FLOOD CONTROL DISTRICT
OF
MARICOPA COUNTY
2801 W. Durango
PHOENIX, AZ 85009

Anderson-Nelson, Inc.

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009

TOWN OF FOUNTAIN HILLS

DAM BREAK ANALYSES

for

Golden Eagle Park Dam
Hesperus Wash Dam
Aspen Dam
North Heights Dam
SunRidge Canyon Dam

REPORT

George V. Sabol Consulting Engineers, Inc.
Scottsdale, Arizona

JANUARY 1996

TOWN OF FOUNTAIN HILLS
MAY 30 1996
ENGINEERING DEPARTMENT

Anderson-Nelson, Inc.

TOWN OF FOUNTAIN HILLS

DAM BREAK ANALYSES

for

Golden Eagle Park Dam
Hesperus Wash Dam
Aspen Dam
North Heights Dam
SunRidge Canyon Dam

REPORT

Registered Professional Engineer (Civil)
CERTIFICATE NO. 17928
GEORGE V. SABOL
Date Signed 5 Feb 96
ARIZONA, U.S.A.

George V. Sabol Consulting Engineers, Inc.
Scottsdale, Arizona

JANUARY 1996

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Purpose	1
Scope	1
Approach and Methodology	5
BACKGROUND	6
Description of Watershed	6
Purpose and History of Dams	6
Description of Dams	7
Classification of Dams	15
Reports	16
FLOOD HYDROLOGY	17
Methodology	17
Verification of Ftn Hills FDS Model	17
Mapping and Survey Information	19
Topographic Maps	19
Soils Maps	22
Land Use Maps	22
Subbasin Delineation and Hydrologic Modeling	22
HEC-1 Flood Routing Diagram	23
PMP	23
Rainfall Losses	24
Methodology	24
Soils	24
Land Use	26
Vegetation Cover	26
Surface Retention Loss	26
Green and Ampt Infiltration Equation Parameters	27
Rainfall Loss Parameters	27
Unit Hydrograph	27
Methodology	27
Time of Concentration	28
Storage Coefficient	28
Time-Area Relation	28
Unit Hydrograph Parameters	29
Channel Routing	29
Storage Routing	29
General	29
Area Capacity Relations	30
Spillway Rating Relations	30
Watershed Model Results	30
General	30
100-year Flood Results	30
Inflow Design Flood Results	31

TABLE OF CONTENTS (continued)

	Page
DAM BREACH HYDROGRAPHS	35
Methodology	35
Sources of Data	35
Sensitivity Analyses	36
Median Grain Size	37
Porosity	37
Unit Weight	37
Internal Friction Angle	37
Cohesive Strength	43
Grain Size Distribution	43
Summary of Sensitivity Analyses	43
Breach Assumptions, Parameters and Results	43
General	43
Aspen Dam	45
North Heights Dam	47
SunRidge Canyon Dam	49
Hesperus Wash Dam	51
Golden Eagle Park Dam	53
FLOOD INUNDATION MAPS	57
General	57
Methodology	57
Inundation Maps	59
REFERENCES	

TABLES

No.	Heading	Page
1	Characteristics and physical data for dams	8
2	Dam size classification rating (ADWR, 1991)	15
3	Summary of single basin watershed model parameters for model verification	19
4	Summary of PMP rainfall, rainfall losses, and rainfall excess for the five Fountain Hills dams	25
5	Summary of 100-year flood results for the five dams from the Fountain Hills FDS report (existing conditions)	32

TABLE OF CONTENTS (continued)

TABLES (continued)

No.	Heading	Page
6	Summary of inflow design flood (0.5 PMF) for four of the dams	34
7	Sensitivity analysis for Aspen Dam - parameters and results	38
8	Sensitivity analysis for North Heights Dam - parameters and results	39
9	Sensitivity analysis for SunRidge Canyon Dam - parameters and results	40
10	Sensitivity analysis for Hesperus Wash Dam - parameters and results	41
11	Sensitivity analysis for Golden Eagle Park Dam - parameters and results	42
12	Parameters and initial conditions for dam breach analyses	44
13	Index for dam break inundation maps	60
14	Summary of flood attenuation and peak discharge travel times	61

FIGURES

No.	Caption	Page
1	Fountain Hills dam break analysis project location map	2
2	Vicinity map	3
3	Location of five ADWR jurisdictional dams in the Town of Fountain Hills	4
4	Sketch of critical features of Golden Eagle Park Dam (No. 4)	9
5	Sketch of critical features of Hesperus Wash Dam (No. 36)	10
6	Sketch of critical features of Aspen Dam (No. 6)	11
7	Sketch of critical features of North Heights Dam (No. 11)	12
8	Sketch of critical features of SunRidge Canyon Dam (No. 7)	13
9	Comparison of PMF generated from the Fountain Hills FDS HEC-1 model and the single basin model for Hesperus Dam	20
10	Comparison of PMF generated from the Fountain Hills FDS HEC-1 model and the single basin model for Aspen Dam	21
11	Inflow, spillway, and breach hydrographs for Aspen Dam	46
12	Inflow, spillway, and breach hydrographs for North Heights Dam	48
13	Inflow, spillway, and breach hydrographs for SunRidge Canyon Dam	50
14	Inflow, spillway, and breach hydrographs for Hesperus Wash Dam	52
15	Inflow, spillway, and breach hydrographs for Golden Eagle Park Dam	55
16	Inflow, spillway, and breach hydrographs for Golden Eagle Park Dam	56

TABLE OF CONTENTS (continued)

EXHIBITS

(following text)

A Drainage basin map and sheet index for Exhibit D

B Soils map

C Land use map

D Subbasin, time of concentration and flood routing map

E HEC-1 routing diagram

PLATES

(bound separately)

1 Flood inundation in Hesperus/Balboa Wash from Hesperus Wash dam break

2 Flood inundation in Hesperus/Balboa Wash from Hesperus Wash dam break

3 Flood inundation in Hesperus/Balboa Wash from Hesperus Wash dam break

4 Flood inundation in Ashbrook Wash from Golden Eagle Park dam break

5 Flood inundation in Ashbrook Wash from Golden Eagle Park dam break

6 Flood inundation in Ashbrook Wash from Golden Eagle Park dam break plus inflow from Hesperus Wash dam spillway release

7 Flood inundation in Ashbrook Wash from Golden Eagle Park dam break plus inflow from Hesperus Wash dam spillway release

8 Flood inundation in Ashbrook Wash from Aspen dam break

9 Flood inundation in Bristol Wash from North Heights dam break

10 Flood inundation in Cloudburst Wash from SunRidge Canyon dam break

11 Flood inundation in Cloudburst Wash from SunRidge Canyon dam break

TABLE OF CONTENTS (continued)

APPENDICES

(bound separately)

A	100-year flood verifications from the Ftn Hills FDS report
B	PMP worksheets
C	Rainfall loss parameter values from the Ftn Hills FDS Future Condition report
D	Clark unit hydrograph parameter values from the Ftn Hills FDS report
E	Channel routing data from the Ftn Hills FDS report
F	Area-capacity and spillway rating relations for the five dams
G	100-year flood results from the Ftn Hills FDS report
H	HEC-1 output for Aspen Dam
I	HEC-1 output for SunRidge Canyon Dam
J	HEC-1 output for North Heights Dam
K	HEC-1 output for Hesperus Wash Dam
L	Breach Program output for Aspen Dam
M	Breach Program output for North Heights Dam
N	Breach Program output for SunRidge Canyon Dam
O	Breach Program output for Hesperus Wash Dam
P	HEC-1 output for Golden Eagle Park Dam
Q	Breach Program output for Golden Eagle Park Dam (piping)
R	Breach Program output for Golden Eagle Park Dam (overtopping)
S	Dam Break output for Hesperus Wash Dam
T	Dam Break output for Golden Eagle Park Dam
U	Dam Break output for Golden Eagle Park plus Hesperus Wash Dams
V	Dam Break output for Aspen Dam
W	Dam Break output for North Heights Dam
X	Dam Break output for SunRidge Canyon Dam

DISKETTES

HEC-1, Dam Breach, Dam Break

(following Appendices)

INTRODUCTION

Purpose

Dam break analyses are performed for five dams in the Town of Fountain Hills, Arizona, for the purpose of preparing Emergency Action Plans for those dams. An Emergency Action Plan, including dam breach inundation map, is required by the Arizona Department of Water Resources (ADWR) for all dams classified as having "high" or "significant" downstream hazard potential (ADWR, Instructions for Filing an Application, May 1991).

The five dams that are the subject of this report are contained within the limits of the Town of Fountain Hills and are north of Palisades Boulevard. The project location is shown in Figure 1, and a vicinity map is shown in Figure 2. A map of the Town of Fountain Hills and the location of the five ADWR jurisdictional dams that are analyzed are shown in Figure 3. There are other jurisdictional dams in the Town of Fountain Hills, and a similar analysis is being performed by AGK Engineers, Inc. The five dams that are reported herein are:

Golden Eagle Park Dam (No. 4)
Hesperus Wash Dam (No. 36)
Aspen Dam (No. 6)
North Heights Dam (No. 11)
SunRidge Canyon Dam (No. 7).

Scope

The intent of this report is to present the results of the dam break analyses for five of the flood control dams in the Town of Fountain Hills. The objective of the analysis is to define, with a reasonable degree of confidence, the flood inundation that would occur downstream of each dam as a result of an inflow design flood and concurrent dam failure. The flood inundation maps will be used in the preparation of Emergency Action Plans by Anderson-Nelson, Inc. This report provides the documentation for the flood inundation maps.

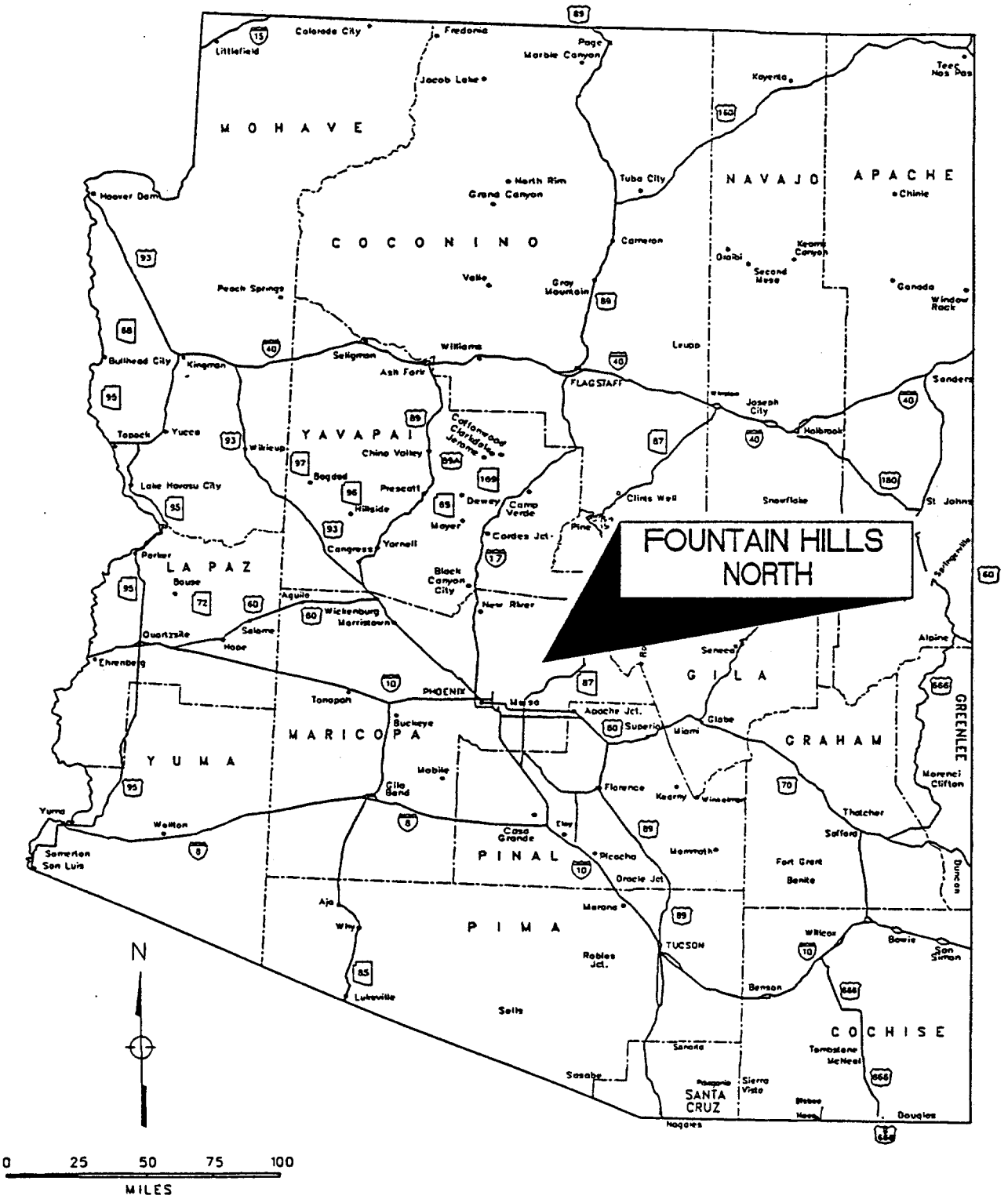


FIGURE 1

Fountain Hills dam break analysis project location map

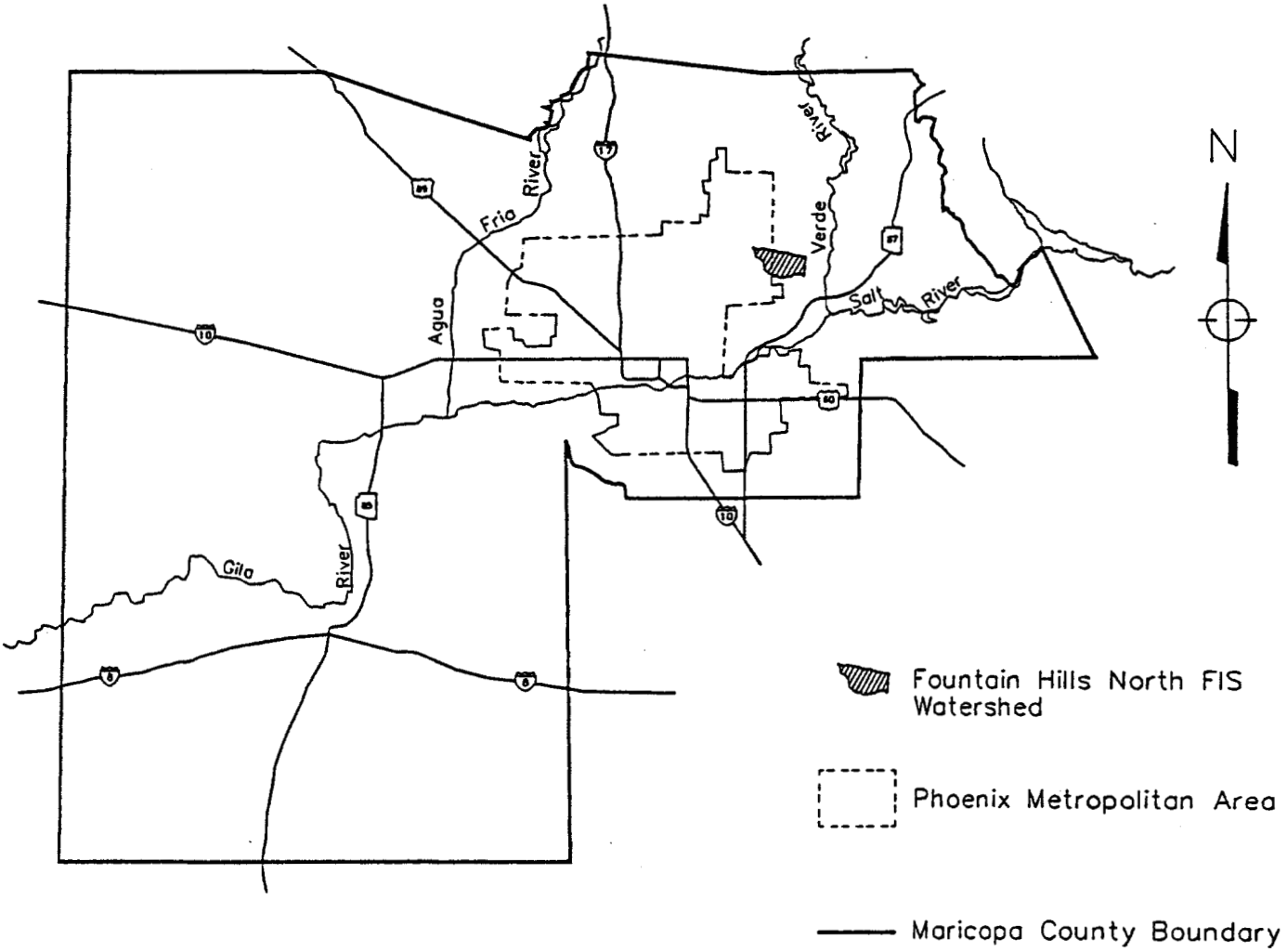


FIGURE 2

Vicinity map

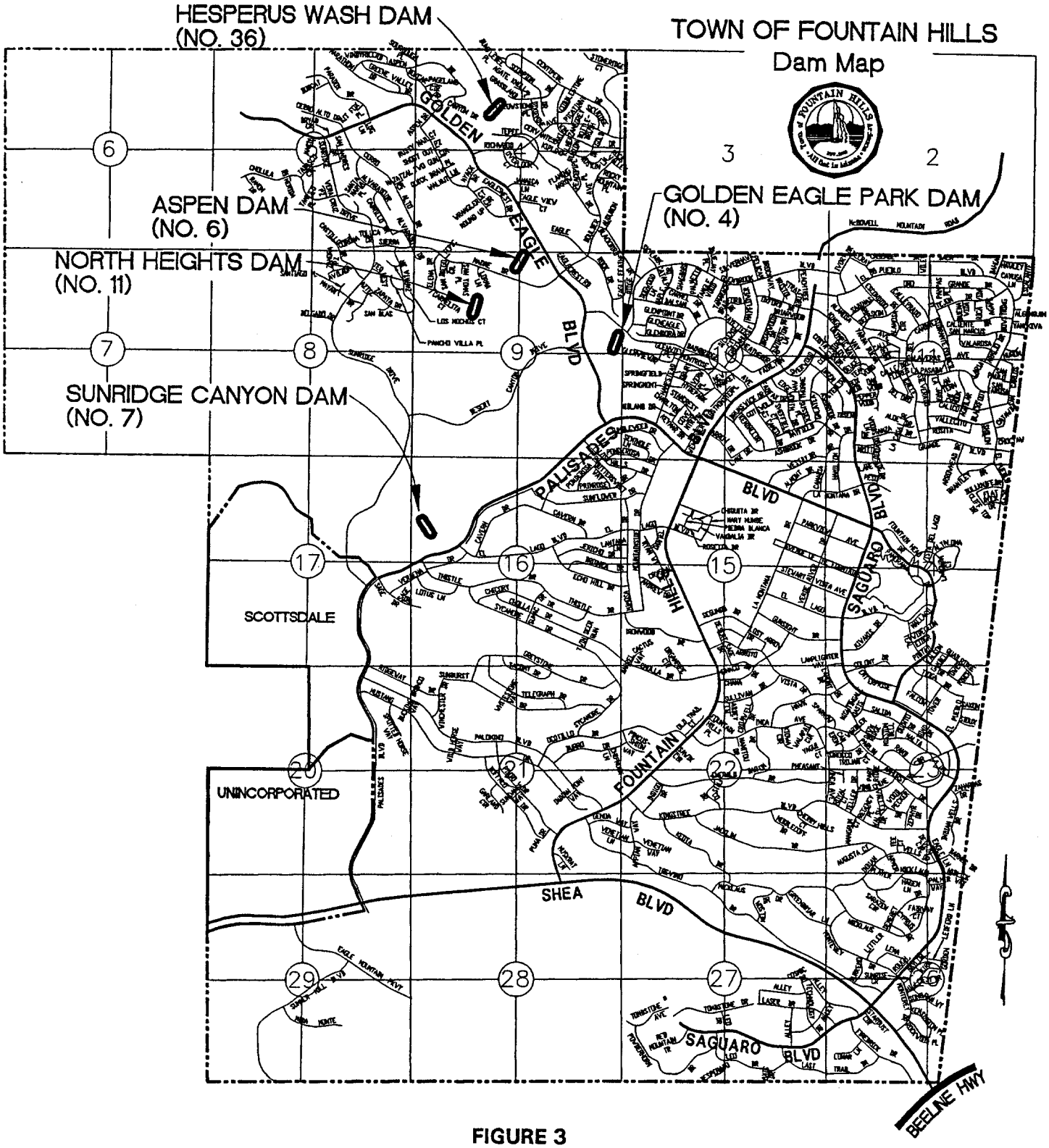


FIGURE 3

Location of five ADWR jurisdictional dams in the Town of Fountain Hills

Approach and Methodology

The analysis of each dam consists of four major elements: (1) flood hydrology, (2) dam breach analysis, (3) determination of the reasonable likely maximum spillway/breach outflow hydrograph, and (4) unsteady flow routing of the spillway/breach outflow hydrograph through a reach of watercourse.

Flood hydrology is performed by estimating the probable maximum flood (PMF) for each dam. The PMF is estimated using currently available probable maximum precipitation (PMP) criteria. The inflow design flood is set at 0.5 PMF as per recommendation by ADWR for small, high hazard dams (ADWR, Guidelines for the Determination of Spillway Capacity Requirements, Draft, May 1991). The characteristics of each dam and the ADWR classification are provided elsewhere in this report.

Dam breach analysis is performed by the National Weather Service (NWS) Breach Program. If the flood hydrology analysis indicates that the dam could reasonably be expected to fail by dam overtopping, then the breach analysis is performed assuming that the inflow design flood overtops the earthen embankment causing dam breach. If it is not reasonable to assume embankment overtopping from the inflow design flood, then dam breach is assumed to occur by piping.

The reasonable likely maximum spillway/breach outflow hydrograph for each dam is determined by an analysis of each dam. It is assumed that dam failure, either by overtopping or by piping, occurs during the inflow design flood and that breach occurs at a time that maximizes the combined outflow from the emergency spillway in conjunction with the breach outflow. Golden Eagle Park Dam exists downstream of Aspen, North Heights, and SunRidge Canyon Dams. Therefore, for Golden Eagle Park Dam it is assumed that one of the three upstream dams fails thus contributing to the inflow to Golden Eagle Park Dam at the time of its failure.

Unsteady flow routing of the reasonable likely maximum spillway/breach outflow hydrograph for each dam is performed by use of the NWS Dam Break Program. The flood inundation area for the critical watercourses are shown in flood inundation maps.

BACKGROUND

Description of Watershed

The watershed is bounded on the north by the McDowell Mountain Park and state owned land, on the east by the Fort McDowell Indian Reservation, and on the west by the City of Scottsdale and McDowell Mountain Park. The southern boundary passes through the Town of Fountain Hills (see Figures 2 and 3). The watershed generally drains from west to east, passing through the Town of Fountain Hills, and ultimately into the Verde River. The five dams that are analyzed are contained within this watershed.

The watershed is a mix of undeveloped mountain and hillslope areas and urban development. Substantial areas zoned for development are still in a natural state. The total watershed, including areas that do not drain to the dams, is 16.5 square miles. The zoned urban area is 10.4 square miles.

The watershed is characterized by steep, rugged mountainous terrain along the west side of the study area, and hillslope and wash bottom for the remainder. The watershed ranges in elevation from a low of 1,504 feet to a high of 4,025 feet in the McDowell Mountains. The typical soil type in the mountain areas is a sandy loam-rock outcrop, in the hillslope areas is a sandy loam, and in the wash bottom areas is a loamy sand. The mountainous areas therefore have a high runoff potential and the hillslopes have a moderate runoff potential.

Purpose and History of Dams

All five of the dams were designed, constructed, and are operated as flood detention dams to reduce downstream discharges from storm runoff. The intent of the dams is to detain storm runoff in the reservoir thus reducing flood hazard for residential and commercial development in the Town of Fountain Hills.

The dams were designed and constructed under the supervision of Trico International, Inc. (Trico). The dams were built by McCulloch Properties, Inc., a property development firm. Four of the dams are currently owned and operated by MCO, and the fifth (Golden Eagle Park Dam) is jointly owned and operated by the Town of Fountain Hills and the Fountain Hills School District. The dams were designed and constructed during

1970 through 1976. The dams are under the jurisdiction of the State of Arizona through the Arizona Department of Water Resources (ADWR). The plans and specifications for the dams were approved by the Arizona Water Commission (presently ADWR), and the dams are licensed and periodically inspected by ADWR.

Description of Dams

The five dams are of earthfill type. Three of the dams (Golden Eagle Park, Hesperus Wash, and SunRidge Canyon) are zoned embankments with internal cores and upstream and downstream shells. The cores are generally finer material with high percentage of clay. The outer zones are coarser material with high percentage of gravel and some cobble. The other two dams (Aspen and North Heights) are homogeneous embankments. Characteristics and physical data for each of the dams are provided in Table 1. Sketches of each dam showing critical elevations and other characteristics that are relevant to the analyses are provided in Figures 4 through 8. Physical properties of the embankment materials are presented in a later section when discussing the dam breach analyses.

Each dam is provided with emergency and principal spillways, and the general characteristics and operation of the spillways are similar for each dam. The emergency spillways are unlined, trapezoidal channels that are excavated generally in cemented soils in either the left or right abutments. The crests of the spillways are provided with concrete sills and are uncontrolled. The downstream spillway channel slopes are steep, providing critical flow at the spillway crests. The channel bed appears to be relatively stable against erosion, and the banks of the channel are protected against erosion by concrete lining or riprap. The channel side slopes are 3H:IV. The width of the emergency spillway crest varies at each dam to accommodate the respective design floods. Characteristics of the emergency spillways are provided in Table 1.

The principal spillway for each dam consists of uncontrolled conduits passing through the embankment at the maximum embankment section. The conduits are reinforced concrete pipe (RCP). Single-barrel, 48 inch diameter RCP are used for the Hesperus Wash, North Heights, and SunRidge Canyon Dams. A single-barrel, 60 inch diameter RCP is used for the Aspen Dam. Originally, the Golden Eagle Park Dam was equipped with a double-barrel, 60 inch diameter RCP principal spillway. In 1989, a sanitary sewer was installed in the lower half of one of the 60 inch RCP conduits, and the sewer line

TABLE 1
Characteristics and physical data for dams

	Golden Eagle Park (No. 4)	Hesperus Wash (No. 36)	Aspen (No. 6)	North Heights (No. 11)	SunRidge Canyon (No. 7)
DAM					
Purpose	flood control	flood control	flood control	flood control	flood control
Earthfill Type	zoned	zoned	homogeneous	homogeneous	zoned
Crest Width, ft.	12.0	12.0	12.0	12.0	12.0
Crest Length, ft.	660.0	1,060.0	840.0	820.0	375.0
Upstream Slope	2:1	2:1	3:1	3:1	2:1
Downstream Slope	2:1	2:1	2:1	2:1	2:1
Dam Crest Elevation, ft	1,721.5	1,894.2	1,843.2	1,818.4	1,932.4
Spillway Crest Elevation, ft	1,714.9	1,889.0	1,835.4	1,810.8	1,924.8
D/S Toe of Dam Elevation, ft	1,693.2	1,851.8	1,805.5	1,776.1	1,882.5
Structure Height, ft. (a)	28.3	42.4	37.7	42.3	49.9
Hydraulic Height, ft. (b)	21.7	37.2	29.9	34.7	42.3
Freeboard, ft (c)	6.6	5.2	7.8	7.6	7.6
EMERGENCY SPILLWAY					
Location	rt. abutment	rt. abutment	lt. abutment	lt. abutment	lt. abutment
Type	uncontrolled	uncontrolled	uncontrolled	uncontrolled	uncontrolled
Shape	trapezoidal	trapezoidal	trapezoidal	trapezoidal	trapezoidal
Side Slope	3:1	3:1	3:1	3:1	3:1
Crest Elevation, ft	1,714.9	1,889.0	1,835.4	1,810.8	1,924.8
Width at Crest, ft	300.0	250.0	250.0	250.0	220.0
PRINCIPAL SPILLWAY					
Type	(2) Circular RCP	Circular RCP	Circular RCP	Circular RCP	Circular RCP
Size, inches	60 (f)	48.0	60.0	48.0	48.0
Length, ft	105.5	172.6	163.2	195.5	210.0
Inlet Invert Elevation, ft	1,694.5	1,851.9	1,808.6	1,779.0	1,884.7
Outlet Invert Elevation, ft	1,693.2	1,851.8	1,805.5	1,776.1	1,882.5
RESERVOIR					
Maximum Storage Capacity, ac-ft (d)	239.0	407.0	341.0	270.0	185.0
Normal Storage Capacity, ac-ft (e)	96.0	276.0	182.0	138.0	94.0
100-yr Water Surface Elevation, ft	1,716.6	1,883.3	1,832.4	1,812.3	1,926.3
WATERSHED					
Drainage Area, sq. mil	7.15	2.91	2.16	2.02	1.59

Notes:
(a) Structure Height = height from D/S Toe to Dam Crest
(b) Hydraulic Height = height from D/S Toe to Spillway Crest
(c) Freeboard = height from Spillway Crest to Dam Crest
(d) Maximum Storage Capacity = capacity at Dam Crest
(e) Normal Storage Capacity = capacity at Spillway Crest
(f) lower half on one RCP outlet is filled with sewer line and concrete

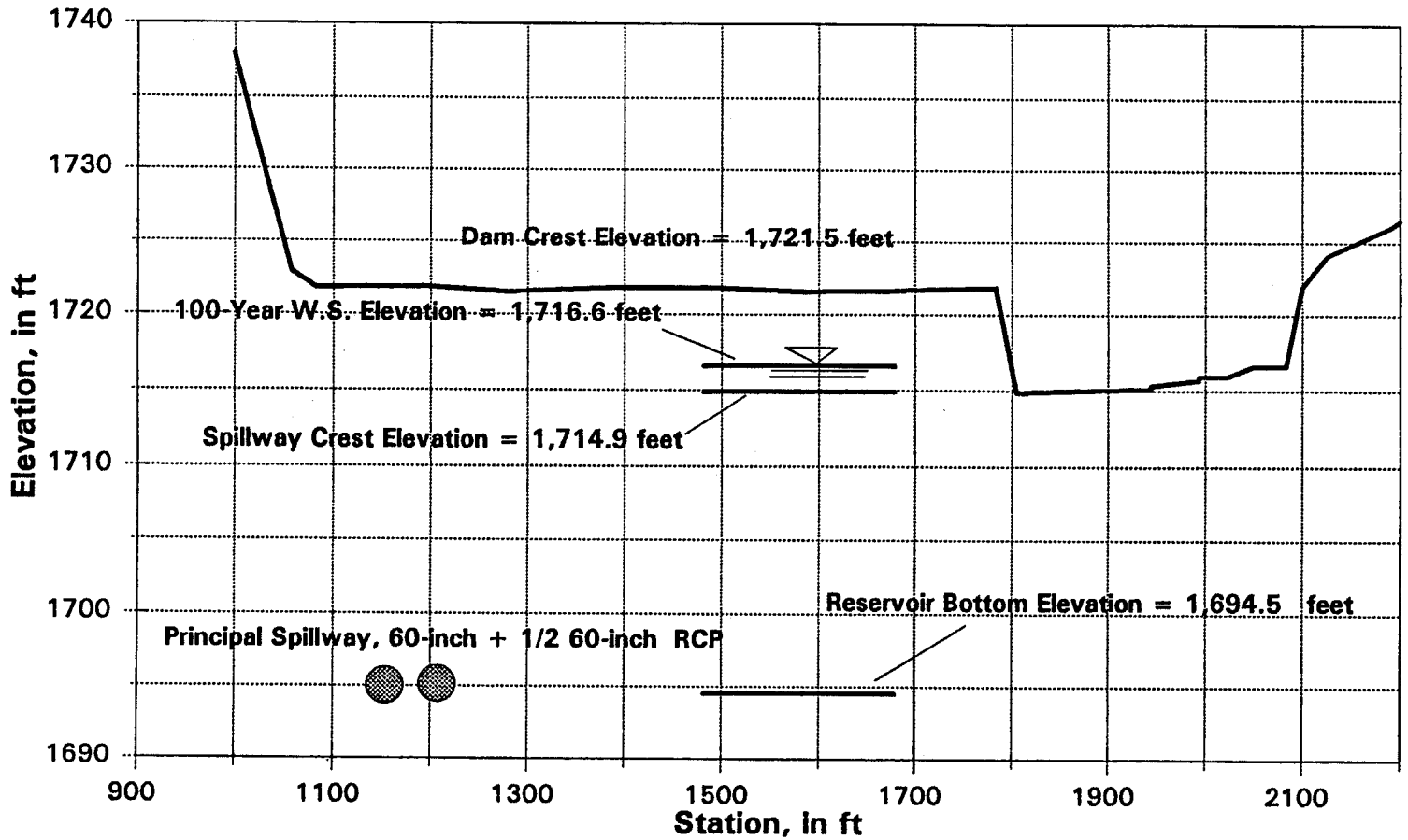


FIGURE 4

Sketch of critical features of Golden Eagle Park Dam (No. 4)

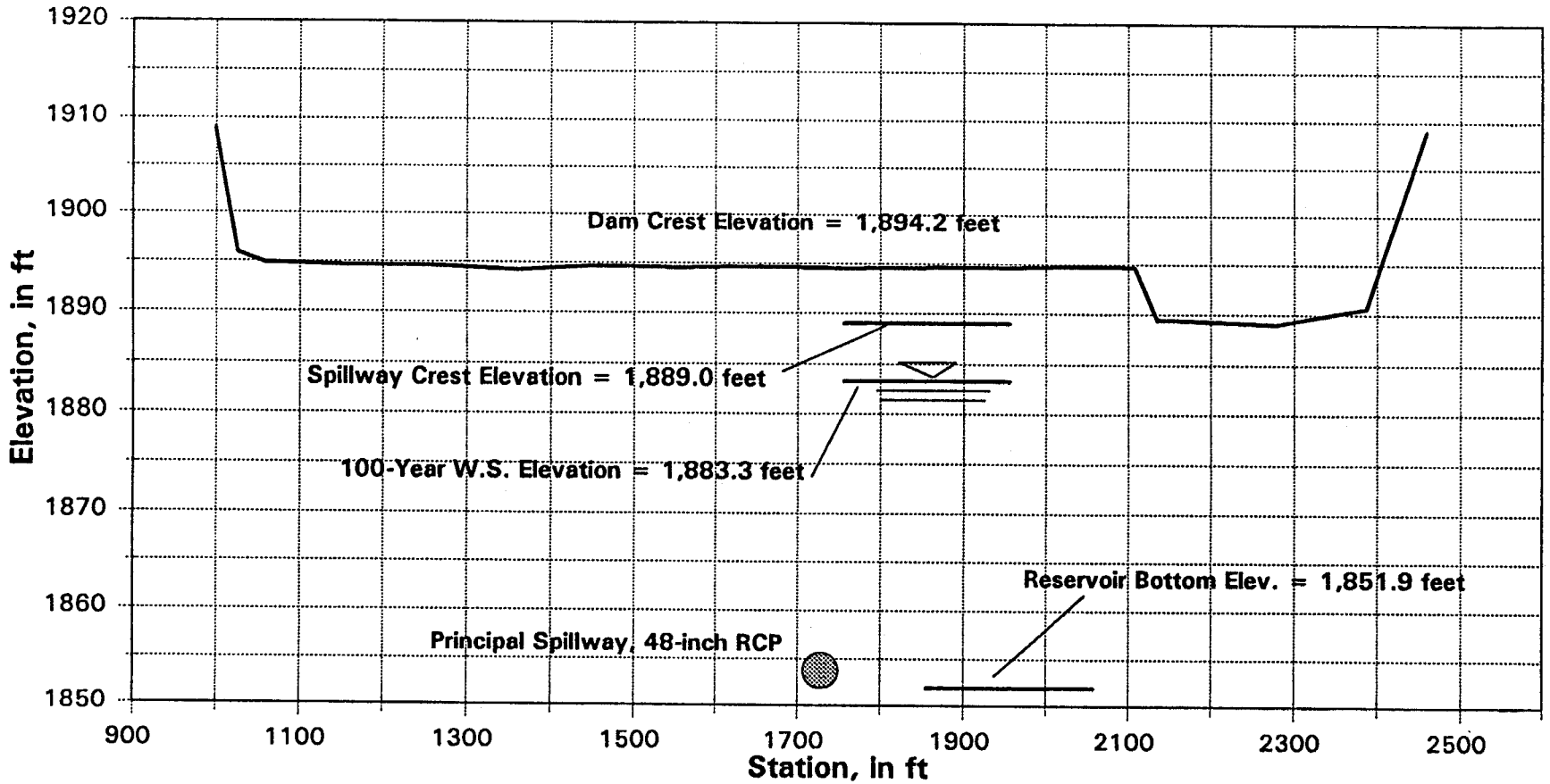


FIGURE 5

Sketch of critical features of Hesperus Wash Dam (No. 36)

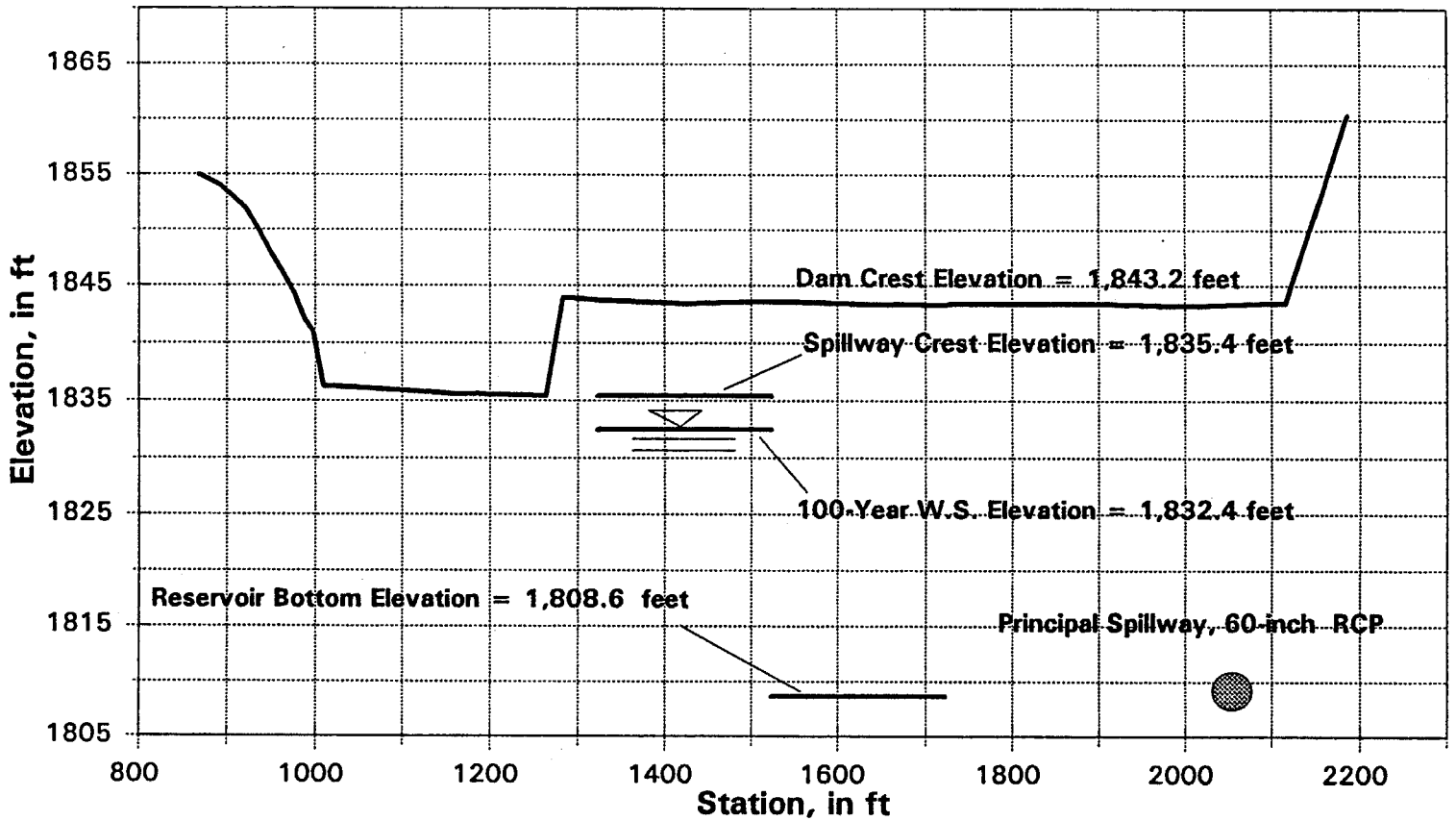


FIGURE 6

Sketch of critical features of Aspen Dam (No. 6)

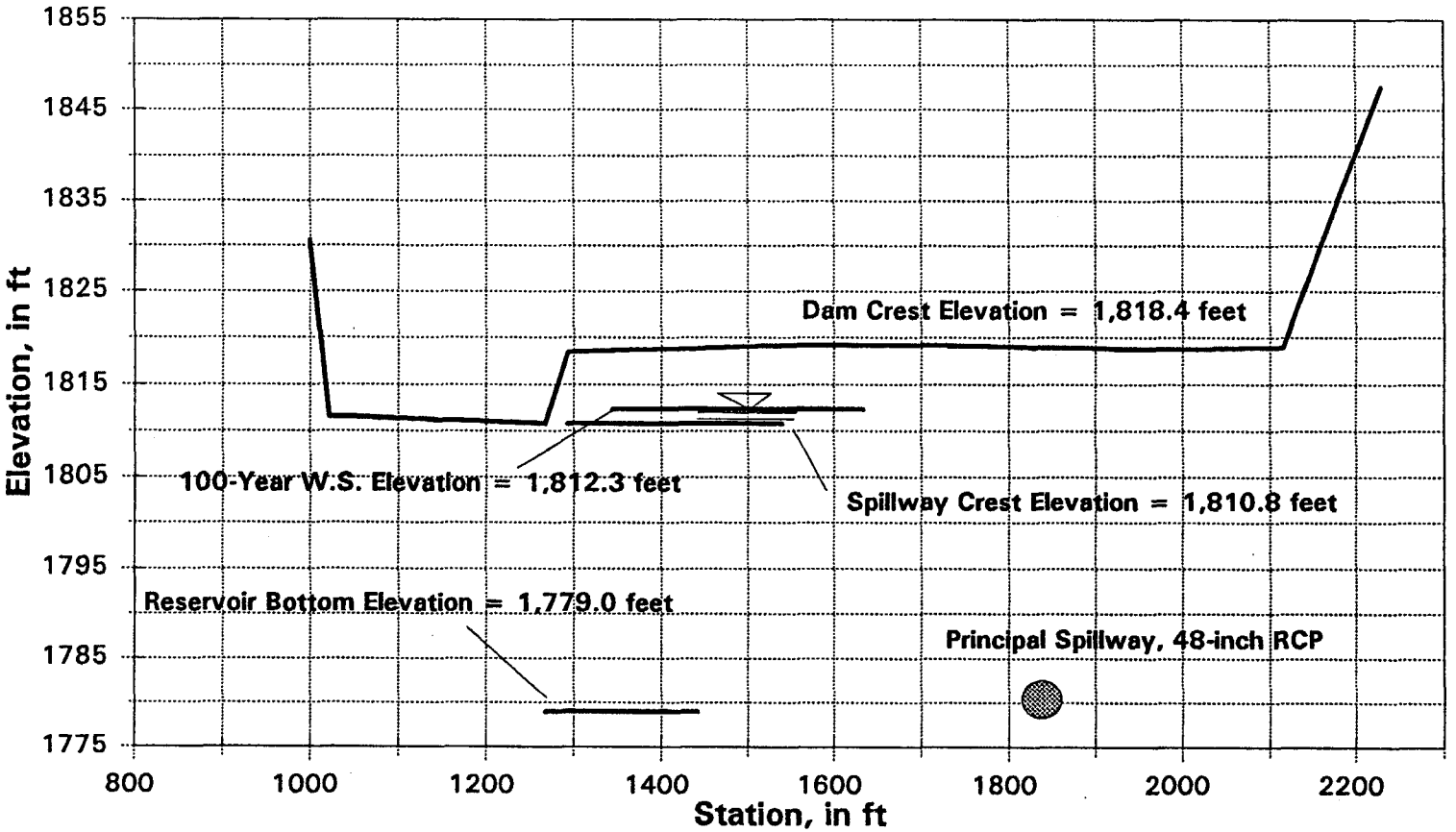


FIGURE 7

Sketch of critical features of North Heights Dam (No. 11)

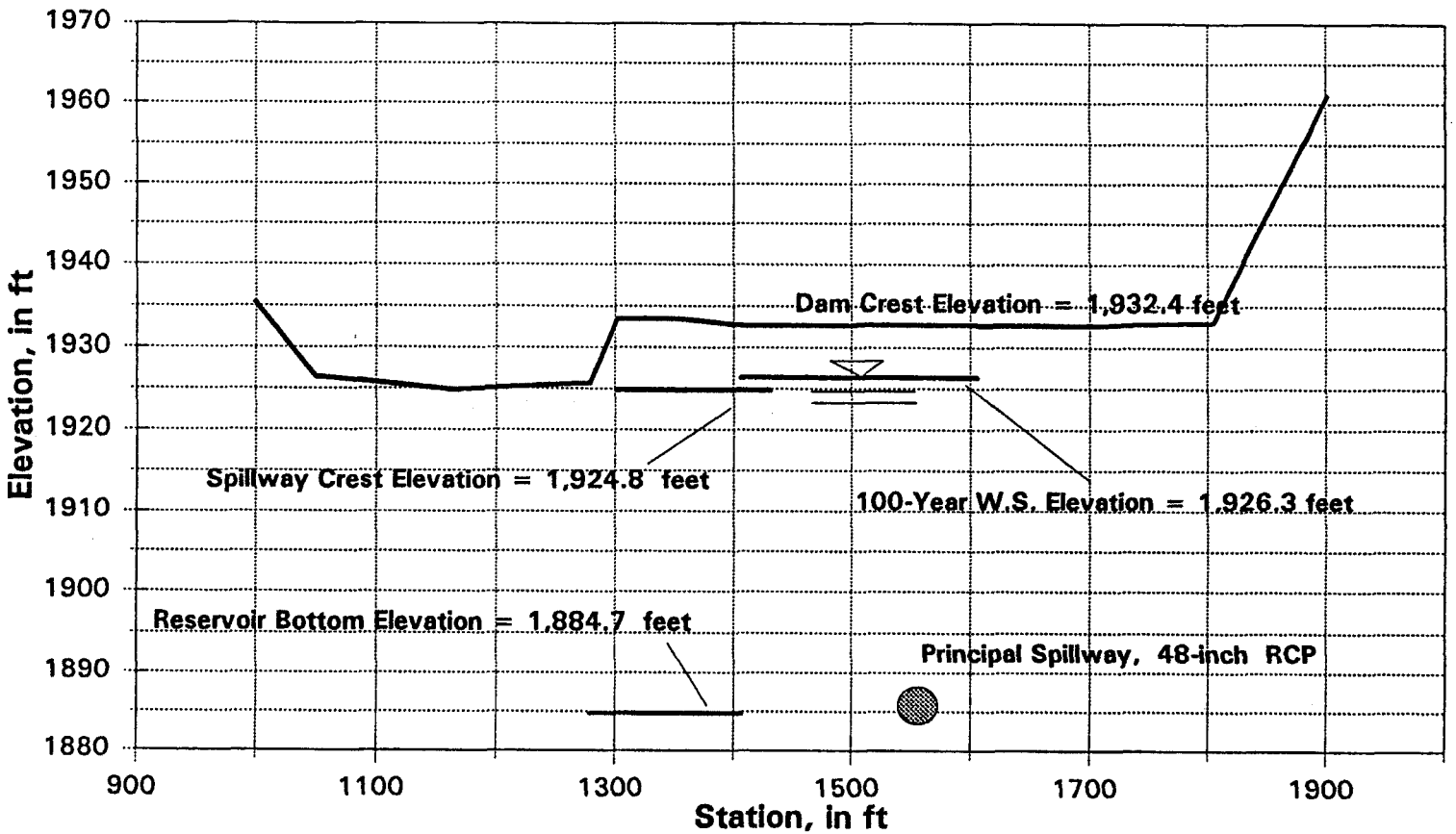


FIGURE 8

Sketch of critical features of SunRidge Canyon Dam (No. 7)

was encased in concrete thus eliminating about the lower 2 feet of flow capacity in that conduit. The modification to the Golden Eagle Park Dam principal spillway was approved by ADWR. The inlet of each principal spillway is equipped with a timber trashrack. The trashrack is intended to keep large debris, such as trees, from entering the outlet conduits, however, small debris, such as brush and trash are able to enter the conduits. The outlet of each principal spillway is equipped with an energy dissipator basin with a short, expanding apron and an end-sill. The outlet is generally at the invert elevation of the downstream receiving channel. Characteristics of the principal spillways are provided in Table 1.

The upstream and downstream faces of the dams are generally unprotected. The faces of the dam are sandy, gravelly material with some coarser material that may have been raked to the outer faces during dam construction.

The detention volumes vary for each dam. The normal storage capacity, which is measured to the emergency spillway crest, ranges from 94 acre-feet for SunRidge Canyon Dam to 276 acre-feet for Hesperus Wash Dam. The maximum storage capacity, which is measured to the dam crest, ranges from 185 acre-feet for SunRidge Canyon Dam to 407 acre-feet for Hesperus Wash Dam. The 100-year water surface elevation was recently estimated for the Fountain Hills (North) Floodplain Delineation Study by George V. Sabol Consulting Engineers, Inc. for the Flood Control District of Maricopa County. The estimated 100-year water surface elevation for each dam and the reservoir storage capacities are shown in Table 1. Notice, from the data in Table 1, that for three of the dams the emergency spillway will operate during the 100-year flood event under existing conditions. Those three dams and the height of the reservoir water surface above the crest of the emergency spillway are: Golden Eagle Park Dam - 1.7 feet, North Heights Dam - 1.5 feet, and SunRidge Canyon Dam - 1.5 feet.

The contributing drainage areas for the dams range from 1.59 square miles to 7.15 square miles, as shown in Table 1. Three of the dams (Aspen, North Heights, and SunRidge Canyon) are contained in the drainage area of Golden Eagle Park Dam. The consequence of spillway operation and potential dam breach of those upstream dams is considered in the dam break analysis of Golden Eagle Park Dam.

Classification of Dams

Dams in Arizona are classified by ADWR in regard to downstream hazard potential and size. Those two factors define the flood criteria that are acceptable to ADWR for the inflow design flood. The dam classification criteria and recommended inflow design flood based on dam classification are contained in Guidelines for the Determination of Spillway Capacity Requirements (ADWR, May 1991).

Using the ADWR criteria, all five dams are classified as "High" downstream hazard potential. This is based on the assessment that there is extensive urban development downstream of each of the dams with more than a small number of habitable structures, and that economic loss as a consequence of dam failure would be excessive. The size classification is based on a rating system using the hydraulic height of the dam and the storage capacity of the reservoir. The height is the vertical distance from the lowest elevation of the downstream toe of the dam to the spillway crest. The storage capacity is the maximum volume of water that can be impounded by the reservoir prior to release through the emergency spillway. Data needed for the classification of these dams are provided in Table 1. Height is listed as Hydraulic Height, and storage capacity is listed as Normal Storage Capacity. The dam size classification for each dam is provided in Table 2.

TABLE 2

Dam size classification rating (ADWR, 1991)

Dam	Height feet	Rating Factor	Reservoir Capacity ac-ft	Rating Factor	Total Rating Factor	Size Classification
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Golden Eagle Park (No. 4)	21.7	0	96	0	0	small
Hesperus Wash (No. 36)	37.2	1	276	0	1	small
Aspen (No. 6)	29.9	1	182	0	1	small
North Heights (No. 11)	34.7	1	138	0	1	small
SunRidge Canyon (No. 7)	42.3	2	94	0	2	small

The downstream hazard potential/size classification of each of these five dams is "High Hazard/Small." The ADWR recommended inflow design flood criteria for each of these dams is the 0.5 probable maximum flood (0.5 PMF). As such, the inflow flood that is used in the assessment of overtopping potential and in the estimation of dam breach hydrographs is the 0.5 PMF.

Related Reports

Three sources of information are used in the dam break analyses:

1) file data for the design and construction of the dams by Trico,
2) the Phase I Inspection Reports under the National Dam Safety Program, by the Arizona Water Commission (presently ADWR) for the Los Angeles District Corps of Engineers, and
3) the Fountain Hills (North) Floodplain Delineation Study by George V. Sabol Consulting Engineers, Inc. for the Flood Control District of Maricopa County. That study is referred to herein as the Ftn Hills FDS.

Information concerning the physical characteristics of the dams and the geotechnical properties of the earthen embankments are obtained from the Trico file data and the Phase I Inspection Reports. Watershed information for the estimation of the inflow design floods (0.5 PMF) and topographic maps for the flood inundation mapping are obtained from the Ftn Hills FDS and more recent mapping. That information and data will be discussed, as appropriate, in subsequent sections of this report.

Field reconnaissance of the dams and the downstream watercourses were conducted during this study. Field surveys of the five dams were performed by a registered land surveyor (Alcocer Land Surveyors) under contract to George V. Sabol Consulting Engineers, Inc. in the performance of the Ftn Hills FDS. Those surveys are used to confirm the critical elevations and dimensions of the dams for hydraulic analysis purposes. As-built measurements were obtained for the dam crest elevation, emergency spillway crest elevation and spillway crest length, and the invert elevations of the principal spillway inlets and outlets. The recent field survey data are used for these critical measurements. The sketches shown in Figures 4 through 8 reflect the field survey data.

FLOOD HYDROLOGY

Methodology

The watershed is modeled using the methodology contained in Drainage Design Manual for Maricopa County, Arizona, Volume 1, Hydrology (Flood Control District of Maricopa County, 1992). The HEC-1 Flood Hydrology Program, version 4.0.1E, dated May 1991 (U.S. Army Corps of Engineers, 1991) is used as the computer code for the numeric model. The probable maximum precipitation (PMP) is determined from Hydrometeorological Report No. 49 (Hansen and others, 1984). Rainfall losses are estimated using the Green and Ampt infiltration equation with an estimate for surface retention loss. The Clark unit hydrograph is used for hydrograph development. Channel routing is performed using the normal depth routing method. Reservoir routing for the five flood detention dams is by the modified Puls method.

Flood hydrology for the watershed was previously performed for the Fountain Hills (North) Floodplain Delineation Study (Ftn Hills FDS) for the Flood Control District of Maricopa County (Contract FCD 92-04) by George V. Sabol Consulting Engineers, Inc. (GVSCE). The purpose of that floodplain delineation study is to estimate the peak discharge from the 100-year storm at key locations in the watershed. That flood hydrology was reviewed and evaluated in regard to its applicability for estimating the spillway inflow design floods for the five dams. Subsequently, the Ftn Hills FDS flood hydrology (with revisions for inputting the PMP) was accepted for the purpose of the present dam break study. The basis for acceptance of that flood hydrology model is presented in the following section.

The results and supporting documentation for the Ftn Hills FDS are presented in three volumes for existing (1992) watershed conditions, and one volume for future (full buildout conditions). That supporting documentation is presented in this report, usually as appendices, where appropriate to provide documentation of the flood hydrology for the dam break analyses.

Verification of Ftn Hills FDS Model

The Ftn Hills FDS flood hydrology model was verified in regard to its ability to adequately estimate 100-year peak discharges. Four methods were used to verify the watershed model. Those verification methods are:

1. Comparison of model results (100-year peak discharges) to recorded USGS streamgage data for representative watersheds.
2. Comparison of model results to estimates using recent USGS regression equations for peak discharges.
3. Comparison of model results to results from previous floodplain delineation studies for other watersheds in Maricopa County.
4. Calibration of the model using recorded rainfall for the 3-4 December 1992 storm and comparison of model results to high water marks behind the five dams.

The results of the four verification methods are presented in the Ftn Hills FDS report (pages 3-57 through 3-68) and that section is provided as Appendix A. Those verifications are all acceptable, resulting in no reason to doubt the validity of the watershed model for 100-year flood hydrology.

It is demonstrated that the Ftn Hills FDS model adequately represents 100-year frequency flood hydrology. However, since that model has extensive model detail (numerous small subbasins with considerable channel routing and hydrograph combination operations) which are necessary for estimating 100-year peak discharges at numerous locations throughout the watershed for floodplain delineation purposes, it is necessary to determine if the model is also adequate to estimate the PMF at each of the dams. This was accomplished by modeling the contributing watershed to a dam using appropriate and simpler modeling technique and by comparing the results of that model to the results obtained with the Ftn Hills FDS model. The watersheds for two of the dams (Hesperus Wash and Aspen) were selected for this comparison. The Hesperus Wash Dam watershed was selected because it is the largest drainage area, and the Aspen Dam watershed was selected because of its long and narrow shape.

Single basin models were prepared for each of those two watersheds. The rainfall loss parameters were estimated by areal averaging the subbasin parameters from the Ftn Hills FDS model. The watershed unit hydrograph was modeled using the Phoenix Mountain S-graph, with unit hydrograph parameters estimated from data in the Ftn Hills FDS report. A summary of the single basin model input parameters is presented in Table 3. The PMP (discussed in a later section) was input to the single basin and the Ftn Hills FDS models.

The results are shown in Figures 9 and 10. The results from the single basin model and the multiple subbasin Ftn Hills FDS model for each watershed are surprisingly similar. Based on these results, it is concluded that the Ftn Hills FDS model is adequate to estimate the PMF for each dam.

TABLE 3

Summary of single basin watershed model parameters for model verification

		Rainfall Loss Parameters			Unit Hydrograph Parameters				
Watershed	Drainage Area	Uniform Loss Rate	Initial Loss	Impervious Area	L	L_{ca}	S	K_n	Lag
	sq. miles	in/hr	inches	%	miles	miles	ft/mile		hours
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hesperus Wash	2.91	0.33	0.22	21.4	5.0	3.0	426	0.033	0.62
Aspen	2.16	0.31	0.17	31.6	4.0	2.4	479	0.033	0.58

Mapping and Survey Information

Topographic Maps - The following U.S. Geological Survey (USGS) 7.5 minute quadrangle maps are available for the watershed:

Granite Reef Dam	-	1974 photorevised, 20-foot contour interval
McDowell Peak	-	1982 photorevised, 10-foot contour interval
Sawik Mountain	-	1982 photorevised, 20-foot contour interval
Fort McDowell	-	1974 photorevised, 20-foot contour interval.

Sections of those maps covering the watershed were raster scanned and converted to a vector based AutoCAD format, and merged to form a single map. That map, and more detailed topographic maps, were used for hydrologic analysis in the Ftn Hills FDS. The USGS based topographic map showing the major subbasin delineation is shown in Exhibit A. (Note: Exhibits A through E are taken directly from the Ftn Hills FDS report without modification.)

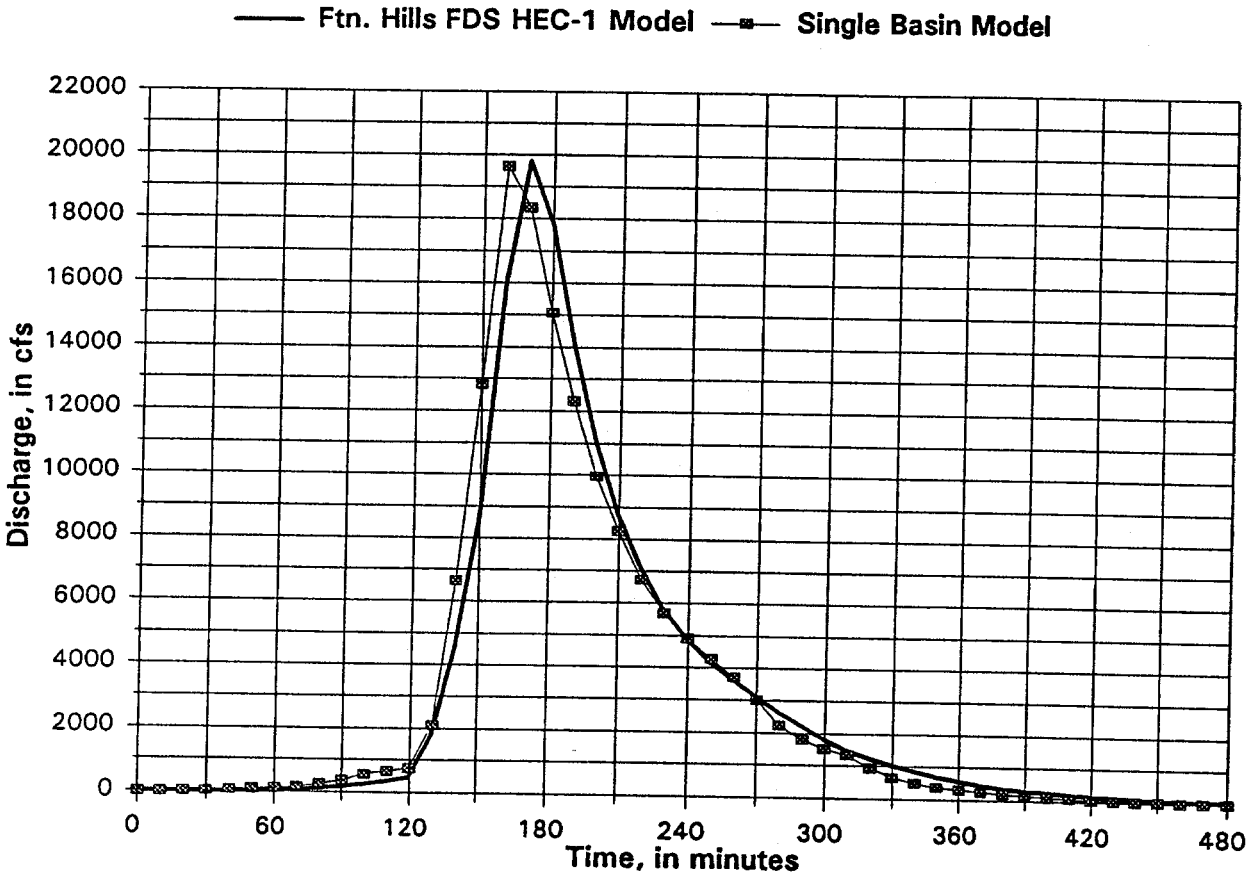


FIGURE 9

Comparison of PMF generated from the Fountain Hills FDS HEC-1 model and the single basin model for Hesperus Wash Dam

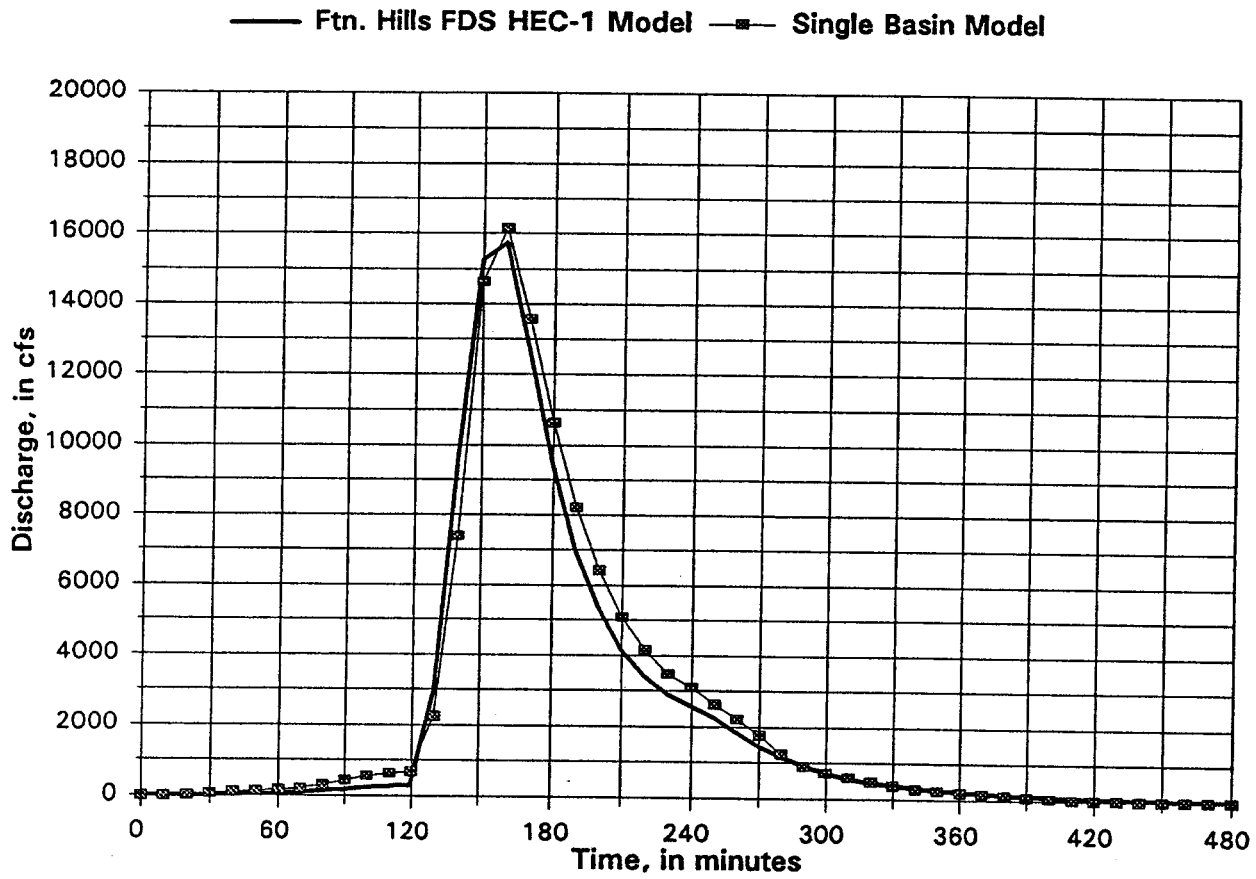


FIGURE 10

Comparison of PMF generated from the Fountain Hills FDS HEC-1 model and the single basin model for Aspen Dam

Detailed topographic mapping of the Town of Fountain Hills was prepared by Kenney Aerial Mapping, Inc. in 1991 for Anderson-Nelson, Inc. under contract with the Town of Fountain Hills. That mapping was used to produce 1 inch = 400 feet, 10-foot contour interval maps for the hydrology portion of the Ftn Hills FDS, and those maps were used for subbasin delineation. Maps at a scale of 1 inch = 200 feet, 2-foot contour interval, are used for the flood inundation mapping. More recent topographic maps that show the land surface grading below the SunRidge Canyon and North Heights Dams were used for those areas.

Soils Maps - A soils map for the watershed is shown in Exhibit B. That map was derived from the soils maps in Soil Survey of Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona (SCS, 1985). Exhibit B also shows the subbasin delineation.

Land Use Maps - Land use for the watershed is shown in Exhibit C. Land use boundaries are derived from the Town of Fountain Hills Zoning Map. The land use map identifies the land use as of 1992, and much of the watershed at that time was not fully developed (the full buildout condition). Land use areas that are identified with a -P (less that 50 percent developed) or with a -N (undeveloped) in Exhibit C are modified in this study to reflect fully developed conditions.

Subbasin Delineation and Hydrologic Modeling - Exhibit A shows the entire watershed that was analyzed for the Ftn Hills FDS. That map is based on USGS quadrangle maps. Exhibit A shows the major subbasin delineation, and the major subbasins for the five dams are:

Hesperus Wash Dam	-	Subbasin 205
Aspen Dam	-	Subbasin 207
North Heights Dam	-	Subbasin 208
SunRidge Canyon Dam	-	Subbasin 209
Golden Eagle Park Dam	-	Subbasin 210 directly, plus all of Subbasins 207, 208 and 209.

More detailed hydrologic mapping is shown in Exhibit D (6 sheets). Exhibit D shows, among other information, both major and minor subbasin delineation, T_c flow paths, and HEC-1 routing paths. Exhibit D is composed of USGS quadrangle maps and the detailed

topographic maps where they are available. The hydrologic mapping shown in Exhibit D is the basis of the HEC-1 hydrologic modeling for the dam inflow design floods.

HEC-1 Flood Routing Diagram - A routing diagram for the HEC-1 model of the watershed is shown in Exhibit E. The HEC-1 model from the Ftn Hills FDS was used to develop the inflow design flood for each dam. However, only the subbasin(s) for each dam, as previously identified, were used in the watershed modeling. The routing diagram (Exhibit E) and the hydrologic maps (Exhibit D) are useful when reviewing the HEC-1 modeling for each dam.

PMP

The inflow design flood for each dam is the 0.5 PMF, as previously discussed. The 0.5 PMF is estimated by first estimating the PMF and then multiplying each discharge ordinate of the PMF by 0.5. The PMF is estimated based on probable maximum precipitation (PMP) on the watershed. For four of the dams (all except Golden Eagle Park Dam) it is assumed that the PMP occurs independently over each of the four contributing watersheds. This assumption maximizes the PMP by using less areal reduction of the PMP based on the smaller contributing watershed areas. Therefore, for those four dams, watershed specific PMPs are developed for each dam.

Estimation of the inflow design flood for Golden Eagle Park Dam is determined in a somewhat different manner. This is because three of the dams (Aspen, North Heights, and SunRidge Canyon) are contained within the Golden Eagle Park Dam watershed. The inflow design flood for Golden Eagle Park Dam is estimated based on the following assumptions. First, it is assumed that the PMP occurs over the total area comprising subbasins 207, 208, 209 and 210. Second, the inflow design flood is contingent upon spillway release and/or breach of the three upstream flood control dams. For the purpose of defining the inflow design flood for Golden Eagle Park Dam, it is assumed that during that flood, one of the three upstream dams will breach and the other two dams will safely pass the inflow through the emergency spillway. The inflow design flood is the combination of the routed spillway release hydrographs from two of the dams, plus the routed hydrograph from the third breached dam, plus the contributing runoff from the 0.5 PMF for subbasin 210. The breached dam is selected to be the one that results in the maximum inflow to Golden Eagle Park Dam. This is discussed in more detail in a later section.

The total contributing watershed area for Golden Eagle Park Dam is 7.15 square miles and a smaller area reduction factor could be used resulting in slightly less rainfall than the PMP for any of the subbasins for the individual dams. (The PMP for the total 7.15 square mile watershed is 13.7 inches.) However, for the intent of simplicity of analysis, the PMP for each individual subbasin is used when estimating the inflow design flood for Golden Eagle Park Dam. Although this method of analysis is somewhat conservative, it has little impact on the dam break analysis or the flood inundation mapping. Additionally, this method is not unnecessarily conservative because contributing runoff below Golden Eagle Park Dam is not modeled and the slightly overestimated rainfall upstream of the dams compensates for the small unmodeled area downstream of the dams.

The PMP is estimated by methods in Hydrometeorological Report No. 49 (HMR 49) (Hansen and others, 1984). The local storm PMP is the critical storm for all of the dams. Worksheets for PMP estimation are provided in Appendix B. Tabulations of the incremental PMP rainfalls for each dam are shown in Table 4.

Rainfall Losses

Methodology - Rainfall losses for each minor subbasin, as delineated in Exhibit D, are estimated by the Green and Ampt infiltration equation with a surface retention loss. The rainfall loss parameters are estimated for the future, full buildout condition of the watershed. The rainfall loss parameters are estimated by methods in the Drainage Design Manual for Micopa County, Volume 1, Hydrology (Flood Control District of Maricopa County, 1992). The analysis of the rainfall loss parameters is presented in the Ftn Hills FDS report. A discussion of the analysis of the rainfall loss parameters is presented, herein, and tabulations of the calculated rainfall loss parameters are provided in the appendices of this report.

Soils - Information on the hydrologic properties of the soils is extracted from the SCS soils report (SCS, 1985). All of the watershed soils are characterized by the SCS as gravelly, very gravelly, extremely gravelly, channery, or cobbly. This means that the soils contain significant quantities of broken rock and cobble.

TABLE 4

Summary of PMP rainfall, rainfall losses, and rainfall excess for the five Fountain Hills dams

	Hesperus Wash Subbasin 205			North Heights Subbasin 208			SunRidge Canyon Subbasin 209			Aspen Subbasin 207			Golden Eagle Park Subbasin 210		
Time	RAINFALL	LOSS	EXCESS	RAINFALL	LOSS	EXCESS	RAINFALL	LOSS	EXCESS	RAINFALL	LOSS	EXCESS	RAINFALL	LOSS	EXCESS
minutes	inch	inch	inch	inch	inch	inch	inch	inch	inch	inch	inch	inch	inch	inch	inch
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.07	0.05	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.07	0.05	0.02	0.07	0.05	0.01
20	0.07	0.05	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.07	0.05	0.02	0.07	0.05	0.01
30	0.07	0.05	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.07	0.05	0.02	0.07	0.05	0.01
40	0.07	0.05	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.07	0.05	0.02	0.07	0.05	0.01
50	0.07	0.05	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.07	0.05	0.02	0.07	0.05	0.01
60	0.07	0.05	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.07	0.05	0.02	0.07	0.05	0.01
70	0.12	0.09	0.03	0.13	0.06	0.07	0.13	0.08	0.06	0.13	0.09	0.04	0.13	0.09	0.04
80	0.12	0.09	0.03	0.13	0.06	0.07	0.13	0.08	0.06	0.13	0.09	0.05	0.13	0.08	0.05
90	0.12	0.09	0.03	0.13	0.06	0.07	0.13	0.07	0.06	0.13	0.09	0.05	0.13	0.08	0.06
100	0.12	0.09	0.03	0.13	0.06	0.07	0.13	0.07	0.06	0.13	0.08	0.05	0.13	0.07	0.06
110	0.12	0.09	0.03	0.13	0.06	0.08	0.13	0.07	0.06	0.13	0.08	0.05	0.13	0.06	0.07
120	0.12	0.09	0.03	0.13	0.05	0.08	0.13	0.07	0.06	0.13	0.08	0.05	0.13	0.06	0.07
130	5.13	0.11	5.02	5.33	0.05	5.27	5.47	0.07	5.39	5.33	0.08	5.25	5.53	0.06	5.47
140	3.17	0.11	3.06	3.27	0.05	3.22	3.33	0.07	3.26	3.27	0.08	3.19	3.37	0.06	3.31
150	1.20	0.10	1.10	1.20	0.05	1.15	1.20	0.06	1.14	1.20	0.07	1.13	1.20	0.05	1.15
160	0.47	0.10	0.37	0.47	0.05	0.42	0.47	0.06	0.41	0.47	0.07	0.40	0.47	0.05	0.42
170	0.47	0.09	0.38	0.47	0.05	0.42	0.47	0.06	0.41	0.40	0.07	0.33	0.43	0.05	0.38
180	0.47	0.09	0.38	0.47	0.05	0.42	0.47	0.06	0.41	0.33	0.07	0.26	0.40	0.05	0.35
190	0.28	0.08	0.20	0.25	0.05	0.20	0.27	0.06	0.21	0.28	0.06	0.22	0.27	0.05	0.22
200	0.28	0.08	0.20	0.25	0.04	0.21	0.27	0.06	0.21	0.28	0.06	0.22	0.27	0.05	0.22
210	0.28	0.08	0.20	0.25	0.04	0.21	0.27	0.06	0.21	0.28	0.06	0.22	0.27	0.05	0.22
220	0.28	0.08	0.21	0.25	0.04	0.21	0.27	0.06	0.21	0.28	0.06	0.22	0.27	0.05	0.22
230	0.28	0.07	0.21	0.25	0.04	0.21	0.27	0.05	0.21	0.28	0.06	0.23	0.27	0.05	0.22
240	0.28	0.07	0.21	0.25	0.04	0.21	0.27	0.05	0.21	0.28	0.06	0.23	0.27	0.05	0.22
250	0.12	0.07	0.04	0.10	0.04	0.06	0.10	0.05	0.05	0.08	0.05	0.03	0.08	0.04	0.04
260	0.12	0.07	0.04	0.10	0.04	0.06	0.10	0.05	0.05	0.08	0.05	0.03	0.08	0.04	0.04
270	0.12	0.07	0.05	0.10	0.04	0.06	0.10	0.05	0.05	0.08	0.05	0.03	0.08	0.04	0.04
280	0.12	0.07	0.05	0.10	0.03	0.07	0.10	0.05	0.05	0.08	0.05	0.03	0.08	0.04	0.04
290	0.12	0.07	0.05	0.10	0.03	0.07	0.10	0.05	0.05	0.08	0.05	0.03	0.08	0.04	0.04
300	0.12	0.07	0.05	0.10	0.03	0.07	0.10	0.04	0.06	0.08	0.05	0.03	0.08	0.04	0.04
310	0.05	0.04	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.05	0.04	0.01	0.05	0.03	0.02
320	0.05	0.04	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.05	0.04	0.01	0.05	0.03	0.02
330	0.05	0.04	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.05	0.04	0.01	0.05	0.03	0.02
340	0.05	0.04	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.05	0.04	0.01	0.05	0.03	0.02
350	0.05	0.04	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.05	0.04	0.01	0.05	0.03	0.02
360	0.05	0.04	0.01	0.05	0.02	0.03	0.05	0.03	0.02	0.05	0.04	0.01	0.05	0.03	0.02
Total	14.70	2.60	12.10	14.70	1.40	13.30	15.00	1.80	13.20	14.70	2.12	12.58	15.00	1.82	13.18

Texturally, the soils are classified in the sandy loam to clay loam range. The rainfall loss characteristics range from moderately high to slow. The soil texture class is used to estimate the hydraulic conductivity (XKSAT) of the soil.

Land Use - Land use in the watershed is classified as "natural" if it is not in an urban or urbanizing portion of the town. Natural land use areas are identified for valley, hillslope and mountain physiographic regions. Urban areas include a number of categories that are representative of the type and density of development. The density of development is related to the Town's Zoning Ordinance. The main use of land use classification is to assess the surface retention loss and to estimate the percent of impervious area and percent of rock outcrop for urban and natural area, respectively.

Details of the land use classification are provided in the Ftn Hills FDS report (pgs. 3-11 through 3-14 and Tables S-2 through S-4). The rainfall loss parameters that are determined as a result of the land use classification are referenced and presented elsewhere in this report.

Vegetation Cover - The density of vegetation cover affects rainfall losses. Estimates of vegetation cover were made during the Ftn Hills FDS through a combination of field observations, measurements of field transects, measurements from 1 inch = 100 feet aerial photographs, and other considerations. The percent vegetation cover is used to adjust the hydraulic conductivity parameter (XKSAT) in the Green and Ampt equation.

Surface Retention Loss - The amount of rainfall that is lost to runoff by surface retention (interception, surface depressions, puddles, etc.) is estimated based on the land use class. The values of surface retention losses are as follows:

Urban (pervious)	-	0.10 inches
Urban (impervious)	-	0.05 inches
Natural (valley)	-	0.35 inches
Natural (hillslope)	-	0.15 inches
Natural (mountain)	-	0.25 inches.

Green and Ampt Infiltration Equation Parameters - Three infiltration equation parameters are needed for the Green and Ampt method; hydraulic conductivity (XKSAT), capillary suction (PSIF), and initial soil moisture content (DTHETA). The percent impervious area (RTIMP) is also needed to estimate rainfall losses. The XKSAT and RTIMP parameters are estimated for each subbasin by calculating composite values based on subbasin, soil and land use maps. During the Ftn Hills FDS project, the various maps were digitized into AutoCAD. Those files were converted to ARC/INFO format, and the subarea of each soil type and land use was calculated for each subbasin. From those areas, the composite values of XKSAT and RTIMP were calculated for each subbasin. The values of PSIF and DTHETA were determined from the composite values of XKSAT. Finally, the XKSAT values were adjusted to account for the effects of vegetation cover. The calculation of the Green and Ampt parameter values is presented in detail in the Ftn Hills FDS report (pgs. 3-8 through 3-10 and Tables S-1 through S-6).

Rainfall Loss Parameters - The final rainfall loss parameters that are used in the HEC-1 models for estimating the PMF are provided in Appendix C. That appendix is taken from the Ftn Hills FDS Future Condition report (Table S-9). Only parameter values for major subbasins 205, 207, 208, 209 and 210 are relevant to the five Fountain Hills dams flood hydrology evaluations.

Using those rainfall loss parameters in the HEC-1 model and the PMP for each subbasin as previously described, the rainfall losses can be estimated. The incremental values of rainfall loss and the rainfall excess (runoff depth) for each of the dam's watershed models are shown in Table 4. Notice that the rainfall loss is relatively small compared to the PMP (10 to 18 percent). This result is not unusual, and in fact is expected, for rainfalls of the intensity of the PMP.

Unit Hydrograph

Methodology - The Clark unit hydrograph, as described in the Maricopa County Hydrology Manual, is used for all subbasins. There is no adjustment or modification of the Clark unit hydrograph parameters from those that were used in the Ftn Hills FDS. Complete documentation on the calculation of the Clark unit hydrograph parameters is presented in the Ftn Hill FDS report (pgs. 3-20 through 3-22 and Tables S-7 through S-10). The Clark

unit hydrograph is a three parameter technique and a discussion of each parameter is presented. The Clark unit hydrograph parameters for each subbasin are summarized in Appendix D.

Time of Concentration - The time of concentration for each subbasin is estimated using the Papadakis and Kazan equation (FCDMC, 1992):

$$Tc = 11.4\, L^{0.50}\, K_b^{0.52}\, S^{-0.31}\, i^{-0.38}$$

where:

T_c	=	time of concentration, in hours
L	=	length of flow path, in miles
S	=	watercourse slope, in feet per mile
K_b	=	watershed resistance coefficient
i	=	average rainfall intensity, during T_c, in inches per hour.

The T_c values that were calculated for the Ftn Hills FDS are used. This means that the i variable is for the 100-year storm rather than the PMP. This assumption is valid because 1) the T_c equation is empirical and is based on data for storms that are less severe than PMP rainfalls, 2) inspection of the T_c values shows that they range from 6 to 35 minutes, and these are reasonable, and 3) as previously demonstrated, the multiple subbasin model, with these T_c values, closely reproduces the results from a single basin model with appropriate unit hydrograph parameters for the PMF.

Storage Coefficient - The storage coefficient for each subbasin is estimated using the equation:

$$R = 0.37\, T_c^{1.11}\, A^{-0.57}\, L^{0.80}$$

where:

R	=	storage coefficient, in hours
T_c	=	time of concentration, in hours
A	=	drainage area, in square miles
L	=	length of flow path, in miles.

Time-Area Relation - One of the three time-area relations from the Maricopa County Hydrology Manual is selected for each subbasin, and that selection is based on the subbasin

physical characteristics. Subbasins with no urbanization are assigned the N-D (natural) time-area relation. Subbasins that are more than 50 percent urbanized are assigned the U-D (urban) time-area relation. Subbasins that are less than 50 percent urbanized are assigned the HEC-1 default time-area relation.

Unit Hydrograph Parameters - The T_c and R input variables are listed in Table S-7 of Appendix D. The selected time-area relation is shown in column 10 of Table S-9 of Appendix C. The T_c and R parameter values that were used are shown in columns 2 and 6, respectively, of Table S-10 of Appendix D.

Channel Routing

Routing of subbasin hydrographs is performed using the normal depth option of HEC-1. The routing reach paths are shown in Exhibit D. Refer to Exhibit E for the routing diagram. Each route operation in the HEC-1 models is identified by the upper and lower concentration numbers which define the reach. For example, the routing operation identified as 501502 is for channel routing from concentration point 501 to concentration point 502.

Routing cross sections are defined using the best available topographic maps or field measurement. Manning "n" values were selected based on the n value report that was prepared for the Ftn Hills FDS project. The n values are composite values for the channel and overbanks for the reach.

The channel routing data for the HEC-1 models is shown in the table of Appendix E. Routing in the HEC-1 PMF models is based on the 100-year, 6-hour, future condition HEC-1 model of the Ftn Hills FDS.

Storage Routing

General - Storage routing through the five flood control structures required area-capacity and spillway rating relations for each dam. These relations were determined in the Ftn Hills FDS based on current data. Those new relations were compared to the Trico design relations, and where discrepancies exist the data and analyses were inspected to determine

the cause of the discrepancies. The new relations are considered the best available. Storage routing in the HEC-1 models is by the modified Puls method.

Area-Capacity Relations - The area-capacity relations were determined by planimetering contours from the 1991 topographic maps. Those relations were extended to about 6.5 feet higher than the top of the embankment. The new area-capacity relations are shown in Appendix F. The Trico design data are listed in Appendix F for comparison purposes.

Spillway Rating Relations - The spillway rating relations were determined by using the HY-8 program to calculate the discharge through the principal spillway, and an uneven weir program to calculate the discharge through the emergency spillway and for discharge over the top of the embankment. The rating curve was extended to about 6.5 feet over the embankment. The new spillway rating relations are shown in Appendix F along with the Trico design data for comparison purposes.

Watershed Model Results

General - The HEC-1 model results for the five dams are presented. The results for the 100-year flood are presented for reference purposes only in regard to the performance of the dams during a 100-year flood. The 100-year flood results are taken from the Ftn Hills FDS report. The results for the PMF for four of the dams (all but Golden Eagle Park Dam) are presented based on the analysis that is reported herein. The PMF and spillway inflow design flood for Golden Eagle Park Dam is not reported in this section because the inflow design flood is a function of the breach analyses for the three upstream dams. The breach analysis for all five dams are reported in the next section and the resulting inflow design flood for Golden Eagle Park Dam is presented in that section.

100-year Flood Results - The results of the 100-year flood analyses for the five dams are reported in the Ftn Hills FDS report (pgs. 3-83 through 3-85 and Figures F-1 through F-5), and those results are contained in Appendix G. Those results are summarized in the following.

The estimated 100-year peak discharge, the peak stage, and maximum storage for each dam are listed in Table 5. From Table 5 it is noted that for three of the dams (Golden Eagle Park, SunRidge Canyon, and North Heights), the principal spillway is not able to pass the 100-year flood without causing the emergency spillway to operate. The flood control dams were designed to pass all of the 100-year flood through the principal spillway without activating the emergency spillway. The best available hydrologic analysis does not indicate that this is the case. The 100-year flood does not cause the dam embankment to be overtopped for any of the dams.

The duration of emergency spillway operation during the 100-year flood is provided in graphs of Appendix G. For Golden Eagle Park Dam, the emergency spillway will operate for about 5.3 hours (see Appendix G, Figure F-1). For SunRidge Canyon Dam, the emergency spillway will operate for about 0.9 hours (see Appendix G, Figure F-3). For North Heights Dam, the emergency spillway will operate for about 0.6 hours (see Appendix G, Figure F-4).

The results discussed are for existing conditions (1992) in the watershed. Under future conditions (full buildout) the peak discharges and maximum water surface elevations are somewhat greater because of the larger impervious area that is expected for the watersheds.

<u>Inflow Design Flood Results</u> - The inflow design floods, for other than Golden Eagle Park Dam, are estimated as 0.5 PMF. The PMF is estimated for each of the four dams and the 0.5 PMF is obtained by multiplying each of the PMF discharge ordinates by 0.5.

The assumed initial condition for the flood control dams at the start of the design storm is that the principal spillway is plugged as a result of an immediately preceding storm of approximately 100-year severity. Therefore, the initial water surface elevation of the flood control pool is the higher of either the emergency spillway crest or the water surface elevation from the 100-year flood. For the purpose of this determination, the future condition hydrology from the Ftn Hills FDS is used.

TABLE 5

Summary of 100-year flood results for the five dams from the Fountain Hills FDS report (existing conditions)

Dam	Emergency Spillway Crest Elev.	100-year, 6-hour				100-year, 24-hour			
		Discharge, cfs		Peak Stage	Peak Storage	Discharge, cfs		Peak Stage	Peak Storage
		in	out	feet	acre-feet	in	out	feet	acre-feet
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Golden Eagle Park	1,715	1,917	957	1,715.8	113	1,967	968	1,715.8	113
Aspen	1,835	1,989	287	1,832.4	141	1,781	275	1,830.5	119
SunRidge Canyon	1,925	1,999	469	1,925.5	100	1,683	351	1,922.9	78
North Heights	1,811	2,231	381	1,811.3	144	1,922	319	1,808.7	111
Hesperus Wash	1,889	2,580	326	1,883.3	177	2,520	321	1,882.2	161

Note: Underlined values indicate that the emergency spillway operates for that flood.

The PMF for each of the four dams was determined using HEC-1 models with input, as described in previous sections. The resultant PMF hydrographs are obtained by multiplying the discharge ordinates by 0.5 to obtain the 0.5 PMF inflow hydrographs. Those inflow hydrographs are then input to HEC-1 storage routing models for each dam. The storage routing models are used to estimate spillway outflow hydrographs and also to assess the overtopping potential for each dam.

The results of the inflow design floods for the four dams are presented in Table 6. Notice that even under the conservative assumption regarding the initial water surface elevation of the flood control pool and the severe hydrologic conditions that are imposed, three of the dams are not overtopped. The fourth, Hesperus Wash Dam, is only overtopped by 0.5 feet.

The HEC-1 output files for estimating the PMF for the four dams (all but Golden Eagle Park), and the 0.5 PMF spillway routing HEC-1 output files for those dams are provided in Appendices H through K. A diskette is provided with HEC-1 input and output files.

The results of the flood hydrology are used in the dam breach analyses. Those analyses and results are presented in the next section.

TABLE 6

Summary of inflow design flood (0.5 PMF) for four of the dams

		PMP/PMF			Inflow Design Flood (0.5 PMF)				
Dam (1)	Drainage Area sq. mi. (2)	PMP inches (3)	Runoff inches (4)	Peak Inflow cfs (5)	Initial Water Surface Elev. feet (6)	Peak Inflow cfs (7)	Maximum Water Surface Elevation feet (8)	Dam Crest Elev. feet (9)	Overtopping Depth feet (10)
Aspen	2.16	14.7	12.6	16,080	1,835.4 [a]	8,040	1,840.7	1,843.2	c
SunRidge Canyon	1.59	15.0	13.2	19,560	1,926.4 [b]	9,780	1,931.1	1,932.4	c
North Heights	2.02	14.7	13.3	24,470	1,812.3 [b]	12,235	1,817.6	1,818.4	c
Hesperus Wash	2.91	14.7	12.1	19,804	1,889.0 a	9,900	1,894.7	1,894.2	0.5

Note: a = emergency spillway crest elevation
b = maximum 100-year water surface elevation (future conditions)
c = inflow design flood does not overtop the dam embankment

DAM BREACH HYDROGRAPHS

Methodology

Hydrographs of discharge from a dam breach, coupled with emergency spillway release, are estimated for each dam. Analyses were performed using the NWS Breach Program. The 0.5 PMF spillway routings for four dams are reported in the previous section. Those results indicate that three of the dams (Aspen, North Heights and SunRidge Canyon) are not overtopped during the 0.5 PMF. The fourth dam (Hesperus Wash) is overtopped, but only by 0.5 feet and overtopping duration is only 26 minutes. Analysis indicates that Hesperus Wash Dam would not breach as a result of such a small overtopping discharge. Therefore, those four dams are analyzed for piping breach only.

It is assumed that piping failure is a result of floods antecedent to the 0.5 PMF of sufficient runoff volume to fill the reservoir to the emergency spillway crest or slightly above the crest. It is also assumed that the storm duration is long enough to maintain the full reservoir condition, or that the principal spillway is sufficiently blocked with debris to keep the reservoir full for an extended time period of several days or more. It is during those assumed conditions that the 0.5 PMF occurs, thus setting the scenario for piping failure during the inflow design flood. The start of piping is set to maximize outflow as a result of breach plus emergency spillway release. The combination of these assumed events is extremely unlikely, but these assumptions are all plausible and they do produce the reasonably likely maximum release from the dam.

The 0.5 PMF inflow design flood and the results of the breach analysis for Golden Eagle Park Dam are reported in this section. The assumed conditions for Golden Eagle Park Dam include those mentioned previously plus the assumption that one of the three upstream dams breaches due to piping during the inflow design flood. The resulting inflow to Golden Eagle Park Dam causes the earthen embankment to be overtopped. Therefore, Golden Eagle Park Dam is analyzed for both overtopping and piping failures. The maximum discharge from those two events is used for downstream inundation analysis and mapping.

Sources of Data

The dam breach analyses are based on the physical properties and characteristics of each dam and spillway. The dam and spillway characteristics in regard to spillway routing

are provided in previous sections. The physical properties of each dam are obtained from data that is on file in the ADWR office. That data generally consist of the Phase I Inspection Reports, engineering reports, and soils reports for the design and construction of each dam. Those data are used, to the extent possible, in selecting appropriate parameters for each dam. More extensive documentation for each dam are not available because of the history of change of ownership of the dams and other factors that resulted in discarded documents by those involved in the design, construction, and operation of those dams. The available data are adequate for the purpose of this study.

Sensitivity Analyses

Hydrologic dam breach analyses involve a degree of uncertainty due to both hydrologic variables and the inherent nonuniformity of the earthen embankment materials. The uncertainty of hydrologic variables is addressed in the flood hydrology and antecedent conditions that are assumed for the breaches. Typically, relatively conservative but reasonable assumptions are made in regard to flood hydrology. The uncertainty that is inherent due to the nonuniformity of the earthen embankment materials is typically addressed by performing a sensitivity analysis. The intent of the sensitivity analysis is to inspect the dam breach consequences (usually quantified in terms of ensuing peak discharge) as a function of assumed parameters for the embankment materials and/or time rates of breach development. Since the Breach Program is used, the sensitivity analysis is performed in regard to key input parameters relative to the physical properties of the embankment materials.

The key physical properties that are investigated in regard to dam breach consequences are:

median grain size (D50)
porosity (POR)
unit weight (UW)
internal friction angle (AFR)
cohesive strength (COH)
grain size distribution (UNFC).

The identifier in parentheses is the variable name in the Breach Program.

The sensitivity analysis is performed by selecting a set of base parameter values for each variable. That selection is based on the best information for the dam that is available. A reasonable range for the value of each parameter is defined, based on available information. Dam breach analyses are then performed using the base parameter values for five of the parameters and allowing the sixth parameter to vary over its range. The results are inspected in regard to peak discharge, times to failure, and breach dimensions. By this method, the critical parameters are identified and reasonable parameter values are selected based on maximizing peak discharges.

The results of the sensitivity analyses are presented in Tables 7 through 11. Although the effect of varying each parameter was inspected in regard to failure times and breach dimensions, only peak discharges, which is the relevant consequence, is reported in Tables 7 through 11. The results of the sensitivity of each parameter are discussed in the following.

Median Grain Size - For all five dams, the selection of median grain size has a measurable impact on peak discharge. In all cases, within the range of grain sizes that are considered, the selection of larger grain size resulted in larger peak discharges. This is particularly evident for the two homogeneous dams (Aspen and North Heights) but, to a lesser extent, is also exhibited for the three zoned dams. The maximum deviation in peak discharge from that obtained with the base parameter value is often less than a few percent, and the maximum deviation is about 10 percent.

Porosity - Porosity has little impact on breach as measured by peak discharge. Generally, the peak discharge varied by less than a percent. The only significant deviation is for Hesperus Wash Dam where there is a 9 percent deviation. That result is due to the relatively low selection of the base value for porosity for the shell of the embankment. Peak discharge increases with increasing porosity.

Unit Weight - Variation in the unit weight, within practical limits as demonstrated for four of the dams, has no effect on the estimated peak discharge.

Internal Friction Angle - Variation in the internal friction angle within practical limits has no effect on the estimated peak discharge for four of the dams. For the fifth dam, the effect is only about 3 percent.

TABLE 7

Sensitivity analysis for Aspen Dam - parameters and results

Base Parameter Values (homogeneous dam)

median grain size, D50	18.9 mm
porosity, POR	0.30
unit weight, UW	125 pcf
internal friction angle, AFR	40 degrees
cohesive strength, COH	0 psf
grain size distribution, UNFC	9.6

Results of Sensitivity Analysis

Parameter (1)	Value (2)	Peak Discharge, cfs (3)
D50	5.0	21,500
"	10.0	23,240
"	15.0	24,210
"	18.9	24,740
"	20.0	24,860
POR	0.25	24,030
"	0.30	24,740
"	0.35	25,100
UW	110	24,740
"	120	24,740
"	125	24,740
"	130	24,740
AFR	30	24,740
"	35	24,740
"	40	24,740
COH	0	24,740
"	100	24,740
UNFC	5	23,430
"	9.6	24,740
"	15	25,320
"	20	25,780

TABLE 8

Sensitivity analysis for North Heights Dam - parameters and results

Base Parameter Values (homogeneous dam)

median grain size, D50	1.63 mm
porosity, POR	0.25
unit weight, UW	133 pcf
internal friction angle, AFR	40 degrees
cohesive strength, COH	0 psf
grain size distribution, UNFC	142

Results of Sensitivity Analysis

Parameter (1)	Value (2)	Peak Discharge, cfs (3)
D50	0.1	21,160
"	0.25	23,430
"	1.63	29,010
"	3.00	30,780
"	3.80	31,610
POR	0.21	28,470
"	0.25	29,010
"	0.30	29,740
"	0.35	30,300
UW	125	29,010
"	133	29,010
"	140	29,010
AFR	30	29,010
"	35	29,010
"	40	29,010
COH	0	29,010
"	100	29,010
UNFC	10	23,810
"	20	25,210
"	50	27,170
"	110	28,280
"	142	29,010

TABLE 9

Sensitivity analysis for SunRidge Canyon Dam - parameters and results

Base Parameter Values (Zoned Dam)

	Core	Shell
median grain size, D50	2.45 mm	2.76 mm
porosity, POR	0.30	0.30
unit weight, UW	132 pcf	136 pcf
internal friction angle, AFR	35 degrees	40 degrees
cohesive strength, COH	200 psf	0 psf
grain size distribution, UNFC	15.8	30.2

Results of Sensitivity Analysis

Parameter	Value		Peak Discharge, cfs
	Core	Shell	
(1)	(2)	(3)	(4)
D50	5.0	2.76	22,540
"	2.45	2.76	22,170
"	1.0	2.76	21,780
"	0.5	2.76	21,320
"	2.45	10.0	23,600
"	2.45	5.0	22,970
POR	0.35	0.30	22,210
"	0.30	0.30	22,170
"	0.25	0.30	22,160
"	0.30	0.35	22,380
"	0.30	0.25	21,860
UW	140	136	22,170
"	132	136	22,170
"	120	136	22,170
"	132	140	22,170
"	132	120	22,170
AFR	40	40	22,170
"	35	40	22,170
"	30	40	22,170
"	35	45	22,170
"	35	35	22,170
COH	500	0	22,170
"	200	0	22,170
"	100	0	22,170
UNFC	30	30.2	22,250
"	20	30.2	22,160
"	15.8	30.2	22,170
"	10	30.2	22,160
"	15.8	50	22,590
"	15.8	40	22,360
"	15.8	20	21,870
"	15.8	15	21,690

TABLE 10

Sensitivity analysis for Hesperus Wash Dam - parameters and results

Base Parameter Values (Zoned Dam)

	Core	Shell
median grain size, D50	0.05 mm	8.4 mm
porosity, POR	0.33	0.14
unit weight, UW	112 pcf	145 pcf
internal friction angle, AFR	35 degrees	40 degrees
cohesive strength, COH	200 psf	0 psf
grain size distribution, UNFC	23.3	5.5

Results of Sensitivity Analysis

Parameter	Value		Peak Discharge, cfs
	Core	Shell	
(1)	(2)	(3)	(4)
D50	0.05	8.4	16,510
"	0.01	8.4	16,510
"	0.10	8.4	16,510
"	0.05	20.0	16,500
"	0.05	15.0	16,450
"	0.05	10.0	16,550
"	0.05	5.0	16,330
POR	0.33	0.14	16,510
"	0.30	0.14	16,510
"	0.25	0.14	16,510
"	0.20	0.14	16,510
"	0.40	0.14	16,510
"	0.33	0.20	16,730
"	0.33	0.25	17,040
"	0.33	0.30	17,480
"	0.33	0.35	18,000
UW	112	145	16,510
"	100	145	16,510
"	90	145	16,510
"	120	145	16,510
"	112	140	16,510
"	112	135	16,510
"	112	130	16,510
"	112	125	16,510
"	112	120	16,510
AFR	35	40	16,510
"	30	40	16,510
"	25	40	16,510
"	35	35	16,510
"	35	30	16,510
"	35	25	16,510
COH	500	0	16,510
"	200	0	16,510
"	100	0	16,510
"	50	0	16,510
"	25	0	16,510
UNFC	23.3	5.5	16,510
"	120	5.5	16,510
"	12	5.5	16,510
"	23.3	2.3	16,500
"	23.3	3.1	16,450
"	23.3	4.6	16,550
"	23.3	9.3	16,330

TABLE 11

Sensitivity analysis for Golden Eagle Park Dam - parameters and results

Base Parameter Values (Zoned Dam)

	Core	Shell
median grain size, D50	0.7 mm	9.5 mm
porosity, POR	0.23	0.23
unit weight, UW	137 pcf	135 pcf
internal friction angle, AFR	38 degrees	40 degrees
cohesive strength, COH	500 psf	0 psf
grain size distribution, UNFC	9.1	10.6

Results of Sensitivity Analysis

Parameter	Value		Peak Discharge, cfs
	Core	Shell	
(1)	(2)	(3)	(4)
D50	0.7	9.5	30,940
"	0.25	9.5	30,900
"	0.075	9.5	30,900
"	0.7	5.0	20,890
"	0.7	2.5	30,900
"	0.7	12.5	30,950
POR	0.23	0.23	30,940
"	0.30	0.23	30,850
"	0.35	0.23	30,760
"	0.20	0.23	30,980
"	0.23	0.30	30,730
"	0.23	0.35	30,710
"	0.23	0.20	31,040
AFR	38	40	30,940
"	35	40	30,940
"	30	40	30,940
"	40	40	30,940
"	38	35	31,510
"	38	30	31,950
COH	1,050	1,050	30,940
"	750	750	30,940
"	500	500	30,940
"	200	200	30,940
"	100	100	33,650
"	0	0	35,860
"	500	500	31,330

Note: Sensitivity was not inspected for UW and UNFC for this dam.

Cohesive Strength - Variation in the cohesive strength has no effect on the estimated peak discharge for four of the dams. For the fifth dam, the effect is only about 1 percent. The base value of the cohesive strength is conservatively assumed to be zero for the two homogeneous dams and for the shells of the three zoned dams.

Grain Size Distribution - Grain size distribution is measured by the ratio of the D90 to D30 grain sizes. When the ratio is less than about 30, there is very little effect on peak discharge by varying the ratio. For one of the dams, a very high value of grain size distribution was tested. For that dam, there is an 18 percent effect on peak discharge.

Summary of Sensitivity Analyses - As long as reasonable values for the embankment material physical properties are used, there is little effect on the estimated peak discharge from embankment breach. The median grain size is the most sensitive physical property. Porosity and grain size distribution have a small effect on estimated peak discharge. Unit weight, internal friction angle, and cohesive strength have no effect on peak discharge unless the parameter values deviate significantly from usual values.

Breach Assumptions, Parameters and Results

General - In all cases, it is assumed that the breach occurs during the 0.5 PMF inflow flood. In the case of failure by piping, the time to start of breach was determined by an iterative process to maximize the outflow that would occur by the combined outflow from the emergency spillway plus the dam breach. Breach by overtopping was also analyzed for Golden Eagle Park Dam and the time to breach in that case is calculated by the Breach Program as a function of the overtopping hydrograph and the physical properties of the dam embankment.

For piping, it is assumed that the piping is initiated along the principal spillway conduit. That is the maximum section of the dam and this assumption is reasonable and it maximizes the breach outflow.

The breach analysis and resulting breach outflow hydrograph is discussed for each dam. The assumed physical properties and initial conditions for each breach analysis are summarized in Table 12. The final breach analysis parameters were selected after the

TABLE 12

Parameters and initial conditions for dam breach analyses

Parameter	Dam				
	Aspen	N. Heights	SunRidge	Hesperus Wash	Golden Eagle Park
(1)	(2)	(3)	(4)	(5)	(6)
Core					
grain size (D50C), mm	18.92	1.63	2.45	0.05	0.7
D90/D30 (UNFCC)	9.6	142	15.8	23.3	118
porosity (PORC)	0.3	0.25	0.3	0.33	0.25
unit weight (UWC), pcf	120	125	120	115	125
internal friction angle (ARFC), degrees	40	40	35	35	38
cohesive strength, (COHC), psf	0	0	200	200	200
Shell					
grain size (D50S), mm	18.92	1.63	2.76	8.4	7.1
D90/D30 (UNFCS)	9.6	142	30.2	21.1	22.1
porosity (PORS)	0.3	0.25	0.3	0.25	0.3
unit weight (UWS), pcf	120	125	120	130	120
internal friction angle (AFRS), degrees	40	40	40	40	40
cohesive strength (COHS), psf	0	0	0	0	0
Dam Face					
upstream slope (ZU)	3H:IV	3H:IV	2H:IV	2H:IV	2H:IV
downstream slope (ZD)	2H:IV	2H:IV	2H:IV	2H:IV	2H:IV
grain size (D50 DF), mm	18.92	1.63	2.76	8.4	16.1
D90/D30 (UNFCDF)	9.6	142	30.2	21.1	10.9
Initial Conditions					
reservior elevation, ft	1,839.6	1,815.0	1,928.9	1,893.3	1,721.5
piping width, ft	0.1	0.1	0.1	0.1	0.1
piping elevation, ft	1,808.8	1,779.2	1,884.8	1,852.0	1,694.7

sensitivity analyses were performed and after the geophysical properties of the dam materials were reinspected. In some cases, the final parameters were revised somewhat from the parameters that were used in the sensitivity analyses. In all cases, the selected physical parameters are considered to be reasonable. The sensitivity analyses has demonstrated that there would be little, if any, effect on the breach peak discharges if the physical parameters are varied any reasonable amount from the values that are used. In general, it is considered that the selected parameters yield conservative results. The breach hydrographs are shown in Figures 11 through 16.

Aspen Dam - The embankment of Aspen Dam is not overtopped by the 0.5 PMF inflow design flood, therefore, only a piping analysis is performed. The piping breach input parameters are shown in Table 12. Selected pages of the Breach Program output are shown in Appendix L. The key results of the piping breach analysis are shown below:

time to start of breach	=	2.48 hours
time to peak outflow	=	2.72 hours
time to maximum breach	=	3.48 hours
breach width at peak outflow	=	28.6 ft.
breach depth	=	34.4 ft.
spillway outflow at peak	=	0.0 cfs
breach outflow at peak	=	24,890 cfs
total peak outflow	=	24,890 cfs.

Note: All times are referenced to the time of start of rainfall for the PMF.

Figure 11 shows the 0.5 PMF inflow hydrograph, the spillway outflow hydrograph without breach, and the combined spillway plus breach outflow hydrograph. The resulting combined outflow hydrograph is used for the flood inundation analysis.

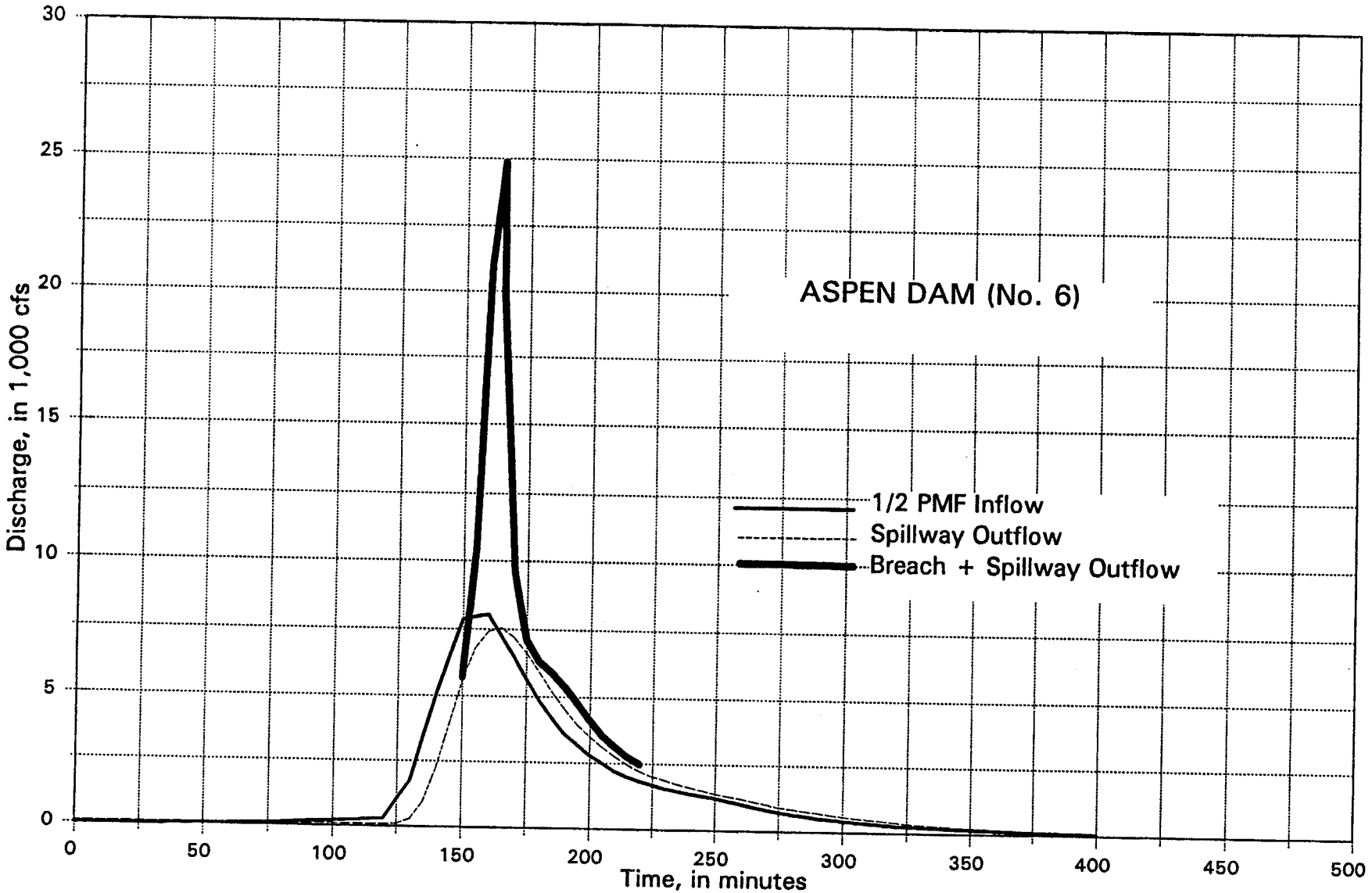


FIGURE 11

Inflow, spillway, and breach hydrographs for Aspen Dam

North Heights Dam - The embankment of North Heights Dam is not overtopped by the 0.5 PMF inflow design flood, therefore, only a piping analysis is performed. The piping breach input parameters are shown in Table 12. Selected pages of the Breach Program output are shown in Appendix M. The key results of the piping breach analysis are shown below.

time to start of breach	=	2.30 hours
time to peak outflow	=	2.51 hours
time to maximum breach	=	3.03 hours
breach width at peak outflow	=	28.9 ft.
breach depth	=	39.2 ft.
spillway outflow at peak	=	0.0 cfs
breach outflow at peak	=	29,210 cfs
total peak outflow	=	29,210 cfs.

Figure 12 shows the 0.5 PMF inflow hydrograph, the spillway outflow hydrograph without breach, and the combined spillway plus breach outflow hydrograph. The resulting combined outflow hydrograph is used for the flood inundation analysis.

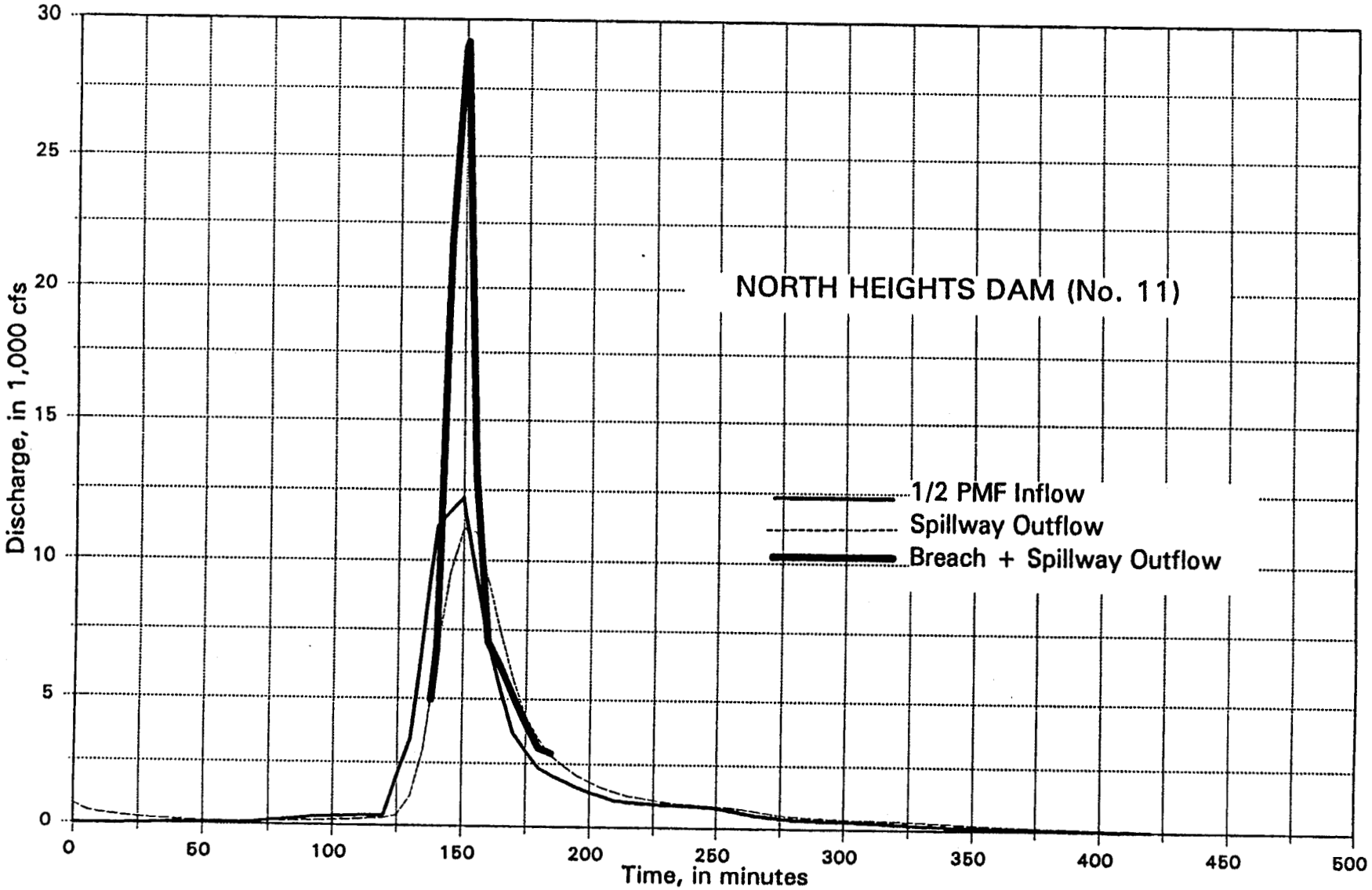


FIGURE 12

Inflow, spillway, and breach hydrographs for North Heights Dam

SunRidge Canyon Dam - The embankment of SunRidge Canyon Dam is not overtopped by the 0.5 PMF inflow design flood, therefore, only a piping analysis is performed. The piping breach input parameters are shown in Table 12. It is noted that although SunRidge Canyon Dam is a zoned embankment, the core does not vary from the shell to the extent that is normal for a zoned dam. Selected pages of the Breach Program output are shown in Appendix N. The key results of the piping breach analysis are shown below:

time to start of breach	=	2.31 hours
time to peak outflow	=	2.51 hours
time to maximum breach	=	3.16 hours
breach width at peak outflow	=	25.6 ft.
breach depth	=	47.6 ft.
spillway outflow at peak	=	0.0 cfs
breach outflow at peak	=	22,290 cfs
total peak outflow	=	22,290 cfs.

Figure 13 shows the 0.5 PMF inflow hydrograph, the spillway outflow hydrograph without breach, and the combined spillway plus breach outflow hydrograph. The resulting combined outflow hydrograph is used for the flood inundation analysis.

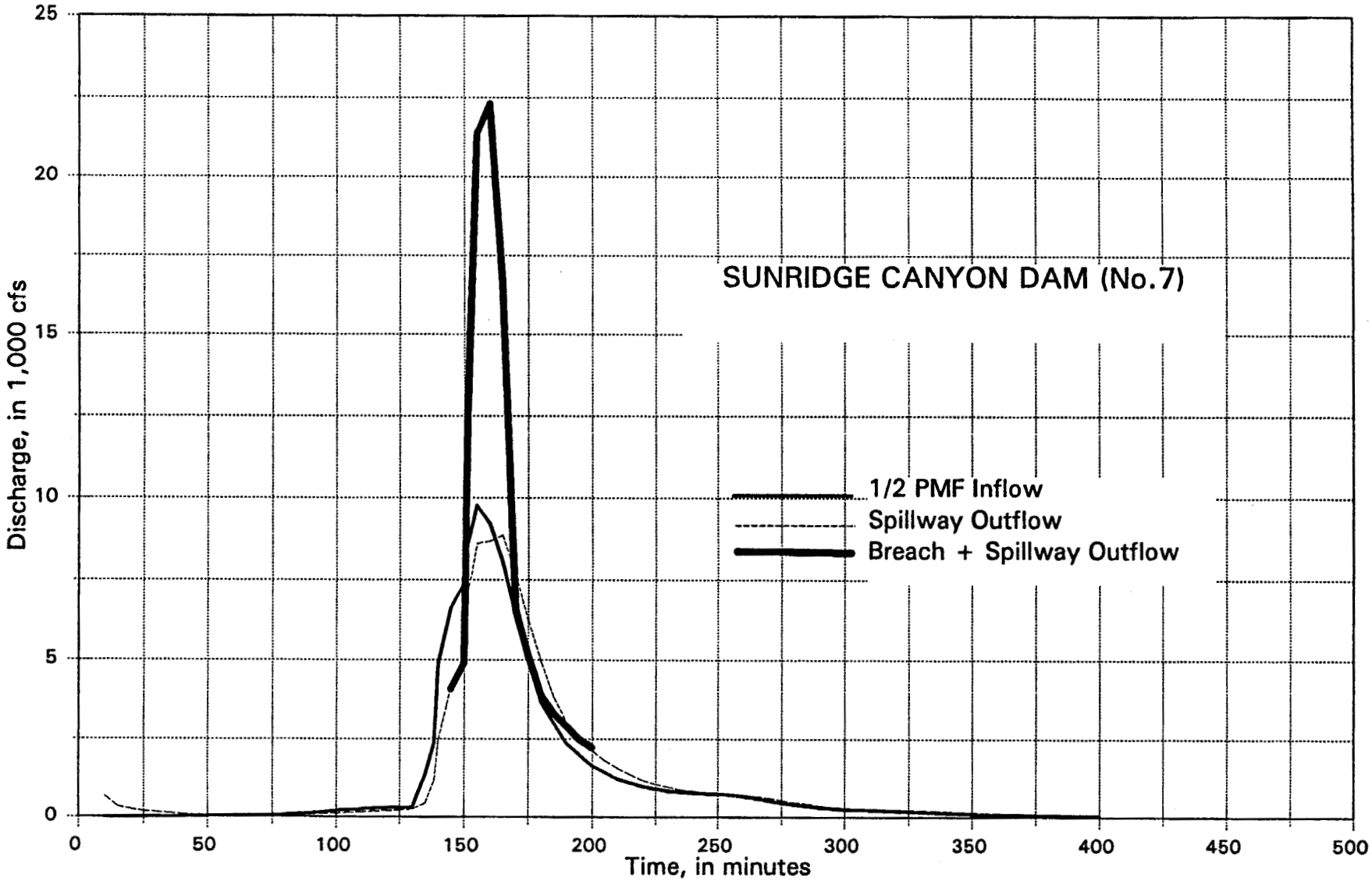


FIGURE 13

Inflow, spillway, and breach hydrographs for SunRidge Canyon Dam

Hesperus Wash Dam - The embankment of Hesperus Wash Dam is overtopped to a maximum depth of 0.5 feet for a total overtopping duration of 26 minutes. Analysis by the Breach Program does not indicate that the embankment will fail by overtopping, therefore, only the results for the piping analysis are presented. The piping breach input parameters are shown in Table 12. Selected pages of the Breach Program output are shown in Appendix O. The key results of the piping breach analysis are shown below:

time to start of breach	=	2.70 hours
time to peak outflow	=	2.99 hours
time to maximum breach	=	3.70 hours
breach width at peak outflow	=	30.0 ft.
breach depth	=	42.2 ft.
spillway outflow at peak	=	0.0 cfs
breach outflow at peak	=	30,150 cfs
total peak outflow	=	30,150 cfs.

Figure 14 shows the 0.5 PMF inflow hydrograph, the spillway outflow hydrograph without breach, and the combined spillway plus breach outflow hydrograph. The resulting combined outflow hydrograph is used for the flood inundation analysis.

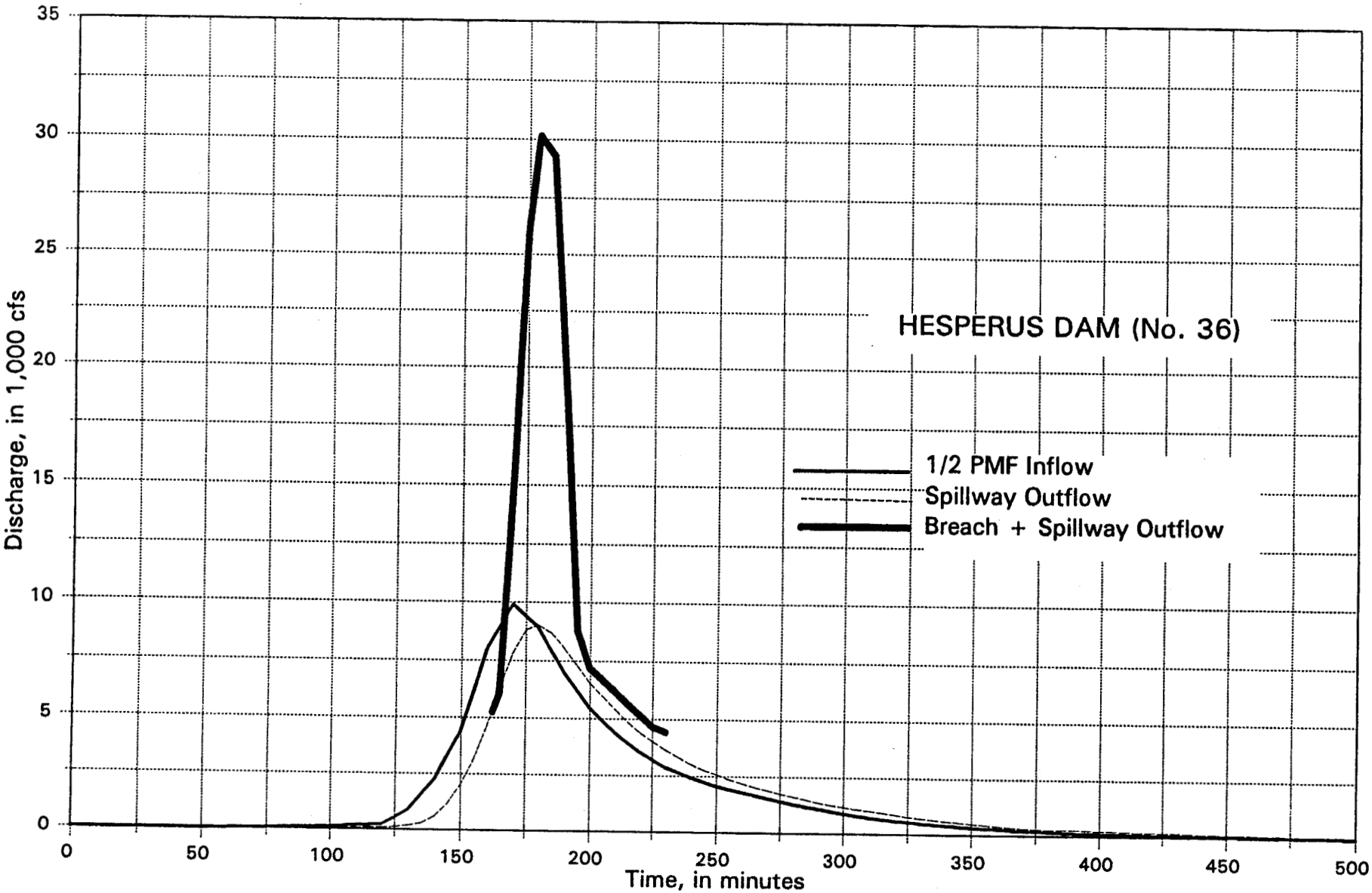


FIGURE 14

Inflow, spillway, and breach hydrographs for Hesperus Wash Dam

Golden Eagle Park Dam - The inflow design flood and subsequent breach analysis for Golden Eagle Park Dam assumes that during the flood both Aspen Dam and SunRidge Canyon Dam are releasing the spillway outflow hydrographs from the 0.5 PMF inflow design floods, and that North Heights Dam fails due to piping and the combined spillway plus breach outflow hydrograph is released. It is also assumed that the watershed above Golden Eagle Park Dam and below the three upstream dams is experiencing a storm of 0.5 PMF magnitude. The HEC-1 Program is used to model the intervening drainage area for the PMP rainfall and the resulting 0.5 PMF runoff hydrograph is determined from that watershed area. The HEC-1 Program is then used to combine the 0.5 PMF inflow hydrograph from the intervening drainage area with the routed spillway release hydrographs from the Aspen and SunRidge Canyon Dams and the routed combined spillway and breach outflow hydrograph from the North Heights Dam. The combined inflow from those sources is the 0.5 PMF inflow design flood for Golden Eagle Park Dam. This assumption is more severe than if no upstream dam breach is assumed, however, it is reasonable for the intent of this study. It is unlikely, and would be unrealistic, to assume that two or three of the upstream dams failed due to piping in estimating the 0.5 PMF inflow design flood for Golden Eagle Park Dam. HEC-1 output files for Golden Eagle Park Dam are provided in Appendix P.

The 0.5 PMF inflow design flood results in overtopping of Golden Eagle Park dam by 3.8 feet, therefore, both overtopping and piping breach analyses are performed. The breach input parameters are shown in Table 12. Selected pages of the Breach Program output are shown in Appendices Q and R for piping breach and overtopping breach, respectively.

The key results of the piping breach analysis are shown below:

time to start of breach	=	2.38 hours
time to peak outflow	=	2.60 hours
time to maximum breach	=	3.38 hours
breach width at peak outflow	=	26.8 ft.
breach depth	=	26.8 ft.
spillway outflow at peak	=	23,130 cfs
breach outflow at peak	=	23,260 cfs
total peak outflow	=	46,390 cfs.

Figure 15 shows the 0.5 PMF inflow hydrograph, the spillway outflow hydrograph without breach, and the combined spillway plus piping breach outflow hydrograph. The resulting combined outflow hydrograph is used for the flood inundation analysis.

The key results of the overtopping breach analysis are shown below:

time to start of breach	=	2.38 hours
time to peak outflow	=	2.63 hours
time to maximum breach	=	4.50 hours
breach width at peak outflow	=	22.7 ft.
breach depth	=	26.8 ft.
spillway outflow at peak	=	16,980 cfs
breach outflow at peak	=	26,450 cfs
total peak outflow	=	43,430 cfs.

Figure 16 shows the 0.5 PMF inflow hydrograph, the spillway outflow hydrograph without breach, and the combined spillway plus overtopping breach outflow hydrograph.

Inspection of these results and Figures 15 and 16 indicates that the piping breach results in a larger peak outflow from Golden Eagle Park Dam, and that breach is used for the flood inundation analysis.

A diskette of Breach Program input and output files is provided for each of the breach analyses.

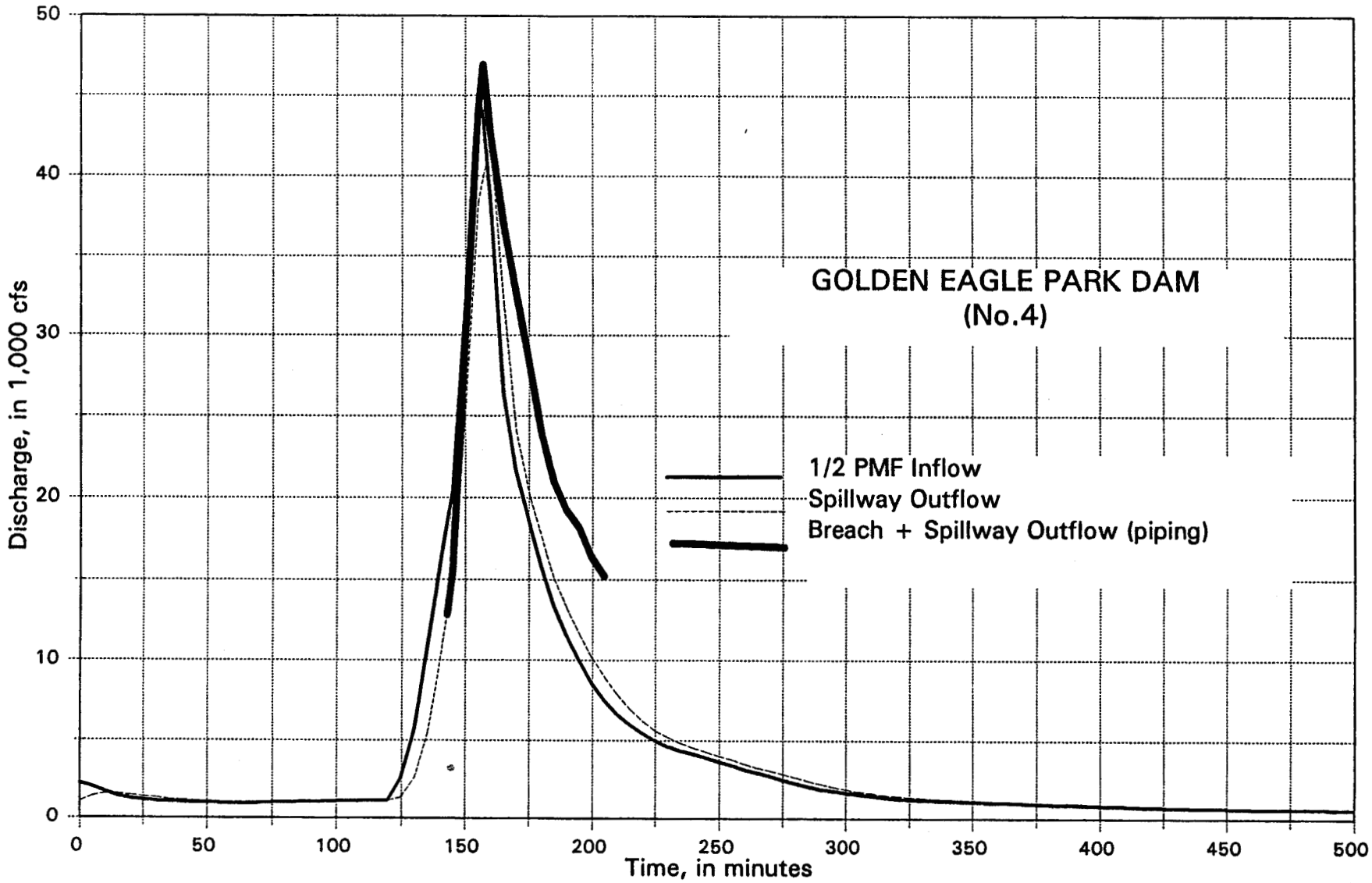


FIGURE 15

Inflow, spillway, and piping breach hydrographs for Golden Eagle Park Dam

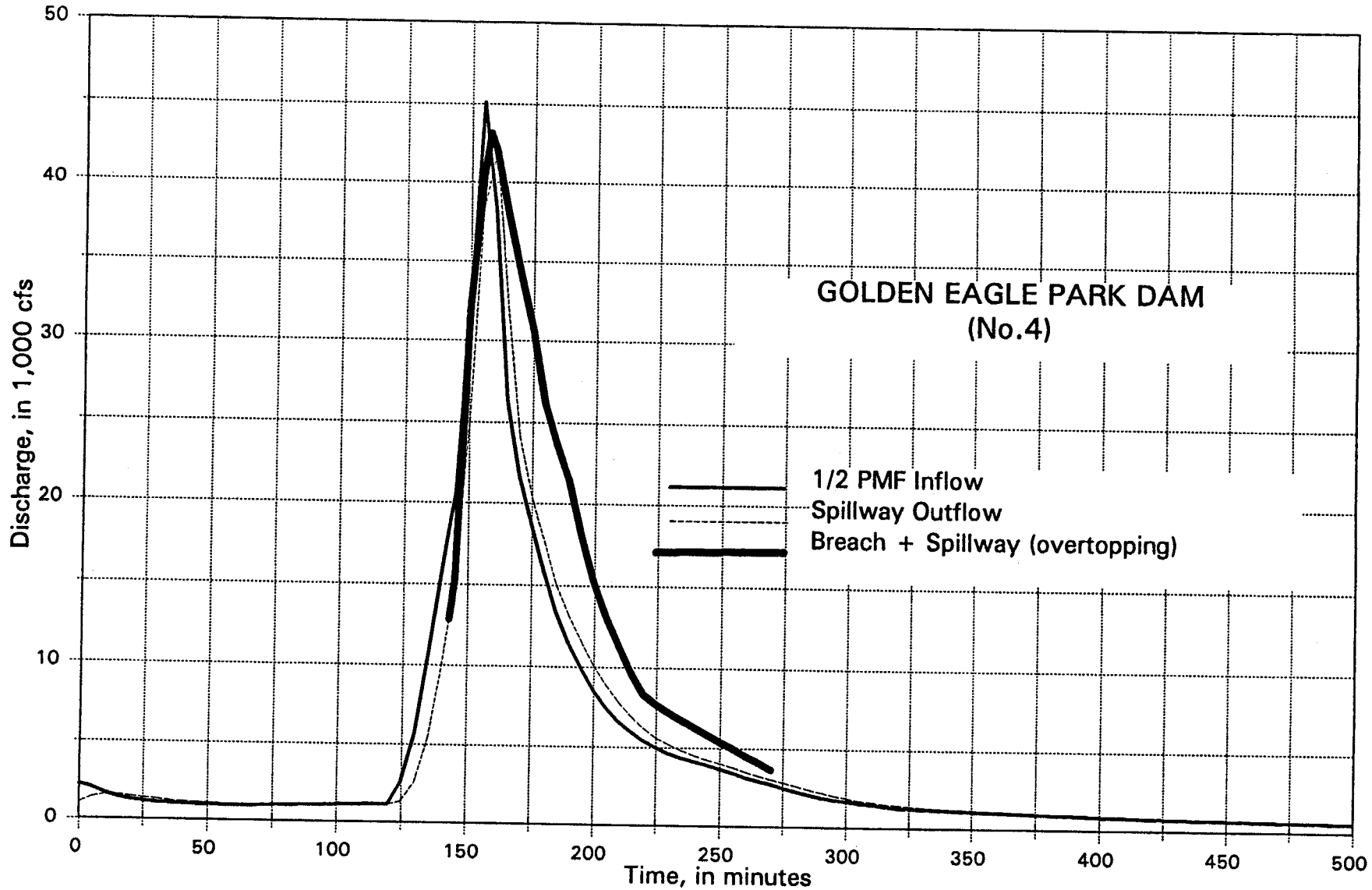


FIGURE 16

Inflow, spillway, and overtopping breach hydrograph for Golden Eagle Park Dam

FLOOD INUNDATION MAPS

General

The watercourses below each dam that are subject to flood inundation as a consequence of dam breach are delineated and the results are presented in this section. The flood inundation analyses are performed by unsteady flow routing of the dam breach hydrographs through the appropriate downstream watercourses. The unsteady flow routing is by the NWS Dam Break Program.

The best available topographic maps are used for each section of watercourse. Three sources of maps are available. Much of the inundation mapping is shown on the topographic maps that were used for the Ftn Hills FDS project. Recent land development and golf course construction resulted in significant grading of the watercourses downstream of SunRidge Canyon and North Heights Dams and the Ftn Hills FDS topographic maps are not adequate for those dam flood inundation zones because of the grading changes. For those two dams, the golf course grading plans were obtained from the golf course designer, Keith Foster & Associates, and those grading plans are used to define the watercourse geometry and for flood inundation mapping. Detailed topographic maps are not available for Ashbrook Wash from the boundary of the Fort McDowell Indian Reservation to the Verde River, and for that section of watercourse, the Granite Reef USGS quadrangle map is used.

Methodology

The dam breach hydrographs that are presented in the previous section are routed by the Dam Break Program through respective watercourses. Watercourse cross section geometry is obtained from the appropriate topographic maps. Where the Ftn Hills FDS maps are used, the cross sections correspond to the HEC-2 floodplain analysis cross sections that were developed for that project. Where either the golf course grading plans or the USGS map are used, the cross section geometry is taken from those maps.

The breach hydrographs are input to the Dam Break models as the inflow to the upper end of each routing reach. The Dam Break program option for developing the breach hydrograph is not used.

For Hesperus Wash Dam, the piping breach hydrography is routed from the dam through Balboa Wash to its confluence with Ashbrook Wash. On the hydrology map (Exhibit D), that routing is from concentration point 536 to concentration point 549.

For Golden Eagle Park Dam, the piping breach hydrograph is routed from the dam through Ashbrook Wash to its confluence with Balboa Wash. For Ashbrook Wash, from its confluence with Balboa Wash to the Verde River, the flood hydrograph at the confluence is the summation of the Golden Eagle Park Dam breach hydrograph at the confluence plus the Hesperus Wash Dam spillway hydrograph routed to the confluence. Those two hydrographs are translated in time so that the peak discharges from the two dams coincide. On the hydrology map (Exhibit D), that routing is from concentration point 599 to concentration point 549 for the Golden Eagle Park Dam breach hydrograph and is from concentration point 549 to the Verde River for the combined Golden Eagle Park Dam breach plus Hesperus Wash Dam spillway release discharge.

For Aspen Dam, the piping breach hydrograph is routed from the dam through Ashbrook Wash to Golden Eagle Park Dam. On the hydrology map (Exhibit D), that routing is from concentration point 560 to concentration point 599.

For North Heights Dam, the piping breach hydrograph is routed from the dam through Bristol Wash (the SunRidge Canyon golf course) to Golden Eagle Park Dam. On the hydrology map (Exhibit D), that routing is from concentration point 578 to concentration point 599.

For SunRidge Canyon Dam, the piping breach hydrograph is routed from the dam through Cloudburst Wash (the SunRidge Canyon golf course) to Golden Eagle Park Dam. On the hydrology map (Exhibit D), that routing is from concentration point 584 to concentration point 599.

The Manning roughness coefficient is input for each routing cross section in the Dam Break program. Roughness coefficients are selected based on field reconnaissance and review of information in the Ftn Hills FDS floodplain delineation HEC-2 models. The routing for Hesperus Wash Dam used channel and overbank composite roughness coefficients that range from about 0.05 to 0.11. The routing for Golden Eagle Park Dam used composite

roughness coefficients that range from about 0.05 to 0.12. The watercourses for those two dams are in a natural condition with reaches of dense vegetation and other significant roughness conditions. The relatively short watercourse below Aspen Dam has roughness coefficients that range from about 0.05 to 0.06. The watercourses below North Heights and SunRidge Canyon Dams are golf courses and the resistance to flow is considerably low. For North Heights and SunRidge Canyon Dams, the coefficients range from about 0.04 to 0.06 and 0.03 to 0.06, respectively.

The Dam Break input and summary of the key output for each of the flood routing analyses are provided in Appendices S through X. The Dam Break input and output files are provided on a diskette.

The results from the Dam Break models for each watercourse are used to produce the flood inundation maps. The calculated water surface elevation of each cross section is marked on the appropriate map. The flood inundation zones are determined by interpolation between the water surface elevations at each cross section. Flood inundation zones immediately downstream of each dam are determined by interpretation of the contour maps to include the area of the emergency spillway and across the dam to the opposite abutment.

Inundation Maps

Inundation maps are shown on Plates 1 through 11. An index of the flood inundation maps is shown in Table 13, and the source of the topographic map for each plate is identified.

The Hesperus Wash Dam flood inundation is shown in Plates 1 through 3. Those plates use the Ftn Hills FDS topographic maps as the base. The Golden Eagle Park Dam flood inundation is shown in Plates 4 through 6, which also use the Ftn Hills FDS topographic maps as the base. The inundation from the combined Golden Eagle Park Dam breach plus the Hesperus Wash Dam spillway release is shown from the confluence of Ashbrook Wash and Balboa Wash to the Verde River on Plates 6 and 7. Plate 6 uses the Ftn Hills FDS topographic map that is available to the boundary of the Town of Fountain Hills. Plate 7 is an aerial photograph of the Ashbrook Wash region from the boundary of the Town of Fountain Hills to the Verde River, and contour lines are shown that are taken from an enlargement of the Granite Reef USGS quad map. That aerial photograph is used in

TABLE 13

Index for dam break inundation maps

Dam	Inundation Map	Map Source
(1)	(2)	(3)
Hesperus Wash	Plate 1	Ftn Hills FDS, sheet 1
	Plate 2	Ftn Hills FDS, sheet 2
	Plate 3	Ftn Hills FDS, sheet 3
Golden Eagle Park	Plate 4	Ftn Hills FDS, sheet 4
	Plate 5	Ftn Hills FDS, sheet 5
	Plate 6	Ftn Hills FDS, sheet 3
	Plate 7	USGS map plus aerial photo
Aspen	Plate 8	Ftn Hills FDS, sheet 5
North Heights	Plate 9	Keith Foster & Assoc., page 4B
SunRidge Canyon	Plate 10	Keith Foster & Assoc., page 4A
	Plate 11	Keith Foster & Assoc., page 4C

place of more detailed topographic mapping. The Aspen Dam flood inundation is shown in Plate 8, which is on the Ftn Hills FDS topographic map. The North Height Dam flood inundation is shown in Plate 9, which is a map of the golf course grading plan. The SunRidge Canyon Dam flood inundation is shown in Plates 10 and 11, which are maps of the golf course grading plan.

A summary of the peak discharge attenuations for each routing reach and the peak discharge travel times are provided in Table 14. All of the routing reach lengths are quite short (less than 3 miles) and the peak discharge attenuation is minimal for most reaches. The peak discharge travel times are very short, and this coupled with the relatively short breach times (typically less than 3 hours) results in the need for rapid evacuation of the affected areas in the event of potential dam breach.

TABLE 14

Summary of flood attenuation and peak discharge travel times

Dam	Routing Reach	Reach Length miles	Peak discharge, in cfs		Travel Time hours
			Start	End	
(1)	(2)	(3)	(4)	(5)	(6)
Hesperus Wash	dam to confluence with Ashbrook Wash	2.80	30,200	26,400	0.58
Golden Eagle Park	dam to confluence with Balboa Wash	1.71	46,400	40,600	0.32
Golden Eagle Park plus Hesperus Wash	confluence of Ashbrook Wash and Balboa Wash to Verde River	1.88	49,300	46,900	0.40
Aspen	dam to Golden Eagle Park Dam	0.61	24,800	23,400	0.26
North Heights	dam to Golden Eagle Park Dam	0.71	29,200	27,700	0.12
SunRidge Canyon	dam to Golden Eagle Park Dam	1.22	22,300	20,300	0.20

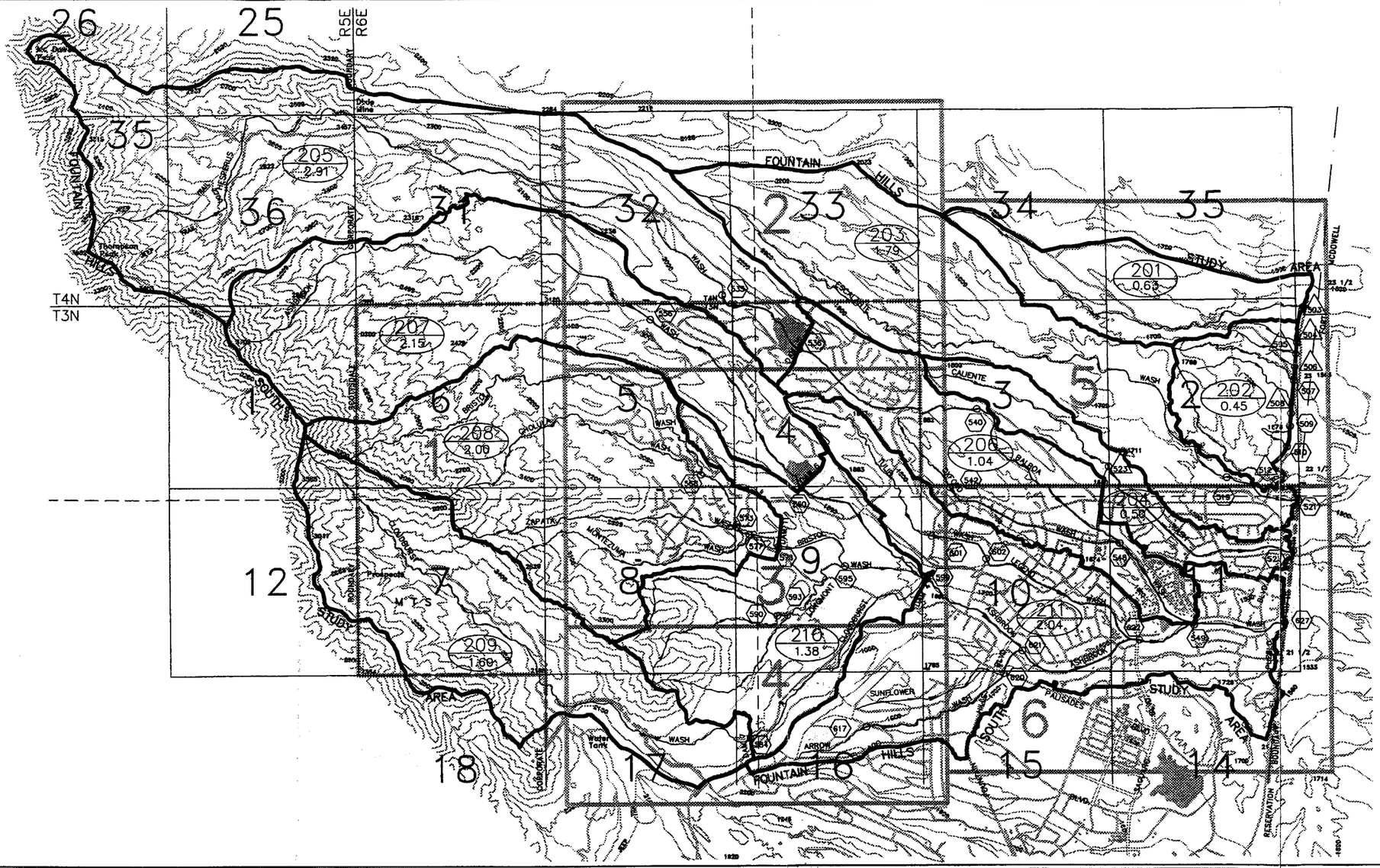
REFERENCES

Flood Control District of Maricopa County, 1992, Drainage Design Manual for Maricopa County, Volume 1, Hydrology: revised 1995, Phoenix, AZ.

Hansen, E.M., Shwarz, F.K., and Riedel, J.T., 1984, Probable maximum precipitation estimates, Colorado River and Great Basin drainages: Hydrometeorological Report No. 49, National Weather Service, Silver Springs, MD, 161 p.

Soil Conservation Service, 1985, Soil survey of Aquila - Carefree area, parts of Maricopa and Pinal Counties, Arizona: U.S. Dept. of Agriculture.

U.S. Army Corps of Engineers, 1991, HEC-1 Flood Hydrology Package, Users Manual: Hydrologic Engineering Center, Davis, CA, 32 p. plus appendices.



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

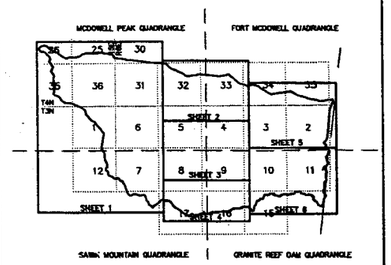
F.C.D. CONTRACT NO. **FCD 92-04**

LEGEND

- MAJOR BASIN NUMBER / AREA IN SQUARE MILES — 201 / 0.63
- KEY CONCENTRATION POINT
- HEC-1 IDENTIFIER AT KEY CONCENTRATION POINT 584
- HEC-1 IDENTIFIER FOR DIVERSION AT KEY CONCENTRATION POINT 523
- MAJOR DRAINAGE BASIN BOUNDARY
- HEC-2 STUDY REACH
- WASH FLOW PATH
- FORT MCDOWELL INDIAN RESERVATION BOUNDARY
- FOUNTAIN HILLS CORPORATE BOUNDARY
- RANGE AND TOWNSHIP BOUNDARY
- USGS QUADRANGLE MAP BOUNDARY
- SECTION LINE
- SHEET BOUNDARY FOR EXHIBIT "D"

NOTES

INDEX MAP



HYDROLOGY EXHIBIT "A"

DRAINAGE BASIN MAP AND SHEET INDEX FOR EXHIBIT "D"

1500 0' 1500 3000

SCALE: 1" = 1500'
CONTOUR INTERVAL = 20FEET

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	–
DESIGN CHK.	N/A	–
PLANS	PK	7/94
PLANS CHK.	TRL	7/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 1

Drawing Name: \P\FHILLS\ACAD\EX-A.dwg
Date: REV. 17 OCT 1994 08:00am

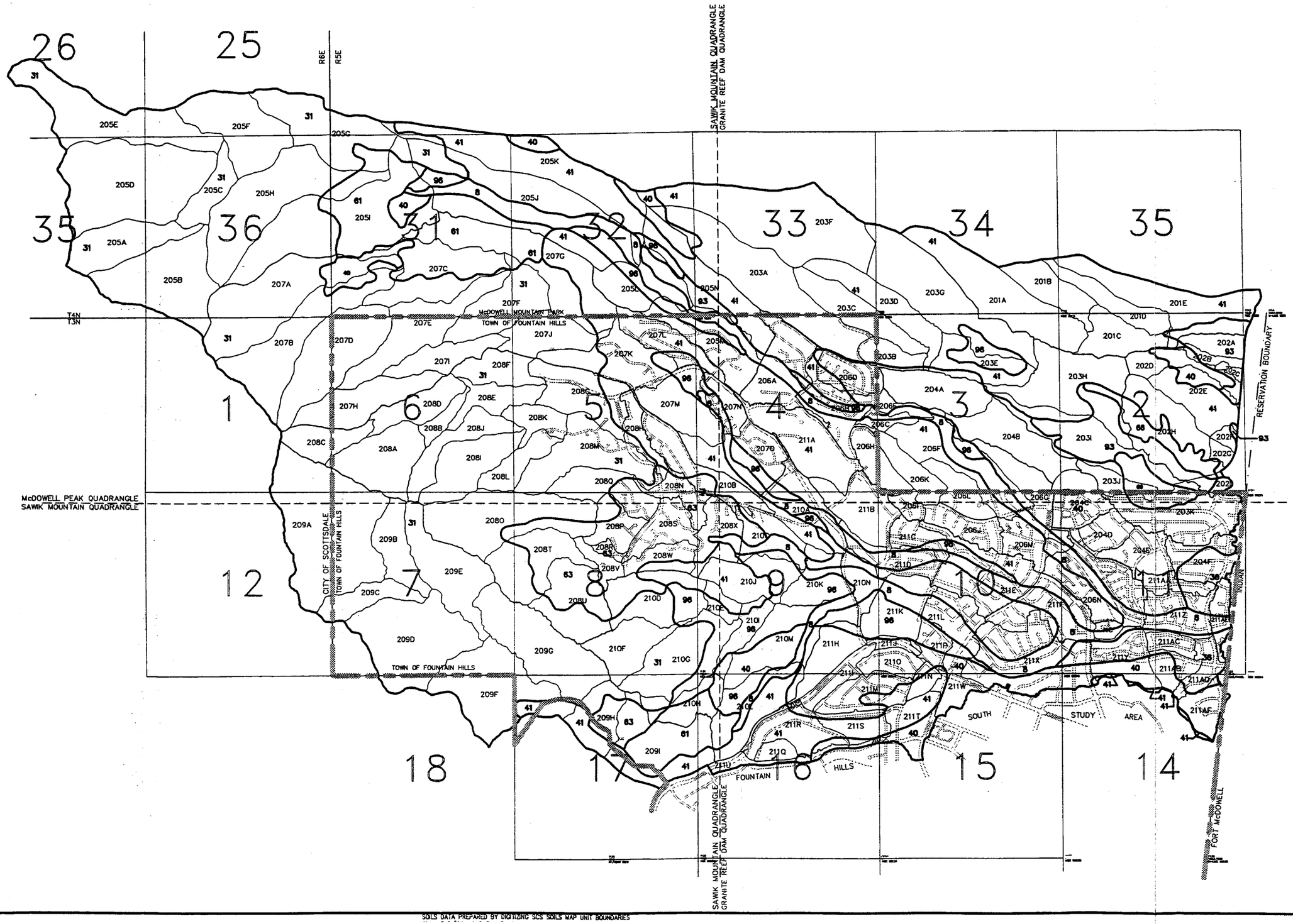
SUMMARY OF 100-YEAR PEAK DISCHARGES FOR DETAILED HYDROLOGIC ANALYSIS STUDY AREA

HEC-1 Identifier	Description	Peak Discharge (cfs)	Area (sm)
D503L	Culvert 503 flow into Ft. McDowell Indian Reservation.	323	0.63
D504L	Culvert 504 flow into Ft. McDowell Indian Reservation.	22	0.67
D505L	Culvert 505 flow into Ft. McDowell Indian Reservation.	14	0.69
D506L	Culvert 506 flow into Ft. McDowell Indian Reservation.	0	0.69
C5070	Culvert 507 on McDowell Mountain Road.	203	0.86
D508R	Culvert 508 flow into Ft. McDowell Indian Reservation.	72	0.10
C509	Culvert 509 flow at Ft. McDowell Indian Reservation.	36	0.01
C510	Culvert 510 flow at Ft. McDowell Indian Reservation.	38	0.01
D512L	Stock Tank flow into Ft. McDowell Indian Reservation.	72	0.20
C519	Escalante Wash start of Floodplain Delineation.	1406	1.59
C521	Escalante Wash at Ft. McDowell Indian Reservation.	1407	1.99
D523L	Culvert 523 flow in Caliente Wash.	266	0.23
C527	Caliente Wash at Ft. McDowell Indian Reservation (Culvert 527).	665	0.50
C535	Hesperus Wash start of Floodplain Delineation.	2520	2.62
C536I	Dam 36, inflow.	2586	2.91
C536O	Dam 36, outflow.	326	2.91
C540	End Hesperus Wash, start Balboa Wash.	560	3.24
C542	Oxford Wash, start of Floodplain Delineation.	153	0.06
C548L	Balboa Wash U/S of confluence with Oxford Wash.	721	3.72
C548R	Oxford Wash U/S of confluence with Balboa Wash.	635	0.32
C548	Confluence of Oxford and Balboa Washes.	1038	4.04
C549L	Balboa Wash U/S of confluence with Ashbrook Wash.	1128	4.19
C549R	Ashbrook Wash U/S of confluence with Balboa Wash.	2112	8.87
C549	Confluence of Balboa and Ashbrook Washes.	3095	13.06

HEC-1 Identifier	Description	Peak Discharge (cfs)	Area (sm)
C556	Ashbrook Wash, start of Floodplain Delineation.	1752	1.64
C560I	Dam 6, inflow.	1989	2.15
C560O	Dam 6, outflow.	287	2.15
C568L	Bristol Wash U/S of confluence with Cholula Wash.	961	0.61
C568R	Cholula Wash U/S of confluence with Bristol Wash.	701	0.46
C568	Confluence of Cholula and Bristol Washes.	1428	1.07
C573L	Bristol Wash U/S of confluence with Zapata Wash.	1460	1.12
C573R	Zapata Wash U/S of confluence with Bristol Wash.	772	0.46
C573	Confluence of Zapata and Bristol Washes.	1872	1.58
C577L	Bristol Wash U/S of confluence with Montezuma Wash.	1872	1.58
C577R	Montezuma Wash U/S of confluence with Bristol Wash.	800	0.34
C577	Confluence of Montezuma and Bristol Washes.	2187	1.92
C578I	Dam 11, inflow.	2231	2.00
C578O	Dam 11, outflow.	381	2.00
C584I	Dam 7, inflow.	1999	1.60
C584O	Dam 7, outflow.	469	1.60
C590L	Longmont Wash Left Branch U/S of confluence with Main Branch.	353	0.17
C590R	Longmont Wash Main Branch U/S of confluence with Main Branch	472	0.25
C590	Confluence of Left and Main Branches of Longmont Wash.	819	0.42
C593L	Longmont Wash Main Branch U/S of confluence with Right Branch.	819	0.42
C593R	Longmont Wash Right Branch U/S of confluence with Main Branch.	158	0.07

HEC-1 Identifier	Description	Peak Discharge (cfs)	Area (sm)
C593	Confluence of Right and Main Branches of Longmont Wash.	972	0.49
C595L	Bristol Wash U/S of confluence with Longmont Wash.	468	2.19
C595R	Longmont Wash U/S of confluence with Bristol Wash.	1119	0.64
C595	Confluence of Longmont and Bristol Washes.	1205	2.83
C599I	Dam 4, inflow.	1967	7.13
C599O	Dam 4, outflow.	966	7.13
C601	Tulip Wash, start of Floodplain Delineation.	462	0.25
C602	End Tulip Wash, start Legend Wash.	635	0.37
C617	Arrow Wash, start of Floodplain Delineation.	270	0.13
C620L	Sunflower Wash U/S of confluence with Arrow Wash (Culvert 611).	151	0.14
C620R	Arrow Wash U/S of confluence with Sunflower Wash (Culvert 619).	335	0.28
C620	Confluence of Sunflower and Arrow Washes.	485	0.42
C621L	Ashbrook Wash U/S of confluence with Arrow Wash.	975	7.64
C621R	Arrow Wash U/S of confluence with Ashbrook Wash.	482	0.42
C621	Confluence of Arrow and Ashbrook Washes.	1184	7.93
C622L	Legend Wash U/S of confluence with Ashbrook Wash.	1121	0.63
C622R	Ashbrook Wash U/S of confluence with Legend Wash.	1384	8.14
C622	Confluence of Legend and Ashbrook Washes.	2053	8.78
C627	Ashbrook Wash at Ft. McDowell Indian Reservation.	3187	13.32

THIS MAP WAS PREPARED USING THE USGS QUADRANGLE MAPS FOR BASE TOPOGRAPHY. REFER TO SECTION 2 OF THE HYDROLOGY REPORT.



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

F.C.D. CONTRACT NO. FCD 92-04

LEGEND

MAJOR DRAINAGE BASIN BOUNDARY	
DRAINAGE SUB-BASIN BOUNDARY	
DRAINAGE SUB-BASIN IDENTIFIER	202A
SCS SOILS MAP UNIT BOUNDARY	
SCS SOILS MAP UNIT IDENTIFIER	41
SECTION LINE	
TOWNSHIP AND RANGE LINE	
USGS QUADRANGLE MAP BOUNDARY	
TOWN OF FOUNTAIN HILLS BOUNDARY	
FORT McDOWELL INDIAN RESERVATION BOUNDARY	

HYDROLOGY EXHIBIT "B"

DRAINAGE SUB-BASIN SOILS MAP

1000 0' 1000 2000

SCALE: 1" = 1000'

CONTOUR INTERVAL = NONE

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	–
DESIGN CHK.	N/A	–
PLANS	PK	10/93
PLANS CHK.	TRL	10/93
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

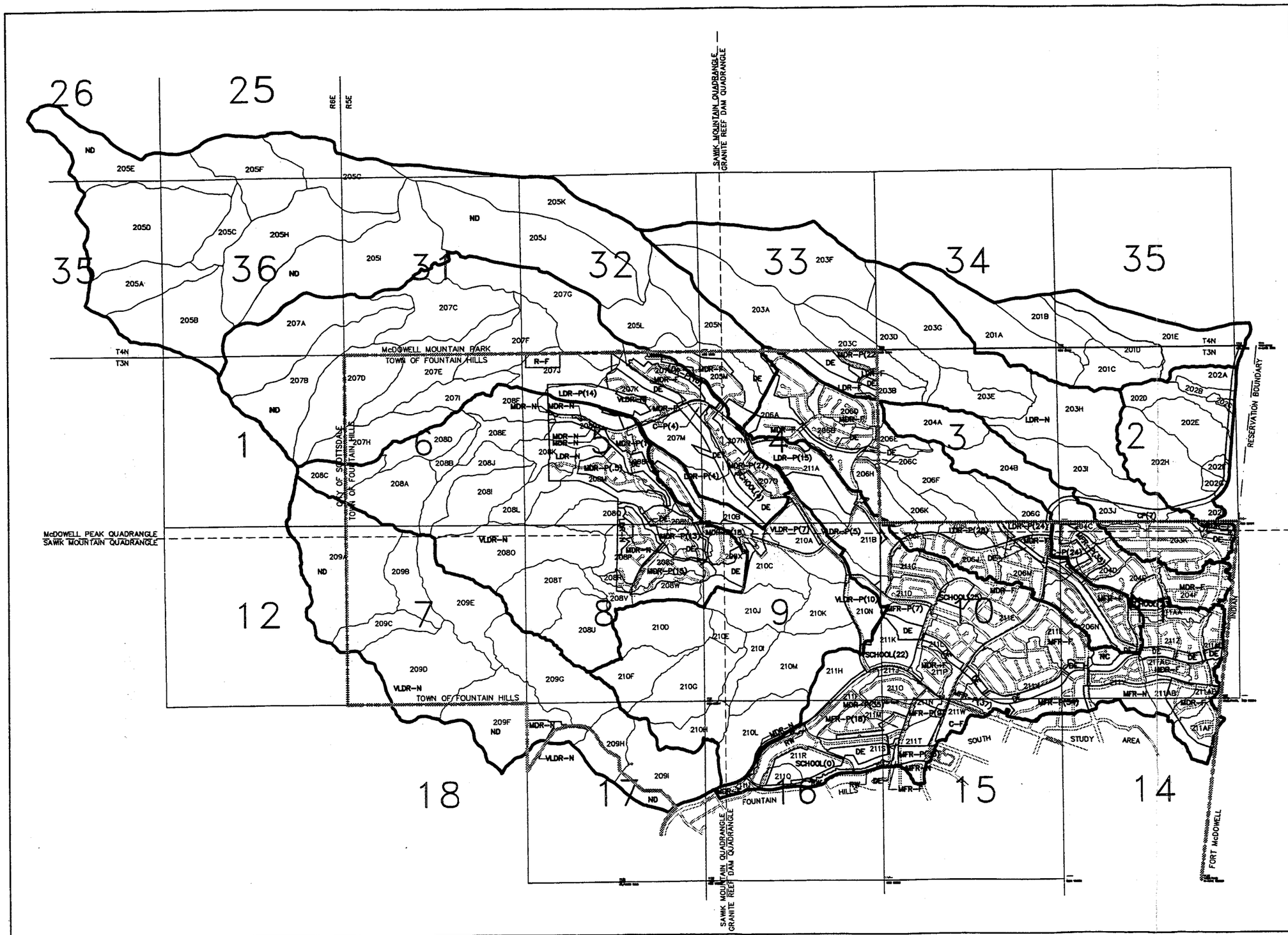
RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 1

SOILS DATA PREPARED BY DIGITIZING SCS SOILS MAP UNIT BOUNDARIES



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

F.C.D. CONTRACT NO. FCD 92-04

LEGEND

MAJOR DRAINAGE BASIN BOUNDARY	
DRAINAGE SUB-BASIN BOUNDARY	
DRAINAGE SUB-BASIN IDENTIFIER	203E
LAND USE BOUNDARY	
LAND USE IDENTIFIERS:	
Very Low Density Residential	VLDR
Light Density Residential	LDR
Medium Density Residential	MDR
Multi-Family Residential	MFR
Commercial	C
Industrial	I
Schools	School
Drainage Easement	DE
Street Right-of-Way	RW
Natural Desert	ND
Qualifers:	
Fully Developed	F
Less Than 50% Developed	P
Undeveloped	N
Value in parenthesis is estimated % impervious	(##)

Example: VLDR-P(23) indicates a partially developed VLDR land use with an estimated average percent impervious value of 23% for the entire parcel.

SECTION LINE	
RANGE AND TOWNSHIP BOUNDARY	
USGS QUADRANGLE MAP BOUNDARY	
TOWN OF FOUNTAIN HILLS BOUNDARY	
FORT McDOWELL INDIAN RESERVATION BOUNDARY	

HYDROLOGY EXHIBIT "C"

DRAINAGE SUB-BASIN LAND USE MAP

1000 0' 1000 2000

SCALE: 1" = 1000'

CONTOUR INTERVAL = NONE

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

DESIGN	BY N/A	DATE –
DESIGN CHK.	N/A	–
PLANS	PK	10/93
PLANS CHK.	TRL	10/93
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

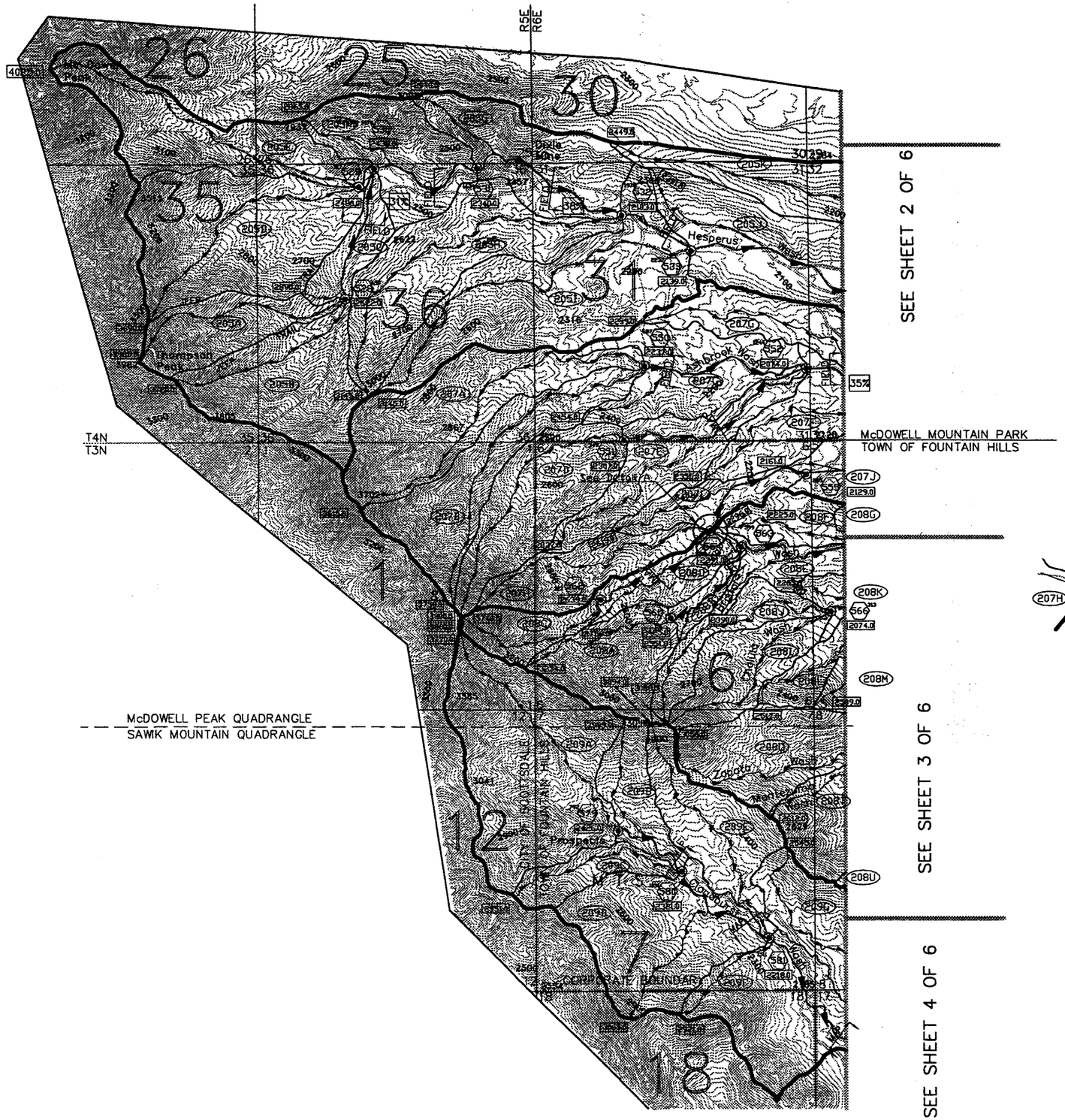
APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 1

Dwg. Name: P:\FTHILLS\VLDTEX-C.dwg
Date: REV. OCT. 17, 1994 08:00am

THIS MAP WAS PREPARED USING THE TOWN OF FOUNTAIN HILLS ZONING MAP (In AutoCAD format) AS A BASE. THE ZONING MAP AUTOCAD FILE IS DATED 11/92.



DETAIL A

THE TOPOGRAPHY ON WHICH THIS MAP IS BASED (USGS MAPPING) CAME FROM THE REFERENCED USGS QUADRANGLE MAPS (7.5 MINUTE, 1"=2000'). ONLY 100-FOOT CONTOURS ARE SHOWN.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

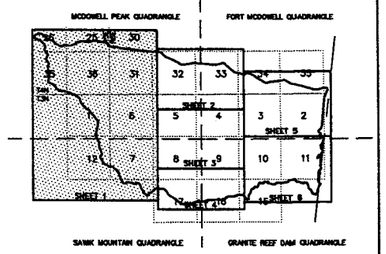
F.C.D. CONTRACT NO. FCD 92-04

LEGEND

NOTE: ALL FLOW RATES ARE FOR THE 100-YEAR PEAK DISCHARGE.

- DRAINAGE SUB-BASIN IDENTIFIER FOR SUBBASIN 207L — 207L
- DRAINAGE SUB-BASIN CONCENTRATION POINT 552 PEAK DISCHARGE IS 1244 cfs — 552
- HEC-1 RESERVOIR ROUTE AT CONCENTRATION POINT 513 INFLOW IS 389 cfs, OUTFLOW IS 389 cfs — 513
- DRAINAGE SUB-BASIN FLOW SPLIT CONCENTRATION POINT 505 PEAK DISCHARGE IS 32 cfs; 18 cfs SPLIT RIGHT, and 14 cfs SPLIT LEFT. — 505
- HEC-1 RESERVOIR ROUTE AND FLOW SPLIT AT CONCENTRATION POINT 523. PEAK INFLOW IS 386 cfs, OUTFLOW IS 286 cfs; 19 cfs SPLIT RIGHT, 266 cfs SPLIT LEFT. — 523
- ELEVATION AT CONCENTRATION POINT OR TOP OF Tc PATH — 1972.0
- VEGETATION COVER DENSITY (FIELD MEASURED) — 35%
- DRAINAGE SUB-BASIN CONCENTRATION POINT
- MAJOR DRAINAGE BASIN BOUNDARY
- DRAINAGE SUB-BASIN BOUNDARY
- HEC-1 ROUTING PATH
- Tc FLOW PATH
- FORT MCDOWELL INDIAN RESERVATION BOUNDARY
- CORPORATE BOUNDARY
- RANGE AND TOWNSHIP BOUNDARY
- USGS QUADRANGLE MAP BOUNDARY
- SECTION LINE
- LIMITS OF 200 SCALE MAPPING
- HEC-1 REACH ROUTE CROSS SECTION LOCATION Ashbrook Wash HEC-2 Section 5.254 — AS-5.254
- Field Survey Cross Section — FIELD
- Cross Section From Available Mapping — MAP
- NON-CONTRIBUTING DRAINAGE AREA

INDEX MAP



HYDROLOGY EXHIBIT "D"

DRAINAGE SUB-BASIN DELINEATION TIME OF CONCENTRATION FLOW PATHS AND FLOOD ROUTING MAP

1000' 0' 1000' 2000'

SCALE: 1"= 1000'

CONTOUR INTERVAL = 20 FEET

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	–
DESIGN CHK.	N/A	–
PLANS	P.K.	8/94
PLANS CHK.	TRL	8/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

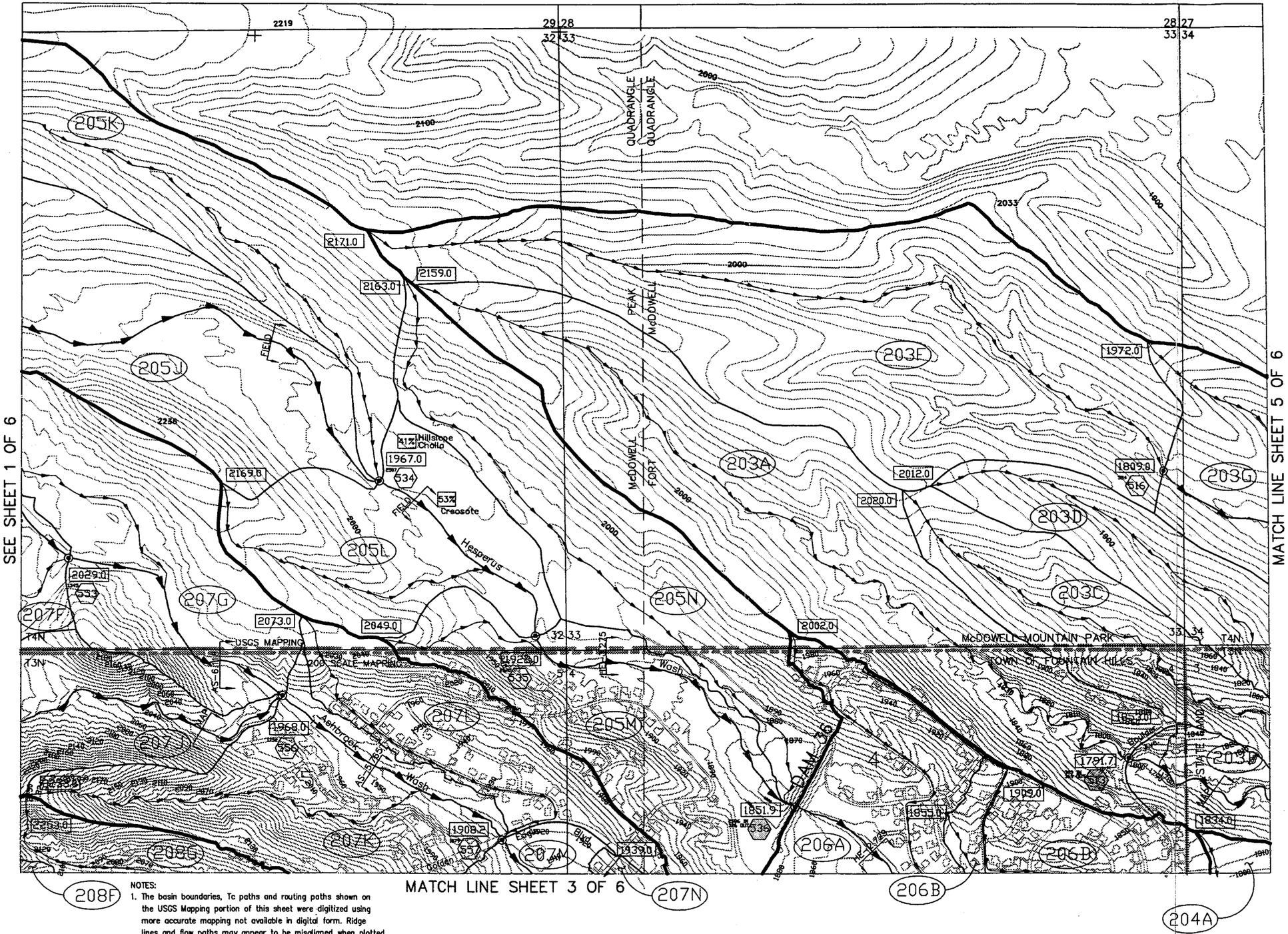
RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 6

Dwg. Name: \P\FTHILLS\ACAD\SHEET1.dwg
Date: REV. 17 OCT 1994 8:03am



NOTES:
1. The basin boundaries, Tc paths and routing paths shown on the USGS Mapping portion of this sheet were digitized using more accurate mapping not available in digital form. Ridge lines and flow paths may appear to be misaligned when plotted on the USGS Mapping in some locations.

200 Scale Mapping: Kennsey Aerial Mapping Flight Date = 8/91

USGS Mapping: US Geological Survey Flight Date = 1962

THE CONTOURS AND PLANIMETRICS FOR THE 200 SCALE MAPPING WERE PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS 1"=200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY DATA PROVIDED BY ANDERSON-NELSON, INC. THE CONTOURS FOR THE USGS MAPPING CAME FROM THE USGS QUADRANGLE MAPS(7.5 MINUTE, 1"=2000'). ONLY 10-FOOT CONTOURS ARE SHOWN FOR THE 200 SCALE MAPPING, AND 20-FOOT CONTOURS FOR THE USGS MAPPING.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

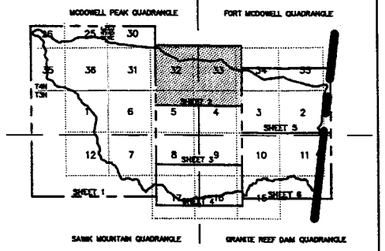
F.C.D. CONTRACT NO. FCD 92-04

LEGEND

NOTE: ALL FLOW RATES ARE FOR THE 100-YEAR PEAK DISCHARGE.

- DRAINAGE SUB-BASIN IDENTIFIER FOR SUBBASIN 207L — 207L
- DRAINAGE SUB-BASIN CONCENTRATION POINT 552 PEAK DISCHARGE IS 1244 cfs — 552
- HEC-1 RESERVOIR ROUTE AT CONCENTRATION POINT 513 INFLOW IS 389 cfs, OUTFLOW IS 369 cfs — 513
- DRAINAGE SUB-BASIN FLOW SPLIT CONCENTRATION POINT 505 PEAK DISCHARGE IS 32 cfs; 18 cfs SPLIT RIGHT, and 14 cfs SPLIT LEFT. — 505
- HEC-1 RESERVOIR ROUTE AND FLOW SPLIT AT CONCENTRATION POINT 523. PEAK INFLOW IS 386 cfs, OUTFLOW IS 286 cfs; 19 cfs SPLIT RIGHT, 266 cfs SPLIT LEFT. — 523
- ELEVATION AT CONCENTRATION POINT OR TOP OF Tc PATH — 1972.0
- VEGETATION COVER DENSITY (FIELD MEASURED) — 35%
- DRAINAGE SUB-BASIN CONCENTRATION POINT
- MAJOR DRAINAGE BASIN BOUNDARY
- DRAINAGE SUB-BASIN BOUNDARY
- HEC-1 ROUTING PATH
- Tc FLOW PATH
- FORT MCDOWELL INDIAN RESERVATION BOUNDARY
- CORPORATE BOUNDARY
- RANGE AND TOWNSHIP BOUNDARY
- USGS QUADRANGLE MAP BOUNDARY
- SECTION LINE
- LIMITS OF 200 SCALE MAPPING
- HEC-1 REACH ROUTE CROSS SECTION LOCATION Ashbrook Wash HEC-2 Section 5.254 — AS-5.254
- Field Survey Cross Section — FIELD
- Cross Section From Available Mapping — MAP
- NON-CONTRIBUTING DRAINAGE AREA

INDEX MAP



HYDROLOGY EXHIBIT "D"

DRAINAGE SUB-BASIN DELINEATION TIME OF CONCENTRATION FLOW PATHS AND FLOOD ROUTING MAP

N

400' 0' 400' 800'

SCALE: 1"= 400'

CONTOUR INTERVAL = VARIES

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	-
DESIGN CHK.	N/A	-
PLANS	PK	8/94
PLANS CHK.	TRL	8/94
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

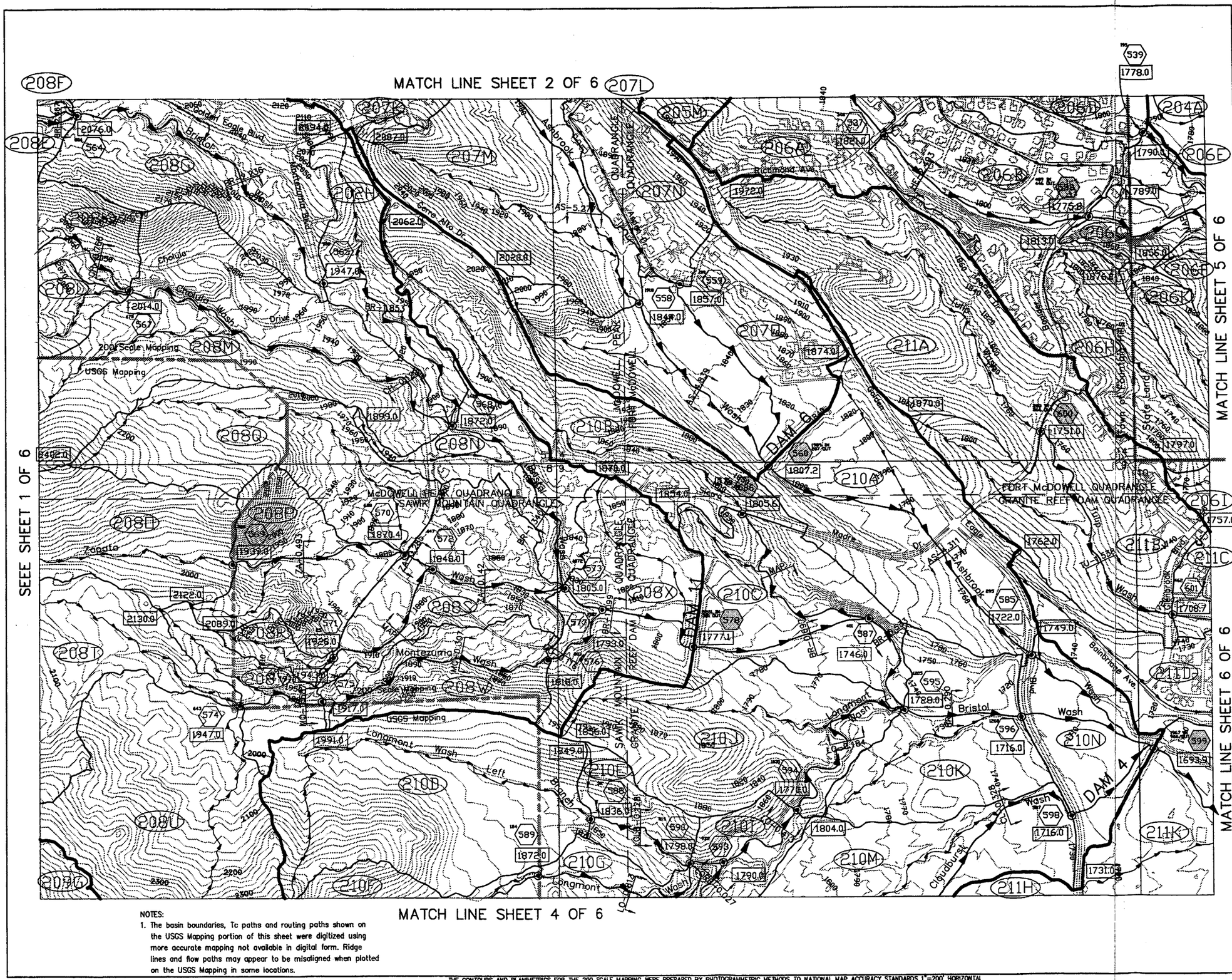
RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 2 OF 6

Dwg. Name: \P\FTHILLS\ACAD\SHEET2.dwg
Date: REV. 17 OCT 1994 8:04am



NOTES:

1. The basin boundaries, Tc paths and routing paths shown on the USGS Mapping portion of this sheet were digitized using more accurate mapping not available in digital form. Ridge lines and flow paths may appear to be misaligned when plotted on the USGS Mapping in some locations.

200 Scale Mapping: Kenney Aerial Mapping Flight Date = 8/91

USGS Mapping: US Geological Survey Flight Date = 1962

THE CONTOURS AND PLANIMETRICS FOR THE 200 SCALE MAPPING WERE PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS 1"=200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY DATA PROVIDED BY ANDERSON-NELSON, INC. THE CONTOURS FOR THE USGS MAPPING CAME FROM THE USGS QUADRANGLE MAPS(7.5 MINUTE, 1"=2000'). ONLY 10-FOOT CONTOURS ARE SHOWN FOR THE 200 SCALE MAPPING, AND 20-FOOT CONTOURS FOR THE USGS MAPPING.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

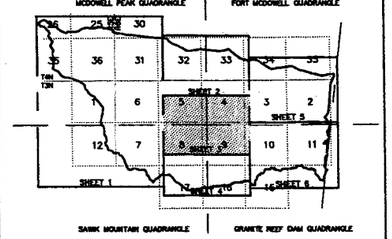
F.C.D. CONTRACT NO. FCD 92-04

LEGEND

NOTE: ALL FLOW RATES ARE FOR THE 100-YEAR PEAK DISCHARGE.

- DRAINAGE SUB-BASIN IDENTIFIER FOR SUBBASIN 207L — 207L
- DRAINAGE SUB-BASIN CONCENTRATION POINT 552 PEAK DISCHARGE IS 1244 cfs — 552
- HEC-1 RESERVOIR ROUTE AT CONCENTRATION POINT 513 INFLOW IS 389 cfs, OUTFLOW IS 369 cfs — 513
- DRAINAGE SUB-BASIN FLOW SPLIT CONCENTRATION POINT 505 PEAK DISCHARGE IS 32 cfs; 18 cfs SPLIT RIGHT, and 14 cfs SPLIT LEFT. — 505
- HEC-1 RESERVOIR ROUTE AND FLOW SPLIT AT CONCENTRATION POINT 523. PEAK INFLOW IS 386 cfs, OUTFLOW IS 286 cfs; 19 cfs SPLIT RIGHT, 266 cfs SPLIT LEFT. — 523
- ELEVATION AT CONCENTRATION POINT OR TOP OF Tc PATH — 1972.0
- VEGETATION COVER DENSITY (FIELD MEASURED) — 35%
- DRAINAGE SUB-BASIN CONCENTRATION POINT
- MAJOR DRAINAGE BASIN BOUNDARY
- DRAINAGE SUB-BASIN BOUNDARY
- HEC-1 ROUTING PATH
- Tc FLOW PATH
- FORT McDOWELL INDIAN RESERVATION BOUNDARY
- CORPORATE BOUNDARY
- RANGE AND TOWNSHIP BOUNDARY
- USGS QUADRANGLE MAP BOUNDARY
- SECTION LINE
- LIMITS OF 200 SCALE MAPPING
- HEC-1 REACH ROUTE CROSS SECTION LOCATION Ashbrook Wash HEC-2 Section 5.254 — AS-5.254
- Field Survey Cross Section — FIELD
- Cross Section From Available Mapping — MAP
- NON-CONTRIBUTING DRAINAGE AREA

INDEX MAP



HYDROLOGY EXHIBIT "D"

DRAINAGE SUB-BASIN DELINEATION TIME OF CONCENTRATION FLOW PATHS AND FLOOD ROUTING MAP

N

400' 0' 400' 800'

SCALE: 1"= 400'

CONTOUR INTERVAL = VARIES

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	–
DESIGN CHK.	N/A	–
PLANS	PK	8/94
PLANS CHK.	TRL	8/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

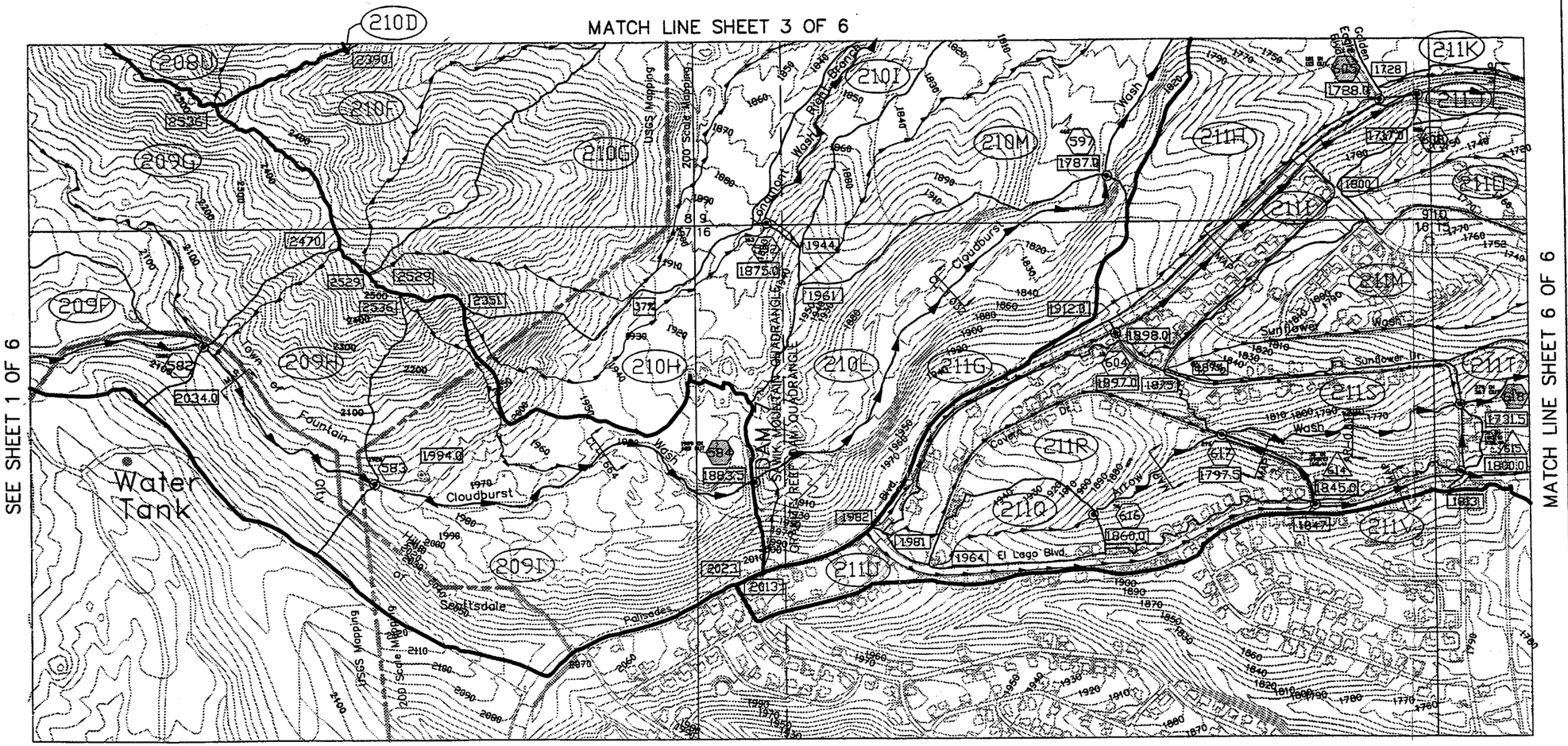
RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 3 OF 6

Dwg. Name: \P\FTHILLS\ACAD\SHEET3.dwg
Date: REV. 17 OCT 1994 08:01am



NOTES:

1. The basin boundaries, Tc paths and routing paths shown on the USGS Mapping portion of this sheet were digitized using more accurate mapping not available in digital form. Ridge lines and flow paths may appear to be misaligned when plotted on the USGS Mapping in some locations.

200 Scale Mapping: Kenney Aerial Mapping
Flight Date = 8/91

USGS Mapping: US Geological Survey
Flight Date = 1962

THE CONTOURS AND PLANIMETRICS FOR THE 200 SCALE MAPPING WERE PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS 1"=200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY DATA PROVIDED BY ANDERSON-NELSON, INC. THE CONTOURS FOR THE USGS MAPPING CAME FROM THE USGS QUADRANGLE MAPS(7.5 MINUTE, 1"=2000'). ONLY 10-FOOT CONTOURS ARE SHOWN FOR THE 200 SCALE MAPPING, AND 20-FOOT CONTOURS FOR THE USGS MAPPING.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

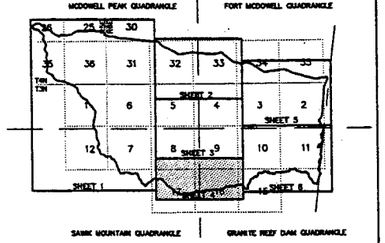
F.C.D. CONTRACT NO. FCD 92-04

LEGEND

NOTE: ALL FLOW RATES ARE FOR THE 100-YEAR PEAK DISCHARGE.

- DRAINAGE SUB-BASIN IDENTIFIER FOR SUBBASIN 207L — 207L
- DRAINAGE SUB-BASIN CONCENTRATION POINT 552 PEAK DISCHARGE IS 1244 cfs — 552
- HEC-1 RESERVOIR ROUTE AT CONCENTRATION POINT 513 INFLOW IS 389 cfs, OUTFLOW IS 369 cfs — 513
- DRAINAGE SUB-BASIN FLOW SPLIT CONCENTRATION POINT 505 PEAK DISCHARGE IS 32 cfs; 18 cfs SPLIT RIGHT, and 14 cfs SPLIT LEFT. — 505
- HEC-1 RESERVOIR ROUTE AND FLOW SPLIT AT CONCENTRATION POINT 521. PEAK INFLOW IS 386 cfs, OUTFLOW IS 286 cfs; 19 cfs SPLIT RIGHT, 266 cfs SPLIT LEFT. — 521
- ELEVATION AT CONCENTRATION POINT OR TOP OF Tc PATH — 1972.0
- VEGETATION COVER DENSITY (FIELD MEASURED) — 35%
- DRAINAGE SUB-BASIN CONCENTRATION POINT
- MAJOR DRAINAGE BASIN BOUNDARY
- DRAINAGE SUB-BASIN BOUNDARY
- HEC-1 ROUTING PATH
- Tc FLOW PATH
- FORT MCDOWELL INDIAN RESERVATION BOUNDARY
- CORPORATE BOUNDARY
- RANGE AND TOWNSHIP BOUNDARY
- USGS QUADRANGLE MAP BOUNDARY
- SECTION LINE
- LIMITS OF 200 SCALE MAPPING
- HEC-1 REACH ROUTE CROSS SECTION LOCATION Ashbrook Wash HEC-2 Section 5.254 — AS-5.254
- Field Survey Cross Section — FIELD
- Cross Section From Available Mapping — MAP
- NON-CONTRIBUTING DRAINAGE AREA

INDEX MAP



HYDROLOGY EXHIBIT "D"

DRAINAGE SUB-BASIN DELINEATION TIME OF CONCENTRATION FLOW PATHS AND FLOOD ROUTING MAP

400' 0' 400' 800'

SCALE: 1"= 400'
CONTOUR INTERVAL = VARIES

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	–
DESIGN CHK.	N/A	–
PLANS	PK	8/94
PLANS CHK.	TRL	8/94

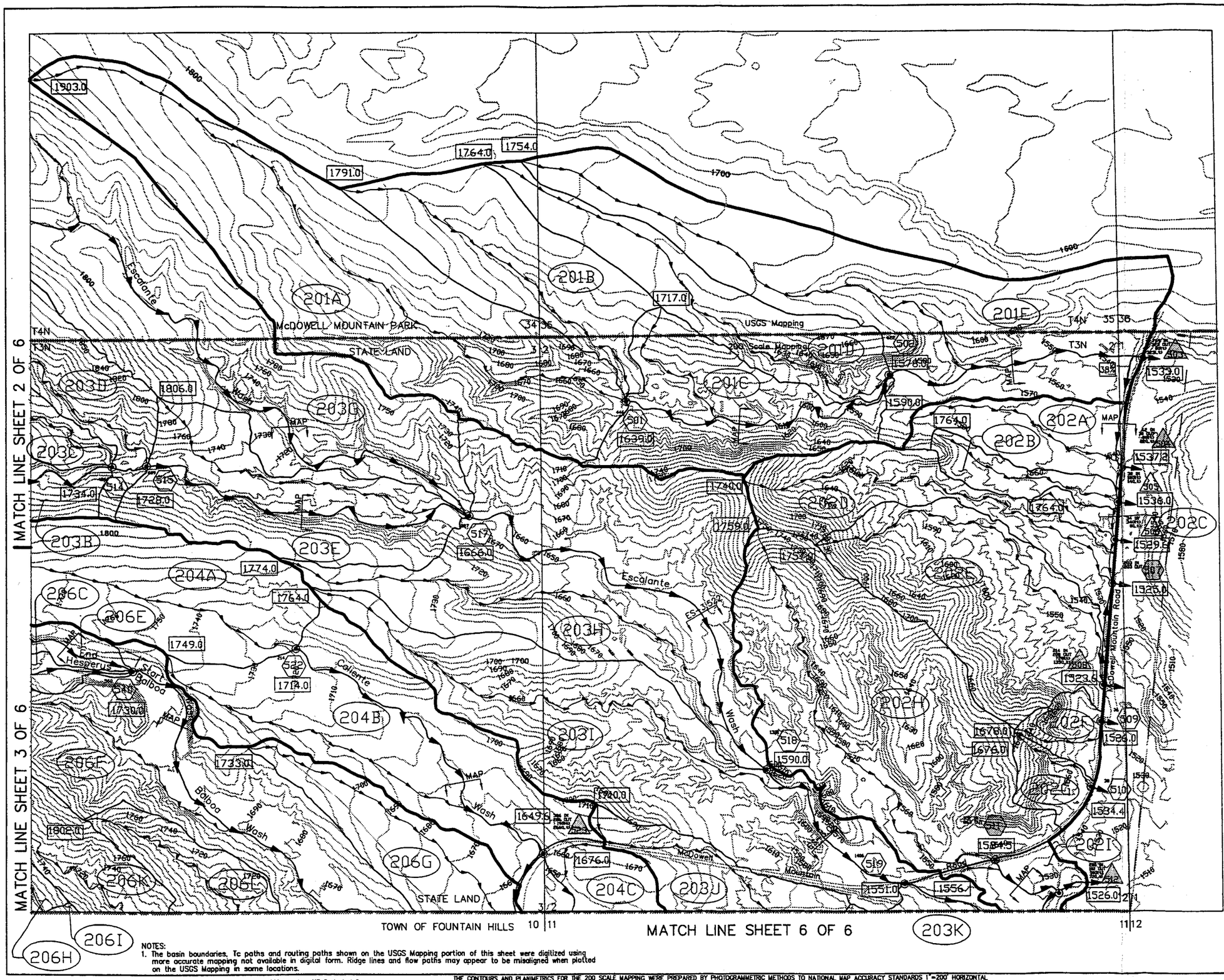
SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE
APPROVED BY: DATE
CHIEF ENGINEER AND GENERAL MANAGER

SHEET 4 OF 6

Dwg. Name: \P\FHILLS\ACAD\SHEET4.dwg
Date: REV 17 OCT 1994 09:15am



NOTES:
1. The basin boundaries, Tc paths and routing paths shown on the USGS Mapping portion of this sheet were digitized using more accurate mapping not available in digital form. Ridge lines and flow paths may appear to be misaligned when plotted on the USGS Mapping in some locations.

200 Scale Mapping: Kenney Aerial Mapping
Flight Date = 8/91

USGS Mapping: US Geological Survey
Flight Date = 1962

THE CONTOURS AND PLANIMETRICS FOR THE 200 SCALE MAPPING WERE PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS 1"=200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY DATA PROVIDED BY ANDERSON-NELSON, INC. THE CONTOURS FOR THE USGS MAPPING CAME FROM THE USGS QUADRANGLE MAPS(7.5 MINUTE, 1"=2000'). ONLY 10-FOOT CONTOURS ARE SHOWN FOR THE 200 SCALE MAPPING, AND 20-FOOT CONTOURS FOR THE USGS MAPPING.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

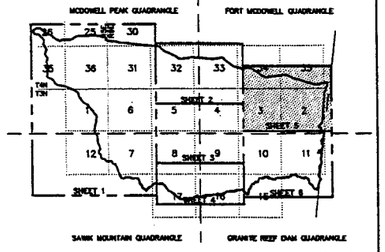
F.C.D. CONTRACT NO. FCD 92-04

LEGEND

NOTE: ALL FLOW RATES ARE FOR THE 100-YEAR PEAK DISCHARGE.

- DRAINAGE SUB-BASIN IDENTIFIER FOR SUBBASIN 207L — 207L
- DRAINAGE SUB-BASIN CONCENTRATION POINT 552 PEAK DISCHARGE IS 1244 cfs — 552
- HEC-1 RESERVOIR ROUTE AT CONCENTRATION POINT 513 INFLOW IS 389 cfs, OUTFLOW IS 369 cfs — 513
- DRAINAGE SUB-BASIN FLOW SPLIT CONCENTRATION POINT 505 PEAK DISCHARGE IS 32 cfs; 18 cfs SPLIT RIGHT, and 14 cfs SPLIT LEFT. — 505
- HEC-1 RESERVOIR ROUTE AND FLOW SPLIT AT CONCENTRATION POINT 523. PEAK INFLOW IS 386 cfs, OUTFLOW IS 286 cfs; 19 cfs SPLIT RIGHT, 266 cfs SPLIT LEFT. — 523
- ELEVATION AT CONCENTRATION POINT OR TOP OF Tc PATH — 1972.0
- VEGETATION COVER DENSITY (FIELD MEASURED) — 35%
- DRAINAGE SUB-BASIN CONCENTRATION POINT
- MAJOR DRAINAGE BASIN BOUNDARY
- DRAINAGE SUB-BASIN BOUNDARY
- HEC-1 ROUTING PATH
- Tc FLOW PATH
- FORT MCDOWELL INDIAN RESERVATION BOUNDARY
- CORPORATE BOUNDARY
- RANGE AND TOWNSHIP BOUNDARY
- USGS QUADRANGLE MAP BOUNDARY
- SECTION LINE
- LIMITS OF 200 SCALE MAPPING
- HEC-1 REACH ROUTE CROSS SECTION LOCATION Ashbrook Wash HEC-2 Section 5.254 — AS-5.254
- Field Survey Cross Section — FIELD
- Cross Section From Available Mapping — MAP
- NON-CONTRIBUTING DRAINAGE AREA

INDEX MAP



HYDROLOGY EXHIBIT "D"

DRAINAGE SUB-BASIN DELINEATION TIME OF CONCENTRATION FLOW PATHS AND FLOOD ROUTING MAP

400' 0' 400' 800'

SCALE: 1"= 400'
CONTOUR INTERVAL = VARIES

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

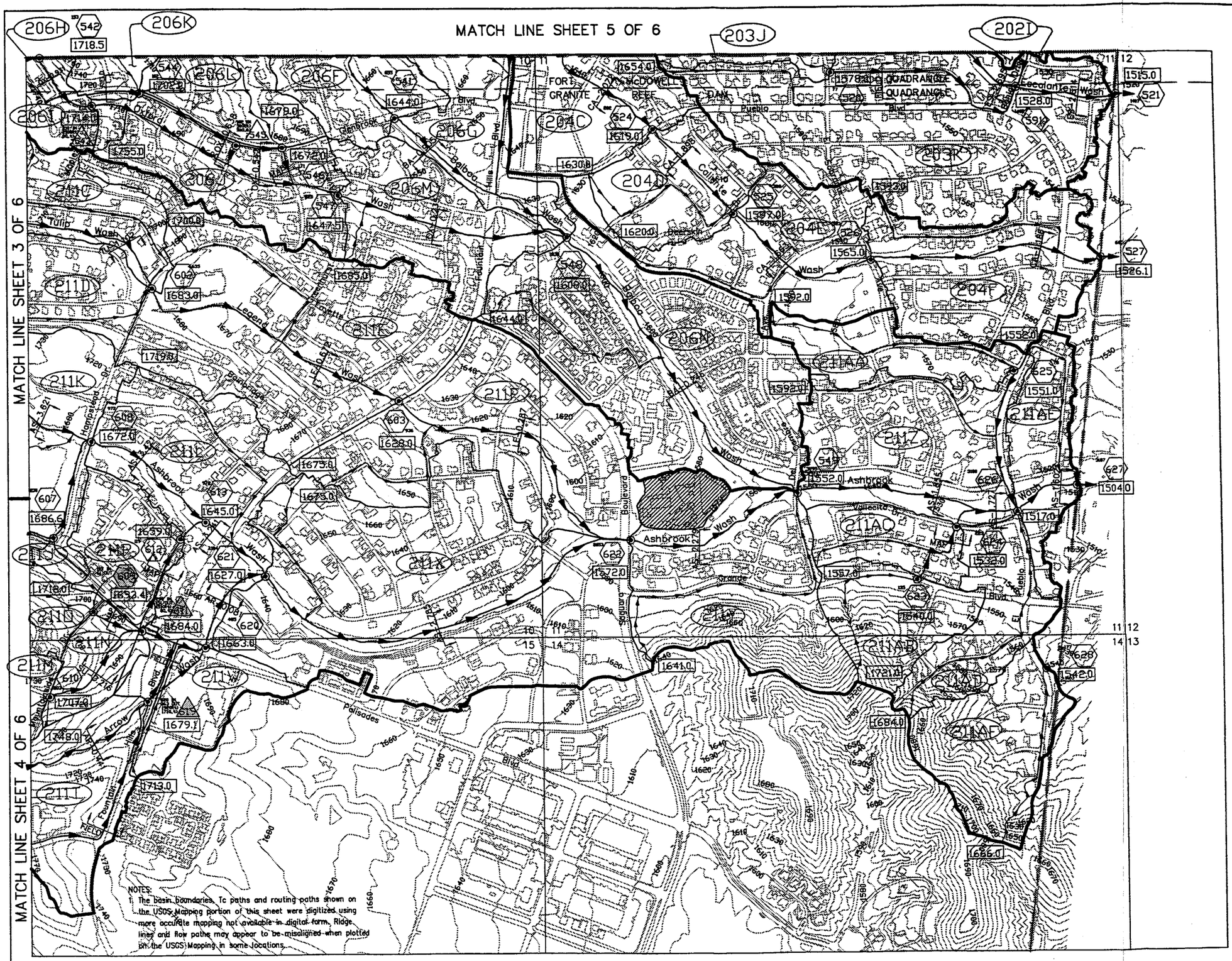
	BY	DATE
DESIGN	N/A	–
DESIGN CHK.	N/A	–
PLANS	PK	8/94
PLANS CHK.	TRL	8/94
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE
APPROVED BY: DATE
CHIEF ENGINEER AND GENERAL MANAGER

SHEET 5 OF 6

Dwg. Name: \P:\FTHILLS\ACAD\SHEET5.dwg
Date: REV. 17 OCT 1994 09:45am



200 Scale Mapping: Kenney Aerial Mapping
Flight Date = 8/91

USGS Mapping: US Geological Survey
Flight Date = 1962

THE CONTOURS AND PLANIMETRICS FOR THE 200 SCALE MAPPING WERE PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS 1"=200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY DATA PROVIDED BY ANDERSON-NELSON, INC. THE CONTOURS FOR THE USGS MAPPING CAME FROM THE USGS QUADRANGLE MAPS(7.5 MINUTE, 1"=2000'). ONLY 10-FOOT CONTOURS ARE SHOWN FOR THE 200 SCALE MAPPING, AND 20-FOOT CONTOURS FOR THE USGS MAPPING.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

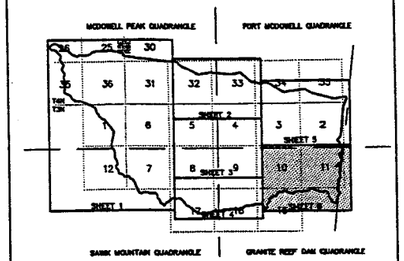
FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

F.C.D. CONTRACT NO. FCD 92-04

LEGEND

NOTE: ALL FLOW RATES ARE FOR THE 100-YEAR PEAK DISCHARGE.

- DRAINAGE SUB-BASIN IDENTIFIER FOR SUBBASIN 207L — 207L
- DRAINAGE SUB-BASIN CONCENTRATION POINT 552 PEAK DISCHARGE IS 1244 cfs — 552
- HEC-1 RESERVOIR ROUTE AT CONCENTRATION POINT 513 INFLOW IS 389 cfs, OUTFLOW IS 369 cfs — 513
- DRAINAGE SUB-BASIN FLOW SPLIT CONCENTRATION POINT 505 PEAK DISCHARGE IS 32 cfs; 18 cfs SPLIT RIGHT, and 14 cfs SPLIT LEFT. — 505
- HEC-1 RESERVOIR ROUTE AND FLOW SPLIT AT CONCENTRATION POINT 523. PEAK INFLOW IS 386 cfs, OUTFLOW IS 286 cfs; 19 cfs SPLIT RIGHT, 266 cfs SPLIT LEFT. — 523
- ELEVATION AT CONCENTRATION POINT OR TOP OF Tc PATH — 1972.0
- VEGETATION COVER DENSITY (FIELD MEASURED) — 35%
- DRAINAGE SUB-BASIN CONCENTRATION POINT
- MAJOR DRAINAGE BASIN BOUNDARY
- DRAINAGE SUB-BASIN BOUNDARY
- HEC-1 ROUTING PATH
- Tc FLOW PATH
- FORT MCDOWELL INDIAN RESERVATION BOUNDARY
- CORPORATE BOUNDARY
- RANGE AND TOWNSHIP BOUNDARY
- USGS QUADRANGLE MAP BOUNDARY
- SECTION LINE
- LIMITS OF 200 SCALE MAPPING
- HEC-1 REACH ROUTE CROSS SECTION LOCATION Ashbrook Wash HEC-2 Section 5.254 — AS-5.254
  - Field Survey Cross Section — FIELD
  - Cross Section From Available Mapping — MAP
- NON-CONTRIBUTING DRAINAGE AREA



HYDROLOGY EXHIBIT "D"

DRAINAGE SUB-BASIN DELINEATION TIME OF CONCENTRATION FLOW PATHS AND FLOOD ROUTING MAP

400' 0' 400' 800'

SCALE: 1"= 400'

CONTOUR INTERVAL = 10 FEET

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	-
DESIGN CHK.	N/A	-
PLANS	PK	8/94
PLANS CHK.	TRL	8/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

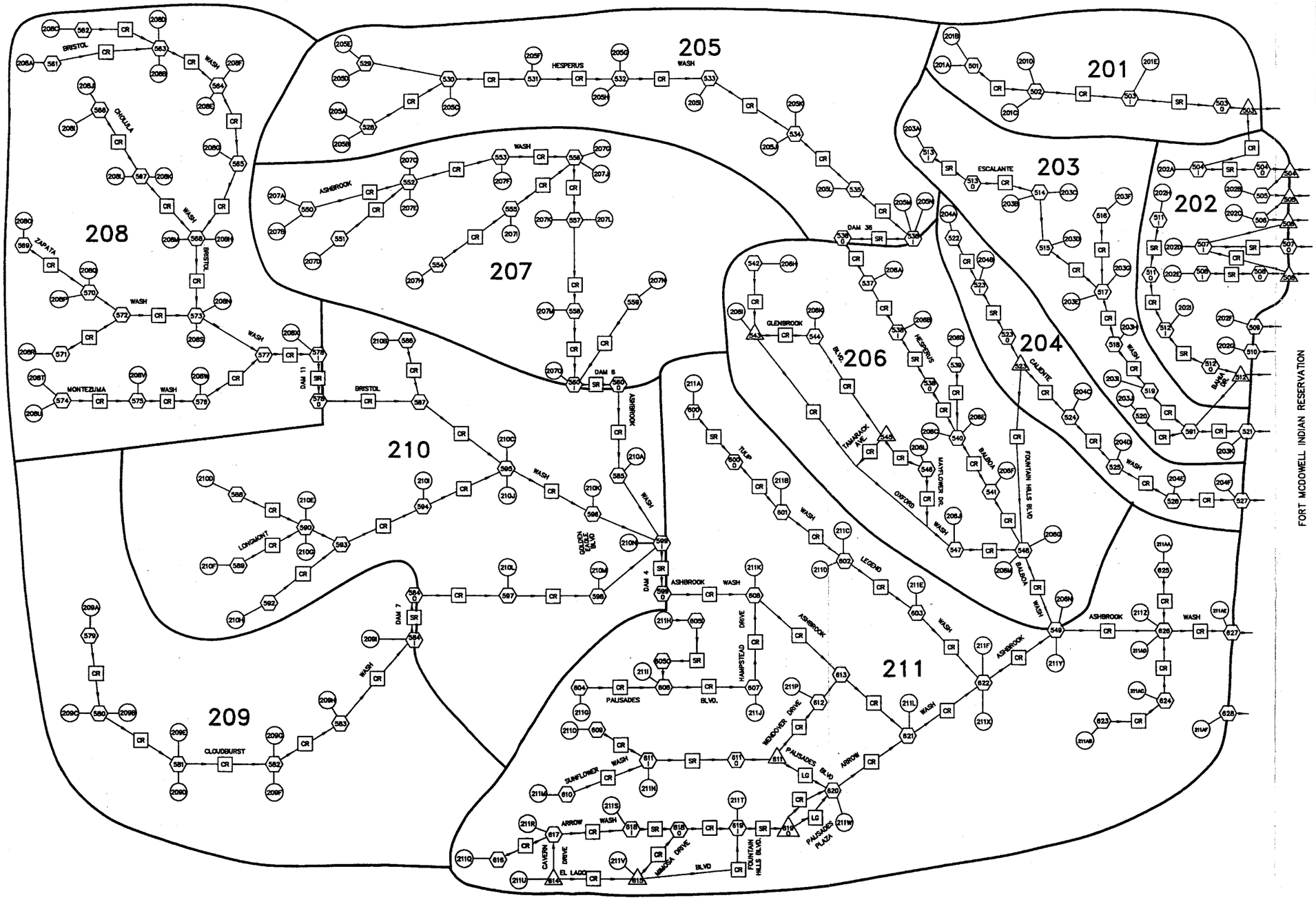
RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 6 OF 6

Dwg. Name: \P\FTHILLS\ACAD\SHEET6.dwg
Date: REV. 17 OCT 1994 10:30am



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF FOUNTAIN HILLS NORTH

F.C.D. CONTRACT NO. 92-04

LEGEND

MAJOR BASIN BOUNDARY	
DIRECTION OF FLOW	
HYDROGRAPH CALCULATION FOR SUB BASIN 207L	207L
HYDROGRAPH COMBINATION OPERATION AND/OR CONCENTRATION POINT AT NODE 544	544
HYDROGRAPH COMBINATION OPERATION AND/OR CONCENTRATION POINT FOR A STORAGE ROUTE OPERATION AT NODE 599 I FOR INFLOW TO STORAGE ROUTE OPERATION O FOR OUTFLOW OF STORAGE ROUTE OPERATION	599 I O
HYDROGRAPH ROUTING OPERATION CR = NORMAL DEPTH CHANNEL ROUTE SR = STORAGE ROUTE LG = LAG ROUTE	CR
DIVERSION OPERATION TO SIMULATE FLOW SPLIT AT NODE 543	543
MAJOR BASIN 202	202

NOTES

EXHIBIT "E"

HEC-1 FLOOD ROUTING DIAGRAM

N

GEORGE V. SABOL CONSULTING ENGINEERS, INC.

	BY	DATE
DESIGN	N/A	–
DESIGN CHK.	N/A	–
PLANS	PK	3/94
PLANS CHK.	TRL	3/94
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 1

Dwg. Name: \P\FTHILLS\ACAD\EX-E.dwg
Date: REV. JUL. 24, 1994 02:45pm