Engineering Services
Final Report

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Dambreak Analysis of Cave Buttes Dam Near Phoenix, Arizona

Prepared for

Flood Control District
of Maricopa County
Phoenix, Arizona

April 1990

Woodward-Clyde Consultants

Consulting Engineers, Geologists and Environmental Scientists

One Gateway
426 N. 44th St., Suite 300
Phoenix, Arizona
(602) 225-0150

Volume 1 of 2
Project No. 8851485F

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1.0 INTRODUCTION

As part of the dam certification requirements set forth by the Arizona Department of Water Resources (ADWR) Dam Safety Division, the Flood Control District of Maricopa County (FCDMC) is required to provide a dam failure analysis as part of an evacuation plan for the Cave Buttes Dam. The dam is located in central Maricopa County, Arizona, upstream of the highly urbanized city of Phoenix. As such, the FCDMC has retained Woodward-Clyde Consultants to provide the dam failure analysis and inundation area mapping for the Cave Buttes Dam. Presented herein are the results of the dam failure and inundation analyses as well as model input data and output.

2.0 SCOPE OF WORK

The objective of this study was to provide a dam failure and inundation analysis as part of an evacuation plan for the Cave Buttes Dam as requested by the Flood Control District of Maricopa County.

Specifically the scope of work included:

- Collection and review of previous studies,
- General review of adopted hydrology data (i.e., Inflow Design Flood)
- Evaluation of most critical PMF situation to develop the BREACH outflow hydrograph,
- Development of piping breach parameters utilizing the National Weather Services Breach model,
- Development of routing criteria based on infield surveys of the downstream reach,
- Routing of inflow design flood to evaluate the degree of inundation (i.e., flow depths, velocities) downstream,
- Development of flood inundation area maps to aid in development of an evacuation plan,
- Evaluation of critical facilities impacted by flooding, and
- Preparation of this report.

A summary of the data collected, analysis performed, results of the analysis and our recommendations are presented following.

3.0 PROJECT DESCRIPTION

Cave Buttes Dam and its three appurtenant dikes are located in Sections 1-4, 9-11, 15, 16 of T4N R3E and Sections 21, 27-29, 33-35 of T5N R3E of Maricopa County, Arizona as shown in Figure 3-1. The main embankment is located about 0.7 miles downstream of the existing old Cave Creek Dam. Cave Buttes Dam controls a watershed area of approximately 191 square miles. The dam was designed to control floodwater and provide storage for a 100-year accumulation of sediment.

Construction of the earthfill dam was completed in March 1980. The main dam embankment, of which the dambreak analysis is to be modeled, has a crest elevation of 1679.1 feet above mean sea level (AMSL) which is about 109 feet above the existing stream bed. The dam crest is about 2260 feet long and approximately 20 feet wide. The upstream slope of the dam was constructed at 2.25:1 (horiz.:vert.) between the top of the dam and elevation 1619.0 and 2.75:1 below elevation 1619.0. The downstream slope of the dam stands at a 2:1 slope. The existing spillway is located approximately 1600 feet northwest of the main embankment. The spillway has a crest length of 510 feet at elevation 1657.1 and is trapezoidal in section with side slopes of 2:1. For details on the three dike structures see reference No. 9B.

The reservoir has a capacity of about 46,000 acre-feet at the spillway crest (elevation 1657.1) with approximately 5700 acre-feet provided for the 100-year sediment accumulation. In addition, the dam will reduce the reservoir inflow design flood (54,000 cfs) to an outflow from the outlet works of 486 cfs, while the existing spillway, excavated in rock, will convey the PMF inflow event (172,000 cfs) with a peak outflow of about 100,600 cfs and 5 feet of freeboard at the dam.

The size and hazard classification assigned to a dam is evaluated based on the safety of the dam as well as the economic, environmental, and potential

loss of life as a result of a dam failure. Based on the guidelines set forth by the State of Arizona Department of Water Resources, Cave Buttes Dam has been classified as a large size, high hazard dam. As a result, the required inflow design flood (IDF) is that of the Probable Maximum Flood (PMF) event. Therefore, the analysis presented following is based on the dam failure as a result of the PMF event.

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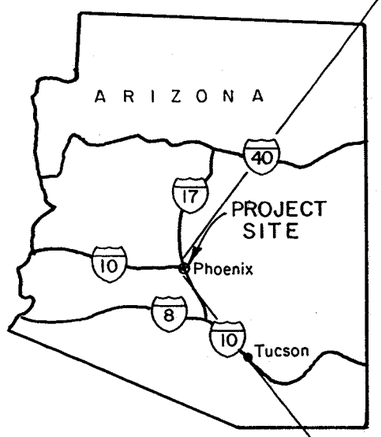
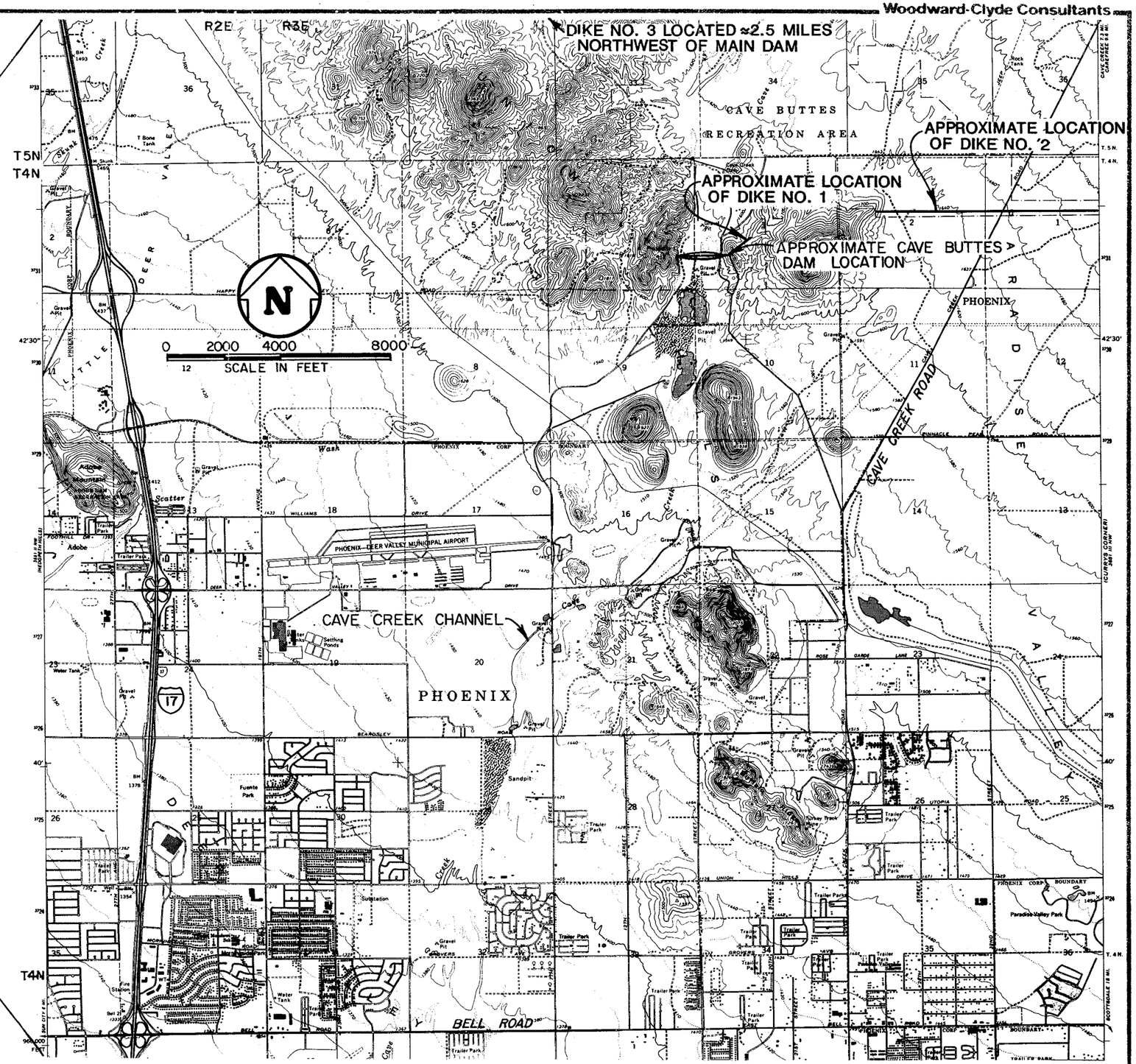


LOCATION MAP

NOT TO SCALE



NOTE: BASE MAP TAKEN FROM USGS 7.5 MINUTE QUADRANGLE MAP FOR UNION HILLS, AZ. (1964; REVISED 1981).

Job No.: 8851485F	LOCATION MAP CAVE BUTTES DAM FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
Prepared by: S.F.R.	
Date: 2/16/90	

124835

FIG. 3-1

4.1 GENERAL

The flood routing model selected for this analysis was the United States National Weather Service's Dam Break Flood Forecasting Model, DAMBRK-88 (Boss DAMBRK Version 2.0). DAMBRK was used to simulate the failure of the dam and to estimate the inundated area caused by the volume of water released. The model contains a breach component which simulates the formation of the dam breach over a designated time period. A second component estimates the reservoir outflow hydrograph resulting from the simulated breach. The third component of the model consists of a dynamic routing technique using the unsteady-state flow equations for estimating the dam break flood wave as it advances through the downstream valley, and computes its travel time and resulting water surface elevations at designated locations.

4.2 MODEL INPUT REQUIREMENTS

The following is a summary of the required input for the DAMBRK model.

Item	Data Required
Hydrology	Inflow design hydrograph
	Base flow in the channel
Breach	Duration of breach
	Side slope
	Final bottom width
	Final bottom elevation

Reservoir	Initial elevation Elevation when breach begins Crest elevation Elevation versus area or volume relationship
Spillway	Elevation Discharge Relationship
Channel	Geometry Manning's roughness coefficient Distance from dam

4.3 MODEL OUTPUT

The following is a summary of the output available using the DAMBRK flood routing model.

- A summary of the input data discussed above,
- A channel slope profile,
- A reservoir depletion table indicating the reservoir characteristics as the dam fails,
- An initial conditions table indicating the initial water elevations along the downstream channel produced by the base flow,
- A profile of maximum water surface elevations along the channel,
- Discharge and stage hydrographs at selected locations.

5.0 DAMBREAK ANALYSIS

5.1 GENERAL

The objective of this study was to provide a dambreak analysis for the Cave Buttes Dam located in central Maricopa County, Arizona upstream of the highly urbanized city of Phoenix. An inflow design flood resulting from the 72-hour Probable Maximum Precipitation (PMP) was considered under dam failure (piping) conditions for the existing Cave Buttes Dam configuration. The limits of the study began at Cave Buttes Dam and extended downstream along the Cave Creek Channel to it's confluence with the Arizona Canal Diversion Channel (ACDC) approximately 11.6 miles downstream.

5.2 HYDROLOGY

For purposes of this study the inflow design flood resulting from the 72-hour PMP (Peak Flow = 172,000 cfs) was adopted for the failure analysis (Ref. 9). Preliminary estimates indicated the 6-hour PMP storm (Peak Flow = 186,000 cfs) would generate a greater peak flow and thus the worst-case flood scenario. Further evaluation indicated the greater volume 72-hour PMP storm generated a more significant breach flood flow (peak outflow ≃ 354,000 cfs) downstream than the 6-hour PMP (peak outflow ≃ 318,000 cfs). Such is the case as a result of large sustained inflows during the time of the breach for the 72-hour PMP versus the 6-hour PMP event. The 72-hour inflow hydrograph used in this analysis is shown on Figure 5-1.

5.3 BREACH CHARACTERISTICS

A dam breach can be defined as a failure of any reservoir structure which allows for an uncontrollable discharge of water. Typically, a failure results from overtopping of the dam or piping. The existing Cave Buttes Dam was designed to handle the PMF event without an overtopping

condition. Therefore, for purposes of this investigation we have assumed the piping condition as the dam failure mode.

For breaches caused by piping, the material is eroded from the downstream slope at the point where the piping flows exit the embankment at which time a cavity is formed. As the piping continues, adjacent embankment material sloughs into the cavity and is washed away. Eventually embankment crest material sloughs into the cavity creating a low point for which water can now flow over the embankment. At this point the piping breach is similar to an overtopping breach (Ref. 6).

For this study the National Weather Service's BREACH model was applied to estimate the dam breach parameters. The BREACH model is a mathematical model used to predict the breach characteristics (size, shape, time of breach) and the breach outflow hydrograph. The model is based on the principles of hydraulics, sediment transport, soil mechanics, the geometric and material properties of the dam, and the reservoir properties (storage volume, spillway characteristics and reservoir inflow rate).

The critical material properties of the dam are the internal friction angle, cohesion strength, and the average grain size diameter. As such, the material properties for the embankment, gathered from Appendices 1A and 1B of the "Gila River Basin, New River and Phoenix City Streams, Arizona, Design Memorandum No. 3, General Design Memorandum - Phase II, Project Design - Part 1," dated July 1976 (Ref. 9B), were evaluated and input with the reservoir properties into the breach model. As a result the following breach parameters were adopted:

Breach Base Width	65 feet
Breach Side Slopes	1.15:1 (Horizontal:Vertical)
Time of Breach Formation	1.66 hours

Independent checks based on anticipated peak outflow given the adopted breach parameters and reservoir properties were used to confirm the adopted breach parameters. In addition, based on the U.S. Army Corps of Engineers Guidelines discussed previously, the parameters used for this analysis appear reasonable. The output for the BREACH model run used in this study is shown in Appendix A.

5.4 RESERVOIR CHARACTERISTICS

The DAMBRK flood routing model requires input defining the existing reservoir and dam embankment to simulate the dam break flood. The input required consists of: 1) the initial reservoir water surface elevation, 2) the dam and spillway crest elevations, 3) the dam and spillway discharge coefficients, 4) breach parameters and 5) the reservoir elevation versus volume relation. For purposes of this study, the initial reservoir water surface elevation was set at 1575.0, approximately 5 feet above the elevation of the bottom of the dam, thus simulating essentially a dry reservoir prior to the inflow design flood (IDF). A dry reservoir was used as the initial condition on the basis that the Cave Buttes Dam has been designed to handle the PMF event as well as operating with no normal pool storage to act as a flood retarding structure. Beginning the model simulation with water stored behind the embankment results in a simulation of a PMF event plus an inflow design flood (IDF) event. For example, to commence the modelling with the initial water surface at spillway crest prior to the IDF, would essentially be simulating back to back PMF rainfall events. The water surface elevation at which time the piping breach begins was set equal to the existing spillway crest elevation (1657.0) to model the piping failure condition. The elevation on the embankment at which the piping cavity initiates was set at about mid-height of the dam at elevation 1610.0 based on historical dam failure information.

An elevation-volume relationship for the Cave Buttes Dam is shown on Figure 5-2 which indicates about 40,900 acre-feet of water is stored in the

reservoir at spillway crest elevation. A summary of the reservoir and breach input is shown in Table 5-1.

5.5 CHANNEL CHARACTERISTICS

The conveyance and storage characteristics of the channel were defined in the DAMBRK model by selecting cross-sections at various distances from the dam, describing significant obstructions to flow and Manning's roughness coefficients at each cross-section.

Cross-sections normal to the flow path were selected at locations that allow development of a reasonable simulation of the actual channel geometry. U.S.G.S topographic maps (10 and 20 foot contour intervals) were used to delineate the flow path and estimate the channel geometry at each section. The cross-section data is input into the DAMBRK model by specifying the width of the section at various elevations. Such is the natural geometry of the Cave Creek channel reach and due to the input format required in the DAMBRK model, several sections were modified for input. Consideration was given to flow areas in the natural channel versus the modified channel sections so as to depict the actual channel geometry. A total of 30 cross-sections were used in the model extending approximately 11.6 miles downstream from Cave Buttes Dam to the confluence with the ACDC.

Manning's roughness coefficient is a parameter which characterizes the hydraulic roughness of a channel. Site visits were made to evaluate potential cross-section locations and collect the data necessary for estimating Manning's roughness coefficient. The downstream channel was observed to evaluate potential flow obstructions and/or flow constrictions.

Two methods were utilized for making "n" value determinations. For open or natural areas, a method developed by Woody L. Crown was used. For urban developed areas, a method for adjustment of Mannings' Roughness Coefficient

for Flooded Urban Areas, developed by Hejl and Kaus was used. Summaries of the two methods are described as follows.

The Crown Method begins with a base "n" value for the earthen material in the channel. Adjustments are made to the base value on the basis of protruding surface irregularities, the amount and type of vegetation and degree of meandering. Calculated "n" values using the Crown Method for channel and overbanks in open land ranged from 0.040 to 0.080.

The Urban "n" value Method begins with a base "n" value between the houses or buildings. Adjustments are made on the basis of longitudinal and transverse spacing of the buildings along the flow path. The procedure used in setting urban "n" value criteria was to calculate "n" values for a variety of typical development types throughout the City of Phoenix. Urban "n" values range from a low of 0.045 for sparsely populated rural areas to a high of 0.180 for high-density multifamily areas. Following is a summary of results for the Phoenix Area.

Development Type	Description	"n" Value
Rural Residential	Sparse development	0.045
Custom lots	Curved streets and lots of room between houses	0.060
Custom lots	Large houses on large lots but arranged perpendicular to flow	0.120
Single family	Open space around houses or curved streets	0.130
Single family	Closed packed with rows of houses perpendicular to flow path	0.160
Multifamily units	Space provided between buildings	0.140
Multifamily units	A minimum of low space between the buildings	0.180
Commercial or Industrial	Only half of the flow path blocked	0.060
Commercial or Industrial	A majority of the flow path blocked	0.170

5.6 ROUTING ANALYSIS

The National Weather Service's DAMBRK-88 Model (Boss DAMBRK Version 2.0) was used to simulate the Cave Buttes Dam failure and flood routing downstream for the 72-hour PMP event. The complexity of the flood wave movement and downstream characteristics warranted several independent model runs to simulate the flood wave routing. The methodology included split flow evaluation as well as lateral inflow and outflow estimations.

The flood flow resulting from the Cave Buttes dambreak will be divided at two locations. Primarily, the flow will be split immediately downstream of the dam. The majority of the flood will flow south along the Cave Creek channel and a portion of it will flow west to Scatter Wash. Flow in both directions will cross the existing Central Arizona Project (CAP) Canal. For purposes of this analysis, based on the magnitude and flow depths of the flood at this location, the affect of the CAP is insignificant. The overbank flows from these two channels will merge together at the east side of the Phoenix-Deer Valley Municipal Airport. Further downstream, the flood will be divided again, flowing to Cave Creek and Scatter Wash. Flow along Scatter Wash will reach and overtop Interstate 17 and while some of the flow continues along Scatter Wash until it converges with the flow in Cave Creek approximately one mile downstream. Inundation of areas both east and west of the interstate continues to the ACDC (Study Limit).

Whenever there was a possibility of divided flow, split-flow analysis was conducted to develop separate hydrographs for the flows immediately downstream of the location.

In order to develop the hydrographs, the United States Army Corps of Engineers HEC-2 computer model was utilized to construct the rating curves. Normal depths due to different flows were calculated for each

section. Rating curves consisted of elevation capacity curves for each channel.

The rating curves were combined to construct a single rating curve which represented the total flow versus elevation. Figure 5-3 illustrates the rating curves for the split-flow analysis which was performed immediately downstream of the Cave Buttes Dam. The three curves in the figure represent the total flow, the portion of flow to Cave Creek, and the portion of flow to Scatter Wash.

To develop the hydrographs for different channels to be input as lateral inflow or outflow, the hydrograph for total flow was matched with the rating curve for total flow. The corresponding hydrographs for each channel were estimated by dividing the flows proportional to the rating curve for each channel.

In addition, hydraulic analyses were conducted to evaluate flows through underpasses along Interstate 17 at respective sections. Flows through the underpasses were generally found to be relatively insignificant and as such any underpass flow effects were considered negligible compared to the overtopping flows along Interstate 17.

A total of five independent model runs were used to simulate the flood wave routing as a result of the divided flow situations at various locations along the downstream reach. Run #1 was used to develop the breach outflow hydrograph and subsequent routing through Section #3 (Mile 0.48). As a result of divided flow (i.e., 307,000 cfs to Cave Creek and 47,000 cfs to Scatter Wash), Run #2 was used to route the Scatter Wash flow from Section #4W through #8W (Mile 1.26 through 2.00). At this location the flows from Section #8W and #8S were routed downstream separately to evaluate the potential for combining flows downstream. Results indicated the combining of flows at Section #9 and as such flow from Run #2 was used as lateral inflow at Section #9 of Run #3. Run #3 then routed the combined Cave Creek

flow from Section #4S through #11 (Mile 1.09 through 3.23) to the second location of apparent divided flow, of which about 60,000 cfs flows into Scatter Wash and approximately 281,000 cfs flows into the Cave Creek channel. The fourth model run (Run #4) was used to route the Scatter Wash flow from Section #12W through #15W (Mile 3.21 through 4.30). At this point the flow from Scatter Wash overtops Interstate 17 and tends to flow in a south-southwest direction. Therefore flows estimated in Run #4 were input as lateral inflow at Section #16 for Run #5. Model run #5 routed the resulting Cave Creek flow from Section #12S through #24 (Mile 3.50 through 11.57), to the confluence of Cave Creek with the ACDC. Figure 5-4 provides a flow chart summarizing the methodology used in developing the flood routing analysis. Model output is shown in Appendix B.

5.7 DAMBREAK ANALYSIS RESULTS

Utilizing the combined results of the five model runs, water surface elevations, arrival times, flow velocities, and overbank flow depths were estimated.

For purposes of the analysis, two water surface elevations have been estimated as part of the study. The maximum stage elevation at each section is a result of the peak flow through the section. Based on site reconnaissance of the downstream reach it is apparent that significant flooding would occur prior to reaching the maximum stage elevation. As a result, a flood elevation defined as that elevation two feet higher than the overbank at each section was estimated. Arrival times were also estimated for both the maximum stage and flood elevations. The arrival times estimated were based on time t=0 being the time at which the piping failure begins (i.e., reservoir water surface elevation at spillway crest El. 1657.0). As a result, the total time for the maximum stage at the ACDC is about 7.0 hours whereas the time to reach the estimated flood elevation was approximately 5.9 hours.

In addition to flood elevations and arrival times, the average flow velocity at each section was estimated. The flow velocities ranged from 1.8 feet per second (fps) at the confluence with the ACDC (Section #24) to 17.2 fps at mile 1.51 (Section #5). The wide range in average flow velocities are a result of the variation between channel flow and overbank flow. At Mile 1.51 (Section #5) the flood wave is primarily within a channel resulting in a higher velocity. At mile 11.57 (Section #24) the flow velocity is affected by the vast overbank flow, which lowers the average flow velocity for the section. Furthermore, the maximum overbank flow depths were estimated and ranged from 2.8 feet at Section #8W to 20.9 feet at Section #4S. Of importance is the resulting overbank flow depth at the Cave Creek confluence with the ACDC which is about 5.2 feet, indicating significant flooding at the downstream limit of the study. In addition, for those areas encountering flow velocities greater than about 10 fps, the potential for scour and erosion may be significant for channel and overbank flow conditions.

A summary of the resulting flow data is shown on Table 5-2. Detailed output for each of the five model runs can be found in Appendix B.

Figure 5.5 summarizes the maximum stage elevation along the Cave Creek Channel reach from Section #12S (Mile 3.50) through Section #24 (Mile 11.57) for the 72-hour PMF event. Similar plots for the remaining portions of the channel reach can be found in Appendix B.

TABLE 5-1

RESERVOIR/BREACH MODEL INPUT SUMMARY

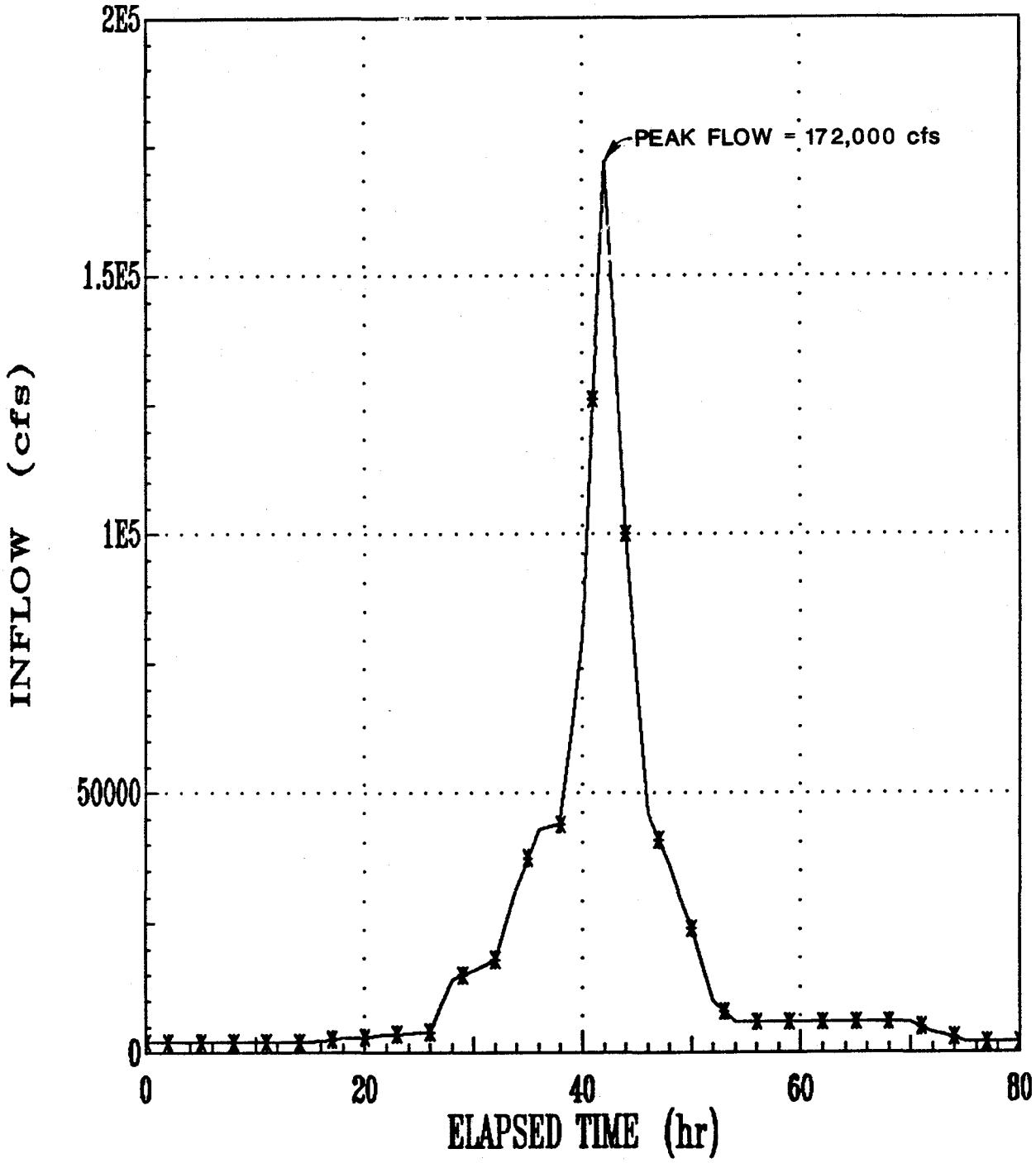
Initial Elevation of Reservoir Surface (YO, ft MSL)	1575.00
Bottom of Dam Elevation (DATUM, ft MSL)	1570.10
Top of Dam Elevation (HD, ft MSL)	1679.10
Water Surface Elevation at Time of Breach (HF, ft MSL)	1657.10
Breach Side Slope (Z)	1.15
Breach Bottom Elevation (YBMIN, ft MSL)	1570.10
Breach Base Width (BB, ft)	65.00
Time of Breach Formation (TFH, hr)	1.66
Uncontrolled Spillway Crest Elevation (HSP, ft MSL)	1657.10
Uncontrolled Spillway Discharge Coefficient (CS)	.00
Spillway Gate Center Elevation (HGT, ft MSL)	.00
Spillway Gate Discharge Coefficient (CG)	.00
Dam Overtopping Discharge Coefficient (CDO)	.00
Turbine Discharge (QT, cfs)	2000.00

TABLE 5-2
DAMBREAK MODEL OUTPUT SUMMARY

CROSS SECTION NUMBER (1)	MILES DOWNSTREAM ALONG CHANNEL	MAXIMUM STAGE ELEVATION (FT-MSL)(2)	TIME TO MAXIMUM STAGE (HR)	ESTIMATED FLOOD ELEVATION (FT-MSL)(3)	TIME TO FLOOD ELEVATION (HR) (4)	MAXIMUM OVERBANK FLOW DEPTH (FT)
1	0.13	1587.2	1.47	1571.0	0.1	18.2
2	0.30	1580.5	1.55	-	-	16.5
3	0.48	1572.6	1.64	1556.0	0.1	18.6
4S	1.09	1550.9	1.75	1532.0	0.1	20.9
5	1.51	1534.5	1.75	-	-	17.5
6	1.83	1518.6	1.82	1506.0	0.3	14.6
7	2.06	1507.2	1.82	-	-	13.2
8S	2.29	1499.9	1.82	1486.0	0.3	15.9
9	2.52	1490.7	1.89	1482.0	0.4	10.7
10	2.98	1476.3	1.96	-	-	4.3
11	3.23	1466.9	2.03	1462.0	0.9	6.9
12S	3.50	1456.6	2.08	1450.0	0.3	8.6
13S	3.84	1438.7	2.24	-	-	8.7
14S	4.16	1434.8	2.32	1422.0	0.4	14.8
15S	4.63	1418.4	2.48	-	-	14.4
16	5.52	1390.3	2.80	1387.0	1.8	5.3
17	6.30	1368.2	3.20	1367.0	2.7	3.2
18	7.44	1338.0	3.76	1332.0	3.0	8.0
19	8.12	1319.9	4.16	1317.0	3.6	4.9
20	9.07	1300.7	5.12	-	-	10.7
21	9.86	1280.9	5.76	1277.0	4.8	5.9
22	10.47	1267.7	6.16	1262.0	5.0	7.7
23	11.23	1245.2	6.72	-	-	11.2
24	11.57	1235.2	6.97	1232.0	5.9	5.2
4W	1.26	1539.7	1.82	1538.0	1.2	3.7
8W	2.00	1502.8	1.96	-	-	2.8
12W	3.21	1455.0	2.03	1453.5	0.7	3.5
13W	3.45	1447.7	2.10	-	-	3.2
14W	3.77	1436.5	2.24	-	-	3.5
15W	4.30	1415.6	2.45	1413.0	1.0	4.6

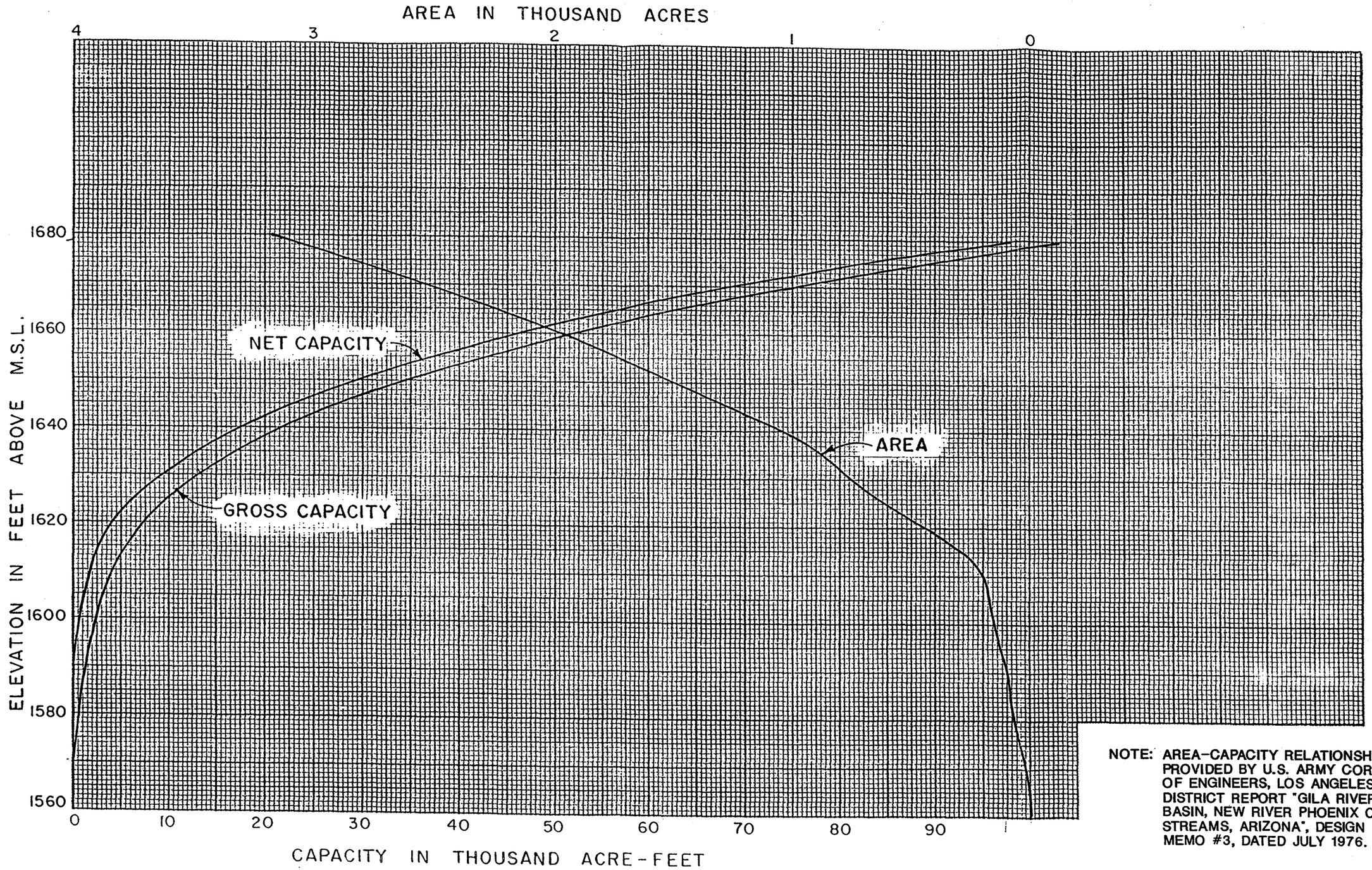
NOTES:

1. Cross sections denoted with a "W" are sections along Scatter Wash and mile locations measured along respective channel.
2. Maximum stage elevation is that elevation resulting from the 72-hour PMP Dambreak Scenario.
3. Time zero is taken as the time at the beginning of the dam failure.
4. Flood elevation is defined as the elevation at which the depth of overbank flow is 2 feet or greater.



Job No. : 8851485F	INFLOW DESIGN FLOOD HYDROGRAPH 72-HOUR PMP
Prepared by : S.F.R.	CAVE BUTTES DAM
Date : 2/16/90	FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FIG. 5-1



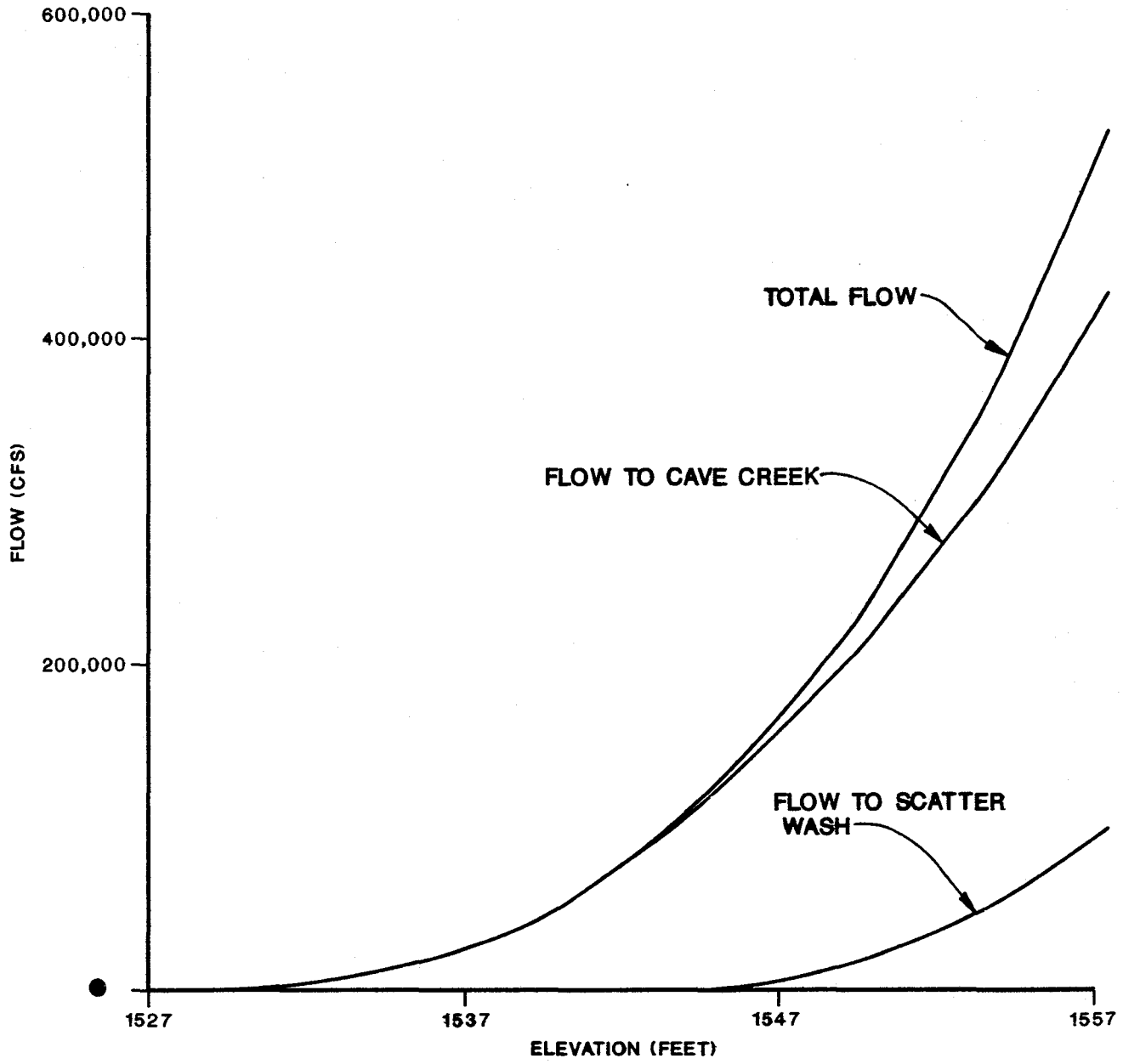
NOTE: AREA-CAPACITY RELATIONSHIP PROVIDED BY U.S. ARMY CORPS OF ENGINEERS, LOS ANGELES DISTRICT REPORT "GILA RIVER BASIN, NEW RIVER PHOENIX CITY STREAMS, ARIZONA", DESIGN MEMO #3, DATED JULY 1976.

Job No. :	8851485F
Prepared by :	S.F.R.
Date :	2/16/90

AREA-CAPACITY CURVES
CAVE BUTTES DAM
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

124835

FIG. 5-2



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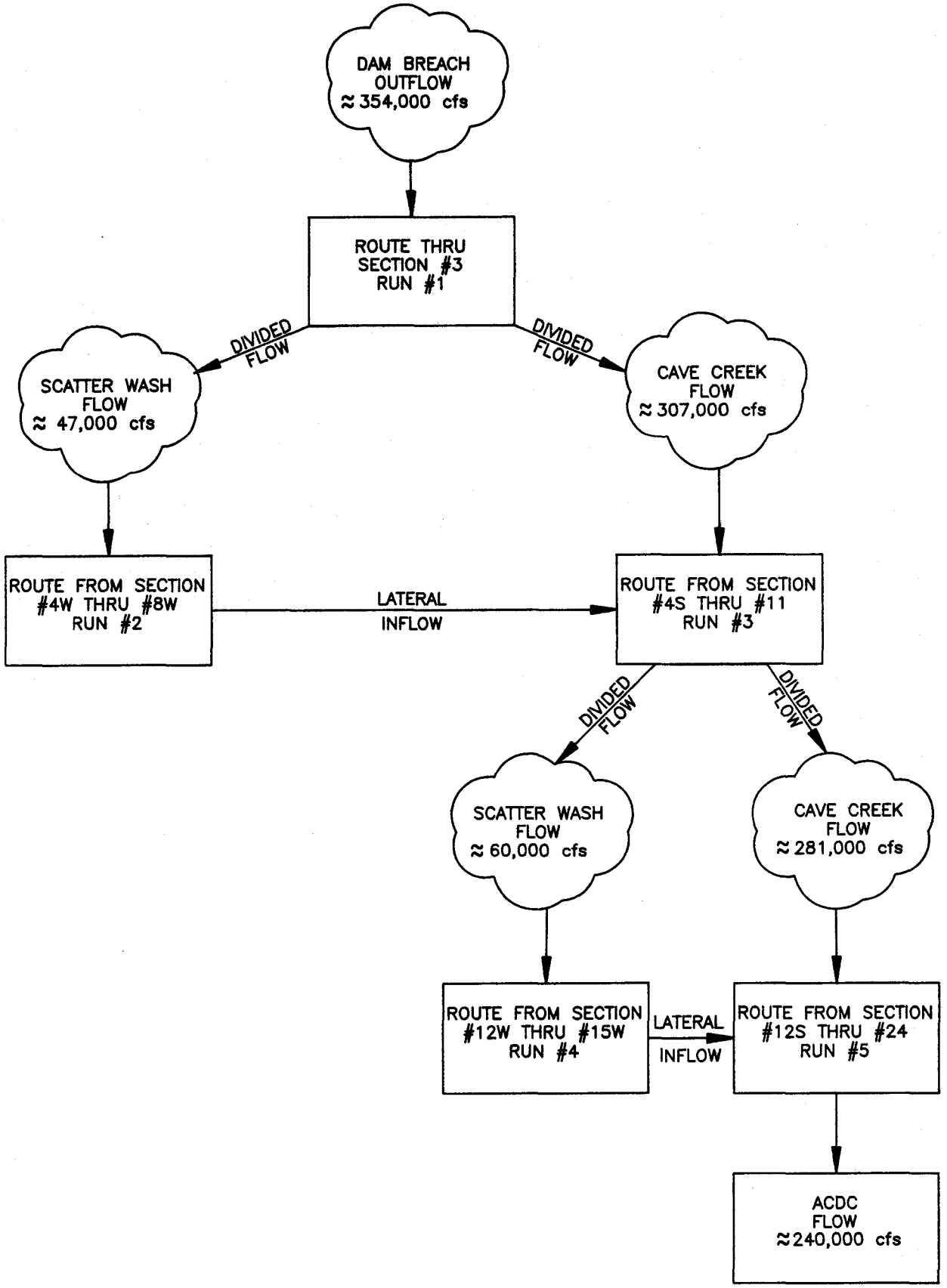
Prepared by :	S.F.R.
Date :	2/16/90

RATING CURVES FOR SPLIT FLOW ANALYSIS

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

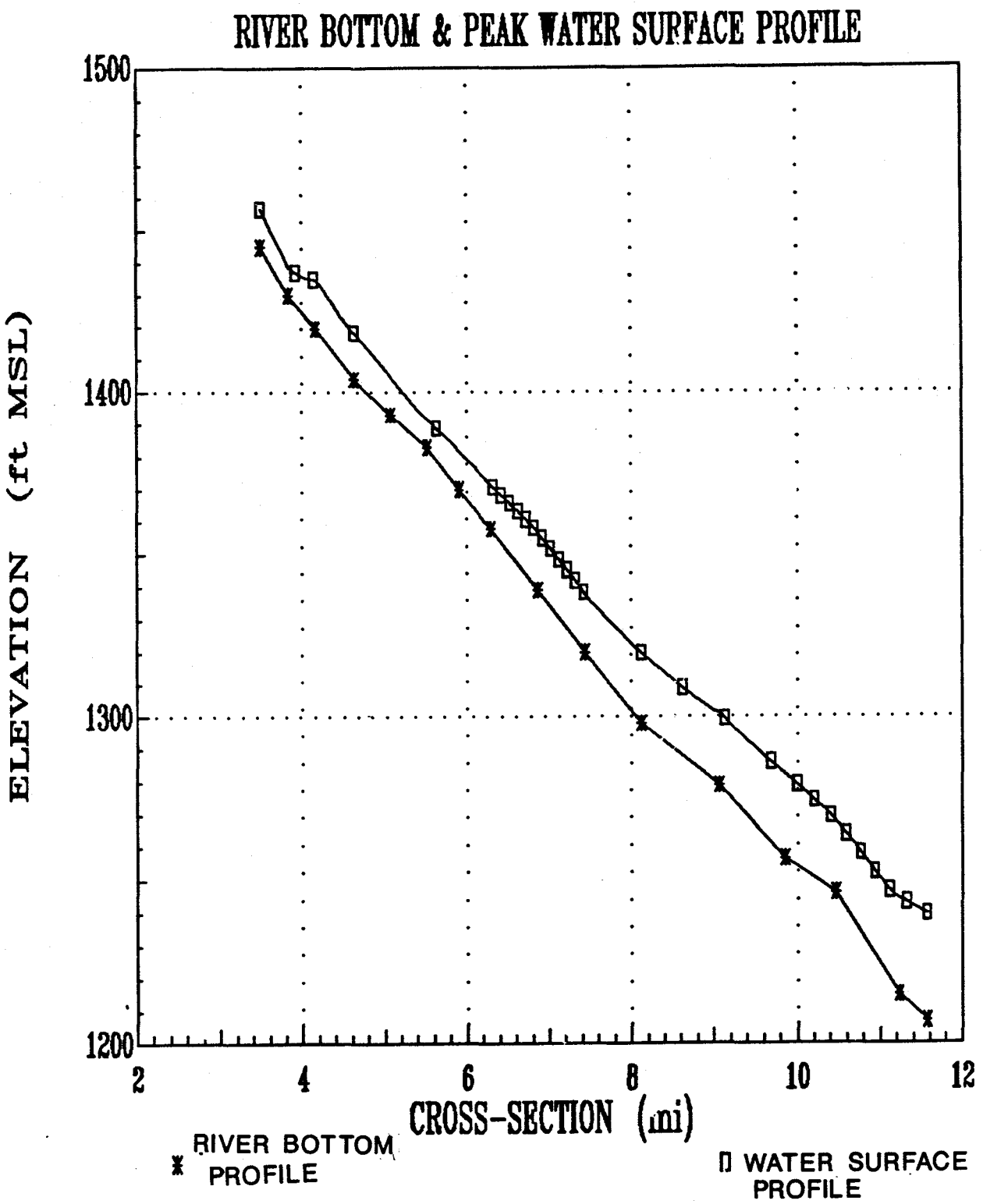
FIG. 5-3



Job No. : 8851485F	DAMBREAK ANALYSIS FLOW CHART CAVE BUTTES DAM FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
Prepared by : S.F.R.	
Date : 2/16/90	

PHOENIX

FIG. 5–4



Job No. : 8851485F	MAXIMUM STAGE ELEVATION PROFILE (SECTION #12S THROUGH #24)
Prepared by : S.F.R.	CAVE BUTTES DAM
Date : 2/16/90	FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FIG. 5-5

6.1 GENERAL

Based on the results given in the DAMBRK model output and summarized in Table 5-2 an inundation area map was prepared (See Figure 6-1). The inundation limits were based on the maximum stage elevation at each channel section. In addition, facilities within the flood inundation area requiring special attention during flood situations (i.e., hospitals, schools, etc.) have been located on the inundation area map.

6.2 INUNDATION AREA

Using output from the DAMBRK model for the 72-hour PMP event summarized in Table 5-2, the inundation area was plotted on 7.5 minute U.S.G.S topographic quadrangle maps (Figure 6-1). The estimated inundation limits were plotted based on the resulting maximum flood stage elevation at each section. In general, as shown on Figure 6-1, the inundation area reaches as far east as 7th Street and as far west as 83rd Avenue. Mapping of the inundation area indicated three additional areas of interest. Two of these areas were the Deer Valley Airport and an area near Bell Road and 51st Avenue. The general topography in these two locations results in average flow depths less than two feet, and as such meet the FEMA flow depth requirement designating a non-flooded area. For this study these two areas were included as part of the inundated area for evacuation purposes and are shown on the inundation map (Figure 6-1) as areas where average flow depths less than two feet occur. The third area of concern lies east of Moon Hill and south of Greenway Road. Modeling near this area did not indicate maximum water surface elevations reaching into the Moon Hill residential area. However, the presence of several tributaries in the area may increase the potential for backwater flow depths greater than two feet resulting from the flood wave. Therefore, as shown on Figure 6-1, the Moon Hill residential area was included as part of the inundated area. In

addition, as a result of the inundation limits dividing developments at various locations, a proposed evacuation limit was delineated in these areas and generally extended the limits of inundation to the nearest main road or highway.

6.3 SOCIAL AND ECONOMIC IMPACTS

As shown on Figure 6-1, the northern portion of the inundation area has little development. The major facility in this area is the Phoenix-Deer Valley Municipal Airport, which will be partially inundated. Further south, the density of residential areas increases and further downstream the area is fully developed.

The principal adverse impacts in the developed areas would be a major disruption of travel and possible damage to critical facilities located in this area as well as potential for loss of life. In addition, those areas encountering flow velocities greater than approximately 10 fps will potentially exhibit significant scour and erosion.

Location of critical facilities are shown on Figure 6-1. The list of the critical facilities was obtained from the Maricopa County Department of Civil Defense and Emergency Services.

An address listing of the critical facilities which fall in the inundation area is shown in Table 6-1.

TABLE 6-1

INUNDATED CRITICAL FACILITY LISTING

List of Schools

1. Northwest Community Christian School
16615 N. 43rd Avenue
Phoenix, AZ 85023

2. Child Care of Arizona
3620 W. Greenway Road
Phoenix, AZ 85023

3. Sunrise Montessori School
3302 W. Larkspur
Phoenix, AZ 85029

4. Union Hills Christian School
19201 N. 19th Avenue
Phoenix, AZ 85027

5. Hansel and Gretel Pre-School
18210 N. 19t Avenue
Phoenix, AZ 85023

6. John Jacobs School
14402 N. 23rd Avenue
Phoenix, AZ 85029

7. Lakeview School
3040 W. Yucca
Phoenix, AZ 85029

8. Moon Mountain School
13425 N. 19th Avenue
Phoenix, AZ 85029

9. Mountain Sky School
16225 N. 7th Avenue
Phoenix, AZ 85023

10. Desert Winds School
19825 N. 15th Avenue
Phoenix, AZ 85027

11. Village Meadows School
2020 W. Morningside Drive
Phoenix, AZ 85023

12. Greenway High School
3930 W. Greenway Road
Phoenix, AZ 85023

13. Moon Valley High School
3625 W. Cactus Road
Phoenix, AZ 85029

14. Thunderbird High School
1750 W. Thunderbird Road
Phoenix, AZ 85023

15. Eagle Ridge School
19801 N. 13th Street
Phoenix, AZ 85024

16. Acacia School
3201 W. Evans Drive
Phoenix, AZ 85023

17. Arroyo School
4535 W. Chollas
Glendale, AZ 85304

18. Chaparral School
3808 W. Joan D'Arc
Phoenix, AZ 85029

19. Cholla School
3120 W. Cholla
Phoenix, AZ 85029

20. Desert Foothills School
3333 W. Baniff
Phoenix, AZ 85023

21. Ironwood School
14850 N. 39th Avenue
Phoenix, AZ 85023

22. St. Jerome's
10815 N. 35th Avenue
Phoenix, AZ 85029

23. Sahuaro School
12835 N. 33rd Avenue
Phoenix, AZ 85029

24. Senita School
10444 N. 39th Avenue
Phoenix, AZ 85021

25. Shaw Butte School
12202 N. 21st Avenue
Phoenix, AZ 85029

26. Sunburst School
14218 N. 47th Avenue
Glendale, AZ 85308

27. Sweetwater School
4602 W. Sweetwater
Glendale, AZ 85304

28. Tumbleweed School
4001 W. Laurel Lane
Phoenix, AZ 85029

29. Constitution School
18440 N. 15th Avenue
Phoenix, AZ 85023

30. Dear Valley Special Education
20402 N. 15th Avenue
Phoenix, AZ 85027

TABLE 6-1
(Continued)

List of Schools (Continued)

31. Emmanuel Ev. Lutheran Church and School
3841 W. Sweetwater Ave.
Phoenix, AZ 85029

32. St. Jerome's
10815 N. 35th Ave.
Phoenix, AZ 85029

33. Mountain Shadows School
19602 N. 45th Ave.
Glendale, AZ 85308

34. Park Meadows School
20012 N. 35th Ave.
Glendale, AZ 85308

35. Sunrise School
17624 N. 31st Ave.
Phoenix, AZ 85023

36. Deer Valley Junior High School
21100 N. 27th Ave.
Phoenix, AZ 85027

37. Desert Sky Junior High School
5130 West Grovers
Glendale, AZ 85308

38. Mirage School
3910 West Grovers
Glendale, AZ 85308

39. Foothills School
15805 N. 63rd Ave.
Glendale, AZ 85306

40. Cactus High School
6330 W. Greenway Road
Glendale, AZ 85306

41. Sierra Vista School
59th Ave.
Glendale, AZ 85308

TABLE 6-1
(Continued)

List of Hospitals/Medical Facilities

1. Metro Emergency Center
   3131 W. Peoria Avenue
   Phoenix

2. Deer Valley Family Physicians
   2525 W. Greenway Road
   Phoenix

3. Family Development Resources
   2302 W. Greenway Road
   Phoenix

4. Arizona Psychological Center
   10640 N. 28th Drive
   Phoenix

5. Christian Care Nursing Center
   11812 N. 19th Avenue
   Phoenix

6. West Valley Camelback Hospital
   5625 W. Thunderbird Rd.
   Glendale, AZ

7. Glendale Surgicenter
   5757 W. Thunderbird Rd.
   Glendale, AZ

8. Phoenix General Healthcare System
   19829 N. 27th Ave.
   Deer Valley, AZ

9. Thunderbird Samaritan Hospital and Health Center
   5555 W. Thunderbird Rd.
   Glendale, AZ

10. Northwest Behavioral Health Assoc.
    5620 W. Thunderbird Rd.
    Glendale, AZ

11. Western Behavioral Professionals
    5410 W. Thunderbird Rd.
    Glendale, AZ

12. Extended Family Nursing Home
    6823 W. Union Hills Dr.
    Glendale, AZ

13. Life Care Center of North Glendale
    13620 N. 55th Ave.
    Glendale, AZ

14. Phoenix Jewish Care Center
    11411 N. 19th Ave.
    Phoenix, AZ

15. Arrowhead Community Hospital & Medical Center
    18701 N. 67th Ave.
    Glendale, AZ

TABLE 6-1
(Continued)

List of Shopping Centers

1. Bell Tower Village
   51st Ave. & Bell Rd.
   Phoenix, AZ

2. Deer Valley Plaza
   19th Ave. & Bell Rd.
   Phoenix, AZ

3. Fountain Square
   7th St. & Bell Rd.
   Phoenix, AZ

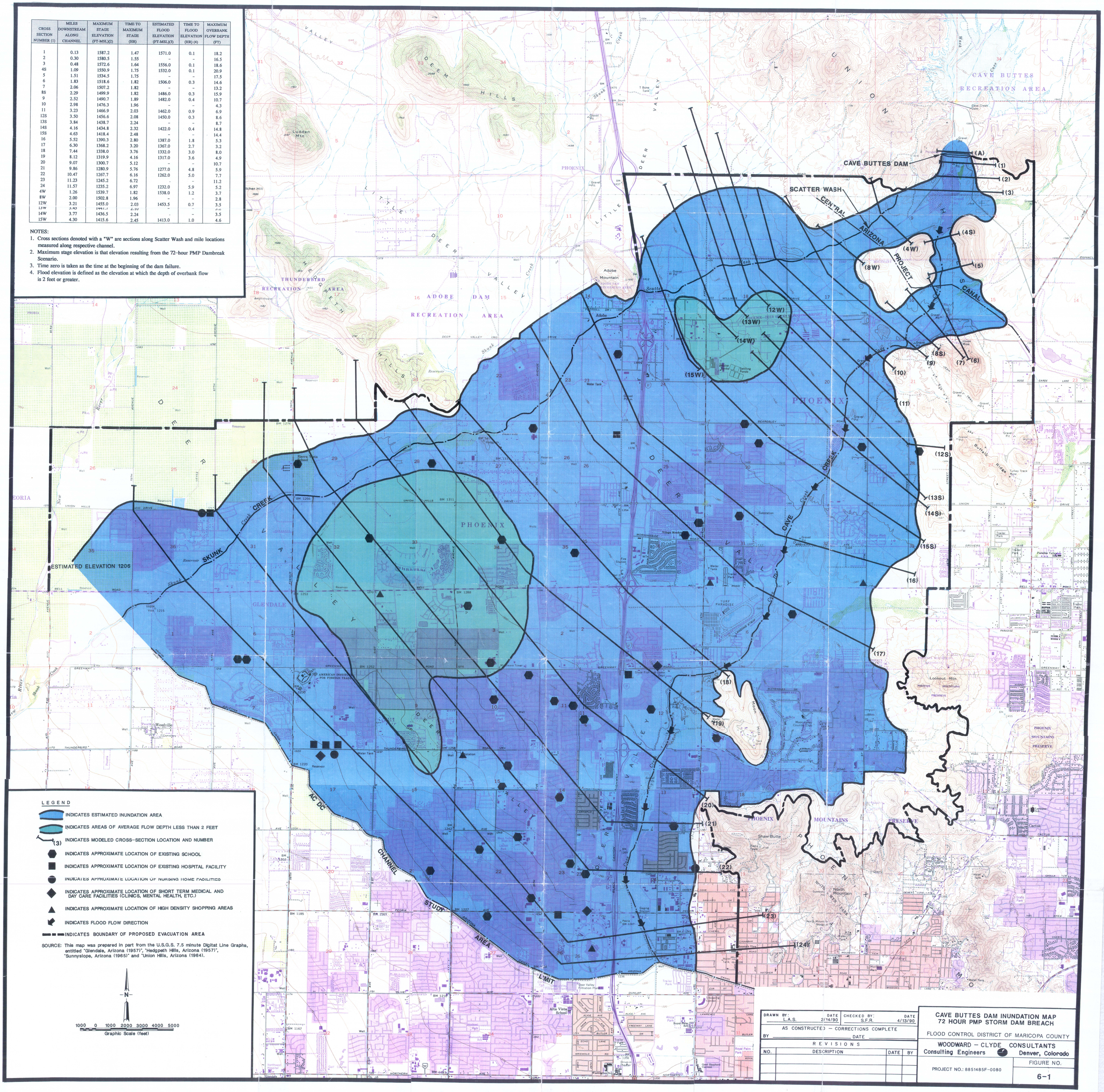
4. Deer Valley center
   43rd Ave. & Thunderbird
   Phoenix, AZ

5. Metrocenter
   Black Canyon Hgwy. & Dunlap Ave.
   Phoenix, AZ

CROSS SECTION NUMBER (1)	MILES DOWNSTREAM ALONG CHANNEL	MAXIMUM STAGE ELEVATION (FT-MSL)(2)	TIME TO MAXIMUM STAGE (HR)	ESTIMATED FLOOD ELEVATION (FT-MSL)(3)	TIME TO FLOOD ELEVATION (HR) (4)	MAXIMUM OVERBANK FLOW DEPTH (FT)
1	0.13	1587.2	1.47	1571.0	0.1	18.2
2	0.30	1580.5	1.55	-	-	16.5
3	0.48	1572.6	1.64	1556.0	0.1	18.6
4S	1.09	1550.9	1.75	1532.0	0.1	20.9
5	1.51	1534.5	1.75	-	-	17.5
6	1.83	1518.6	1.82	1506.0	0.3	14.6
7	2.06	1507.2	1.82	-	-	13.2
8S	2.29	1499.9	1.82	1486.0	0.3	15.9
9	2.52	1490.7	1.89	1482.0	0.4	10.7
10	2.98	1476.3	1.96	-	-	4.3
11	3.23	1466.9	2.03	1462.0	0.9	6.9
12S	3.50	1456.6	2.08	1450.0	0.3	8.6
13S	3.84	1438.7	2.24	-	-	8.7
14S	4.16	1434.8	2.32	1422.0	0.4	14.8
15S	4.63	1418.4	2.48	-	-	14.4
16	5.52	1390.3	2.80	1387.0	1.8	5.3
17	6.30	1368.2	3.20	1367.0	2.7	3.2
18	7.44	1338.0	3.76	1332.0	3.0	8.0
19	8.12	1319.9	4.16	1317.0	3.6	4.9
20	9.07	1300.7	5.12	-	-	10.7
21	9.86	1280.9	5.76	1277.0	4.8	5.9
22	10.47	1267.7	6.16	1262.0	5.0	7.7
23	11.23	1245.2	6.72	-	-	11.2
24	11.57	1235.2	6.97	1232.0	5.9	5.2
4W	1.26	1539.7	1.82	1538.0	1.2	3.7
8W	2.00	1502.8	1.96	-	-	2.8
12W	3.21	1455.0	2.03	1453.5	0.7	3.5
13W	3.45	1447.7	2.10	-	-	3.6
14W	3.77	1436.5	2.24	-	-	3.5
15W	4.30	1415.6	2.45	1413.0	1.0	4.6

NOTES:

1. Cross sections denoted with a "W" are sections along Scatter Wash and mile locations measured along respective channel.
2. Maximum stage elevation is that elevation resulting from the 72-hour PMP Dambreak Scenario.
3. Time zero is taken as the time at the beginning of the dam failure.
4. Flood elevation is defined as the elevation at which the depth of overbank flow is 2 feet or greater.



LEGEND

- INDICATES ESTIMATED INUNDATION AREA
- INDICATES AREAS OF AVERAGE FLOW DEPTH LESS THAN 2 FEET
- (3) INDICATES MODELED CROSS-SECTION LOCATION AND NUMBER
- INDICATES APPROXIMATE LOCATION OF EXISTING SCHOOL
- INDICATES APPROXIMATE LOCATION OF EXISTING HOSPITAL FACILITY
- INDICATES APPROXIMATE LOCATION OF NURSING HOME FACILITIES
- INDICATES APPROXIMATE LOCATION OF SHORT TERM MEDICAL AND DAY CARE FACILITIES (CLINICS, MENTAL HEALTH, ETC.)
- INDICATES APPROXIMATE LOCATION OF HIGH DENSITY SHOPPING AREAS
- INDICATES FLOOD FLOW DIRECTION
- INDICATES BOUNDARY OF PROPOSED EVACUATION AREA

SOURCE: This map was prepared in part from the U.S.G.S. 7.5 minute Digital Line Graphs, entitled "Glendale, Arizona (1957)", "Hedgpeth Hills, Arizona (1957)", "Sunnyslope, Arizona (1965)" and "Union Hills, Arizona (1964).

N

1000 0 1000 2000 3000 4000 5000
Graphic Scale (feet)

DRAWN BY: L.A.S.	DATE 2/14/90	CHECKED BY: S.F.R.	DATE 4/13/90
AS CONSTRUCTED — CORRECTIONS COMPLETE			
BY		DATE	

REVISIONS

NO.	DESCRIPTION	DATE	BY

CAVE BUTTES DAM INUNDATION MAP
72 HOUR PMP STORM DAM BREACH

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

WOODWARD – CLYDE CONSULTANTS
Consulting Engineers Denver, Colorado

PROJECT NO.: 8851485F-0080

FIGURE NO. 6-1

7.0 CONCLUSIONS

The overall objective of this study was to provide a dam failure and inundation analysis as part of an evacuation plan for the Cave Buttes Dam in accordance with the dam certification requirements set forth by the Arizona Department of Water Resources Dam Safety Division.

For purposes of this analysis, a PMF event (peak inflow = 172,000 cfs) was used in the National Weather Service's DAMBRK-88 (Boss version 2.0) to simulate the flood wave movement as a result of a dam failure (piping) condition. The limits of our study extended downstream to the confluence of Cave Creek with the ACDC. Based on the results, a flood depth of 2 feet or less, a Federal Emergency Management Agency (FEMA) requirement, was not accomplished in the study reach.

Results indicated that under the adopted dam breach conditions (i.e. 72-hour PMP), that in approximately 7.0 hours, from the actual beginning of breach, overbank flow depths ranging from 2.8 feet to 20.9 feet were estimated in the channel reach area from the dam to the ACDC. Of importance, is the resulting overbank flow depth at the Cave Creek confluence with the ACDC which is about 5.2 feet, thus resulting in significant flooding at the downstream limit of the study. Further analysis is recommended downstream of the ACDC to evaluate fully the impacts of a potential Cave Buttes Dam failure. Additionally, development in the Phoenix area is increasing, resulting in changing conditions downstream of Cave Buttes Dam, As a result, the extent of the inundated area and the effects of a Cave Buttes dambreak may change in the future. Therefore, it is recommended that such a study be revisited periodically to evaluate the impacts of the potential flooding as a result of new development.

8.0 GENERAL INFORMATION

Results and conclusions presented in this report are based partly on technical analysis and available information, partly on our understanding of site conditions and partly on our general experience with projects of a similar nature. The models used are based on sound scientific principles, tested successfully on existing reservoirs and are applicable to this dam and reservoir. Consequently, we believe the results and conclusions of this study represent a sound evaluation of the project.

Woodward-Clyde Consultants warrants that our services are performed within the limits prescribed by our clients, with the usual thoroughness and competence of the engineering profession. No other warranty or representation either expressed or implied, is included or intended in our proposals, contracts or reports.

9.0 CREDITS

The analysis was made under the general supervision of Ms. Carol Forrest and Dr. John W. Andrew, Responsible Professional and Project Manager, respectively. Mr. Scott Randall and Mr. Arsalan Dadkhah conducted the analysis. In addition, the staff of the Flood Control District of Maricopa County (Dr. Davar Khalili) provided valuable assistance and direction during the compilation of this report.

10.0 REFERENCES

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