PHASE II REPORT
VOLUME I
DAM-BREAK ANALYSIS
BUCKEYE FLOODWATER RETARDING STRUCTURE #1, #2, AND #3
FOR THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
FCD PROJECT 88-63

DAMES & MOORE

D&M Job No. 15448-003-022
June 28, 1990

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June 28, 1990

D&M Job No. 15448-003-022

Flood Control District of
Maricopa County
3335 West Durango Street
Phoenix, Arizona 85009

Attention: Mr. Joe Rumann, Hydrologist III

Phase II Report
Dam-Break Analysis
Buckeye Floodwater Retarding
Structures #1, #2, and #3
for the Flood Control District
of Maricopa County
FCD Project 88-63

Gentlemen:

Enclosed please find Dames & Moore's final submittal on the above referenced report. This submittal includes:

- five bound copies of the Phase II Report
- two sets of floppy discs of the DAMBRK computer model files
- three copies of the reduced computer printouts and copies of the supporting calculations in three-ring binders
- one unbound set of the three appendices for duplication and distribution, if desired
- one original copy of Figure 2 for duplication and distribution, if desired

This submittal completes Dames & Moore's scope of work for this project.

We have enjoyed completing this project for the Flood Control District of Maricopa County. Please contact us if you have any questions.

Very truly yours,

DAMES & MOORE

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1.0 INTRODUCTION

1.1 OBJECTIVES AND SCOPE OF WORK

1.1.1 Objectives

This report presents the results of Dames & Moore's Phase II dam-break analysis for the Buckeye Floodwater Retarding Structures (FRSs) #1, #2, and #3 located north of the Gila River and east of the Hassayampa River in Western Maricopa County, Arizona (see Figure 1). This work was completed under the terms of contract number FCD 88-63 between the Flood Control District of Maricopa County (FCD) and Dames & Moore. Phase I of this project consisted of a hydrologic analysis of the upslope portions of the Buckeye watershed and was submitted to the FCD on January 23, 1990 (Dames & Moore 1990).

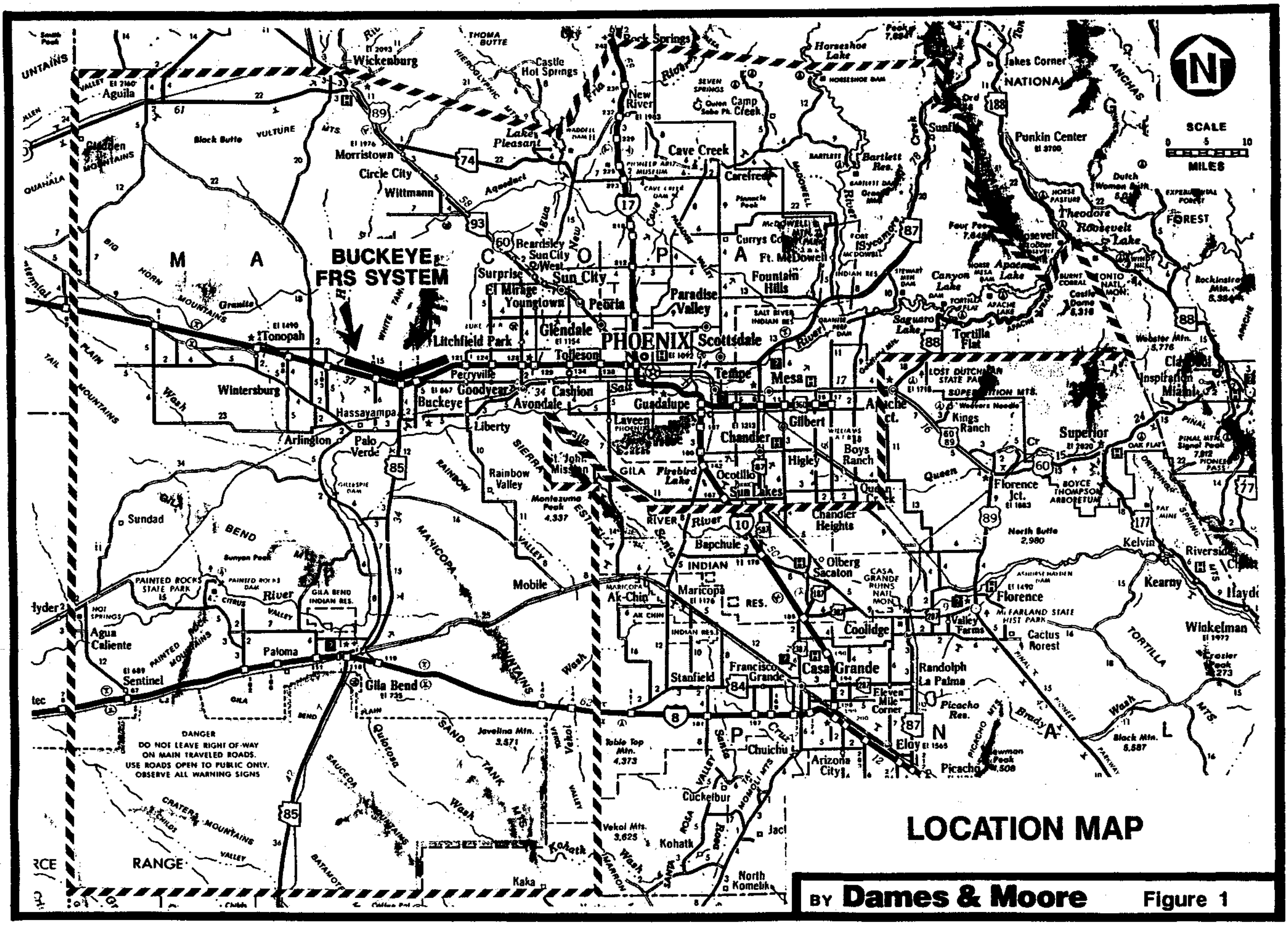
The objectives of the Phase II analyses are as follows:

- o Development of inundation maps delineating flood depths and travel times in areas likely to be flooded due to postulated breaches in FRS #1, #2, and #3.
- o Development of evacuation plans to minimize potential flood damages and loss of life resulting from the aforementioned postulated breaches.

1.1.2 Scope of Work

The scope of work required to accomplish the abovementioned objectives is detailed in Contract No. FCD-88-63. A summary of the main technical tasks inlcuded in this scope of work is given below:

- o Development of potential dam-break scenarios for each structure
- o Identification of failure hydrographs for each structure
- o Development of input data for dam-break analysis using the National Weather Service DAMBRK model
- o Dam-break flood routing and identification of inundated areas and structures



LOCATION MAP

BY **Dames & Moore** Figure 1

- o Identification of economic and social impacts associated with postulated dam failure

- o Preparation of a report for the dam-break analysis and evacuation plan including inundation maps.

1.2 DESCRIPTION OF EXISTING FACILITIES

The locations, size and hazard classifications, and design-basis floods for the three Buckeye FRSs are shown below:

STRUCTURE: Buckeye FRS #1, (AZ No. 7-42)
LOCATION: T1N, R4W, SEC 6-10, 14, 15, T1N, R5W, SEC 1-3, 12;
T2N, R5W, SEC 34, 35
SIZE CLASSIFICATION: Medium
HAZARD CLASSIFICATION: High
INFLOW DESIGN FLOOD: PMF

STRUCTURE: Buckeye FRS #2 (AZ No. 7-44)
LOCATION: T1N, R3W, SEC 7-10, T1N, R4W, SEC 13, 14
SIZE CLASSIFICATION: Medium
HAZARD CLASSIFICATION: High
INFLOW DESIGN FLOOD: PMF

STRUCTURE: Buckeye FRS #3 (AZ No. 7-45)
LOCATION: T1N, R3W, SEC 2, 3 10; T2N R3W, SEC 36
SIZE CLASSIFICATION: Medium
HAZARD CLASSIFICATION: High
INFLOW DESIGN FLOOD: PMF

The general locations of these three FRSs are shown on Figure 1. More specific information on the location of the three FRSs is presented on Figure 2.

The three FRSs were designed and constructed by the Soil Conservation Service of the U.S. Department of Agriculture. The intended purpose of the three FRSs was to protect the lower portions of the Buckeye watershed area from excessive and potentially damaging surface water flows from the upslope portions of the watershed. The structures were designed to detain runoff from storms up to and including the storm with a one percent exceedance level (the 100-year event). The three FRSs were designed to function as a single system with the detained flows cascading west to eventual outfall to the Hassayampa River. Ungated low level outlets serve as principal spillways releasing runoff to the west (see Figure 2).

Free surface emergency spillways were provided for each FRS to provide controlled discharge for storms in excess of the 100-year event. Emergency spillway discharges do not cascade to other FRSs but flow generally to the south toward the Gila River floodplain from FRSs #2 and #3 and west to the Hassayampa River from FRS #1. Selected engineering design data for the three FRSs are presented in Table 1.1.

Table 1.1

SELECTED ENGINEERING DESIGN DATA FOR BUCKEYE FRS SYSTEM

		FRS Identification		
	Units	Buckeye #1	Buckeye #2	Buckeye #3
Embankment				
Length	Miles	7.0	2.3	3.0
Maximum Height	Feet	48	26	34
Crest Elevation	Feet	1088.0[a]	1117.0	1170.0
Principal Spillway				
Conduit Diameter	Inches	60	48	30
Emergency Spillway				
Crest Width	Feet	800	350	400
Crest Elevation	Feet	1079.8	1111.2	1163.2
Reservoir				
Surface Area				
@ E. Spillway Crest	Acres	1137	150	180
@ Dam Crest	Acres	1952	235	335
Storage Volume				
@ E. Spillway Crest	Acre Feet	8200	780	1220[b]
@ Dam Crest	Acre Feet	19024	1920	2786

[a] Buckeye FRS #1 embankment crest includes a 5580-foot-long level section at elevation 1088.0 feet, a 31,500-foot-long level section at elevation 1089.5 feet and a 600-foot-long sloping transition section between the two level sections.

[b] See Phase I report (Dames & Moore 1990)

Ref: Arizona Water Commission 1979, a, b

1.3 DESCRIPTION OF DAM-BREAK STUDY AREA

The study area defined for the dam-break analysis includes only that portion of the Buckeye watershed which is down slope of the Buckeye FRS system (see Figure 2). The study area includes a total of about 92 square miles located south of the three FRSs and west of the Phoenix metropolitan area (see Figure 1). The ground in the study area is a mild sloping alluvial area primarily covered by irrigated cropland. Undeveloped areas are arid with sparse vegetation and creosote-brush association ground cover.

Drainage is generally to the south or southwest away from the FRS system. The Hassayampa River flows generally from north to south, and its 100-year floodplain limit, located using flood insurance rate maps (FEMA 1988), comprises the western boundary of the study area. The Hassayampa River outfalls to the Gila River about nine miles south of the west end of Buckeye FRS #1. The Gila River flows generally east to west about six to nine miles south of the Buckeye FRS system. The 100-year floodplain boundary, located using floodplain delineation maps for the Gila River (FCD 1988), forms the southern boundary of the study area (See Figure 2).

The Buckeye watershed south of the FRSs is a highly developed agricultural area (see Figure 3). Table 1.2 presents the approximate land use distribution within the study area.

Table 1.2

STUDY AREA LAND USE

Type of Land Use	Percent of Total Watershed Area
Cropland	68%
Residential and Commercial	7%
Undeveloped	25%
	100%

The area predominantly consists of cropland with cotton being the main crop. Within the farmed areas an irrigation network consisting of major canals, laterals and sublaterals is highly developed.

Table 1.3 lists major non-farm developed areas. The locations of the noted areas are shown on Figure 3.

Residential dwellings within the study area consist of mobile homes and frame or block houses. Most of the dwellings within the Town of Buckeye are block or frame single story buildings on concrete foundations at grade. Dwellings outside of the Town of Buckeye proper consist of approximately 50% mobile homes and 50% frame or block houses. Approximately 30 to 35% of the mobile homes in the area are on concrete or block foundations, the remaining mobile homes are supported by non-anchored posts and are one to two feet above existing grade.

Commercial development within the study area is predominantly associated with the agricultural industry, i.e., cotton ginning services, farm implement sales, seed and fertilizer sales, etc. Other types of businesses within the study area are typical of small communities, i.e., supermarkets, convenience stores, laundromats, etc. Most of the commercial buildings are on concrete foundations at grade.

The transportation network within the study area includes the two major highways listed in Table 1.3 and arterial county roads aligned north-south or east-west along most section lines. Many dirt or gravel roads have been constructed to provide access to the fields (see Figures 2 and 3).

Table 1.3

MAJOR DEVELOPED AREAS SOUTH OF BUCKEYE FRSs, UPSLOPE OF GILA AND HASSAYAMPA RIVER FLOODPLAINS

Name	Description	Closest FRS	Approximate Distance to Nearest FRS (miles)
Town of Buckeye	Incorporated town and main population/business center within the study area.	#2	3.6
Palo Verde	Residential Area	#1	6.3
Hopeville	Residential Area	#1	0.4
Developed Area #1	Residential Area	#2	0.8
Developed Area #2	Mobile Home/RV Park	#2	0.4
Developed Area #3	Residential Area	#3	1.5
Interstate 10 Highway	Major transporation route aligned east to west across study area.	#1,#2,#3	300 feet
State Highway 85	2-lane secondary highway aligned east to west across the study area and through the town of Buckeye then south towards Yuma.	#1,#2	4.7
Southern Pacific Railroad	Major railroad transportation route aligned east to west across study area.	#1,#2,#3	4.6
Roosevelt Canal	Irrigation Canal	#1,#2,#3	1.7 to 3.0
Buckeye Canal	Irrigation Canal	#1,#2,#3	4.5 to 6.4
Buckeye Municipal Airport	Landing field for small planes	#1	1.0
Luke U.S. Air Force Base Auxiliary Landing Field	Closed landing field	#3	1.7
Detention Basin	White Tanks FRS #4	#3	2.1
Buckeye Substation	Electrical Substation	#2	100 feet

1.4 OVERVIEW OF MODELING APPROACH

The objective of the modeling study is to identify areas and major structures that are likely to be inundated due to postulated breaches in Buckeye FRSs #1, #2, and #3 after performing dam-break analyses using the National Weather Service DAMBRK model. To accomplish this objective, critical locations have to be identified on each structure where there is potential for the occurrence of seepage and/or overtopping breach resulting in significant environmental and property damage. For each of these locations, possible breach dimensions (e.g., bottom width, shape, and sideslope) and times for the development of breach are estimated using data for recorded breaches in other dams, empirical relationships, and the BREACH model of the National Weather Service (MacDonald and Monopolis 1984; Fread 1988).

The initial hydrologic conditions for each breach scenario are determined from the results of the hydrologic analyses completed as Phase I of this study (Dames & Moore 1990). The dam-break flood hydrograph is routed across the downslope area using the 1989 version of the National Weather Service Dam-Break Flood Forecasting model (Fread 1984, 1988a). This model simulates supercritical as also mixed subcritical/supercritical flows across the downslope area. In addition, it automatically determines the computational distance step which circumvents convergence/stability constraints and algorithmic limitations imposed by rapidly expanding cross-sections and sudden changes in bottom slopes.

The results of dam-break flood routing are sensitive to the breach characteristics, cross-sectional data, and resistance coefficients (Manning's n values) for the areas downslope of the respective FRSs. The methods and assumptions used to estimate the breach characteristics for piping and overtopping failures of each structure are described in Section 2.1. The cross-sectional data used in this modeling study are based on 1 inch = 2000 feet topographic maps of the area with contour intervals of 10 or 20 feet.

The areas downslope of these FRSs are very flat with almost no identifiable channels or floodplains. Thus, the streamlines of the jet emanating from the breached section of the dam would have a fan-shaped spread. To simulate the fanlike spread of the dam-break flood wave propagating across these nearly flat alluvial fans, the cross-sections of the downslope flow areas were taken to be similar to the arcs of circles in plan. In this way, the streamlines of the flood wave would be approximately normal to the cross-sections.

The resistance coefficients (Manning's n values) assigned to the downslope flow areas are presented in Section 2.3.

The National Weather Service DAMBRK model does not simulate dry bed conditions on the downstream side of the dam. To circumvent this limitation, it is assumed that there is a constant flow of 500 cubic feet per second (cfs) downslope of the floodwater structure at the time of seepage failure due to antecedent or concurrent storms and/or leakage through the embankment prior to failure. The concurrent storm for seepage failure is assumed to be the 100-year 24-hour precipitation event. For overtopping failure of FRS #1 and FRS #3, the concurrent PMP storm on the areas downslope of the structures is assumed to produce a constant flow of 1500 cfs. For overtopping failure of FRS #2, a constant flow of 500 cfs is assumed because the dam-break flood peak for this case is relatively low. The concurrent storm for overtopping failure of FRS #1, #2 and #3 is assumed to be the 6-hour local storm PMP. The justifications for these assumptions are presented in section 2.2 of this report. These flows are small fractions of the dam-break flood peaks expected for the breach scenarios analyzed in this study. Therefore, minor differences in their magnitudes would not alter the results of the study.

The parameters of dam-break analysis used as input for the DAMBRK model for each FRS are described in Section 2.0 and the results of the analyses are presented in Section 3.0.

The dam-break flood routing computations presented herein assume that the emergency spillway for each FRS would remain fully operative during the passage of the concurrent flood hydrograph and the occurrence of the postulated breach. For most situations, this appears to be a realistic condition. If, under certain unusual circumstances, the emergency spillways become fully or partially inoperative, then the maximum water surface elevations in the reservoir and in the downslope areas for the overtopping breaches would be somewhat higher than those presented herein. The flow areas of the dam-break flood waves for all the overtopping breaches analyzed in this study are extremely large. Therefore, the additional breach outflows resulting from blockages in the emergency spillways are not likely to cause any significant increase in the maximum flood elevations in the downslope areas. Approximate computations indicating the increases in flood elevations for the aforementioned unusual situation are abstracted in Table 1.4.

Table 1.4

ESTIMATED INCREASES IN PREDICTED DAM-BREAK FLOOD ELEVATIONS HYPOTHESIZING THAT EMERGENCY SPILLWAYS ARE INOPERATIVE[a]

Dam-Break Flood Dischage (cfs)	Estimated Flow Velocity (ft/sec)	Approx. Flow Area (sq. ft.)	Max. Water Surface Elevation (ft)	Approx. Max. Spillway Discharge[b] (cfs)	Approx. Rise In Flood Elevation[c] (ft)
Overtopping Failure - FRS #1 at Station 892+00 Spillway Crest EL. = 1079.8 ft. Width of Spillway Crest = 800 ft.					
207,288	7.8	26,575	1088.9 (see Table 3.1)	59,295	2.2
Overtoping Failure - FRS #2 at Station 300+00 Spillway Crest EL. = 1111.2 ft. Width of Spillway Crest = 350 ft.					
60,092	4.7	12,786	1117.6 (see Table 3.4)	15,300	1.2
Overtopping Failure - FRS #3 Spillway Crest EL. = 1163.2 ft. Width of Spillway Crest = 400 ft.					
Station 161+40					
73,286	4.6	15,932	1170.5 (see Table 3.6)	21,301	1.3
Station 88+00					
80,932	4.9	16,517	1170.5 (see Table 3.7)	21,301	1.3

a These calculations provide only ball park estimates
b Spillway discharge coefficient = 2.7
c Near the middle of the routing reach

The contour interval of the maps used for this study is ten feet. With the accuracy of estimates provided by these maps, the ball park increases in flood elevations shown in Table 1.4 are judged to be insignificant.

2.0 PARAMETERS FOR DAM-BREAK ANALYSIS

2.1 *POSTULATED DAM-BREAK SCENARIOS*

2.1.1 Floodwater Retarding Structure #1

2.1.1.1 Collection And Review Of Structural Data

Floodwater Retarding Structure #1 (FRS #1) is located immediately north of Interstate-10, east of the Hassayampa River approximately nine miles north of the confluence of the Hassayampa and Gila rivers (see Figure 1). From Station 555+00 of the embankment near the Hassayampa River to the eastern end at Station 931+80, it is approximately 37,680 feet in length. This structure has a homogeneous earth section made up of Earthfill Type I. According to the terminology of the Soil Conservation Service, this means an earthen embankment with a toe drain. The dimensions of this structure pertinent to this study are shown in Table 2.1.

Table 2.1

PERTINENT DIMENSIONS OF FRS #1

Elevation of dam crest	
Stations 555+00 to 870+00	1089.5 feet
Stations 870+00 to 876+00	Sloped Transition
Stations 876+00 to 931+80	1088.0 feet
Elevation of bottom of foundation excavation	1050.0 feet
Downstream slope	2H:1V
Upstream slope	3H:1V
Width of crest	14 feet
Elevation of crest of emergency spillway	1079.8 feet
Width of emergency spillway crest	800 feet
Length of earthen embankment	37,680 feet

Storm water is released from FRS #1 through an ungated low-level outlet and channel to the Hassayampa River. For releases of limited quantities of water from low areas behind this structure, gated low level outlets have also been provided at different locations along the embankment. For the sake of conservatism, it is assumed that during a severe flood event or during a dam-break situation, the releases through the above-mentioned low-level outlets would be insignificant. During severe flood events, flood outflow from this structure enters the Hassayampa River through the emergency spillway located near the western end of the embankment.

The storage capacity and surface area of this impoundment at different water surface elevations are shown in Table 2.2.

Table 2.2

ELEVATION-AREA-STORAGE DATA FOR FRS #1

Elevation (feet)	Surface Area (acres)	Storage Capacity (acre-feet)
1060	0	0
1064	50	200
1068	120	750
1072	430	2,000
1076	760	4,500
1078	950	6,300
1079.8[a]	1,145	8,200
1082	1,390	10,400
1084	1,580	13,200
1086	1,760	16,600
1088.0[b]	1,950	20,300
1090	2,060	25,000

[a] Crest of emergency spillway
[b] Crest of embankment

According to the classification of the Arizona Department of Water Resources, it is a medium size dam with high hazard potential. The dam-break flood wave from postulated breaches in this structure are expected to move generally south to southwest towards the floodplains of the Gila and Hassayampa rivers.

2.1.1.2 Identification Of Potential Dam-Break Scenarios

A perusal of the USGS 7-1/2 minute quadrangle maps and drawings coupled with a joint site reconnaissance by FCD staff and Dames & Moore revealed that there are two critical locations for postulated seepage-induced breaches on this embankment, i.e., Stations 792+00 and 662+00. During the site reconnaissance, it was discovered that there are no visible indications of any one section of the embankment being significantly weaker than the other. Recognizing that from a geotechnical standpoint, a breach may be equally likely to occur anywhere along the embankment, the above-mentioned critical locations have been selected for the following reasons:

- The first breach section at Station 792+00 is located on a natural channel and about 4,000 feet upslope of some buildings and residences. Thus the potential for erosional damage to the dam and catastrophic damage associated with a breach at this location is judged to be higher than a similar breach at any other location.

- The second breach section at Station 662+00 is located immediately upslope of a highway underpass, about 5,000 feet upstream of the Buckeye Municipal Airport, and approximately 6,000 feet upslope of some buildings and residences. The attenuation of the dam-break flood wave due to temporary storage behind the I-10 embankment is expected to be relatively small for a breach at this location because of a wide passage for flood water provided by the highway underpass. Also, because of the proximity of the airport and buildings to the location of the breach, the potential for catastrophic damage is expected to be relatively high.

A critical location for a breach due to overtopping of the embankment is at Station 892+00 where the crest of the embankment is at elevation 1088.0 feet. At this location, the embankment crosses a natural wash. Thus the potential for erosion may be relatively high. The dam-break flood wave resulting from an overtopping breach at this location is likely to damage portions of Interstate-10, the Roosevelt Canal, and the levee along the Roosevelt Canal. Interstate-10 is within 200 feet and the Roosevelt Canal is about 12,000 feet downslope from the location of this breach.

The locations of the breaches selected for dam-break analysis for failures due to seepage and overtopping of this embankment are shown on Figure 2. Relevant structural data for the embankment at these three locations are abstracted in Table 2.3.

Table 2.3

STRUCTURAL DATA FOR FRS #1 AT THE SELECTED BREACH LOCATIONS

Data	Seepage Failure		Overtopping Failure
	First Breach Section	Second Breach Section	Third Breach Section
Location	Station 662+00	Station 792+00	Station 892+00
Elevation of Dam Crest (ft.)	1089.5	1089.5	1088.0
Ground Elevation (ft.)	1069.2	1060.6	1054.0
Elevation of Bottom of Excavation (ft.)	1066.5	1057.2	1042.0
Height of Embankment (ft.)	23.0	32.3	46.0

The dam failure mechanisms investigated in this study include overtopping and seepage. During the field visit, it was noticed that there is virtually no grass cover or riprap protection on the crest or along the downstream slope of the embankment. The material forming the embankment is judged to be fairly erodible. Therefore, it is assumed that an overtopping breach would commence as soon as the dam is overtopped by one foot (Gee, 1984). On the other hand, a breach due to seepage is assumed to occur when the reservoir is full up to the crest of the emergency spillway. The dimensions of postulated breaches for these two modes of failure have been estimated using three independent methods. The proposed dimensions to be used in this study are selected using the aforementioned estimates as guides. Brief descriptions of the three methods are given in the following paragraphs.

Method 1 - Recorded data for breaches in selected earth dams (longer than 500 feet) caused by overtopping or seepage are abstracted in Table 2.4.

Table 2.4

BREACH PARAMETERS FOR RECORDED DAM FAILURES

Name of Dam	Length (ft)	Height (ft)	Top Width of Breach (ft)	Ratio of top width of breach to dam Height	Depth of Breach (ft)	Duration of Failure (min)
Lake Avalon, New Mexico	1,380	48[a]	450	9.4	48	120
Dells, Wisconsin	960	59[a]	370	6.3	59	40
Horse Creek, Colorado	600	55	200	3.6	42	180
Hatch Town, Utah	780	65	640	9.8	65	240
Lyman, Arizona	840	65[a]	350	5.4	65	NR
Goose Creek, South Carolina	2,300	20	100	5.0	13	NR
Pudding Stone, California	825	50	300	6.0	35	180
Sinker Creek, Idaho	1,100	70[a]	300	4.3	70	120
Frenchman, Montana	2,900	40[a]	800	20.0	40	180
Wheatland, Wyoming	6,600	45[a]	150	3.3	45	90
Teton, Idaho	3,100	305	150	0.5	261	240
Kelly Barnes Lake, Georgia	500	26[a]	450	17.3	26	30
Elk City, Oklahoma	850	30	150	5.0	30	NR
Coedty	860	36	220	6.1	NR	30
Erindale	700	36	130	3.6	15	30
Lower Otay	565	130	565	4.3	130	15
Machhu II	13,700	197	1,768	9.0	197	120
South Fork	930	72	400	5.5	NR	45

[a]Estimated values
NR = Not reported

Sources: 1. A Classification of Dam Failures, F.A. Johnson and P. Illes, Water Power and Dam Construction, Dec. 1976.
2. Engineering News Record, McGraw-Hill Book Co., New York
3. Singh and Snorrason, 1982

A perusal of the data presented in Table 2.4 indicates that the top widths of breaches in long earthen embankments have varied from 100 to 1,768 feet, the depth of the breach has generally been equal to the height of the dam, and the time of failure has varied from 15 minutes to 4 hours. The ratio of the top width of breach to the height of dam has varied from 3.3 to 20 except for Teton Dam where this ratio was 0.5. The median of the ratios is about 5.5. For a breach with side slopes of 1H:1V, this corresponds to a bottom width of about 3.5 times the height of the dam. With side slopes of

0.5H:1V, it corresponds to a bottom width of about 4.5 times the height of the dam.

With an analysis of 52 dam failures, Singh and Scarlatos (1988) estimated a mean value of 4.18 with a standard deviation of 2.62 and a range of 0.84 to 10.93 for the ratio of the top width of breach to the height of dam. Recognizing that the 52 dams used to compute these values included both long (greater than 500 feet in length) and short (smaller than 500 feet in length) embankments, a ratio of 5.5 between the top width of breach and height of dam or water depth behind the dam for long embankments of relatively small heights appears to be reasonably conservative.

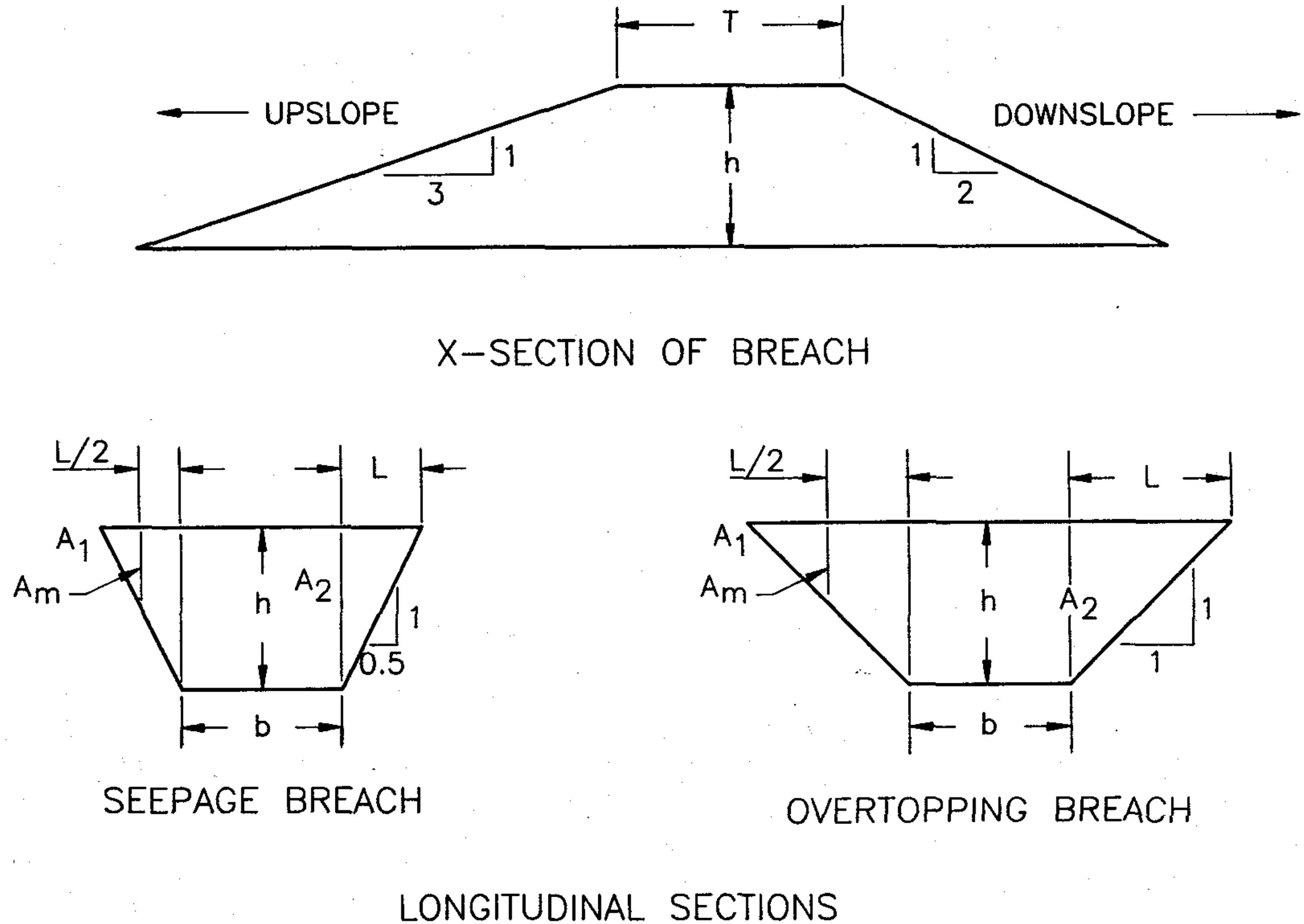
Method 2 - After a study of 42 dam failures, MacDonald and Monopolis (1984) developed a straight line relationship between the logarithms of a breach formation factor (in acre-ft^2) and the volume of material removed during breach (in cubic yards). This relationship may be approximated by the following equation:

$$V = 3.19 \ (Wh_w)^{0.7653} \qquad (2.1)$$

where, Wh_w = breach formation factor = outflow volume of water in acre feet x depth of water above breach base in feet, and

V = volume of material removed during breach in cubic yards

The side slopes of 23 breaches reported in the aforementioned publication (MacDonald and Monopolis 1984) ranged from 1H:6.7V to 1H:0.5V. Engineering judgment suggests that the side slopes of breaches due to seepage may be somewhat steeper than those due to overtopping. For purposes of this study, it is assumed that the side slopes of breaches due to seepage would be 0.5H:1V whereas the side slopes of overtopping breaches would be 1H:1V (Houston 1985). A typical cross-section and longitudinal sections of postulated breaches due to seepage and overtopping are shown in Figure 4. To compute the volumes of material removed during a breach, the following equations have been used:



TYPICAL SECTIONS OF POSTULATED BREACHES

Figure 4

$$V = \frac{1}{27} \left(b \times (Th + 2.5\, h^2) + \frac{L}{3} (A_1 + 4A_m + A_2) \right) \qquad (2.2)$$

where,
- V = volume of material removed in cubic yards,
- b = bottom width of breach in feet,
- T = width of dam crest in feet = 14 feet,
- h = depth of breach in feet,
- 2.5 = average of side slopes of the embankment,
- L = base of the triangular portion of breach in feet = 0.5h for seepage breach and h for overtopping breach,
- A_1 = area of breach cross section at the edge along its top width in square feet = 0,
- A_2 = area of breach cross-section in the rectangular portion in square feet = $Th + 2.5h^2$, and
- A_m = area of breach cross section at the mid-point of the base of the triangular portion in square feet = $0.5Th + 2.5(0.5h)^2$.

The value of V is estimated from Equation 2.1. Knowing V, Equation 2.2 is used to estimate the value of b.

Method 3 - The National Weather Service (NWS) has developed a breach erosion model for earthen dams (Fread 1988) which estimates the size and shape of the breach using the D_{50}, unit weight, angle of internal friction, cohesive strength, and Manning's roughness coefficient for the embankment material, geometric parameters for the embankment and downstream channel, elevation-area data for the impoundment, initial reservoir water surface elevation, and the inflow hydrograph at the time of failure. The model results are sensitive to the aforementioned embankment material properties.

Using the three methods described previously, (top width to water depth ratio of 5.5, MacDonald and Monopolis, and NWS), breach dimensions have been estimated for the three locations identified in Table 2.3 for failures due to seepage and overtopping. The resulting values along with the breach dimensions proposed to be used for this analysis are shown in Table 2.5.

The authors of the second method (MacDonald and Monopolis 1984) indicate that the relationships developed by them may not be appropriate for extremely wide or narrow embankments or embankments which have other unique characteristics that influence their breaching patterns. Also, the data used by these authors (MacDonald and Monopolis) were limited and, in some cases, were inferred from general descriptions. In some cases, different breach dimensions and other data have been reported for the same dam in different publications. The breach widths given by this method are generally larger than those given by the other two methods.

In simulating the dam-break flood wave for Buffalo Creek Dam in West Virginia, Fread (1984) used a breach bottom width of 4.25 times the height of the dam and reported that the average breach width for earth dams is 1 to 3 times the height of the dam (Johnson and Illes 1976). Most of the values given by the MacDonald and Monopolis approach are beyond this range.

In view of the above, the bottom widths of breaches proposed for the current analysis are taken to be larger than those given by Methods 1 and 3. In general, the values given by the MacDonald and Monopolis approach appear to be overly conservative.

Table 2.5

ESTIMATED WIDTHS OF BREACHES FOR FRS #1

Breach Location and Type of Failure	Bottom Width of Breach (feet) Method 1 (top width = 5.5 x depth of water)	Method 2 MacDonald and Monopolis (1984)	Method 3 Breach Model[c] (Fread, 1988)	Selected Width
1. Station 662+00 Seepage failure[a] Reservoir water surface EL = 1079.8 Depth of water = 13.3 ft. Depth of breach = 23.0 ft.	60	367	220	250
2. Station 792+00 Seepage failure[a] Reservoir water surface EL = 1079.8 ft. Depth of water = 22.6 ft. Depth of breach = 32.3 ft.	102	291	48	150
3. Station 892+00 Overtopping failure[b] Reservoir water surface EL = 1089.0 ft Depth of water = 47.0 ft. Depth of breach = 46.0 ft.	161	563	329	350

[a] Bottom width = 4.5 x depth of water above base of breach with side slopes of 0.5H:1V.

[b] Bottom width = 3.5 x depth of water above base of breach with side slopes of 1H:1V.

[c] D_{50} = 0.035 mm; porosity = 0.2; unit weight = 100 lbs/ft^2; angle of internal friction = 40°; cohesive strength = 250 lbs/ft^2; and Manning's n = 0.025 for embankment material.

Comparing the breach depth of 23.0 to 32.3 feet for seepage failure shown in Table 2.5 with those listed in Table 2.4, a duration of 30 minutes appears to be reasonable for the occurrance of the postulated seepage breaches in this structure. For the overtopping breach depth of 46.0 feet, a failure time of 90 minutes appears to be reasonably conservative.

2.1.2 Floodwater Retarding Structure #2

2.1.2.1 Collection And Review Of Structural Data

Floodwater Retarding Structure #2 (FRS #2) is located north of Interstate-10, east of FRS #1 and discharges to the latter through an ungated low-level outlet and an approximately 12,000-foot long outflow channel (Figure 2). From the starting Station 203+50 at its eastern end to the western end at Station 331+64, it is approximately 12,814 feet in length. It has a homogeneous earth section made up of Earthfill Type I. The dimensions of this structure pertinent to this study are shown in Table 2.6.

Table 2.6

PERTINENT DIMENSIONS OF FRS #2

Elevation of dam crest	1117.0 feet
Elevation of bottom of foundation excavation	1098.5 feet
Downstream slope	2H:1V
Upstream slope	3H:1V
Width of crest	14 feet
Elevation of crest of emergency spillway	1111.2 feet
Width of emergency spillway crest	350 feet
Length of earthen embankment	12,814 feet

Storm water is released from FRS #2 through the ungated low-level outlet and channel to FRS #1. For releases of limited quantities of water from low areas behind this structure, gated low-level outlets have also been provided at different locations along the embankment. For the sake of conservatism, it is assumed that during a severe flood event or during a dam-break situation, the releases through the above-mentioned low-level outlets would be insignificant. During severe flood events, flood outflow from this structure passes through the emergency spillway located near the western end of the embankment and flows generally south toward the Gila River floodplain (see Figure 2). The dam-break flood wave from a postulated breach in this structure is also expected to move generally south toward the floodplain of the Gila River.

The storage capacity and surface area of this impoundment at different water surface elevations are shown in Table 2.7.

Table 2.7

ELEVATION-AREA-STORAGE DATA FOR FRS #2

Elevation (feet)	Surface Area (acres)	Storage Capacity (acre-feet)
1100	1	0
1102	21	38
1104	42	113
1106	69	225
1108	98	375
1110	130	625
1111.2[a]	150	780
1112	161	900
1114	193	1,250
1116	223	1,650
1117.0[b]	240	1,880
1118	254	2,125
1120	288	2,712

[a] Crest of emergency spillway
[b] Crest of embankment

According to the classification of the Arizona Department of Water Resources, it is a medium dam with high hazard potential.

2.1.2.2 Identification Of Potential Dam-Break Scenarios

This structure is similar to FRS #1 in design and construction. Recognizing that a postulated breach may be equally likely to occur anywhere along this embankment, a critical location is judged to be at station 300+00. This section is approximately 1,100 feet upslope from the I-10 interchange with Miller Road (see Figure 2). Thus the dam-break flood wave generated by a breach at this location is likely to travel downstream through this interchange with relatively small attenuation. The breach section is approximately 3,500 feet upslope of a cluster of residences and other buildings. Thus the potential for catastrophic damage due to a breach at this location is expected to be higher than a similar breach at any other location.

Relevant structural data for the embankment at this location are abstracted in Table 2.8.

Table 2.8

STRUCTURAL DATA FOR FRS #2 AT THE SELECTED BREACH LOCATION

Location	Station 300+00
Elevation of dam crest	1117.0 ft.
Ground elevation	1099.4 ft.
Elevation of bottom of excavation	1098.5 ft.
Height of embankment	18.5 ft.

The dam failure mechanisms investigated for this structure include seepage and overtopping.

The bottom widths of postulated breaches in this structure estimated by the three methods described in Section 2.2 along with the widths selected to be used for this study are shown in Table 2.9. To be conservative, the selected width for overtopping failure has been taken to be higher than that given by any of the three methods. This is because the width estimated by the breach model (Method 3) for this case is more than that estimated by the MacDonald and Monopolis method.

Table 2.9

ESTIMATED WIDTHS OF BREACHES FOR FRS #2

Breach Location and Type of Failure	Bottom Width of Breach (feet): Method 1 (top width = 5.5 x depth of water)	Method 2 MacDonald and Monopolis (1984)	Method 3 Breach Model[c] (Fread, 1988)	Selected Width
Station 300+00				
(a) Seepage failure[a] Reservoir water surface EL = 1111.2 ft. Depth of water = 12.7 ft. Depth of breach = 18.5 ft.	57	81	23	60
(b) Overtopping failure[b] Reservoir water surface EL = 1118.0 ft. Depth of water = 19.5 ft. Depth of breach = 18.5 ft.	68	250	268	270

[a] Bottom width = 4.5 x depth of water above base of breach with side slopes of 0.5H:1V.

[b] bottom width = 3.5 x depth of water above base of breach with side slopes of 1H:1V.

[c] D_{50} = 0.035 mm; porosity = 0.2; unit weight = 100 lbs/ft^3; angle of internal friction = 40°; cohesive strength = 250 lbs/ft^2; and Manning's n = 0.025 for embankment material.

Comparing the breach depth of 18.5 feet shown in Table 2.9 with those listed in Table 2.4, a duration of 30 minutes appears to be reasonable for the occurrence of the postulated breaches in this structure.

2.1.3 Floodwater Retarding Structure #3

2.1.3.1 Collection And Review Of Structural Data

Floodwater Retarding Structure #3 (FRS #3) is located north of Interstate-10 and east of FRS #2 and is connected to the latter through an ungated low-level outlet and an approximately 1,400-foot-long outflow channel (Figure 2). From the starting Station 26+70 at its eastern end to

Station 195+21.08 on the western end, it is approximately 16,851 feet in length. This structure is made up of homogeneous compacted earthfill with a coarser-grained drainage zone in the downstream portion. The dimensions of this structure pertinent to this study are shown in Table 2.10.

Table 2.10

PERTINENT DIMENSIONS OF FRS #3

Elevation of dam crest	1170.0 feet
Elevation of bottom of foundation excavation	1142.0 feet
Downstream slope	2H:1V
Upstream slope	3H:1V
Width of crest	14 feet
Elevation of crest of emergency spillway	1163.2 feet
Width of emergency spillway crest	400 feet
Length of earthen embankment	16,851 feet

Storm water is released from FRS #3 through the ungated low-level outlet and outflow channel connecting the western end of the structure to FRS #2. For releases of limited quantities of water from low areas behind this structure, gated low level outlets have been provided at different locations along the embankment. For the sake of conservatism, it is assumed that during a severe flood event, or during a dam-break situation, the releases through the above-mentioned low-level outlets would be insignificant. During severe flood events, flood outflow from this structure occurs through the emergency spillway located near the eastern end and flows generally south to the floodplain of the Gila River as shallow sheet flow, down roads or through poorly defined washes (see Figure 2). The dam-break flood wave from postulated breaches in this structure is also expected to move generally south toward the floodplain of the Gila River.

The storage capacity and surface area of this impoundment at different water surface elevations are shown in Table 2.11.

Table 2.11

ELEVATION-AREA-STORAGE DATA FOR FRS #3

Elevation (feet)	Surface Area (acres)	Storage Capacity (acre-feet)
1149	0	0
1150	2	2
1152	9	20
1154	43	90
1156	78	190
1158	115	350
1160	153	630
1162	190	910
1163.2[a]	210	1,220
1164	223	1,350
1166	264	1,900
1168	298	2,490
1170.0[b]	335	3,020
1172	372	3,600
1174	410	4,160

[a] Crest of emergency spillway
[b] Crest of embankment

According to the classification of the Arizona Department of Water Resources, it is a medium dam with high hazard potential.

2.1.3.2 Identification Of Potential Dam-Break Scenarios

This structure is similar to FRSs #1 and #2 in design and construction. Recognizing that a postulated breach may be equally likely to occur anywhere along this embankment, two critical locations have been identified at Stations 88+00 and 161+40, respectively (see Figure 2). The location at Station 88+00 is approximately 6,000 feet upslope of a closed landing field and 8,000 feet upslope of a cluster of buildings. The other location at Station 161+40 is approximately 7,000 feet upslope of a cluster of buildings. Thus the potential for catastrophic damage due to a breach at either of these locations is expected to be higher than a similar breach at other locations. Both breach sections are located on existing small washes and there would be no major obstructions in the paths of the postulated dam-break flood waves. Thus the attenuation of the dam-break flood wave upstream of the aforementioned residences is expected to be minimal.

Relevant structural data for the embankment at these two locations are abstracted in Table 2.12.

Table 2.12

STRUCTURAL DATA FOR FRS #3 AT THE SELECTED BREACH LOCATIONS

Data	First Breach Section	Second Breach Section
Location	Station 88+00	Station 161+40
Elevation of Dam Crest (ft.)	1170.0	1170.0
Ground Elevation (ft.)	1151.6	1142.4
Elevation of Bottom of Excavation (ft.)	1148.2	1142.0
Height of Embankment (ft.)	21.8	28.0

The dam failure mechanisms investigated for this structure include seepage and overtopping.

The bottom widths of postulated breaches at the aforementioned locations have been estimated by the three methods described in Section 2.2. The resulting values along with the proposed breach widths are shown in Table 2.13.

Table 2.13

ESTIMATED WIDTHS OF BREACHES FOR FRS #3

Breach Location and Type of Failure	Bottom Width of Breach (feet): Method 1 (top width = 5.5 x depth of water)	Method 2 MacDonald and Monopolis (1984)	Method 3 Breach Model[c] (Fread, 1988)	Selected Width
1. Station 88+00				
(a) Seepage failure[a] Reservoir water surface EL = 1163.2 ft Depth of water = 15.0 ft. Depth of breach = 21.8 ft.	68	97	54	75
(b) Overtopping failure[b] Reservoir water surface EL = 1171.0 ft. Depth of water = 22.8 ft. Depth of breach = 21.8 ft.	80	296	245	250
2. Station 161+40				
(a) Seepage failure[a] Reservoir water surface EL = 1163.2 ft. Depth of water = 21.2 ft. Depth of breach = 28.0 ft.	95	77	44	95
(b) Overtopping failure[b] Reservoir water surface EL = 1171.0 ft. Depth of water = 29.0 ft. Depth of breach = 28.0 ft.	102	218	170	200

[a] Bottom width = 4.5 x depth of water above base of breach with side slopes of 0.5H:1V.

[b] bottom width = 3.5 x depth of water above base of breach with side slopes of 1H:1V.

[c] D_{50} = 0.035 mm; porosity = 0.2; unit weight = 100 lbs/ft^3; angle of internal friction = 40°; cohesive strength = 250 lbs/ft^2; and Manning's n = 0.025 for embankment material.

Comparing the breach depths of 21.8 to 28.0 feet shown in Table 2.13 with those listed in Table 2.4, a duration of 30 minutes appears to be reasonable for the occurrence of the postulated breaches in this structure.

2.2 INITIAL HYDROLOGIC CONDITIONS

2.2.1 Floodwater Retarding Structure #1

2.2.1.1 Overtopping Failure

Detailed hydrologic analyses for this structure were performed during Phase I of this study (Dames & Moore 1990). The results of these analyses indicate that if the emergency spillway remained fully operational, then the PMF resulting from the 72-hour general storm PMP would overtop the embankment by 0.7 foot and the PMF resulting from the 6-hour local storm PMP would overtop it by 1.9 feet. The maximum reservoir storage during these two storms is estimated to be 21,847 and 24,697 acre-ft, respectively. Thus, so far as dam-break flood elevations downstream of the embankment are concerned, a breach occurring during the 6-hour local storm PMP event would be more critical.

The embankment crest includes a 5580-feet-long level section at elevation 1088.0 feet, a 31,500-feet-long level section at elevation 1089.5 feet, and a 600-feet-long sloping transition section between the above two level sections. The material along the crest of the embankment is such that wave splashing may result in severe erosion. Therefore, it is assumed that dam failure due to wave overtopping may ensue as soon as the freeboard between the top of the embankment and reservoir water surface elevation approaches 1.0 foot.

Dam-break flood routing computations have been performed using the 1989 version of the NWS Dam-Break model with the simultaneous computation method for dynamic routing in the reaches upslope and downslope of the structure. This model becomes unstable for dry bed initial conditions in the downslope areas. To circumvent this computational problem, it is assumed that there is a low-flow channel downstream of the dam with a small constant flow of 500 cfs at the time of the breach. This flow is less than one-percent of the maximum estimated breach outflow (see Section 3.1.1) and is not expected to affect the predicted maximum water surface elevations in the downslope areas resulting from the dam-break flood.

Other hydrologic variables used to define the initial and other relevant conditions for the dam-break model are shown in Table 2.14.

Table 2.14

INITIAL AND OTHER RELEVANT CONDITIONS FOR DAM-BREAK MODELING OF FRS #1 DUE TO OVERTOPPING FAILURE

Conditions	Numerical Description
Breach Location	Station 892+00
Inflow Hydrograph	6-hour local storm PMP
Reservoir water surface elevation when computations commence	1079.8 feet
Length of Reservoir	1.515 mile
Reservoir water surface elevation when failure of dam commences	1087.0 feet
Spillway crest elevation	1079.8 feet
Width of uncontrolled spillway	800 feet
Spillway discharge coefficient	2.7
Elevation of embankment crest (minimum)	1088.0 feet
Length of overflow section of embankment	5580 feet
Discharge coefficient for earthen embankment	2.7
Elevation of bottom of breach after full development	1060.0 feet
Bottom width of breach after full development	350 feet
Sideslopes of breach	1H:1V
Time for full development of breach	1.5 hours

2.2.1.2 Seepage Failure

As stated in Section 2.1.1.2, there are two critical locations for piping failure of this structure, i.e., at Station 662+00 and 792+00, respectively. The dam-break flood routing computations for postulated breaches at each of these stations have been made using the simultaneous computation method of dynamic routing included in the 1989 version of the NWS DAMBRK model (Fread 1984; Fread 1988a).

Usually, seepage failure would occur under clear weather conditions. However, it is possible that a portion of the watershed may experience some rain at the time seepage failure occurs at the dam site. To account for this eventuality, it is assumed that the postulated seepage breaches are concurrent with a 100-year 24-hour storm in the watershed; the reservoir water surface elevation at the beginning of the storm is at the crest of the emergency spillway; and the antecedent and concurrent storms on areas downslope of the embankment produce a constant flow of 500 cfs in the flowpath on the downstream side of the breach (see Section 1.3). Note that these assumptions are reasonably conservative. Besides, the pre-existing constant flow of 500 cfs circumvents the computational problem associated with dry-bed channel routing using the NWS DAMBRK model.

The hydrologic variables used to define the initial and other relevant conditions for dam-break flood routing due to seepage breaches at the abovementioned locations are shown in Table 2.15.

Table 2.15

INITIAL AND OTHER RELEVANT CONDITIONS FOR DAM-BREAK MODELING OF FRS #1 DUE TO SEEPAGE FAILURE

Conditions	Numerical Description: Seepage Breach at Station 662+00	Seepage Breach at Station 792+00
Inflow Hydrograph	100-year 24-hour storm	100-year 24-hour storm
Reservoir water surface elevation when computations commence	1079.8 feet	1079.8 feet
Length of reservoir	1.515 mile	1.515 mile
Reservoir water surface elevation when failure of dam commences	1079.8 feet	1079.8 feet
Spillway crest elevation	1079.8 feet	1079.8 feet
Width of uncontrolled spillway	800 feet	800 feet
Spillway discharge coefficient	2.7	2.7
Initial center elevation of seepage pipe	1063.0 feet	1063.0 feet
Elevation of bottom of breach after full development	1060.0 feet	1060. feet
Bottom width of breach after full development	250 feet	150 feet
Sideslopes of breach	0.5H:1V	0.5H:1V
Time for full development of breach	0.5 hour	0.5 hour

2.2.2 Floodwater Retarding Structure #2

2.2.2.1 Overtopping Failure

Detailed hydrologic analyses for this structure were performed during Phase I of this study (Dames & Moore 1990). The results of these analyses indicate that if the emergency spillway remains fully operative, then the PMF resulting from a 72-hour general storm PMP would pass with a freeboard of 1.6 feet below the top of the embankment and that resulting from a 6-hour local storm PMP would overtop the embankment by 0.6 feet. Therefore, so far as dam-break flood elevations downslope of the embankment are concerned, a breach occurring during the 6-hour local storm PMP event would be more critical. The material along the crest of the embankment is such that wave splashing may result in severe erosion. Therefore, it is assumed that dam failure due to wave overtopping may ensue as soon as the freeboard between the top of the embankment and reservoir water surface elevation approaches 1.0 feet.

Dam-break flood routing computations for the structure have been performed with the NWS Dam-Break model using the simultaneous computation method for dynamic routing in the reaches upslope and downslope of the structure. This model becomes unstable for dry bed conditions in the downslope areas. To avoid this computational problem, it is assumed that a downslope channel is present with a small constant flow of 500 cfs at the time of the breach. This flow is less than one percent of the maximum breach outflow and is not expected to affect the maximum water surface elevations in the downslope areas resulting from the dam-break flood (see section 3.2.1).

Other hydrologic variables used to define the initial and other relevant conditions for the model are shown in Table 2.16.

Table 2.16

INITIAL AND OTHER RELEVANT CONDITIONS FOR DAM-BREAK MODELING OF FRS #2 DUE TO OVERTOPPING FAILURE

Conditions	Numerical Description
Breach Location	Station 300+00
Inflow Hydrograph	6-hour local storm PMP
Reservoir water surface elevation when computations commence	1111.2 feet
Length of Reservoir	0.246 mile
Reservoir water surface elevation when failure of dam commences	1116.0 feet
Spillway crest elevation	1111.2 feet
Width of uncontrolled spillway	350.0 feet
Spillway discharge coefficient	2.7
Elevation of embankment crest	1117.0 feet
Length of overflow section of embankment (Dames & Moore 1990)	9,455 feet
Discharge coefficient for earthen embankment	2.7
Elevation of bottom of breach after full development	1100.0 feet
Bottom width of breach after full development	270 feet
Sideslopes of breach	1H:1V
Time for full development of breach	0.5 hour

2.2.2.2 Seepage Failure

The dam-break flood routing computations for this case have been performed using the simultaneous computation method of dynamic routing in the reaches upslope and downslope of the structure. To avoid computational problems associated with dry-bed channel routing, the downslope area is assumed to have a small channel with a constant flow of 500 cfs at the time of the breach. This flow is a very small percentage of the anticipated maximum breach outflow and is not expected to affect the maximum water surface elevations in the downslope areas resulting from the dam-break flood (see section 3.2.2).

Usually, seepage failure would occur under clear weather conditions. However, it is possible that a portion of the watershed may experience some rain at the time piping failure occurs at the dam site. To account for this eventuality, it is assumed that there is an inflow into the reservoir equivalent to the 100-year flood hydrograph and piping failure occurs when the reservoir elevation is at the crest of the emergency spillway (viz. elevation 1111.2 feet). The hydrologic analyses performed during Phase I of this study (Dames & Moore, 1990) indicated that the 100-year flood volume would not fill the reservoir up to the crest of the emergency spillway if the starting condition is a completely empty reservoir. Therefore, for the sake of conservatism, it is assumed that the 100-year flood and piping failure occur when the water surface elevation is at elevation 1111.2 feet. The volume of the 100-year flood runoff is estimated to be 740 acre-feet (Dames & Moore 1990). Thus, the 100-year inflow hydrograph is expected to fill the reservoir at least to elevation 1111.2 feet even with the assumed constant outflow of 500 cfs.

The hydrologic variables used to define the initial and other relevant conditions for the dam-break model are shown in Table 2.17.

Table 2.17

INITIAL AND OTHER RELEVANT CONDITIONS FOR DAM-BREAK MODELING OF FRS #2 DUE TO SEEPAGE FAILURE

Conditions	Numerical Description
Breach location	Station 300+00
Inflow hydrograph	100-year, 24-hour storm
Reservoir water surface elevation when computations commence	1111.2 feet
Length of reservoir	0.246 mile
Reservoir water surface elevation when failure of dam commences	1111.2 feet
Spillway crest elevation	1111.2 feet
Width of uncontrolled spillway	350 feet
Spillway discharge coefficient	2.7
Elevation of bottom of breach after full development	1100.0 feet
Bottom width of breach after full development	60 feet
Sideslopes of breach	0.5H:1V
Time for full development of breach	0.5 hour

2.2.3 Floodwater Retarding Structure #3

2.2.3.1 Overtopping Failure

As stated in Section 2.1.3.2, there are two critical locations for overtopping breaches in this embankment, viz., Station 88+00 and Station 161+40.

Detailed hydrologic analyses for this structure were performed during Phase I of this study (Dames & Moore 1990). The results of these analyses indicated that if the emergency spillway remains fully operative, then the PMF resulting from 72-hour general storm PMP would not overtop the dam except through wave splashing. The estimated maximum reservoir water surface elevaton for this case is 1.95 ft. below the crest of the embankment (EL. 1170.0 ft.). However, the PMF resulting from the 6-hour local storm PMP would overtop the dam by 0.67 ft. Therefore, the dam-break scenario for this case is assumed to occur during the 6-hour local storm PMP.

The embankment crest consists of a 16,851-feet-long level section (Dames & Moore 1990) and is comprised of moderately erodible material such that wave splashing may result in severe erosion. Therefore, it is assumed that dam failure due to wave overtopping may ensue as soon as the freeboard between the top of the embankment and reservoir water surfave elevation is reduced to 1.0 ft.

Dam-break flood routing computations have been made using the 1989 version of the NWS Dam-Break model with the simultaneous computation method for dynamic routing (Fread 1988a). To circumvent the computational problem associated with dry-bed initial conditions in this model, it is assumed that there is a low-flow channel downslope of the dam with a small constant flow of 1,500 cfs at the time of the breach. This flow is about two percent of the estimated maximum breach outflow (see section 3.3.1) and is not expected to affect the predicted maximum water surface elevations in the downslope areas resulting from the dam-break flood.

Other hydrologic variables used to define the initial and other relevant conditions for the dam-break model for the two breach locations mentioned previously are shown in Table 2.18.

Table 2.18

INITIAL AND OTHER RELEVANT CONDITIONS FOR DAM-BREAK MODELING OF FRS #3 DUE TO OVERTOPPING FAILURE

Conditions	Numerical Description: Overtopping Breach at Station 88+00	Numerical Description: Overtopping Breach at Station 161+40
Inflow Hydrograph	6-hour local storm PMP	6-hour local storm PMP
Reservoir water surface elevation when computations commence	1163.2 feet	1163.2 feet
Length of reservoir	0.5 mile	0.5 mile
Reservoir water surface elevation when failure of dam commences	1169.0 feet	1169.0 feet
Spillway crest elevation	1163.2 feet	1163.2 feet
Width of uncontrolled spillway	400 feet	400 feet
Spillway discharge coefficient	2.7	2.7
Elevation of embankment crest	1170.0 feet	1170.0 feet
Length of overflow section of embankment	16,851 feet	16,851 feet
Discharge coefficient for earthern embankment	2.7	2.7
Elevation of bottom of breach after full development	1149.0 feet	1149.0 feet
Bottom width of breach after full development	250 feet	200 feet
Side slopes of breach	1H:1V	1H:1V
Time for full development of breach	0.5 hour	0.5 hour

2.2.3.2 Seepage Failure

As stated in Section 2.1.3.2, there are two critical locations for piping failure of this structure, viz., Station 88+00 and Station 161+40.

The dam-break flood routing computations for postulated breaches at these locations have been made using the simultaneous computation method of dynamic routing included in the 1989 version of the NWS DMBRK model (Fread 1984; Fread 1988a).

Usually, seepage failure would occur under clear weather conditions. However, it is possible that a portin of the watershed may experience some rain at the time piping failure occurs at the dam site. To account for this eventuality, it is assumed that the postulated seepage breaches are concurrent with a 100-year 24-hour storm in the watershed; the reservoir water surface elevation at the beginning of the storm is at the crest of the emergency spillway; and the antecedent and concurrent storms on areas downslope of the embankment produce a constant flow of 500 cfs in the flowpath on the downstream side of the breach. The pre-existing constant flow of 500 cfs circumvents the computational problem associated with dry-bed channel routing using the NWS DAMBRK model.

The hydrologic variables used to define the initial and other relevant conditions for dam-break flood routing due to piping breaches at the aforementioned locations are shown in Table 2.19.

Table 2.19

INITIAL AND OTHER RELEVANT CONDITIONS FOR DAM-BREAK MODELING OF FRS #3 DUE TO SEEPAGE FAILURE

	Numerical Description	
Conditions	Piping Breach at at Station 88+00	Piping Breach at at Station 161+40
Inflow Hydrograph	100-year 24-hour storm	100-year 24-hour storm
Reservoir water surface elevation when computations commence	1163.2 feet	1163.2 feet
Length of reservoir	0.5 mile	0.5 mile
Reservoir water surface elevation when failure of dam commences	1163.2 feet	1163.2 feet
Spillway crest elevation	1163.2 feet	1163.2 feet
Width of uncontrolled spillway	400 feet	400 feet
Spillway discharge coefficient	2.7	2.7
Initial center elevation of seepage pipe	1152.0 feet	1152.0 feet
Elevation of bottom of breach after full development	1149.0 feet	1149.0 feet
Bottom width of breach after full development	75 feet	95 feet
Side slopes of breach	0.5H:1V	0.5H:1V
Time for full development of breach	0.5 hour	0.5 hour

2.3 GEOMETRY OF DOWNSLOPE FLOW AREAS

2.3.1 Floodwater Retarding Structure #1

As stated in Section 2.1.1.2 there are three locations of potential breaches in this structure (see Table 2.3). The geometry of flow areas downslope of each of these locations is summarized in the following sections.

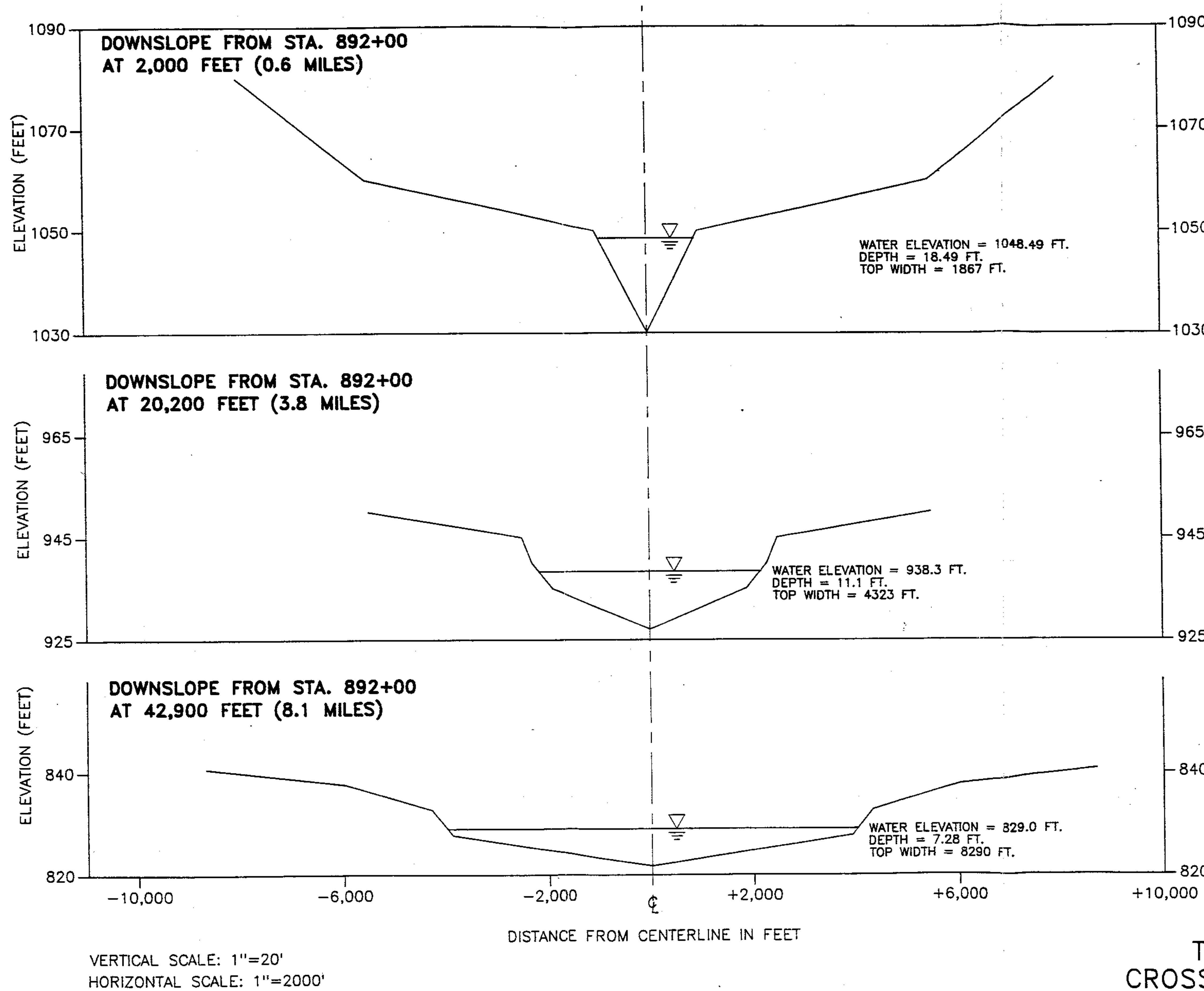
2.3.1.1 Geometry of Flow Area Downslope of Overtopping Breach at Station 892+00

The flowpath downslope from the breach at this location is comprised of a relatively flat terrain up to a distance of about 2,000 feet. Thereafter, the dam-break flood would enter the Hassayampa River channel on the west and travel downstream to the confluence of the Hassayampa and Gila rivers. The average slope in the upper 2.7 miles of the flowpath is about 0.69 percent. That for the lower 6.0 miles is about 0.44 percent. In the upper 2.6 miles, the flowpath is oriented southwest and is comprised of the eastern floodplain and a portion of the main channel of the Hassayampa River. Thereafter, the flowpath is along the main channel and floodplain of the Hassayampa River (see Figure 2). In the upper 2.7 miles, the dam-break flood wave would spread in the shape of a fan skewed to the west. To keep the cross-sections in this reach nearly perpendicular to the anticipated flowlines, this alignment had to be curved in plan (USACOE 1982). The flow area in this reach is represented by six cross-sections oriented along curved alignments in plan. These cross-sections were developed from the 1 inch = 2000 feet, 10-feet contour interval maps (USGS) of the area. For the remaining reach of 6.0 miles, the flowpath is along the Hassayampa River and the cross-sections are oriented perpendicular to the stream channel. For this lower reach, eleven cross-sections have been developed using HEC-2 input data used for the FEMA Flood Insurance Re-Study (Cella Barr Associates 1975) and the 1 inch = 2000 feet, USGS 10-foot contour maps (USGS) of the area. In all, seventeen cross-sections were developed for the entire reach of 8.7 miles from the location of the breach to the confluence of the Hassayampa and Gila rivers. Each cross-section is defined by six pairs of top widths and elevations (Fread 1988a).

To account for the unusual energy loss in the fanlike expanding dam-break floodwave, an expansion coefficient of -1.0 has been used in the model (Fread 1984; Fread 1988a).

The flowpath for the postulated dam-break floodwave will consist of the river bed and floodplain of the Hassayampa River and adjoining areas covered with brush, natural features, and man-made structures. To account for the increasing resistance to flow as the flow depth widens and the flow depth increases, variable Manning's roughness coefficients have been used as explained in Table 2.20.

Three typical cross-sections of the flowpath between the embankment and the Gila River are shown on Figure 5.



TYPICAL CROSS–SECTIONS
DOWNSLOPE FROM STATION 892+00
Figure 5

Table 2.20

ADOPTED MANNING'S ROUGHNESS COEFFICIENTS

Sequence number of top width-elevation pair (starting from channel bottom)	Manning n	Description of Channel Roughness[a]
1	0.040	Applicable to flow channels in clay and sandy loam; irregular sideslopes, bottom and cross-section; grass on slopes and small drainage ditches.
2	0.045	Applicable to dredged channels, irregular sideslopes and bottom, in black, wax clay at top to yellow clay at bottom sides covered with small saplings and brush, slight and gradual variation cross-section or large drainage ditches with no vegetation and less than 2.5 feet hydraulic radius or earth channels with some irregularity in shape or relatively short distances with no vegetation except grass on channel, bank, and overbank flow area.
3	0.050	Applicable to dredged channels with very irregular sideslopes and bottom, in dark colored waxy clay, with growth of weeds and grass or earth channels with stark aquatic growth or smooth earth channel with shrubs or small trees in channel and on bank.
4,5, and 6	0.055	Applicable to floodplains with light brush and trees or earth channels with somewhat irregular channel alignment and essentially a grass overbank flow area except for vegetation along edge of channel.

[a]Chow 1959; USBR 1987; Barfield et al 1981; and Lee and Essex 1983.

2.3.1.2 Geometry of Flow Area Downslope of Seepage Breach at Station 792+00

The dam-break flood wave emanating from the breach at this location will travel south to the floodplain and main channel of the Hassayampa River (see Figure 2). This flowpath is comprised of relatively flat terrain with an average slope of about 0.63 percent. The outflow from the breach at this location is also expected to spread in a fanlike shape. To simulate this flow situation, the cross-sections of the downslope areas are oriented along curved alignments in plan. In all 12 cross-sections were developed for the flow reach of about 4.5 miles between the embankment and the main stem of the Hassayampa River. Each cross-section is defined by six pairs of top widths and elevations.

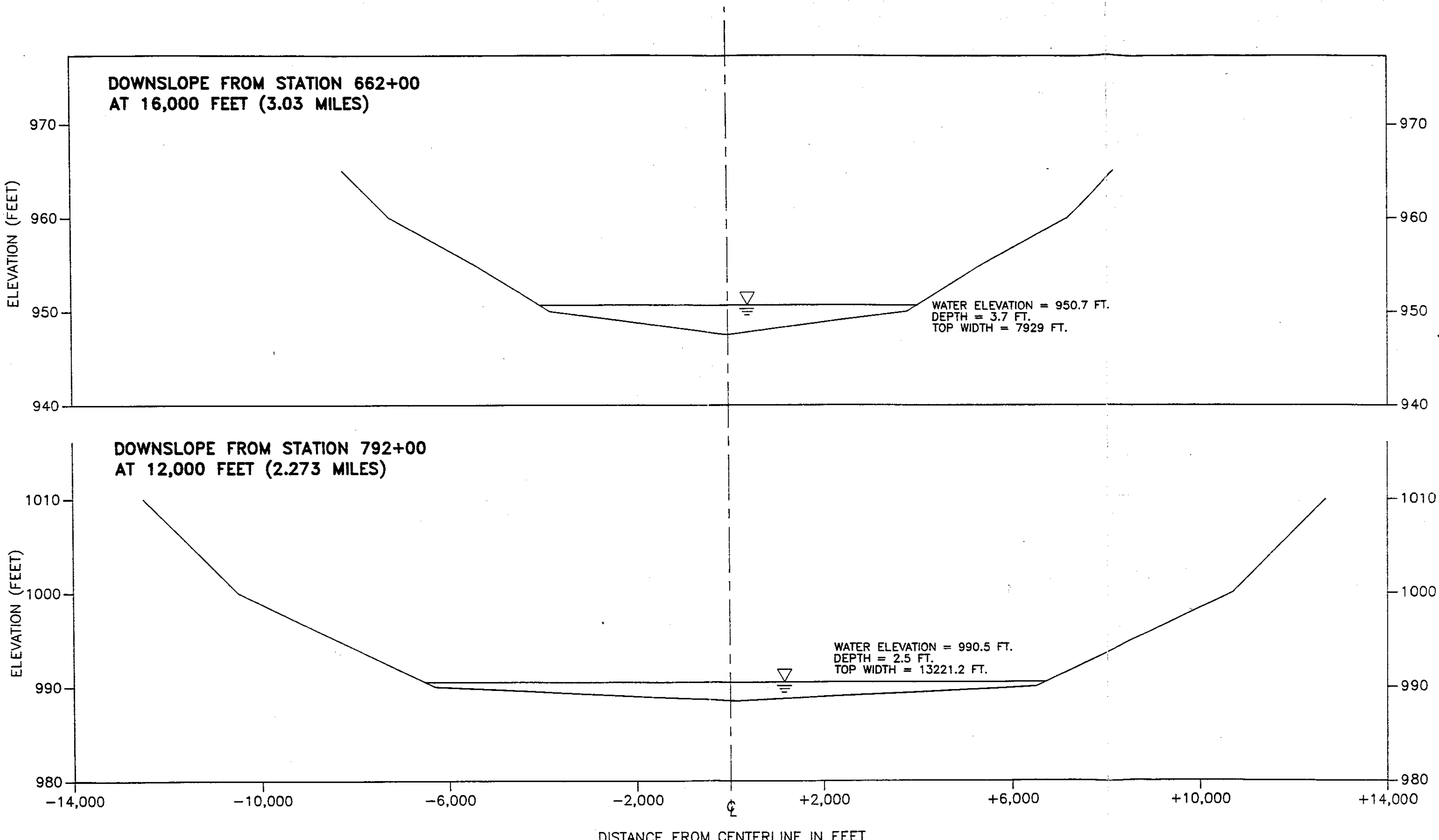
To account for the unusual flow expansion from one curved cross-section to the next downslope, an energy loss coefficient of -1.0 has been used in the model. (Fread 1988, Fread 1988a)

The existing flowpaths on the downslope side of this structure are in the form of shallow small channels. The downslope areas experience occasional sheet flow type conditions and are covered by sparse brush and natural and man-made features. To account for the increasing flow resistance of these areas as the flowpath widens and the flow depth increases, variable Manning's roughness coefficients have been used as shown in Table 2.20.

A typical cross section of the flowpath between the embankment and the Gila River is shown on Figure 6.

2.3.1.3 Geometry of Flow Area Downslope of Seepage Breach at Station 662+00

The dam-break flood wave emanating from the breach at this location will travel south to the floodplain of the Gila River (see Figure 2). This flowpath is comprised of a relatively flat-terrain with an average slope of about 0.6 percent. In this reach the contours are nearly parallel to the embankment extending over a mile or more in a direction transverse to the flowpath of the discharge from the postulated breach. As for the seepage



VERTICAL SCALE: 1"=10'
HORIZONTAL SCALE: 1"=2000'

TYPICAL CROSS–SECTIONS
DOWNSLOPE FROM STATIONS 792+00 AND 662+00
Figure 6

breach at station 792+00, the outflow from the breach is expected to spread in a fanlike shape. To simulate this flow situation, the cross-sections of the downslope areas are oriented along curved alignments in plan (USACOE 1982). This ensures that the cross-sections are nearly perpendicular to the anticipated flow lines. In all 18 cross-sections were developed for the flow reach of about 6.6 miles between the embankment and the floodplain of the Gila River. Each cross-section is defined by six pairs of top widths and elevations.

To account for the unusual flow expansion from one curved (in plan) cross-section to the next downslope, an energy loss coefficient of -1.0 has been used in the model.

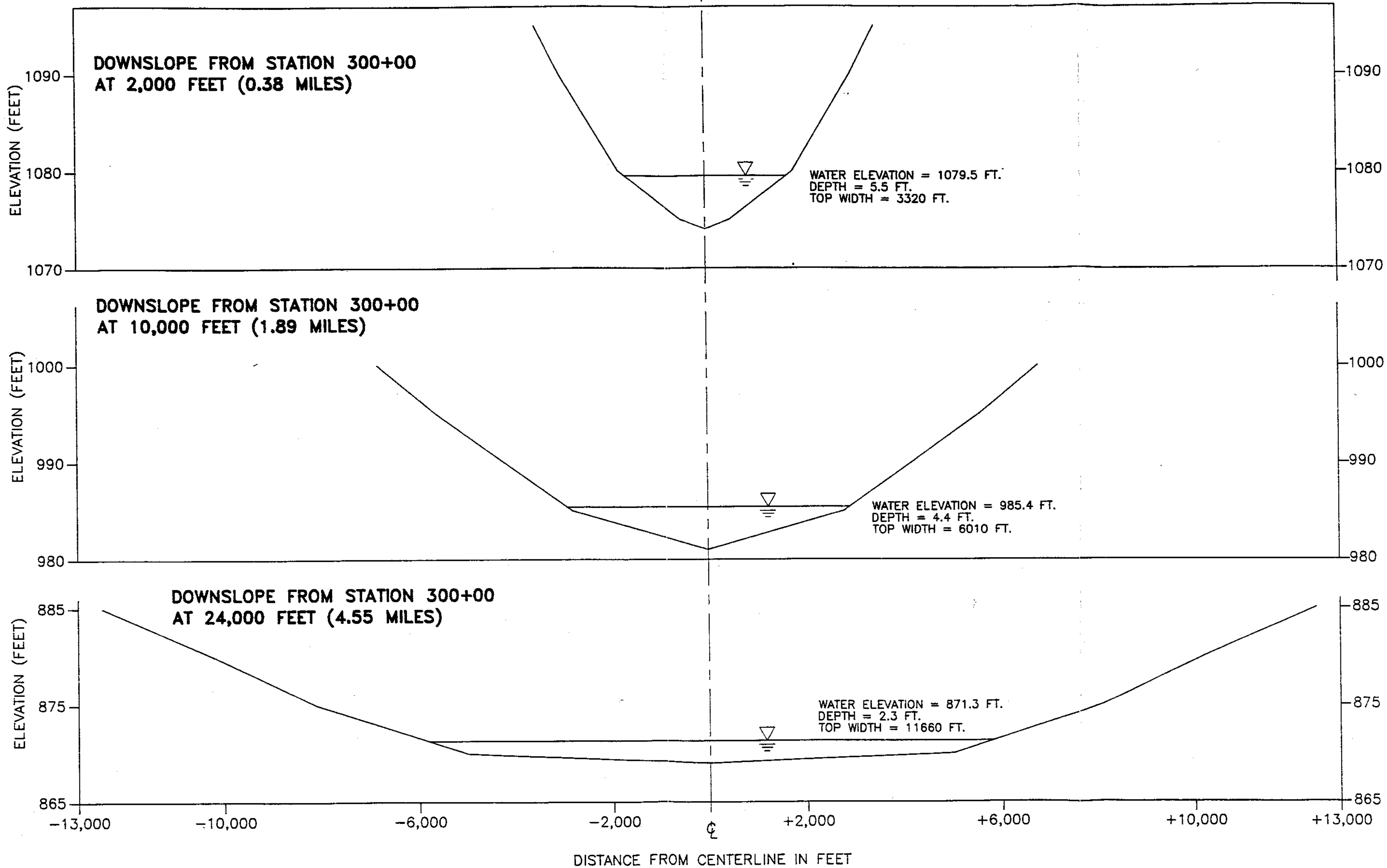
The flow conditions, flowpaths, and ground cover conditions in the flow reach represented by the 18 cross-sections for this dam-break scenario are similar to those for the piping breach at Station 792+00. Therefore, the same Manning's roughness coefficients have been used for this case as well (see Table 2.20).

A typical cross section of the flowpath between the embankment and the Gila River is shown on Figure 6.

2.3.2 Floodwater Retarding Structure #2

2.3.2.1 Geometry of Flow Areas Downslope of Breaches at Station 300+00

The dam-break flood wave emanating from the breach at this location will travel south to the floodplain of the Gila River (see Figure 2). This flowpath is comprised of nearly flat plains having an average slope of about 0.93 percent from the toe of the embankment to the Gila River. In this reach of about 5.3 miles, the contours are nearly parallel to the embankment extending over a mile or two in a direction transverse to that of the flow from the postulated breach. Thus, if the cross-sections are taken normal to a line joining the location of the breach to the Gila River along the thalweg of the flowpath, there would be no high ground on either side which could be identified as banks. Because of the topography of the area



VERTICAL SCALE: 1"=10'
HORIZONTAL SCALE: 1"=2000'

TYPICAL
CROSS-SECTIONS
DOWNSLOPE FROM STATION 300+00
Figure 7

downstream of the embankment, the flow would spread out in the shape of a fan. To keep the cross-sections nearly perpendicular to the anticipated flow lines, it was necessary to lay out cross-sections in a curved alignment (USACE, 1982). In all 20 cross-sections were developed for the reach from the embankment to the Gila River. Each cross-section is defined by six pairs of top widths and elevations. Three typical cross-sections downslope from FRS #2 and Station 300+00 are presented on Figure 7.

Since the cross-sections are curved in plan, there is significant flow expansion from one cross-section to the next one downslope. To account for this unusual energy loss in expanding flows, an expansion coefficient of -1.0 has been used in the model.

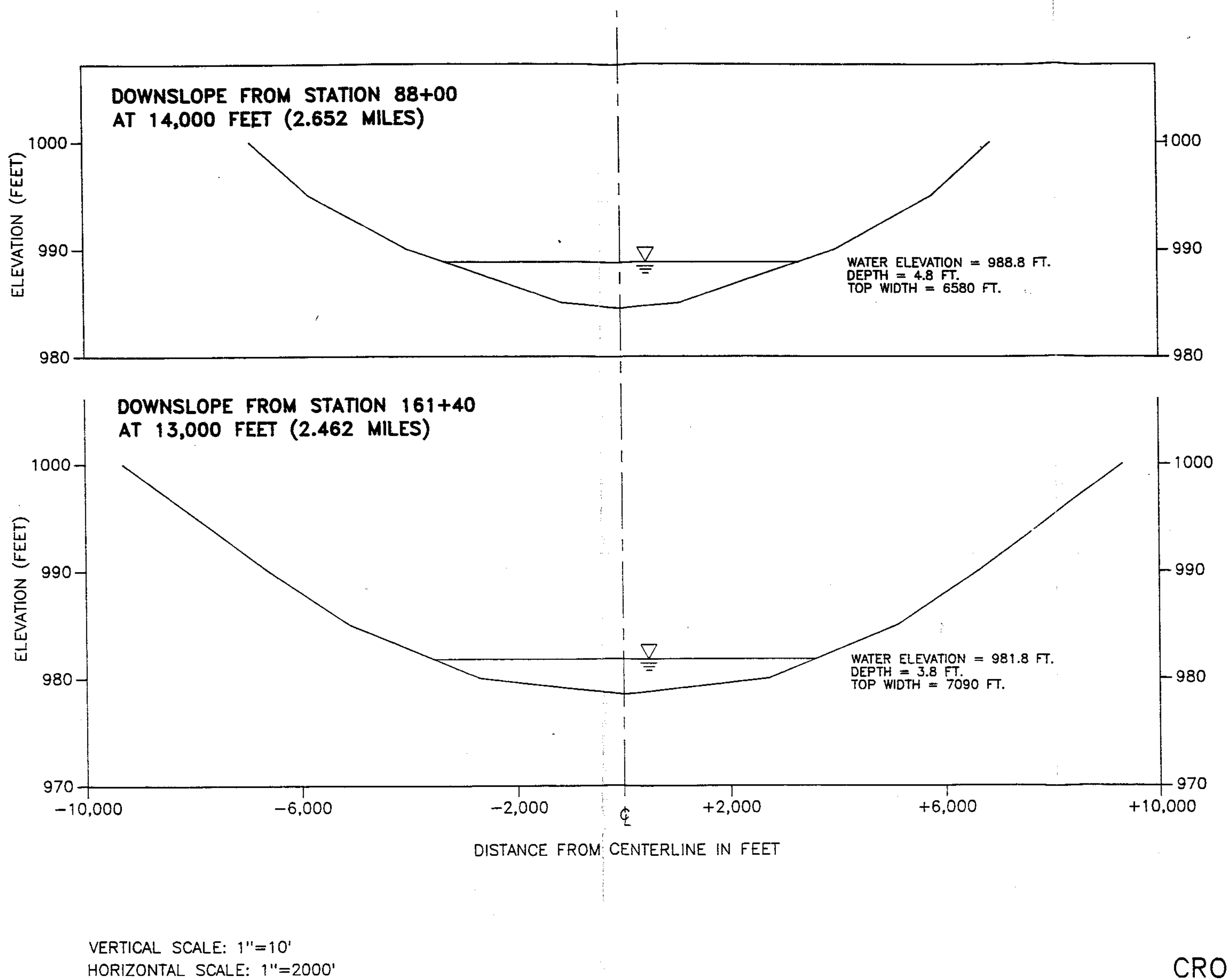
The existing flow paths on the downslope side of the structure are in the form of shallow small channels. The downslope areas experience occasional sheet flow type conditions. The outflow from the breach may scour a wide channel which will provide unusual resistance to flow. The simulation of this mobile-bed phenomenon is beyond the capability of the NWS dam-break model. To account for the increasing resistance to flow as the flow path widens and the flow depth increases, variable Manning's roughness coefficients have been used as shown in Table 2.20.

Three typical cross sections of the flowpath between the embankment and the Gila River are shown on Figure 7.

2.3.3 Floodwater Retarding Structure #3

2.3.3.1 Geometry of Flow Areas Downslope of Breaches at Station 161+40

The dam-break flood wave emanating from the breaches at this location will travel south to the floodplain of the Gila River (see Figure 2). This flowpath is comprised of relatively flat terrain. Therefore, the dam-break flood waves are expected to spread in a fanlike shape. To keep the cross-sections nearly normal to the flow lines, their alignment had to be curved in plan (USACOE 1982). Therefore, the flow areas for the 4.7-mile reach between Station 161+40 and the floodplain of the Gila



TYPICAL CROSS-SECTIONS
DOWNSLOPE FROM STATIONS 161+40 AND 88+00
Figure 8

River are represented by 18 curved (in plan) cross-sections. Each of these cross-sections is defined by six pairs of top widths and elevations (Fread 1988a).

To account for the unusual energy loss in the fanlike expanding dam-break flood wave, an expansion coefficient of -1.0 has been used in the model (Fread 1984; Fread 1988a).

The ground cover, soil characteristics, and general topography of the flow areas downslope of the breaches at this locatin are similar to those for areas downslope of FRS #1 and FRS #2. Therefore, the same Manning's roughness coefficients are used for this case as well (see Table 2.20).

A typical cross-section of the flowpath between the location of the breaches and the floodplain of the Gila River is shown on Figure 8.

2.3.3.2 Geometry of Flow Areas Downslope of Breaches at Station 88+00

The dam-break flood wave emanating from the breaches at this location will travel south to the floodplain of the Gila River (see Figure 2). This flowpath is comprised of relative flat terrain. Therefore, the dam-break flood waves are expected to spread in a fanlike shape. To keep the cross-sections nearly normal to the flowlines, their alignment had to be curved in plan (USACOE 1982). In all 20 curved cross-sections were developed to represent flow areas for the 5.3-mile reach between the location of the breach and the floodplain of the Gila River. Each of these cross-sections is defined by six pairs of top widths and elevations (Fread 1988a).

For reasons explained in Section 2.3.3.1, an expansion coefficient of -1.0 and the Manning's n values of Table 2.20 have been used for this case as well.

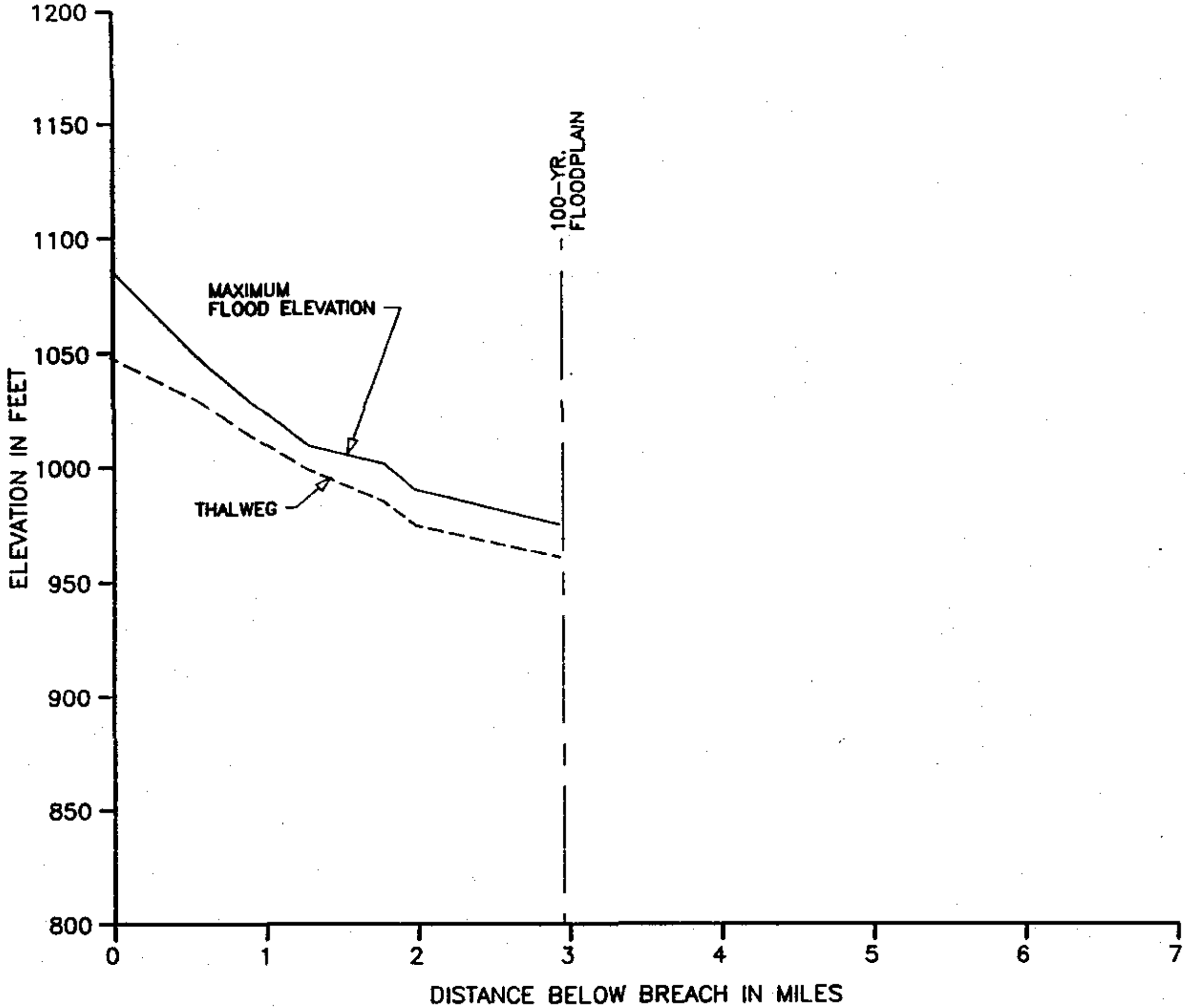
A typical cross-section of the flowpath between the location of the breaches and the floodplain of the Gila River is shown in Figure 8.

3.0 DAM-BREAK FLOOD ROUTING

3.1 FLOODWATER RETARDING STRUCTURE #1

3.1.1 Overtopping Failure

The dam-break flood routing computations for overtopping failure at Station 892+00 were made using the data presented in Sections 2.2.1.1 and 2.3.1.1. The resulting profile of peak outflow and the maximum flood depths, maximum flow velocities and travel times of peak flood flows in the reach between the embankment and the Gila River are shown on Figure 9. During the passage of the dam-break flood wave from the location of the breach to the Gila River, the peak outflows, maximum flood elevations, travel times, and maximum flow velocities at different locations are estimated to be as shown in Table 3.1. The travel time of the maximum flood elevation through the 8.7 mile reach between the embankment and the Gila River is estimated to be about 5.7 hours. The contour lines showing equal estimated maximum flood depths and the isochromes showing the equal estimated times of arrival of the leading edge of the flood wave are presented in plan view on a contour map on Figure 2 and on an aerial photograph on Figure 3. A copy of the output of the NWS Dam-Break Flood Routing Model for this case is included in Volume II of this report.



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS
FRS #1, STATION 892+00: OVERTOPPING FAILURE
Figure 9

Table 3.1

PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES,
AND MAXIMUM FLOW VELOCITIES
(DAM-BREAK FLOOD WAVE DUE TO OVERTOPPING FAILURE OF FRS #1 AT STATION 892+00)

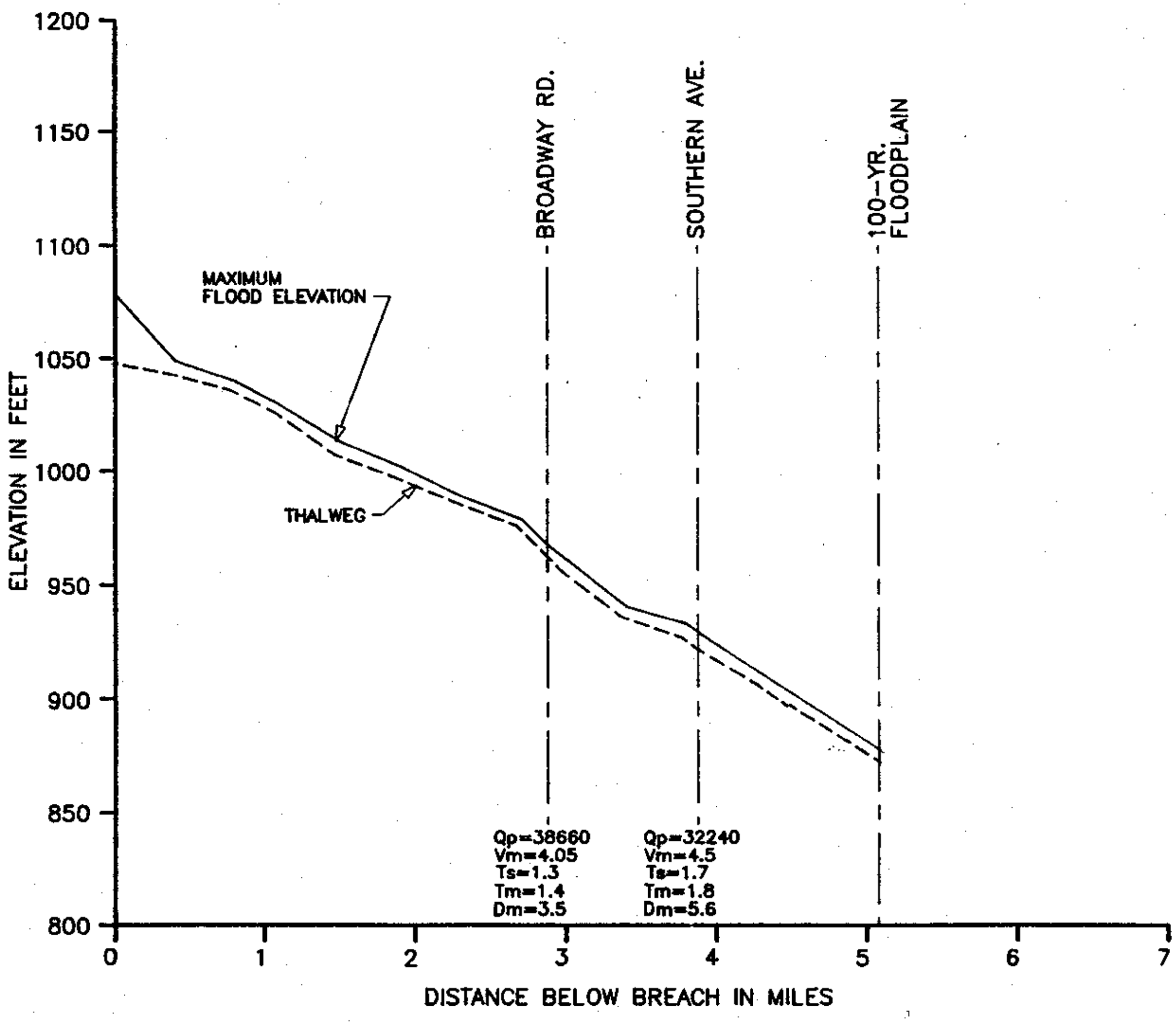
Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1088.9	220,076	-	-
0.57	1048.9	220,076	4.2	11.6
1.0	1028.6	218,081	4.3	11.4
2.0	995.3	210,113	4.5	9.1
3.0	957.9	208,900	4.6	7.2
4.0	930.6	207,288	4.9	7.8
5.3	902.8	205,458	5.0	7.6
6.0	884.0	204,476	5.2	5.3
7.0	861.4	202,969	5.4	5.6
8.0	836.8	201,957	5.6	5.8
8.7[a]	820.2	201,127	5.7	4.4

[a] At Gila River floodplain

3.1.2 Seepage Failure

3.1.2.1 Seepage Breach at Station 792+00

The dam-break flood routing computations for this case were made using the data presented in Section 2.2.1.2 and 2.3.1.2. The resulting profile of peak outflows and the maximum flood depths, maximum flow velocities and travel times of peak flood flows in the reach between the embankment and the Hassayampa River are shown on Figure 10. The dam-break flood peaks, maximum flood elevations, travel times, and maximum flow velocities at different locations between the embankment and the Hassayampa River are shown in Table 3.2. The travel time of the maximum flood elevation through the 4.5 mile reach between the embankment and the Hassayampa River is estimated to be about 2.1 hours. The contour lines showing equal estimated maximum flood depths and the isochromes showing the equal estimated times of arrival of the leading edge of the flood wave are presented in plan view on a contour map on Figure 2 and on an aerial photograph on Figure 3. Note that there are several incised washes in the



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS
FRS #1, STATION 792+00: SEEPAGE FAILURE
Figure 10

area downslope from this breach and these washes will experience flood depths greater than the average flow depths which the lines on Figures 2 and 3 represent. A copy of the output of the NWS Dam-Break Flood Routing for this case is included in Volume II of this report.

Table 3.2

PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES
(DAM-BREAK FLOOD WAVE DUE TO SEEPAGE FAILURE OF FRS #1 AT STATION 792+00)

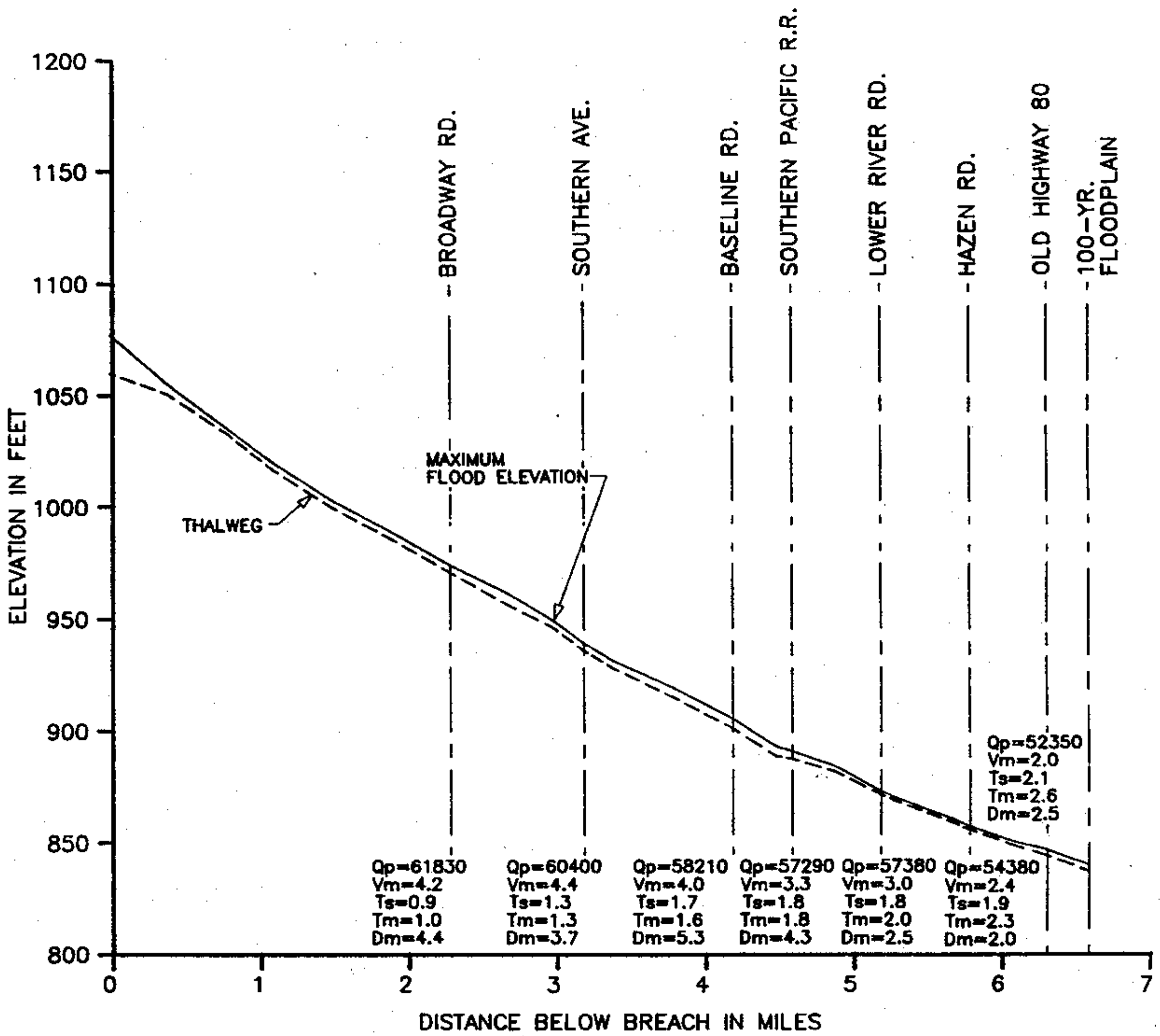
Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1079.8	40,888	-	-
0.57	1046.0	40,233	0.60	3.5
1.0	1033.8	39,766	0.75	3.1
1.5	1015.2	39,580	0.90	4.6
2.0	999.7	39,226	1.07	3.7
2.5	984.6	38,868	1.30	2.6
3.0	964.0	38,664	1.45	4.1
3.5	940.2	37,950	1.70	3.4
4.0	925.1	37,206	1.90	4.5
4.5[a]	903.6	36,993	2.07	4.2

[a] In the Hassayampa River channel

Note that the peak outflows and maximum flood elevations resulting from an overtopping failure (Table 3.1) are significantly larger than those shown in Table 3.2. However, the travel times of the flood wave associated with the overtopping failure are also larger than those resulting from a piping failure.

3.1.2.2 Seepage Breach at Station 662+00

The dam-break flood routing computations were made using the data presented in Section 2.2.1.2 and 2.3.1.3. The resulting profile of peak outflows and the maximum flood depths, maximum flow velocities and travel times of peak flood flows in the reach between the embankment and the Gila River are shown on Figure 11. The dam-break flood peaks, maximum flood elevations, travel times, and maximum flow velocities at different locations



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS
FRS #1, STATION 662+00: SEEPAGE FAILURE

Figure 11

betwen the embankment and Gila River floodplain are shown in Table 3.3. The travel time of the maximum flood elevation through the 6.6 mile reach between the embankment and Gila River floodplain is estimated to be about 2.8 hours. The contour lines showing equal estimated maximum flood depths and the isochrones showing the equal estimated times of arrival of the leading edge of the flood wave are presented in plan view on a contour map on Figure 2 and on an aerial photograph on Figure 3. A copy of the output of the NWS Dam-Break Flood Routing Model for this case is included in Volume II of this report.

Table 3.3

PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES (DAM-BREAK FLOOD WAVE DUE TO SEEPAGE FAILURE OF FRS #1 AT STATION 662+00)

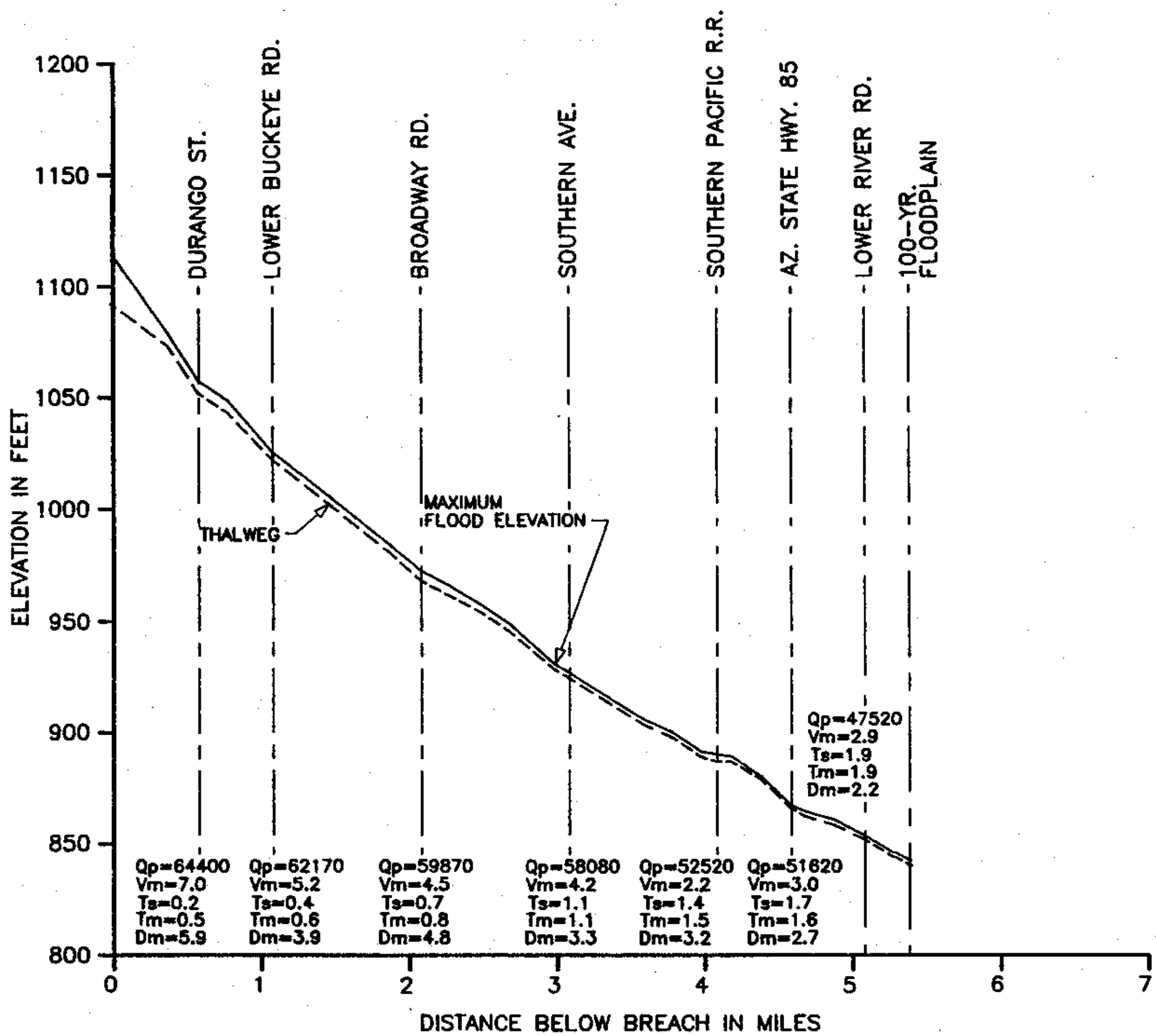
Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1079.8	64,748	-	-
0.38	1056.8	64,748	0.5	5.7
1.0	1027.3	63,339	0.65	4.5
2.0	986.2	62,137	0.93	4.2
3.0	950.7	60,482	1.22	4.2
4.0	913.9	58,876	1.55	4.1
5.0	882.0	56,514	1.97	3.0
6.0	853.3	53,929	2.40	3.6
6.6[a]	840.5	50,652	2.89	2.0

[a] At Gila River floodplain

3.2 FLOODWATER RETARDING STRUCTURE #2

3.2.1 Overtopping Failure

The dam-break flood routing computations were made using the data presented in Sections 2.2.2.1 and 2.3.2.1. The resulting profile of peak outflows and the maximum flood depths, maximum flow velocities and travel times of peak flood flows in the reach between the embankment and the Gila River are shown on Figure 12. During the passage of the dam-break flood wave from the location of the breach to the Gila River, the peak outflows,



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS

FRS #2, STATION 300+00: OVERTOPPING FAILURE

Figure 12

maximum flood elevations, travel times, and maximum flow velocities are estimated to be as shown in Table 3.4. The travel time of the maximum flood elevation is estimated to be 1.75 hours. The contour lines showing equal estimated maximum flood depths and the isochromes showing the equal estimated times of arrival of the leading edge of the flood wave are presented in plan view on a contour map on Figure 2 and on an aerial photograph on Figure 3. A copy of the output of the NWS Dam-Break Flood Routing Model is included in Volume II of this report.

Table 3.4

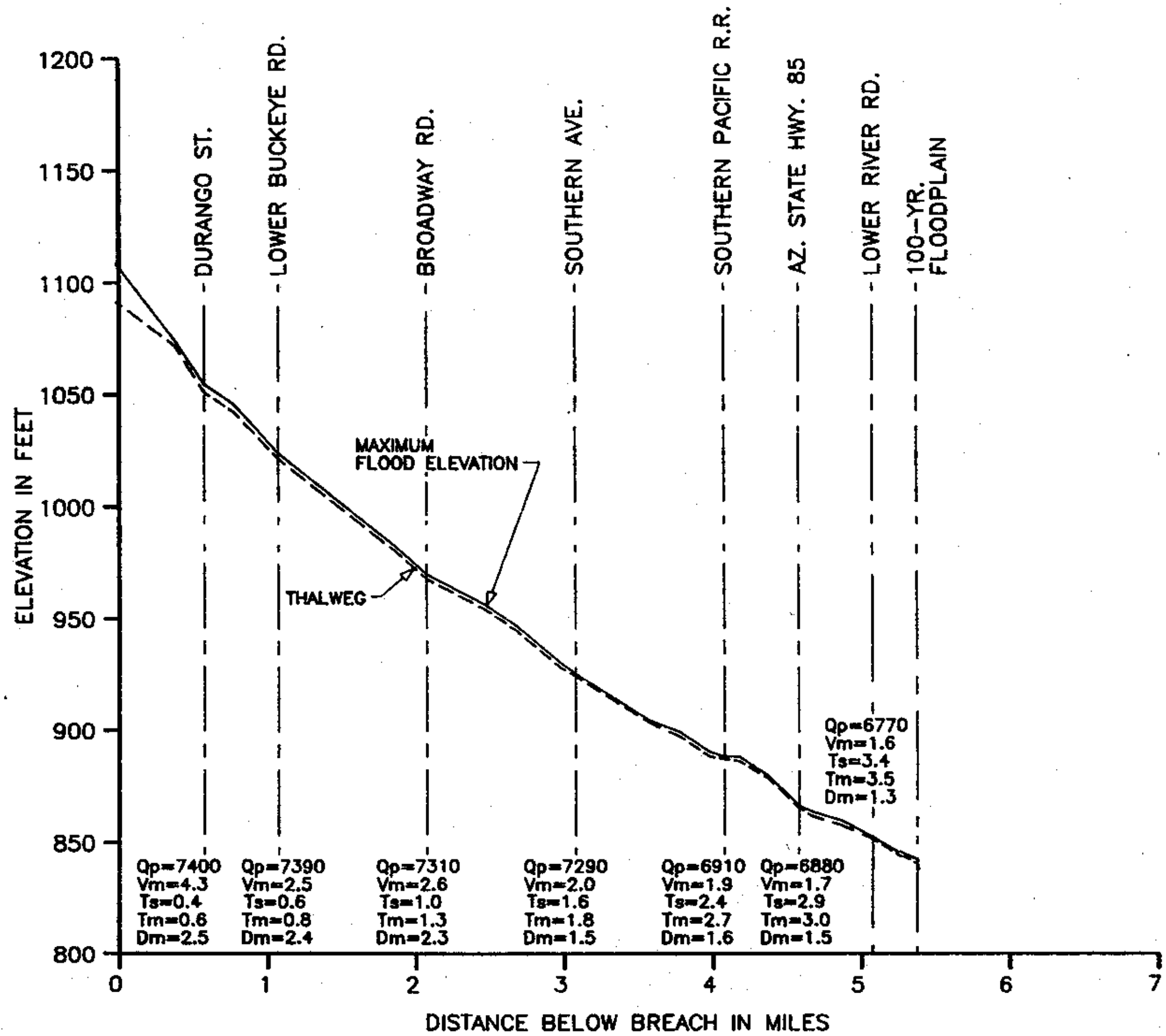
PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES (DAM-BREAK FLOOD WAVE DUE TO OVERTOPPING FAILURE OF FRS #2 AT STATION 300+00)

Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1117.6	66,561	--	--
0.38	1079.5	66,561	2.5	6.7
1.0	1035.2	63,092	2.6	5.8
1.52	1006.5	61,462	2.8	5.3
2.0	979.2	60,501	2.9	4.7
2.5	959.2	59,390	3.0	4.3
3.0	933.9	58,316	3.1	4.2
3.5	911.6	57,063	3.3	4.0
4.0	892.3	54,739	3.5	2.6
4.5	876.1	54,038	3.6	4.4
5.0	858.1	47,847	3.9	2.3
5.3[a]	846.3	46,875	4.0	3.4

[a] At Gila River

3.2.2 Seepage Failure

The dam-break flood routing computations for this case were made using the data presented in Sections 2.2.2.2 and 2.3.2.1. The resulting profile of peak outflows and the maximum flood depths, maximum flow velocities and travel times of peak flood flows in the reach between the embankment and the Gila River are shown on Figure 13. During the passage of the dam-break flood wave from the location of the breach to the Gila River, the peak outflow, maximum flood elevation, travel time and maximum flow



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS
FRS #2, STATION 300+00: SEEPAGE FAILURE
Figure 13

velocity are estimated to change as shown in Table 3.5. The travel time of the maximum flood elevation is estimated to be 3.37 hours. The contour lines showing equal estimated maximum flood depths and the isochrones showing the equal estimated times of arrival of the leading edge of the flood wave are presented in plan view on a contour map on Figure 2 and on an aerial photograph on Figure 3. A copy of the output of the NWS Dam-Break Flood Routing Model is included in Volume II of this report.

Table 3.5

PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES (DAM-BREAK FLOOD WAVE DUE TO SEEPAGE FAILURE OF FRS #2 AT STATION 300+00)

Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1111.3	7,467	--	--
0.51	1066.4	7,421	0.6	3.8
1.0	1032.8	7,396	0.75	2.8
1.52	1004.3	7,347	1.1	2.9
2.0	978.5	7,326	1.2	2.9
2.5	957.2	7,296	1.5	2.6
3.0	932.1	7,269	1.8	2.1
3.54	908.4	7,246	2.0	2.3
4.0	890.5	7,124	2.5	1.1
4.5	873.4	6,914	2.9	1.8
5.0	857.8	6,830	3.2	1.5
5.3[a]	845.2	6,773	3.6	1.7

[a] At Gila River

It may be noted that the peak outflows and maximum flood elevations shown in Table 3.5 include the breach outflow as well as the contribution of the 100-year inflow hydrograph and therefore, represent a reasonably conservative situation. Even these outflows are 11 to 14 percent of those for the overtopping breach shown in Table 3.4. Therefore, the results of a breach due to seepage/piping may not be relevant in the development of inundation maps and evacuation plans for this structure.

3.3 FLOODWATER RETARDING STRUCTURE #3

3.3.1 Overtopping Failure

3.3.1.1 Overtopping Breach at Station 161+40

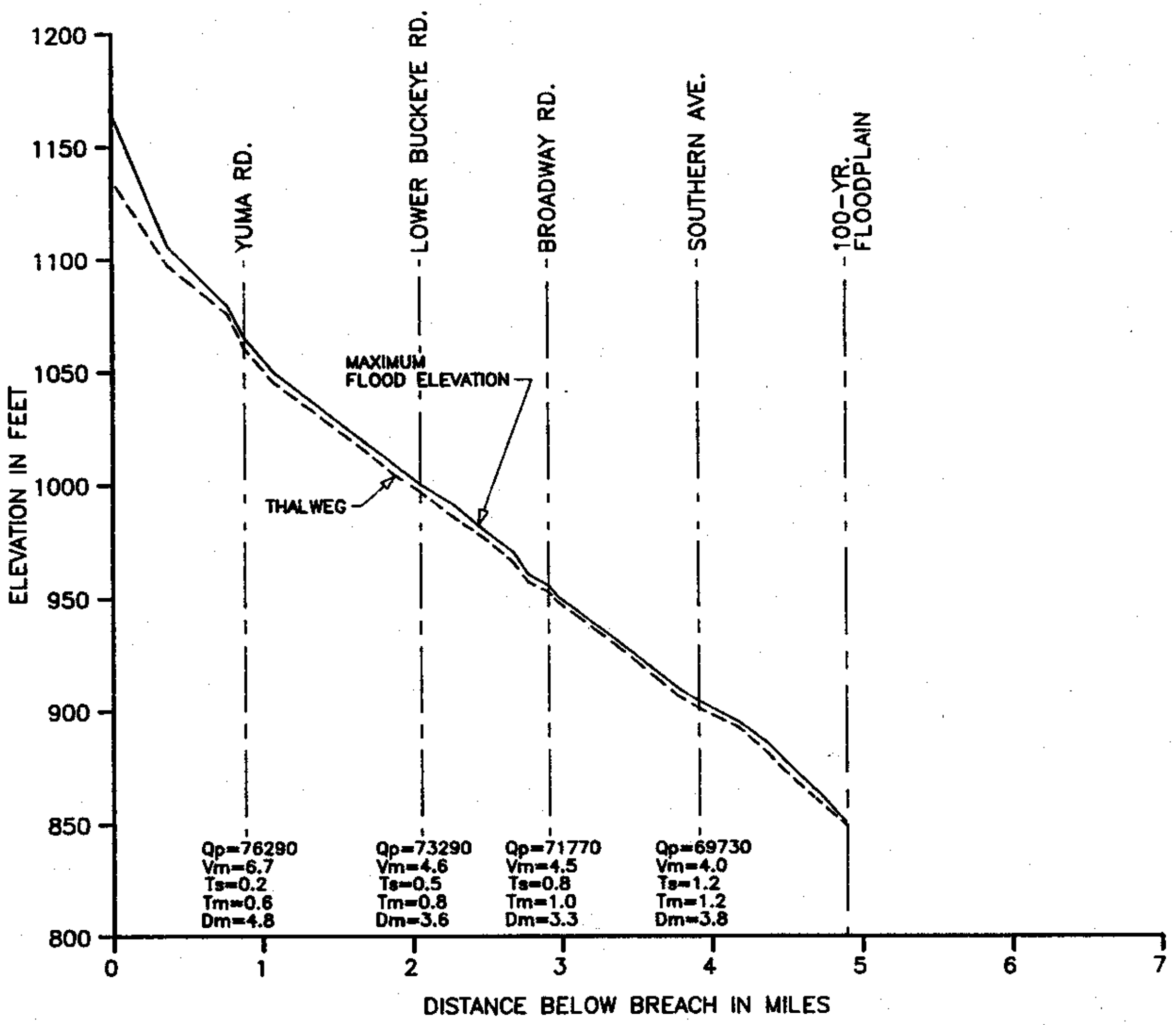
The dam-break flood routing computations for this case were made using the data presented in Section 2.2.3.1 and 2.3.3.1. The resulting profile of peak outflows, maximum flood elevations, and travel times of peak flood flows in the reach between the location of the breach and the Gila River are shown on Figure 14. The peak outflows, maximum flood elevations, travel times, and maximum flood velocities are estimated to be as shown in Table 3.6. The travel time of the maximum flood elevation through the entire reach of 4.7 miles is estimated to be about 4.4 hours. A copy of the output of the NWS Dam-Break Flood Routing Model is included in Volume II of this report.

Table 3.6

PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES (DAM-BREAK FLOOD WAVE DUE TO OVERTOPPING FAILURE OF FRS #3 AT STATION 161+40)

Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1170.5	79,129	--	--
0.5	1098.0	78,231	3.5	8.2
1.1	1052.4	75,638	3.6	6.6
1.7	1021.0	74,120	3.7	5.4
2.1	1001.6	73,286	3.8	4.6
2.5	981.8	72,759	3.9	4.8
3.0	952.0	71,676	4.0	4.6
3.5	928.3	70,947	4.1	4.8
4.0	904.5	69,457	4.3	3.7
4.36[a]	885.8	69,163	4.4	3.7

[a] At Gila River



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS
FRS #3, STATION 161+40: OVERTOPPING FAILURE
Figure 14

3.3.1.2 Overtopping Breach at Station 88+00

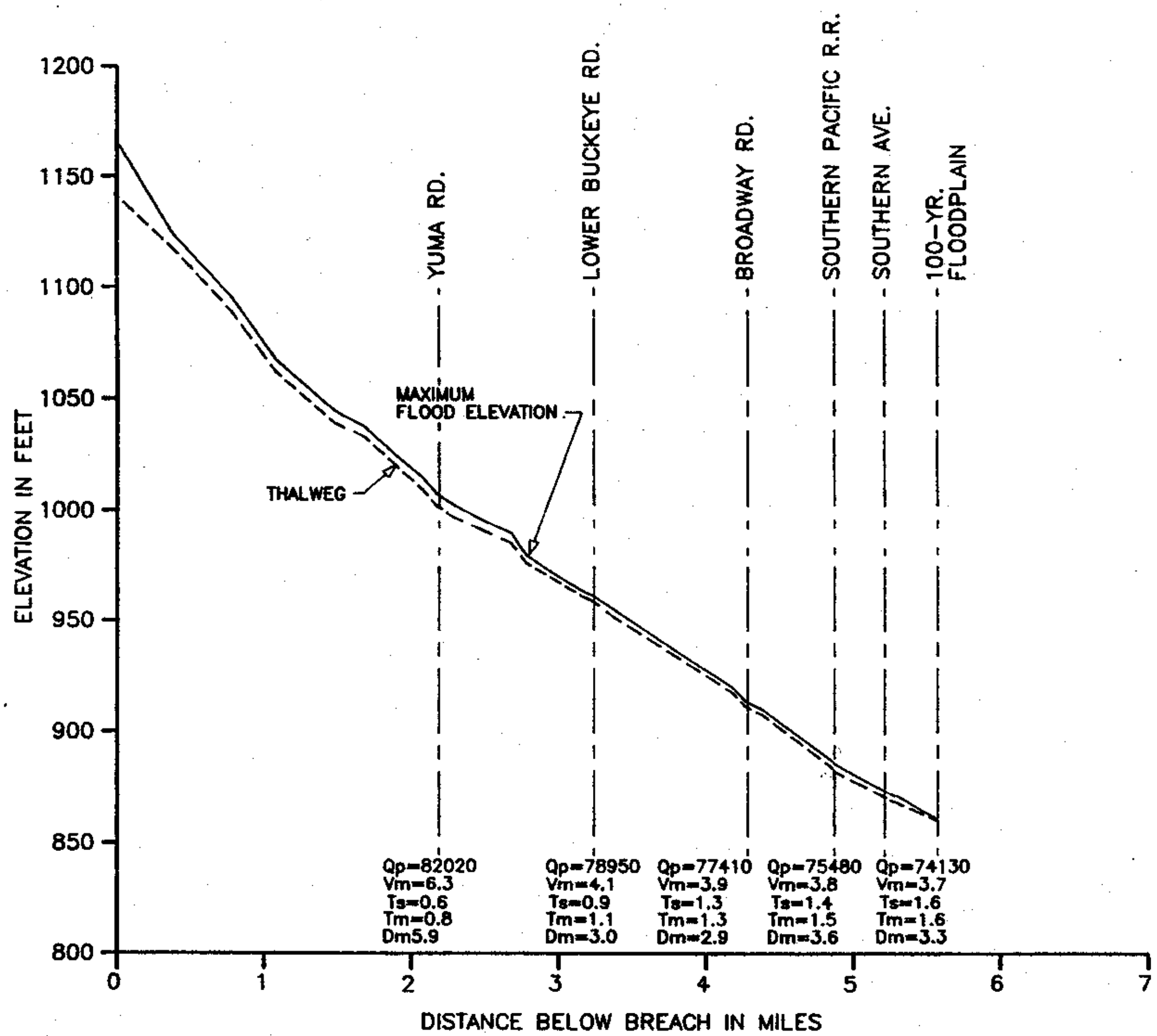
The dam-break flood routing computations were made using the data presented in Section 2.2.3.1 and 2.3.3.2. The resulting profile of peak outflows, maximum flood elevations, and travel times of peak flood flows in the reach between the embankment and the Gila River are shown on Figure 15. During the passage of the dam-break flood wave from the location of the breach to the Gila River, the peak outflows, maximum flood elevations, travel times, and maximum flow velocities are estimated to be as shown in Table 3.7. The travel time of the maximum flood elevation through the entire reach of 5.3 miles is estimated to be about 4.7 hours. A copy of the output of the NWS Dam-Break Flood Routing Model is included in Volume II of this report.

Table 3.7

PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES (DAM-BREAK FLOOD WAVE DUE TO OVERTOPPING FAILURE OF FRS #3 AT STATION 88+00)

Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1170.5	90,056	--	--
0.5	1116.4	88,730	3.5	8.2
1.0	1079.8	86,433	3.6	7.1
1.5	1046.5	84,510	3.7	5.4
2.0	1016.2	82,328	3.8	6.3
2.5	995.3	80,932	3.9	4.9
3.0	973.3	79,422	4.0	4.5
3.5	950.7	78,398	4.1	4.3
4.0	929.4	78,042	4.3	3.9
4.5	904.6	76,989	4.4	3.8
5.0	882.9	75,145	4.5	3.6
5.3[a]	872.0	74,125	4.7	3.8

[a] At Gila River



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS
FRS #3, STATION 88+00: OVERTOPPING FAILURE
Figure 15

3.3.2 Seepage Failure

3.3.2.1 Seepage Breach at Station 161+40

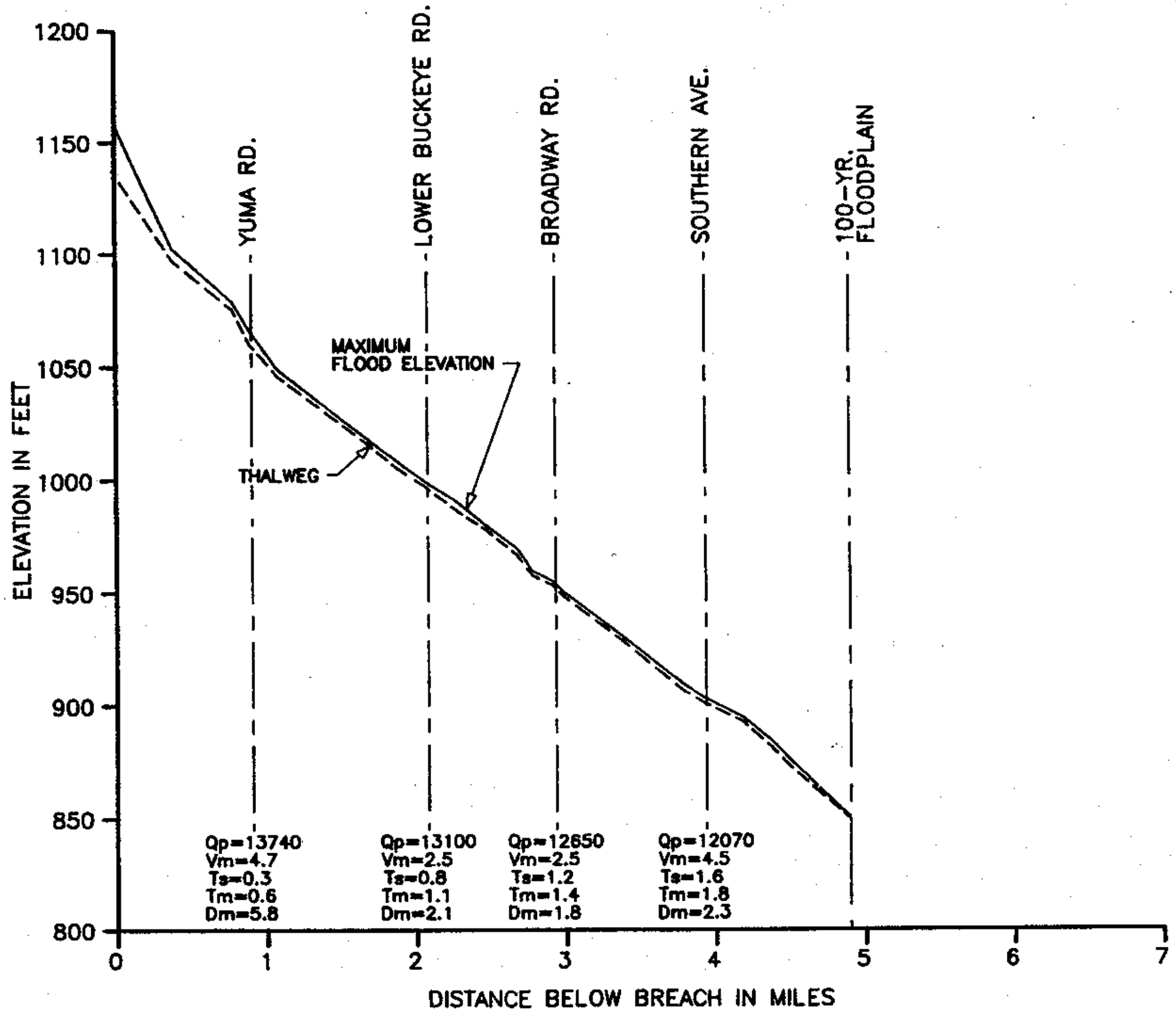
The dam-break flood routing computations for this case were made using the data presented in Sections 2.2.3.2 and 2.3.3.1. The resulting profile of peak outflows, maximum flood elevations, and travel times of peak flood flows in the reach between the embankment and Gila River floodplains are shown on Figure 16. The peak outflows, maximum flood elevations, travel times, and maximum flow velocities at different locations between the embankment and Gila River are shown in Table 3.8. The travel time of the maximum flood elevation through the 4.7-mile reach between the location of the breach and Gila River is estimated to be about 2.3 hours. A copy of the output of the NWS Dam-Break Flood Routing Model for this case is included in Volume II of this report.

Table 3.8

PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS, TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES (DAM-BREAK FLOOD WAVE DUE TO SEEPAGE FAILURE OF FRS #3 AT STATION 161+40)

Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1163.2	14,088	--	--
0.5	1094.9	13,965	0.5	4.6
0.95	1064.5	13,718	0.6	5.0
1.52	1029.7	13,460	0.8	2.9
2.08	1000.1	13,106	1.1	2.5
2.46	980.1	13,022	1.3	2.9
3.0	950.6	12,576	1.5	2.6
3.49	926.6	12,244	1.7	2.8
3.98	902.5	11,827	2.1	2.1
4.7[a]	864.1	11,598	2.3	3.0

[a] At Gila River



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS
FRS #3, STATION 161+40: SEEPAGE FAILURE
Figure 16

3.3.2.2 Seepage Breach at Station 88+00

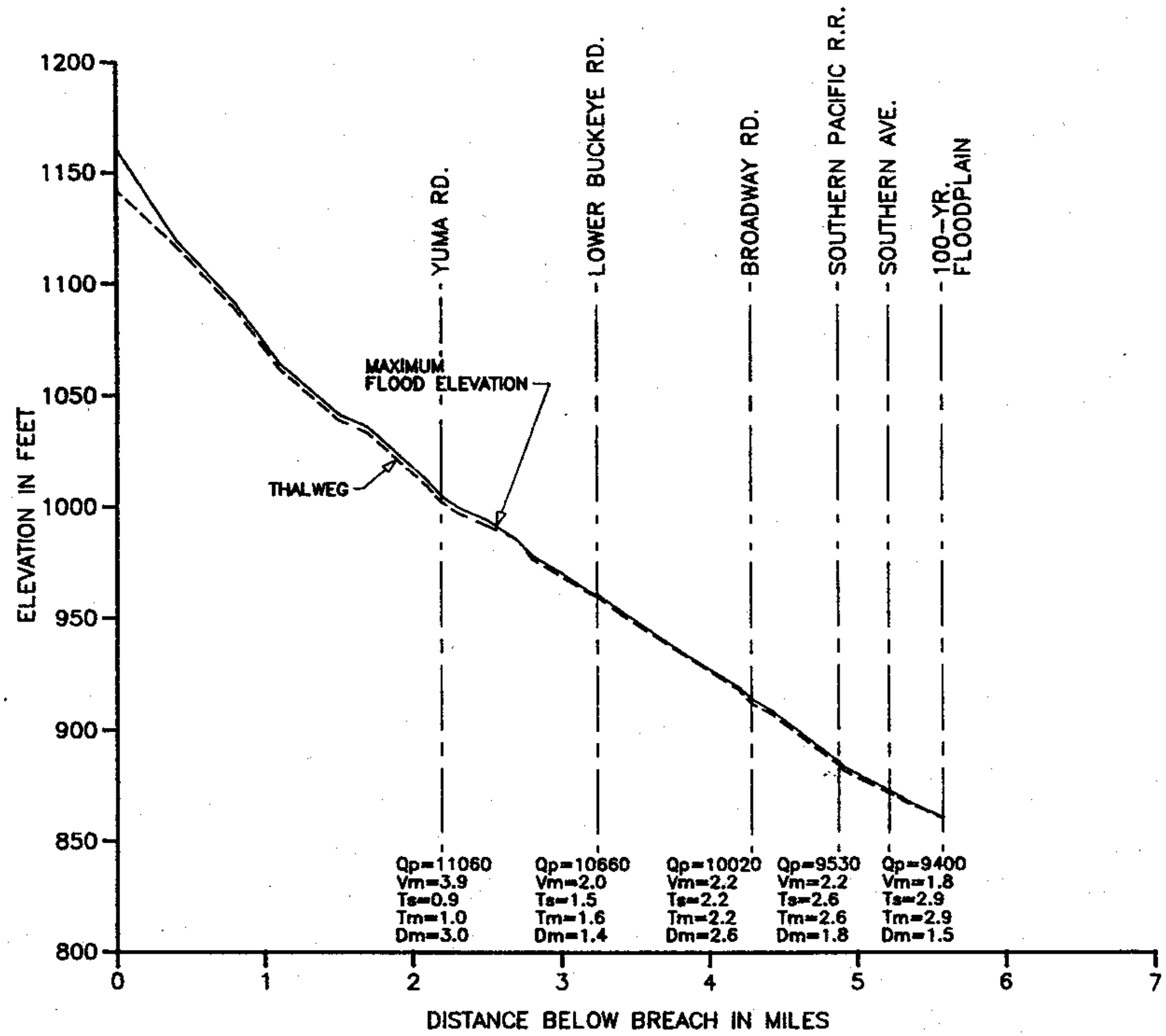
The dam-break flood routing computations for this case were made using the data presented in Section 2.2.3.2 and 2.3.3.2. The resulting profile of peak outflows, maximum flood elevations, and travel times of peak flood flows in the reach between the embankment and Gila River floodplain are shown on Figure 17. The peak outflows, maximum flood elevations, travel times, and maximum flow velocities at different locations between the embankment and Gila River are shown in Table 3.9. The travel time of the maximum flood elevation through the 5.3-mile reach between the location of the breach and Gila River is estimated to be about 2.9 hours. A copy of the output of the NWS Dam-Break Flood Routing Model for this case is included in Volume II of this report.

Table 3.9

**PEAK OUTFLOWS, MAXIMUM FLOOD ELEVATIONS,
TRAVEL TIMES, AND MAXIMUM FLOW VELOCITIES
(DAM-BREAK FLOOD WAVE DUE TO SEEPAGE FAILURE OF FRS #3 AT STATION 88+00)**

Distance from Breach (miles)	Maximum Flood Elevation (feet)	Peak Outflow (cfs)	Travel Time (hours)	Maximum Velocity (ft/sec)
0	1163.2	11,661	--	--
0.5	1112.9	11,543	0.5	4.5
1.0	1076.8	11,402	0.7	3.9
1.52	1043.3	11,270	0.8	3.2
2.1	1013.1	11,077	1.0	4.1
2.5	992.9	10,962	1.2	2.8
3.0	971.5	10,855	1.4	2.4
3.52	949.1	10,511	1.7	2.4
4.0	928.1	10,268	2.0	1.8
4.45	905.3	9,763	2.4	2.0
5.0	881.3	9,476	2.7	2.0
5.3[a]	870.4	9,379	2.9	1.8

[a] At Gila River



NOTES:
Qp = THE PEAK FLOW RATE IN CUBIC FEET PER SECOND.
Vm = THE MAXIMUM VELOCITY OF FLOW IN FEET PER SECOND.
Ts = THE TIME OF FLOOD WAVE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Tm = THE TIME OF PEAK FLOW RATE IN HOURS REFERENCED TO DAM-BREAK INITIATION.
Dm = THE MAXIMUM FLOOD DEPTH IN FEET.

RESULTS OF DAM-BREAK ANALYSIS

FRS #3, STATION 88+00: SEEPAGE FAILURE

Figure 17

4.0 ECONOMIC AND SOCIAL IMPACTS

4.1 ECONOMIC IMPACTS

An economic analysis of flood damages resulting from the worst-case dam-break scenario was completed for each of the three FRSs. The analysis included: assessing the type, use, and number of structures and properties in the study area; developing estimated values for the structures and properties; estimating the value of the contents of the buildings based on known or suspected use; and developing flood damage verses depth relationships for the buildings including damages to both the structures and contents.

The locations selected as worst-case dam-break scenarios from an economic viewpoint for each FRS are:

FRS #1	Station 662+00
FRS #2	Station 300+00
FRS #3	Station 161+40

Only stations where dam-breaks were modeled were considered in the selection process. The dam-break locations listed above were selected as worst-case scenarios from an economic viewpoint based on the number of structures and cultivated acreage located within the inundated downslope areas. The damage estimate developed at each of the selected stations represents the estimated economic damages impacted on the downslope areas due to the single dam-break event and the degree of flooding associated with it based on the results of the computer modeling.

To facilitate the economic analysis, property within the study area was divided into general categories, and properties within each category were assigned unit costs which were representative of the average unit value. Table 4.1 presents the general categories and the assigned unit values used for this study. The categories listed were selected based on a site visit and aerial photo review of the study area. The average unit values listed were developed based upon telephone interviews with local property assessors, realtors, Maricopa County Agricultural Extension Office personnel, Arizona State University's Real Estate Center personnel, business owners and business managers within the Buckeye area, and engineering judgment. The estimated value of a building's contents were expressed as a percentage of a building's unit value for the purpose of this study (see Table 4.1). The percentages presented in Table 4.1 were selected based on data provided by the U.S. Army Corps of Engineers and engineering judgment (USACOE, 1990).

Table 4.1

ESTIMATED UNIT PROPERTY VALUES WITHIN THE STUDY AREA

Type of Property	Average Unit Value (per structure)	Value of Contents Expressed as a Percentage of the Unit Property Value
Single Family Residence	$ 60,500	50%
Mobile Home	16,000	150%
Recreational Vehicle[a]	10,000	75%
Small Business	135,000	113%
Large Business	750,000	113%
Cotton Gin Facility	1,000,000	100%
Church	125,000	50%
Public School	1,250,000	50%
Public Buildings	200,000	50%
Farms	120,000	97%

[a] For recreational vehicles being used as a temporary residence.

The flood damage versus depth relationships used for this analysis were developed by the Federal Emergency Management Agency (FEMA) and provided to Dames & Moore by the U.S. Army Corps of Engineers (USACOE, 1990a). The data list typical damage sustained at a given flood depth above the building floor as a percentage of the structural and the content value of a property.

The results of each computer modeled dam-break were plotted on USGS topographic maps. Flood depths, rounded to the nearest 0.5 feet, were evaluated within the inundated area and the number of properties experiencing flooding at various depths were quantified and classified according to the types of properties listed in Table 4.1. Flood depths used for damage assessment were then adjusted to reflect the presence of slightly raised foundations for buildings (-0.5 feet) and mobile homes placed on concrete or steel posts (-1.0 feet). The anticipated dollar value of the damages sustained to structures and their contents due to flooding was then estimated by applying the appropriate FEMA damage factors.

Damages to crops as a result of flooding was assumed to be the loss of one year's harvest in all inundated areas. This unit cost was estimated to be $1,012 per acre. The cost to repair roads, railways, canals, the FRS itself, and other facilities along with economic losses associated with transportation delays and lost wages was assumed to be 15 percent of the total of the structural, contents, and crop damages sustained during the dam-break event.

4.1.1 Floodwater Retarding Structure #1

The results of the economic analysis for FRS #1 are presented in Table 4.2. It was estimated that a seepage failure at Station 662+00 would cause $9,344,155 in structural damage, $3,306,644 in contents damage, $6,476,800 in crop damage, and $1,897,620 in miscellaneous damages for a total of $14,548,419 in overall damages.

4.1.2 Floodwater Retarding Structure #2

The results of the economic analysis for FRS #2 are presented in Table 4.3. It was estimated that an overtoppping failure at Station 300+00 would cause $17,067,140 in structural damage, $13,076,100 in contents damage, $3,137,200 in crop damage, and $4,521,486 in miscellaneous damages for a total of $34,664,726 in overall damages.

4.1.3 Floodwater Retarding Structure #3

The results of the economic analysis for FRS #3 are presented in Table 4.4. It was estimated that an overtopping failure at Station 161+40 would cause $4,254,460 in structural damage, $1,880,114 in contents damage,

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Table 4.2

ECONOMIC EVALUATION OF FLOODING DUE TO A SEEPAGE FAILURE OF FRS #1

Dam-Break Modeled at Station 662+00

A Flood Depth (ft)	B Effective Flood Depth (ft)	C Structures Affected By Flooding	D Units	E Number of Units	F Estimated Unit Value ($)	G Estimated Contents Value (%)	H Unit Value of Contents ($) F x G/100	I Total Value of Structures ($) E x F	J Total Value of Contents ($) E x H	K FEMA Damage Factor for Structures	L FEMA Damage Factor for Contents	M Estimated Structures Damage ($) I x K	N Estimated Contents Damage ($) J x L	O Total Estimated Damage ($) M + N
7.0	6.5	Single Family Homes	Each	10.0	60,500	50	30,250	605,000	302,500	.42	.47	254,100	142,175	396,275
	6.0	Mobile Homes	Each	30.0	16,000	150	24,000	480,000	720,000	.80	.78	384,000	561,600	945,600
	6.5	Church	Each	1.0	125,000	50	62,500	125,000	62,500	.42	.48	52,500	30,000	82,500
4.5	4.0	Small Businesses	Each	7.0	135,000	113	152,550	945,000	1,067,850	.28	.35	264,600	373,748	638,348
4.0	3.5	Single Family Homes	Each	3.0	60,500	50	30,250	181,500	90,750	.28	.36	50,820	32,670	83,490
	3.0	Mobile Homes	Each	1.0	16,000	150	24,000	16,000	24,000	.73	.64	11,680	15,360	27,040
	3.5	Small Businesses	Each	1.0	135,000	113	152,550	135,000	152,550	.28	.32	37,800	48,816	86,616
	3.5	Large Businesses	Each	1.0	750,000	113	847,500	750,000	847,500	.28	.36	210,000	305,100	515,100
	3.5	Cotton Gin	Each	1.0	1,000,000	100	1,000,000	1,000,000	1,000,000	.28	.32	280,000	320,000	600,000
3.5	3.0	Single Family Homes	Each	2.0	60,500	50	30,250	121,000	60,500	.27	.35	32,670	21,175	53,845
2.5	2.0	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.20	.32	108,900	87,120	196,020
	2.0	Small Businesses	Each	3.0	135,000	113	152,550	405,000	457,650	.20	.24	81,000	109,836	190,836
	2.0	Farm Facilities	Each	3.0	120,000	97	116,400	360,000	349,200	.20	.32	72,000	111,744	183,744
2.0	1.5	Single Family Homes	Each	7.0	60,500	50	30,250	423,500	211,750	.17	.27	71,995	57,173	129,168
	1.5	Small Businesses	Each	2.0	135,000	113	152,550	270,000	305,100	.17	.21	45,900	64,071	109,971
	1.0	Mobile Homes	Each	1.0	16,000	150	24,000	16,000	24,000	.43	.27	6,880	6,480	13,360
	1.5	Farm Facilities	Each	1.0	120,000	97	116,400	120,000	116,400	.17	.27	20,400	31,428	51,828
1.5	1.0	Single Family Homes	Each	13.0	60,500	50	30,250	786,500	393,250	.13	.23	102,245	90,448	192,693
	1.0	Small Businesses	Each	11.0	135,000	113	152,550	1,485,000	1,678,050	.13	.17	193,050	285,269	478,319
	1.0	Public School	Each	1.0	1,250,000	50	625,000	1,250,000	625,000	.13	.17	162,500	106,250	268,750
	1.0	Farm Facilities	Each	5.0	120,000	97	116,400	600,000	582,000	.13	.23	78,000	133,860	211,860
1.0	0.5	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.11	.17	59,895	46,283	106,178
	0.0	Mobile Homes	Each	2.0	16,000	150	24,000	32,000	48,000	.08	.03	2,560	1,440	4,000
	0.5	Farm Facilities	Each	1.0	120,000	97	116,400	120,000	116,400	.11	.17	13,200	19,788	32,988
	0.5	Church	Each	2.0	125,000	50	62,500	250,000	125,000	.11	.14	27,500	17,500	45,000
0.5	0.0	Single Family Homes	Each	7.0	60,500	50	30,250	423,500	211,750	.08	.11	33,880	23,293	57,173
	-0.5	Mobile Homes	Each	2.0	16,000	150	24,000	32,000	48,000	.04	.00	1,280	0	1,280
	0.0	Farm Facilities	Each	5.0	120,000	97	116,400	600,000	582,000	.08	.11	48,000	64,020	112,020
	0.0	Cotton Gin	Each	2.0	1,000,000	100	1,000,000	2,000,000	2,000,000	.08	.10	160,000	200,000	360,000
		Cultivated Land	Acre	6,400.0	1,012		0	6,476,800	0	1.00	.00	6,476,800	0	6,476,800
	Subtotal													12,650,799
	x 15% for damage to roads & Utilities													1,897,620
	TOTALS							21,097,800	12,746,200			9,344,155	3,306,644	14,548,419

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Table 4.3

ECONOMIC EVALUATION OF FLOODING DUE TO AN OVERTOPPING FAILURE OF FRS #2

Dam-Break Modeled at Station 300+00

A Flood Depth (ft)	B Effective Flood Depth (ft)	C Structures Affected By Flooding	D Units	E Number of Units	F Estimated Unit Value ($)	G Estimated Contents Value (%)	H Unit Value of Contents ($) F x G/100	I Total Value of Structures ($) E x F	J Total Value of Contents ($) E x H	K FEMA Damage Factor for Structures	L FEMA Damage Factor for Contents	M Estimated Structures Damage ($) I x K	N Estimated Contents Damage ($) J x L	O Total Estimated Damage ($) M + N
5.0	4.0	Mobile Homes	Each	10.0	16,000	150	24,000	160,000	240,000	.78	.70	124,800	168,000	292,800
4.5	3.5	Mobile Homes	Each	5.0	16,000	150	24,000	80,000	120,000	.75	.67	60,000	80,400	140,400
4.0	3.0	Mobile Homes	Each	5.0	16,000	150	24,000	80,000	120,000	.73	.64	58,400	76,800	135,200
	3.5	Single Family Homes	Each	1.0	60,500	50	30,250	60,500	30,250	.28	.36	16,940	10,890	27,830
	3.5	Farm Facilities	Each	1.0	120,000	97	116,400	120,000	116,400	.28	.36	33,600	41,904	75,504
3.5	2.5	Mobile Homes	Each	5.0	16,000	150	24,000	80,000	120,000	.67	.57	53,600	68,400	122,000
3.0	2.0	Mobile Homes	Each	6.0	16,000	150	24,000	96,000	144,000	.62	.49	59,520	70,560	130,080
	2.5	Single Family Homes	Each	137.0	60,500	50	30,250	8,288,500	4,144,250	.23	.33	1,906,355	1,367,603	3,273,958
	2.5	Small Businesses	Each	3.0	135,000	113	152,550	405,000	457,650	.23	.27	93,150	123,566	216,716
	2.5	Churches	Each	2.0	125,000	50	62,500	250,000	125,000	.23	.27	57,500	33,750	91,250
	2.5	Public Schools	Each	1.0	1,250,000	50	625,000	1,250,000	625,000	.23	.27	287,500	168,750	456,250
	2.5	Public Buildings	Each	1.0	200,000	50	100,000	200,000	100,000	.23	.27	46,000	27,000	73,000
2.5	1.5	Mobile Homes	Each	6.0	16,000	150	24,000	96,000	144,000	.52	.38	49,920	54,720	104,640
	2.0	Single Family Homes	Each	222.0	60,500	50	30,250	13,431,000	6,715,500	.20	.32	2,686,200	2,148,960	4,835,160
	2.0	Small Businesses	Each	24.0	135,000	113	152,550	3,240,000	3,661,200	.20	.24	648,000	878,688	1,526,688
	2.0	Churches	Each	5.0	125,000	50	62,500	625,000	312,500	.20	.24	125,000	75,000	200,000
	2.0	Public Buildings	Each	1.0	200,000	50	100,000	200,000	100,000	.20	.24	40,000	24,000	64,000
	2.0	Large Businesses	Each	2.0	750,000	113	847,500	1,500,000	1,695,000	.20	.32	300,000	542,400	842,400
2.0	1.0	Mobile Homes	Each	5.0	16,000	150	24,000	80,000	120,000	.43	.27	34,400	32,400	66,800
	1.5	Single Family Homes	Each	267.0	60,500	50	30,250	16,153,500	8,076,750	.17	.27	2,746,095	2,180,723	4,926,818
	1.5	Small Businesses	Each	11.0	135,000	113	152,550	1,485,000	1,678,050	.17	.21	252,450	352,391	604,841
	1.5	Churches	Each	3.0	125,000	50	62,500	375,000	187,500	.17	.21	63,750	39,375	103,125
	1.5	Public Schools	Each	1.0	1,250,000	50	625,000	1,250,000	625,000	.17	.21	212,500	131,250	343,750
	1.5	Public Buildings	Each	1.0	200,000	50	100,000	200,000	100,000	.17	.21	34,000	21,000	55,000
	1.5	Large Businesses	Each	2.0	750,000	113	847,500	1,500,000	1,695,000	.17	.27	255,000	457,650	712,650
1.5	.5	Mobile Homes	Each	4.0	16,000	150	24,000	64,000	96,000	.26	.15	16,640	14,400	31,040
	1.0	Single Family Homes	Each	228.0	60,500	50	30,250	13,794,000	6,897,000	.13	.23	1,793,220	1,586,310	3,379,530
	1.0	Small Businesses	Each	11.0	135,000	113	152,550	1,485,000	1,678,050	.13	.17	193,050	285,269	478,319
	1.0	Churches	Each	8.0	125,000	50	62,500	1,000,000	500,000	.13	.17	130,000	85,000	215,000
	1.0	Public Schools	Each	1.0	1,250,000	50	625,000	1,250,000	625,000	.13	.17	162,500	106,250	268,750
	1.0	Public Buildings	Each	2.0	200,000	50	100,000	400,000	200,000	.13	.17	52,000	34,000	86,000
	1.0	Large Businesses	Each	4.0	750,000	113	847,500	3,000,000	3,390,000	.13	.23	390,000	779,700	1,169,700
1.0	.0	Mobile Homes	Each	6.0	16,000	150	24,000	96,000	144,000	.08	.03	7,680	4,320	12,000
	0.5	Single Family Homes	Each	52.0	60,500	50	30,250	3,146,000	1,573,000	.11	.17	346,060	267,410	613,470
	0.5	Small Businesses	Each	9.0	135,000	113	152,550	1,215,000	1,372,950	.11	.14	133,650	192,213	325,863
	0.5	Large Businesses	Each	1.0	750,000	113	847,500	750,000	847,500	.11	.14	82,500	118,650	201,150
	0.5	Cotton Gin	Each	1.0	1,000,000	100	1,000,000	1,000,000	1,000,000	.11	.17	110,000	170,000	280,000
	0.5	Farm Facilities	Each	1.0	120,000	97	116,400	120,000	116,400	.11	.17	13,200	19,788	32,988
0.5	-0.5	Mobile Homes	Each	103.0	16,000	150	24,000	1,648,000	2,472,000	.04	.00	65,920	0	65,920
	.0	Single Family Homes	Each	11.0	60,500	50	30,250	665,500	332,750	.08	.11	53,240	36,603	89,843
	.0	Small Businesses	Each	7.0	135,000	113	152,550	945,000	1,067,850	.08	.10	75,600	106,785	182,385
	.0	Large Businesses	Each	1.0	750,000	113	847,500	750,000	847,500	.08	.11	60,000	93,225	153,225
		Cultivated Land	Acre	3,100.0	1,012		0	3,137,200	0	1.00	.00	3,137,200	0	3,137,200
	Subtotal													30,143,240
	x 15% for damage to roads & Utilities													4,521,486
	TOTALS							85,671,200	54,613,050			17,067,140	13,076,100	34,664,726

DAMES & MOORE JOB NUMBER 15448-003-022
BUCKEYE FRS PHASE II: DAM-BREAK ANALYSIS
FOR THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

Table 4.4

ECONOMIC EVALUATION OF FLOODING DUE TO AN OVERTOPPING FAILURE OF FRS #3

Dam-Break Modeled at Station 161+40

A Flood Depth (ft)	B Effective Flood Depth (ft)	C Structures Affected By Flooding	D Units	E Number of Units	F Estimated Unit Value ($)	G Estimated Contents Value (%)	H Unit Value of Contents ($) F x G/100	I Total Value of Structures ($) E x F	J Total Value of Contents ($) E x H	K FEMA Damage Factor for Structures	L FEMA Damage Factor for Contents	M Estimated Structures Damage ($) I x K	N Estimated Contents Damage ($) J x L	O Total Estimated Damage ($) M + N
5.0	4.5	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.29	.39	157,905	106,178	264,083
4.5	4.0	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.28	.37	152,460	100,733	253,193
4.0	3.5	Single Family Homes	Each	11.0	60,500	50	30,250	665,500	332,750	.28	.36	186,340	119,790	306,130
3.5	3.0	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.27	.35	147,015	95,288	242,303
	2.5	Mobile Homes	Each	2.0	16,000	150	24,000	32,000	48,000	.73	.64	23,360	30,720	54,080
	3.0	Small Businesses	Each	1.0	135,000	113	152,550	135,000	152,550	.27	.29	36,450	44,240	80,690
3.0	2.5	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.23	.33	125,235	89,843	215,078
	2.5	Farm Facilities	Each	1.0	120,000	97	116,400	120,000	116,400	.23	.33	27,600	38,412	66,012
	2.5	Cotton Gin	Each	1.0	1,000,000	100	1,000,000	1,000,000	1,000,000	.23	.33	230,000	330,000	560,000
2.5	2.0	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.20	.32	108,900	87,120	196,020
	1.5	Mobile Homes	Each	1.0	16,000	150	24,000	16,000	24,000	.52	.38	8,320	9,120	17,440
	2.0	Cotton Gin	Each	1.0	1,000,000	100	1,000,000	1,000,000	1,000,000	.20	.32	200,000	320,000	520,000
2.0	1.5	Single Family Homes	Each	9.0	60,500	50	30,250	544,500	272,250	.17	.27	92,565	73,508	166,073
1.5	1.0	Single Family Homes	Each	14.0	60,500	50	30,250	847,000	423,500	.13	.23	110,110	97,405	207,515
	0.5	Mobile Homes	Each	2.0	16,000	150	24,000	32,000	48,000	.26	.15	8,320	7,200	15,520
1.0	0.5	Single Family Homes	Each	10.0	60,500	50	30,250	605,000	302,500	.11	.17	66,550	51,425	117,975
	0.0	Mobile Homes	Each	2.0	16,000	150	24,000	32,000	48,000	.08	.03	2,560	1,440	4,000
	0.5	Farm Facilities	Each	1.0	120,000	97	116,400	120,000	116,400	.11	.17	13,200	19,788	32,988
	0.5	Cotton Gin	Each	1.0	1,000,000	100	1,000,000	1,000,000	1,000,000	.11	.17	110,000	170,000	280,000
	0.5	Small Businesses	Each	1.0	135,000	113	152,550	135,000	152,550	.11	.14	14,850	21,357	36,207
0.5	0.0	Single Family Homes	Each	20.0	60,500	50	30,250	1,210,000	605,000	.08	.11	96,800	66,550	163,350
	-0.5	Mobile Homes	Each	13.0	16,000	150	24,000	208,000	312,000	.04	.00	8,320	0	8,320
		Cultivated Land	Acre	2,300.0	1,012		0	2,327,600	0	1.00	.00	2,327,600	0	2,327,600
	Subtotal													6,134,574
	x 15% for damage to roads & Utilities													920,186
	TOTALS							12,752,100	7,315,150			4,254,460	1,880,114	7,054,760

$2,327,600 in crop damage, and $920,186 in miscellaneous damages for a total of $7,054,760 in overall damages.

4.2 SOCIAL IMPACTS

4.2.1 General

The estimation of social impacts associated with postulated breaches in FRS #1, #2 and #3 is highly subjective. It is very hard to express these impacts in terms of monetary values. The anticipated social impacts resulting from the aforementioned breaches are divided into the following broad categories:

(i) Community Disruption - This includes permanent disruption in the community living of people or groups of people whose homes may be significantly damaged so that they may not want or be able to return in the vicinity of their original residences; permanent relocation of people whose jobs may be lost because the businesses or farm facilities employing them may have suffered significant damage so that it may not be profitable for them to restart in the vicinity of their original locations. For the purposes of this study, it is assumed that businesses, facilities, and residences subjected to a flood depth equal to or more than 4.5 feet will fall in this category.

(ii) Trauma Damage - This includes trauma associated with flood havoc suffered by children in schools and people in areas where the dam-break flood depth equals or exceeds 2.5 feet resulting in relocation to temporary shelter houses.

(iii) Public Inconvenience - This includes public inconvenience due to temporary closure of schools, churches, stores, and streets and temporary discontinuance of electricity, water, gas, and telephone services. It is assumed that areas subjected to a flood depth equal to or more than 1.5 feet will fall in this category.

(iv) Temporary Loss of Jobs or Means of Livelihood - This includes working people in areas where businesses, cultivation, and other activities will be temporarily suspended because of flooding, post-flood cleanup operations, and disruption to communications. This category of social impacts will be applicable to areas subjected to flood depths of 0.5 to 2.5 feet.

For a preliminary estimate of the number of people subjected to the aforementioned social impacts, the habitation densities of different types of structures are assumed to be as shown in Table 4.5.

Table 4.5

HABITATION DENSITIES OF DIFFERENT TYPES OF STRUCTURES

Structure	Approximate Habitation Density
Single Family Home	4
Mobile Home	2
Church	1
Small Business	10
Large Business	100
Cotton Gin	8
Farm Facilities	6
Cultivated Land[a]	1 per 100 acre
Public Schools[b]	1000
Public Buildings[b]	100

[a] Refers to people dependent on cultivation for livelihood
[b] Assumes a full working day situation

4.2.2 Social Impacts of Breaches in FRS #1

Using the information given in Section 4.2.1 and Table 4.2, the social impacts associated with a breach in FRS #1 are estimated to be as follows:

- The community living of approximately 171 people is likely to be permanently disrupted because the resulting flood damages may induce the affected homeowners, church, and small business to relocate to some other safer location farther from their original locations. Approximately 395 people may witness and be affected by flood havoc and may experience some kind of trauma related to uncontrolled sudden inundation of property due to catastrophic events like a dam-break. A total of about 1,643 people will be sujected to inconvenience for a few days or weeks due to the closure of farm facilities, public schools, small businesses, and wet and muddy residences. Assuming that an inundation depth of 0.5 to 2.5 feet will not result in loss of jobs in churches and schools, a total of about 330 people are likely to be temporarily out of work due to temporary closure of small businesses, farm facilities, and cotton gins.

4.2.3 Social Impacts of Breaches in FRS #2

Using the information given in Section 4.2.1 and Table 4.3, the social impacts associated with a postulated breach in FRS #2 are estimated to be as follows:

- The community disruption will be limited to about 30 mobile-home owners. However, some form of trauma will be experienced by about 3,197 people. This is because the inundated area likely to fall in the trauma-damage category will include a public school, 360 single family homes, two large businesses, and two public buildings. Flood-induced public inconvenience will be felt by about 8,326 people due to the closure of public schools, public buildings, small and large businesses, churches, and farm facilities, and wet and muddy residences. In addition, about 1665 people may be temporarily out of work due to temporary closure of small and large businesses, farming, and cotton gins. This assumes that no loss of job will result from temporary closure of churches, schools, and public buildings.

4.2.4 Social Impacts of Breaches in FRS #3

Using the information presented in Section 4.2.1 and Table 4.4, the social impacts associated with a postulated breach in FRS #3 are estimated to be as follows:

- The disruption of community living will be experienced by about 72 people living in single family homes downslope from the embankment. The trauma resulting from sudden onslaught of the dam-break flood wave will be felt by about 262 people. The public inconvenience is likely to be limited to about 358 people mainly because of wet and muddy residences and temporary closure of one small business within the inundated area. It is expected that about 55 people could be temporarily out of work due to temporary suspension of cultivation and closure of one small business and two cotton gins.

5.0 EVACUATION PLAN

The dam-break analysis study for the Buckeye FRS system includes an assessment of the warning and evacuation alternatives that could be employed in the event of dam failure. The following text outlines the existing evacuation and warning resources within the study area, discusses the disaster plan alternatives, and presents the recommended plan based on Dames & Moore's evaluations.

5.1 EXISTING RESOURCES

5.1.1 Flood Warning System

The existing warning system and evacuation procedures for the FRS system are outlined in Maricopa County's Peacetime Disaster Plan (MCDCD&ES 1989) and pertain only to FRS #1. No disaster plans are known to have been developed for FRS #2 or #3.

Under the current plan, FCD personnel are responsible for monitoring the situation at FRS #1 and then notifying the Maricopa County Department of Civil Defense and Emergency Services (MCDCD&ES) of possible or actual flood problems associated with the FRS. The County Sheriff's Department is responsible for warning the public and directing evacuation efforts.

The warning system currently consists of a siren located in the Town of Buckeye, radio and television broadcasts, the local telephone system, and the County Sheriff's office which performs door to door notification and broadcasts warnings over patrol car loudspeakers. There are also eight other alert sirens located within the study area (see Figure 2); however, these sirens are part of the Palo Verde Nuclear Electric Generating Plant's warning system and are not part of the peacetime disaster plan for FRS #1.

There are currently three levels of evacuation specified in the peacetime disaster plan; voluntary, recommended, and directed evacuation. Routes and methods to be used for an evacuation are to be determined on-site as the situation unfolds.

5.1.2 Transportation Routes

Although the Buckeye area has many roads located along section lines, only a limited number of them provide transportation routes away from the study area. Roads that could be used as evacuation routes to the west include I-10, Baseline Road, Old U.S. Highway 80, and Narramore Road. Of these four potential western evacuation routes, three include bridged crossings of the Hassayampa River; Narramore Road has a dip crossing through the river. Potential eastward evacuation routes include I-10, Van Buren Street, Lower Buckeye Road, Broadway Road, Southern Avenue, Yuma Road, and State Highway 85 (U.S. 80). Southern routes include Jackrabbit Trail, Airport Road, Miller Road, and State Highway 85 (U.S. 80). Of these four southern routes only three provide bridged access across the Gila River; Miller Road is a dip crossing.

Possible northern evacuation routes include Johnson Road, Sun Valley Parkway, (Palo Verde Road south of FRS #1), and Miller Road. Northern evacuation routes could be used in an emergency situation theoretically; however, the public may be apprehensive about moving toward the perceived source of flood problems during an evacuation event. In addition, the Miller Road option should probably not be considered as an evacuation route since the FRS #2 emergency spillway discharges will flood this road and the road dead ends in the hills just upslope of I-10.

The Southern Pacific Railroad tracks could be considered an evacuation route but because of the time required to position, load and displace a train, the railroad is not considered a practical evacuation route.

5.2 DAM-BREAK ANTECEDENT CONDITIONS

The dam-break evacuation plan should take into consideration conditions antecedent to the dam-break event. Most significant of these conditions will be the fact that a major storm event will probably have occurred over the FRS watershed. In fact, for an overtopping failure, an event well in excess of the 100-year storm will have occurred and the emergency spillways will be in use.

If the emergency spillways of FRS #2 or #3 are in use, flows may overtop I-10 and the Department of Public Safety or Department of Transportation may have already closed the freeway as much as several hours prior to the FRSs being overtopped. With the FRS #2 or #3 emergency spillways discharging, there will already be an area of flooding extending downslope from the spillway across the dam-break study area. Roads will be flooded and possibly closed and some portion of the population will already be exposed to flooding.

In all probability, a storm of such magnitude as needed to produce FRS emergency spillway discharges will have also provided heavy rainfall over the dam-break study area. This would cause local ponding, some closure of roads and a public awareness that a major natural event has occurred. To a large degree, persons in the area will be primarily concerned with getting to their homes or places of business and protecting their own personal property and that of their close neighbors. If there is a coincident power outage, persons who normally watch television or listen to the radio for news will have access to news information only if they use battery powered equipment, an electrical generator, or their car radios. However, if there is not a power outage, it is possible that the percentage of persons listening to the radio or watching television may be higher because of the storm severity.

Local inflows from storm runoff irrigation canals and distribution systems may fill these facilities and cause overtopping of downslope levees, etc. A major storm in the Buckeye area may be largely independent of flows in the Hassayampa or Gila rivers. However, it should probably be assumed that any dip river crossings may be closed due to flows and not available for evacuation routes. In addition, a major flow in the Gila River could overtop the bridge approaches on State Highway 85 since the bridge system can not pass the 100-year event. Other bridges may have a similar problem.

5.3 EVACUATION ALTERNATIVES

A variety of alternatives are available to initiate and complete an evacuation for a possible dam-break in one or more of the FRSs. The two major elements of a dam break evacuation are the flood warning system and the evacuation process itself.

5.3.1 Flood Warning System

The flood warning system must be timely, easily recognizable, safe, efficient and flexible to be effective regardless of the potential dam-break location. For instance, unless FRS #2 is involved, residents of the Town of Buckeye probably need only an "alert" level warning. If they were to evacuate to the east and FRS #3 breached, they may move directly into the path of the flood wave, whereas they would probably have been safe remaining in the town.

The flood warning system should make maximum use of existing facilities or developed systems and should also utilize, wherever possible, multiple use of facilities. For instance the Town of Buckeye's fire siren could be programmed such that a long continuous signal calls the volunteer fire department, while a repeated series of short blasts indicates an evacuation scenario. Similarly, a remotely-operated electronic display along I-10 near Citrus Road which warns westbound motorists of dust storms further west could also advise motorists to exit the freeway at the Jackrabbit Trail exit during a potential dam-break situation at the Buckeye FRSs.

Already on-line warning systems, such as television and radio announcements are invaluable tools and during a critical situation, could provide site specific instructions as to which roads to use and which direction to move. The County Sheriff's office and Town of Buckeye police department vehicles should all be equipped with loudspeakers with sufficient volume to be heard inside closed homes up to a block away. Personnel from these agencies must have pre-assigned areas to cover and must be able to accurately interpret the potential flood information so that explicit instructions can be provided on relatively short notice.

Personnel assigned to monitor the FRSs during storm events should include a primary and an alternative for any on-site monitoring. Any remote sensing equipment, such as float switches with telemetry, should be reliable and dependable at interpreting potential dam-break problems in a timely manner.

5.3.2 Evacuation Processes

The areas downslope of the FRSs are mostly rural and the process of evacuating the areas must therefore stress adequate lead time for evacuation warning and equipment and manpower commitments sufficient to implement the evacuation plan in the necessary time frame. Once area residents are in vehicles and on the road, the problem becomes one of traffic control and assisting stragglers; a problem which does not require sophisticated personnel training.

The evacuation process needs to be a process of timely, well-thought out decisions effected by a rigid chain of command and control which maximizes decisions and minimizes discussion. The scenarios where more than one agency is trying to make the same decision and where one agency receives conflicting directions from one or more other agencies must be avoided at all costs.

5.4 RECOMMENDED EVACUATION PLANS

An evacuation plan has been prepared for each of these Buckeye FRSs. Since these are intended to be stand alone documents, they are included with this report as appendices A, B and C. The evacuation plans were generally modeled after the Maricopa County, Arizona Peacetime Disaster

Plan, Annex B-Storms and Floods. A separate plan was prepared for each of the three FRSs, however, because of their close proximity, hydraulic connections and use of common evacuation routes, it is highly recommended that the three evacuation plans be bound together and used as a single document.

The recommended evacuation plans were formulated to make the best use of already in place facilities and inter-agency agreements. As such, no new warning systems or road upgrades, etc. are specifically recommended. However, persons responsible for zoning, development approvals and road improvements must take into account the potential dam-break situations as development continues in the areas downslope from the FRS.

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EMERGENCY SPILLWAY
BUCKEYE FRS #1
EMERGENCY SPILLWAY
BUCKEYE FRS #2
BUCKEYE FRS #3
EMERGENCY SPILLWAY
WHITE TANKS FRS #4
McDOWELL RD.
SUN VALLEY PARKWAY
R5W R4W
R4W R3W
R3W R2W
T2N
T1N
T1S
BUCKEYE
VALLEY
ESTIMATED FLOOD DEPTHS
2-3 FEET
3-4 FEET
4-5 FEET
5-6 FEET
>6 FEET
REFERENCE: USGS 7.5 MINUTE QUADRANGLES FOR ARIZONA
WAGNER WASH WELL 1988, WHITE TANK MOUNTAINS SE 1957,
WINTERSBURG 1984, BUCKEYE NW 1971, VALENCIA 1971,
PERRYVILLE 1971, ARLINGTON 1988, HASSAYAMPA 1971,
BUCKEYE 1971, AVONDALE SW 1971.
LEGEND:
100-YEAR FLOODPLAIN
EMBANKMENT
UNDERGROUND CONDUIT
FLOODWAY OR CHANNEL
2 FT. WATER PEAK DEPTH CONTOUR
30 MIN. FLOOD WAVE ISOCRONE
88+00 DAM-BREAK ANALYSIS POINT
SCALE
0 2000 4000
FEET
N
MAP OF
BUCKEYE FRS
DAM-BREAK STUDY AREA
FCD Project Number 88-63
Dames & Moore Job No.
15448-003-022
By: Dames & Moore
June 1990
Figure 2

PHOTOGRAPH OF BUCKEYE FRS DAM-BREAK STUDY AREA

FCD Project Number 88-63
Dames & Moore Job No.
15448-003-022

By: Dames & Moore | June 1990 | Figure 3

APPENDIX A

EVACUATION PLAN
FOR
BUCKEYE FLOODWATER RETARDING STRUCTURE #1
(AZ NO. 7-42)
MARICOPA COUNTY, ARIZONA

Prepared for

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
FCD PROJECT 88-63

Prepared by

DAMES & MOORE
15448-003-022

JUNE, 1990

EVACUATION PLAN

FOR

BUCKEYE FLOODWATER RETARDING STRUCTURE #1

MARICOPA COUNTY, ARIZONA

INTRODUCTION

The Buckeye Floodwater Retarding Structure #1 (FRS #1) protects a portion of the area near Buckeye, Arizona from extensive runoff during severe storm events. However, the possibility exists that the FRS may suffer a dam-break failure releasing damaging and potentially lethal flood flows across the FRS downslope area. This plan was formulated to provide for a rapid and effective evacuation of the FRS downslope area in the event such a failure can be anticipated.

Although this plan is meant to be a stand alone document, the FRS itself does not stand alone, but is only one part of the Buckeye FRS system. The safety and evacuation status of the entire system as well as flows in the adjacent rivers, etc. must be taken into consideration during implementation of this plan.

I. SITUATION

A. MAPS

1. Figure 1 is enclosed to identify the area of concern.

2. Figure 2 is the primary map for this activity. Figure 2 shows potential flood depths and times of peak flood depth over the evacuation area.

3. County and state road maps may be referenced for extending evacuation routes.

B. AREA AFFECTED

The affected area is identified as the FRS downslope area (FRSDA). It is bounded on the north by the FRS and on the south by the Gila River. The approximate east and west boundaries are Oglesby Road and the Hassayampa River, respectively (see Figure 2).

C. FLOOD FLOWS

In the event of a dam-break failure of the FRS, deep and fast moving water will emanate from the dam-break location and flow generally south toward the Gila River. If the dam-break event can be successfully anticipated, prompt implementation of this evacuation plan may be adequate to evacuate the FRSDA to prevent loss of life and possibly reduce property damages.

II. OBJECTIVE

The objective of this evacuation plan is to provide a mutually acceptable plan for prompt, organized and effective evacuation of the FRSDA. The keys to achieving this objective are sound, timely decision making, assertive and timely communications and rapid implementation of the plan. Also key to the successful implementation of this plan will be prior public awareness of the situation and total cooperation of all parties.

III. RESPONSIBILITIES

A variety of agencies are involved in the implementation of this plan. Several agencies are involved in the decision-making process and several are involved in the implementation activities. A schematic diagram is presented in Figure 3 to show lines of communication. The responsibilities and various tasks assigned to each agency are described in the following text. Note that other agencies may be involved in supporting the post-evacuation situation, but these key agencies listed below are the agenices believed necessary to complete the evacuation itself.

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a. The Flood Control District of Maricopa County (FCD) is responsible for selecting the level of dam-break warning. The FCD is also responsible for providing recommendations to the Maricopa County Department of Civil Defense and Emergency Services (MCDCD&ES) so that MCDCD&ES can select what type of evacuation effort should be in effect. The FCD will complete on-site evaluations, review dam design and operating criteria and consult with other knowledgeable agencies to assess the safety of the structure and to select the level of warning.

b. The FCD will solicit data from the National Weather Service (NWS) regarding weather predictions and will maintain open communications with MCDCD&ES, as necessary, to effect timely communications and initiation of the evacuation should it be required.

c. The FCD will be responsible for providing, prior to an actual evacuation event, public awareness and education regarding the potential dam-break situation, the methods of warning to be used in an emergency and the evacuation process.

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a. The Arizona Department of Water Resources (ADWR) - Safety of Dams Section and the U.S. Soil Conservation Service (SCS) will be responsible for providing the FCD with technical consulting services to assist in evaluating the safety of the structures. SCS, as the designer of the structures and ADWR as the state's technical dam evaluation agency, have detailed knowledge of the structures.

b. ADWR and SCS will be available for consultation during emergencies and will provide on-site evaluations (if necessary and time permits) to help evaluate the safety of the FRS.

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a. The MCDCD&ES will be responsible for selection of the types of evacuation required and implementation of all communication and support services necessary to complete the evacuation. The responsibility for initiation and coordination of the evacuation will be with the MCDCD&ES.

b. The MCDCD&ES will notify the media, affected city governments, the Red Cross, appropriate county and state departments, the County Sheriff, local police departments and the state Department of Public Safety of the type of evacuation in effect and will complete follow up action to make sure that the evacuation occurs as planned.

5. CITY GOVERNMENTS

a. The local city governments will be responsible for evacuation of their own facilities and for the evacuation activities within their corporate limits.

b. The city governments will be responsible for preparing evacuation plans as necessary and for coordination with adjacent cities and MCDCD&ES during the planning stages.

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a. The various fire departments will be responsible for any emergency actions not foreseeable during the normal evacuation processes. As such, they will constitute a force in reserve and should not be tasked with assisting in the evacuation itself.

b. The fire department will respond to automobile accidents, fires, rescue operations, etc. as directed by the various police agencies and coordinated with MCDCD&ES.

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LOCAL POLICE DEPARTMENTS
DEPARTMENT OF PUBLIC SAFETY

a. The various police agencies will be tasked with most of the field activities of the evacuation. They will receive direction from MCDCD&ES as to what type of evacuation is required.

b. The County Sheriff will complete the evacuation of most of the FRSDA since most of this land is under county jurisdiction.

c. The local police departments will complete the evacuation of any areas within the corporate limits. The local police departments will be responsible for notifying, before the issue arises, both the County Sheriff and MCDCD&ES of the areas they will and will not cover.

d. The Department of Public Safety (DPS) will be responsible for closure of Interstate-10 (I-10) and all state highways and making sure that all freeway entrance ramps are closed to preclude traffic access. DPS can coordinate with other state agencies to place and man barriers, as necessary.

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a. Support services both during and immediately after the evacuation may need to be provided by various county and state departments and the Red Cross. These support services may be requested by either MCDCD&ES or by the police staff.

b. County departments may be requested to provide temporary signage, road barricades, etc. during the evacuation.

c. State departments may be requested to assist DPS with re-routing I-10 traffic around the FRSDA.

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a. The Arizona National Guard is responsible for assisting with evacuation and providing area security as requested by state emergency services.

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The following definitions are provided relative to the evacuation process.

a. Levels of warning. These are general definitions which should be applied with qualified technical judgment and allowing for conservation in approach.

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Directed Evacuation Status - upon declaration of local emergency by head of government affected, all endangered persons are directed to immediately evacuate to safe area(s).

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The evacuation process will involve a series of generally sequential steps. Each of these steps is described below.

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Task 3	FCD determines if **alert warning level** is appropriate. If not, process is on hold or stops.
Task 4	If **alert warning level** is selected, FCD notifies MCDCD&ES, ADWR and SCS. MCDCD&ES notifies County Sheriff, city governments, DPS, other state and county departments. City governments notify local police. MCDCD&ES dispatches notices to media to heighten public awareness of potential problems and requests the public to monitor media broadcasts. **Voluntary evacuation status** is suggested, if appropriate.
Task 5	All involved agencies activate reserve or off duty personnel to staff office facilities. County Sheriff dispatches vehicles to northern portion of FRSDA. DPS, ADOT and county highway stage vehicles and barricades in preparation for road closures.
Task 6	FCD continues to monitor site conditions. Key personnel should be made available for decision making. ADWR and SCS should be contacted if necessary. Additional technical support staff may be asked to move to the site. Backup communication systems are brought on line.
Task 7	FCD determines that **imminent failure warning level** is appropriate. FCD evaluates adjacent structures and notifies MCDCD&ES of **imminent failure warning level** and situation at adjacent structure(s).
Task 8	MCDCD&ES determines that **recommended evacuation status** is appropriate. MCDCD&ES requests DPS to close I-10 and detour traffic. MCDCD&ES requests media to disseminate **recommended evacuation status** messages with specific evacuation routes and directions of travel. Note that at this level of warning the emergency spillways of Buckeye FRSs #2 and #3 may be discharging with resulting downslope road closures. MCDCD&ES notifies County Sheriff, city governments and other state and county departments of **recommended evacuation status.**
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Task 10	County Sheriff begins broadcasting on-site warnings of **recommended evacuation status** from north to south across the FRSDA paying particular attention to areas where deep water could occur and where the flood travel times are the shortest (see Figure 2). Note that some members of the County Sheriff staff must remain near the northern end of the FRSDA since the evacuation status could change from recommended to directed very quickly.

Task 11 City government and local police begin broadcasting **recommended evacuation status** to corporate areas. Fire departments are placed on full alert.

Task 12 MCDCD&ES establishes an on-site command post with the County Sheriff. MCDCD&ES provides evacuation for persons lacking transportation, ill and injured persons. For these classes of persons, the **imminent failure warning level** initiates a **directed evacuation status**. MCDCD&ES notifies Red Cross of evacuation.

Task 13 MCDCD&ES directs evacuees without destinations to congregate care centers.

Task 14 MCDCD&ES organizes and establishes security for FRSDA. No one is allowed to enter the FRSDA without police approval.

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Task 20 FCD and MCDCD&ES continue to monitor adjacent FRSs and dam-break flood wave, as necessary, until the danger is past and cleanup can commence. If an adjacent FRS is still at an alert or **imminent failure warning level**, evacuees should not be allowed back into the FRSDA.

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It is imperative for the successful planning of any evacuation that the planners are able to visualize the larger picture. Sometimes during a dam-break evacuation, the evacuees move into the worst flood potential area instead of away from it. The concept of preparing a detailed evacuation plan with specific directions and evacuation routes for specific areas will not work for this FRSDA. The specific routes and directions must be selected based upon the local and adjacent conditions at the time the evacuation is required. The thoughts presented below should be kept in mind during the planning and execution of a detailed dam-break evacuation.

a. Most dam-break situations occur in narrow steep valleys where the shortest path to safety is the path over which the evacuees gain the most elevation in the shortest period of time. This is not the case for this FRSDA.

b. Evacuation using I-10 will only be possible during a voluntary evacuation. Since I-10 is immediately downslope of the Buckeye FRS system, vehicles on I-10 will be in the most danger during imminent or actual failure warning status. Evacuation north to I-10 should be encouraged during an alert warning level but discouraged during the imminent or actual failure warning status. This may cause some confusion which should be anticipated and avoided, to the extent possible.

c. Most support facilities for evacuees are east of the FRSDA but there may be situations where evacuation to the west may be safer. For instance, if both Buckeye FRSs #2 and #3 are in an imminent failure warning status, all evacuees are told to move east and then Buckeye FRS #3 fails, but Buckeye FRS #2 does not, lives may be jeopardized unnecessarily.

d. Emergency spillway discharges from Buckeye FRSs #2 and #3 may close some of the north-south roads and most of the east-west roads along one or two alignments. Evacuation planning should focus primarily on movement to the south and then to the east if these emergency spillways are discharging.

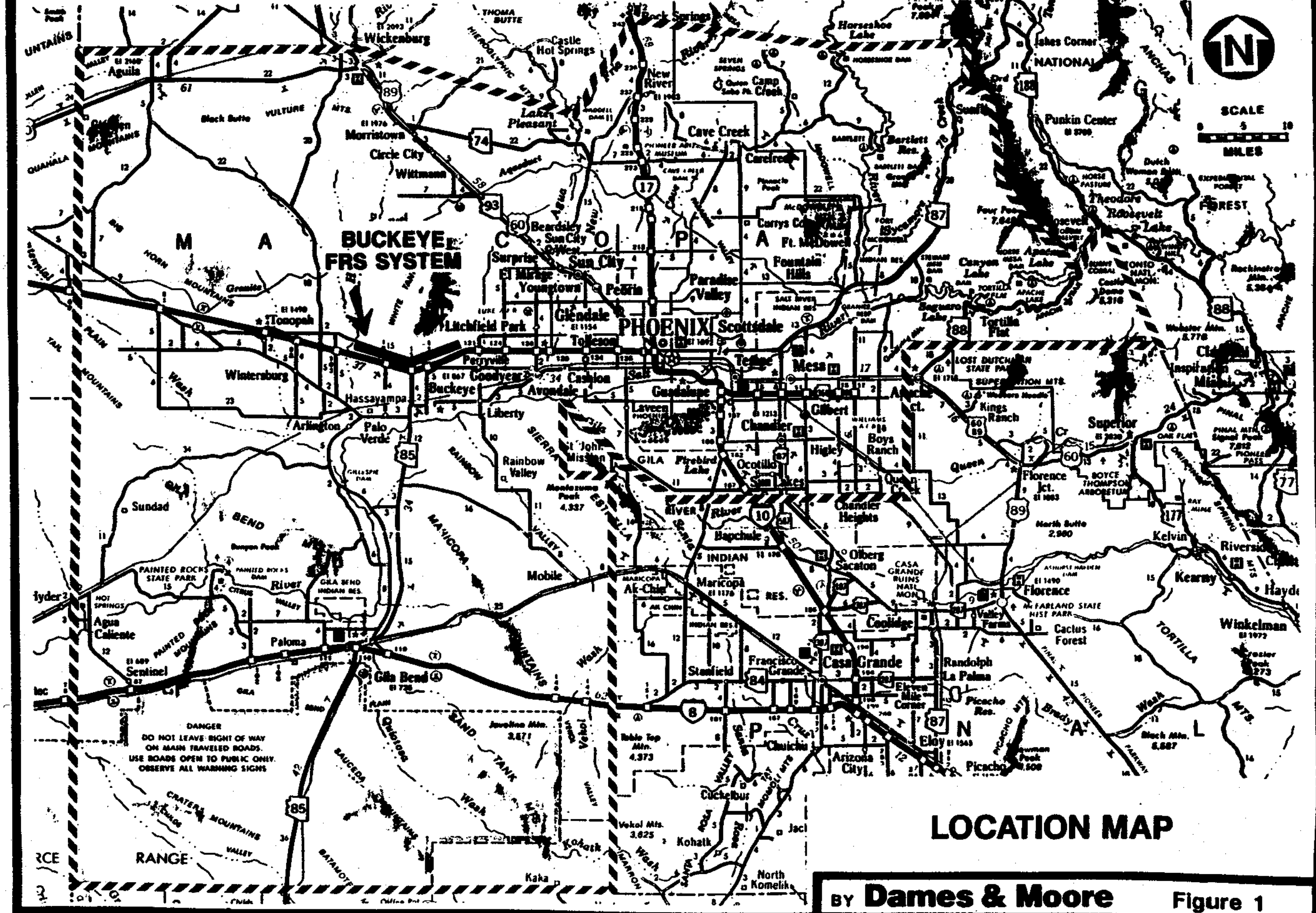
e. In general, evacuation to the south is desirable since motor vehicles can travel well in excess of the velocity of the leading edge of the dam-break flood flow. Even an evacuation directly south along the peak flood flow path could save lives because flows further south are shallower and have slower velocities.

f. Evacuation to the east or west has the potential to move an evacuee from a safe location to the worst flood depth with a movement of only one or two miles.

g. The fire department warning siren in Buckeye and some of the church bells in the area could be incorporated into the evacuation warning system. This will require a significant public education effort in order to be effective. An auditory warning is useless unless it can be heard, properly interpreted and responded to in a correct and timely manner. In addition, the auditory warning must be followed up with the police vehicle broadcasts and house to house warnings anyway.

h. Personnel on foot, in vehicles and in mobile homes (in decreasing order) are most at risk during a flood flow. Mobile homes should be anchored to the ground in any area where a dam-break flood flow could occur to provide refuge in case notification is not timely enough for evacuation.

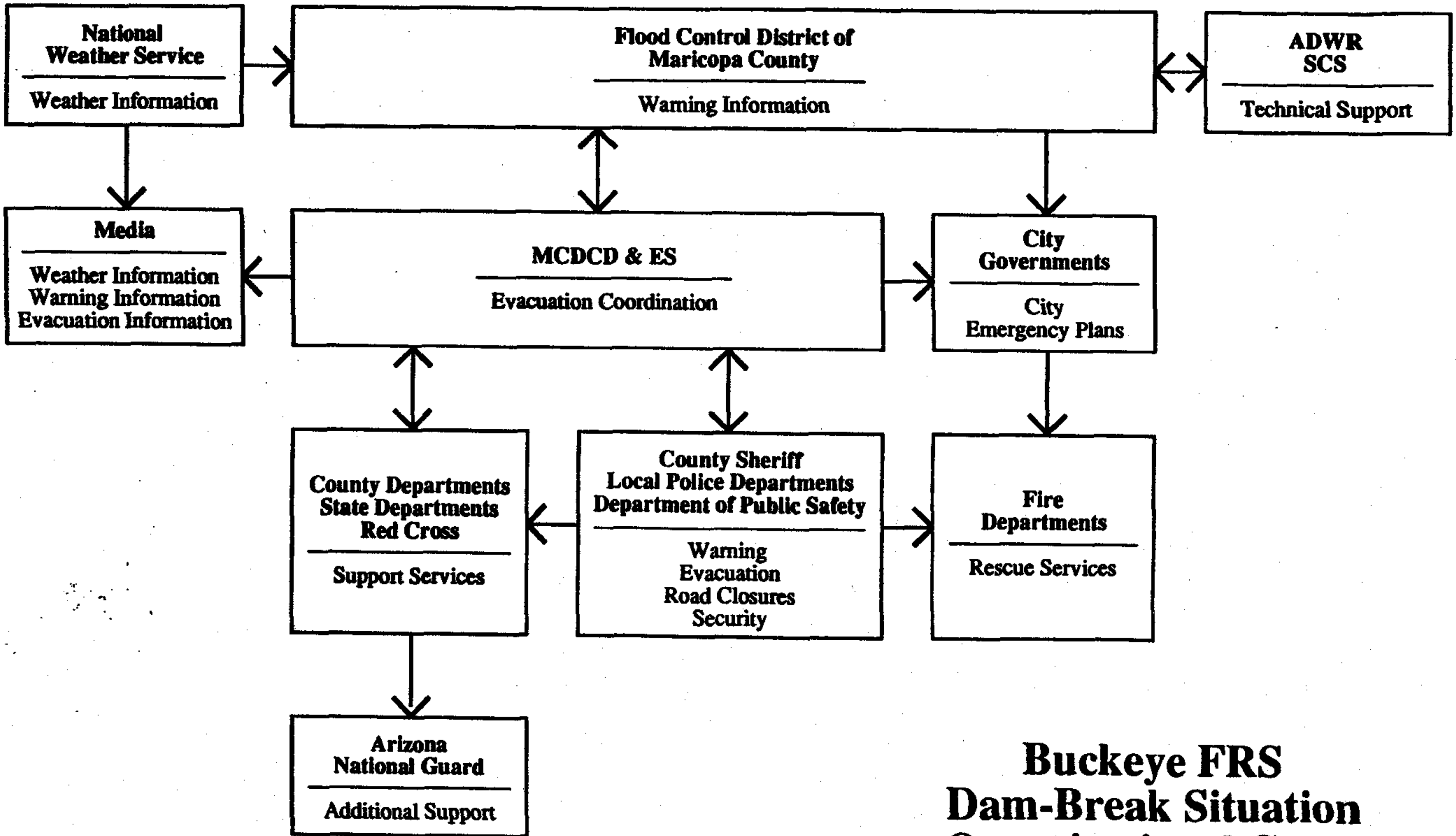
i. The key to the success of an evacuation is prior education of the affected public. The affected public must be generally aware of the potential problem, know specifically how legitimate warning information will be provided (and can be verified) and that prompt response on their part may not only save their lives, but will allow agency personnel to concentrate on their neighbors who may be less prepared.



LOCATION MAP

BY **Dames & Moore**

Figure 1



Buckeye FRS Dam-Break Situation Organizational Chart

Figure 3

APPENDIX B

EVACUATION PLAN
FOR
BUCKEYE FLOODWATER RETARDING STRUCTURE #2
(AZ NO. 7-44)
MARICOPA COUNTY, ARIZONA

Prepared for

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
FCD PROJECT 88-63

Prepared by

DAMES & MOORE
15448-003-022

JUNE, 1990

EVACUATION PLAN
FOR
BUCKEYE FLOODWATER RETARDING STRUCTURE #2
MARICOPA COUNTY, ARIZONA

INTRODUCTION

The Buckeye Floodwater Retarding Structure #2 (FRS #2) protects a portion of the area near Buckeye, Arizona from extensive runoff during severe storm events. However, the possibility exists that the FRS may suffer a dam-break failure releasing damaging and potentially lethal flood flows across the FRS downslope area. This plan was formulated to provide for a rapid and effective evacuation of the FRS downslope area in the event such a failure can be anticipated.

Although this plan is meant to be a stand alone document, the FRS itself does not stand alone, but is only one part of the Buckeye FRS system. The safety and evacuation status of the entire system as well as flows in the adjacent rivers, etc. must be taken into consideration during implementation of this plan.

I. SITUATION

A. MAPS

1. Figure 1 is enclosed to identify the area of concern.

2. Figure 2 is the primary map for this activity. Figure 2 shows potential flood depths and times of peak flood depth over the evacuation area.

3. County and state road maps may be referenced for extending evacuation routes.

B. AREA AFFECTED

The affected area is identified as the FRS downslope area (FRSDA). It is bounded on the north by the FRS and on the south by the Gila River. The approximate east and west boundaries are Watson Road and Oglesby Road, respectively (see Figure 2).

C. FLOOD FLOWS

In the event of a dam-break failure of the FRS, deep and fast moving water will emanate from the dam-break location and flow generally south toward the Gila River. If the dam-break event can be successfully anticipated, prompt implementation of this evacuation plan may be adequate to evacuate the FRSDA to prevent loss of life and possibly reduce property damages.

II. OBJECTIVE

The objective of this evacuation plan is to provide a mutually acceptable plan for prompt, organized and effective evacuation of the FRSDA. The keys to achieving this objective are sound, timely decision making, assertive and timely communications and rapid implementation of the plan. Also key to the successful implementation of this plan will be prior public awareness of the situation and total cooperation of all parties.

III. RESPONSIBILITIES

A variety of agencies are involved in the implementation of this plan. Several agencies are involved in the decision-making process and several are involved in the implementation activities. A schematic diagram is presented in Figure 3 to show lines of communication. The responsibilities and various tasks assigned to each agency are described in the following text. Note that other agencies may be involved in supporting the post-evacuation situation, but these key agencies listed below are the agenices believed necessary to complete the evacuation itself.

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   a. The Flood Control District of Maricopa County (FCD) is responsible for selecting the level of dam-break warning. The FCD is also responsible for providing recommendations to the Maricopa County Department of Civil Defense and Emergency Services (MCDCD&ES) so that MCDCD&ES can select what type of evacuation effort should be in effect. The FCD will complete on-site evaluations, review dam design and operating criteria and consult with other knowledgeable agencies to assess the safety of the structure and to select the level of warning.

   b. The FCD will solicit data from the National Weather Service (NWS) regarding weather predictions and will maintain open communications with MCDCD&ES, as necessary, to effect timely communications and initiation of the evacuation should it be required.

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   a. The local city governments will be responsible for evacuation of their own facilities and for the evacuation activities within their corporate limits.

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a. Support services both during and immediately after the evacuation may need to be provided by various county and state departments and the Red Cross. These support services may be requested by either MCDCD&ES or by the police staff.

b. County departments may be requested to provide temporary signage, road barricades, etc. during the evacuation.

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a. The Arizona National Guard is responsible for assisting with evacuation and providing area security as requested by state emergency services.

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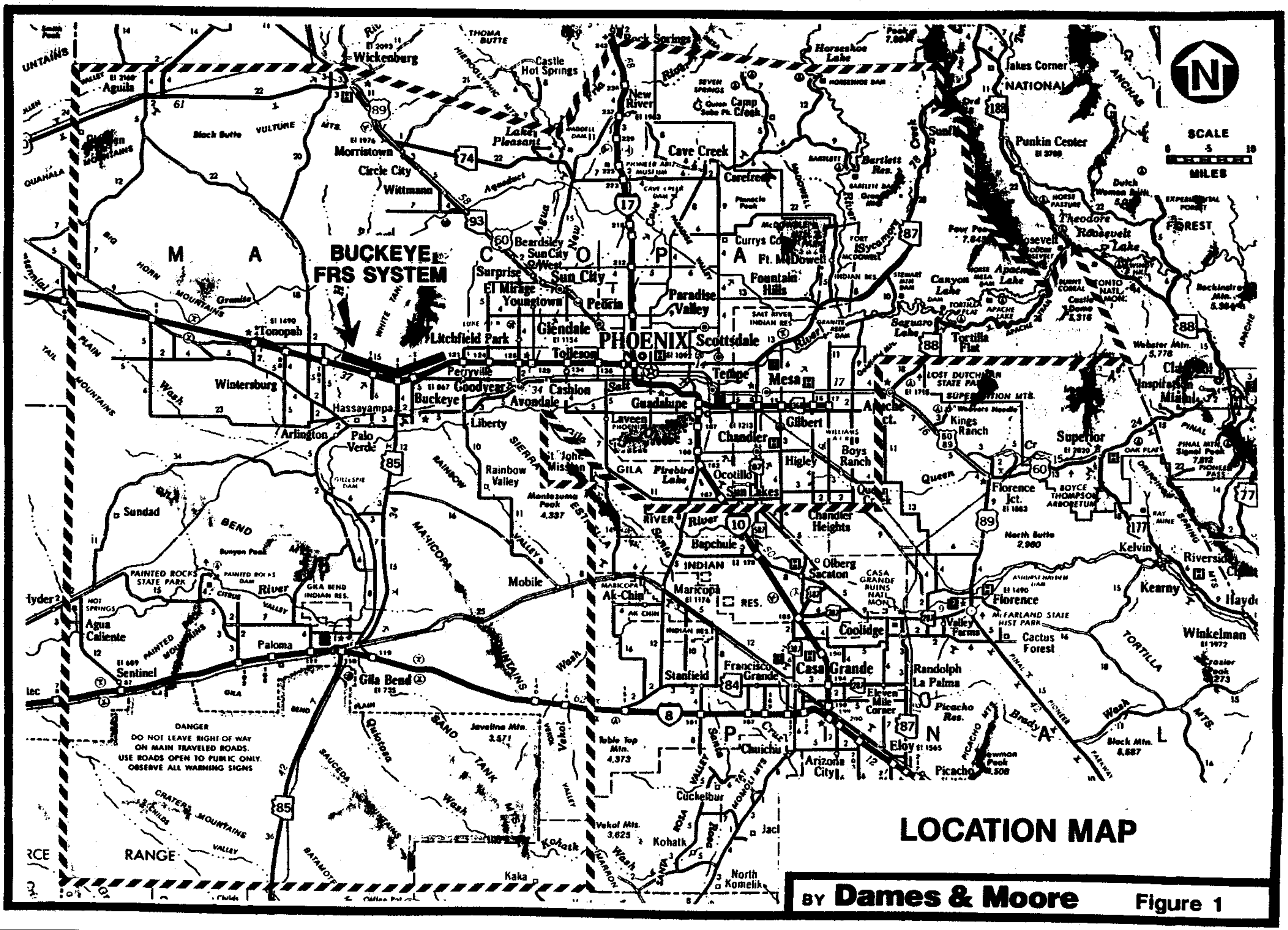
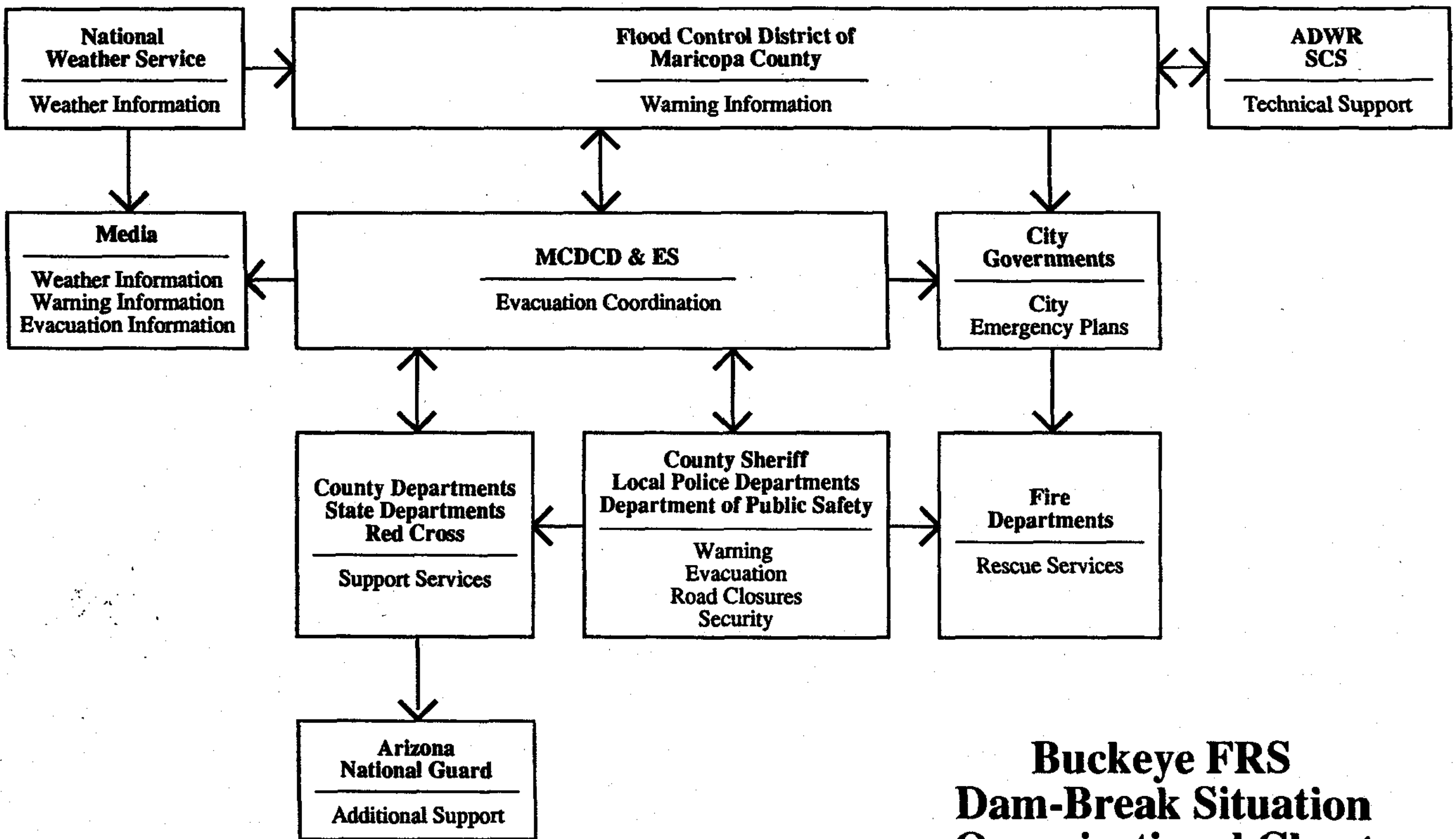


LOCATION MAP

BY **Dames & Moore** Figure 1



Buckeye FRS Dam-Break Situation Organizational Chart

Figure 3

APPENDIX C

EVACUATION PLAN
FOR
BUCKEYE FLOODWATER RETARDING STRUCTURE #3
(AZ NO. 7-45)
MARICOPA COUNTY, ARIZONA

Prepared for

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
FCD PROJECT 88-63

Prepared by

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EVACUATION PLAN

FOR

BUCKEYE FLOODWATER RETARDING STRUCTURE #3

MARICOPA COUNTY, ARIZONA

INTRODUCTION

The Buckeye Floodwater Retarding Structure #3 (FRS #3) protects a portion of the area near Buckeye, Arizona from extensive runoff during severe storm events. However, the possibility exists that the FRS may suffer a dam-break failure releasing damaging and potentially lethal flood flows across the FRS downslope area. This plan was formulated to provide for a rapid and effective evacuation of the FRS downslope area in the event such a failure can be anticipated.

Although this plan is meant to be a stand alone document, the FRS itself does not stand alone, but is only one part of the Buckeye FRS system. The safety and evacuation status of the entire system as well as flows in the adjacent rivers, etc. must be taken into consideration during implementation of this plan.

I. SITUATION

A. MAPS

1. Figure 1 is enclosed to identify the area of concern.
2. Figure 2 is the primary map for this activity. Figure 2 shows potential flood depths and times of peak flood depth over the evacuation area.
3. County and state road maps may be referenced for extending evacuation routes.

B. AREA AFFECTED

The affected area is identified as the FRS downslope area (FRSDA). It is bounded on the north by the FRS and on the south by the Gila River. The approximate east and west boundaries are Jackrabbit Trail and Cemetery Road, respectively (see Figure 2).

C. FLOOD FLOWS

In the event of a dam-break failure of the FRS, deep and fast moving water will emanate from the dam-break location and flow generally south toward the Gila River. If the dam-break event can be successfully anticipated, prompt implementation of this evacuation plan may be adequate to evacuate the FRSDA to prevent loss of life and possibly reduce property damages.

II. OBJECTIVE

The objective of this evacuation plan is to provide a mutually acceptable plan for prompt, organized and effective evacuation of the FRSDA. The keys to achieving this objective are sound, timely decision making, assertive and timely communications and rapid implementation of the plan. Also key to the successful implementation of this plan will be prior public awareness of the situation and total cooperation of all parties.

III. RESPONSIBILITIES

A variety of agencies are involved in the implementation of this plan. Several agencies are involved in the decision-making process and several are involved in the implementation activities. A schematic diagram is presented in Figure 3 to show lines of communication. The responsibilities and various tasks assigned to each agency are described in the following text. Note that other agencies may be involved in supporting the post-evacuation situation, but these key agencies listed below are the agenices believed necessary to complete the evacuation itself.

1. FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

   a. The Flood Control District of Maricopa County (FCD) is responsible for selecting the level of dam-break warning. The FCD is also responsible for providing recommendations to the Maricopa County Department of Civil Defense and Emergency Services (MCDCD&ES) so that MCDCD&ES can select what type of evacuation effort should be in effect. The FCD will complete on-site evaluations, review dam design and operating criteria and consult with other knowledgeable agencies to assess the safety of the structure and to select the level of warning.

   b. The FCD will solicit data from the National Weather Service (NWS) regarding weather predictions and will maintain open communications with MCDCD&ES, as necessary, to effect timely communications and initiation of the evacuation should it be required.

   c. The FCD will be responsible for providing, prior to an actual evacuation event, public awareness and education regarding the potential dam-break situation, the methods of warning to be used in an emergency and the evacuation process.

2. NATIONAL WEATHER SERVICE

   a. The NWS is responsible for monitoring local rainfall events and providing short-term and long-term weather predictions.

   b. The NWS will notify the FCD of weather conditions as necessary to assist the FCD evaluate the safety of the FRS.

   c. The NWS will also directly notify the media to provide weather "watches" and "warnings" bulletins to the public.

3. ARIZONA DEPARTMENT OF WATER RESOURCES
   U.S. SOIL CONSERVATION SERVICE

   a. The Arizona Department of Water Resources (ADWR) - Safety of Dams Section and the U.S. Soil Conservation Service (SCS) will be responsible for providing the FCD with technical consulting services to assist in evaluating the safety of the structures. SCS, as the designer of the structures and ADWR as the state's technical dam evaluation agency, have detailed knowledge of the structures.

   b. ADWR and SCS will be available for consultation during emergencies and will provide on-site evaluations (if necessary and time permits) to help evaluate the safety of the FRS.

4. MARICOPA COUNTY DEPARTMENT OF CIVIL DEFENSE AND EMERGENCY SERVICES

   a. The MCDCD&ES will be responsible for selection of the types of evacuation required and implementation of all communication and support services necessary to complete the evacuation. The responsibility for initiation and coordination of the evacuation will be with the MCDCD&ES.

   b. The MCDCD&ES will notify the media, affected city governments, the Red Cross, appropriate county and state departments, the County Sheriff, local police departments and the state Department of Public Safety of the type of evacuation in effect and will complete follow up action to make sure that the evacuation occurs as planned.

5. CITY GOVERNMENTS

   a. The local city governments will be responsible for evacuation of their own facilities and for the evacuation activities within their corporate limits.

   b. The city governments will be responsible for preparing evacuation plans as necessary and for coordination with adjacent cities and MCDCD&ES during the planning stages.

6. FIRE DEPARTMENTS

a. The various fire departments will be responsible for any emergency actions not foreseeable during the normal evacuation processes. As such, they will constitute a force in reserve and should not be tasked with assisting in the evacuation itself.

b. The fire department will respond to automobile accidents, fires, rescue operations, etc. as directed by the various police agencies and coordinated with MCDCD&ES.

7. COUNTY SHERIFF
LOCAL POLICE DEPARTMENTS
DEPARTMENT OF PUBLIC SAFETY

a. The various police agencies will be tasked with most of the field activities of the evacuation. They will receive direction from MCDCD&ES as to what type of evacuation is required.

b. The County Sheriff will complete the evacuation of most of the FRSDA since most of this land is under county jurisdiction.

c. The local police departments will complete the evacuation of any areas within the corporate limits. The local police departments will be responsible for notifying, before the issue arises, both the County Sheriff and MCDCD&ES of the areas they will and will not cover.

d. The Department of Public Safety (DPS) will be responsible for closure of Interstate-10 (I-10) and all state highways and making sure that all freeway entrance ramps are closed to preclude traffic access. DPS can coordinate with other state agencies to place and man barriers, as necessary.

8. COUNTY DEPARTMENTS
STATE DEPARTMENTS
RED CROSS

a. Support services both during and immediately after the evacuation may need to be provided by various county and state departments and the Red Cross. These support services may be requested by either MCDCD&ES or by the police staff.

b. County departments may be requested to provide temporary signage, road barricades, etc. during the evacuation.

c. State departments may be requested to assist DPS with re-routing I-10 traffic around the FRSDA.

d. The Red Cross may need to provide emergency support and housing for displaced residents.

9. ARIZONA NATIONAL GUARD

a. The Arizona National Guard is responsible for assisting with evacuation and providing area security as requested by state emergency services.

IV. EXECUTION

1. DEFINITIONS

The following definitions are provided relative to the evacuation process.

a. Levels of warning. These are general definitions which should be applied with qualified technical judgment and allowing for conservation in approach.

Alert Warning Level - major storm or series of storms is occurring or just occurred.

Imminent Failure Warning Level - minimum freeboard is violated or seepage is noted on downstream face of embankment.

Actual Failure Warning Level - embankment is being overtopped or piping of embankment materials is observed.

b. Status of evacuation.

Voluntary Evacuation Status - persons perceive the hazard and leave the area of their own volition. No official assistance is required.

Recommended Evacuation Status - official note is made of the threat and endangered persons are encouraged to leave. Some people may request assistance. All persons requiring special transportation should be evacuated at this time.

Directed Evacuation Status - upon declaration of local emergency by head of government affected, all endangered persons are directed to immediately evacuate to safe area(s).

2. EXECUTION PROCESS

The evacuation process will involve a series of generally sequential steps. Each of these steps is described below.

Task 1 NWS notifies both FCD and media of weather information.

Task 2 Based on Task 1, FCD dispatches staff in radio equipped vehicles to FRS. FCD notifies MCDCD&ES and city governments of dispatching effort and also of arrival time on site.

Task 3 FCD determines if **alert warning level** is appropriate. If not, process is on hold or stops.

Task 4 If **alert warning level** is selected, FCD notifies MCDCD&ES, ADWR and SCS. MCDCD&ES notifies County Sheriff, city governments, DPS, other state and county departments. City governments notify local police. MCDCD&ES dispatches notices to media to heighten public awareness of potential problems and requests the public to monitor media broadcasts. **Voluntary evacuation status** is suggested, if appropriate.

Task 5 All involved agencies activate reserve or off duty personnel to staff office facilities. County Sheriff dispatches vehicles to northern portion of FRSDA. DPS, ADOT and county highway stage vehicles and barricades in preparation for road closures.

Task 6 FCD continues to monitor site conditions. Key personnel should be made available for decision making. ADWR and SCS should be contacted if necessary. Additional technical support staff may be asked to move to the site. Backup communication systems are brought on line.

Task 7 FCD determines that **imminent failure warning level** is appropriate. FCD evaluates adjacent structures and notifies MCDCD&ES of **imminent failure warning level** and situation at adjacent structure(s).

Task 8 MCDCD&ES determines that **recommended evacuation status** is appropriate. MCDCD&ES requests DPS to close I-10 and detour traffic. MCDCD&ES requests media to disseminate **recommended evacuation status** messages with specific evacuation routes and directions of travel. Note that at this level of warning the emergency spillways of Buckeye *FRSs #2 and #3 may be discharging with resulting* downslope road closures. MCDCD&ES notifies County Sheriff, city governments and other state and county departments of **recommended evacuation status.**

Task 9 DPS closes I-10 at both ends and closes all on ramps through FRSDA.

Task 10 County Sheriff begins broadcasting on-site warnings of **recommended evacuation status** from north to south across the FRSDA paying particular attention to areas where deep water could occur and where the flood travel times are the shortest (see Figure 2). Note that some members of the County Sheriff staff must remain near the northern end of the FRSDA since the evacuation status could change from recommended to directed very quickly.

Task 11 City government and local police begin broadcasting **recommended evacuation status** to corporate areas. Fire departments are placed on full alert.

Task 12 MCDCD&ES establishes an on-site command post with the County Sheriff. MCDCD&ES provides evacuation for persons lacking transportation, ill and injured persons. For these classes of persons, the **imminent failure warning level** initiates a **directed evacuation status**. MCDCD&ES notifies Red Cross of evacuation.

Task 13 MCDCD&ES directs evacuees without destinations to congregate care centers.

Task 14 MCDCD&ES organizes and establishes security for FRSDA. No one is allowed to enter the FRSDA without police approval.

Task 15 FCD determines that **actual failure warning level** is appropriate. FCD evaluates adjacent structures and notifies MCDCD&ES of **actual failure warning level** and situations at adjacent structure(s). FCD positions staff to monitor flows across FRSDA.

Task 16 MCDCD&ES determines that **directed evacuation status** is appropriate. MCDCD&ES requests media to disseminate **directed evacuation status** messages with specific evacuation routes and directions of travel. Note that the emergency spillways of FRSs #2 and #3 may be discharging with resulting downslope road closures. MCDCD&ES notifies County Sheriff, city governments and other state and county departments of **directed evacuation status**.

Task 17 County Sheriff begins broadcasting warnings of **directed evacuation status** from north to south across the FRSDA paying particular attention to areas where deep water could occur and where flood travel times are the shortest (see Figure 2). County Sheriff staff initiate house to house notification of areas where directed to do so.

Task 18 City government and local police begin broadcasting **directed evacuation status** to corporate areas. House to house notification is initiated where required.

Task 19 MCDCD&ES directs evacuees without destinations to congregate care centers.

Task 20 FCD and MCDCD&ES continue to monitor adjacent FRSs and dam-break flood wave, as necessary, until the danger is past and cleanup can commence. If an adjacent FRS is still at an **alert** or **imminent failure warning level**, evacuees should not be allowed back into the FRSDA.

3. EVACUATION PLANNING

It is imperative for the successful planning of any evacuation that the planners are able to visualize the larger picture. Sometimes during a dam-break evacuation, the evacuees move into the worst flood potential area instead of away from it. The concept of preparing a detailed evacuation plan with specific directions and evacuation routes for specific areas will not work for this FRSDA. The specific routes and directions must be selected based upon the local and adjacent conditions at the time the evacuation is required. The thoughts presented below should be kept in mind during the planning and execution of a detailed dam-break evacuation.

a. Most dam-break situations occur in narrow steep valleys where the shortest path to safety is the path over which the evacuees gain the most elevation in the shortest period of time. This is not the case for this FRSDA.

b. Evacuation using I-10 will only be possible during a voluntary evacuation. Since I-10 is immediately downslope of the Buckeye FRS system, vehicles on I-10 will be in the most danger during imminent or actual failure warning status. Evacuation north to I-10 should be encouraged during an alert warning level but discouraged during the imminent or actual failure warning status. This may cause some confusion which should be anticipated and avoided, to the extent possible.

c. Most support facilities for evacuees are east of the FRSDA but there may be situations where evacuation to the west may be safer. For instance, if both Buckeye FRSs #2 and #3 are in an imminent failure warning status, all evacuees are told to move east and then Buckeye FRS #3 fails, but Buckeye FRS #2 does not, lives may be jeopardized unnecessarily.

d. Emergency spillway discharges from Buckeye FRSs #2 and #3 may close some of the north-south roads and most of the east-west roads along one or two alignments. Evacuation planning should focus primarily on movement to the south and then to the east if these emergency spillways are discharging.

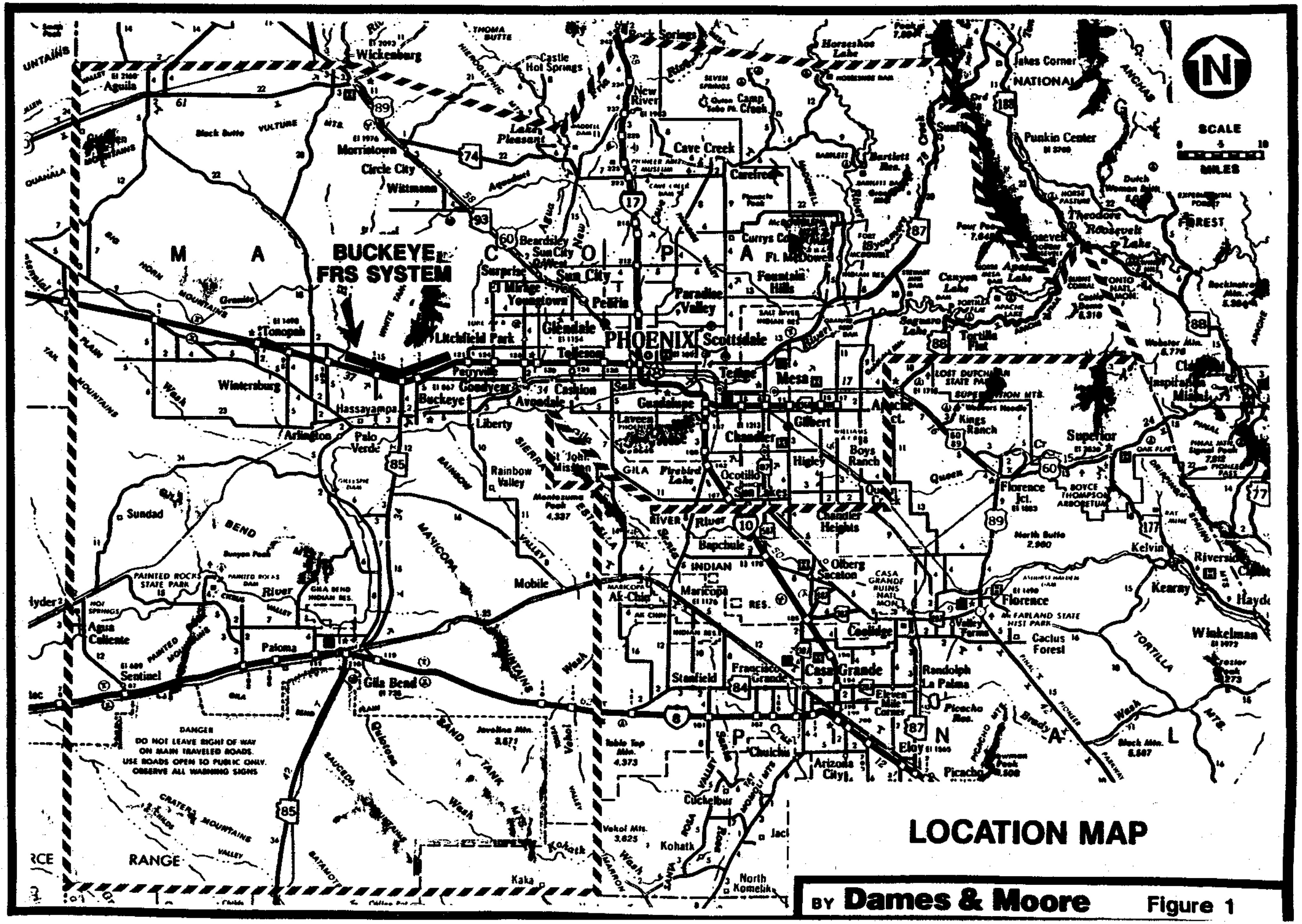
e. In general, evacuation to the south is desirable since motor vehicles can travel well in excess of the velocity of the leading edge of the dam-break flood flow. Even an evacuation directly south along the peak flood flow path could save lives because flows further south are shallower and have slower velocities.

f. Evacuation to the east or west has the potential to move an evacuee from a safe location to the worst flood depth with a movement of only one or two miles.

g. The fire department warning siren in Buckeye and some of the church bells in the area could be incorporated into the evacuation warning system. This will require a significant public education effort in order to be effective. An auditory warning is useless unless it can be heard, properly interpreted and responded to in a correct and timely manner. In addition, the auditory warning must be followed up with the police vehicle broadcasts and house to house warnings anyway.

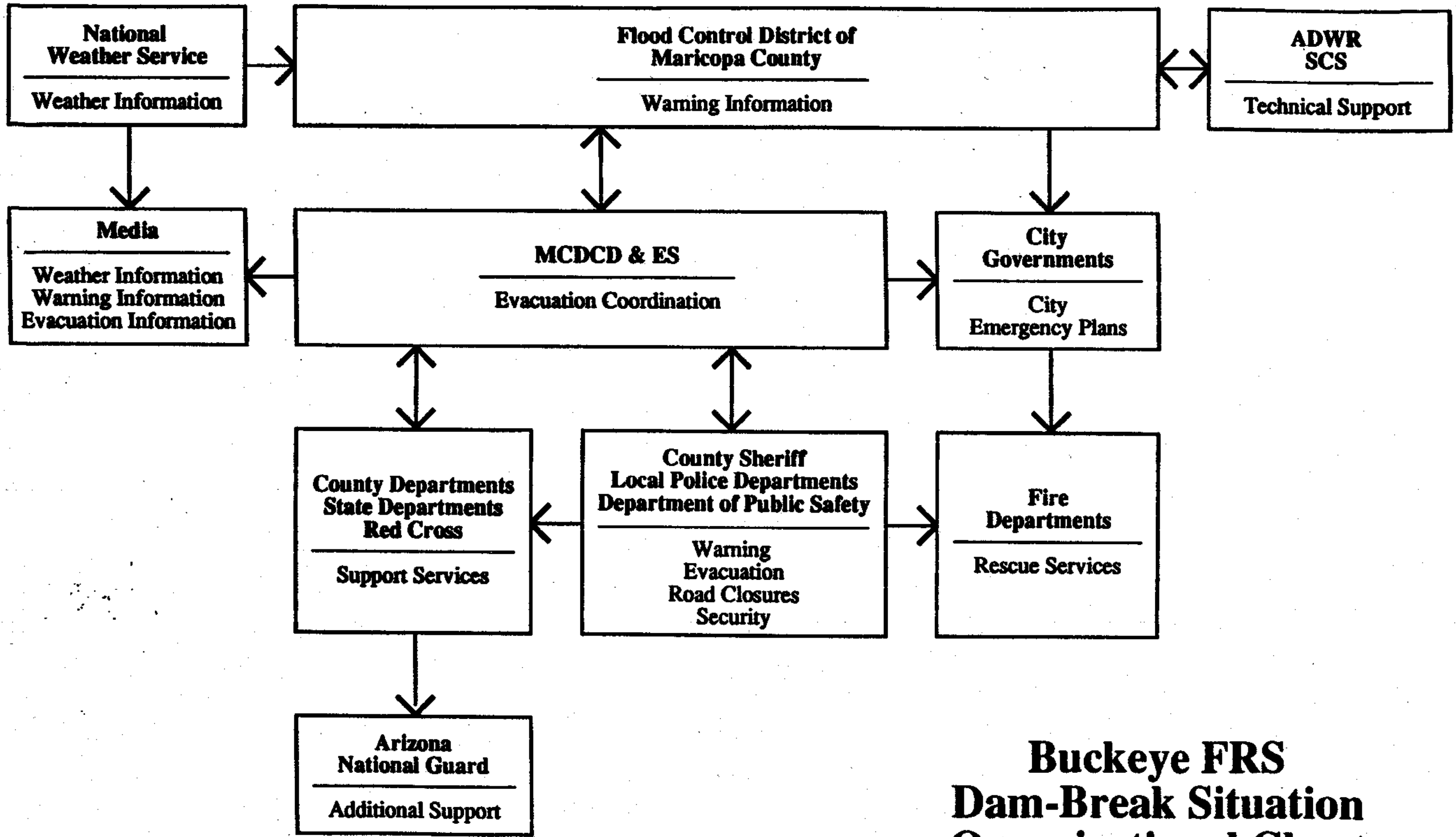
h. Personnel on foot, in vehicles and in mobile homes (in decreasing order) are most at risk during a flood flow. Mobile homes should be anchored to the ground in any area where a dam-break flood flow could occur to provide refuge in case notification is not timely enough for evacuation.

i. The key to the success of an evacuation is prior education of the affected public. The affected public must be generally aware of the potential problem, know specifically how legitimate warning information will be provided (and can be verified) and that prompt response on their part may not only save their lives, but will allow agency personnel to concentrate on their neighbors who may be less prepared.



LOCATION MAP

BY **Dames & Moore** Figure 1



Buckeye FRS
Dam-Break Situation
Organizational Chart

Figure 3