms; however, December, January, and February are typically the wettest months of the year. The gentle and long-duration rains result from storms that originate in the Pacific Ocean and move inland across the country (Cella Barr et. al., 1988). The frequency of the seasonal rainfall events and the relatively high total annual rainfall are not conducive to debris flow formation, since the fine materials may be washed from the coarse soils on a regular basis.

Geology/Lithology

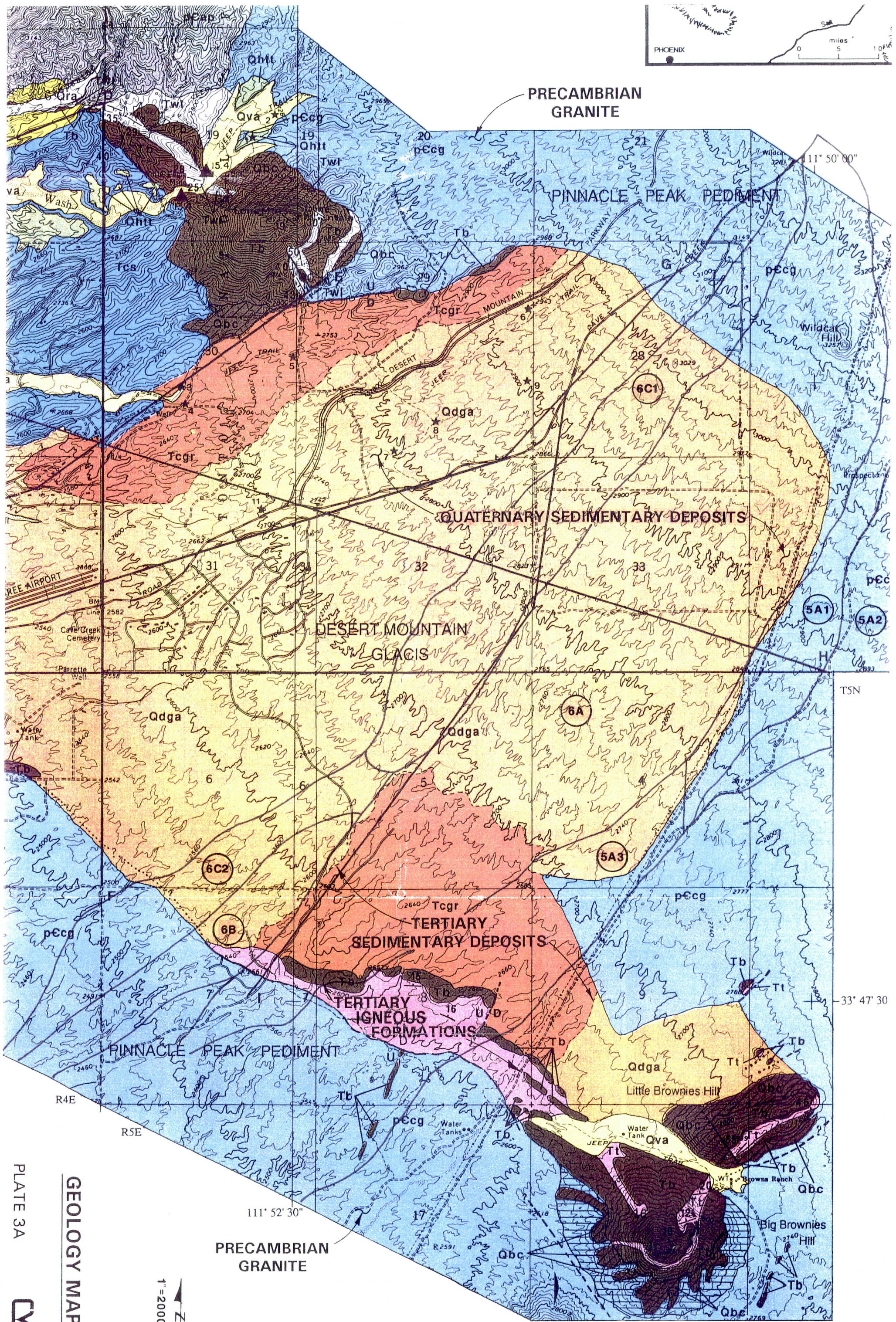
- Soil Conservation Service (SCS) soil mapping study indicates that the surface soils of the watersheds are primarily comprised of very gravely loams and very gravelly sandy loams (SCS, 1986). Field observation and the SCS soil mapping study indicates that these soils are covered by a layer of pebbles and cobbles, often referred to as desert pavement, that protects the underlying material from erosion (Plate 2). The geologic mapping by Doorn & Péwé (1991) indicates that the base or bedrock formations in the area are predominantly Precambrian Granites and other igneous rocks, which are typically highly resistant to weathering (see Plate 3). Doorn and Péwé (1991) also indicate that the unconsolidated Desert Mountain Glacis Alluvium is composed of relatively coarse material, with only 8 percent of its composition being comprised of silt and clay sized particles (see Plate 3 and Appendix B for gradation data). Hence, the composition, structure, and parent material of the soils in the watersheds for Washes 5 & 6 are not conducive to the formation of debris flows.

Topography

- Between Cave Creek Road and the upper limits of the watershed, the channel slopes for Washes 5 & 6 range from approximately 1.5 to 2.2 percent (Plate 1). The channel profile for Wash 6A is shown in Figure 1. Also shown in Figure 1 are three longitudinal profiles along fan surfaces in Utah where debris flows were documented by Croft (1967), as presented by French (1987). In addition, the Los Angeles County Flood Control District (LACFCD) studied in detail recorded debris flow events in Los Angeles County, where channel slopes range from 7 to 37 percent (LACFCD, 1979). Figure 1 clearly illustrates that the channel slopes for Washes 5 & 6 are quite mild when compared with washes in Utah and California where debris flows have been

Closeup of typical soil surface conditions within the watersheds for Washes 5 & 6. Note the absence of silt and clay at the surface.

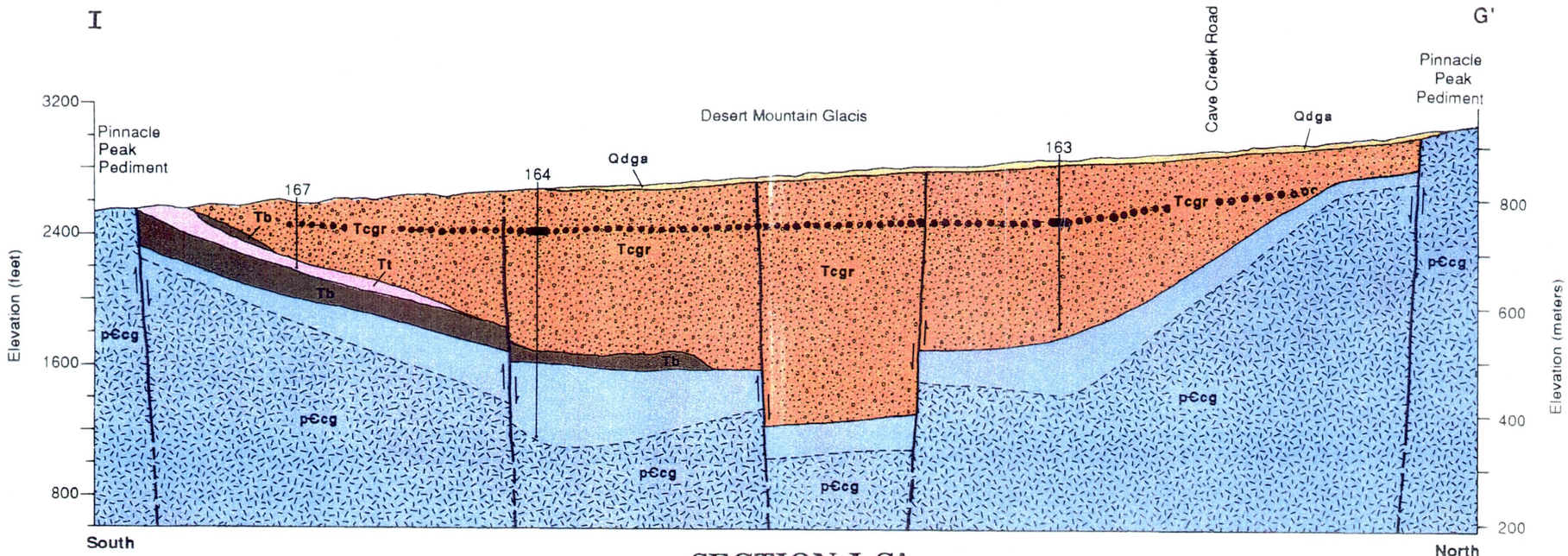
PLATE 2 - TYPICAL SURFACE SOIL



Geology by T. L. Péwé (1984-1989), P. L. Doorn (1986-1989), R. Kenny (1984-1985), J. T. Bales (1984-1985), and T.L. Gorey (1986-1989)

PLATE 3A

GEOLOGY MAP



SECTION I-G'

PLATE 3A SYMBOLS

contact
dashed where gradational or inferred

fault
dashed where inferred, dotted where buried
U = upthrown side and
D= downthrown side

20 strike and dip of bedding

70 strike and dip of foliation

A — A' location of geologic cross section

21.7 location of K-Ar dated sample (age in millions of years)

4 location and sample number for grain-size analyses

DESERT MOUNTAIN GLACIS ALLUVIUM Unconsolidated Sedimentary

Qdga Tan to gray, unconsolidated, moderately to poorly sorted, poorly bedded, grus-rich deposit composed of 52% gravel, 40% sand, and 8% silt and clay; contains subangular clasts up to 12 in. (granite), and up to 24 in. (basalt and minor amounts of meta-argillite), in diameter; 3 to 33 ft thick; predominantly grus; locally contains up to 20% basalt, argillite, and/or rhyolite clasts derived from nearby sources.

Grapevine Member Consolidated Sedimentary

Tcgr Tan to gray, moderately to locally poorly consolidated, moderately bedded, moderately to poorly sorted, granitic fanglomerate with subangular clasts in silty-sand matrix; locally interbedded with sand lenses; clasts up to 3 in., and locally up to 24 in., in diameter; calcium-carbonate layers up to 0.04 in. thick within layers of fine- and medium-grained gravel; clasts larger than 0.4 in. in diameter consist of 75% granite-grus, 19% basalt, 4% meta-argillite, 1% undifferentiated metamorphic rocks, and 1% other materials.

CAMELBACK GRANITE Igneous Intrusive

p€cg Yellow to tan to reddish-brown, massive, spheroidally weathered, coarse-grained granite with potassium-feldspar crystals up to 4 in. long; locally contains fine-grained, highly resistant, aplite dikes up to 16 ft thick that weather into near-vertical cliffs and peaks; locally contains xenoliths of meta-argillite; granitic pediment surface veneered with tan, unconsolidated, moderately bedded, moderately sorted, decomposed granite fragments in silty matrix with angular to subangular clasts of granite and local adjacent bedrock up to 12 in. in diameter; veneer up to 40 ft thick. **Horizontal hatched pattern:** tan, unconsolidated, unstratified, moderately sorted, decomposed granite fragments in silty matrix; locally 450+ ft thick and composed of 100% decomposed granite.

PLATE 3B SYMBOLS

contact - *dashed where inferred*

fault - *dashed where inferred, dotted where buried; arrows indicate direction of relative motion along the fault*

160 well
- *number is well number (Table 2, Appendix B)*
- *length of vertical line below surface represents well depth as per vertical scale*
- *thick line indicates water level in well at time of well completion (Table 2); dotted where water table may be inferred*

GEOLOGY MAP

(Doorn & Péwé, 1991)

FEMA Designated Washes 5,6A,6B & 6C

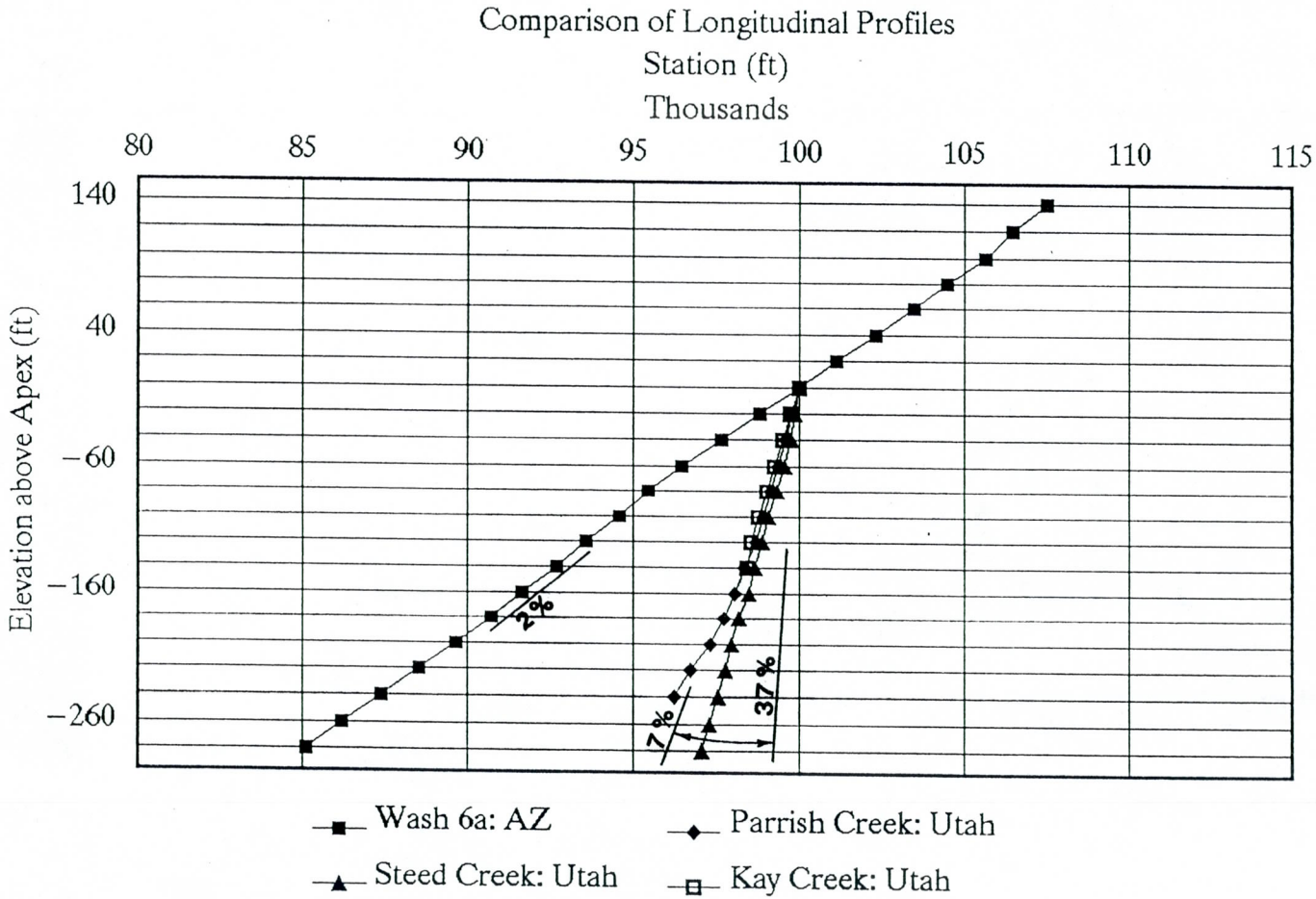


FIGURE 1

documented. Therefore, this data indicates that the channel slopes for Washes 5 & 6 are not conducive and quite probably inadequate for debris flow formation.

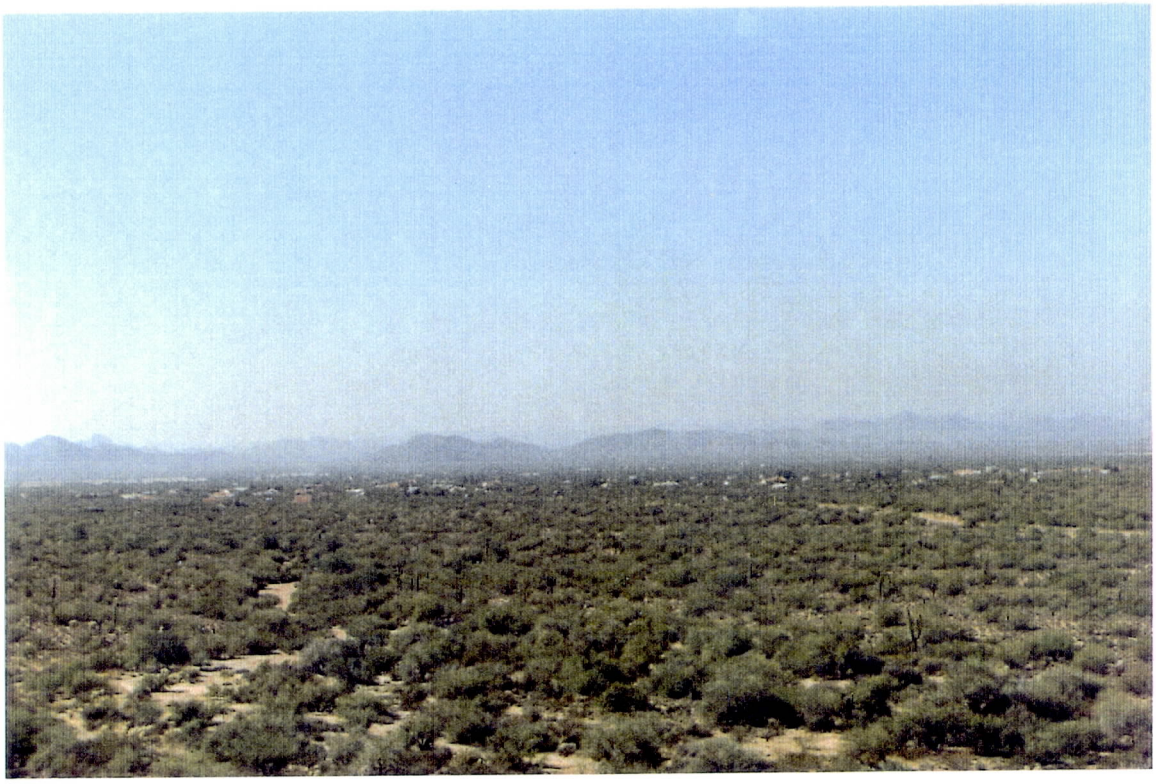
Land Use/Vegetation

- The drainage basins for Washes 5 & 6 are located primarily within an undisturbed desert area, with only interspersed low density residential development. The vegetation within the drainage basin is comprised predominantly of creosote bush, ironwood, palo verde, saguaro cacti, and other varieties of cacti. Field observations indicate that the area is not subject to extensive grazing or recreational use. The overall vegetation in the area is judged to be in good condition, with 50 to 80 percent ground cover. To illustrate the typical vegetation conditions in the drainage basin, photographs taken of the watershed are shown in Plate 4.

To evaluate the potential for the formation of debris and/or mud flows, the watersheds for Washes 5 & 6 have been evaluated with respect to several factors conducive to the formation of debris flows. As indicated above, the hydrometeorologic, geologic, lithologic, topographic, and current vegetation conditions in the watersheds for Washes 5 & 6 are not conducive to the formation of debris flows.

In response to severe debris flow problems, the Los Angeles County Flood Control District (LACFCD) conducted detailed studies and developed a method to estimate the volume of debris associated with debris flow events (LACFCD, 1979). This study by the LACFCD is the most detailed and well documented analysis of debris flow events found during our literature review and is the only study found that included a procedure for estimating the sediment yield from a debris flow event. Los Angeles County is at nearly the same latitude as Maricopa County and does include desert areas along the eastern boundaries of the county. Hence, the potential applicability of the LACFCD methodology to Washes 5 & 6 has been investigated.

Looking northeast at the watersheds for Washes 5 & 6 (Note: Wash 5 crossing of Lone Mountain Road in lower left corner)



Looking southwest at FEMA designated alluvial fans 5, 6A, 6B & 6C (Note: Wash 5 in foreground)

PLATE 4 - VEGETATION CONDITIONS

The methodology developed by the LACFCD is based on recorded events measured on eight watercourses within Los Angeles County. The eight watercourses evaluated in the study have drainage areas ranging from 0.17 to 2.46 square miles and channel slopes ranging from 7.3 to 36.5 percent. The LACFCD's report indicates that a special effort was made to select those watersheds which could be considered representative of the area. The LACFCD's documentation for their methodology is quite detailed and given in Appendix A.

Table 1 is a summary of pertinent physiographic features of the watersheds for Washes 5 & 6. Table 2 is a comparison of the physiographic features for Washes 5 & 6 and the watercourses studied by the LACFCD. As indicated in Table 2, the channel slopes and relief ratios for Washes 5 & 6 are well below those of the LACFCD's study watersheds and the limits on the LACFCD's debris nomograph (see Appendix A); hence, the LACFCD's methodology is inappropriate for Washes 5 & 6. Since the LACFCD's methodology was developed as a general methodology to be applied to the wide range of conditions observed in Los Angeles County, this comparison strongly indicates that the watersheds for Washes 5 & 6 lack the slopes and relief ratios required to generate debris flows.

Table 1: Physiographic Features

Wash ID	Average Channel Slope	Delta Height[1] (ft)	Length (ft)	Relief Ratio[2]
5	0.019	825	38,760	0.021
6A	0.022	785	28,200	0.028
6B	0.020	280	12,140	0.023
6C	0.021	870	32,420	0.027

[1] Delta Height is the total change in elevation within the watershed
[2] Relief Ratio = Delta Height/Length

Table 2: Comparison of Physiographic Features

Feature	LACFCD Study Watersheds	Washes 5 & 6 Watersheds
Drainage Area (sq. mi.)	0.17 - 2.46	0.43 - 3.54
Channel Slope	7.3 - 36.5% mean = 23%	1.5 - 2.2% mean = 2% ±
Relief Ratio	0.122 - 0.445 mean = 0.29	0.021 - 0.028 mean = 0.025

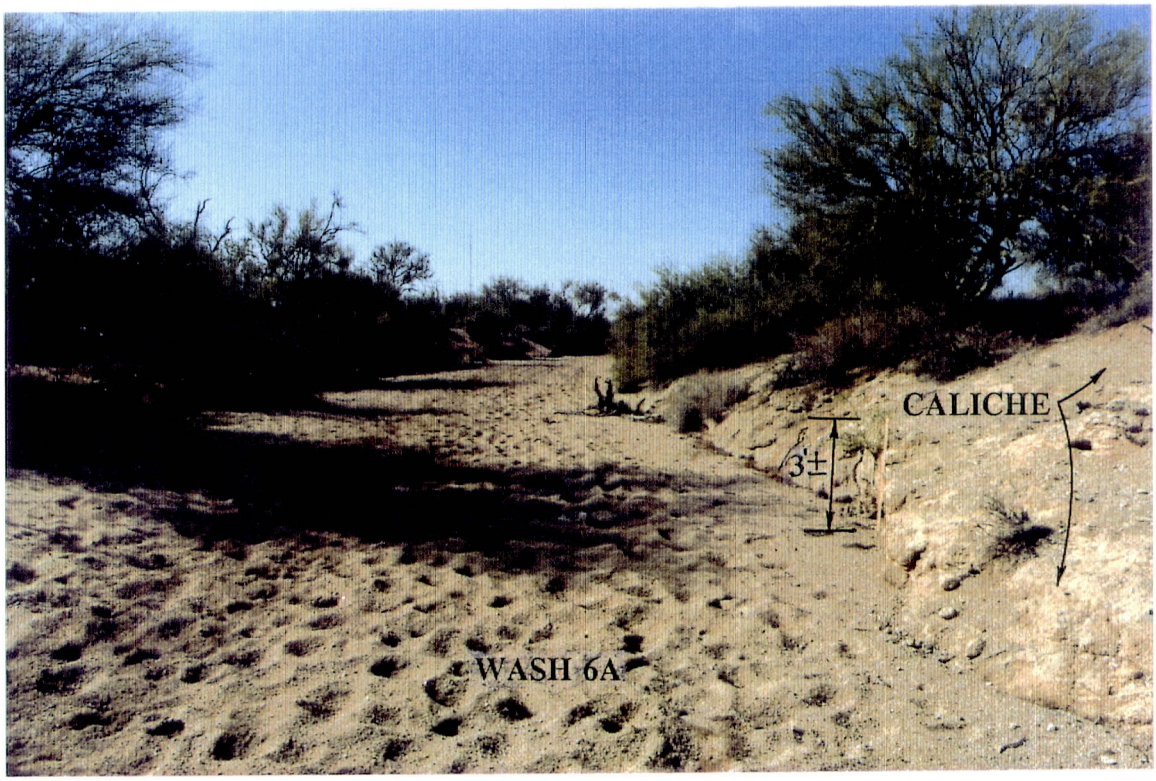
2.3 Depth and Velocity Hazards

High-velocity flow refers to conditions where water velocities may be as high as 15 to 30 feet per second (fps) (FEMA, 1989). In general high-velocity flows can result in significant hydrodynamic forces on structures, bank erosion, and localized scour adjacent to structures.

To evaluate the potential flow depths and velocities corresponding to the 100-year event, uniform flow calculations have been performed for cross sections taken at various locations along Washes 5 & 6 (Appendix B). The locations of the cross sections analyzed are shown on Plates 1, 5 & 6. As indicated on Plate 5, several of the cross sections are in locations where the highest flow velocities and depths would be expected.

The results of the uniform flow analyses are given in Appendix B and summarized in Table 3. It is recognized that computed uniform flow velocities are average velocities and do not reflect the maximum velocity that may occur at a cross section; however, uniform flow velocities can provide a good estimate of the predominant flow velocity along the bed and banks of a watercourse.

As indicated in Table 3, the computed uniform flow velocities range from 4 to 7 feet per second, with the exception of Section 5. However, the channel at Section 5 and many of the other cross sections analyzed are incised and stabilized by caliche in the banks and/or bed



Looking downstream along Wash 6, approximately 0.5 mile downstream of Scottsdale Road. Note exposed caliche along banks.

Looking downstream along Wash 6B-C, approximately 1/8 mile downstream of Scottsdale Road. Note exposed caliche along bed and banks.

PLATE 7 - EXPOSED CALICHE ALONG WASHES

material, as shown in Plate 7; therefore, the flow is contained by naturally stabilized banks. The computed velocities are typically well below 7 fps for the 100-year discharge in locations where the highest velocities are expected. In many locations, the 100-year discharge will spread out and flow in wide shallow overbanks with velocities far less than those computed for Sections 1-9, as demonstrated in the calculations for sections A through Q (Appendix B). Table 3 also illustrates that the preliminary FIRM maps and the FEMA methodology result in an inadequate description of the flood hazards along the main channels of Washes 5 & 6.

Table 3: Uniform Flow Computations for Locations Along Washes 5 & 6

					FEMA[2]	
X-Sec ID	**Wash**	**Q_{100}[1] (cfs)**	**Depth**	**Velocity (fps)**	**Depth (ft)**	**Velocity (fps**
1	6b & c	1655	2.4	6.5	2	6
2	6b & c	1655	2.5	6.0	2	6
3	6b & c	995	2.9	5.0	2	6
4	6b & c	552	2.2	5.3	2	5
5	6a	3215	6.4	12.7	3	8
6	6b & c	386	2.6	5.4	1	4
7	6b & c	166	1.2	4.1	1	4
8	6a	3215	2.5	5.6	1	4
9	5	475	1.2	6.9	1	4

[1] Approximate 100-year discharge at the cross section per WRA hydrology (WRA, 1992).

[2] Based on preliminary FIRM maps.

3.0 FEMA Alluvial Fan Methodology

3.1 Explicit and Implicit Assumptions

In recognition of the special flood hazards associated with alluvial fans, FEMA has adopted a methodology for assessing flood hazards on active alluvial fans, for flood insurance purposes (FEMA, 1991). This methodology is based explicitly and implicitly on the following assumptions:

1. Flood Path: During major flood events on active alluvial fans, the flow will not spread evenly over the total surface of the fan; rather, the flow is confined to channels that migrate across the fan over time. Below the apex of the fan or a zone of permanent channel entrenchment, the flow will erode a channel at random locations any place on the fan surface. That is, it is no more probable for the flow to follow an old flow path than it is to follow a new one (French, 1987)(Dawdy, 1979)(FEMA, September 1990).

2. Channel Configuration: A flood flow over a fan surface will erode a channel that can be approximated as a rectangular channel (French, 1987)(FEMA, Sept. 1990). Furthermore, in the "multiple channel" region, the total width of the channels is 3.8 times the width of the single channel above the bifurcation point (FEMA, Sept. 1990). Dawdy and Hill (1987) indicate that it is "further assumed that alluvial fans are steep enough so that the discharge soon forms a channel and the discharge can be used to estimate channel dimensions."

3. State of Flow: Flow across a fan surface will occur at critical depth and velocity. The channel that the flood flow forms will adjust its dimensions to maintain the critical flow condition (FEMA, Sept. 1990). However, the FEMA 37 guidelines (FEMA, 1991) do indicate that normal flow conditions may exist in the multiple channel region.

4. Probability of Flooding: The probability of a point on the fan being flooded during a particular flood event decreases from the apex of the fan to the toe of the fan because of the widening or expansion of the fan surface in the downslope direction. This expansion provides a greater transverse distance over which a channel of given width can occur (French, 1987).

5. Avulsions: The terminology of avulsion as used by FEMA refers to the possibility that during a major flow event the flow may suddenly abandon one channel and form a new channel (French, 1987)(Dawdy, 1979).

6. Fan Apex Flood Discharge Frequency Distribution: Log Pearson Type III is an appropriate distribution for flood flows emanating from the fan apex (FEMA, Sept. 1990). Local or "on-fan" runoff does not contribute to the flows emanating from the fan apex (FEMA, Sept. 1990).

7. Coalescent Fans: In the case of coalescent alluvial fans, the probability of a point being flooded is estimated by computing the probability of flooding from each source, and then combining these probabilities for the point, under the assumption that the probabilities are independent (French, 1987)(FEMA, Sept. 1990).

3.2 Applicability to Washes 5 & 6

As presented in Section 2.1, the FEMA regulations regarding alluvial fan flood zones are far more restrictive than for other types of flood zones (FEMA, 1990). Hence, it is very important to local government agencies and private land owners that the alluvial fan methodology and alluvial fan flood zones be applied and designated appropriately. Therefore, it is essential that all of the assumptions associated with the FEMA alluvial fan methodology be appropriate to the study area.

The assumptions associated with the FEMA alluvial fan methodology are presented in detail in Section 3.1. However, the assumptions regarding flood paths and channel configurations (i.e., Assumptions 1 & 2) are the most pertinent with respect to Washes 5 & 6 and the crux of the alluvial fan methodology. These two assumptions hinge on the ability of the 100-year flood event to erode a new channel along any path down the fan surface. For this to be possible, several important conditions must exist within the designated fan zone. First of all, the surface material within the fan zone must be readily erodible. Secondly, the slope down the fan surface must be sufficient to allow the flood flow to have adequate transport capacity to rapidly erode new channels.

An important natural feature that can be very erosion resistant is caliche. Caliche is a chemical deposit of calcium-carbonate, which forms in and near the surface of soils over long periods of time (Cella Barr et. al., 1988) (Doorn and Péwé, 1991). Hence, the presence of caliche is very important when evaluating the applicability of the fan methodology.

Cella Barr et. al (1987) has prepared a detailed geology and soils study for part of the area mapped in the preliminary FIRM's. In this study, Cella Barr et. al (1987) concluded that: "Construction difficulties may be encountered in some areas due to caliche development. Continuous caliche horizons were not encountered during this study; however, surface exposures of well indurated caliche were observed at several localities. Caliche development should be anticipated during planning phases for the area." (p. 43)

Plates 8 and 9 are from the Cella Barr report. These plates indicate that the primary geologic units in the study area (i.e., Qfg, Qfg1, & Qfg2) all have a "strong potential of occurrence" of caliche (Cella Barr et. al., 1988). As indicated in Plates 8 & 9, the Qal geologic unit is comprised of the modern stream deposits and stream terraces. However, it is important to note that the report does point out the following (Cella Barr et. al., 1988). "The Qal deposits

consist of poorly-to-moderately-sorted coarse to fine sand and silt of undetermined thickness. While these sediments are not calichified, caliche deposits commonly occur along the banks and in the stream beds of the washes especially where the stream cuts the older alluvial units." (p. 17) Examples of exposed caliche along Wash 6 are shown in Plate 7. The presence of caliche is important since it is highly erosion resistant and is an indicator of lengthy periods of stability.

Hence, the results and conclusions by Cella Barr et. al (1988) clearly indicates that the geologic and soil conditions within FEMA designated Fans 5 & 6 are such that flood flows will not erode new channels at random locations any place on the "fan surfaces," due to the erosion resistant nature of caliche. This conclusion is in direct conflict with the flood path and channel configuration assumptions (i.e. Assumptions 1 & 2) of the FEMA alluvial fan methodology. That is, it is far more probable for future flood flows will follow existing topographic features rather than erode new channels. In addition, recent geologic/ geomorphologic evaluations of FEMA designated Fans 5 & 6 further conclude that Fans 5 & 6 are not "active" alluvial fans based on surface topography and geologic features (WRA, 1992).

3.3 Evaluation of FEMA's Analysis of Washes 5 & 6

The current FEMA 37 - *Flood Insurance Study: Guidelines and Specifications for Study Contractors* (March 1991) requires in STEPs 1 & 2 of the alluvial fan analysis, that the following information be documented and analyzed to determine the boundaries of the area subject to alluvial fan flooding and the apex for each flooding source (FEMA, 1991).

Excerpts from FEMA 37, page A5-6:

STEP1 - Item 2:

"2. An explanation demonstrating that flow paths below the apex are unpredictable."

STEP2 - Items 1 & 4

"1. A topographic map showing the boundaries of the areas subject to alluvial fan flooding. If barriers (either natural or manmade) to the possible flowpaths or channels exist and warrant consideration in defining the conditional probabilities, they should be shown and clearly labeled (including any 'threshold' discharges or depth necessary to breach them). This map should also show the division between the single-channel and multiple-channel regions."

"4. A report describing the topographic and geomorphologic analysis performed."

STEP2 - General Requirement

"The report should describe, in detail, and justify the use of all assumptions made in the analysis. (Those described by Dawdy can serve as a starting point)."

It is recognized that the floodplain study for Washes 5 & 6 was conducted based on the 1985 FEMA 37 guidelines and that the previous release of FEMA 37 (1985) does not directly request, from the Study Consultant (SC), the information indicated above. However, it should also be recognized that determination of the area subject to alluvial fan flooding is a critical step and requires detailed analysis of the area. Hence, the above information, currently requested by FEMA, should have been at least compiled and evaluated as part of the floodplain study.

In a letter dated September 9, 1991, the technical support data for the preliminary FEMA maps were requested from FEMA by CVL. Mr. Ed Mifflin, from Michael Baker Jr., Inc. (MBJ), the Technical Evaluation Contractor (TEC), responded and sent the calculations that he had prepared and used to delineate the floodplains along Washes 5 & 6. In a second letter dated November 13, 1991, CVL requested specific information regarding the analysis performed by MBJ and technical support data used to determine the boundaries of the area subject to alluvial fan flooding. MBJ responded with the letter (dated December 4, 1991) included in Appendix C.

Evaluation of the analysis performed by Michael Baker Jr., Inc. (MBJ) and the corresponding documentation indicates that the FEMA Alluvial Fan Methodology has been mis-applied to Washes 5 & 6 for the following reasons:

a) As documented in Section 3.2, the findings of the *Geology and Soils Study* by Cella Barr et. al (1988) clearly indicates that the geologic and soil conditions of "FEMA Fans 5 & 6" are such that flood flows cannot erode new channels during a single event at random locations on the "fan surface," as assumed by the FEMA methodology. The Cella Barr et. al. report was available to MBJ during their analysis.

b) The FEMA fan methodology and the "fan" program are based on the assumption that a flood flow will adjust its channel dimensions to maintain the critical flow condition (FEMA, Sept. 1990); however, MBJ concluded that "below apexes 5 & 6a, 6b, and 6c, the gradients are not steep enough to maintain critical depths" (MBJ, 1991) and that direct application of the FEMA "fan" program to Washes 5 & 6 is inappropriate. In order to complete the analysis of Washes 5 & 6, MBJ then modified the results of the fan model such that normal depth calculations were substituted for critical depth calculations for the <u>single channel region</u>. This substitution is in direct conflict with the basic assumptions of the methodology and the FEMA 37 guidelines (FEMA, 1985). The FEMA 37 guidelines indicate that normal depth may be appropriate for only the <u>multiple channel region</u>.

c) At locations along Washes 5 & 6, where defined flow splits occur, MBJ estimated probability splits or the probability that 100% of the flow will follow each of the existing flow paths based on "the relative sizes (in terms of topwidth) of the existing washes as shown on aerial photographs" (MBJ, December 4, 1991). However, the

FEMA methodology assumes that, below the apex or a zone of permanent channel entrenchment, the flow will erode a channel at random locations; hence, the FEMA methodology assumes that it is no more probable for the flow to follow an old or existing path than it is to follow a new one (French, 1987) (Dawdy, 1979) (FEMA, Sept. 1990). Therefore, assigning "probability splits" to existing flow paths is inconsistent with the FEMA methodology and FEMA 37 guidelines (FEMA, 1985). In addition, the "probability split" assumption by MBJ is inconsistent with the geomorphologic, geologic, soil, and hydraulic conditions along Washes 5 & 6. Moreover, MBJ is indirectly acknowledging that the wash banks and land forms below the "apices" are stable and that stable bifurcations occur, even though this concept is in direct conflict with the basic assumptions of the FEMA methodology and the FEMA 37 guidelines. Furthermore, the assumed geomorphologic relationship between "top widths" and the probability that 100% of the flow will follow each of the existing flow paths has never been documented (in a refereed publication) nor accepted by the scientific community.

d) In the December 4, 1992 letter, MBJ provided the following explanation for demonstrating that flow paths below the apex (apices) are unpredictable.

> "Field reconnaissance shows that the surface material in the area is sand and gravel. The area is therefore very susceptible to erosion. The washes in the area contain the same material, making them an abundant source of sediment available for transport and deposition. The susceptibility to erosion and the sediment supply available in the area have resulted in the drainage pattern that exists. That pattern is characterized by numerous splits in the existing washes. The number of splits (and consequently the number of existing washes) increases, and the flood-carrying capacity decreases, with a decrease in elevation (downslope). Future flood paths in such an area are unpredictable."

There are serious flaws in MBJ's explanation.

i) The *Geology and Soils Study* by Cella Barr et. al. (1988) documents that geologic units in the study area exhibit mildly to strongly developed caliche deposits and that erosion resistant caliche deposits commonly occur along the banks and beds of the washes. Therefore, there are landform/soils that are very old and erosion resistant (within the FEMA designated "fan areas" of Washes 5 & 6).

ii) MBJ states in their explanation that the washes bifurcate and have a lower capacity as they extend downstream. This merely indicates that the flow paths in the study area exhibit a complex pattern. Furthermore, detailed topography (ie, 1" = 100', 2' C.I.) available to MBJ for a portion of the study area indicates that there is very significant relief within "fans 5 & 6" and that the main channels carrying flows from the upper watershed can be identified. In addition, a detailed geomorphological analysis (Water Resources Associates, 1992) indicates that many of the surface land forms in the "fan" areas are greater than ten thousand years old. It is recognized that the multiple bifurcations complicate the task of estimating the flow in each of the main channels; however, the flow paths can be identified and delineated, with detailed topography, photography, and field investigation, as indicated in the FIRM workmaps (February, 1992) submitted as part of this appeal by the local communities.

e) In a letter (dated January 30, 1989) from Cella Barr Associates (CBA), to FEMA, CBA responded to the following comment from MBJ:

"CBA should keep in mind that before a point qualifies as an 'apex' the modeler must determine that all runoff from the drainage area above that point passes through it, not just nearby."

Yet, MBJ failed to identify and/or acknowledge the well defined channel bifurcation located in the upper watershed of Wash 5. This channel bifurcation is shown in Plate 1 and documented in detail in the report titled *Hydrologic Review of FEMA Designated Washes 5, 6A, 6B, & 6C* by CVL (1992). This channel bifurcation clearly indicates that the criteria for identifying apices were not maintained; therefore, the location of the apex indicated on the preliminary FIRM maps is invalid for Wash 5 (and Wash 4 - which is also impacted by the bifurcation).

Yet, locating the apex upstream of the bifurcation is not consistent with the FEMA alluvial fan methodology either, since the drainage area would be much less than 1 square mile and Wash 5 is well defined/incised & stable upstream and downstream of the bifurcation. Hence, the channel bifurcation of Wash 5 in the upper watershed is additional evidence that the FEMA alluvial fan methodology has been mis-applied.

f) The FEMA alluvial fan methodology assumes that local or "on-fan" runoff does not contribute to the flow emanating from the fan apex (Assumption #6). On actual alluvial fans this assumption is appropriate. However, Plate 1 clearly indicates that Washes 5 & 6 exhibit tributary flow patterns and that significant drainage areas downstream of the FEMA designated "apices" contribute runoff to the main channels of Washes 5 & 6. Furthermore, the significance of the local drainage is demonstrated in Section 4.2 of this report.

It is also important to note that the December 4, 1991 letter from MBJ indicated that Cella Barr Associates is the Study Contractor (SC) and that MBJ is the Technical Evaluation Contractor (TEC). Yet, the technical support data that CVL has received from MBJ/FEMA indicates that MBJ has performed all of the hydrologic and hydraulic analyses used to prepare the preliminary FIRM maps.

It is also important to note that the Flood Control District of Maricopa County (FCDMC) has strongly disputed the application of the alluvial fan methodology to the study area, (eg, letter dated January 5, 1990). FEMA responded in a letter dated March 7, 1990 (Appendix C).

In the FCDMC's letter (1/5/90), reference is made to "calcified or silicated soil banks" and that it is not believed "that the erosion of channel banks as defined in the (fan) model can be technically substantiated by geomorphic or soil data." As indicated in the letter given in Appendix C, FEMA responded to the FCDMC's specific inquiries with general and unsubstantiated statements concerning "unconsolidated material" and references to "width depth relationships" based on studies in New Mexico, California and Nevada; yet:

a) FEMA states on the first page of the letter that "the alluvial fan flooding methodology is very site specific..."

b)FEMA/MBJ has a geology/soil report by Cella Barr et. al. (1988) that clearly indicates that there is highly erosion resistant caliche in the "fan areas" and exposed in the bed and banks along Washes 5 & 6, which strongly implies that application of the fan methodology is inappropriate; and

c)MBJ does not appear to have a site specific and comprehensive report addressing the applicability of the FEMA alluvial fan methodology to Washes 5 & 6 (as of February, 1992). Therefore, this correspondence between FEMA and the FCDMC indicates that the alluvial fan methodology has been mis-applied, due to the lack of verification and documentation to substantiate the applicability of the fan model to Washes 5 & 6, despite inquiries by a local agency.

4.0 Wash Corridor Delineations

The technical data presented in this report clearly indicates that application of the FEMA alluvial fan methodology to Washes 5 & 6 is inappropriate and results in floodplain delineations

that inadequately reflect the true flood hazards associated with Washes 5 & 6. As a joint effort involving hydrologists, engineers, geologists/geomorphologists, and floodplain administrators from the Flood Control District of Maricopa County (FCDMC), the City of Phoenix (COP), the City of Scottsdale (COS), the Arizona Geologic Survey (AGS), Water Resources and Associates (WRA) and CVL, the flooding characteristics of Washes 5 & 6 have been identified and the flood hazard zones have been delineated for Washes 5 & 6. As indicated in the recommended floodplain delineation maps (FIRM Work Maps, February, 1992), wash corridors delineate the areas subject to Zone A - non-alluvial flood hazards, in a manner consistent with the NFIP regulations (FEMA, 1990). Delineation of the wash corridors is based upon geomorphologic and hydraulic evaluation of Washes 5 & 6.

4.1 Geomorphological Basis

Washes 5 & 6, currently and for the past several hundred thousand years, flow across two geologic basins named the Carefree and the Paradise Valley Basins (Doorn & Péwé, 1991) (CBA et. al., 1988). These basins are the result of basin and range tectonic disturbances. Regional block faulting along steeply-inclined normal faults produced closed basins into which alluvium or clastic sediments have accumulated for millions of years. The Carefree and Paradise Valley Basins are separated by Precambrian granites and scattered Tertiary igneous formations (see Plates 1 & 3). The Carefree Basin is located in the northeast portion of the study area; whereas, the Paradise Valley Basin is located in the southwest portion of the study area.

The Precambrian granites and the Tertiary igneous formations are highly erosion resistant formations that have the effect of concentrating the runoff from the Carefree Basin into the well defined channels of Washes 5 & 6A. However, upstream and downstream of these highly erosion and weathering resistant formations, Washes 5 & 6 flow across sediment filled basins at moderate slopes between 1 to 2 percent as both riverine and shallow sheet flow.

The geomorphological characteristics of Washes 5 & 6 are primarily a result of the soil structure of the alluvium, landform slopes, and the hydraulic characteristics of the surface runoff events. Within the Paradise Valley Basin, Washes 5 & 6 exhibit the following characteristics:

a) The main channels of Washes 5 & 6 have formed over a long period of time and have relatively stable banks that are stabilized by caliche & vegetation.

b) The main channels of Washes 5 & 6 may have capacity for only frequent runoff events.

c) Washes 5 & 6 lack the hydraulic characteristics required to erode a channel that has capacity for infrequent or high magnitude events.

d) A main channel may bifurcate into multiple main channels that may or may not recombine downstream.

e) During infrequent events, the flow may overtop the banks of the main channel(s) and disperse as shallow sheet flow or shallow flow in small local drainage swales.

f) Local runoff flowing in shallow swales is collected by the main channel(s) of Washes 5 & 6 that extend further up into the watershed; that is, the washes exhibit tributary flow characteristics unlike alluvial fans.

g) Washes 5 & 6 exhibit complex, but not random or unpredictable flow paths.

As Washes 5 & 6 enter the northeast edge of the Paradise Valley Basin, Washes 5 & 6 begin to divide and exhibit both riverine and shallow sheet flow patterns. This occurs primarily due to the soil structure of the alluvium, land form slopes, and the hydraulic characteristics of the surface runoff events.

The surface soils of the alluvium in the Paradise Valley Basin, within the study area, are moderately to highly erosion resistant due to calcium carbonate cementing of the soil particles (CBA, 1988). However, the erosion resistant characteristics of the soil are not homogeneous.

It is this non-homogeneous nature of the soil characteristics that is partially responsible for the complex, but not random, flow patterns associated with Washes 5 & 6.

The existing flow patterns of Washes 5 & 6 indicate that the watercourses lack the slope and hydraulic characteristics required to erode a channel that has capacity for infrequent events, such as the 100-year event. Hence, storm runoff during infrequent events may overtop the bank(s) of the main channel(s) and disperse as shallow sheet flow or shallow low velocity flow in small local drainage swales. The flow that disperses from the main channels may or may not return to the main channel from which it left; however, the main channels do collect the flow from the local drainage swales (see Plate 1). Therefore, the soil structures, landform slopes, and the hydraulic characteristics of the surface runoff events along Washes 5 & 6 results in riverine type flooding with flow depths greater than one foot being confined to the main channels and sheet flow with average depths less than one foot occurring along the overbanks. Hence, it is the main channels of Washes 5 & 6 that warrant the Zone A flood hazard designation, in accordance with the NFIP regulations and FEMA guidelines (FEMA, 1991). Whereas, the areas subject to sheet flow (with average depths less than one foot) warrant the Zone X flood hazard zone, in accordance with NFIP regulations and FEMA guidelines (FEMA, 1991).

It is important to note that the local drainage swales typically have very little unconsolidated bed material due to the erosion resistant nature and small size of the local drainage basins. Whereas the main channels, which carry flows from the upper watersheds, typically have a veneer of unconsolidated bed sediments that differs from the bank material in color and gradation (CBA et. al., 1988). This veneer of coarse grained material is continuously passing through the wash systems and is the "erodible" material observed by MBJ.

4.2 Delineation of the Wash Corridors

The technical data presented in this report clearly indicates that the alluvial fan designation and application of the alluvial fan methodology to Washes 5 & 6 is inappropriate and results in floodplain delineations that inadequately reflect the flood hazards associated with Washes 5 & 6. This report identifies the geomorphological and hydraulic characteristics of Washes 5 & 6. Based on these characteristics of Washes 5 & 6, flood hazard zones have been delineated along Washes 5 & 6 in a manner consistent with the National Flood Insurance Program (NFIP) regulations (FEMA, 1990).

As a joint effort involving the Flood Control District of Maricopa County (FCDMC), the City of Phoenix (COP), the City of Scottsdale (COS), the Arizona Geologic Survey (AGS), Water Resources Associates (WRA), and CVL, floodplain delineation maps have been prepared for Washes 5 & 6 that best reflect the flood hazards along the washes in a manner consistent with the NFIP regulations. The floodplain delineation maps for Washes 5 & 6 depict wash corridors that extend from the Precambrian granite/Tertiary igneous formations, that divide the Carefree and Paradise Valley Basins, to either the CAP dikes or the Cave Creek flood plains. The wash corridors delineate the areas subject to Zone A non-alluvial fan flood hazards as defined by the NFIP. Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined by approximate methods (FEMA, 1991). As presented and documented in detail in this report, the geomorphological and hydraulic characteristics of Washes 5 & 6 are such that only the delineated corridors warrant the Zone A (non-alluvial fan) designation, based on the NFIP regulations.

Normal depth calculations and the following criteria have been used to delineate Zone A: non-alluvial fan floodplains for FEMA designated Washes 5, 6A, 6B, & 6C, as depicted in the FIRM Workmaps (February, 1992).

1) The corridor/floodplain boundaries delineate the areas along the main channels that are potentially subject to flow depths greater than one foot, during the 100-year event. Areas within the corridor/floodplain boundaries are designated as "Zone A: Non-Alluvial Fan." Since the corridor/floodplain boundaries have been delineated based on normal depth calculations (an approximate method per FEMA 37 guidelines), the Zone A - Non-Alluvial Fan designation is appropriate and consistent with the FEMA 37 guidelines and the NFIP regulations (FEMA, 1991) (FEMA, 1990).

2) Zone X was designated to those areas where:

   a) the average depth is less than 1 foot during the 100-year flood;

   b) drainage area is less than 1 square mile; or

   c) there is protection by levees from the 100-year flood.

Figure 2 illustrates a typical wash cross section, the 100-year floodplain or wash corridor, and the corresponding flood insurance rate zones. As indicated in Figure 2, areas adjacent to the designated 100-year floodplains may be subject to shallow flooding with depths less than 1 foot. The uniform flow computations for the cross section, shown in Figure 2, are given in Appendix B and indicate an important aspect of the hydraulic characteristics of the main channels of Washes 5 & 6. As flow overtops the banks of the main channel and disperses into the shallow overbank areas, the capacity of the wash typically increases dramatically.

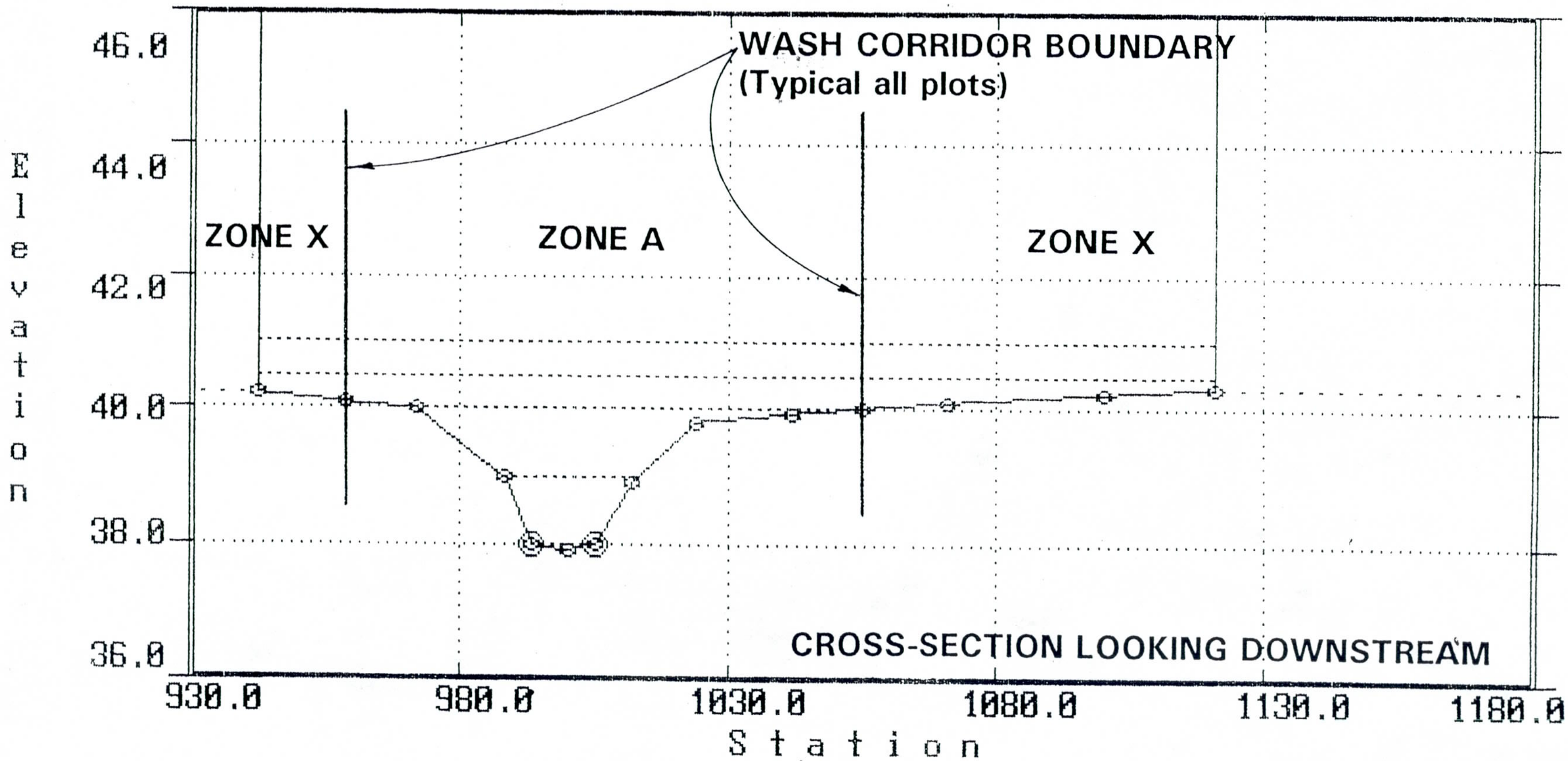
To evaluate the hydraulic characteristics of the main channels of Washes 5 & 6, cross sections were taken, from detailed topographic mapping with 2 ft. contour intervals, for each of the main channels along the 1940 feet elevation contour line. The estimated capacities of each of the main channels were calculated using the Manning Equation for water surface elevations corresponding to:

SECTION M

««««««««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 38.0 Q= 0.7cfs V= 1.2fps WSEL= 40.5 Q= 678.0cfs V= 4.9fps
WSEL= 39.0 Q= 110.8cfs V= 5.8fps WSEL= 41.0 Q= 1524.1cfs V= 6.7fps
WSEL= 40.0 Q= 320.0cfs V= 5.2fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0211



TYPICAL CROSS-SECTION

FIGURE 2

a) the lowest overbank elevation at either the left or right wash corridor boundary, that defines the Zone A floodplain;

b) 0.5 feet above the lowest overbank elevation at a Zone A floodplain boundary; and

c) 1.0 feet above the lowest overbank elevation at a Zone A floodplain boundary.

Tables 4 through 7 compare the channel capacities to estimated 100-year discharges for each channel. The 100-year discharges are conservatively estimated as the sum of the local runoff and the runoff from the upper watersheds located in the Carefree Basin. Tables 4 through 7 and the support documentation given in Appendix B indicate that:

a) the Wash Corridors indicated on the recommended floodplain delineation maps have capacity for the 100-year event and appropriately delineate the areas subject to "Zone A - Non alluvial fan" flood hazards;

b) each wash corridor has from approximately 18% to 300% of additional capacity above the estimated 100-year event, with average and overbank flow depths below one foot.

c) the local runoff is a significant component of the total 100-year event; and

d) <u>average</u> overbank flow depths are well below 1 foot and therefore warrant the "Zone X" designation.

SOILS SERIES AND HYDROLOGIC SOIL GROUPS

MAP SYMBOL	SERIES NAME	DESCRIPTION	HYDROLOGIC SOIL GROUP
1,2	ANTHO	SANDY LOAM	B
6	ANTHONY	SANDY LOAM	B
33	EBA	CLAY	C
44	EBON	CLAY	C
54	GILA	SANDY LOAM	B
63	GUNSIGHT	SANDY LOAM	B
90, 91	MOMOLI	SANDY LOAM	B
96	PIMALENO	CLAY LOAM	B
98	PINAMT	SANDY CLAY LOAM	B
122	VADO	SANDY LOAM	B
63, 31	ROCK OUTCROP		D

AGUILA — CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA NO. 35

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.

This soil survey was compiled in 1978 by the U.S. Department of Agriculture, Soil Conservation Service and cooperating agencies.

SHEET NO. 35

AGUILA — CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA

TABLE 4: CAPACITY COMPUTATIONS FOR WASH CORRIDORS
NORTHERN SPLIT OF WASHES 6a, 6b, & 6c
SECTIONS A,B,C, & D

	DESCRIPTION	SEC A	SEC B	SEC C (1)	SEC D (2)	TOTALS
COMPUTED CHANNEL CAPACITIES						
1	Capacity(cfs) @ lowest over-bank elevation at the Corridor Boundary	277	204	124	529	1134
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	672	531	546	1464	3213
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	2171	1359	1190	1464	6184
APPROXIMATE 100 YEAR DISCHARGES(cfs)						
4a	Approx Percent of Upper Water-shed discharge based on topography	10	20	30	40	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	165	331	496	662	1654.6
4c	Upper Drainage Area(sq mi)	0.177	0.355	0.532	0.709	1.773
5a	Percent of Local Drainage Area	65	10	8	17	100
5b	Local Drainage Area (sq mi)	3.50	0.54	0.43	0.92	5.39
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	1226	458	397	577	2658
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	1391	789	893	1239	4312
8	Additional Capacity (percent) ((ROW 3)/(ROW 7)) - 1	56.0%	72.3%	33.3%	18.2%	43.4%

(1) Existing Tatum Ranch drainage corridor improvements along south (ie, left) bank.

(2) Existing Tatum Ranch drainage corridor improvements along left & right banks.

TABLE 5: CAPACITY CALCULATIONS FOR WASH CORRIDORS
SOUTHERN SPLIT OF WASHES 6a, 6b, & 6c
SECTIONS E, F, & G

	DESCRIPTION	SEC E	SEC F	SEC G	TOTALS
COMPUTED CHANNEL CAPACITIES					
1	Capacity(cfs) @ lowest over-bank elevation at the Corridor Boundary	248	757	48	1053
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	708	1199	422	2329
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	1736	1747	1383	4866
APPROXIMATE 100 YEAR DISCHARGES(cfs)					
4a	Approx Percent of Upper Water-shed discharge based on topography	15	15	70	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	83	83	386	551.525
4c	Upper Drainage Area(sq mi)	0.047	0.047	0.219	0.3129
5a	Percent of Local Drainage Area	25	25	50	100
5b	Local Drainage Area (sq mi)	0.34	0.34	0.67	1.34
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	352	352	496	1199
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	434	434	882	1751
8	Additional Capacity (percent) ((ROW 3)/(ROW 7)) - 1	299.6%	302.1%	56.8%	177.9%

TABLE 6: CAPACITY CALCULATIONS FOR WASH CORRIDORS
WASH 6a
SECTIONS H, I, J, K, & L

	DESCRIPTION	SEC H	SEC I	SEC J	SEC K	SEC L	TOTALS
COMPUTED CHANNEL CAPACITIES							
1	Capacity(cfs) @ lowest overbank elevation at the Corridor Boundary	683	131	176	259	36	1285
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	1079	633	586	733	582	3613
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	1825	1468	1303	1294	1585	7475
APPROXIMATE 100 YEAR DISCHARGES(cfs)							
4a	Approx Percent of Upper Watershed discharge based on topography	30	15	15	20	20	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	964	482	482	643	643	3212.9
4c	Upper Drainage Area(sq mi)	0.946	0.473	0.473	0.631	0.631	3.154
5a	Percent of Local Drainage Area	16	18	18	24	24	100
5b	Local Drainage Area (sq mi)	0.30	0.34	0.34	0.45	0.45	1.88
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	331	355	355	411	411	1452
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	1295	837	837	1053	1053	4665
8	Additional Capacity (percent) ((ROW 3)/(ROW 7)) - 1	41.0%	75.3%	55.6%	22.9%	50.5%	60.2%

TABLE 7: CAPACITY CALCULATIONS FOR WASH CORRIDORS
WASH 5
SECTIONS M,N,O,P, & Q

	DESCRIPTION	SEC M	SEC N	SEC O	SEC P	SEC Q	TOTALS
COMPUTED CHANNEL CAPACITIES							
1	Capacity(cfs) @ lowest over-bank elevation at the Corridor Boundary	320	1156	209	992	319	2996
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	678	1848	565	1741	763	5595
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	1524	2989	1345	2763	1355	9976
APPROXIMATE 100 YEAR DISCHARGES(cfs)							
4a	Approx Percent of Upper Water-shed discharge based on topography	25	40	15	10	10	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	712	1140	427	285	285	2849.0
4c	Upper Drainage Area(sq mi)	0.773	1.236	0.463	0.309	0.309	3.090
5a	Percent of Local Drainage Area	10	22	20	25	20	97
5b	Local Drainage Area (sq mi)	0.40	0.87	0.79	0.99	0.79	3.85
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	381	568	540	596	540	2084
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	1093	1707	967	880	825	4933
8	Additional Capacity (percent)	39.4%	75.1%	39.1%	213.8%	64.3%	102.2%

5.0 Conclusions and Recommendations

This report presents a detailed geomorphologic description of FEMA designated washes. In addition, this report provides technical analyses and evaluations addressing:

a) the special flood hazards associated with alluvial fan flooding and the insignificant potential for these hazards to occur along Washes 5 & 6;

b) the in-applicability of FEMA's alluvial fan methodology to Washes 5 & 6;

c) MBJ's mis-application of the fan methodology to Washes 5 & 6; and

d) a technically superior method for delineating flood hazards along Washes 5 & 6, based upon geomorphologically sound principles.

The technical evaluations/analyses and supporting documentation provided in this report substantiate the following conclusions:

a) the hydrometeorologic, geologic, lithologic, topographic, land form and wash slopes, and vegetation characteristics of the upper watersheds for Washes 5 & 6 indicate that the existing watershed conditions are inadequate for the formation of debris flows, which is considered the primary hydraulic process responsible for formation and modification of alluvial fan surfaces;

b) uniform flow computations indicate that the preliminary FIRM maps, based on the alluvial fan methodology, provide an inadequate description of the velocity and inundation flood hazards along washes 5 & 6;

c) geologic and geomorphologic evaluations indicate that application of the FEMA alluvial fan methodology to Washes 5 & 6 is in contradiction to the basic assumptions of the methodology and is therefore inappropriate;

d) MBJ <u>has not</u> i) adequately justified the application of the FEMA alluvial fan model for delineating floodplains for Washes 5 & 6; ii) adequately documented the floodplain

delineation study, and iii) conducted the study in a manner inconsistent with the FEMA 37 guidelines (FEMA, 1991) (FEMA, 1985); and

e) the wash corridors, as delineated by the local agencies on the FIRM Workmaps (February, 1992) more appropriately define the flood hazards along Washes 5 & 6.

Based on the technical evaluations presented or referenced in this report, it is recommended that FEMA:

a) dismiss the floodplains delineated for Washes 5 & 6, as shown on the preliminary FIRMs (dated July 9, 1991), as being inadequate and inappropriate;

b) dismiss any future application of the alluvial fan methodology to Washes 5 & 6 as being inappropriate; and

e) adopt the "wash corridor" floodplains as delineated and recommended by the local agencies.

6.0 References

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APPENDIX A

LACFCD DEBRIS FLOW METHODOLOGY

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
DAMS AND CONSERVATION BRANCH

REPORT

ON

DEBRIS REDUCTION STUDIES

FOR

MOUNTAIN WATERSHEDS

by

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assisted by

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November 1959
Second Printing May 1979

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APPENDIX D

Development of a Method to Predict Erosion Rates

The determination of the volume of debris which might be produced as a result of a given future storm on a particular watershed has in the past been based on previous experience. However, it was felt that to accomplish the task of making a complete debris potential appraisal of the mountainous areas tributary to the Los Angeles Coastal Plain, watershed variables which might affect debris production should be identified and tested in an effort to develop a relationship that would make possible reliable computations of debris potential as reflected by these influences within the watershed.

To accomplish this, the first task was to list all specific storms for which sizeable debris production rates had been recorded. Next, debris basin and debris dam records were examined, and those watersheds containing structures with fairly long histories were selected for study. A special effort was exerted to isolate those watersheds which could be considered representative of the general area in which they were located. As a rule, there was difficulty in estimating the quantity of debris which could be said to have resulted from a particular storm, as the debris records for the most part showed only the year-to-year volume which had entered the basin. However, a few watersheds had experienced debris flows of such magnitude as to have warranted immediate surveys, and these provided probably the most accurate debris data available. Table D-1 lists the eight watersheds in this category that were selected for this study.

TABLE D-1
Watersheds Selected for Study of Debris Production Rates

Name	Location	Mountain Range	Area (sq. mi.)
Little Santa Anita	Near Sierra Madre	Central San Gabriel	2.46
West Ravine	Near Altadena	Central San Gabriel	0.24
Shields	Near La Crescenta	Central San Gabriel	0.23
Pickens	Near La Crescenta	Central San Gabriel	1.70
Hall-Beckley	Near La Crescenta	Central San Gabriel	0.68
Sunset	Near Burbank	Verdugo	0.43
Birmingham	Near Burbank	Verdugo	0.17
Nichols	Near Hollywood	Santa Monica	0.92

After the selection of the study watersheds, a detailed investigation of the storms associated with each important debris movement was undertaken. The rainfall amounts, which are recorded as 24-hour totals for each of these storms, were provided by a network of rain gages strategically located through the foothill and mountain areas. Inspection of the data on rainfall and the occurrence of storms lasting two or more days revealed that, as a rule, there was one particular 24-hour period during which a major portion of the storm's total was recorded. Therefore, any debris flow associated with this storm was presumed to have occurred during the same period as the greatest 24-hour storm total. The mean 24-hour depth over each of the selected watersheds for each storm of interest was then computed from isohyetal maps prepared from the data recorded by these gages. It is readily acknowledged that normally the intensity of a storm, as well as its total amount, would be considered a determining factor in the development of flood flows with which debris movements are normally associated. However, due to the relatively limited information on rainfall intensities available and also the realization that the inclusion of an intensity factor in any relationship to be devised would provide an infinite number of situations which could

be anticipated, it was believed desirable to use the maximum 24-hour total as a measure of storm influence on debris production. Hydrologic techniques were then employed to obtain an expression relating 24-hour rainfall amount to mean daily flow on a unit area basis for each of the study watersheds. Little Santa Anita Canyon, for which mean daily flow records have been compiled by the U. S. Geological Survey throughout the period under study, was used as a control watershed for this computation.

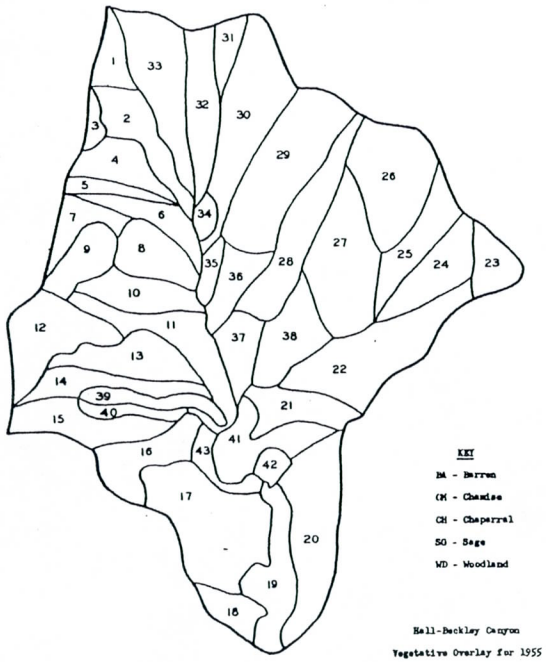
The geological characteristics of the area were given next consideration for it is evident that they also must exert considerable influence on debris production rates. This is especially true in the mountain areas of the Coastal Plain which are made up of highly fractured underlying rock that rapidly weathers to form loose, easily eroded surface material. However, due to the intense faulting, heaving, and buckling which these mountains have undergone in geological history, the surface soils are quite varied in character in any particular watershed. The frontal range or scarp of the San Gabriel Mountains is formed principally of the pre-Cretaceous metamorphics intruded by granitic rocks; the Verdugo Mountains are highly weathered metamorphic and granitic rocks; and the Santa Monica Mountains are an arched sedimentary series of conglomerates, sandstones, and shales cut by volcanic flows, and overlying a core of metamorphic rock.

Soil samples were taken in each of the study watersheds on the basis of a random sampling network. Attempts to correlate this soil data made evident the fact that the task was hopeless because of the heterogeneous nature of the soil mantle. It was discovered that within any particular watershed practically the full range found in any of the eight study watersheds could be obtained. Thus, the conclusion was reached that in each of the study watersheds, and this would be true in general for all watersheds of major concern in this area, an abundance of readily erodible material was available.

Vegetation, long recognized as a major deterrent to erosion, was inspected carefully from vantage points in each study watershed and a vegetation overlay prepared. With the aid of large-scale aerial photos, each species category was delineated in the field such that the finished overlay showed the vegetation type and density of cover for each sub-area. These overlays differed from watershed to watershed as the result of fires, landslides, works of man, and various non-uniform soil, moisture, and exposure conditions.

Vegetation was expressed as one of eight classifications: barren, sage, sage-chamise, chamise, chamise-chaparral, chaparral-woodland, and woodland. The various species included in each classification are shown in Table D-2. Density of cover for each category was evaluated by the ocular method on the following rating scale: 0, 20, 40, 60, 80, and 100 per cent cover. Species identification and verification photographs were taken to be used as a control to facilitate uniform cover rating from watershed to watershed. These are shown in Photos D-1 through D-14.

In the office, these variations were given mathematical significance in order that their effect might be evaluated in the over-all determination of the relationship between watershed influences and debris production. After much experimentation, a suitable weighting procedure was evolved for expressing the effectiveness of the watershed vegetative cover as a single number. This number was designated the Vegetation Index. Figure D-1 shows the mapping and computation procedure described above, using the Hall-Beckley watershed vegetative conditions for 1955 as an example. As shown by the watershed overlay reproduced at the left of the figure, each sub-area whose vegetation was predominantly a certain type and percent cover was delineated. The acreage in each sub-area was determined and posted in the correct square of the form shown in the center. Percent of total area contained in each square was computed, both as to vegetative type and percent cover, as shown at the side and bottom of this form, and these percentages, when combined with the index points according to the weighting system developed, gives the "Vegetation Index."



KEY

BA - Barren

CM - Chamise

CH - Chaparral

SG - Sage

WD - Woodland

Hall-Buckley Canyon

Vegetative Overlay for 1955

Area Number	Vegetative Type and Percent of Cover	Area (acres)
1	30% CH-CM	5.1
2	40% CH-CM	10.2
3	50% CH-CM	2.0
4	70% CM	7.1
5	40% CH-CM	3.0
6	40% CH-CM	6.1
7	80% CH-CM	6.1
8	30% CH-CM	8.1
9	30% CH-CM	7.1
10	60% CH-CM	8.1
11	80% CH-CM	12.2
12	50% CM	15.2
13	70% CH-CM	10.2
14	30% CH-CM	8.1
15	100% CH-CM	10.2
16	50% CM	11.2
17	100% CM	24.4
18	50% CM	6.1
19	70% WD	12.2
20	60% CM	18.3
21	100% CH-WD	7.1
22	100% CH-WD	22.3
23	100% CM	6.1
24	50% CM	11.1
25	50% CM	9.1
26	75% CM	18.3
27	90% CM	20.3
28	70% CM-WD	15.2
29	70% CM	23.3
30	100% CM	21.3
31	100% CM	4.0
32	60% CM	10.2
33	60% CH-CM	17.3
34	80% WD	2.0
35	20% CH-CM	2.0
36	30% CM-WD	7.1
37	40% CH-CM	6.1
38	75% CH-CM	10.2
39	70% WD	4.0
40	80% CH-CM	3.0
41	60% CH-CM	9.1
42	60% WD	2.0
43	70% CH-CM	4.0
	BA	5.4
		431.5

COMPUTATION OF VEGETATION INDEX

Percent of Cover	Barren	Sage	Sage-Chamise	Chamise	Chamise-Chaparral	Chaparral	Chaparral-Woodland	Woodland	Total	Adjusted Total	Percent of Total
Barren	5.4								5.4	5.5	1.3
0-20%					#35- 2.0				2.0	2.0	0.5
21-40%					# 1- 5.1 # 2- 10.2 # 5- 3.0 # 6- 6.1 # 8- 8.1 # 9- 7.1 #14- 8.1 #37- 6.1 53.8		#36- 7.1		60.9	61.5	14.1
41-60%				#12- 15.2 #16- 11.2 #18- 6.1 #32- 10.2 42.7	# 3- 2.0 #10- 8.1 #33- 17.3 #41- 9.1 36.5	#20- 18.3 #24- 11.1 #25- 9.1 38.5		#42- 2.0	119.7	121.0	27.7
61-80%				# 4- 7.1	# 7- 6.1 #11- 12.2 #13- 10.2 #36- 10.2 #40- 3.0 #43- 4.0 45.7	#26- 18.3 #29- 23.3 41.6	#28- 15.2	#19- 12.2 #34- 2.0 #39- 4.0 18.2	127.8	129.1	29.6
81-100%				#17- 24.4	#15- 10.2	#23- 6.1 #27- 20.3 #30- 21.3 #31- 4.0 51.7	#21- 7.1 #22- 22.3 29.4		115.7	116.9	26.8
Total	5.4			74.2	148.2	131.8	51.7	20.2	431.5		
Adjusted Total	5.5			75.0	149.7	133.2	52.2	20.4		436.0	
Percent of Total	1.3			17.2	34.3	30.5	12.0	4.7			100.0

NOTE: Areas designated as barren consist of fire roads and erosion scars.

Item Rated	Index Points	1955 Percent of Total	1955 Points
Barren	0	1.3	0
Sage	1	0	0
Sage-Chamise	2	0	0
Chamise	3	17.2	51.6
Chamise-Chaparral	5	34.3	171.5
Chaparral	8	30.5	244.0
Chaparral-Woodland	6	12.0	72.0
Woodland	5	4.7	23.5
Sub-total			562.6
Barren	0	1.3	0
20% Cover	3	0.5	1.5
40% Cover	9	14.1	126.9
60% Cover	15	27.7	415.5
80% Cover	18	29.6	532.8
100% Cover	20	26.8	536.0
Sub-total			1,612.7
Total			2,175.3
Index = $\frac{(\text{Total})}{100}$			21.75

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
DEBRIS REDUCTION STUDIES REPORT
JULY 1959
*****

TYPICAL EXAMPLE OF DETERMINATION OF VEGETATION INDEX

FIG. D-1

FIGURE REDUCED FOR SECOND PRINTING

TABLE D-2
Vegetative Groups and Included Species

Group No.	Group Name	Vegetation Species Included
1	Sage	White Sage (Salvia apiana), Black Sage (Salvia mellifera), California Buckwheat (Eriogonum fasciculatum), Wild Pea, Black Mustard (Brassica Nigra), California Sagebrush (Artemisia californica)
2	Sage-Chamise	Contains species from Groups 1 and 3
3	Chamise	Chamise (Adenostoma fasciculatum), Bush Monkeyflower (Diplacus longiflorus), Yucca (Yucca whipplei), Spanish Broom, Mule Fat (Baccharis viminea)
4	Chamise-Chaparral	Contains species from Groups 3 and 5
5	Chaparral	Scrub Oak (Quercus dumosa), California Live Oak (Quercus agrifolia), Laurel Sumac (Rhus laurina), Chaparral Whitehorn (Ceanothus leucodermis), Christmas Berry (Photinia arbutifolia), Hairy Ceanothus (Ceanothus oliganthus), Manzanita, and Mountain Mahogany
6	Chaparral-Woodland	Contains species from Groups 5 and 7
7	Woodland	Sycamore, Canyon Live Oak (Quercus chrysolepis), Pines and Spruces of all varieties, and Alder

NOTE: Vegetative species of a next higher group may have been included in a lower classification if the species were small in size. For example, an area designated as 100 percent chamise may contain some small chaparral plants.

PHOTO D-1

Area designated as 100% woodlands and consists mostly of live oak.

PHOTO D-2

Area designated as 60% woodlands, with the following species represented: live oak, alders, and pine varieties.

PHOTO D-3

Area designated as 100% chaparral with the following species represented: live oak, scrub oak, laurel sumac, manzanita, hairy ceanothus, and chaparral whitethorn.

PHOTO D-4

Area designated as 20% chaparral with the following species represented: scrub oak, hairy ceanothus, and Christmas berry.

PHOTO D-5

Area designated as 80% chamise and chaparral with the following species represented: chamise, scrub oak, ceanothus, white sage, manzanita, and mountain mahogany.

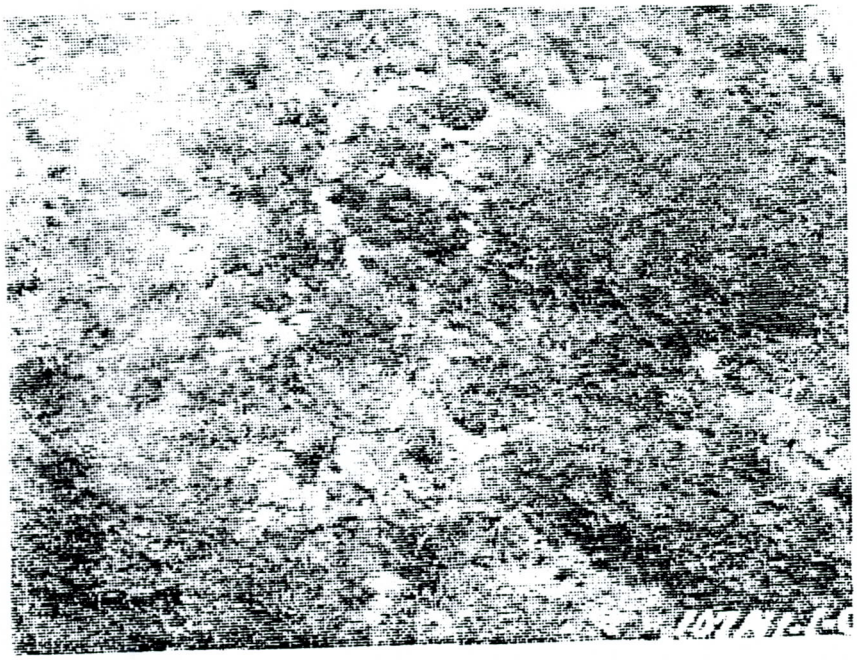


PHOTO D-6

Area designated as 60% chamise and chaparral with the following species represented: chamise, black sage, scrub oak, Christmas berry, California buckwheat, and yucca.

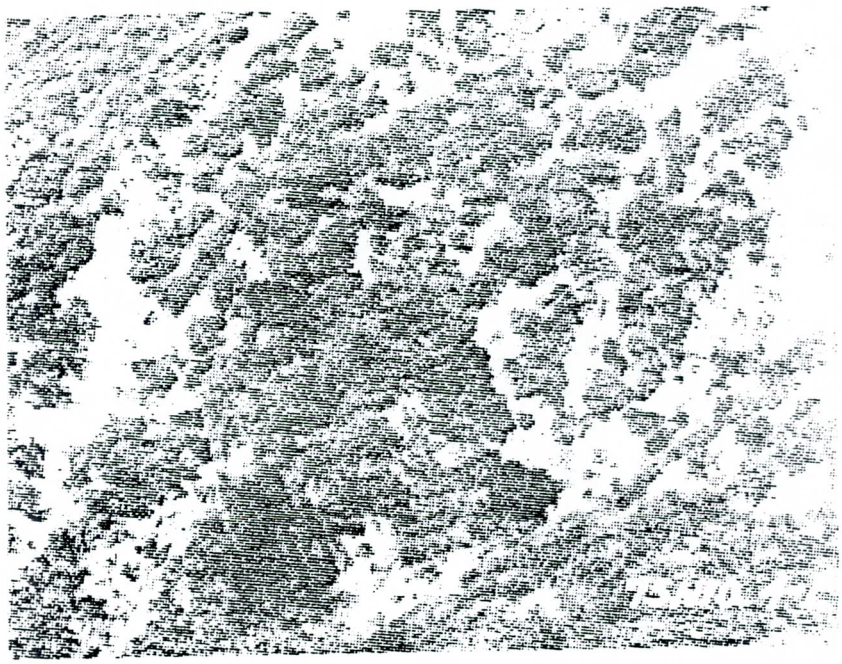


PHOTO D-7

Area designated as 30% chamise and chaparral with the following species represented: chamise, ceanothus, scrub oak, California buckwheat, and white sage.

PHOTO D-8

Area designated as 100% chamise with the following species represented: chamise, yucca, manzanita, scrub oak, and ceanothus.

PHOTO D-9

Area designated as 60% chamise with the following species represented: chamise, black sage, California buckwheat, and yucca.

PHOTO D-10

Area designated as 60% sage and chamise with the following species represented: chamise, white sage, California buckwheat, yucca, California sagebrush, and grass.

PHOTO D-11

Area designated as 35% sage and chamise with the following species represented: chamise, California buckwheat, and white sage.

PHOTO D-12

Area designated as 10% sage and chamise with the following species represented: black mustard, yucca, laurel sumac, and California buckwheat.

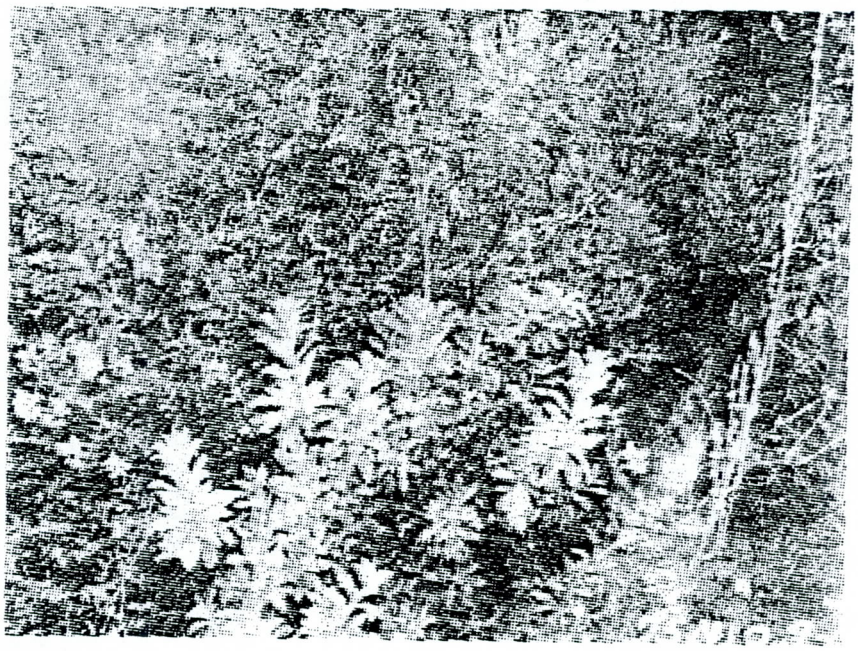


PHOTO D-13

Close-up of area designated as 80% sage with the following species represented: white sage, California buckwheat, yucca, and wild pea.

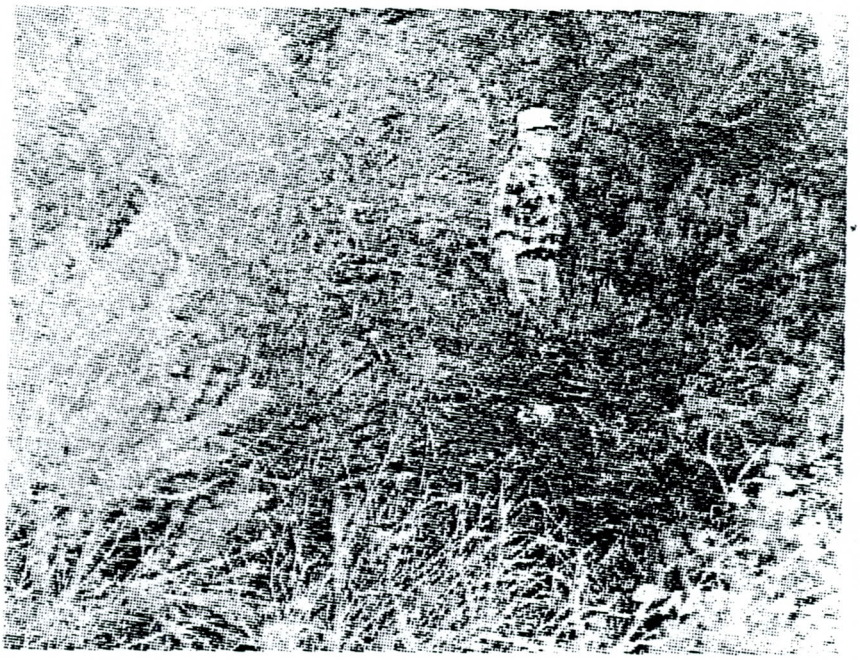


PHOTO D-14

Close-up of area designated as 100% chamise and chaparral with the following species represented: chamise, scrub oak, Christmas berry, and black sage.

Since the storms and consequent large debris flows had occurred a number of years before this study was initiated, current vegetative conditions required correction to those periods. This was accomplished by adjusting vegetation by use of vegetative recovery curves (see Appendix E) from time of last burn such that it matched 1938 vegetation as shown on aerial photos flown that year and the 1955 observed vegetation. Intermediate values for other years could then be estimated, based on these recovery curves.

From the physiographic features of each watershed as shown on U. S. Geological Survey topographic maps, it was possible to determine the various ratios and constants which would serve to set one watershed apart from another with respect to physical geography. The factors which were deemed important in any attempt to establish a relationship between debris and watershed physiography are listed with a brief discussion of each.

Drainage Area—the plane area contained within the watershed boundaries above the point of study. The drainage boundaries are outlined on a U. S. G. S. quadrangle sheet, and the included area is planimetered and recorded in square miles.

Average Basin Slope—a measure of the average slope that exists within a watershed. With the aid of enlarged quadrangle sheets, the average distance between each successive 100-foot contour is determined. When divided into the 100-foot vertical distance, the average tangent or slope between successive contours is obtained. The area included between each successive pair of 100-foot contours is then planimetered. The summation of the products of the successive slopes and the area each represents, when divided by the total plane area, gives the average basin slope.

Surface Area—the total exposed area which is susceptible to erosion. It is the product of the plane area between successive 100-foot contours and the secant of the slope between the same two contours. Both the plane area and the slope are those already recorded above for computing the average basin slope. The summation of the individual segments is the total surface area.

Ratio of Surface Area to Drainage Area—a dimensionless ratio expressing the relationship between the surface area and the plane area.

Area-Altitude Relationship—a measure of the distribution of ground plane area, or horizontal cross-sectional area, of a land mass with respect to elevation, expressed in the form of an area versus altitude curve. Data necessary in the plotting of an area-altitude curve is obtained by planimetering the area included between the upper drainage limits and each 100-foot contour, starting with the lowest. The ratios of each of these successive areas to the total area provides the abscissa points. The ratio of the vertical distances to each of these contours above the lowest point to the total relief, provides successive ordinates. The area in square inches under a curve drawn through these points is the significant indicator desired in the computation.

Elongation Ratio—a measure of the shape of a watershed. The diameter of a circle having an area equal to the area of a particular watershed, when divided by the maximum watershed length measured parallel to the main drainage channel, produces this ratio.

Average Channel Slope—a measure of the average channel gradient. This is simply the total rise from point of study to the highest point in the watershed, divided by the horizontal distance between these two points as measured along the main drainage channel.

Mean Exposure—a measure of the mean direction in which the watershed slopes are facing. With all slope faces of a particular watershed outlined on an enlarged U. S. G. S. quadrangle, a template marked with eight compass points is placed and oriented. The azimuth of the line which most nearly crosses the contours at right angles is noted and the area of that slope face is recorded. The summation of the areas represented by each azimuth, when divided

by the total area, is converted to a percent exposure representing a particular azimuth point. These percentages are then weighted to give a mean exposure.

Relief Ratio—a measure of the relative steepness of a watershed. It is the ratio of the total vertical dimension (from point of study to the highest point in the watershed) to the horizontal distance parallel to the main channel (from point of study to the drainage divide).

Stream Order—a measure of stream development. Stream orders are numbered in succession beginning with the smallest watercourse and progressing to the largest. First-order streams begin generally at the headwaters and are the smallest. Two first-order streams join to form a second order, two second-order streams join to form a third order, etc. The final order is determined by the degree of drainage development.

Drainage Density—a measure of the degree of drainage development expressed as a ratio. After sketching the complete drainage pattern on an aerial photo, an overlay is made from which the number of streams of each order and their lengths are determined. The drainage density is computed by summing the total lengths of streams in miles and dividing by the drainage area in square miles.

Mean Stream Length—a measure of the distance stream flow travels with increased erosion potential. This figure is obtained by summing the products of the stream lengths and the number of streams of each order and dividing by the total number of streams.

Mean Bifurcation Ratio—the ratio of the number of streams of one order to the number of streams of the next higher order. Thus, there is one less bifurcation ratio in each drainage area than there are stream order numbers. A weighted mean bifurcation ratio, as developed by Strahler (1953) and used in this study, was obtained by multiplying the bifurcation ratio of each successive pair of orders by the total number of streams involved in the ratio and taking the mean of the sum of these values.

Standard Deviation from Uniform Slope—a statistic indicating the deviation of the channel slope from the slope of the line representing uniform slope. A straight line is drawn from the canyon mouth to the highest point in the stream channel at the headwaters to represent a line of uniform slope. The deviation of selected profile points from this line is measured and the standard deviation, as used in statistics, is computed.

As previously stated, the computation of the physiographic features of the watersheds was easily completed with measurements taken from the topographic maps. Table D-3 is a compilation of all significant data computed for the eight watersheds considered in this study.

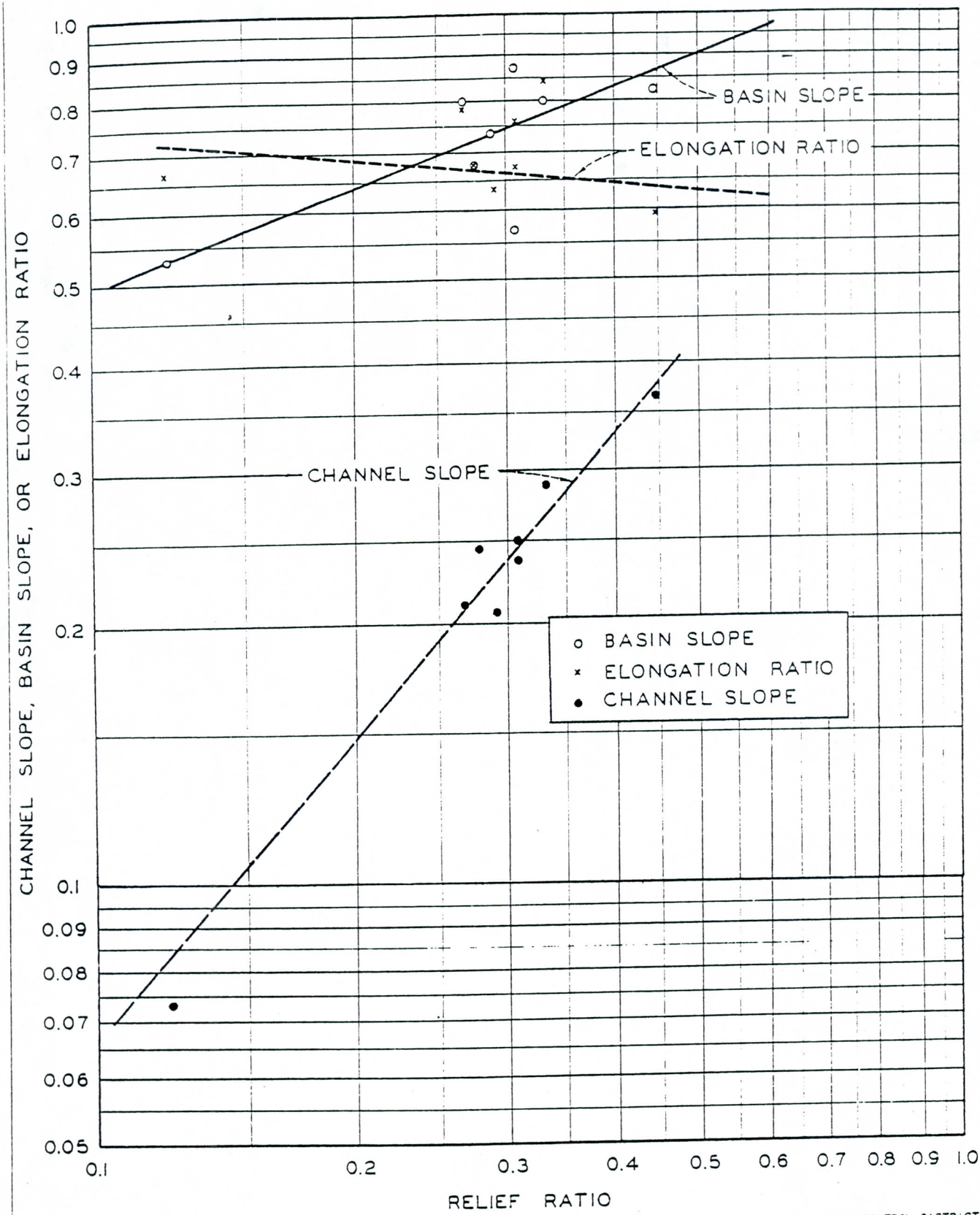
An exhaustive study, made to eliminate any of the factors which could not be shown to materially affect debris production, resulted in an expression relating directly only functions of Area, 24-hour Storm Total, Relief Ratio, and Vegetation Index to debris production. It was found that interrelationships existed between several of the factors originally considered in the study and although some of these factors do not appear in the equation, their effect is manifested through the use of some related factor. For example, channel slope, basin slope, and elongation ratio, when plotted against relief ratio, indicated enough regularity to make plausible their expression as functions of relief ratio. These relationships are shown in Figure D-2. (It will be noted that these curves are controlled by points near their extremities. The watershed with the lowest relief ratio, or the flattest of the study watersheds, is Nichols Canyon; the watershed with the highest relief ratio, or the steepest of the group, is Shields Canyon.)

Investigation was made of antecedent rainfall to determine, if possible, from the data available, the effect of antecedent rainfall on runoff. A study of the relationship between soil moisture, evapo-transpiration, and field capacity, etc., in connection with 21-day antecedent rainfall, supplemented by data provided by experiments at the San Dimas Experimental Forest, made it

TABLE D-3

TABULATION OF DATA
ON
EIGHT WATERSHEDS SELECTED FOR STUDY OF DEBRIS PRODUCTION INFLUENCES

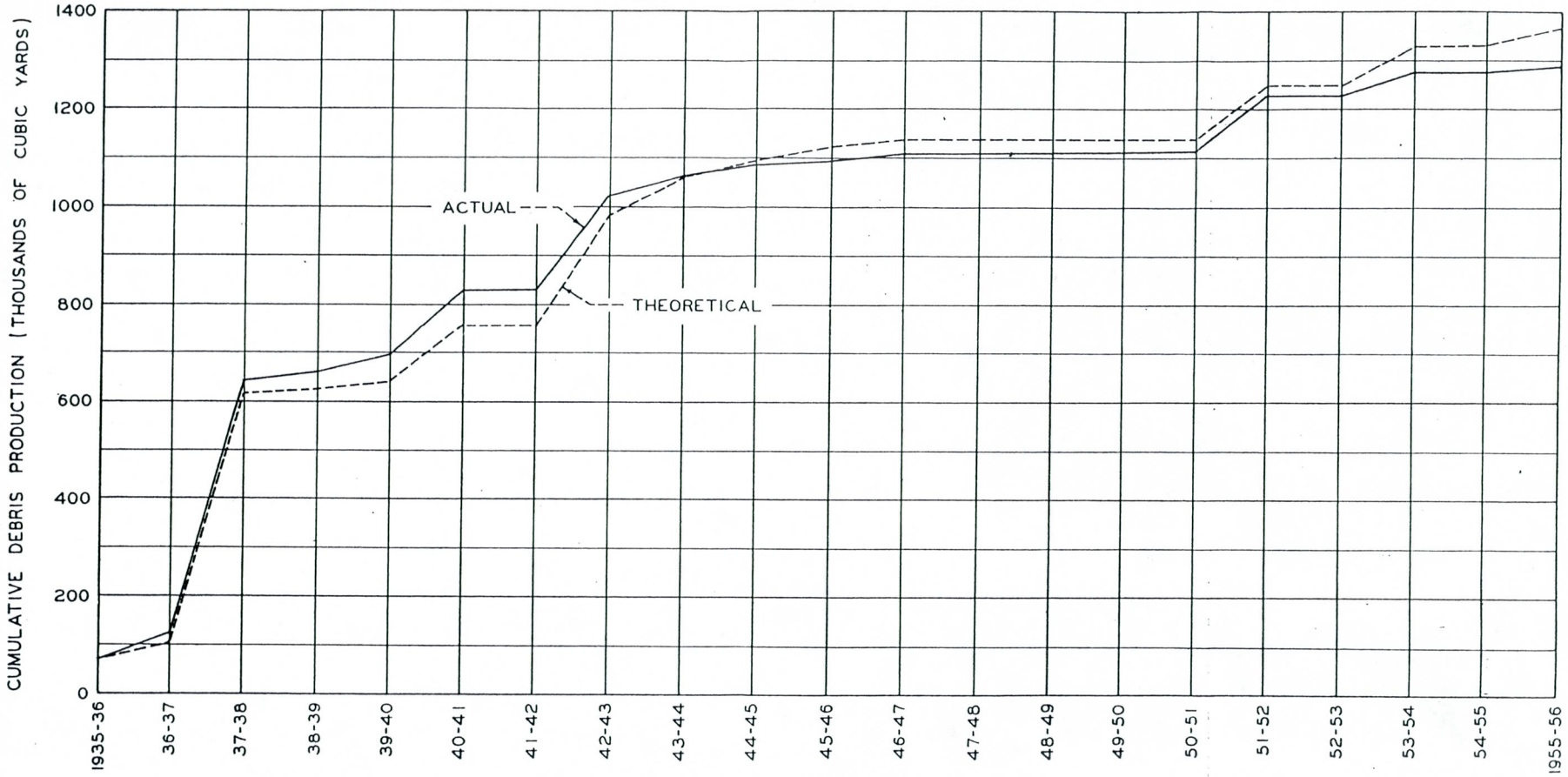
WATERSHED NAME	DRAINAGE AREA (ACRES)	VEGETATION INDEX	MEAN BASIN EXPOSURE	ELONGATION RATIO	RELIEF RATIO	AREA UNDER AREA-ALTITUDE CURVE (SQ. IN.)	AVERAGE BASIN SLOPE	AVERAGE CHANNEL SLOPE	RATIO OF SURFACE AREA TO PLANE AREA	DRAINAGE DENSITY	STANDARD DEVIATION FROM UNIFORM SLOPE	MEAN BIFURCATION RATIO	STREAM LENGTHS (FEET)	CALCULATED PEAK DISCHARGE (C.S.M.)	EROSION RATE CU. YDS./SQ.MI
HALL-BECKLEY	434.0	1938: 12.79 1943: 19.41 1952: 22.16 1955: 21.75	S 21.6° W	0.751	0.307	49.07	86.7%	25.0%	1.33	31.49	16.6	5.26	346 1- 287 2- 416 3- 751 4- 3000 5- 3050	1938: 328 1943: 354 1952: 149	1938: 117,000 1943: 57,440 1952: 19,380
SHIELDS	147.8	1938: 12.04 1943: 14.89 1952: 16.22 1955: 16.43	S 7.2° W	0.593	0.445	44.78	82.0%	36.5%	1.30	29.59	16.6	6.58	318 1- 262 2- 399 3- 761 4- 3315	1938: 358 1943: 358 1952: 160	1938: 135,420 1943: 21,460 1952: 33,750
PICKENS	1086.0	1938: 11.30 1943: 17.76 1952: 14.31 1955: 19.79	S 26.6° W	0.783	0.268	50.80	79.8%	21.0%	1.31	21.82	14.8	6.35	423 1- 345 2- 453 3- 1535 4- 4439 5- 2301	1938: 296 1943: 372 1952: 128	1938: 82,980 1943: 24,140 1952: 5,500
SUNSET	278.0	1938: 17.00 1943: 18.00 1952: 19.00 1955: 19.22	S 42.3° W	0.841	0.333	51.47	80.4%	28.9%	1.28	39.35	17.2	5.65	350 1- 296 2- 486 3- 983 4- 1382 5- 420	1938: 247 1943: 321 1952: 155	1938: 15,350 1943: 2,750 1952: 8,000
BIRMINGHAM	106.2	1954: 1.62 1955: 1.62 1955: 3.10	S 30.6° W	0.673	0.278	45.81	67.7%	24.4%	1.21	51.56	20.3	6.94	203 1- 166 2- 295 3- 487 4- 650 5- 2196	1954: 12 1955: 12 1955: 23	1954: 31,620 1955: 32,860 1955: 15,670
NICHOLS	589.2	1938: 21.01 1943: 21.32 1952: 20.78 1955: 21.72	S 7.65° E	0.664	0.122	52.58	52.8%	7.3%	1.13	27.65	2.7	5.43	363 1- 289 2- 526 3- 872 4- 1758 5- 4543	1938: 173 1943: 166 1952: 52	1938: 19,570 1943: 4,780 1952: 12,610
WEST RAVINE	154.2	1938: 16.66 1943: 20.13 1952: 21.27 1955: 19.98	S 22.5° W	0.672	0.309	36.08	56.5%	23.6%	1.13	42.42	22.0	6.52	260 1- 205 2- 362 3- 552 4- 1590 5- 2603	1938: 305 1943: 361 1952: 117	1938: 122,500 1943: 27,500 1952: 12,920
LITTLE SANTA ANITA	1579.2	1938: 19.12 1943: 20.08 1954: 13.32 1955: 13.32	S 11.0° E	0.634	0.291	48.07	73.6%	20.6%	1.24	43.41	14.1	6.32	425 1- 337 2- 698 3- 1266 4- 3982 5-10800	1938: 311 1943: 296 1954: 92 1954: 71 1954: 30	1938: 25,840 1943: 9,180 1954: 23,170 1954: 6,690 1954: 2,510



LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
DEBRIS REDUCTION STUDIES REPORT
JULY 1959

INTERRELATIONSHIP OF WATERSHED PHYSIOGRAPHIC FEATURES

FIG. D-7



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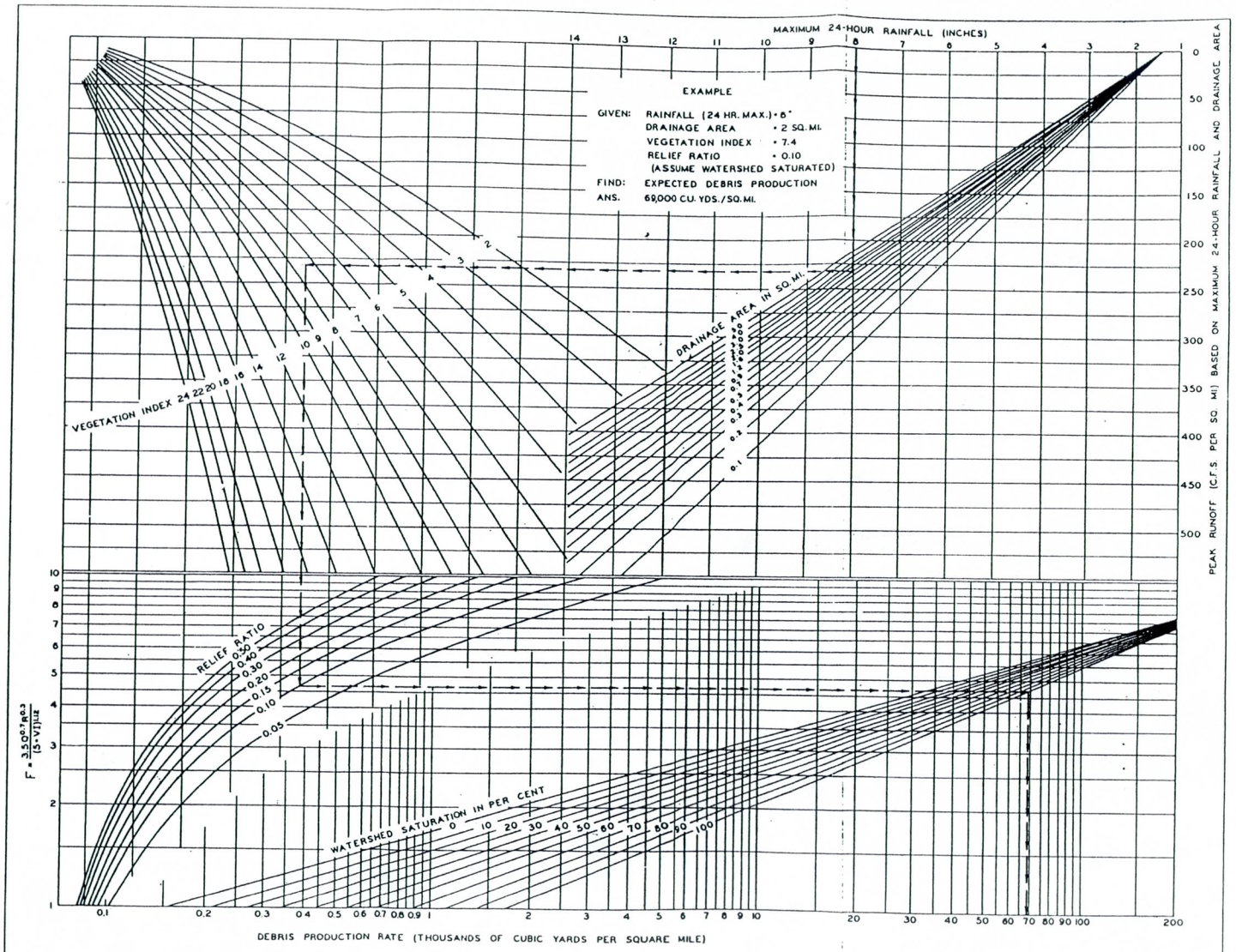
ACTUAL AND THEORETICAL DEBRIS PRODUCTION COMPARED

FIG. D-4



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DEBRIS REDUCTION STUDIES REPORT
JULY 1958

GRAPHIC SOLUTION OF DEBRIS PRODUCTION EQUATION

FIG. 6-3

possible to show a variation in debris production resulting from a given storm, depending upon the degree of watershed wetness expressed as a percentage.

With the group of variables known to be related either directly or inversely to debris production, and with the compilation of debris production totals, there remained only to find the constants and exponents which would produce the best relationship. A comprehensive and systematic trial procedure was followed which allowed thorough testing of various exponents, both with individual factors and with groups of factors. This resulted in a final grouping of points which gave the least deviation from a curve to these points. The equation of this curve is:

$$\text{Debris Production Rate in cu.yds./sq.mi.} = \frac{35{,}600\ Q^{1.67} Rr^{0.72}}{(5 - V.I.)^{2.67}}$$

where Q is the peak runoff expressed in cubic feet per second per square mile resulting from the maximum 24-hour rainfall of a given storm; Rr is the Relief Ratio of the watershed; and V. I. is the Vegetation Index. The graphic solution of this equation for varying conditions of rainfall, relief ratio, and drainage area is given in Figure D-3. The previously determined effect of antecedent rainfall was used at this point to scale down these values which were for conditions of various degrees of wetness, to provide curves giving reduced rates for watershed conditions less than saturated.

These curves were originally derived from only the very best data available which actually included a relatively few events. However, before their use could be justified or recommended, a test was made to confirm their accuracy. For this purpose, twelve debris basins were selected for which District records covered a 20-year period (1935-55). Debris-producing storms within this period occurred on these watersheds under varying conditions of vegetative cover, making for a generally ideal test period. With isohyetal maps prepared for every storm at each basin and vegetation indices adjusted to individual seasons, a thorough comparison of actual debris production versus theoretical was undertaken. Debris production was computed for each storm at each basin with the aid of the debris production equation. The computed volumes were tabulated, both singly and as a cumulative volume. For the same periods and storms, the actually recorded debris production amount was entered in an adjoining column with a cumulative total also recorded. Grouping all the study watersheds and taking the storm-by-storm, year-by-year accumulation of debris theoretically produced by the group as a whole, and comparing it to the year-by-year accumulation which the records show was produced, it was found that the theoretical volume differed from the actual by only 2 percent, which was considered well within the limits required for planning purposes. The results of this comparative study are shown in Figure D-4. The theoretical curve as shown was purposely made to coincide with the actual curve through the 1936-37 season to eliminate the use of a few possibly erroneous debris production figures of the first two seasons.

APPENDIX B

UNIFORM FLOW CALCULATIONS

COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

Project FIRM Appeal

Project No.

Sheet No. 1 of 1

Calculated by DWD Date 2/92

Checked by Date

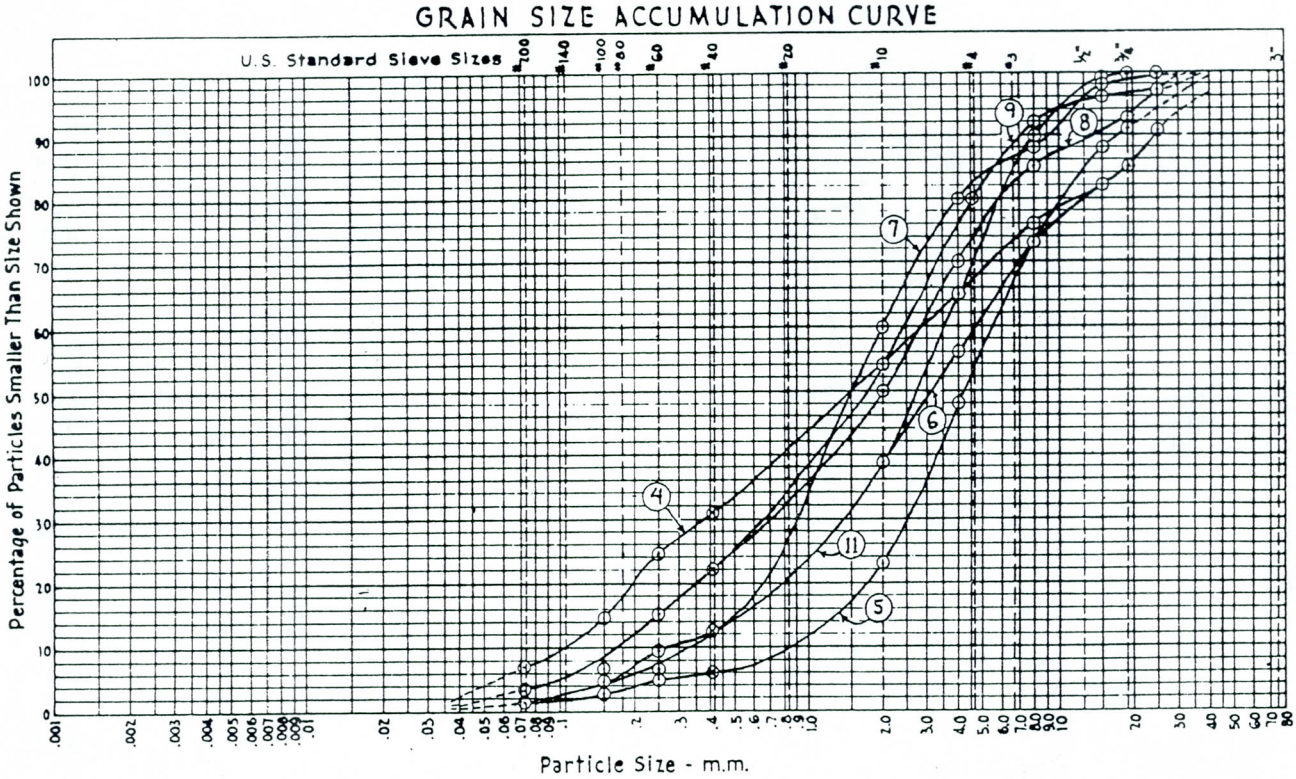

Figure 39. Grain-size accumulation curves for seven samples of Desert Mountain Glacis Alluvium (Qdga). Data from Péwé, 1985. See Plate 1 for locations of samples used in grain-size analyses. (Sample no. 10 was not analyzed.)

Gradation Curves for the "Desert Mountain Glacis Alluvium located in the Upper Watersheds of Washes 5 & 6 (Source: Doorn & Péwé, 1991)

Note: • Curves indicate ≈ 8% silt & clay

• Data available/published 1985

COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

Project FIRM APPEAL
Project No.
Sheet No. 1 of 1
Calculated by DWD Date 2/92
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Numeric Basis for Uniform Flow Computations

Eq. (1) : $Q = \frac{1.486}{n_e} S^{1/2} R^{2/3} A$ Source: (Chow, 1959)

Eq. (2) : $n_e = \left[\frac{\sum A_i (n_i^{1.5})}{A} \right]^{2/3}$ Source: (French, 1985)

Eq. (3) : $A = \sum A_i$

Eq. (4) : $D = \frac{A}{T_w}$ Source: (Chow, 1959)

Where:

Q = Discharge (cfs)

S = Slope of Hydraulic Grade Line (Estimated with bedslope) (ft/ft)

R = Hydraulic Radius (ft) $= A/WP$

A = Flow Area (ft^2)

A_i = incremental flow Area (ft^2)

WP = Wetted Perimeter (ft)

D = Hydraulic Depth (ft)

n_e = Equivalent Manning-n Value

Source: Chow, Open-Channel Hydraulics, McGraw Hill, New York, 1959.

Source: French, Open Channel Hydraulics, McGraw Hill, New York, 1985

Project FIRM
Project No.
Sheet No. of
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 1 - Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC1.SEC

No. of Cross Section Points:	19	Bed Slope:	0.01800	Max Elev:	9.4
Bank Stations.....Left:	978.0	Right....:	1018.0	Min Elev:	4.6
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	9.4	910.0	2)	8.0	931.0	3)	7.0	956.0	4)	6.0	975.0
5)	4.6	978.0	6)	4.6	1000.0	7)	4.6	1018.0	8)	6.0	1024.0
9)	6.4	1038.0	10)	6.4	1059.0	11)	6.0	1070.0	12)	5.4	1084.0
13)	6.0	1092.0	14)	6.0	1105.0	15)	6.7	1117.0	16)	6.0	1132.0
17)	5.2	1138.0	18)	6.0	1152.0	19)	8.0	1185.0			

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
7.03	1655.0	6.5	1.041	0.035	1.2	213.9	256.0	214.6
5.00	68.5	4.1	1.173	0.026	0.4	42.6	16.5	42.7
6.00	463.4	6.0	1.155	0.029	0.8	91.0	76.9	91.6

NOTES:

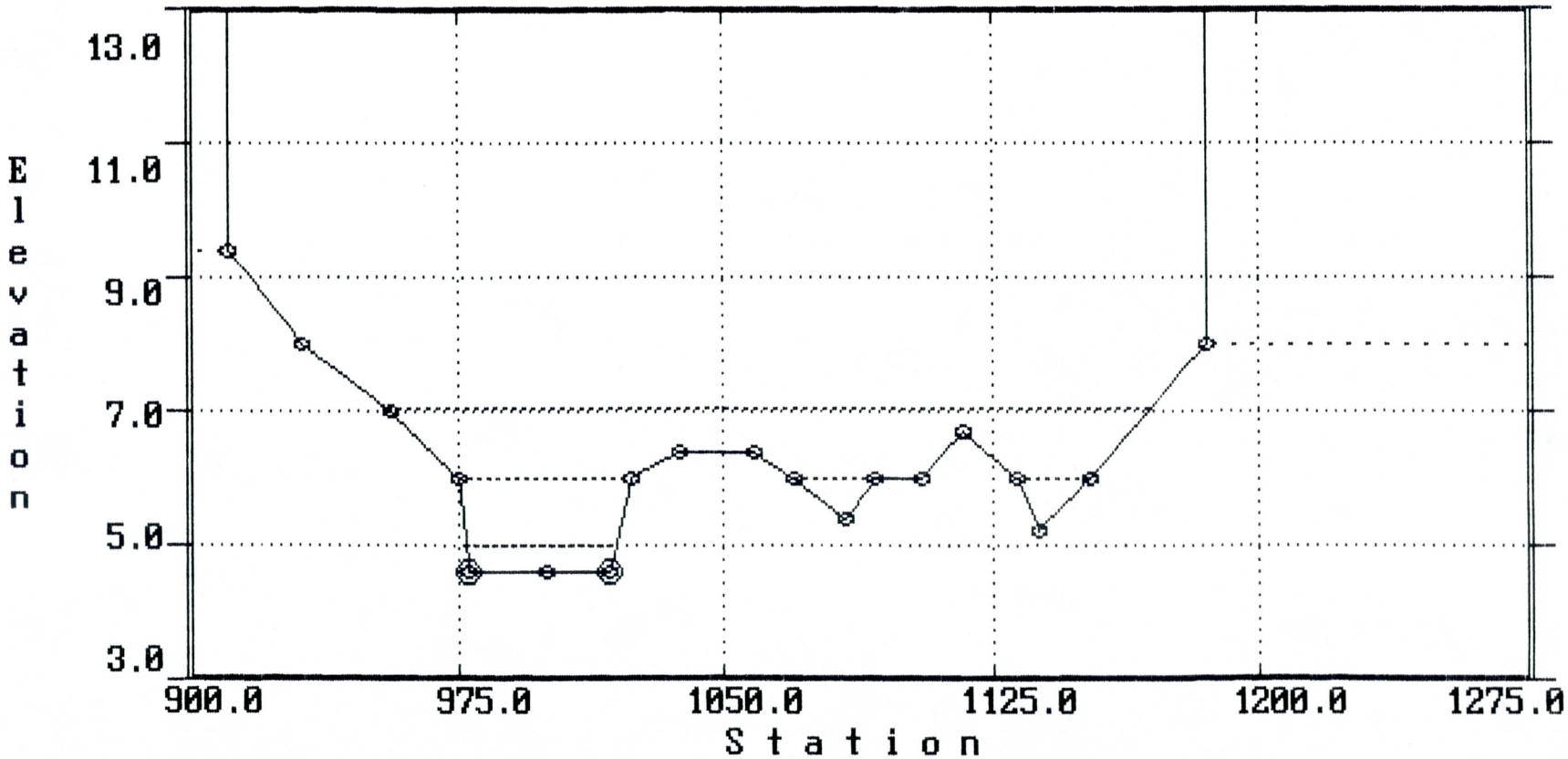
$Q_{100} \cong 1655$ cfs

$D_{max} = 2.4'$

SEC 1

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 7.0 Q= 1655.0cfs V= 6.5fps
WSEL= 5.0 Q= 68.5cfs V= 4.1fps
WSEL= 6.0 Q= 463.4cfs V= 6.0fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0180



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Project FIRM
Project No.
Sheet No. of
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 2 - Plates 5&6

CROSS SECTION PARAMETERS: FILENAME: SEC2.SEC

No. of Cross Section Points:	18	Bed Slope:	0.01600	Max Elev:	81.3
Bank Stations.....Left:	988.0	Right....:	1018.0	Min Elev:	76.2
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	78.7	792.0	2)	78.0	828.0	3)	78.8	846.0	4)	78.9	863.0
5)	78.2	876.0	6)	78.0	898.0	7)	76.8	918.0	8)	76.8	935.0
9)	77.1	957.0	10)	77.5	972.0	11)	76.3	988.0	12)	76.3	1000.0
13)	76.2	1018.0	14)	78.0	1032.0	15)	80.0	1053.0	16)	80.2	1060.0
17)	80.2	1061.0	18)	81.3	1090.0						

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
78.70	1655.0	6.0	0.943	0.036	1.2	224.3	277.9	224.6
77.00	111.6	3.4	0.937	0.030	0.4	80.6	32.9	80.6
78.00	846.4	5.7	0.958	0.035	1.1	134.0	148.1	134.2

NOTES:

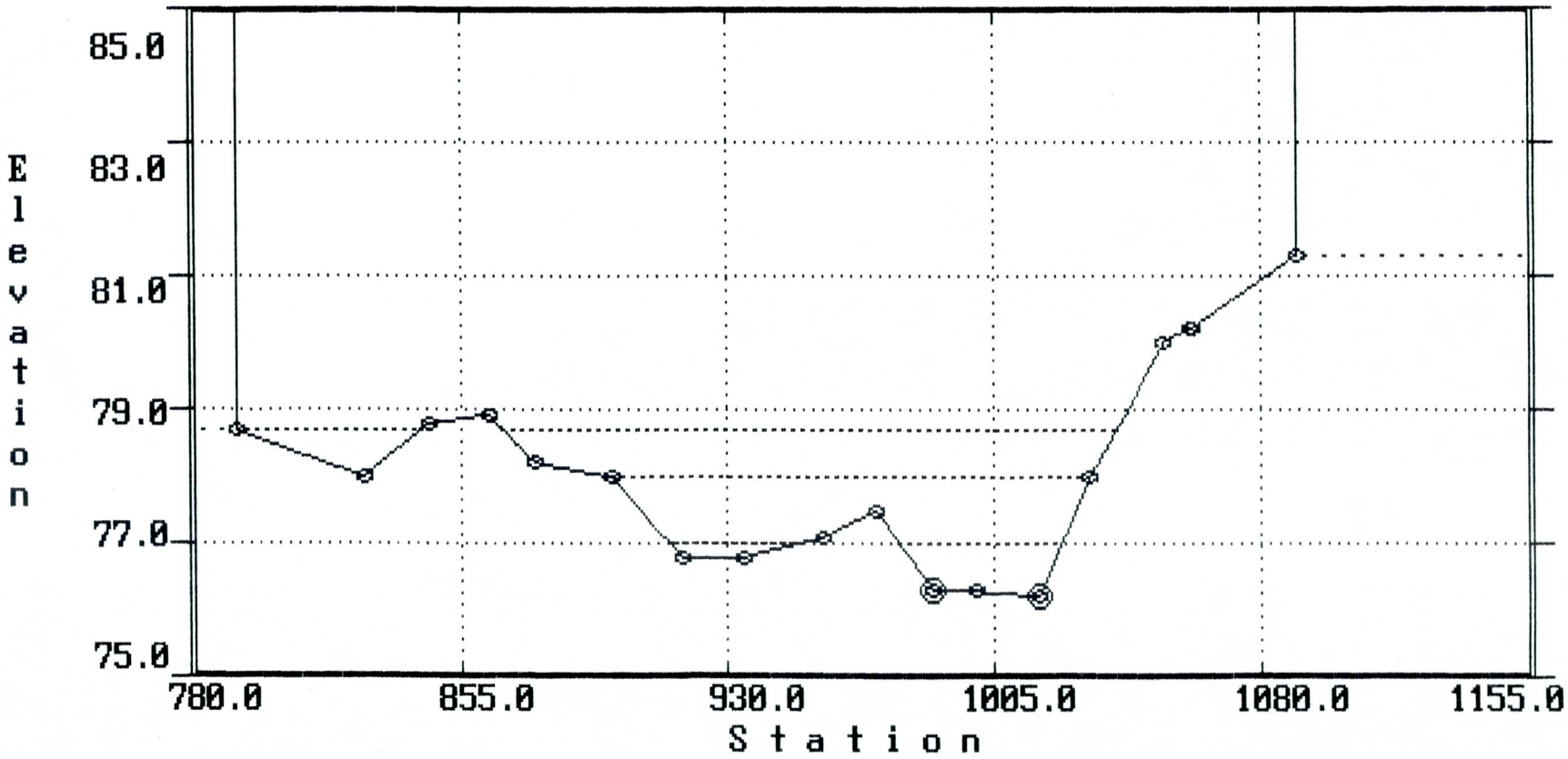
$Q_{100} \approx 1655$ cfs

$D_{max} = 78.7 - 76.2 = 2.5'$

SEC 2

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 78.7 Q= 1655.0cfs V= 6.0fps
WSEL= 77.0 Q= 111.6cfs V= 3.4fps
WSEL= 78.0 Q= 846.4cfs V= 5.7fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0160



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Project FIRM
Project No.
Sheet No. of
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UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 3 – Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC3.SEC

No. of Cross Section Points:	13	Bed Slope:	0.01700	Max Elev:	47.0
Bank Stations.....Left:	990.0	Right....:	1008.0	Min Elev:	44.3
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	46.5	910.0	2)	46.0	930.0	3)	46.0	940.0	4)	46.6	965.0
5)	46.0	980.0	6)	44.3	990.0	7)	44.3	1008.0	8)	46.0	1011.0
9)	47.0	1030.0	10)	47.0	1075.0	11)	46.1	1090.0	12)	46.1	1105.0
13)	47.0	1125.0									

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
47.16	994.9	5.0	0.923	0.036	0.9	215.0	198.0	215.7
45.00	74.5	5.1	1.153	0.027	0.6	23.4	14.5	23.6
46.00	330.7	7.9	1.207	0.029	1.3	31.0	41.7	31.6
47.00	865.2	5.3	0.943	0.036	1.0	170.0	164.4	170.7

NOTES:

$Q_{100} \approx 995$ cfs

$D_{max} = 47.16 - 44.3 = 2.9'$

SEC 3

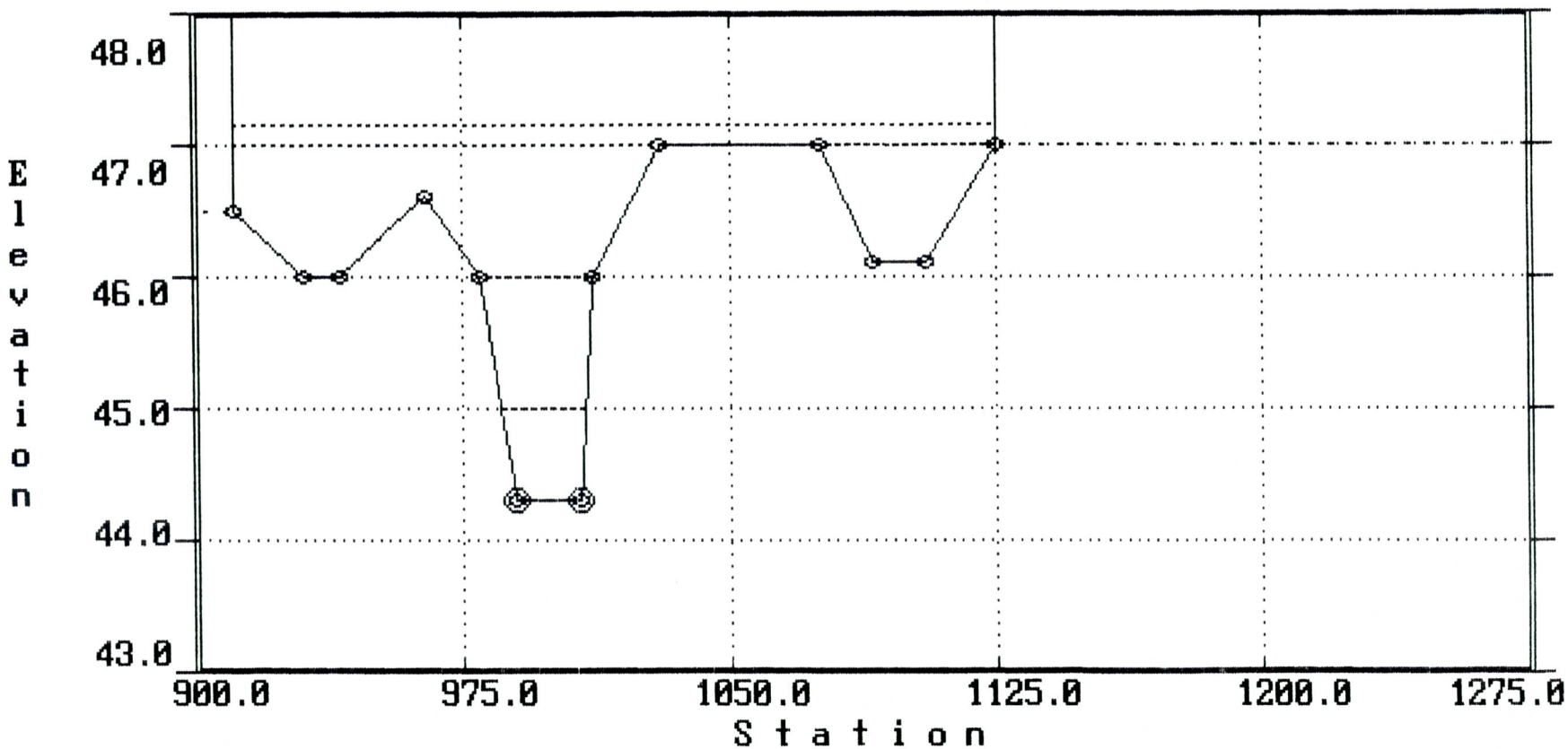
«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 47.2 Q= 994.9cfs V= 5.0fps WSEL= 47.0 Q= 865.2cfs V= 5.3fps

WSEL= 45.0 Q= 74.5cfs V= 5.1fps

WSEL= 46.0 Q= 330.7cfs V= 7.9fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0170



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Project FIRM
Project No.
Sheet No. of
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 4 - Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC4.SEC

No. of Cross Section Points:	8	Bed Slope:	0.01800	Max Elev:	6.3
Bank Stations.....Left:	992.0	Right....:	1005.0	Min Elev:	3.4
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.045	CHANNEL..:	0.025	ROB.....:	0.045

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	6.3	945.0	2)	6.0	960.0	3)	4.0	985.0	4)	3.4	992.0
5)	3.4	1005.0	6)	4.0	1010.0	7)	5.0	1040.0	8)	6.0	1075.0

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
5.57	552.0	5.3	0.889	0.040	1.1	94.8	104.3	94.9
4.00	42.0	3.7	0.962	0.032	0.5	25.0	11.4	25.1
5.00	269.0	4.7	0.890	0.038	0.9	67.5	57.6	67.6

NOTES:

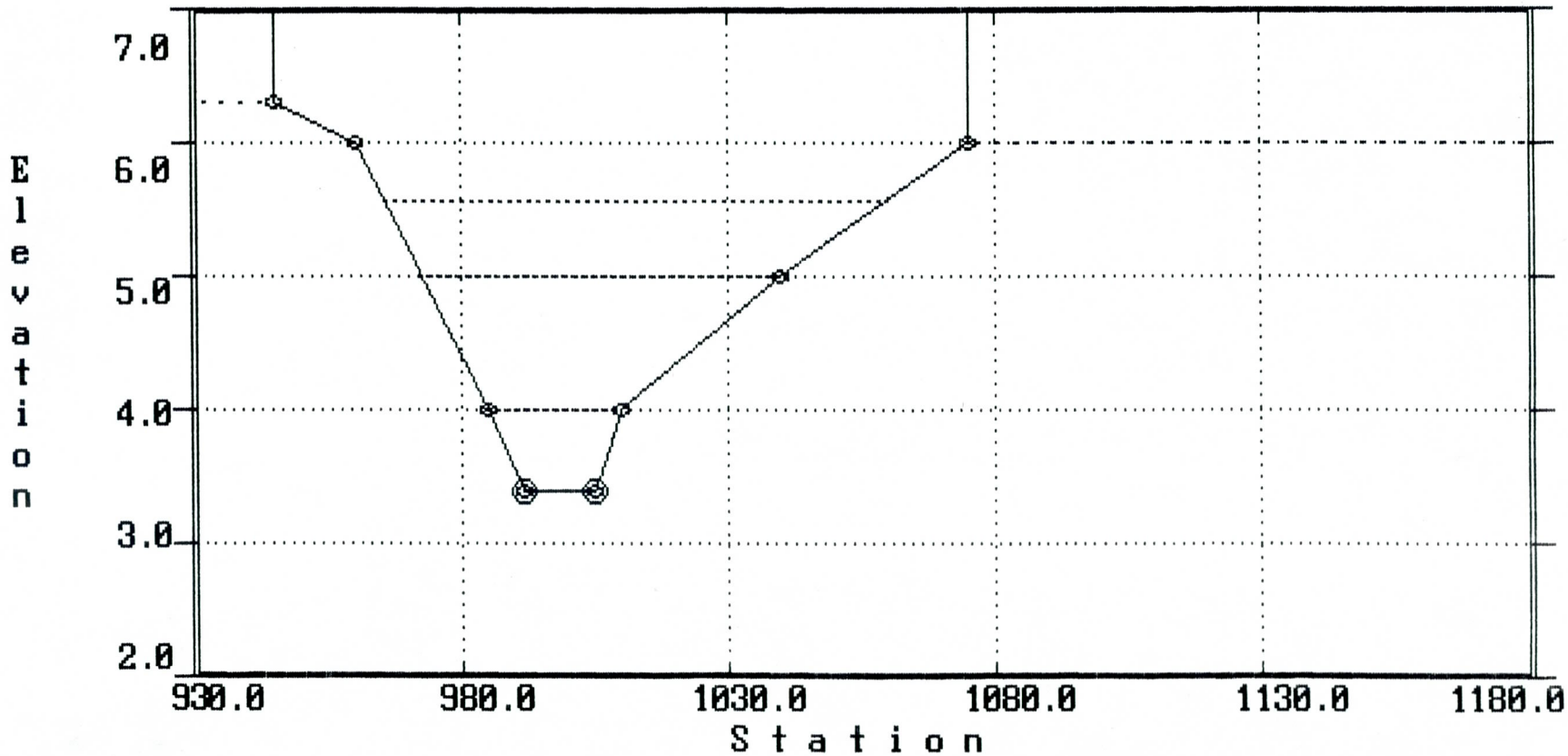
$Q_{100} \doteq 552$ cfs

$D_{max} = 5.57 - 3.4 = 2.2'$

SEC 4

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 5.6 Q= 552.0cfs V= 5.3fps
WSEL= 4.0 Q= 42.0cfs V= 3.7fps
WSEL= 5.0 Q= 269.0cfs V= 4.7fps
Manning-n Values...LOB: 0.045 CHANNEL: 0.025 ROB: 0.045 SLOPE = 0.0180



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Project FIRM
Project No.
Sheet No. of
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 5 - Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC5.SEC

No. of Cross Section Points:	14	Bed Slope:	0.01600	Max Elev:	67.0
Bank Stations.....Left:	990.0	Right....:	1007.0	Min Elev:	57.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.045	CHANNEL..:	0.025	ROB.....:	0.045

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	66.3	951.0	2)	66.0	960.0	3)	64.0	967.0	4)	62.0	976.0
5)	60.0	980.0	6)	58.0	985.0	7)	57.0	990.0	8)	57.0	1007.0
9)	58.0	1010.0	10)	60.0	1019.0	11)	62.0	1026.0	12)	64.0	1034.0
13)	66.0	1060.0	14)	67.0	1090.0						

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
63.42	3214.9	12.7	1.107	0.037	4.1	62.0	253.4	64.0
58.00	119.1	5.7	1.090	0.029	0.8	25.0	21.0	25.3
59.00	385.3	7.8	1.103	0.032	1.5	32.0	49.5	32.6
60.00	785.1	9.2	1.103	0.034	2.2	39.0	85.0	39.9
61.00	1343.3	10.6	1.107	0.035	2.8	44.5	126.8	45.7
62.00	2045.8	11.8	1.111	0.036	3.5	50.0	174.0	51.6

NOTES:

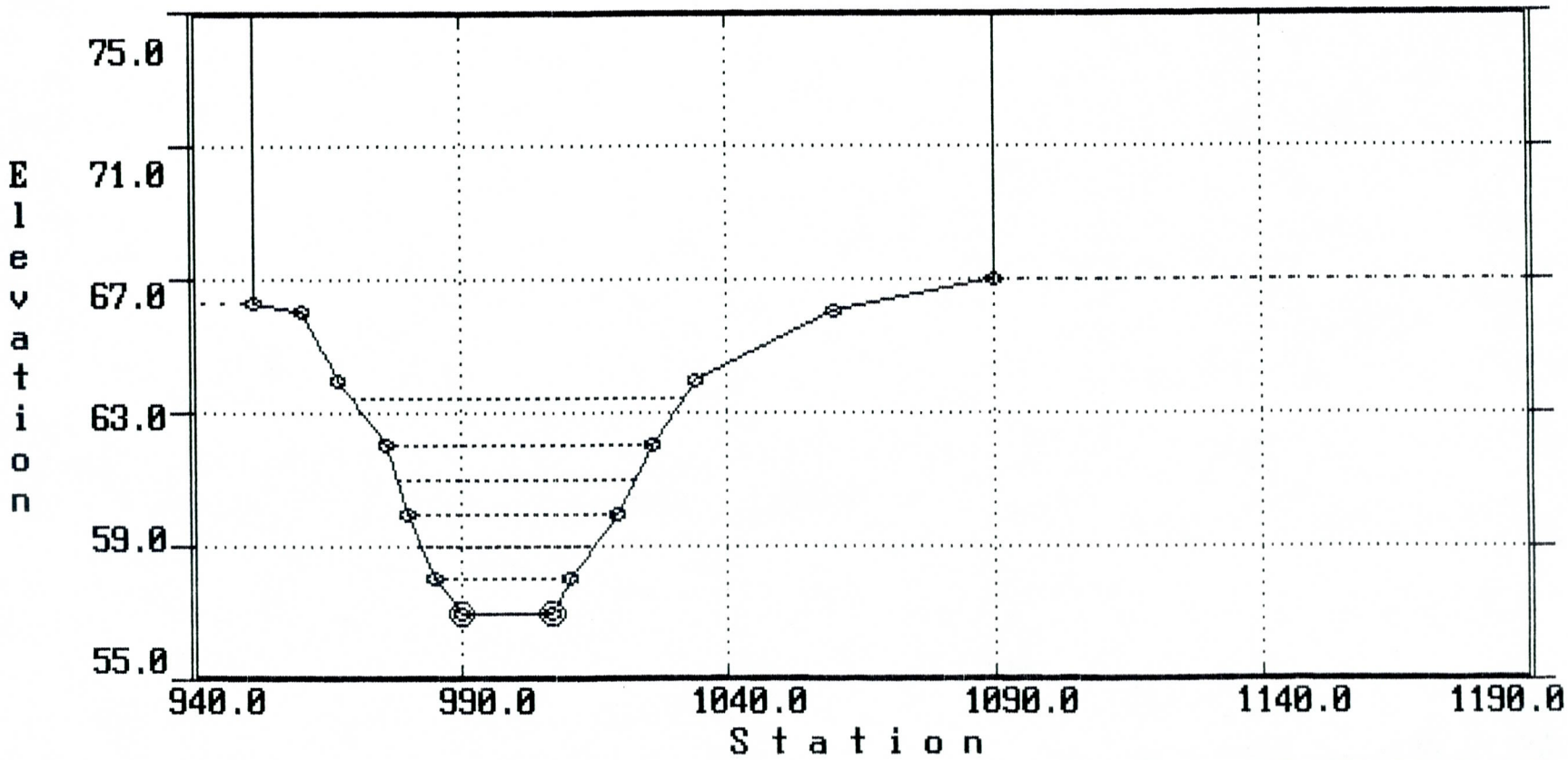
$Q_{100} \approx 3215$ cfs

$D_{max} = 63.42 - 57.0 = 6.4'$

SEC 5

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 63.4 Q= 3214.9cfs V= 12.7fps WSEL= 60.0 Q= 785.1cfs V= 9.2fps
WSEL= 58.0 Q= 119.1cfs V= 5.7fps WSEL= 61.0 Q= 1343.3cfs V= 10.6fps
WSEL= 59.0 Q= 385.3cfs V= 7.8fps WSEL= 62.0 Q= 2045.8cfs V= 11.8fps
Manning-n Values...LOB: 0.045 CHANNEL: 0.025 ROB: 0.045 SLOPE = 0.0160



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Project FIRM
Project No.
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UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 6 — Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC6.SEC

No. of Cross Section Points:	19	Bed Slope:	0.02000	Max Elev:	37.7
Bank Stations.....Left:	995.0	Right....:	1005.0	Min Elev:	34.0
Encroachment Stations..Left:	920.0	Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.045

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.5	620.0	2)	40.0	635.0	3)	38.0	670.0	4)	36.7	715.0
5)	36.0	730.0	6)	35.6	735.0	7)	36.0	750.0	8)	38.0	765.0
9)	37.8	790.0	10)	36.0	805.0	11)	36.0	815.0	12)	37.4	845.0
13)	37.0	905.0	14)	37.7	920.0	15)	36.0	985.0	16)	34.0	995.0
17)	34.0	1005.0	18)	36.0	1015.0	19)	36.7	1045.0			

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
36.59	386.0	5.4	0.991	0.037	0.9	77.4	71.4	77.9
35.00	82.4	5.5	1.117	0.031	0.8	20.0	15.0	20.2
36.00	294.0	7.3	1.122	0.034	1.3	30.0	40.0	30.4

NOTES:

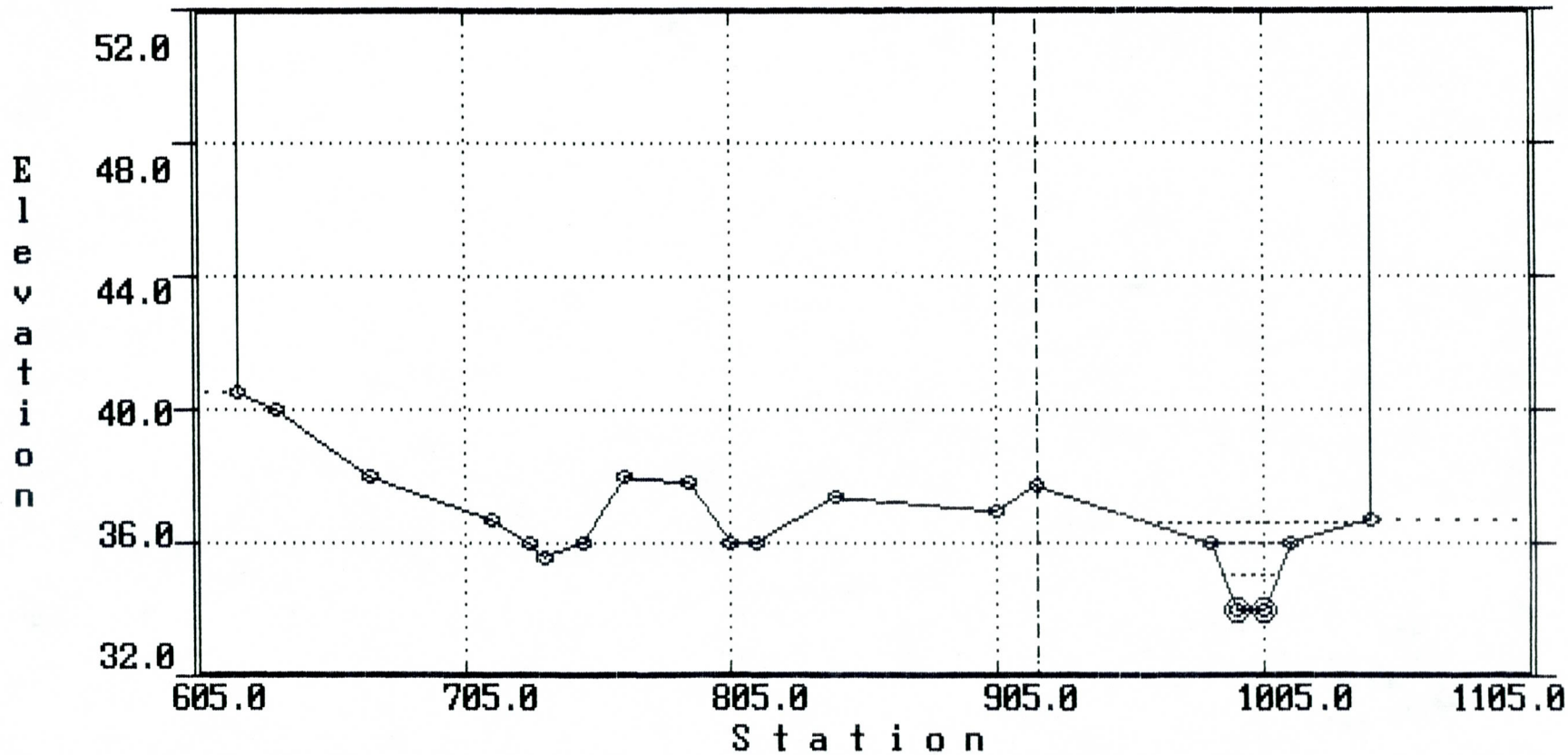
$Q_{100} \approx 386$ cfs

$D_{max} = 36.59 - 34 = 2.6'$

SEC 6

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 36.6 Q= 386.0cfs V= 5.4fps
WSEL= 35.0 Q= 82.4cfs V= 5.5fps
WSEL= 36.0 Q= 294.0cfs V= 7.3fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.045 SLOPE = 0.0200



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Project FIRM
Project No.
Sheet No. of
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 7 - Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC7.SEC

No. of Cross Section Points:	10	Bed Slope:	0.01600	Max Elev:	78.0
Bank Stations.....Left:	980.0	Right....:	1021.0	Min Elev:	64.3
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.045	CHANNEL..:	0.025	ROB.....:	0.045

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	72.0	890.0	2)	70.0	907.0	3)	68.0	925.0	4)	66.0	960.0
5)	64.5	980.0	6)	65.3	1000.0	7)	64.3	1021.0	8)	66.0	1040.0
9)	68.0	1080.0	10)	78.0	1130.0						

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
65.49	166.0	4.1	0.927	0.033	0.6	67.5	40.6	67.6
65.00	33.0	2.6	0.831	0.033	0.3	41.7	12.7	41.8
66.00	430.8	5.5	0.979	0.034	1.0	80.0	78.3	80.2
67.00	1222.4	6.9	0.991	0.036	1.5	117.5	177.1	117.7

NOTES:

$Q_{100} \approx 166$ cfs

$D_{max} = 65.49 - 64.3 = 1.2'$

SEC 7

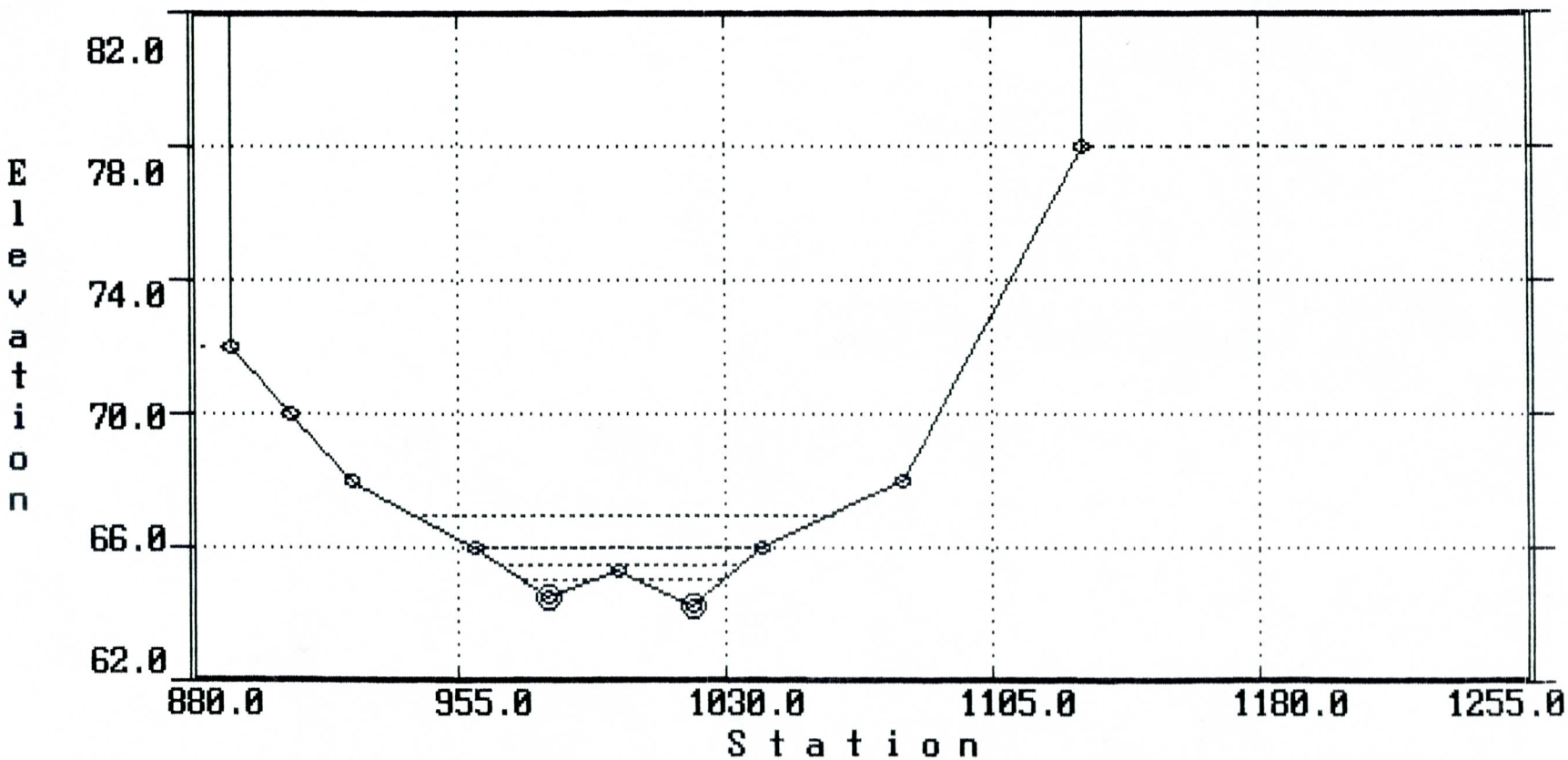
«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 65.5 Q= 166.0cfs V= 4.1fps WSEL= 67.0 Q= 1222.4cfs V= 6.9fps

WSEL= 65.0 Q= 33.0cfs V= 2.6fps

WSEL= 66.0 Q= 430.8cfs V= 5.5fps

Manning-n Values...LOB: 0.045 CHANNEL: 0.025 ROB: 0.045 SLOPE = 0.0160



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Project FIRM
Project No.
Sheet No. of
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 8 – Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC8.SEC

No. of Cross Section Points:	19	Bed Slope:	0.01500	Max Elev:	10.1
Bank Stations.....Left:	985.0	Right....:	1010.0	Min Elev:	7.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.045	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	10.1	940.0	2)	10.0	952.0	3)	8.0	972.0	4)	7.0	985.0
5)	7.0	1010.0	6)	8.0	1020.0	7)	8.8	1050.0	8)	8.3	1070.0
9)	8.1	1150.0	10)	8.4	1180.0	11)	8.0	1210.0	12)	8.0	1225.0
13)	8.7	1240.0	14)	8.5	1270.0	15)	8.8	1295.0	16)	8.0	1315.0
17)	7.5	1335.0	18)	8.0	1355.0	19)	8.7	1400.0			

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
9.48	3215.0	5.6	0.862	0.039	1.3	442.8	576.2	443.1
8.00	166.6	3.6	0.869	0.033	0.5	88.0	46.5	88.1
9.00	1519.6	4.2	0.808	0.038	0.8	438.0	363.7	438.2

NOTES:

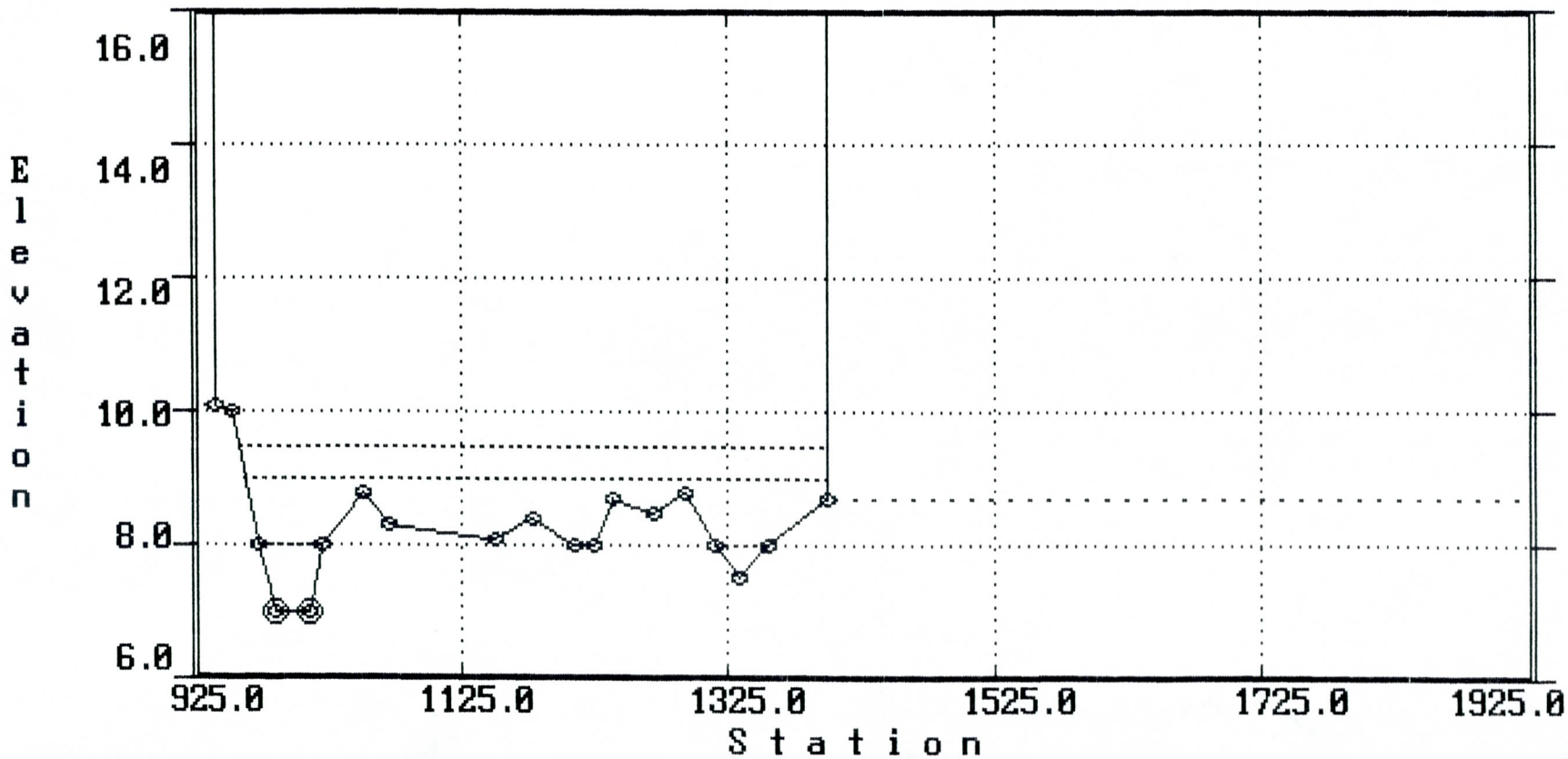
$Q_{100} \cong 3215$ cfs

$D_{max} = 9.48 - 7.0 = 2.5'$

SEC 8

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 9.5 Q= 3215.0cfs V= 5.6fps
WSEL= 8.0 Q= 166.6cfs V= 3.6fps
WSEL= 9.0 Q= 1519.6cfs V= 4.2fps
Manning-n Values...LOB: 0.045 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0150



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Project FIRM
Project No.
Sheet No. of
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section 9 – Plates 5 & 6

CROSS SECTION PARAMETERS: FILENAME: SEC9.SEC

No. of Cross Section Points:	20	Bed Slope:	0.01800	Max Elev:	44.8
Bank Stations.....Left:	975.0	Right....:	1019.0	Min Elev:	41.5
Encroachment Stations..Left:	905.0	Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	44.5	670.0	2)	44.0	700.0	3)	42.5	715.0	4)	43.0	725.0
5)	43.5	755.0	6)	43.8	775.0	7)	43.0	795.0	8)	43.0	805.0
9)	43.6	835.0	10)	43.4	850.0	11)	43.2	865.0	12)	44.0	880.0
13)	44.8	905.0	14)	44.6	930.0	15)	44.0	949.0	16)	42.0	965.0
17)	41.5	975.0	18)	41.5	1019.0	19)	42.0	1021.0	20)	44.0	1040.0

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
42.70	475.0	6.9	1.220	0.029	1.0	68.3	68.5	68.4
42.00	107.7	4.3	1.136	0.027	0.4	56.0	25.0	56.1

NOTES:

$Q_{100} \approx 475$

SEC 9

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 42.7 Q= 475.0cfs V= 6.9fps
WSEL= 42.0 Q= 107.7cfs V= 4.3fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0180

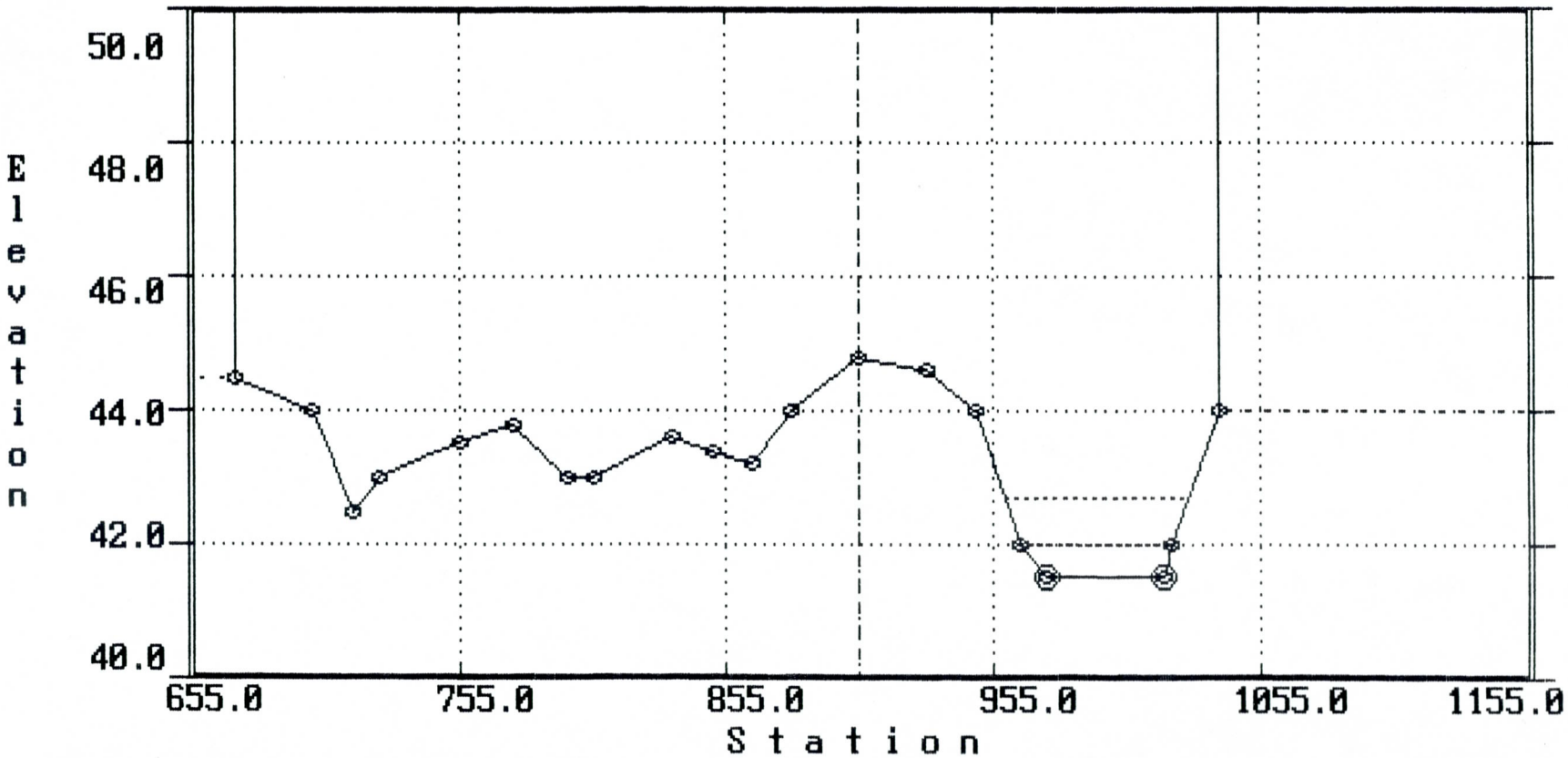

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TABLE 4: CAPACITY COMPUTATIONS FOR WASH CORRIDORS
NORTHERN SPLIT OF WASHES 6a, 6b, & 6c
SECTIONS A,B,C, & D

	DESCRIPTION	SEC A	SEC B	SEC C [1]	SEC D [2]	TOTALS
COMPUTED CHANNEL CAPACITIES						
1	Capacity(cfs) @ lowest over-bank elevation at the Corridor Boundary	277	204	124	529	1134
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	672	531	546	1464	3213
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	2171	1359	1190	1464	6184
APPROXIMATE 100 YEAR DISCHARGES(cfs)						
4a	Approx Percent of Upper Water-shed discharge based on topography	10	20	30	40	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	165	331	496	662	1654.6
4c	Upper Drainage Area(sq mi)	0.177	0.355	0.532	0.709	1.773
5a	Percent of Local Drainage Area	65	10	8	17	100
5b	Local Drainage Area (sq mi)	3.50	0.54	0.43	0.92	5.39
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	1226	458	397	577	2658
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	1391	789	893	1239	4312
8	Additional Capacity (percent) ((ROW 3)/(ROW 7)) - 1	56.0%	72.3%	33.3%	18.2%	43.4%

(1) Existing Tatum Ranch drainage corridor improvements along south (ie, left) bank.

(2) Existing Tatum Ranch drainage corridor improvements along left & right banks.

TABLE 5: CAPACITY CALCULATIONS FOR WASH CORRIDORS
SOUTHERN SPLIT OF WASHES 6a, 6b, & 6c
SECTIONS E, F, & G

	DESCRIPTION	SEC E	SEC F	SEC G	TOTALS
COMPUTED CHANNEL CAPACITIES					
1	Capacity(cfs) @ lowest over-bank elevation at the Corridor Boundary	248	757	48	1053
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	708	1199	422	2329
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	1736	1747	1383	4866
APPROXIMATE 100 YEAR DISCHARGES(cfs)					
4a	Approx Percent of Upper Water-shed discharge based on topography	15	15	70	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	83	83	386	551.525
4c	Upper Drainage Area(sq mi)	0.047	0.047	0.219	0.3129
5a	Percent of Local Drainage Area	25	25	50	100
5b	Local Drainage Area (sq mi)	0.34	0.34	0.67	1.34
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	352	352	496	1199
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	434	434	882	1751
8	Additional Capacity (percent) ((ROW 3)/(ROW 7)) - 1	299.6%	302.1%	56.8%	177.9%

TABLE 6: CAPACITY CALCULATIONS FOR WASH CORRIDORS
WASH 6a
SECTIONS H, I, J, K, & L

	DESCRIPTION	SEC H	SEC I	SEC J	SEC K	SEC L	TOTALS
COMPUTED CHANNEL CAPACITIES							
1	Capacity(cfs) @ lowest overbank elevation at the Corridor Boundary	683	131	176	259	36	1285
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	1079	633	586	733	582	3613
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	1825	1468	1303	1294	1585	7475
APPROXIMATE 100 YEAR DISCHARGES(cfs)							
4a	Approx Percent of Upper Watershed discharge based on topography	30	15	15	20	20	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	964	482	482	643	643	3212.9
4c	Upper Drainage Area(sq mi)	0.946	0.473	0.473	0.631	0.631	3.154
5a	Percent of Local Drainage Area	16	18	18	24	24	100
5b	Local Drainage Area (sq mi)	0.30	0.34	0.34	0.45	0.45	1.88
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	331	355	355	411	411	1452
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	1295	837	837	1053	1053	4665
8	Additional Capacity (percent) ((ROW 3)/(ROW 7)) - 1	41.0%	75.3%	55.6%	22.9%	50.5%	60.2%

TABLE 7: CAPACITY CALCULATIONS FOR WASH CORRIDORS
WASH 5
SECTIONS M,N,O,P, & Q

	DESCRIPTION	SEC M	SEC N	SEC O	SEC P	SEC Q	TOTALS
COMPUTED CHANNEL CAPACITIES							
1	Capacity(cfs) @ lowest over-bank elevation at the Corridor Boundary	320	1156	209	992	319	2996
2	Capacity(cfs) @ 0.5′ above lowest overbank elevation at the Corridor Boundary	678	1848	565	1741	763	5595
3	Capacity(cfs) @ 1.0′ above lowest overbank elevation at the Corridor Boundary	1524	2989	1345	2763	1355	9976
APPROXIMATE 100 YEAR DISCHARGES(cfs)							
4a	Approx Percent of Upper Water-shed discharge based on topography	25	40	15	10	10	100
4b	Upper watershed discharge(cfs) based on WRA's HEC-1 model	712	1140	427	285	285	2849.0
4c	Upper Drainage Area(sq mi)	0.773	1.236	0.463	0.309	0.309	3.090
5a	Percent of Local Drainage Area	10	22	20	25	20	97
5b	Local Drainage Area (sq mi)	0.40	0.87	0.79	0.99	0.79	3.85
6	Local Runoff(cfs) based on CSM data for "STREAMS 5 & 6"	381	568	540	596	540	2084
7	Total Runoff(cfs) based on FCDMC's CSM curves & WRA HEC-1 model(ROW 4b + ROW 6)	1093	1707	967	880	825	4933
8	Additional Capacity (percent)	39.4%	75.1%	39.1%	213.8%	64.3%	102.2%

Project FIRM
Project No.
Sheet No. 1 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section A - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECA2.SEC

No. of Cross Section Points:	17	Bed Slope:	0.01250	Max Elev:	40.3
Bank Stations.....Left:	970.1	Right....:	980.0	Min Elev:	38.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	670.0	2)	40.0	750.0	3)	40.0	800.0	4)	39.7	830.0
5)	39.6	850.0	6)	40.0	865.0	7)	40.3	900.0	8)	40.2	925.0
9)	40.0	950.0	10)	40.0	970.0	11)	38.0	970.1	12)	38.0	980.0
13)	39.0	1020.0	14)	39.7	1045.0	15)	39.8	1075.0	16)	40.0	1120.0
17)	40.3	1200.0									

COMPUTED PARAMETERS:

	WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
	39.00	98.5	3.3	0.750	0.035	0.6	50.0	29.9	50.9
	39.50	243.5	4.1	0.773	0.037	0.9	67.8	59.4	69.3
(1)	39.80	277.0	3.2	0.719	0.037	0.6	142.5	86.9	144.2
(2)	40.30	671.8	2.6	0.667	0.039	0.5	530.0	255.6	531.9
(3)	40.80	2171.0	4.2	0.741	0.039	1.0	530.0	520.6	531.9

NOTES:

(1) Elevation at lowest overbank elev. @ the corridor boundary

(2) 0.5' above the lowest overbank elevation

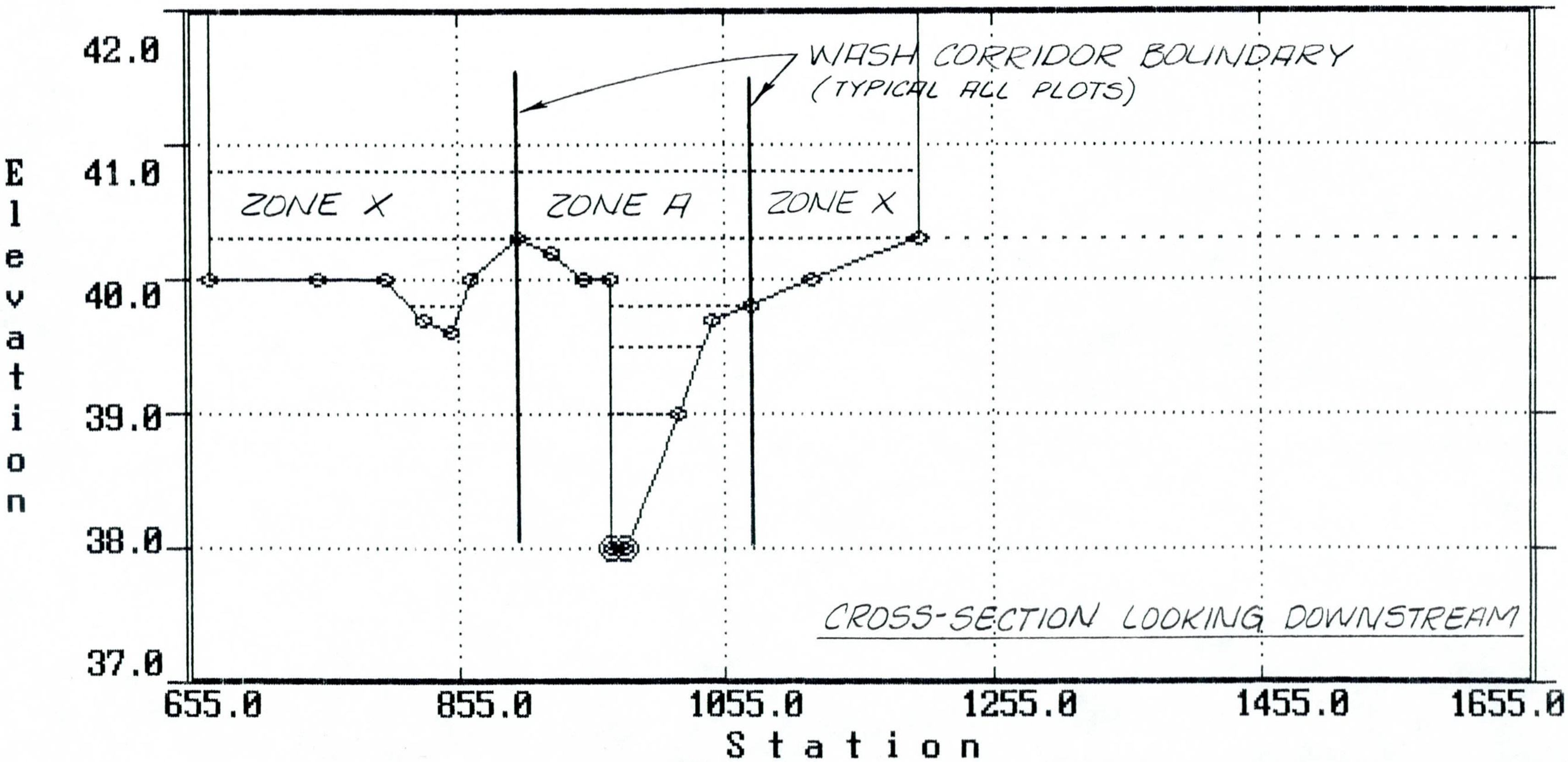
(3) 1.0' above

SECTION A

««««««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 39.0 Q= 98.5cfs V= 3.3fps WSEL= 40.3 Q= 671.8cfs V= 2.6fps
WSEL= 39.5 Q= 243.5cfs V= 4.1fps WSEL= 40.8 Q= 2171.0cfs V= 4.2fps
WSEL= 39.8 Q= 277.0cfs V= 3.2fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0125



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Project FIRM
Project No.
Sheet No. 2 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section B - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECB2.SEC

No. of Cross Section Points:	8	Bed Slope:	0.01880	Max Elev:	41.0
Bank Stations.....Left:	990.0	Right....:	1025.0	Min Elev:	38.5
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	840.0	2)	39.5	940.0	3)	38.8	990.0	4)	38.5	1000.0
5)	38.9	1025.0	6)	40.0	1050.0	7)	40.5	1070.0	8)	41.0	1080.0

COMPUTED PARAMETERS:

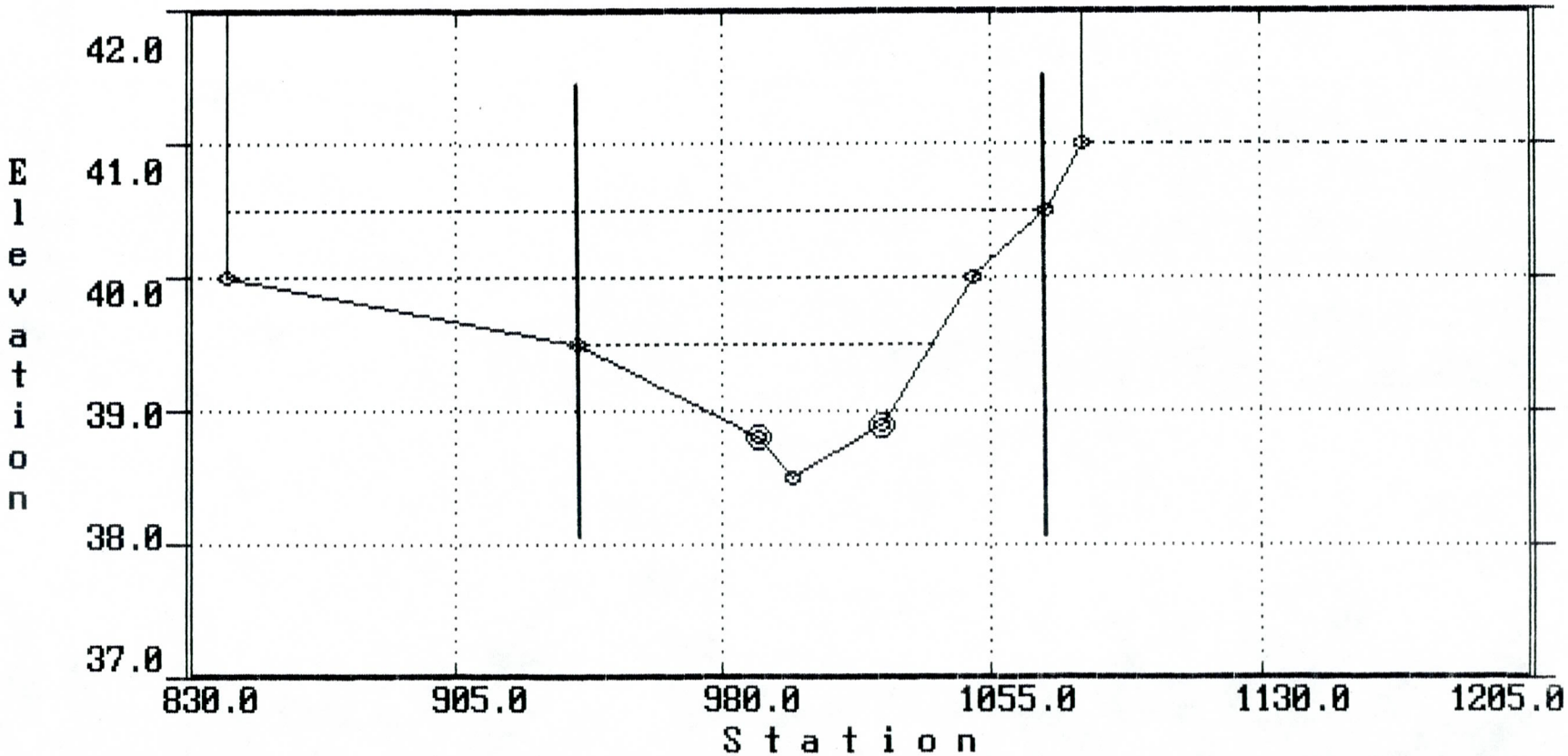
	WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
(1)	39.50	203.6	4.1	1.005	0.032	0.5	98.6	50.1	98.7
(2)	40.00	531.0	4.2	0.945	0.035	0.6	210.0	127.2	210.0
(3)	40.50	1359.2	5.7	0.994	0.036	1.0	230.0	237.2	230.0

NOTES:

SECTION B

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 39.5 Q= 203.6cfs V= 4.1fps
WSEL= 40.0 Q= 531.0cfs V= 4.2fps
WSEL= 40.5 Q= 1359.2cfs V= 5.7fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0188



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Project FIRM
Project No.
Sheet No. 3 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section C - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECC2.SEC

No. of Cross Section Points:	9	Bed Slope:	0.01670	Max Elev:	40.5
Bank Stations.....Left:	1000.0	Right....:	1020.0	Min Elev:	37.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	950.0	2)	40.5	952.0	3)	40.5	957.0	4)	40.0	960.0
5)	38.0	985.0	6)	37.0	1000.0	7)	37.3	1020.0	8)	37.9	1070.0
9)	38.0	1130.0									

COMPUTED PARAMETERS:

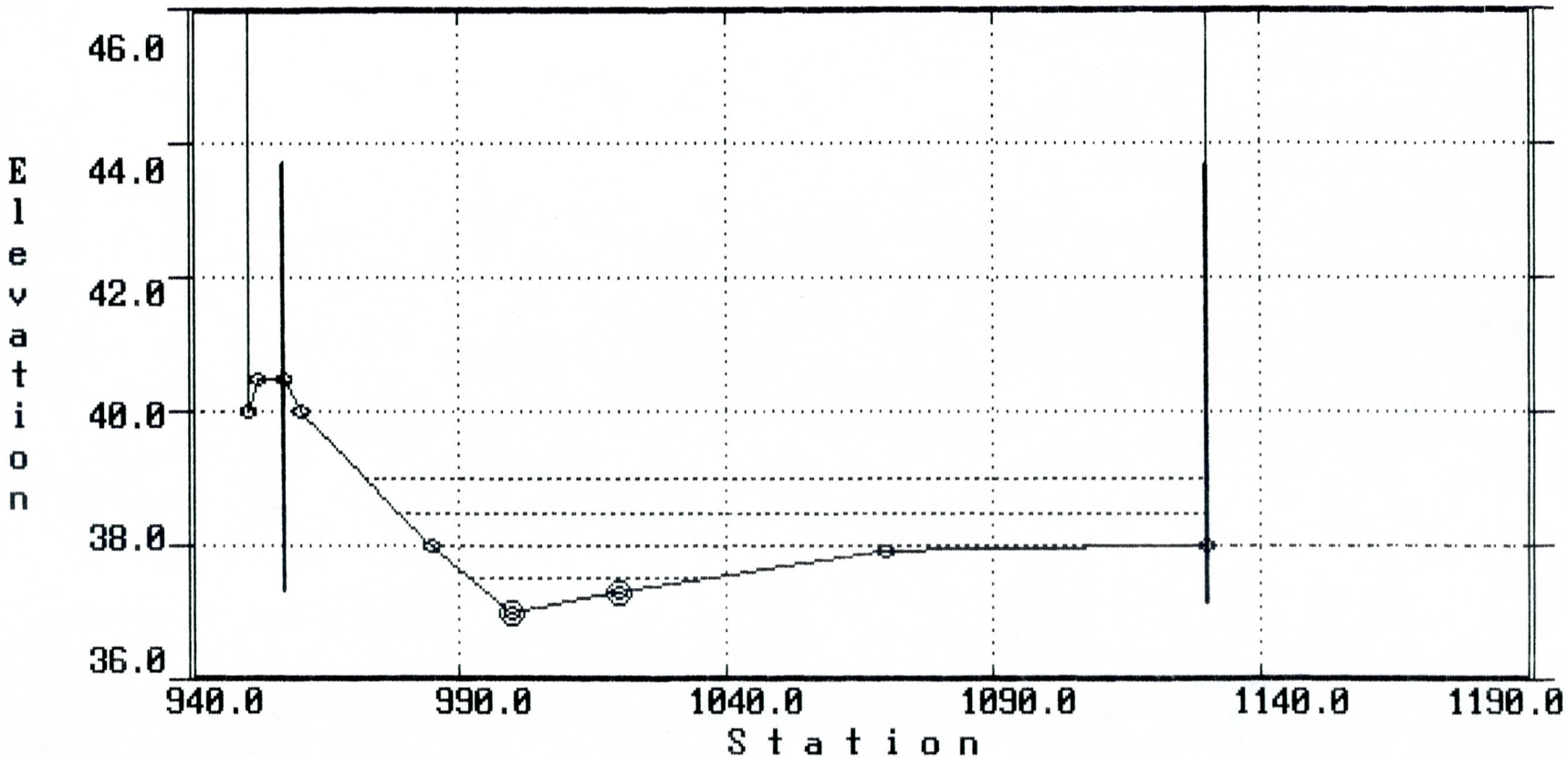
WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
37.50	25.6	2.4	0.875	0.030	0.2	44.2	10.5	44.2
(1) 38.00	123.8	2.6	0.802	0.035	0.3	145.0	47.5	145.0
(2) 38.50	546.1	4.5	0.883	0.037	0.8	151.3	121.6	151.3
(3) 39.00	1189.8	6.0	0.939	0.037	1.3	157.5	198.7	157.6

NOTES:

SECTION C

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 37.5 Q= 25.6cfs V= 2.4fps WSEL= 39.0 Q= 1189.8cfs V= 6.0fps
WSEL= 38.0 Q= 123.8cfs V= 2.6fps
WSEL= 38.5 Q= 546.1cfs V= 4.5fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0167



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Project FIRM
Project No.
Sheet No. 4 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section D - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECD2.SEC

No. of Cross Section Points:	11	Bed Slope:	0.01600	Max Elev:	41.9
Bank Stations.....Left:	980.0	Right....:	1030.0	Min Elev:	37.9
Encroachment Stations..Left:	955.0	Right....:	1075.0		
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	945.0	2)	41.9	950.0	3)	41.9	955.0	4)	40.0	970.0
5)	38.0	980.0	6)	37.9	1000.0	7)	38.0	1030.0	8)	40.0	1070.0
9)	40.2	1075.0	10)	40.2	1080.0	11)	40.0	1085.0			

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
38.00	2.6	1.0	0.804	0.025	0.0	50.0	2.5	50.0
39.00	393.6	6.1	1.146	0.028	0.9	75.0	65.0	75.1
39.20	529.1	6.6	1.155	0.029	1.0	80.0	80.5	80.1
39.70	945.8	7.7	1.166	0.030	1.3	92.5	123.6	92.7
40.20	1464.3	8.5	1.169	0.031	1.6	106.6	173.2	106.8

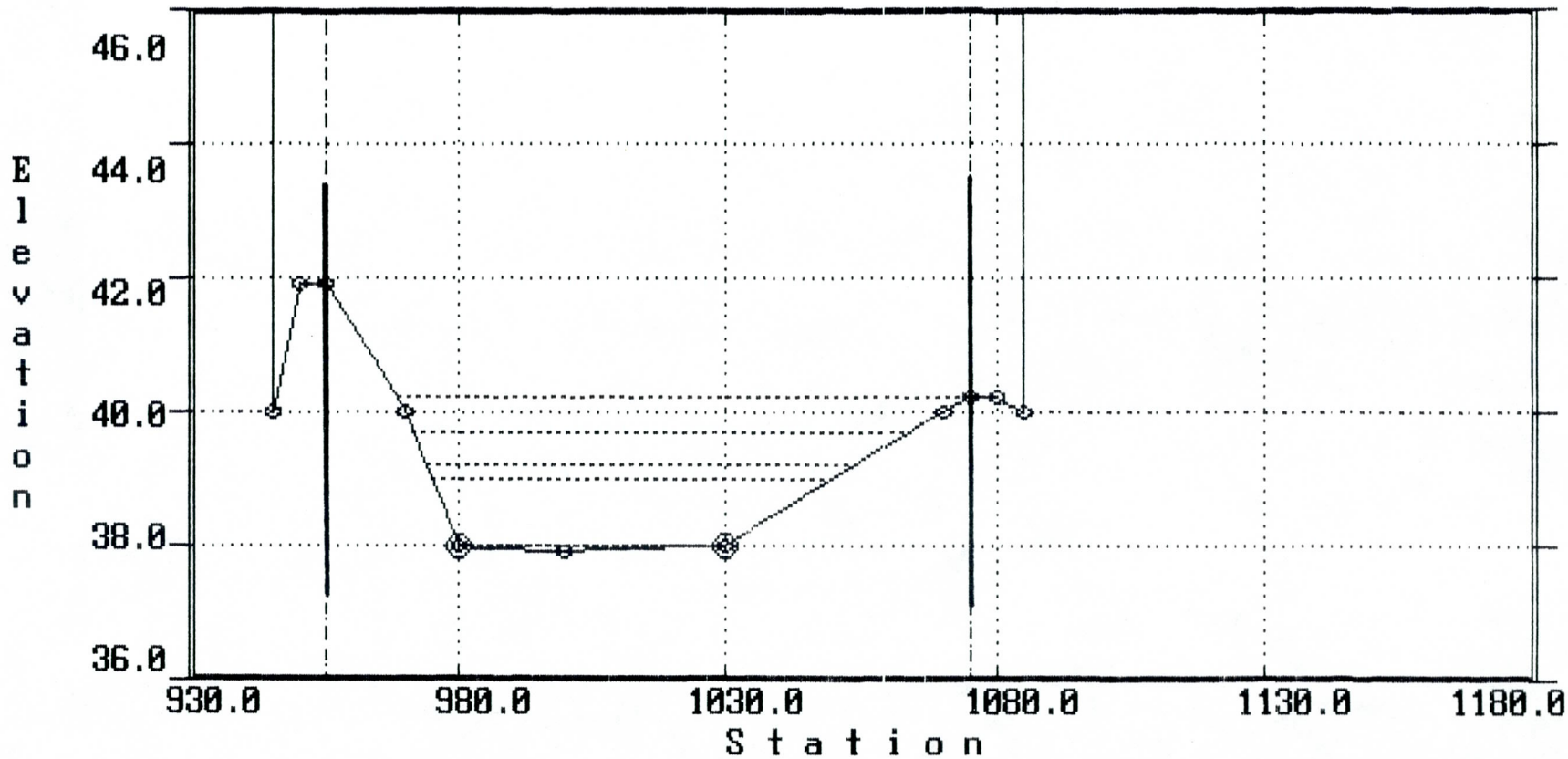
NOTES:

SECTION D

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL=	38.0	Q= 2.6cfs	V= 1.0fps	WSEL=	39.7	Q= 945.8cfs	V= 7.7fps
WSEL=	39.0	Q= 393.6cfs	V= 6.1fps	WSEL=	40.2	Q= 1464.3cfs	V= 8.5fps
WSEL=	39.2	Q= 529.1cfs	V= 6.6fps				

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0160



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Project FIRM
Project No.
Sheet No. 5 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section E - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECE2.SEC

No. of Cross Section Points:	12	Bed Slope:	0.01820	Max Elev:	40.0
Bank Stations.....Left:	991.0	Right....:	1009.0	Min Elev:	38.6
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	858.0	2)	39.7	896.0	3)	39.7	932.0	4)	39.6	951.0
5)	38.7	991.0	6)	38.6	1000.0	7)	38.6	1009.0	8)	39.0	1028.0
9)	39.8	1037.0	10)	40.0	1060.0	11)	39.8	1079.0	12)	39.7	1107.0

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
39.00	30.8	2.5	0.866	0.032	0.2	50.3	12.6	50.3
39.50	175.7	3.9	0.917	0.035	0.6	78.2	44.7	78.2
39.70	247.9	4.0	0.909	0.036	0.6	103.9	62.2	103.9
40.20	707.8	4.1	0.879	0.038	0.7	249.0	171.1	249.1
40.70	1735.5	5.9	0.950	0.038	1.2	249.0	295.6	249.1

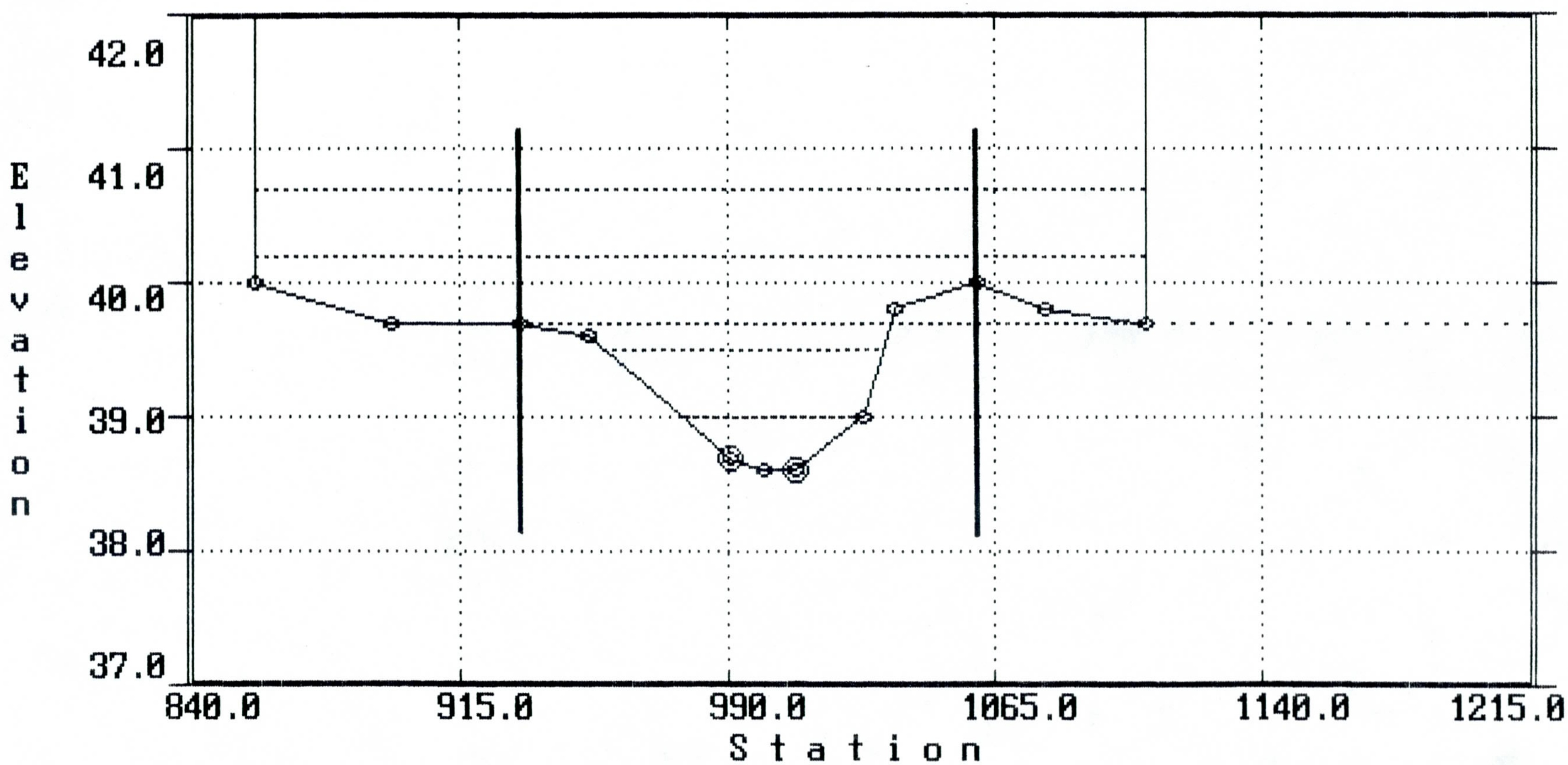
NOTES:

SECTION E

«««««««««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 39.0 Q= 30.8cfs V= 2.5fps WSEL= 40.2 Q= 707.8cfs V= 4.1fps
WSEL= 39.5 Q= 175.7cfs V= 3.9fps WSEL= 40.7 Q= 1735.5cfs V= 5.9fps
WSEL= 39.7 Q= 247.9cfs V= 4.0fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0182



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Project FIRM
Project No.
Sheet No. 6 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section F - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECF2.SEC

No. of Cross Section Points:	13	Bed Slope:	0.01480	Max Elev:	40.0
Bank Stations.....Left:	983.0	Right....:	1010.0	Min Elev:	35.5
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	858.0	2)	39.6	881.0	3)	39.0	911.0	4)	38.7	929.0
5)	38.0	952.0	6)	36.3	983.0	7)	36.0	991.0	8)	35.5	1000.0
9)	36.0	1010.0	10)	37.2	1032.0	11)	38.0	1055.0	12)	39.3	1078.0
13)	39.5	1115.0									

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
36.00	13.6	2.9	1.011	0.025	0.3	19.0	4.8	19.0
37.00	221.5	5.0	1.013	0.030	0.8	58.1	44.2	58.2
38.00	756.6	6.1	0.981	0.033	1.2	103.0	123.9	103.1
38.50	1199.0	6.6	0.977	0.035	1.4	128.3	181.7	128.4
39.00	1746.6	6.9	0.970	0.035	1.6	161.7	253.4	161.9

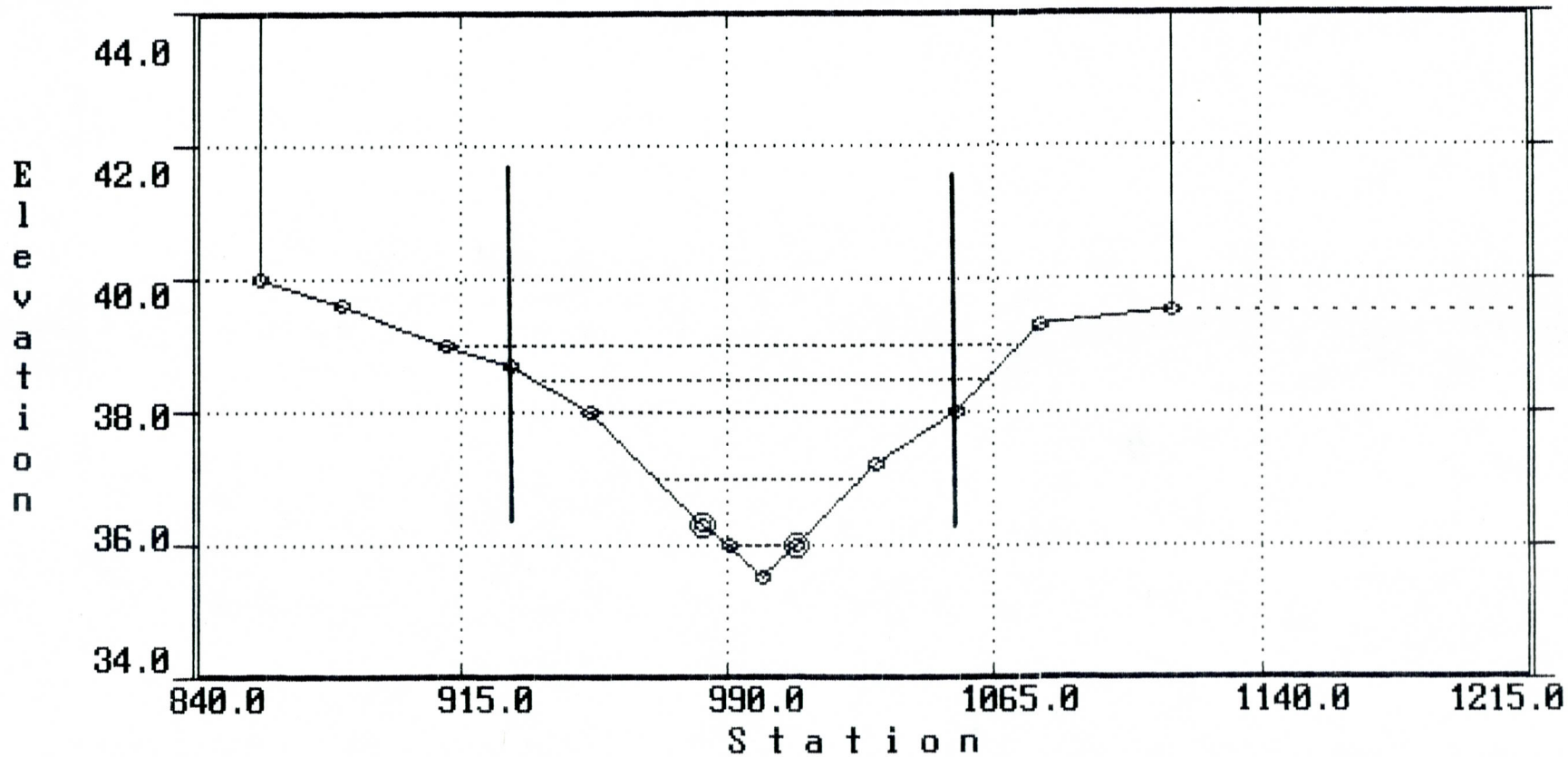
NOTES:

SECTION F

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 36.0 Q= 13.6cfs V= 2.9fps WSEL= 38.5 Q= 1199.0cfs V= 6.6fps
WSEL= 37.0 Q= 221.5cfs V= 5.0fps WSEL= 39.0 Q= 1746.6cfs V= 6.9fps
WSEL= 38.0 Q= 756.6cfs V= 6.1fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0148



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Project FIRM
Project No.
Sheet No. 7 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section G- Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECG2.SEC

No. of Cross Section Points:	16	Bed Slope:	0.01790	Max Elev:	40.6
Bank Stations.....Left:	890.0	Right....:	931.0	Min Elev:	38.9
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.6	778.0	2)	40.5	810.0	3)	40.0	836.0	4)	39.5	858.0
5)	39.1	890.0	6)	38.9	911.0	7)	39.3	931.0	8)	39.8	948.0
9)	39.7	973.0	10)	40.0	988.0	11)	39.1	1000.0	12)	39.3	1007.0
13)	39.4	1037.0	14)	39.4	1085.0	15)	40.0	1150.0	16)	40.5	1183.0

COMPUTED PARAMETERS:

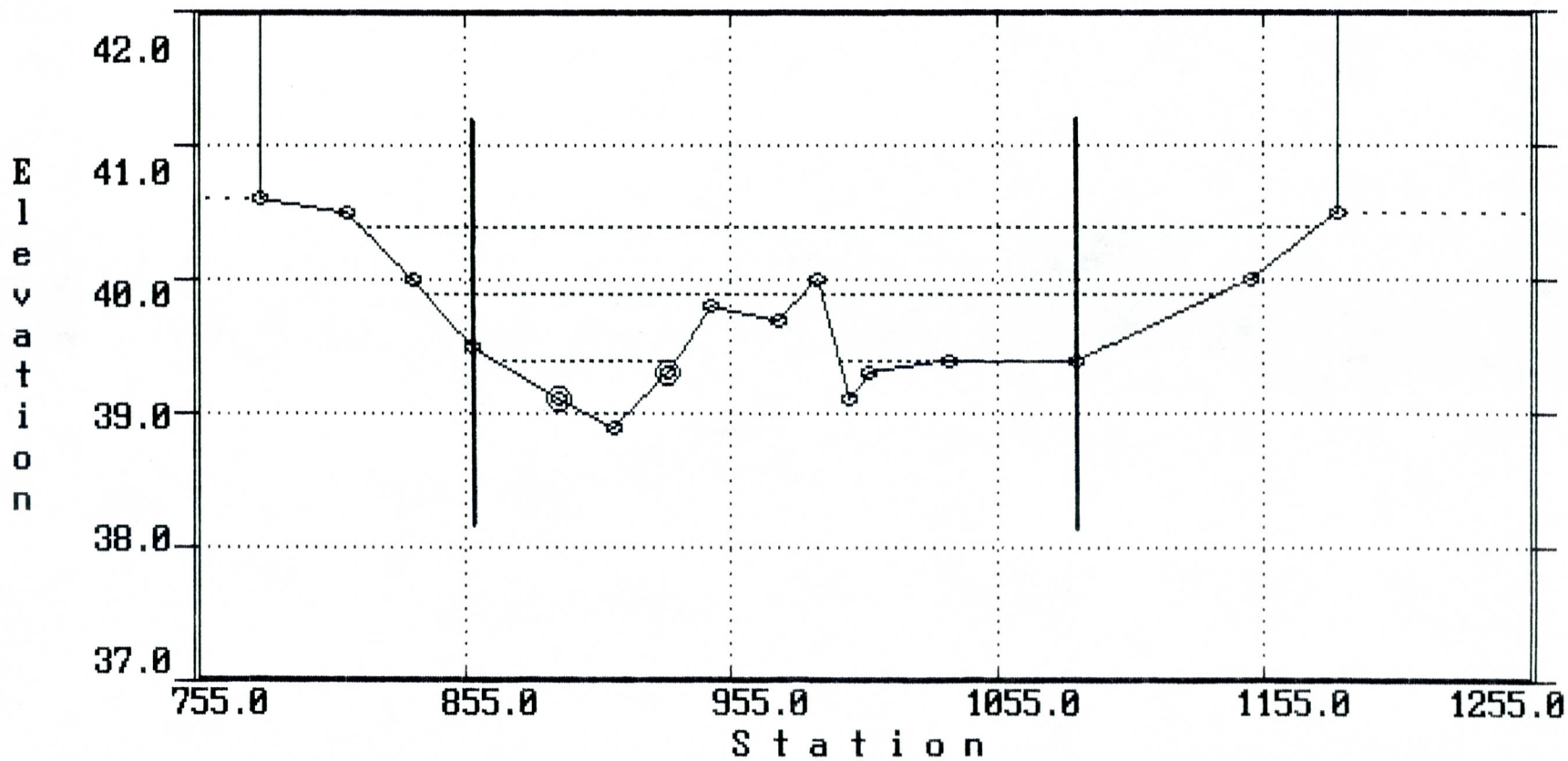
WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
39.00	0.8	1.1	0.851	0.025	0.0	15.5	0.8	15.5
39.40	48.1	2.2	0.879	0.030	0.2	109.4	21.7	109.4
39.90	422.4	3.2	0.844	0.036	0.4	292.4	131.5	292.5
40.40	1383.1	4.7	0.906	0.037	0.8	361.2	296.9	361.3

NOTES:

SECTION G

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 39.0 Q= 0.8cfs V= 1.1fps WSEL= 40.4 Q= 1383.1cfs V= 4.7fps
WSEL= 39.4 Q= 48.1cfs V= 2.2fps
WSEL= 39.9 Q= 422.4cfs V= 3.2fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0179



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Project FIRM
Project No.
Sheet No. 8 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section H - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECH2.SEC

No. of Cross Section Points:	15	Bed Slope:	0.02400	Max Elev:	41.5
Bank Stations.....Left:	987.0	Right....:	1009.0	Min Elev:	35.6
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	41.5	818.0	2)	41.1	842.0	3)	40.2	860.0	4)	40.1	900.0
5)	40.0	908.0	6)	39.8	931.0	7)	39.2	950.0	8)	38.0	970.0
9)	37.0	987.0	10)	36.0	997.0	11)	35.6	1000.0	12)	36.0	1009.0
13)	37.0	1030.0	14)	38.0	1050.0	15)	38.3	1081.0			

COMPUTED PARAMETERS:

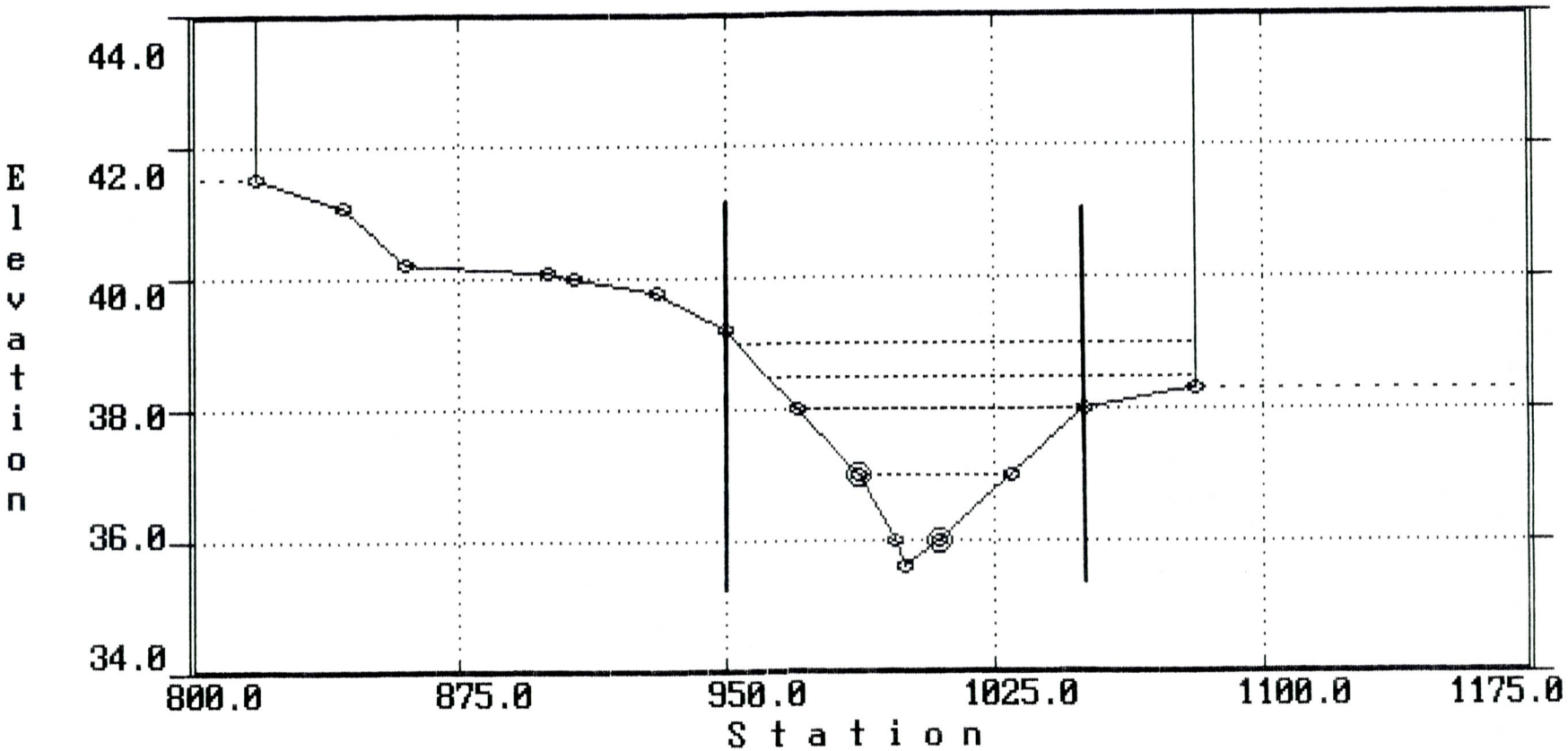
WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
37.00	175.8	5.9	1.242	0.031	0.7	43.0	29.9	43.1
38.00	682.9	7.5	1.232	0.034	1.1	80.0	91.4	80.2
38.50	1078.5	7.5	1.197	0.035	1.2	119.3	144.3	119.5
39.00	1825.1	8.9	1.228	0.036	1.6	127.7	206.1	127.9

NOTES:

SECTION H

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 37.0 Q= 175.8cfs V= 5.9fps WSEL= 39.0 Q= 1825.1cfs V= 8.9fps
WSEL= 38.0 Q= 682.9cfs V= 7.5fps
WSEL= 38.5 Q= 1078.5cfs V= 7.5fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0240



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Project FIRM
Project No.
Sheet No. 9 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section I - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECI2.SEC

No. of Cross Section Points:	12	Bed Slope:	0.02110	Max Elev:	40.1
Bank Stations.....Left:	1033.0	Right....:	1047.0	Min Elev:	39.3
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	940.0	2)	40.1	962.0	3)	40.0	975.0	4)	39.8	990.0
5)	39.8	1000.0	6)	39.8	1010.0	7)	39.5	1033.0	8)	39.4	1047.0
9)	40.0	1066.0	10)	39.8	1085.0	11)	39.4	1100.0	12)	39.3	1120.0

COMPUTED PARAMETERS:

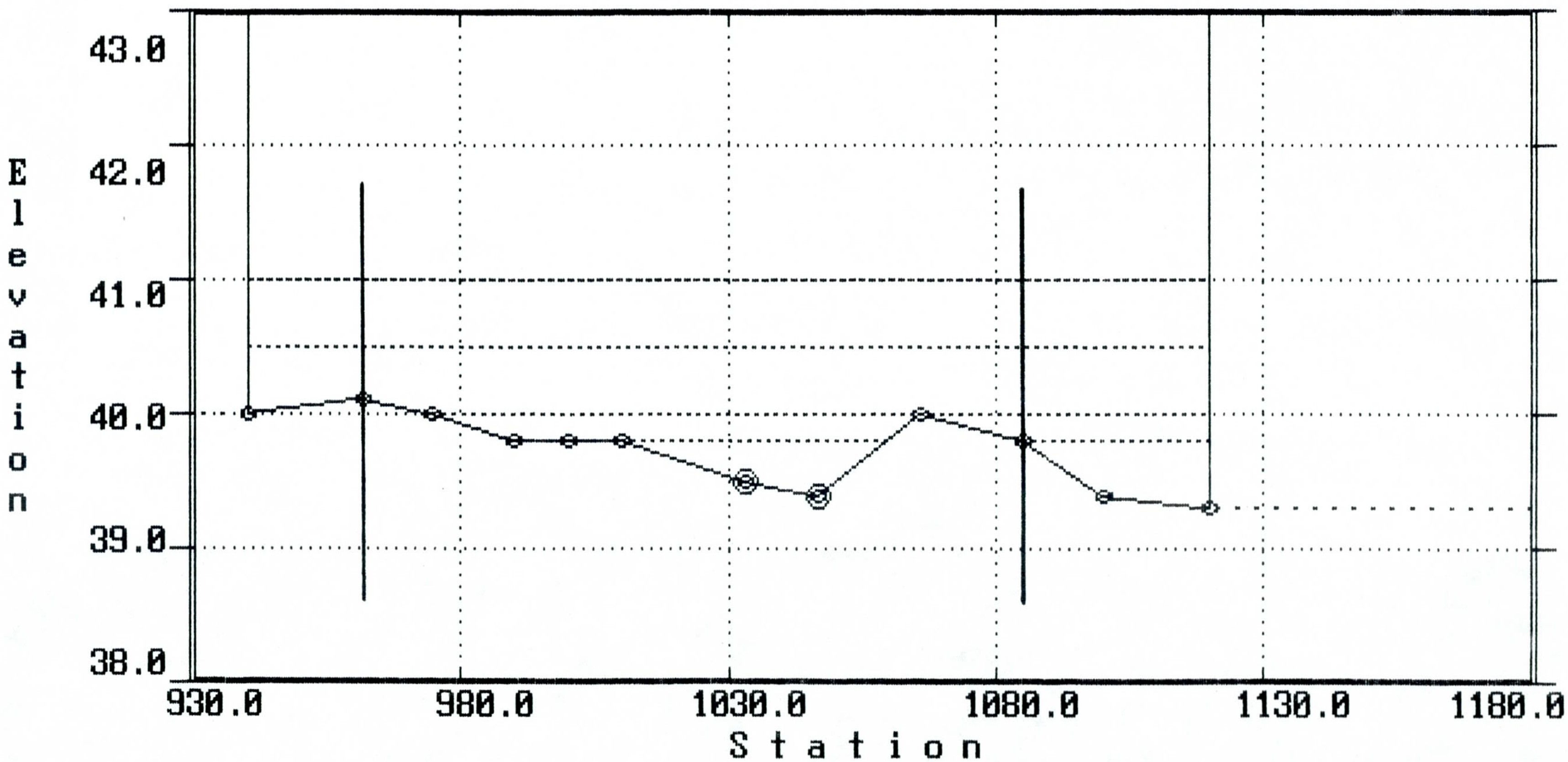
WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
39.80	55.7	2.4	0.825	0.037	0.3	84.7	22.9	84.7
40.00	130.5	2.7	0.837	0.038	0.3	145.0	47.8	145.0
40.50	632.8	4.6	0.942	0.039	0.8	180.0	136.1	180.0
41.00	1468.2	6.5	1.021	0.039	1.3	180.0	226.1	180.0

NOTES:

SECTION I

««««««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 39.8 Q= 55.7cfs V= 2.4fps WSEL= 41.0 Q= 1468.2cfs V= 6.5fps
WSEL= 40.0 Q= 130.5cfs V= 2.7fps
WSEL= 40.5 Q= 632.8cfs V= 4.6fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0211



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Project FIRM
Project No.
Sheet No. 10 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section J - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECJ2.SEC

No. of Cross Section Points:	16	Bed Slope:	0.01670	Max Elev:	40.7
Bank Stations.....Left:	993.0	Right....:	1005.0	Min Elev:	37.5
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	39.3	845.0	2)	39.5	865.0	3)	39.4	895.0	4)	39.1	920.0
5)	39.6	950.0	6)	39.4	972.0	7)	38.7	987.0	8)	38.0	993.0
9)	37.5	1000.0	10)	38.0	1005.0	11)	38.5	1010.0	12)	39.0	1020.0
13)	40.0	1042.0	14)	40.2	1051.0	15)	40.5	1077.0	16)	40.7	1100.0

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
38.00	9.1	3.0	1.072	0.025	0.3	12.0	3.0	12.0
39.00	119.5	4.6	0.991	0.032	0.7	39.4	26.1	39.6
39.40	176.3	3.4	0.861	0.035	0.5	109.8	52.3	110.0
39.90	585.6	4.1	0.855	0.038	0.7	194.8	141.6	195.0
40.40	1303.1	5.3	0.898	0.038	1.1	223.3	244.4	223.5

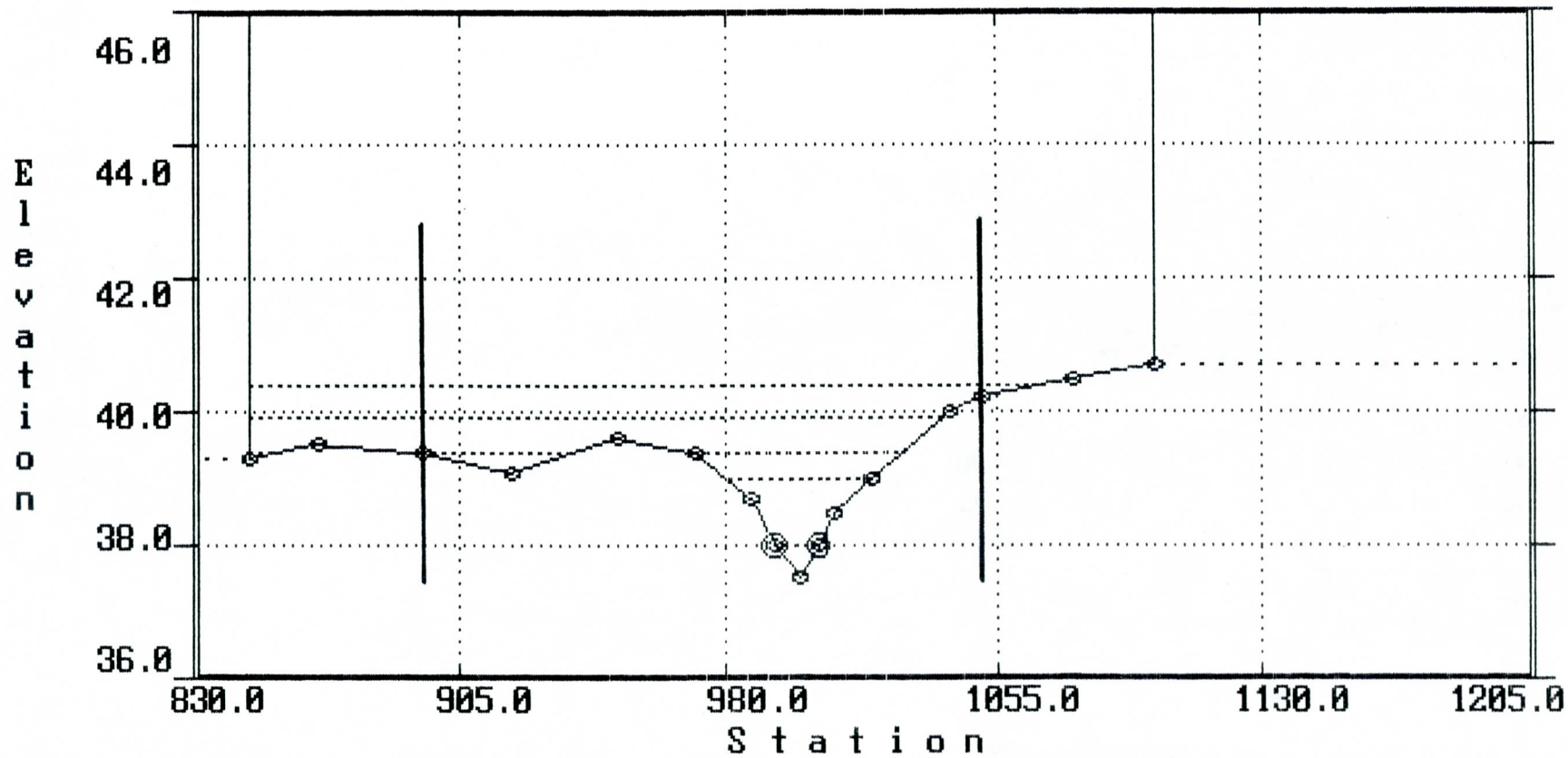
NOTES:

SECTION J

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 38.0 Q= 9.1cfs V= 3.0fps WSEL= 39.9 Q= 585.6cfs V= 4.1fps
WSEL= 39.0 Q= 119.5cfs V= 4.6fps WSEL= 40.4 Q= 1303.1cfs V= 5.3fps
WSEL= 39.4 Q= 176.3cfs V= 3.4fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0167



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Project FIRM
Project No.
Sheet No. 11 of 92
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section K - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECK2.SEC

No. of Cross Section Points:	14	Bed Slope:	0.01680	Max Elev:	40.2
Bank Stations.....Left:	993.0	Right....:	1010.0	Min Elev:	38.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	948.0	2)	39.4	976.0	3)	38.6	993.0	4)	38.0	1000.0
5)	38.2	1010.0	6)	38.4	1021.0	7)	38.9	1047.0	8)	39.0	1073.0
9)	38.0	1086.0	10)	38.6	1098.0	11)	39.1	1108.0	12)	39.2	1125.0
13)	40.0	1142.0	14)	40.2	1200.0						

COMPUTED PARAMETERS:

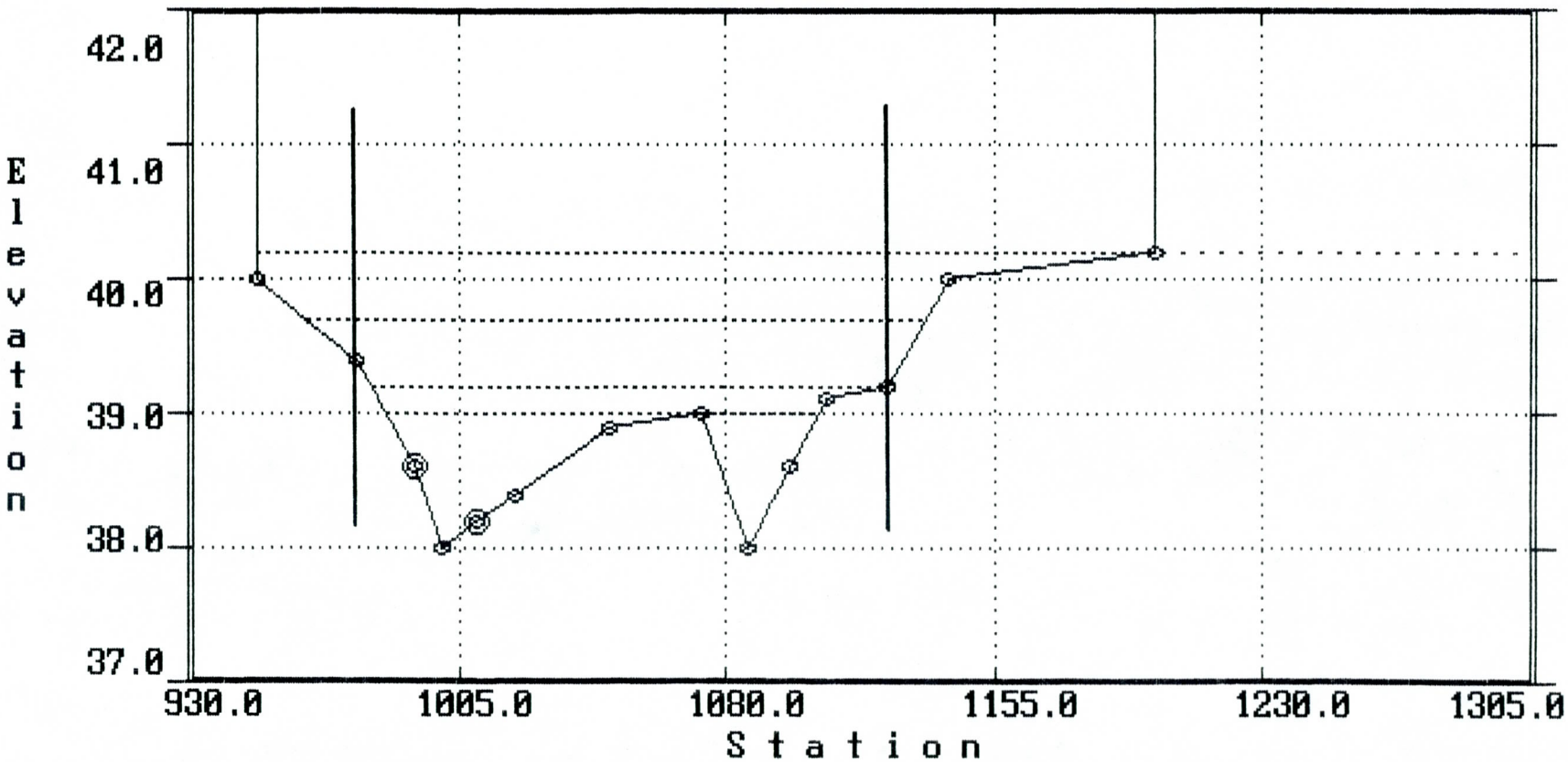
WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
39.00	148.2	3.0	0.809	0.036	0.4	121.5	50.2	121.6
39.20	258.7	3.4	0.827	0.037	0.5	144.8	76.1	144.9
39.70	732.7	4.7	0.882	0.038	0.9	173.6	154.9	173.8
40.20	1293.8	5.1	0.891	0.038	1.0	252.0	254.7	252.1

NOTES:

SECTION K

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 39.0 Q= 148.2cfs V= 3.0fps WSEL= 40.2 Q= 1293.8cfs V= 5.1fps
WSEL= 39.2 Q= 258.7cfs V= 3.4fps
WSEL= 39.7 Q= 732.7cfs V= 4.7fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0168



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Project_____
Project No._____
Sheet No._____ of_____
Calculated by_____ Date_____

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

CROSS SECTION PARAMETERS: FILENAME: SECL2.SEC

No. of Cross Section Points:	17	Bed Slope:	0.01360	Max Elev:	40.0
Bank Stations.....Left:	988.0	Right....:	1010.0	Min Elev:	39.6
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	39.9	857.0	2)	40.0	870.0	3)	40.0	888.0	4)	39.6	901.0
5)	39.8	912.0	6)	40.0	933.0	7)	40.0	958.0	8)	39.8	988.0
9)	39.8	1000.0	10)	39.9	1010.0	11)	40.0	1035.0	12)	39.9	1037.0
13)	40.0	1058.0	14)	39.9	1085.0	15)	39.8	1100.0	16)	39.7	1117.0
17)	40.0	1158.0									

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
40.00	35.9	1.1	0.562	0.038	0.1	258.0	31.9	258.0
40.50	582.3	3.2	0.722	0.039	0.6	301.0	182.4	301.0
41.00	1584.6	4.8	0.797	0.039	1.1	301.0	332.9	301.0

NOTES:

SECTION L

«««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 40.0 Q= 35.9cfs V= 1.1fps
WSEL= 40.5 Q= 582.3cfs V= 3.2fps
WSEL= 41.0 Q= 1584.6cfs V= 4.8fps
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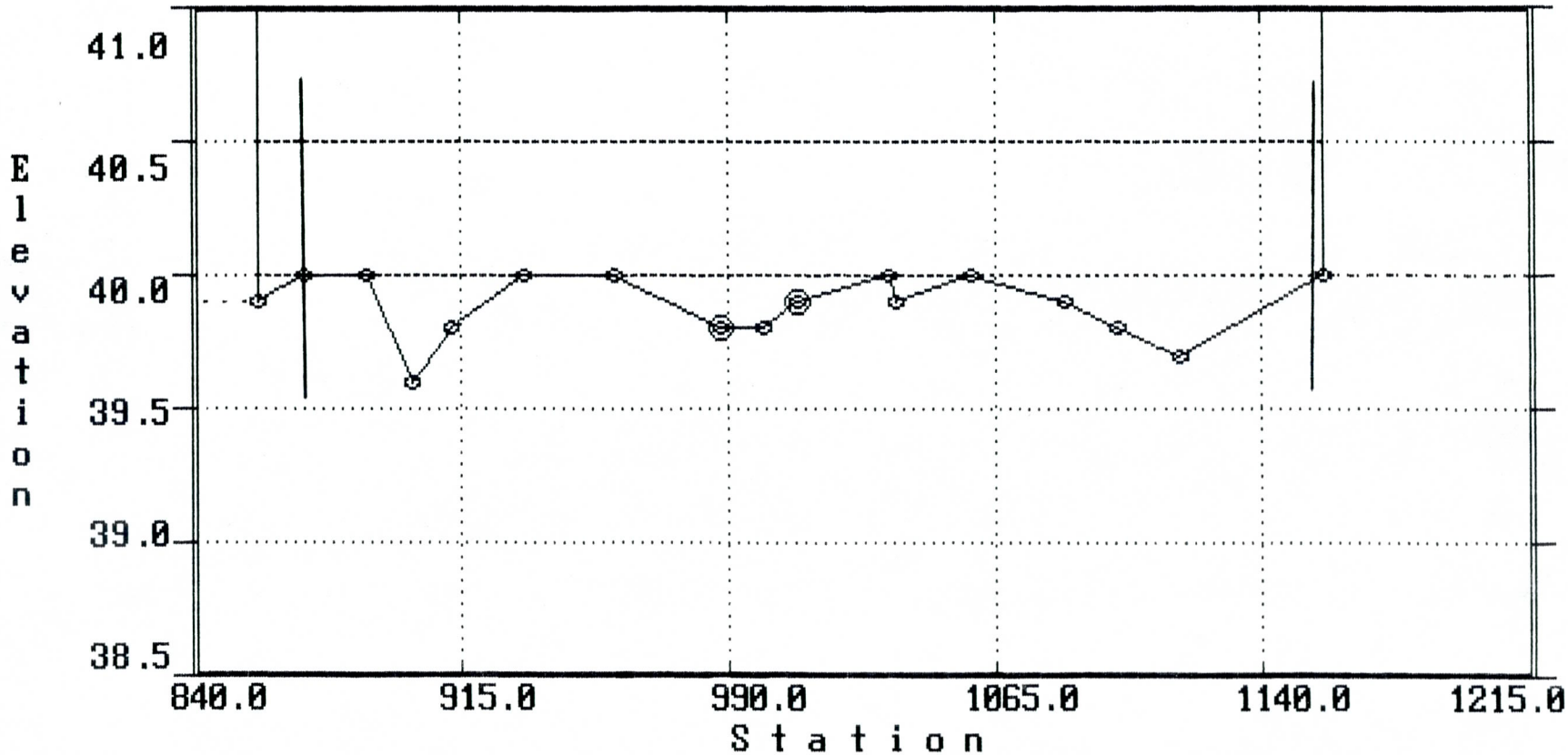

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Project FIRM
Project No.
Sheet No. 13 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section M - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECM2.SEC

No. of Cross Section Points:	14	Bed Slope:	0.02110	Max Elev:	40.3
Bank Stations.....Left:	993.0	Right....:	1005.0	Min Elev:	37.9
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.2	942.0	2)	40.1	958.0	3)	40.0	972.0	4)	39.0	988.0
5)	38.0	993.0	6)	37.9	1000.0	7)	38.0	1005.0	8)	38.9	1012.0
9)	39.8	1024.0	10)	39.9	1042.0	11)	40.0	1055.0	12)	40.1	1071.0
13)	40.2	1100.0	14)	40.3	1121.0						

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
38.00	0.7	1.2	0.923	0.025	0.0	12.0	0.6	12.0
39.00	110.8	5.8	1.185	0.030	0.8	25.3	19.0	25.5
40.00	320.0	5.2	1.050	0.034	0.7	83.0	62.1	83.2
40.50	678.0	4.9	0.985	0.037	0.8	179.0	138.1	179.2
41.00	1524.1	6.7	1.047	0.038	1.3	179.0	227.6	179.2

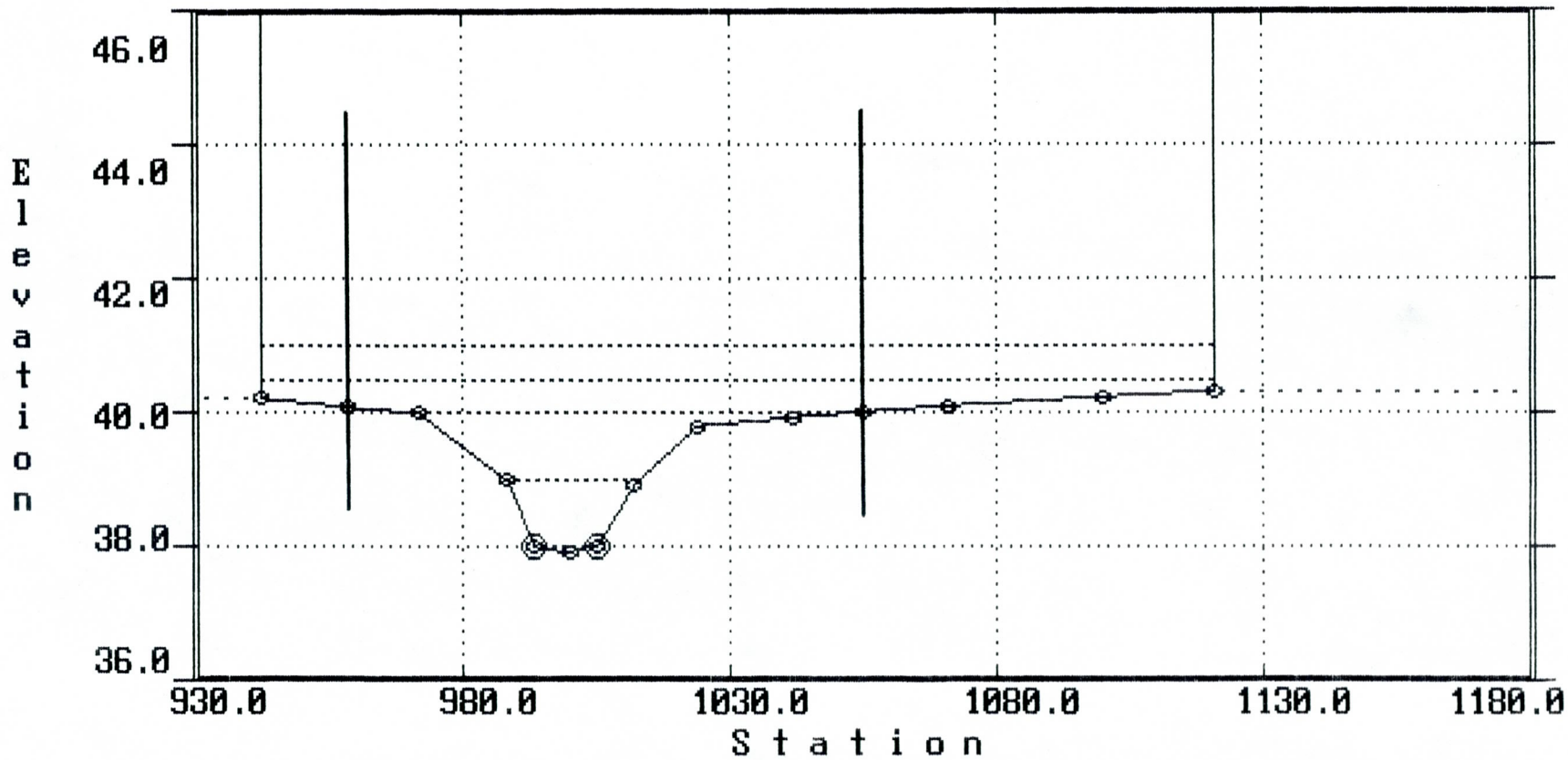
NOTES:

SECTION M

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 38.0 Q= 0.7cfs V= 1.2fps WSEL= 40.5 Q= 678.0cfs V= 4.9fps
WSEL= 39.0 Q= 110.8cfs V= 5.8fps WSEL= 41.0 Q= 1524.1cfs V= 6.7fps
WSEL= 40.0 Q= 320.0cfs V= 5.2fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0211



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Project FIRM
Project No.
Sheet No. 14 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section N - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECN2.SEC

No. of Cross Section Points:	20	Bed Slope:	0.02430	Max Elev:	42.1
Bank Stations.....Left:	995.0	Right....:	1004.0	Min Elev:	37.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	42.1	920.0	2)	42.0	930.0	3)	40.9	962.0	4)	40.0	980.0
5)	38.0	995.0	6)	37.0	1000.0	7)	38.0	1004.0	8)	37.8	1012.0
9)	38.0	1016.0	10)	38.7	1025.0	11)	38.0	1037.0	12)	37.9	1047.0
13)	38.0	1058.0	14)	37.4	1068.0	15)	37.5	1078.0	16)	38.0	1094.0
17)	39.3	1108.0	18)	39.4	1123.0	19)	39.6	1143.0	20)	40.0	1168.0

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
38.00	47.6	2.5	0.877	0.037	0.2	78.0	19.2	78.3
39.00	732.4	6.1	1.063	0.038	1.0	117.3	120.0	117.7
39.40	1156.0	6.8	1.090	0.039	1.2	138.5	169.1	139.0
39.90	1847.8	7.4	1.108	0.039	1.4	181.0	250.1	181.5
40.40	2989.2	8.7	1.149	0.039	1.8	196.0	345.4	196.5

NOTES:

SECTION N

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»

Project FIRM
Project No.
Sheet No. 15 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section O - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECO2.SEC

No. of Cross Section Points:	11	Bed Slope:	0.01730	Max Elev:	40.0
Bank Stations.....Left:	980.0	Right....:	1025.0	Min Elev:	38.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	40.0	908.0	2)	39.7	937.0	3)	39.6	952.0	4)	39.4	980.0
5)	38.0	1000.0	6)	38.1	1007.0	7)	39.3	1025.0	8)	39.3	1046.0
9)	39.3	1065.0	10)	39.0	1088.0	11)	38.4	1112.0			

COMPUTED PARAMETERS:

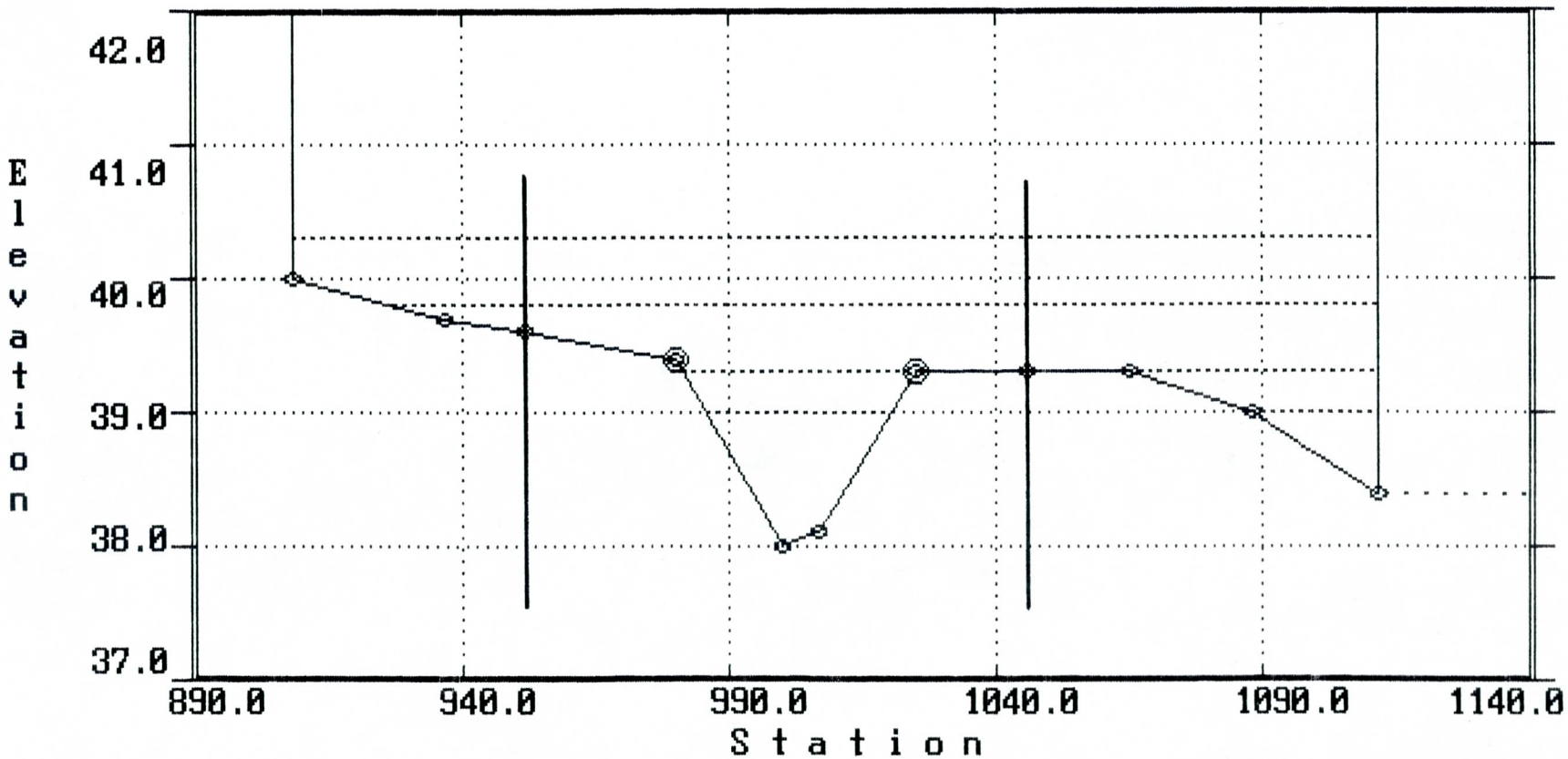
WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
39.00	107.4	4.0	1.030	0.029	0.5	58.8	27.1	58.9
39.30	209.4	4.2	1.009	0.031	0.5	90.6	49.5	90.7
39.80	565.0	4.5	0.951	0.034	0.7	184.7	126.5	184.8
40.30	1345.2	5.9	0.993	0.035	1.1	204.0	226.6	204.1

NOTES:

SECTION O

«««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 39.0 Q= 107.4cfs V= 4.0fps WSEL= 40.3 Q= 1345.2cfs V= 5.9fps
WSEL= 39.3 Q= 209.4cfs V= 4.2fps
WSEL= 39.8 Q= 565.0cfs V= 4.5fps
Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0173



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Project FIRM
Project No.
Sheet No. 16 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section P - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECP2.SEC

No. of Cross Section Points:	13	Bed Slope:	0.01720	Max Elev:	42.0
Bank Stations.....Left:	992.0	Right....:	1008.0	Min Elev:	39.8
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	41.1	947.0	2)	42.0	968.0	3)	41.9	986.0	4)	40.0	992.0
5)	39.8	1000.0	6)	40.0	1008.0	7)	40.9	1012.0	8)	42.0	1022.0
9)	42.0	1040.0	10)	40.0	1053.0	11)	39.9	1068.0	12)	40.0	1089.0
13)	42.0	1111.0									

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
40.00	4.0	1.0	0.682	0.033	0.1	52.0	3.8	52.0
41.00	335.8	4.9	0.922	0.036	0.9	77.6	68.4	78.0
42.00	991.6	5.8	0.943	0.037	1.2	146.0	171.1	146.7
42.50	1741.4	6.9	0.976	0.038	1.5	164.0	253.1	164.7
43.00	2762.7	8.2	1.016	0.038	2.0	164.0	335.1	164.7

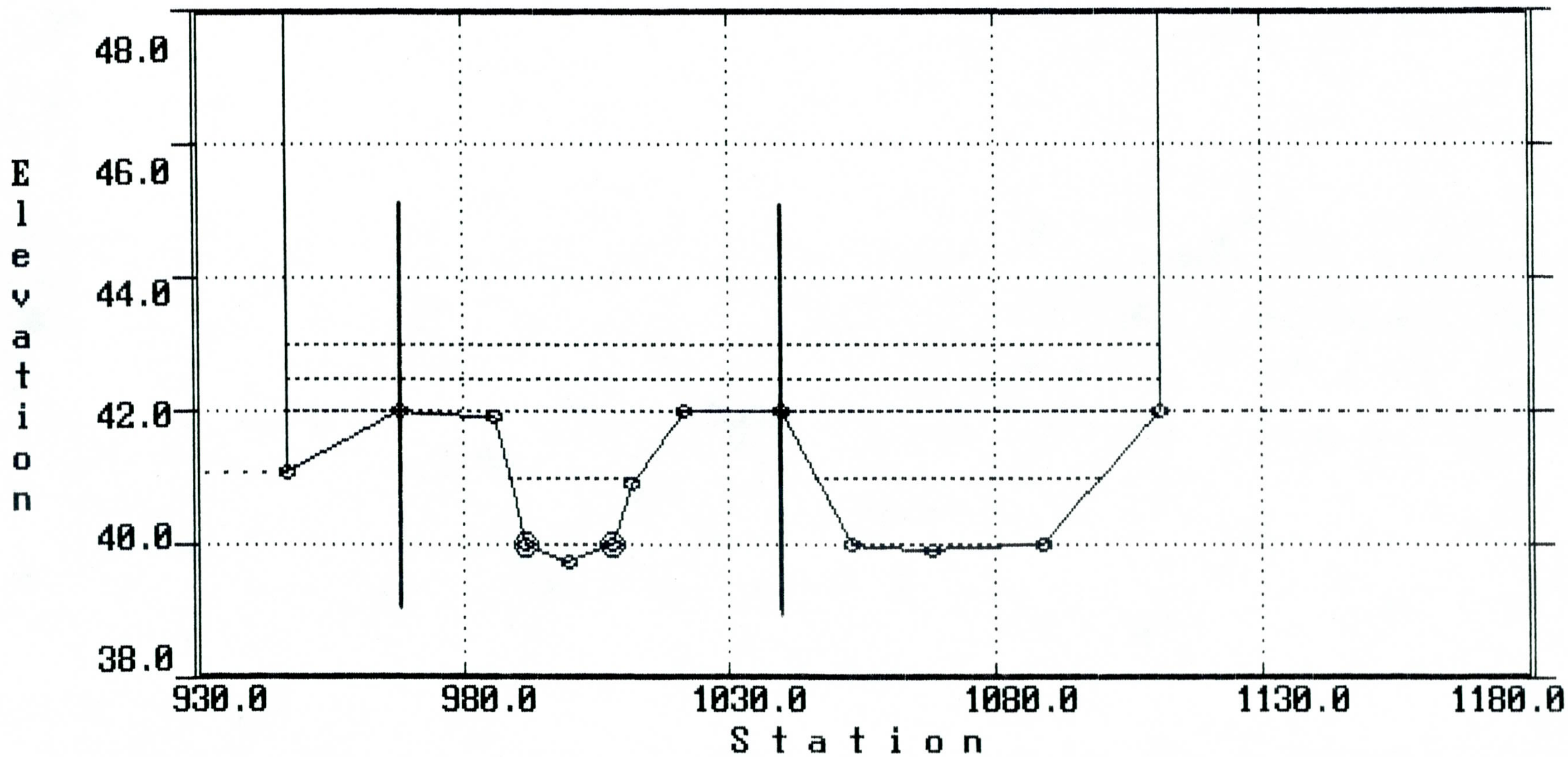
NOTES:

SECTION P

««««««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

WSEL= 40.0 Q= 4.0cfs V= 1.0fps WSEL= 42.5 Q= 1741.4cfs V= 6.9fps
WSEL= 41.0 Q= 335.8cfs V= 4.9fps WSEL= 43.0 Q= 2762.7cfs V= 8.2fps
WSEL= 42.0 Q= 991.6cfs V= 5.8fps

Manning-n Values...LOB: 0.040 CHANNEL: 0.025 ROB: 0.040 SLOPE = 0.0172



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Project FIRM
Project No.
Sheet No. 17 of 17
Calculated by DWD Date 2/92

UNIFORM FLOW COMPUTATIONS

LOCATION/DESCRIPTION:

Section Q - Plate 1

CROSS SECTION PARAMETERS: FILENAME: SECQ2.SEC

No. of Cross Section Points:	12	Bed Slope:	0.01440	Max Elev:	42.7
Bank Stations.....Left:	1000.0	Right....:	1012.0	Min Elev:	38.0
Encroachment Stations..Left:		Right....:			
Manning-n Values.....LOB:	0.040	CHANNEL..:	0.025	ROB.....:	0.040

CROSS SECTION POINTS:

No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.	No.	Elev.	Sta.
1)	42.7	930.0	2)	42.5	942.0	3)	42.0	962.0	4)	41.2	970.0
5)	40.0	980.0	6)	38.0	1000.0	7)	38.2	1012.0	8)	38.8	1022.0
9)	39.7	1033.0	10)	39.4	1057.0	11)	39.1	1082.0	12)	38.6	1104.0

COMPUTED PARAMETERS:

WSEL	Q(cfs)	V(fps)	Fr No.	ne	D(ft)	TW(ft)	A(sf)	WP(ft)
39.00	78.4	3.2	0.819	0.034	0.5	52.0	24.6	52.1
39.70	319.3	3.8	0.802	0.037	0.7	121.0	84.2	121.2
40.20	762.6	5.2	0.855	0.038	1.2	125.7	145.9	125.8
40.70	1354.8	6.5	0.896	0.038	1.6	129.8	209.7	130.0

NOTES:

SECTION Q

««««««««««««««««««««««««««««««««« CROSS SECTION PLOT »»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»»

```
WSEL=    39.0 Q=     78.4cfs V=  3.2fps WSEL=    40.7 Q=   1354.8cfs V=  6.5fps
WSEL=    39.7 Q=    319.3cfs V=  3.8fps
WSEL=    40.2 Q=    762.6cfs V=  5.2fps
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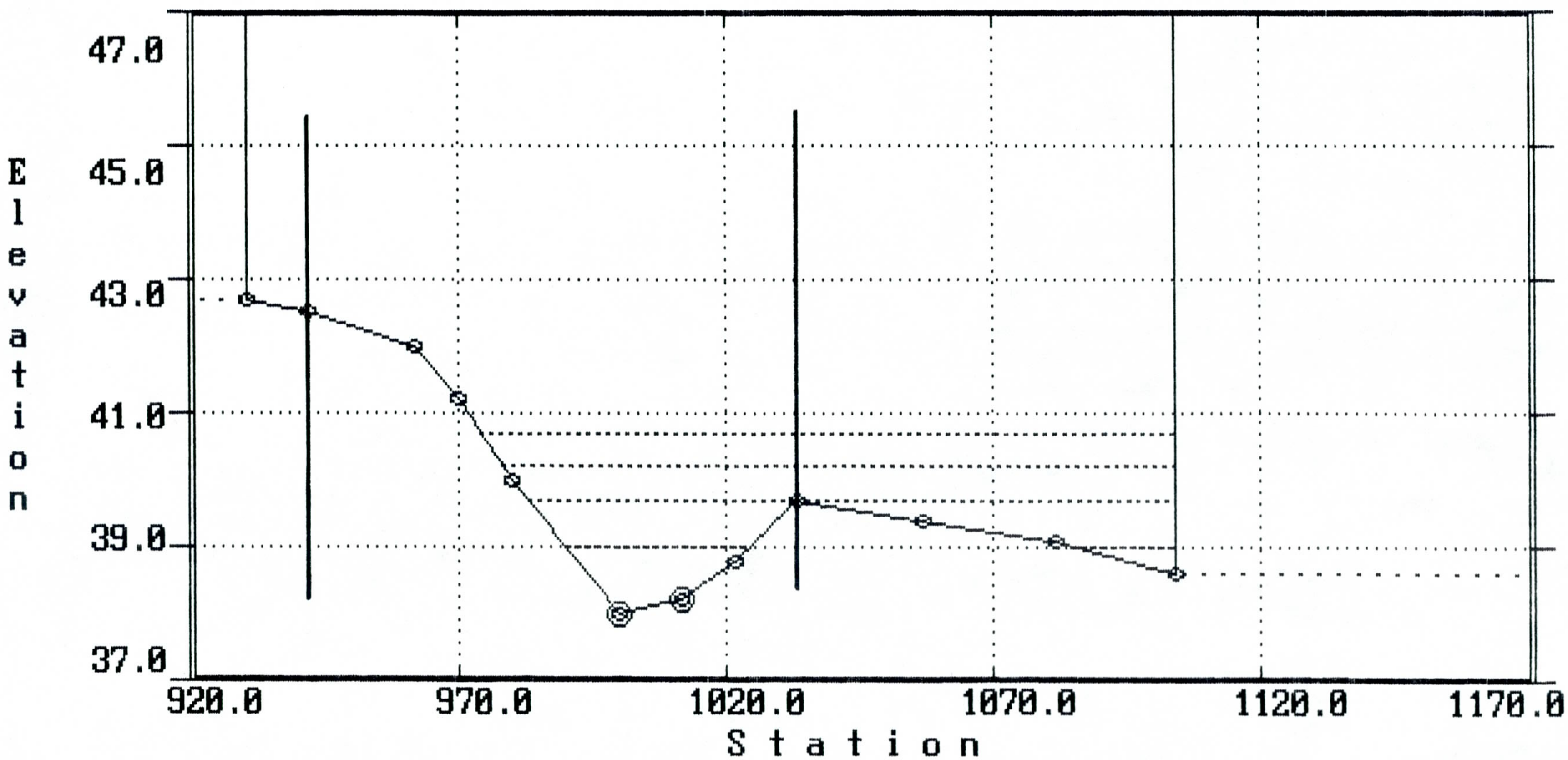

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APPENDIX C

REFERENCED CORRESPONDENCE

2075 North Sixth Avenue
Tucson, Arizona 85705
(602) 624-7401

CELLA BARR ASSOCIATES

January 30, 1989

FEB 03 '89

Mr. Ray Lenaburg
Federal Emergency Management Agency
Region IX, Building 105
Presidio of San Francisco
San Francisco, California 94129

Re: **Hydrologic Analyses for Alluvial Fans in Scottsdale, Arizona**
Maricopa County Flood Insurance Study
Contract EMW-88-C-2603
CBA File No. 04856-02-79

Dear Ray:

Please find enclosed our response to the Technical Evaluation Contractor (TEC), Michael Baker, Jr., Inc.'s review comments pertaining to the hydrologic study performed by CBA for the Scottsdale Alluvial Fan Flood Insurance Study. This response has been prepared in accordance with the results of our meeting held on December 19, 1988 to discuss the comments. We very much appreciate the effort that you made to meet with us on this project.

For your information, also attached are copies of the following materials: 1) the response letter to the Maricopa County Flood Control District addressing the District's review comments pertaining to the hydrologic study; and 2) a copy of the Addendum to the hydrologic study containing the proposed revisions and the accompanying cover letter to the remaining review agencies.

Again Ray, thank you for your input to this study. At this time we are proceeding with the hydraulic modeling of the designated six alluvial fans in the study area. Please do not hesitate to call me if you have any questions or need further information.

Sincerely yours,

CELLA BARR ASSOCIATES

Marie S. Pearthree

Marie S. Pearthree
Project Manager, Hydrology Services

Bori A. Touray

Bori Touray
Project Hydrologist

MSPsdh

Enclosure

xc: Mr. Jim Nelson, CBA
Mr. John Wise, CBA

RESPONSE TO REVIEW COMMENTS CONCERNING
CBA REPORT ENTITLED "HYDROLOGIC ANALYSIS OF
SCOTTSDALE ALLUVIAL FANS 1-6, MARICOPA COUNTY, ARIZONA"
CBA File No. 04856-02-74/BAT-123

Introduction

Since receiving review comments on the report entitled "Hydrologic Analysis of Scottsdale Alluvial Fans 1-6, Maricopa County, Arizona" from the Technical Evaluation Contractor, Michael Baker, Jr., Inc. on November 7, 1988, a detailed field survey of the study area was conducted and a meeting was held with the Federal Emergency Management Agency (FEMA) Project Officer for Region IX, Mr. Ray Lenaburg, on December 19, 1988. The outcome of the field survey and the agreements reached at the meeting are presented below in response to the review comments.

General

Comment:

The flood-frequency curves defined by the rainfall-runoff models predict discharge values. For the more frequent floods, they seem too high. For example, the flood-frequency curve for Alluvial Fan Number 1 predicts a two-year flood discharge of 400 cubic feet per second (cfs). The drainage area above the apex of Alluvial Fan Number 1 is approximately 1.8 square miles. The regional equation developed by the U.S. Geological Survey (USGS) for this area predicts a two-year flood discharge of approximately 60 cfs. That value was estimated with a mean basin elevation of 2,500 feet and a mean annual precipitation of 12 inches. The flood-frequency curve for Alluvial Fan Number 2 predicts a two-year flood discharge of 1,700 cfs. The USGS regional equation, using the mean basin elevation and mean annual precipitation mentioned above and a drainage area of 8.26 square miles, predicts a two-year flood discharge of approximately 175 cfs for Alluvial Fan Number 2.

Response:

The FEMA document entitled, "Guidelines and Specifications for Study Contractors," dated September 1985, directs the study contractor to use any valid existing flood flow frequency analysis conducted by a Federal, State or local agency that authoritatively establishes the discharges for an ungauged stream under consideration. These guidelines are contained in Section 2-6. The local agency, namely City of Scottsdale, commissioned a hydrologic and hydraulic analysis in 1987-88 of the total area contained within the Scottsdale city limits, including the present Flood Insurance Study (FIS) area. This analysis included detailed modeling of existing flooding conditions utilizing the Army Corps of Engineers' HEC-1 computer model. Upon

completion of this model by Robert L. Ward, P.E., Consulting Engineer and a thorough review by the City of Scottsdale, the City accepted the discharges computed by the model. The City specifically requested that these discharges be employed in the present FIS for consistency between the Flood Insurance Rate Maps that will result from the FIS and the master drainage plan being prepared for the City of Scottsdale by Water Resources Associates and their subcontractor, Robert L. Ward. For this reason, and in accordance with the guidelines stated above from FEMA, the discharges resulting from the HEC-1 model prepared for the City of Scottsdale were employed in the present FIS.

The regional equations developed by the U.S. Geological Survey (USGS) represent average conditions for the entire region. Because the equations are a result of statistical analysis, they are biased towards areas whose basin characteristics fall within the range of values used for generating the equations. The regression equations relate the peak discharges to basin area, mean basin elevation and mean annual precipitation. Though these characteristics were the only ones found to be statistically significant for the given region, according to ADOT-RS-15(121) Final Report, many analytical techniques show that the time of concentration, or basin lag time, and soil type also play major roles in determining peak discharges.

Data obtained from the Agricultural Research Service of the U.S. Department of Agriculture (USDA) indicate that the discharges computed for the study area by the HEC-1 model are possible for desert regions. For example, a statistical analysis of small watersheds in southeastern Arizona indicates that a two-square mile area can generate a flow of approximately 380 cfs for the two-year flood event (Lane 1985; see the attached reference). This compares very well with the calculated discharge of 400 cfs for a 1.8-square mile drainage area for the same frequency.

Although Section 2-6 of the FEMA guidelines directs the study contractor to use any valid flood flow frequency analysis, Appendix A5-4a states that flows should be computed from appropriate regional methods. These two directives contradict each other. Although the USGS regional equations exist for the area, it is not advisable to use them according to Arizona Department of Transportation (ADOT) staff (see the attached memorandum from George Lopez-Cepero, ADOT). The ADOT experience is that the discharges obtained by the regression analysis are considerably less than measured discharges for the streams that were studied.

The Scope of Work prepared for this FIS and accepted by FEMA proposed that the Soil Conservation Service (SCS) TR-55, SCS TR-20 or HEC-1 computer models be used to calculate the discharges, with concurrence from the community and the FEMA Project Officer. At the Time and Cost meetings held in Phoenix, Arizona, for the entire Maricopa

County FIS, it was noted that a HEC-1 model was available for the study area and should be used. The FEMA Project Officer, Mr. Ray Lenaburg, agreed with the utilization of this model to compute discharges for the Scottsdale Alluvial Fans.

Comment:

The six flood frequency curves are similar. Their standard deviations range from 0.35 to 0.41. The USGS equations, when fit to a log-normal curve, yield a standard deviation of approximately 0.65. If the rainfall-runoff model predicts a reasonable 100-year flood discharge, then using too low of a standard deviation will result in overestimating the values of the more frequent flood discharges and underestimating the values of the less frequent flood discharges. Equivalently, overestimating the values of more frequent flood discharges will result in too low of a standard deviation. It seems that the method used by CBA to prepare the hydrologic report resulted in overestimating the values of the more frequent flood discharges.

Response:

Standard deviations for the proposed discharges, calculated by using the Log-Pearson Type III distribution described in the alluvial fan model, range from 0.37 to 0.53 with an average of 0.45. The standard deviations for the USGS equations range from 0.68 to 0.71 with an average of 0.70. One would expect that the standard deviation for the study area will be high due to variability of floods in semi-arid regions; however, analysis of available discharges in the region shows otherwise.

To gain further insight into the value of the standard deviation for this region, 172 streams with measured discharges were analyzed by CBA staff. The standard deviations for the resulting flood frequency curves range from 0.27 to 1.12 with an average of 0.58. On this basis, the standard deviations for the proposed FIS discharges appear to be reasonable.

Comment:

Delineating the drainage areas above the six apexes shown on the watershed map enclosed with the hydrologic report does not show the same drainage areas defined by CBA. Using the USGS 7.5-Minute Series topographic maps, we defined ten drainage areas and, therefore, 10 apexes, affecting the area. Many of those apexes were "upfan" from the apexes shown in the report. Some of them are in areas labeled "inactive area" on the watershed map, Figure 2.1 of the report. However, the topographic information and the hydrologic model itself indicate that floodflows can go in more than one

direction below the ten apexes that we have identified. CBA should keep in mind that before a point qualifies as an "apex" the modeler must determine that all runoff from the drainage area above that point passes through it, not just nearby.

Response:

According to the Scope of Work for this FIS, six alluvial fans are to be studied. Analysis of additional fan apices, if included in the study, would require a change in the Scope of Work and associated fees.

The "inactive areas" shown on Figure 2.1 are based on a detailed geomorphic study that included several field investigations, examination of current SCS soils maps, and study of aerial photographs and topographic maps. Additional field work was concluded recently, the purpose of which was to verify whether the mapped areas are "active" or "inactive" in terms of hydraulics. Apex locations have been modified accordingly. Floodflows from the contributing drainage areas above the fan apices will pass through the apex locations. Please refer to the following discussions of each alluvial fan for more detailed information concerning this topic.

<u>Alluvial Fan Number 1</u>

Comment:

Approximately 1.34 square miles drain to a point approximately one mile east of the apex of Alluvial Fan Number 1. That area is labeled Runoff Area 2070 on the watershed map. The alluvial fan below Apex Number 1 is subject to flooding from that additional 1.34-square mile area. Apparently, CBA does not intend to consider it in their analysis.

Response:

The argument is well noted. There is a potential for flow to breakover between the fan apex previously identified for Stream No. 1 and the stream channel system draining Runoff Area 2070. For this reason, CBA proposes to include Runoff Area 2070 in the analysis of Alluvial Fan Number 1. The discharge calculation has been revised to include the additional 1.34-square mile drainage area. At the direction of the FEMA Project Officer, the fan apex has been relocated midway between the two stream systems draining areas 2060 and 2070 at Concentration Point 2065A. The area upstream of the apex mapped as "active" will be labeled Zone A. Because of the two stream systems upstream of this apex, the applicability of the multiple

channel model was considered for the apex area. However, according to the FEMA guidelines and as discussed with Mr. Ed Mifflin from Michael Baker, Jr., Inc., the multiple channel model applies to areas where a single channel begins to break into multiple channels below the apex. Where a multiple channel cannot be identified, the canyon slope/fan slope ratio method as outlined in the FEMA guidelines should be used. The apex area does not satisfy the requirements for a multiple channel model; therefore this will not be utilized at Concentration Point C2051.

Comment:

A large area on the east side of the alluvial fan is labeled "inactive area". That area is shown on the soils map, Figure 2.2 of the report, as sandy loam - the same material that is in the "active area". The soils map does not show a boundary or different soil groups where the watershed map indicates a change, and the topographic map does not indicate a change across the boundary. In other words, the area seems to be mislabeled and, in fact, subject to alluvial fan flooding.

Response:

The geomorphic study performed specifically for this FIS indicates that the SCS soil mapping may not be accurate in this area, based on the characteristics of the soils and amount of dissection of the topography. After further field study of this area, it was determined that a small strip of the area can be subject to alluvial fan flooding even though the soils might not show recent flooding (see Figure 1). The rest of the area to the east, which will remain mapped as an "inactive" area, will be delineated as Zone A.

<u>Alluvial Fan Number 2</u>

Comment:

Approximately 1.01 square miles drain to a point approximately 0.8 mile south of Apex Number 2. That area is composed of Runoff Areas 2000, 2005, and 2010 shown on the watershed map. The concentration point (CP) for that drainage area is labeled 2012 in the hydrologic model. However, because of the diversion modeled above CP 2004, the HEC-1 output cannot be used to estimate flows at CP 2012. Doing so would imply that the amount of flow traversing Alluvial Fan Number 2 by way of CP 2012 is predictable. That is contrary to the Alluvial Fan Methodology. The east side of Alluvial Fan Number 2 is subject to flooding from CP 2012. Therefore, it seems that CBA should consider that additional 1.01-square mile drainage area when analyzing Alluvial Fan Number 2.

Response:

The apex of Alluvial Fan Number 2 is located at C51 where Diversion 2004 occurs. Flows from Runoff Areas 2000, 2005 and 2010 concentrate at CP 2012, which is 0.8 miles south of the apex. The USGS topographic map and aerial photographs indicate that the flows concentrating at CP 2012 cannot pass through the apex of Alluvial Fan Number 2. The map and photos further indicate that CP 2012 is a secondary apex. The area drained by the stream at this apex is only one square mile, and since the apex and downstream fan area are located within the boundaries of Alluvial Fan 2, the FEMA Project Officer directed that only the primary fan (Alluvial Fan 2) be modeled. The resulting depths and velocities from this fan will override those of the secondary fan. The difference in drainage area size and length of channel contributing runoff to Alluvial Fan 2 and the secondary fan apex suggests that the peak discharge from the secondary fan will pass long before that of the primary fan; hence the secondary fan will have a negligible influence on the primary fan.

Comment:

An area on the east side of Alluvial Fan Number 2, in Section 17 of Township (T.) 4 North (N.), Range (R.) 5 East (E.), is labeled as clay loam on the soils map. Although this type of soil indicates that the area may not be subject to alluvial fan flooding, the topographic map does not show a barrier to floodflow that would indicate that the area is not subject to alluvial fan flooding. Analysis of the flood risk in this area may require an onsite inspection to resolve this apparent discrepancy.

Response:

An onsite inspection of the area has been carried out. A significant topographic ridge, 10 to 15 feet high, exists along the boundary of the inactive area downstream of the apex. This ridge gradually fades in the upstream direction towards the fan apex. Based on the field inspection, it is our professional opinion that this area is potentially subject to flooding from minor interior watersheds, although not subject to alluvial fan processes of erosion and deposition. The FEMA Project Officer agreed that this area should be labeled as a Zone A.

Alluvial Fan Number 3

Comment:

Not all of the runoff from Runoff Area 35 of the watershed map flows through Apex Number 3. For example, it seems that runoff from

Pinnacle Peak would travel west of the apex. We delineated the drainage area boundary above Apex Number 3 on the USGS topographic map and measured an area of 0.44 square mile. CBA proposes to use a drainage area of 1.29 square miles.

Response:

We concur with this comment. The HEC-1 model has been revised to reflect the change in area. Field reconnaissance shows that the apex for Alluvial Fan Number 3 is at Alma School Road approximately one-third of a mile south of Jomax Road. The upstream drainage area is approximately 0.51 square mile.

Comment:

An area on the east side of the alluvial fan is labeled "inactive" on the watershed map. The soils map and the shape of the contours indicate that this area may not be subject to alluvial fan flooding. However, the topographic map does not show a barrier to flow that would keep floodwaters from Apex Number 3 from entering this area. Analysis of the flood risk in this area may require an onsite investigation to resolve this apparent discrepancy.

Response:

An onsite investigation has been carried out confirming that the area on the east side of the alluvial fan is "inactive". Channels are incised within this area, resulting in a general topographic ridge of 9 to 10 feet between the active and inactive area. The area is, therefore, not subject to alluvial fan processes, but does appear to be subject to some potential flooding from the local watersheds. At the direction of the FEMA Project Officer, this area will be delineated as a Zone A.

<u>Alluvial Fan Number 4</u>

Comment:

We delineated the drainage area boundary on the USGS topographic maps and measured a drainage area of 9.19 square miles. CBA listed a drainage area of 14.02 square miles for Apex Number 4 in Table 3.5 of their report. The topographic maps indicate that approximately 2.15 square miles, composed of Runoff Areas 22, 23, and 24, drain to a point approximately two miles northeast of Apex Number 4. That point is labeled C24 on the watershed map.

Flows from that point do not necessarily travel to Apex Number 4 as modeled. In fact, the USGS topographic map, Currys Corner, shows a flow path from CP C24 that is at least 500 feet east of Apex

Number 4. That same flow path can convey flood water from Runoff Areas 25 and 26 and part of Runoff Area 21. Those areas should not be included in the drainage area for Apex Number 4; however, they are included in that drainage area in the hydrologic model used by CBA.

Response:

The drainage area upstream of the apex of Alluvial Fan Number 4 (Concentration Point C27) is approximately 9.3 square miles if Runoff Areas 22, 23 and 24 are excluded. These areas (22, 23 and 24) drain to C24 to the east. Although the USGS topographic map indicates that the flow from C24 does not reach C27, aerial photographic mapping at a scale of one (1) inch = 400 feet dated September 1988, shows that runoff generated by areas 22, 23 and 24 primarily flows to the apex of Alluvial Fan Number 4. The apex location for this fan has also been moved northward to the location where runoff from C24 flows into the stream channel for Alluvial Fan Number 4. Aerial photographs indicate an obvious fan apex at this location. The HEC-1 model has also been revised to reflect the areas contributing flow to this Concentration Point.

Two finger-shaped active areas, one starting at Concentration Point C19C and the other starting in the middle of Area 22, join at a point just upstream of Concentration Point C27. The combined "active" areas continue as a narrow band to the apex of Alluvial Fan 4 at C27. The finger-shaped active areas upstream of the apex will be modeled using discharges at the upstream ends of these areas (at C19C and C22A).

The "active" and "inactive" areas are separated by distinct topographic boundaries both along the east and west sides of the "active" area. Due to potential for flooding from local watersheds, portions of the "inactive" areas will be delineated as Zone A or Zone X up to where contributing drainage areas are less than one square mile.

<u>Alluvial Fan Number 5</u>

Comment:

The USGS topographic map and the hydrologic model indicate that the apex of this alluvial fan is approximately 3.5 miles northeast of Apex Number 5 shown on the watershed map. That point is the diversion modeled at CP 1481 on the watershed map. The area directly below that point is labeled "inactive" on the watershed map. However, as "diversion" implies, flows can take different paths below this point. The line labeled Stream Number 5 on the watershed map traverses the "inactive" area. It seems that a more detailed analysis of this area is needed. Resolving the apparent contradiction between the soils and topographic information may require an onsite investigation.

Response:

A more detailed analysis of this area has been carried out in the field. Between the diversion at C1481, which is near Lone Mountain, to S1500 exist two finger-shaped "active" areas and a large "inactive" area, which consists of braided channel systems within dissected topography containing old (Pleistocene-age) soils. Based on the field survey and input from the FEMA Project Officer, the apex will be located at Concentration Point C1481, and narrow alluvial fans will be modeled within the two finger-shaped "active" areas. At the direction of the FEMA Project Officer, one cone-shaped fan will be modeled beginning at a location between Dynamite Road and Dixileta Drive at the limit of the "inactive" area (see Figure 1). This cone-shaped fan will be modeled from this location through the "active" area to the southern limit of the study area. The discharge at CP 1481 will be used to delineate the finger-shaped alluvial fans between Lone Mountain and the active cone area. The discharge at Concentration Point C1500A will be used for the rest of the downstream fan. Adjacent "inactive" areas will be delineated as Zone A.

Comment:

Apex Number 5 is apparently modeled as a concentration point for Runoff Area 1500 on the watershed map. That runoff area does not have a concentration point. Runoff from Runoff Area 1500 will be spread over the entire width of the area. At the elevation of Apex Number 5, runoff will be spread over a width of approximately 3,000 feet. There does not seem to be any point below CP 1481 where the flow would be concentrated. That is, Apex Number 5 seems to be on the alluvial fan surface.

Response:

Stream No. 5 was originally chosen for study primarily on the basis of the USGS quad sheets. Based on the more thorough review of aerial photographs and soils maps and the field investigations performed since then, the apex location has been revised. As stated above, Apex Number 5 will be relocated to C1481 which is 3.5 miles northeast of the current location. Channel incisement downstream within the finger-shaped "active" areas is minimal and the geomorphic mapping indicates that these areas are potentially subject to fan processes. Placement of an alluvial fan apex at this location is conservative with regard to delineating downstream flooding and erosional hazards.

Alluvial Fan Number 6

Comment:

Our comments concerning this fan are similar to those concerning Alluvial Fan Number 5. We delineated the boundaries of various drainage areas on the topographic maps. Those delineations indicated that two concentration points should be modeled as alluvial fan apexes. Those points are approximately 4.0 and 5.5 miles northeast of Apex Number 6 shown on the watershed map. The concentration points are labeled int he hydrologic model as C1390 and C1441. They are in sections 14 and 12, respectively, of T.5N., R.4E.

Response:

Concentration Points C1390 and C1441 were examined in the field. They are both located in dissected "inactive" areas with bedrock close to the surface and contained within channel banks. Except for narrow alluvial channels, the areas below these points are not subject to alluvial fan flooding; however, at the direction of the FEMA Project Officer, these areas will be labeled Zone A as they are potentially subject to general flooding conditions.

Comment:

A flow path is shown on the USGS topographic map, Cave Creek, from the apex at C1390 to a point on the 1,880-foot contour line approximately 6,500 feet west of Apex Number 6, also on the 1,880-foot contour line. That path is through an area labeled "inactive" on the watershed map. The line labeled "Stream Number 6" is also in the "inactive" area.

A small "strip" of "active area" is shown on the watershed map. That "strip" runs between the apex at C1441 and a point on the 1,880-foot contour line approximately 2,000 feet southeast of Apex Number 6.

There are also flow paths from both Cp C1390 and CP C1441 that pass through Apex Number 6. It would seem, therefore, that Apex Number 6 is in an area of coalescent alluvial fans, approximately five miles below their apexes.

Response:

Based on field inspection and a detailed review of aerial photographs and input from the FEMA Project Officer, the apex for Alluvial Fan Number 6 will be relocated to a point just north of Dixileta Drive in Runoff Area 1460 (Concentration Point 1460A). This apex is located within the small "strip" of active area, along a stream of much

greater significance with regard to conveyance of flow than that originally chosen for study. Aerial photographs also show an existing flow split at this location.

An additional fan apex will also be located at the northernmost limit of the "active" areas upstream. Adjacent inactive areas will be mapped as Zone A. The discharge at C1441 will be used to model the downstream "active" strip of alluvial fan between C1441 and C1460A.

Federal Emergency Management Agency

Washington, D.C. 20472

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Mr. Joe Tram
Floodplain Branch Manager
Maricopa County Flood Control District
3335 West Durango Street
Phoenix, Arizona 85009

Dear Mr. Tram:

This is in response to your letter, dated January 5, 1990, regarding the use of our alluvial fan flooding methodology in the area that you refer to as **"the Scottsdale area."** In particular, you asked questions in a list of 10 items. In your letter, you refer to an enclosed map that was prepared by the U.S. Geological Survey (USGS) and entitled "Map Showing Distribution and Estimated Thickness of Alluvial Deposits in the Phoenix Area, Arizona." You also refer to the U.S. Soil Conservation Service (SCS) report that was the subject of your letter to us dated August 30, 1989, and a document handed out at the Alluvial Fan Short Course presented at the 13th Annual Conference of the Association of State Floodplain Managers, Inc.

Although our review of the study for the Scottsdale area has not been completed, we have attempted to answer your questions below. The questions are highlighted, and they appear in the order in which they were asked in your letter.

1.) Based upon SCS and USGS there is minimal source of alluvium. As such, how can the model be applied?

The alluvial fan flooding "methodology" is very site-specific. When the flowpaths below a certain point (apex) are unpredictable, the inherent uncertainty must be taken into account when defining the 100-year flood. Applying the methodology is the appropriate way to account for that uncertainty. The lack of a "significant" sediment source in the mountain watershed does not render flowpaths predictable and, therefore, does not preclude the use of the methodology. Because we are still looking into the site-specific conditions, we cannot comment on how the fans will be modeled at this time.

The paragraph that precedes Item 1 in your letter indicates that you believe that because the USGS map shows the watershed as consolidated rock, there is no significant sediment source, and thus the methodology does not apply. As noted above, the lack of a significant sediment source does not preclude the use of the methodology.

We believe, however, that the watersheds are a source of sediment. Consider 1 square mile of one of the mountain watersheds with a 1/2-inch deep sediment layer over consolidated rock. That 1 square mile can be shown on the USGS map within one of the following categories:

1. Alluvium more than 1,200 feet thick
2. Alluvium 800 to 1,200 feet thick
3. Alluvium 400 to 800 feet thick
4. Alluvium less than 400 feet thick
5. Consolidated Rock

Given these choices, one would choose category 5, consolidated rock. However, note that the 1 square mile has more than 1 million cubic feet of sediment available for transport -- a very significant amount.

The SCS report describes the soils in the mountain watersheds as sand and gravel, 10 to 20 inches deep -- significantly more than our 1/2-inch example. Page 54 of the SCS report contains a photograph showing how the area looks. The sediment source is evident in that photograph.

2.) The model assumes independent events, but does not allow the runoff to spread over the area. Water cannot flow 2-5 miles longitudinally at velocities of 7 feet per second at depths of 2 to 3 feet in an unconfined channel without spreading out. The model uses artificial channel banks to contain flows and generate artificially high elevations instead of having flow spreading uniformly over the land. Is this realistic?

Flows do not spread out across the entire alluvial fan. The methodology was first proposed by Dawdy in 1979 because, as he wrote,

> Flows rarely spread evenly over the surface of an alluvial fan. Typically, flow is concentrated in an identifiable temporary channel, or it is confined to only portions of the fan surface.

Item 2 continues as follows:

Based upon sheetflow conditions, with no bank containment, runoff would not attain these heights or depths but would spread until it is contained at unspecified widths weiring over calcified or silicated soil banks. Why doesn't the model address this?

The highly erosive nature of alluvial fan flooding coupled with the loose, unconsolidated material that makes up the fan result in floodflows forming their own "temporary channel" (see above). Modeling the topography as a rigid boundary would be contrary to the actual field conditions.

3.) The model assumes when avulsions occur the probability of getting flooded is high due to the uncertainty of not knowing where the avulsion will take place. Conversely, based upon the principals of continuity, if the probability of being flooded is increased in one place, it stands to reason the probability of being flooded must be reduced in another. Where is this accounted for in the model?

An avulsion does not decrease the probability of any point being hit by a flood. Page 17 of the "handout" referenced in your letter provides the following explanation:

> During a flood event, the flow may abandon the path it has been taking and follow a new one....Because points on the alluvial fan below the avulsion may be in the path taken by the flood flow either before or after the avulsion occurs, their probability of being hit by the flood is greater than if the avulsion had not occurred.

A simple analogy may clarify the point. Consider the toss of a "fair" coin. The probability that the outcome is "heads" is 0.5; the probability that the outcome is "tails" is 0.5. If heads is tossed, we hit point A; if tails is tossed, we hit point B. Now, if two coins are tossed, the probability of point A being hit is increased to 0.75. Note that the probability of point B being hit is also 0.75 (i.e., it does not decrease if a second coin is tossed).

4.) The model assumes avulsions occur at the apex of the fan. As denoted on the study maps, there is minimal sediment to cause avulsions at the apex. Based upon the soil profiles within the SCS report and the desert varnish, or magnesium oxide, which take thousands of years to form on rocks, it is apparent that this is not an area where sediment movement is actively taking place. Why is it modeled as such?

The methodology does not assume that avulsions occur at the apex. However, in many cases, such an assumption is very reasonable, and the situation should be modeled accordingly.

Our response to Item 1 has already addressed questions regarding the "sediment source" and the fact that a lack of "active sediment movement" does not preclude the use of our methodology.

5.) The model assumes that in theory flows erode the sides of a channel, increasing the channel width until the change in width per change in depth equals -200. I do not believe that the erosion of channel banks as defined in the model can be technically substantiated by geomorphic or soil data. Based upon the soil profiles within the SCS report and the desert varnish, or magnesium oxide, it is apparent that this is not an area where sediment movement is actively taking place. If erosion and stream bed meander were taking place as defined in the alluvial fan model, this natural happening would not be occurring. This indicates to me that the topography is relatively stable and that these soils or rocks have not moved in over a thousand years, let alone the 100 years under which FEMA regulates. Is this a correct assumption?

The width-depth relationship that you refer to resulted from field observations of actual alluvial fan floods in New Mexico. As explained in the handout, that relationship is used to derive the relationship between the width of the path of an alluvial fan flood and the peak discharge of an alluvial fan flood (i.e., the width is approximately 9.4 times the two-fifths power of the peak discharge). The "reasonableness" of the width-discharge relationship is discussed in the Dawdy paper.

Subsequent to the publication of the Dawdy paper, a study was performed for FEMA by DMA Consulting Engineers to check various aspects of the methodology. The width-discharge relationship was consistently verified in all of the actual flooding events studied. Those events took place in California and Nevada.

The width-discharge relationship was derived and has been verified through field investigations covering a wide geographic range in the Southwest. To that extent, the relationship is "correct." Please note, however, that if site-specific information exists that demonstrates that some other relationship between peak discharge, width of the flood path, and depth and velocity of the floodwaters should be used, the methodology can be modified to incorporate it.

6.) The model assumes that in theory that flows erode the channel banks. If that is the case, then runoff would be contained within channel banks and there would be no sheetflow. In essence, all finished floor elevations and stabilization should be based from the invert of the nearest channel since this is the invert that is used in the "equivalent channel" to calculate velocities and depth. Are these depths realistic?

Floodpaths on alluvial fans do not necessarily follow existing channels. Alluvial fan flooding forms its own path through erosion. Thus, finished floor elevations should not be referenced to the invert of the nearest channel.

The relationship discussed in Item 5 predicts that 1,000 cubic feet per second, for example, would follow a path 150 feet wide and flow at a depth of less than 2 feet. Many would describe that flow as "sheetflow."

7.) The model assumes conveyance based upon an "equivalent channel" in generating hydraulic parameters. It does not take into consideration overbank flow or sheet flooding in generating roughness coefficients or velocities nor does it take into consideration sinuosity of channels or flowpaths. Is this a correct assumption?

Equation (45) of the handout describes the cumulative width of multiple channels as a function of peak discharge. The note that immediately follows Equation (45) explains that the description is equivalent to 3.8 times the description given for a single channel. The intent of the note and the use of the notion "equivalent channel" that follows in the handout is to make it easier to understand the derivation of the multiple-channel option of the methodology. By noting the equivalence, one can solve the problem in the multiple-channel region in a manner parallel to that already used to solve the problem in the single-channel region.

8.) The model assumes that the elevations are smooth along a contour. Based upon field investigation and the USGS quad sheets for this area, this is not correct. Why model it as such?

Figure 4 of the handout, entitled "'Smooth' Contours for Width Measurements," was used to clarify what is meant by the "width" of the fan. Because, under the simplest conditions, the probability of a point on the fan being hit by a

given flood is inversely proportional to the fan width, the proper measurement of that width is crucial to mapping alluvial fan flood hazards. If the actual length of a contour between the fan boundaries was used as the fan width, then, because of the additional length resulting from measuring every turn or wind, that probability (and thus the depth and velocity values shown on the map) would be too low.

9.) The model assumes downstream of bifurcated areas that the depth and velocities of flows can be estimated from Manning's equation where the cross-sectional area and the hydraulic radius are based upon the "equivalent channel," which includes the roughness coefficient. Why doesn't it take into consideration the increased roughness based upon sheetflow or the true field cross-sectional area and hydraulic radius of a cross section?

Because the roughness coefficient is an input parameter in the alluvial fan flooding methodology, the modeler, not the model, must consider the roughness coefficient.

The "true" area and hydraulic radius of any flowpath during such a dynamic event as an alluvial fan flood change during the flood. Experience has shown, however, that the floodflow tends to form its own path to reduce the energy that is necessary to transport the floodwaters and sediment. The noncohesive materials that make up alluvial fans offer little resistance to that tendency. The field evidence collected so far demonstrates that the flowpaths are wide and shallow with somewhat "flat" bottoms. That is, they can be approximated as wide rectangles--or more precisely, the hydraulic radius can be approximated as the depth of water.

10.) The model generates depths and velocities from an "equivalent channel." Yet these same depths and velocities are supposed to be used to establish and protect finished floors from flooding and erosion on topography with elevation differences along the "smooth contour" greater than the elevations generated by the model. Is this sound floodplain management?

We believe that elevating structures above the predicted depths on fill that can withstand the predicted velocities is sound floodplain management. Please note that those elevation requirements are minimum requirements. Because the flood hazards shown on our maps pertain to given points within the Special Flood Hazard Area (SFHA), the hazard that will be realized somewhere, but not at any particular point, within the SFHA with a probability of 0.01 in any given year may be greater than that shown on our maps. Therefore, we strongly urge communities to develop a "whole fan" management plan that pursues the goal of no flood-related losses within the SFHA.

Following the 10-item list, your letter states:

Dawdy's paper proposes that this model be only used on active fans. SCS indicates this area is not an active fan and USGS classifies a majority of this area as bedrock.

We have not found such a proposal in the Dawdy paper. A cursory review of the USGS map that you submitted and the Study Contractor map indicates that none of the area proposed as being subject to alluvial fan flooding has been identified as bedrock.

The letter also states the following: **FEMA indicates on Page 18 of their report, avulsions only occur at the apex of the fan....**

Page 18 of the handout contains a note that points out the implications of using an "avulsion factor" to account for avulsions. That note is cautionary and concerns the use of a modeling parameter.

The statement ends by saying that the apex is "**considered as solid bedrock;**" and "**as such**" (i.e., as solid bedrock), you "**question whether avulsions are occurring.**"

Because the draft study is still being reviewed, we do not know if and how avulsions will be modeled. However, the presence of bedrock does not make avulsions impossible.

The final statement in your letter is the following quote from the Dawdy paper: "Braided flow is not a problem with the slopes which occur on alluvial fans...." The quote comes from the conclusion section of the paper. Dawdy devotes the section to discussing possible "problems" that one may encounter when applying the methodology. For example, avulsions are not addressed in his proposed methodology. He notes that avulsions are a problem. That is, as Dawdy explains in the paper, because avulsions are not considered, "the probability of an event crossing a contour at a point is probably greater than that derived." In the context of the Dawdy paper, a "problem" is something that would cause the proposed methodology to give erroneous results. To summarize, we would paraphrase the quote as follows: "Braided flow is handled nicely by the methodology...."

We trust that this letter has addressed the points raised in your letter. If you have any questions regarding this matter, please call Mrs. Cynthia M. Croxdale of my staff in Washington, D.C., at (202) 646-3458.

Sincerely,

John L. Matticks
Chief, Risk Studies Division
Federal Insurance Administration

cc: Mr. D. E. Sagramoso, P.E.
Floodplain Administrator, Flood Control
District of Maricopa County

Mr. John Wise
Cella Barr Associates

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Larry E. Sullivan, R.L.S.
Glen W. Roth, P.E.
Richard Lee Kreidson, R.L.S.

September 9, 1991

Federal Emergency Management Agency
Federal Insurance Administration
Risk Studies Division
500C Street, SW Room 422
Washington, DC 20472

Att: Mr. Karl Mohr

Re: Flood Insurance Study for N.E. Scottsdale and Unincorporated Maricopa County (Community Numbers 045012 & 040037)

Dear Mr. Mohr:

As I indicated during our phone conversation on the 6th of September, I am evaluating the potential impacts of the new alluvial fan flood plains or AO Zones on future and existing private development. I am therefore requesting any pertinent technical data for fans 5, 6a, 6b, & 6C, including but not limited to the following:

a) Hydrologic analyses including watershed delineation maps;
b) Alluvial fan analyses including model input parameters & fan delineation work maps;
c) Geological investigations including land form maps.

Please inform me as soon as possible of the required reproduction costs associated with this request. I can be contacted by phone at (602) 264-6831 or by FAX at (602) 264-0928. I thank you for your time and cooperation.

Sincerely,

COE & VAN LOO
Consultants, Inc.

David W. Dust, P.E.
Project Engineer

DWD:rbb
110001LT.070

cc: Mark Borushko, SunCor
Paul Kienow, City of Phoenix
Douglas Tymins, Broad Inc.

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Richard Lee Knudson, R.L.S.

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David W. Dust, P.E.
Jeff Phister, P.E.
James C. Taschner, P.E.
Charles W. Ballinger, P.E.
E. Thompson Van Loo, P.E., R.L.S.

November 13, 1991

Federal Emergency Management Agency
Federal Insurance Administration
Risk Studies Division
500C Street, SW Room 422
Washington, DC 20472

Att: Mr. Karl Mohr

Re: Flood Insurance Study for NE Scottsdale and Unincorporated Maricopa County (Community Numbers 045012 and 040037)

Dear Mr. Mohr:

In a letter to you dated September 9, 1991 (copy enclosed) *Coe & Van Loo Consultants, Inc., (CVL)* requested any pertinent technical data for fans 5, 6A, 6B and 6C. This information is necessary for us to complete an evaluation of the methodology and technical approach used by the study contractor (SC).

Supporting technical data was received from the SC (Michael Baker, Jr.) and accompanied by a transmittal letter dated September 26, 1991 (copy enclosed), a list of the items received was attached. Their timely response is appreciated. Not included with the technical data were the following items.

a) "An explanation demonstrating that flowpaths below the apex (apices) are unpredictable."

b) An explanation of the selection of the avulsion coefficient.

c) Identification of "barriers to flow (natural or manmade) that render some areas more flood prone than others."

d) "A report describing the topographic and geomorphologic analysis performed."

The above items are required for documenting alluvial fan floodplain studies, as specified in the publication *Flood Insurance Study, Guidelines and Specifications for Study Contractors*, FEMA 37, 1991.

In addition, the following clarifications regarding the data received from the SC are also requested:

a) Justification for the "probability splits" along fans 5 & 6 indicated in the data received from the SC.

b) An explanation for the modifications to fan model computed contour widths indicated on the calculation sheets for the single channel regions.

Please inform me, or Mr. David Dust, P.E., as soon as possible of the required reproduction costs associated with this request. I can be contacted by telephone at (602) 264-6831 or by FAX at (602) 264-0928.

Thank you for your assistance and timely response.

Sincerely,

COE & VAN LOO
Consultants, Inc.

Paul W. R. Hoskin, P.E.
Vice President

PWRH:rbb
110001LT.090
Enclosures

cc: Mark Borushko, SunCor
Mark Voigt, Stanford Ranch
Paul Kienow, City of Phoenix
Joe Tram, FCDMC

CVL

Baker

Michael Baker Jr., Inc.
1420 King Street - Sixth Floor
Alexandria, Virginia 22314-2788

(703) 838-0400
FAX (703) 836-0130

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DEC 6 1991
COE & VAN LOO
PHOENIX, AZ

December 4, 1991

Mr. Paul W. R. Hoskin, P.E.
Vice President
Coe & Van Loo Consultants, Inc.
4550 North 12th Street
Phoenix, Arizona 85014-4291

Dear Mr. Hoskin:

This is in response to your letter dated November 13, 1991, to Mr. Karl Mohr of the Federal Emergency Management Agency (FEMA). In that letter, you requested supporting technical data to supplement the information that we forwarded to you on September 26, 1991. In particular, you requested the following information.

a. **An explanation demonstrating that flowpaths below the apex (apices) are unpredictable.**

Field reconnaissance shows that the surface material in the area is sand and gravel. The area is therefore very susceptible to erosion. The washes in the area contain the same material, making them an abundant source of sediment available for transport and deposition. The susceptibility to erosion and the sediment supply available in the area have resulted in the drainage pattern that exists. That pattern is characterized by numerous splits in the existing washes. The number of splits (and consequently the number of existing washes) increases, and the flood-carrying capacity decreases, with a decrease in elevation (downslope). Future flood paths in such an area are unpredictable.

b. **An explanation of the selection of the avulsion coefficient.**

Field reconnaissance of the stream indicates that the areas above apex 5 contain quite a bit of vegetative debris. Aerial photographs and topographic maps also indicate that each of the three entrenched channels below the apex becomes substantially narrower. Because of these two factors, the probability of an avulsion during a given flood event was taken to be 0.5.

The probability of an avulsion during a given flood event passing through apexes 6a, 6b, or 6c was taken to be negligible.

c. **Identification of barriers to flow (natural or manmade) that render some areas more flood prone than others.**

No barriers to flow were found except for the dike at the Cave Butte Recreation Area.

d. **A report describing the topographic and geomorphologic analysis performed.**

Topographic and geomorphic analyses are performed to identify the areas subject to alluvial fan flooding and to estimate the relative likelihood of points within those areas being inundated by a given flood. The areas subject to alluvial fan flooding were identified on the interim map transmitted to the Cities of Phoenix and Scottsdale and to the Maricopa County Flood Control District with a letter dated October 29, 1990. Exhibit 2 to that letter describes the analysis performed. Because a copy of that letter and the exhibits were sent to you in response to your request dated September 9, 1991, they are not enclosed with this transmittal.

You also requested information to clarify two other points:

a. **Justification for the "probability splits" along fans 5 & 6 indicated in the data received from the SC.**

The relative likelihood of points within the areas identified on the interim map being inundated by a given flood is shown on the flow diagrams included with the data that were transmitted in response to your request of September 9. The values shown on those diagrams depict the probability that a given flood would take the path indicated by the arrows. Those values were estimated using the relative sizes (in terms of topwidths) of the existing washes as shown on aerial photographs.

b. **An explanation for the modifications to fan model computed contour widths indicated on the calculation sheets for the single channel regions.**

Below apexes 5 and 6a, 6b, and 6c, the gradients are not steep enough to maintain critical depths. Therefore, the flow values corresponding to the various depths and velocities were recalculated using normal depth. Those computations are given in the sheets that were sent to you entitled "Single Channel--Normal Depth." The modifications that you refer to are the result of using the "normal depth" flows rather than the "critical depth" flows that our computer program uses.

We trust that this information will enable you to complete your evaluation. Please note that the Study Contractor (SC) for this study is Cella Barr Associates, Inc. Baker is the Technical Evaluation Contractor (TEC). The study was performed using FEMA 37, Flood Insurance Study Guidelines and Specifications for Study Contractors, dated September 1985. If you require additional assistance, please call Ed Mifflin of our staff at (703) 838-0400.

Sincerely,

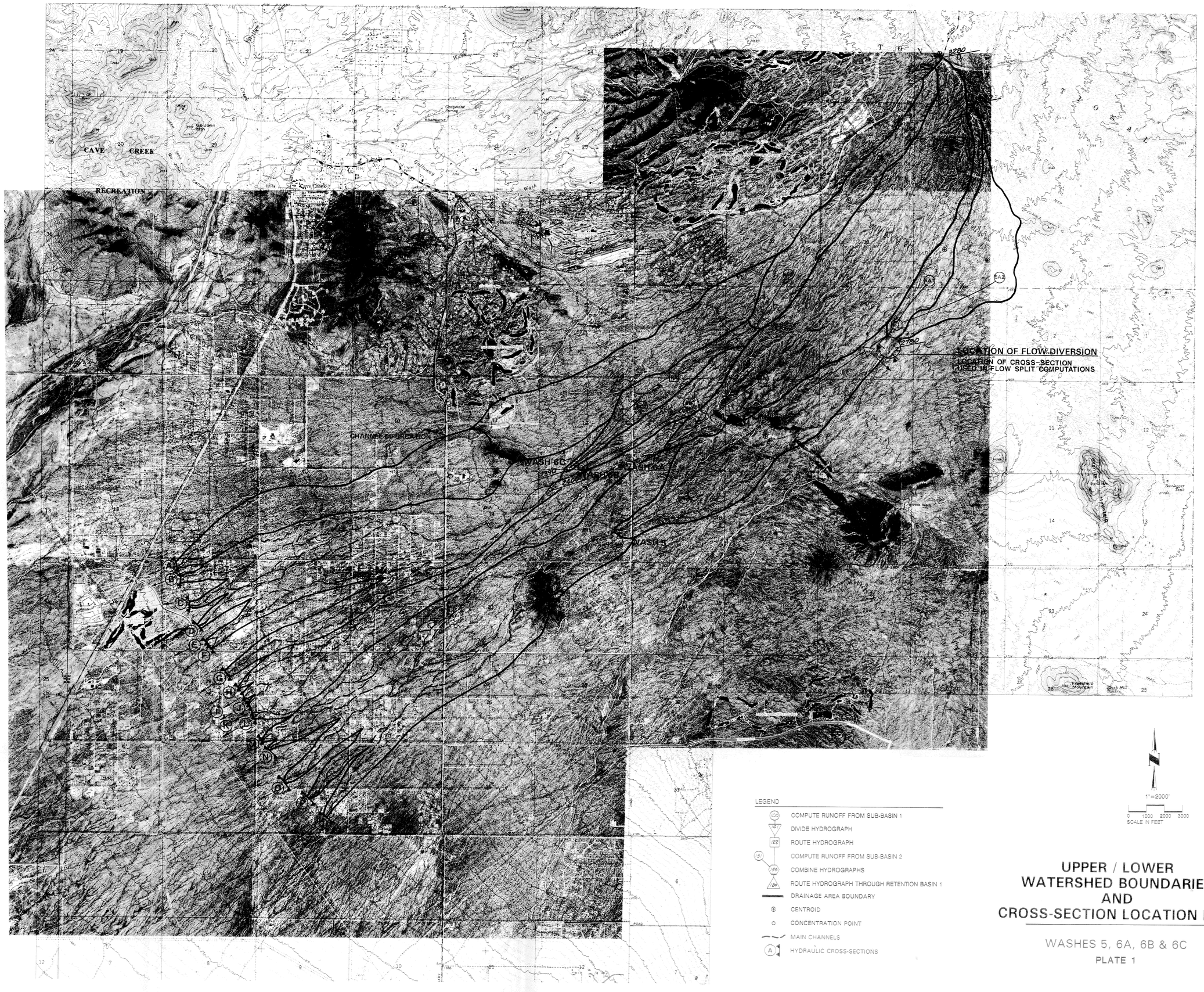
MICHAEL BAKER JR., INC.

David J. Greenwood
Project Manager

cc: Mr. William Erickson
Floodplain Administrator
City of Scottsdale

Mr. Joe Tram
Flood Control District of
Maricopa County

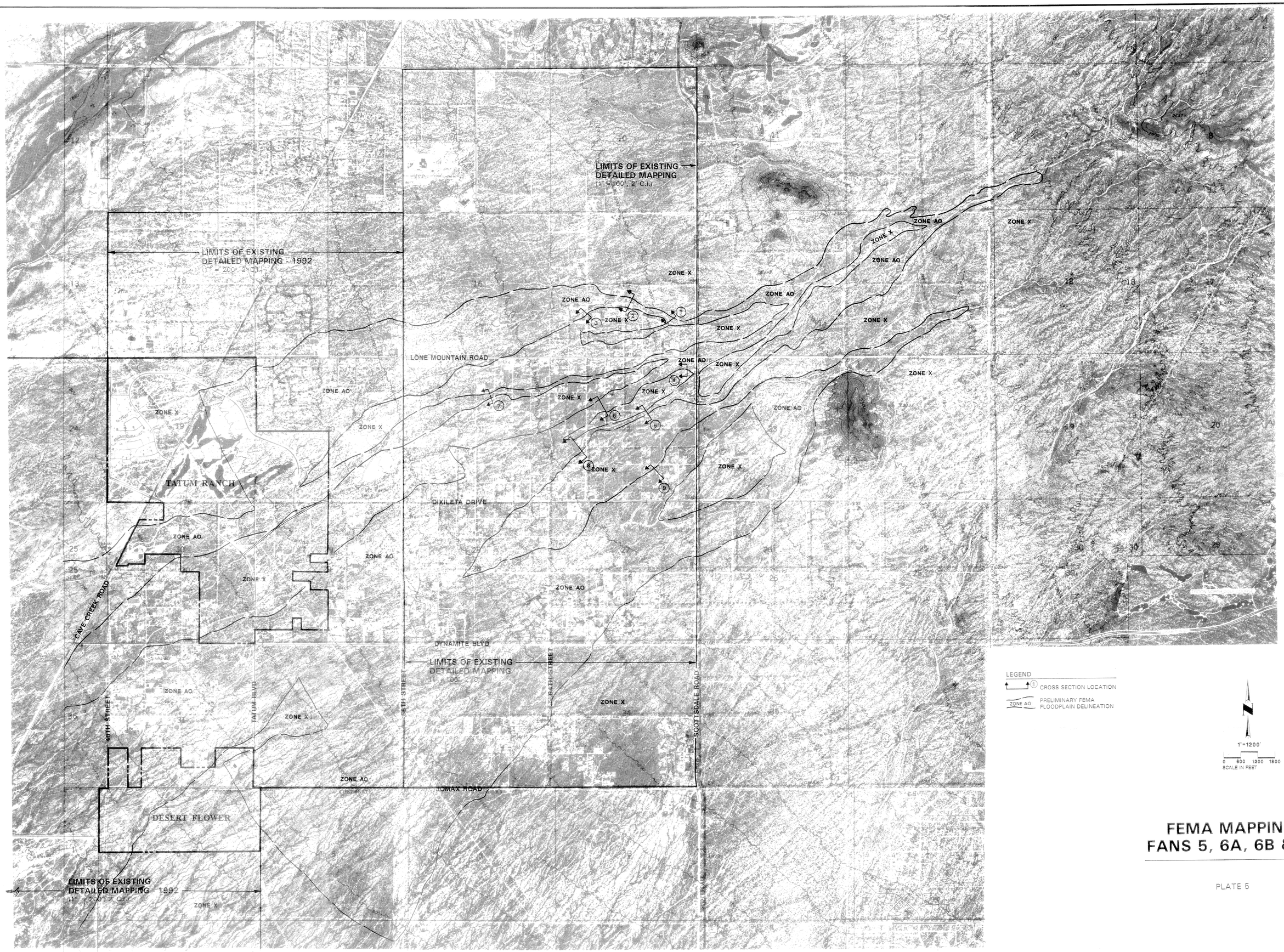
Mr. Paul E. Kienow, P.E.
Floodplain Management Engineer
City of Phoenix



UPPER / LOWER WATERSHED BOUNDARIES AND CROSS-SECTION LOCATION MAP

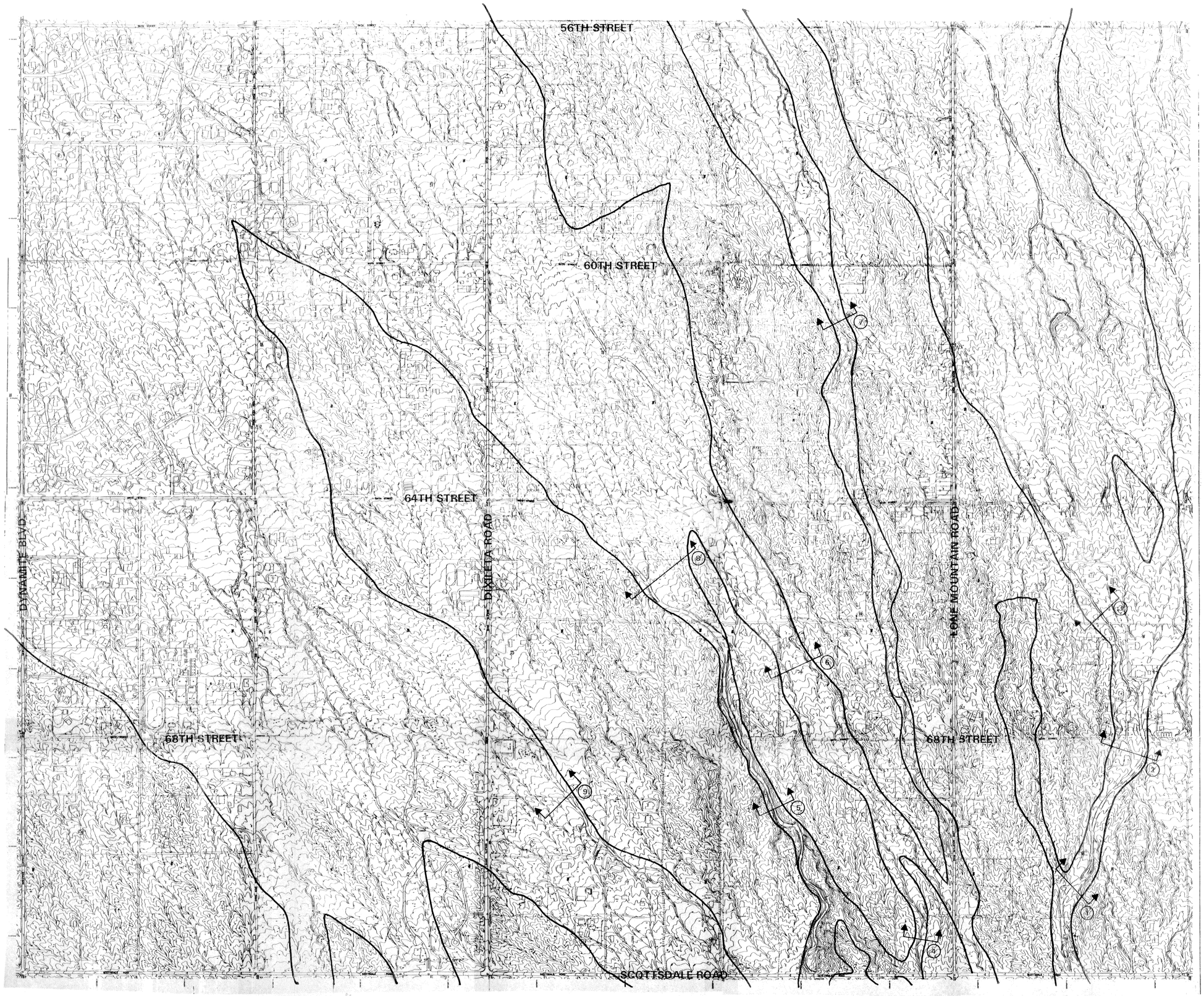
WASHES 5, 6A, 6B & 6C

PLATE 1



FEMA MAPPING-
FANS 5, 6A, 6B & 6C

PLATE 5



0 500 1000
SCALE: 1" = 500'

LEGEND

CROSS SECTION LOCATION

PRELIMINARY FEMA FLOODPLAIN DELINEATIONS

WASHES 5 & 6

CROSS SECTION LOCATION MAP

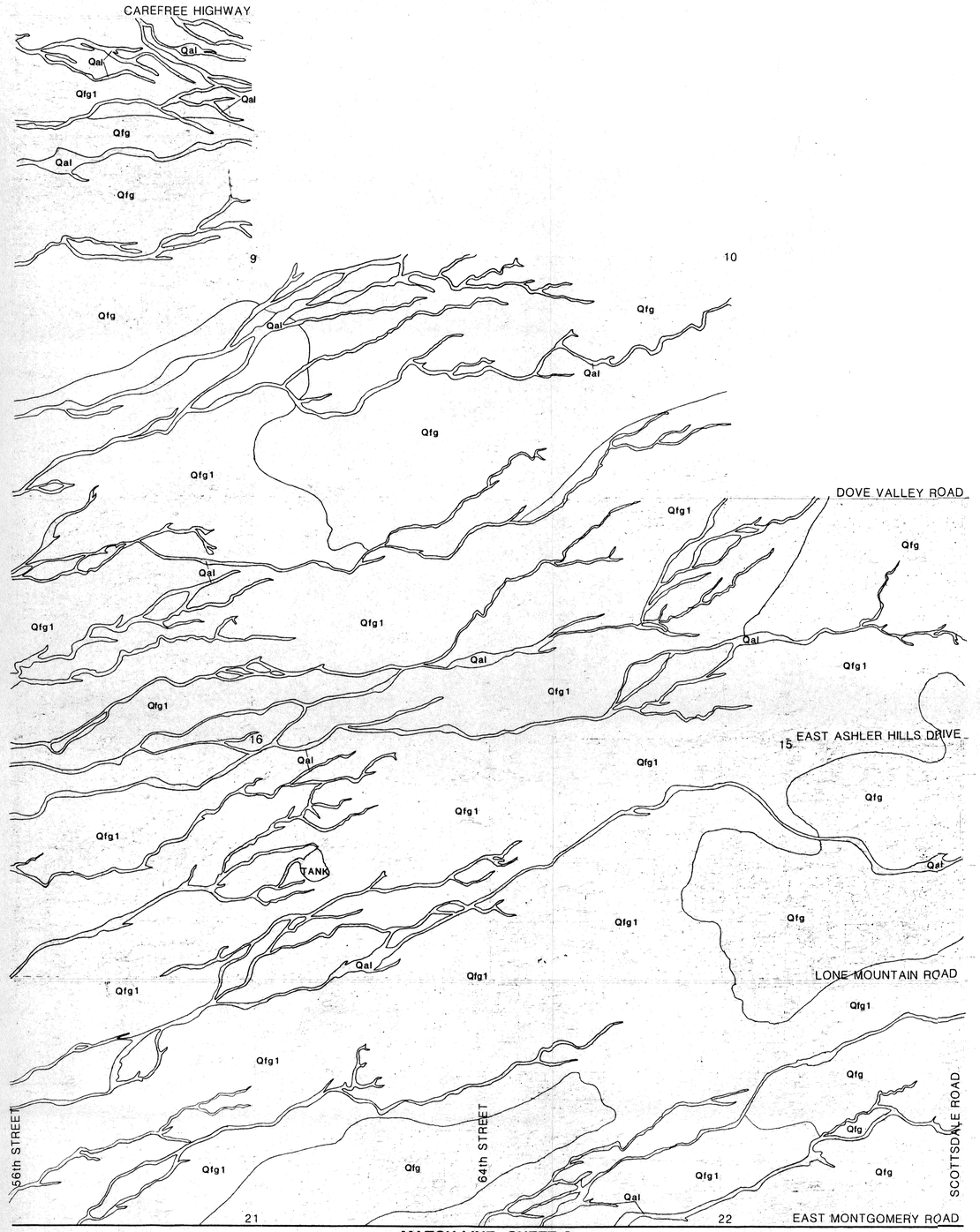
PLATE 6

COE & VAN LOO
PLANNING · ENGINEERING · LANDSCAPE ARCHITECTURE
4550 NORTH 12TH STREET
PHOENIX ARIZONA 85014
TELEPHONE (602) 264-6831

		REVISIONS	DATE	BY
DESIGNED	DWD			
DRAWN	REP			
CHECKED	DWD			
DATE	12/91			

CVL

SHEET
OF



MATCH LINE SHEET 2

EXPLANATION

Qal

Quaternary Alluvium: Light brown sand and gravel deposts in modern stream channels; poorly stratified; poorly sorted; unconsolidated; uncemented; 40% to 60% medium-to coarse-grained sand; 20% to 30% gravel; 10% to 30% silt. Unit also includes overbank and terrace deposits which contain slightly increased amounts of silt.

Qfg, Qfg1, Qfg2

Quaternary Fine-grained Deposits: Alluvial fan sedimentary deposits consisting of poorly-sorted, poorly-bedded, moderately- to strongly-calichified alluvium averaging 20% to 30% angular to subangular to subrounded gravel with clasts ranging to several inches in diameter in a matrix of 45% to 75% sand, silt and clay. The unit is subdivided into three map units which grade into each other. Subdivisions are based on the erosional characteristics of each unit, clay content, and general color variations.
The Qfg unit is deeply dissected and consists of moderate brown to light brown to greyish red alluvium.
The Qfg1 unit is moderately dissected and consists of light brown to moderate brown to moderate reddish brown alluvium.
The Qfg2 unit is mildly dissected and consists of moderate brown to light brown to dark yellowish brown alluvium.

Approximate location of contact between geologic units.

Reference: Pewe, T.L., Bales, J., Montz, M., 1983, Reconnaissance Environmental Geology of Northern Scottsdale, Maricopa County, Arizona 1:24000 Scale.

N

SCALE 1" = 500'

GEOLOGIC CONSIDERATIONS FOR LAND USE

GEOLOGIC ACTIVITY	GEOLOGIC UNITS			
	Qal	Qfg	Qfg1	Qfg2
SEISMICITY				
Faulting	1	1	1	1
Earthquakes	1	1	1	1
LAND SUBSIDENCE				
Subsidence	2	2	2	2
Earth Fissures	2	2	2	2
SLOPE STABILITY				
Boulder-rolling	1	1	1	1
Landslides	1	1	1	1
CALICHE DEVELOPMENT	1	3	3	3
RADON POTENTIAL	2	2	2	2
FLOODING	3	1	1.5	2

EXPLANATION:
1 = Slight potential of occurrence of geologic activity
2 = Moderate potential of occurrence of geologic activity
3 = Strong potential of occurrence of geologic activity

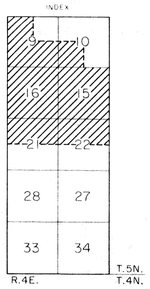
See text for more detailed descriptions of individual geologic unit descriptions.

LEGEND

- WASH
- BLOCK WALL
- FENCE
- PAVED ROAD
- DIRT ROAD
- UTILITY POLE
- BUILDING
- ROAD SIGN
- HORIZ / VERT CNTRL PT
- SAGUARO
- VERT CNTRL PT

ENVIRONMENTAL GEOLOGY

INDEX

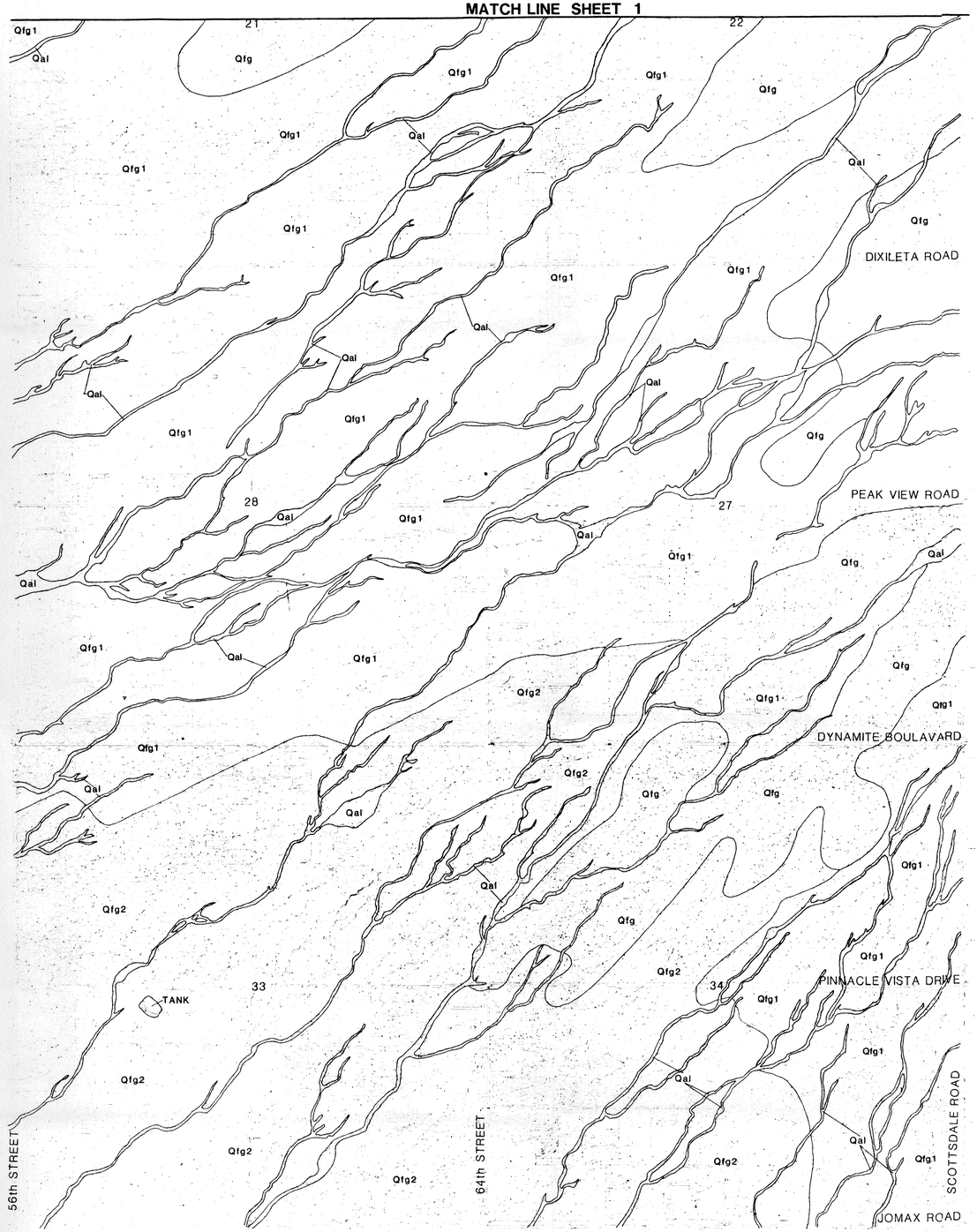


NOTE:
Information presented hereon has been provided as a general guide and is not a substitute for site specific analyses.

Survey: Standage and Truitt Engineering, Ltd.
Mapping by: Kenney Aerial Mapping, Inc.

FOUR PEAKS GEOLOGICAL SERVICES	CITY OF SCOTTSDALE ARIZONA
CBA CELLA BARR ASSOCIATES 5002 North 19th Avenue Phoenix, Arizona 85015 (602) 242-2999	GEOLOGY AND SOILS STUDY FOR 9-SQUARE MILE AREA IN NORTH SCOTTSDALE
	DATE MAY 1988 SHEET 1 OF 2

PLATE 8



EXPLANATION

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GEOLOGIC CONSIDERATIONS FOR LAND USE

GEOLOGIC ACTIVITY	GEOLOGIC UNITS Qal	Qfg	Qfg1	Qfg2
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SLOPE STABILITY				
Boulder-rolling	1	1	1	1
Landslides	1	1	1	1
CALICHE DEVELOPMENT	1	3	3	3
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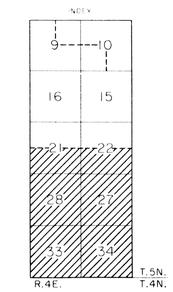
ENVIRONMENTAL GEOLOGY



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FOUR PEAKS GEOLOGICAL SERVICES

CBA CELLA BARR ASSOCIATES 5062 North 19th Avenue Phoenix, Arizona 85015 (602) 242-2999

CITY OF SCOTTSDALE
ARIZONA

GEOLOGY AND SOILS STUDY FOR 9-SQUARE MILE AREA IN NORTH SCOTTSDALE

DATE MAY 1988 SHEET 2 of 2

PLATE 7