National Security Technologies LLC

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DOE/NV/25946--005

FLOOD ASSESSMENT

AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE, NEVADA TEST SITE, NYE COUNTY, NEVADA

July 2006

DISCLAIMER

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FLOOD ASSESSMENT

AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE, NEVADA TEST SITE, NYE COUNTY, NEVADA

Prepared By

National Security Technologies
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July 2006

Prepared for

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
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Abstract

A flood assessment was conducted for the Radioactive Waste Management Site (RWMS) in Area 3 of the Nevada Test Site to determine whether the Area 3 RWMS is located within a 100-year flood hazard as defined by the Federal Emergency Management Agency (FEMA), and to provide both 100-year and 500-year discharges for design of flood protection.

Potential flooding of the Area 3 RWMS can occur as alluvial fan flooding and sheet flow. The FEMA has developed methods to determine the 100-year flood hazard from these types of flooding. This flood assessment was conducted following criteria for flood hazard determination required by FEMA to provide hydrologic and hydraulic information for design of flood protection structures for the facility.

The study area encompasses the (approximately) 780-square kilometer Yucca Flat watershed. However, review of topographic maps and aerial photographs of Yucca Flat, in addition to field investigations, indicates that only a portion of this region, approximately 94 square kilometers, could directly impact the Area 3 RWMS. This smaller drainage area encompasses portions of the Halfpint Range, including Paiute Ridge, Jangle Ridge, Carbonate Ridge, Slanted Buttes, Cockeyed Ridge, and Banded Mountain. The Area 3 RWMS is located on coalescing alluvial fans emanating from this drainage area.

In the arid Southwest, rainfall-runoff models are typically used to estimate flood discharges. Rainfall-runoff models were developed for the Area 3 RWMS flood assessment using the HEC-1, Flood Hydrograph Package, a model developed by the U.S. Army Corps of Engineers. The HEC-1 model-generated peak discharges are incorporated into the FEMA FAN model to define flood hazards on identified alluvial fans within the study area. The HEC-1 model-generated discharges are also used to calculate sheet flow depths, where appropriate. Methods to determine both alluvial fan and sheet flow hazard areas are described in this report.

The Area 3 RWMS is not located within the FEMA-designated 100-year, 6-hour flood-hazard zone of either the Jangle Ridge or Paiute Ridge alluvial fans. Calculated 100-year sheet flow depths within the Area 3 RWMS vicinity are less than 0.3 meter; therefore, the Area 3 RWMS is not located within a 100-year, 6-hour flood-hazard zone.

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Preface

This report was originally prepared under the same title in 1996 by Julianne J. Miller, formerly of Bechtel Nevada, as an internal document. As part of National Security Technologies' (NSTec's) current scope for closure planning for the Area 3 Radioactive Waste Management Site, this report has been updated and submitted for approval for public release so it will be accessible for public review and for citation in future documents. This report has been updated by revising it to conform to current editorial standards of NSTec and of the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office. The original data and conclusions are unchanged.

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Acronyms and Abbreviations

AMC	antecedent moisture condition
CCRFCD	Clark County Regional Flood Control District
CFR	Code of Federal Regulations
cm	centimeter(s)
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
FEMA	Federal Emergency Management Agency
ft	foot (feet)
km^2	square kilometers
LP3	Log-Pearson Type III (flood discharge frequency distribution)
m	meter(s)
mi^2	square miles
NOAA	National Oceanic and Atmospheric Administration
NTS	Nevada Test Site
RWMS	Radioactive Waste Management Site
SCS	Soil Conservation Service
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WRC	Water Resources Council

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1.0 Introduction

1.1 Location

A flood assessment was conducted at the Area 3 Radioactive Waste Management Site (RWMS) at the Nevada Test Site (NTS) in Nye County, Nevada (Figure 1-1). The study area encompasses the watershed of Yucca Flat, a closed basin approximately 780 square kilometers (km^2) (300 square miles [mi^2]) in size. The focus of this effort was on a drainage area of approximately 94 km^2 (36 mi^2), determined from review of topographic maps and aerial photographs to be the only part of the Yucca Flat watershed that could directly impact the Area 3 RWMS. This smaller area encompasses portions of the Halfpint Range, including Paiute Ridge, Jangle Ridge, Carbonate Ridge, Slanted Buttes, Cockeyed Ridge, and Banded Mountain. The Area 3 RWMS is located on coalescing alluvial fans emanating from this drainage area.

1.2 Purpose

Flood assessment is one of several subtasks related to site characterization studies at or near the Area 3 RWMS. The Area 3 RWMS must comply with the following principal federal and state regulations and criteria pertaining to flooding:

- Executive Order 11988, "Floodplain Management"
- Title 10 Code of Federal Regulations (CFR) 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements"
- Title 40 CFR 264.18, "Location Standards for Hazardous Waste Management Facilities"
- Title 40 CFR 270.14, "General Requirements for a Hazardous Waste Facility"
- Title 44 CFR 1.9, "Floodplain Management and Protection of Wetlands"
- U.S. Department of Energy (DOE) Order 6430.1A, "General Design Criteria"

This study focuses on the potential 100-year flood hazard at the Area 3 RWMS, but also includes an estimate of the 500-year flood discharge. This flood assessment does not evaluate any erosion hazards, however, other site characterization studies that do address these issues are being conducted at the Area 3 RWMS (*Area 5 Radioactive Waste Management Site, Addendum to Performance Assessment*, *January 2006* and the *Area 3 Characterization Report*, 2006.

1.3 Objective

The flood assessment was conducted to meet the requirements of DOE Orders by determining the 100-year, 6-hour flood hazard near the Area 3 RWMS, and to provide 100-year and 500-year discharges for flood protection design, using site-specific approaches for the hydrologic and hydraulic analyses. This flood assessment was conducted following criteria for flood hazard determination required by the Federal Emergency Management Agency (FEMA, 1991).

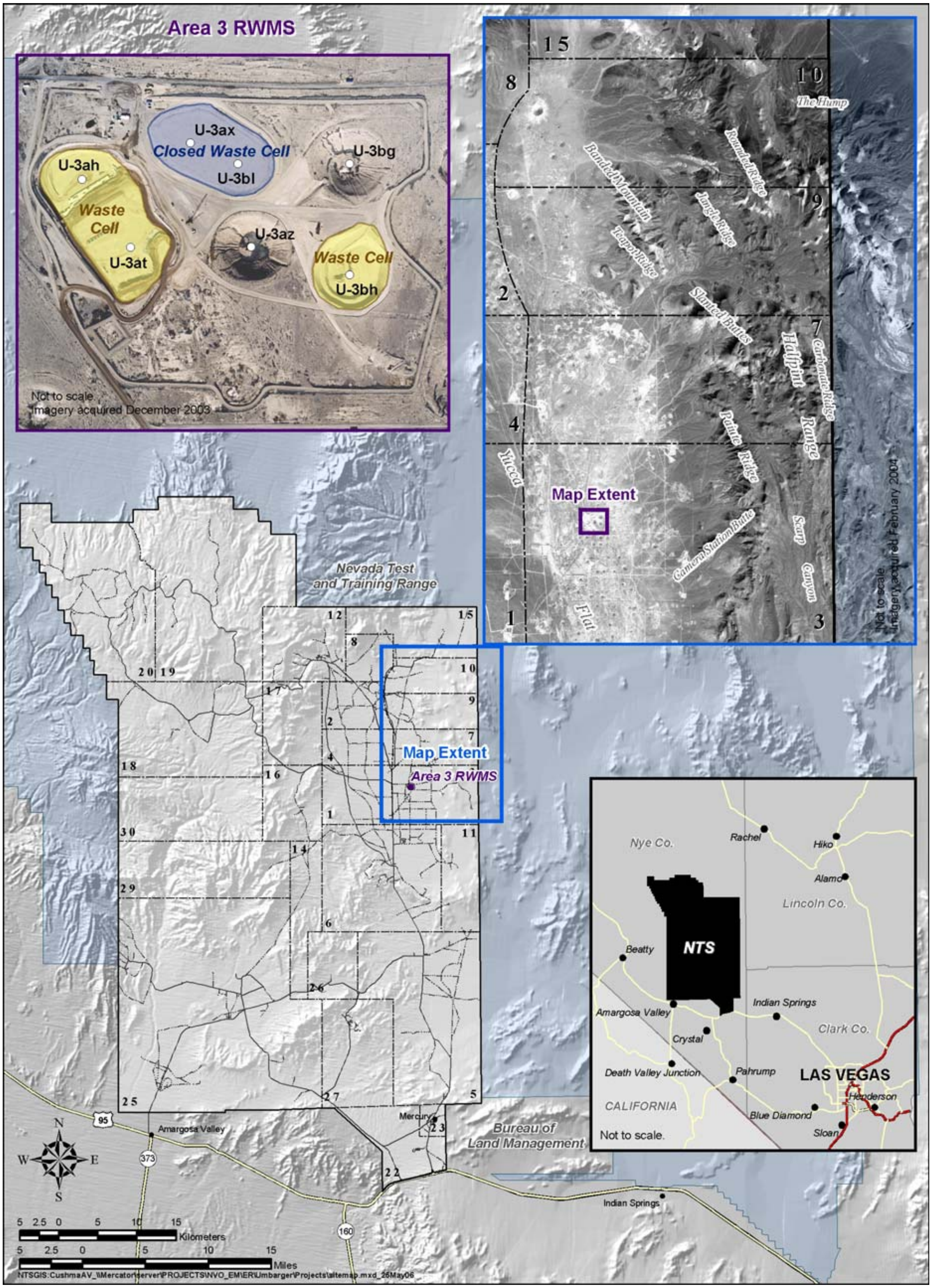

Figure 1-1. Location Map and Physiographic Features of the Nevada Test Site and the Area 3 Radioactive Waste Management Site

2.0 Descriptions of Yucca Flat Watershed and Alluvial Fans

2.1 Introduction

The watershed area for Yucca Flat, a closed basin, is approximately 780 km^2 (300 mi^2). It encompasses parts of the NTS and parts of the Nevada Test and Training Range to the north and east of the NTS, in both Nye and Lincoln counties. The smaller (approximately 94 km^2 [36 mi^2]) drainage area within Yucca Flat that could directly impact the Area 3 RWMS was divided into 20 subbasins (Table 2-1; Figure 2-1).

Table 2-1. Subbasins Addressed in the Area 3 RWMS Flood Assessment

Subbasin Name	Symbol	Area km^2 (mi^2)
Jangle Ridge 1	JR1	1.8 (0.7)
Jangle Ridge 2	JR2	8.3 (3.2)
Jangle Ridge 3	JR3	4.5 (1.7)
Jangle Ridge 4	JR4	5.8 (2.2)
Jangle Ridge 5	JR5	4.3 (1.7)
Jangle Ridge 6	JR6	2.4 (0.9)
Jangle Ridge 7	JR7	1.0 (0.4)
Jangle Ridge 8	JR8	0.4 (0.2)
Jangle Ridge 9 [a]	JR9	19.9 (7.7)
Paiute Ridge 1	PR1	4.7 (1.8)

Subbasin Name	Symbol	Area km^2 (mi^2)
Paiute Ridge 2	PR2	6.1 (2.3)
Paiute Ridge 3	PR3	1.1 (0.4)
Paiute Ridge 4	PR4	0.4 (0.2)
Paiute Ridge 5	PR5	0.4 (0.2)
Paiute Ridge 6 [b]	PR6	4.9 (1.9)
Reitman Seep 1	RS1	3.3 (1.3)
Reitman Seep 2	RS2	8.0 (3.1)
Reitman Seep 3	RS3	5.4 (2.1)
North Paiute Ridge 1	NPR1	1.2 (0.5)
North Paiute Ridge 2	NPR2	8.4 (3.2)

Note:
[a] Subbasin Jangle Ridge 9 (JR9) is the Jangle Ridge alluvial fan.
[b] Subbasin Paiute Ridge 6 (PR6) is the Paiute Ridge alluvial fan.

2.2 Definition of an Alluvial Fan Apex

There are two distinct ways to define the apex of an alluvial fan: (1) based on its geomorphology, and (2) as defined by FEMA for regulatory purposes. The geomorphic apex of an alluvial fan is the intersection of the mountain front and the piedmont plain. On many alluvial fans, a channel is entrenched into the proximal, and possibly the middle part, of the fan (Bull, 1964). Fans with entrenched channels have the active apex farther down the fan. FEMA defines the apex as the point below which the flow path of the major stream that formed the fan becomes unpredictable and flooding of the fan can occur (FEMA, 1991) (Figure 2-2). The FEMA definition was used in this study to determine the active apexes of the alluvial fans within the study area, as they represent points of bifurcation that meet regulatory criteria under FEMA's Flood Hazard Mapping Program (FEMA, 1991).

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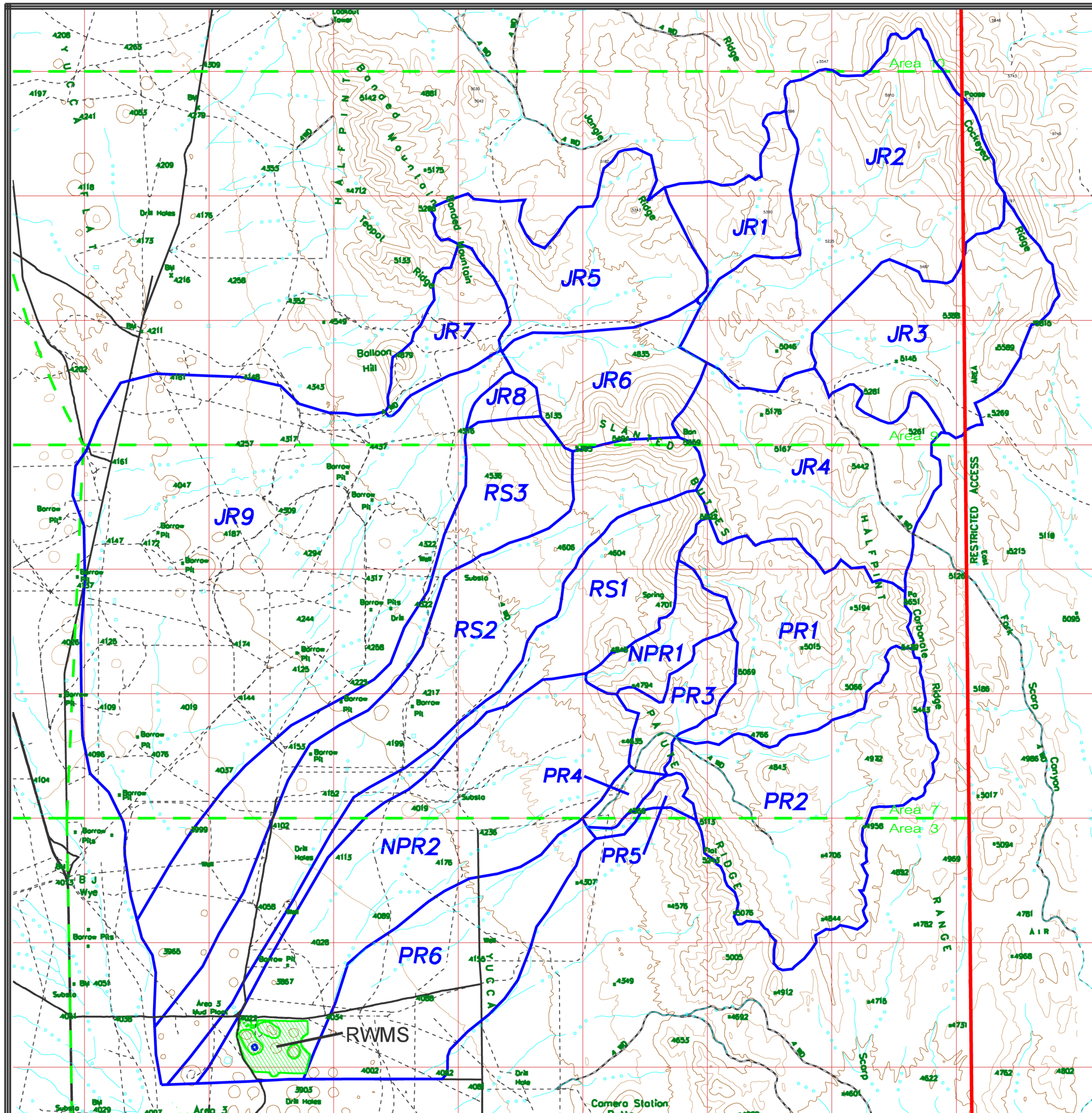

EXPLANATION

WATERSHED BOUNDARY

JR4 WATERSHED SUB-BASIN NAME

NTS BOUNDARY

NTS AREA BOUNDARY

RWMS AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE (RWMS).

MAP INFORMATION

BASE MAP FROM USGS QUADRANGLES (1:24,000), OAK SPRING (1986), PAIUTE RIDGE (1986), YUCCA FLAT (1986), AND JANGLE RIDGE (1986), NYE COUNTY, NEVADA.

NOTES:
FT = FEET
FPS = FEET PER SECOND
USGS = US GEOLOGICAL SURVEY
4100 = ELEVATION IN FEET

STATE OF NEVADA

LOCATION MAP

1 : 60000

1000 0 2000 4000 6000 8000 10000

FEET

CONTOUR INTERVAL = 100 FEET

Figure 2–1

WATERSHED MAP OF THE AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE VICINITY

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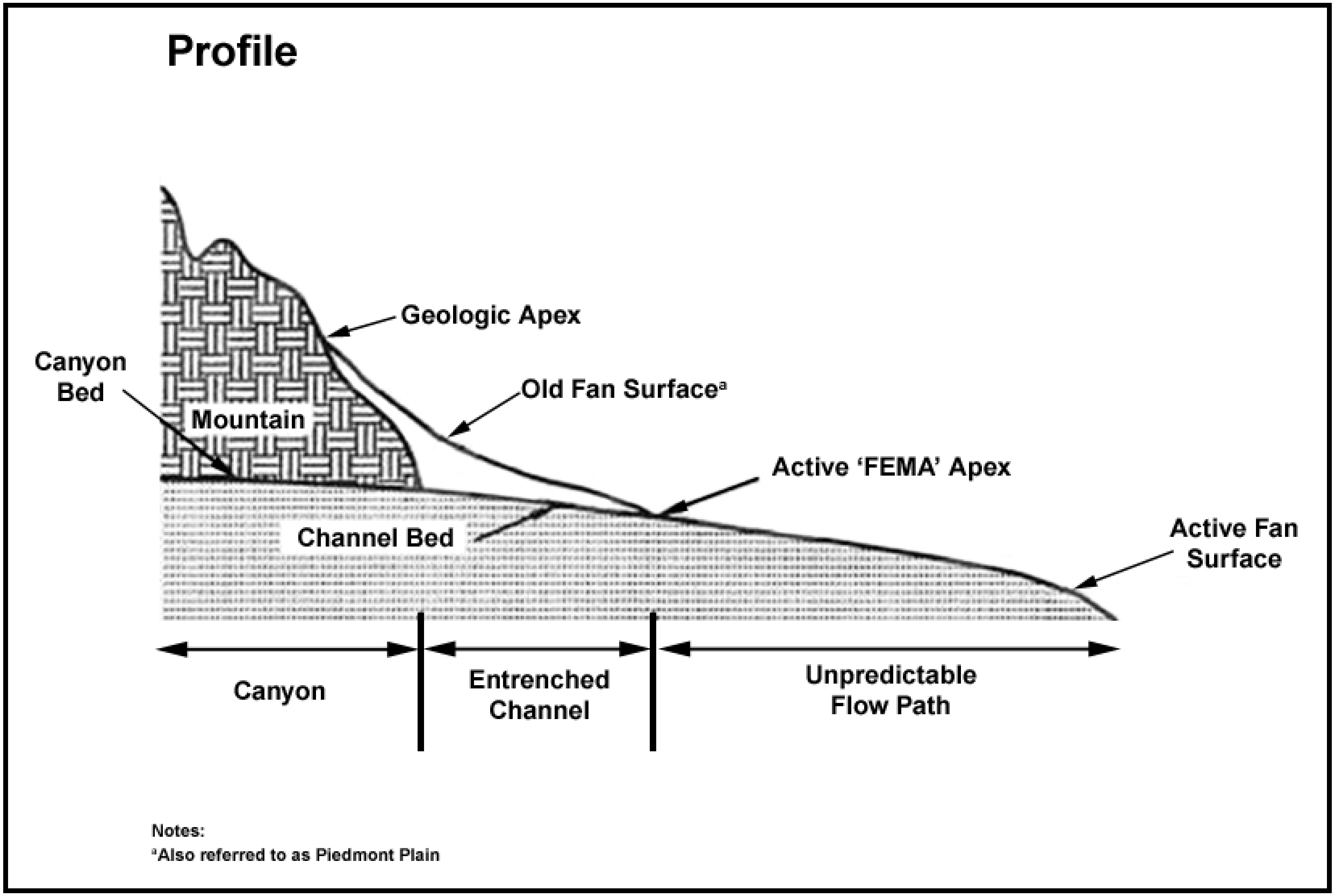

Figure 2-2. Idealized Alluvial Fan Profile

2.3 Jangle Ridge Alluvial Fan

The Jangle Ridge watershed covers 48.3 km^2 (18.7 mi^2) and is located north-northeast of the Area 3 RWMS (Figure 2-1). The watershed drains toward the Area 3 RWMS from an area that is bordered to the north by Jangle Ridge and Banded Mountain, to the east by Cockeyed Ridge, and to the south by Slanted Buttes. The watershed was divided into nine separate subbasins (Table 2-1), including Jangle Ridge alluvial fan, located north-northeast of the Area 3 RWMS, which emanates from the Jangle Ridge area.

The apex of the fan is located where the flow path of the channel becomes unpredictable. The channel located above the apex of the Jangle Ridge alluvial fan is incised approximately 1 meter (m) (3 feet [ft]). Parts of the fan surface are covered by desert pavement, although a significant part of the surface has been disturbed by human activities. Vegetation covers 25 to 30 percent of the surface.

2.4 Paiute Ridge Alluvial Fan

The Paiute Ridge watershed covers 17.6 km^2 (6.8 mi^2) and is located northeast of the Area 3 RWMS (Figure 2-1). The watershed drains toward the Area 3 RWMS bordered to the north by Slanted Buttes, to the east by Carbonate Ridge, and to the south by Paiute Ridge. The watershed was divided into six separate subbasins (Table 2-1), including Paiute Ridge alluvial fan (located northeast of the Area 3 RWMS) which emanates from the Paiute Ridge area. Parts of the fan surface are covered by desert pavement, although much of the surface has been disturbed by human activities. Vegetation covers 25 to 30 percent of the surface.

2.5 Reitman Seep Subbasins

The Reitman Seep watershed covering 16.7-km^2 (6.5-mi^2) drains from the western front of Slanted Buttes toward the Area 3 RWMS and is divided into three subbasins (Figure 2-1; Table 2-1). The lower parts of these subbasins extend into Yucca Flat as coalescing alluvial fans along the mountain front. In terms of hydraulic engineering, the flow systems on these landforms are distributary flow systems.

The proximal parts of these coalescing alluvial fans are characterized by channels incised 0.3 to 0.6 m (1 to 2 ft) across the surface. Channel depths decrease downgradient until sheet flow, typical of areas of low relief and poorly established drainage systems, occurs on the distal parts of the coalescing alluvial fans. Parts of the fan surface are covered by desert pavement, although much of the surface has been disturbed by human activities. Vegetation covers 25 to 30 percent of the surface.

2.6 North Paiute Ridge Subbasins

The North Paiute watershed covering 9.6-km^2 (3.7-mi^2) drains from the western front of Slanted Buttes and Paiute Ridge towards the Area 3 RWMS and was divided into two subbasins (Figure 2-1; Table 2-1). The lower regions extend into Yucca Flat as coalescing alluvial fans with distributary flow systems.

The proximal parts of these coalescing alluvial fans are characterized by channels incised 0.3 to 0.6 m (1 to 2 ft) across the surface. Channel depths decrease down gradient until sheet flow occurs on the distal parts of the coalescing alluvial fans. Parts of the fan surface are covered by desert pavement, although much of the surface has been disturbed by human activities. Vegetation covers 20 to 35 percent of the surface.

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3.0 Hydrology

3.1 Methods

Standard statistical methods used to determine flood discharges for a specific return period are not applicable to most watersheds in the arid Southwest because most of the watersheds in the region are generally ungaged and stream discharge information is thus unavailable. Furthermore, arid watersheds that do not have discharge data usually have a short period of record and many years of no flow. Thus, rainfall-runoff models typically are used to estimate flood discharges for the Southwest.

For this flood assessment, rainfall-runoff models were generated using the HEC-1 computer program developed by the U.S. Army Corps of Engineers (USACE), 1990a. In the *Clark County Hydrologic Criteria and Drainage Design Manual* published by the Clark County Regional Flood Control District (CCRFCD, 1990), the HEC-1 computer program is listed as an acceptable tool for estimating discharges and for generating hydrographs for watersheds within Clark County, Nevada. The hydrologic approach described in the CCRFCD Manual (1990) was developed for Clark County from studies conducted by Water Resourse Council (WRC) Engineering and the USACE.

For this study, methods in the CCRFCD Manual (1990) were used to produce the input parameters required for the HEC-1 computer program (USACE, 1990a). The methods described in the CCRFCD Manual (1990) were considered the best approach for estimating discharges for the flood assessment of the Area 3 RWMS for the following reasons:

- Local and federal agencies (e.g., FEMA) accept the methods in the CCRFCD Manual (1990).
- The study area is near Clark County.
- The physical setting and flood-producing storms at the Area 3 RWMS are similar to those of Clark County.
- Clark County is the nearest local jurisdiction with a hydrologic method based on region-specific information.

The Soil Conservation Service (SCS) unit hydrograph option in the HEC-1 computer program (USACE, 1990a) was used in the hydrologic models. The SCS unit hydrograph is widely used in rainfall-runoff models and is recommended as an option in the CCRFCD Manual (1990). Input parameters required to run the HEC-1 computer program (USACE, 1990a) using the SCS unit hydrograph option are:

- Precipitation parameters (depth of precipitation, storm duration and time distribution, and depth-area ratios),
- Drainage areas (subbasin areas),
- Precipitation losses (curve numbers),

- Lag time (each subbasin),
- Channel routing parameters.

The procedure used to obtain the parameters for this study generally followed methods described in the CCRFCD Manual (1990), where a detailed description of how these parameters are determined may be found. The following sections provide an overview of how these parameters were determined for this study, including descriptions and reasons for any deviations from the methods provided in the CCRFCD Manual (1990).

3.1.1 Precipitation

Rainfall events that cause flooding on the NTS and in southern Nevada are usually convectional storms. According to Christenson and Spahr (1980), summer convectional storms would most likely be flood-generating storms at the NTS. These storms are normally characterized as short-duration (6 hours or less), high-intensity storms over a localized area. Methods regarding precipitation parameters in the CCRFCD Manual (1990) assume that summer convectional storms are the likely precipitation event to produce flooding in Clark County. In an analysis of precipitation records for southern Nevada, WRC Engineering and the USACE determined that a 6-hour rainfall event should be the design storm (CCRFCD, 1990). A 6-hour mass curve (intensity of rainfall per 15-minute interval over the 6-hour design storm) was developed, and a relationship between precipitation depth and storm size (depth-area ratio) was determined. These parameters are discussed in more detail in the following sections.

3.1.1.1 Point Precipitation Values

As specified in the CCRFCD Manual (1990), the design depths of precipitation for the 6-hour storms were taken from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Volume VII (U.S. Department of Commerce [DOC], 1973). The 100-year, 6-hour point precipitation value of 4.1 centimeters (cm) (1.6 inches [in.]) (DOC, 1973) compares well with the 4.6-cm (1.8-in.) value generated from a figure developed by R.H. French (1983) for the Cane Springs precipitation gauge (Figure 3-1).

The CCRFCD Manual (1990) requires that point precipitation values listed in DOC (1973) be used to determine point precipitation. However, the CCRFCD Manual (1990) specifies that rainfall events above the 2-year storm be adjusted according to the recurrence interval level of interest and the appropriate 6-hour depth area reduction factors (see Section 500 of CCRFCD Manual [1990]). Correction factors were identified from studies conducted by WRC Engineering and the USACE for Clark County (CCRFCD, 1990) based on available rainfall data, primarily from the Las Vegas Valley, and may not be applicable for the Area 3 RWMS study area.

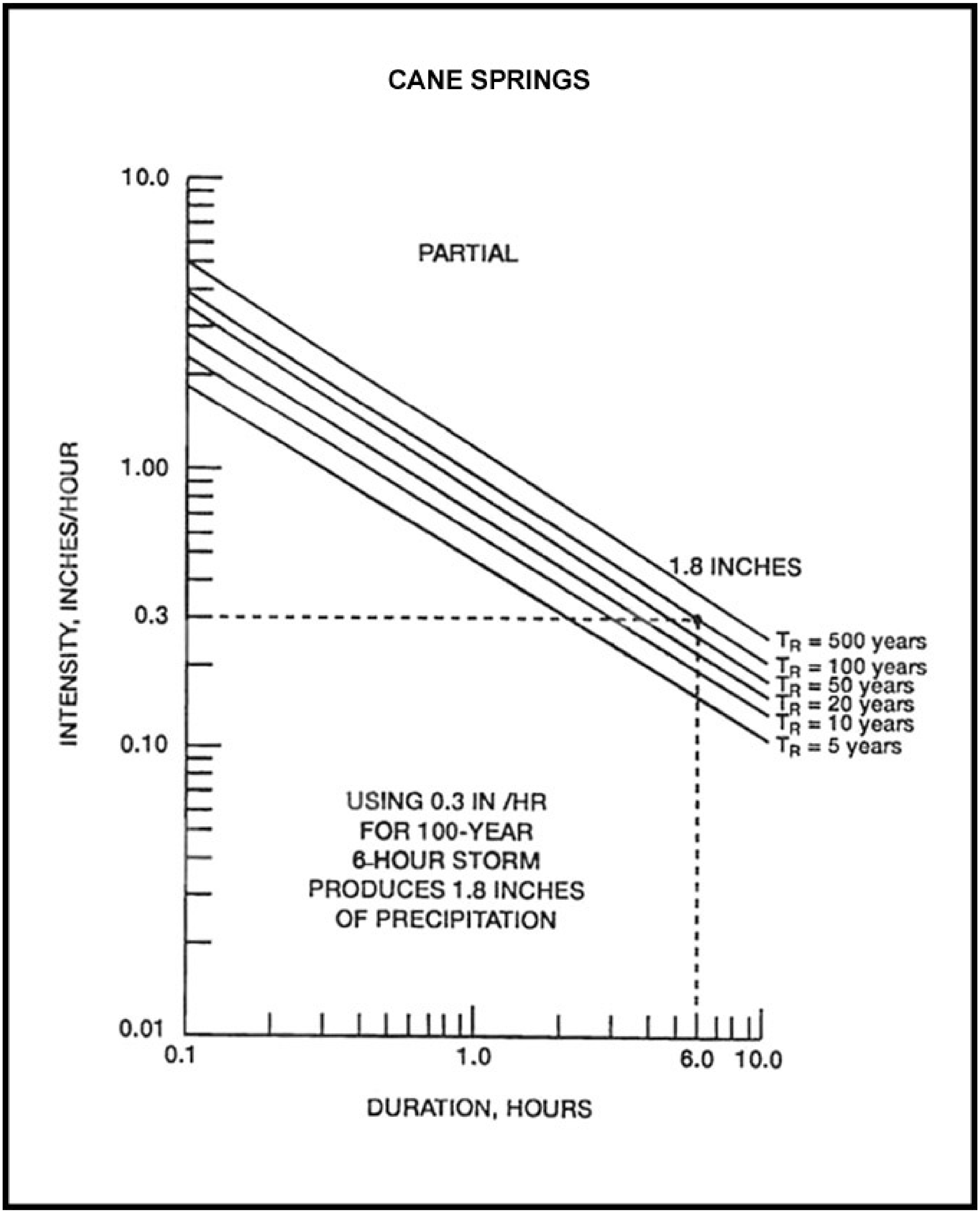


Figure 3-1. Intensity Duration Relationships for Various Return Periods, Cane Springs, Nevada Test Site, Nevada (modified from R.H. French, 1983)

R.H. French (1983) hypothesized that the southern part of Nevada can be divided into three precipitation zones: an excess zone, a transition zone, and a deficit zone (Figure 3-2). Based on this division, the Las Vegas valley is located in the excess zone and the NTS is located in the transition zone. R.H. French (1983) further hypothesized that the excess zone is a result of storms tracking up the Colorado River valley, and the influence of the river on precipitation values decreases with distance away from the Colorado River valley. The precipitation analyses by R.H. French (1983) supports this hypothesis and suggest that uncorrected precipitation values at the NTS are more applicable than precipitation values corrected by factors specified in the CCRFCD Manual (1990). Thus, the authors used the nonadjusted values from DOC (1973) for the hydrologic models in this flood assessment.

3.1.1.2 Storm Duration and Time Distribution

Clark County has adopted two 6-hour storm distribution tables to be used to generate discharges for areas less than or greater than 26 km^2 (10 mi^2) (CCRFCD, 1990). These storm distributions were used for the subbasins in the hydrologic models for the Area 3 RWMS. A mass curve of the two storm distributions is shown in Figure 3-3.

3.1.1.3 Depth-Area Ratios

During a flood-producing storm, point precipitation values probably would not apply to an entire drainage basin. Depth-area ratios that reduce the point precipitation value for a watershed as a function of area have been developed for arid regions. Clark County uses the depth-area ratios for 6-hour storms that were developed by the USACE for Clark County and vicinity (CCRFCD, 1990) (Table 3-1). These depth-area ratios are a modification of ratios developed by Zehr and Myers (1984) for arid watersheds in Arizona and New Mexico. Ratios in the CCRFCD Manual (1990) were used in the 6-hour storm hydrologic models for the Area 3 RWMS.

3.1.2 Drainage Areas

The Yucca Flat watershed was delineated using 7.5-minute and 30- × 60-minute U.S. Geological Survey (USGS) topographic quadrangle maps. The Jangle Ridge, Paiute Ridge, Reitman Seep, and North Paiute Ridge subbasins (Figure 1-2) were delineated using 7.5-minute USGS topographic quadrangle maps. Table 3-2 lists the maps used to delineate these areas. Drainage basin delineations were verified by study of color aerial photographs and by field investigations. The areas of the Yucca Flat watershed and the four subbasins were determined using a planimeter on the topographic maps listed in Table 3-2.

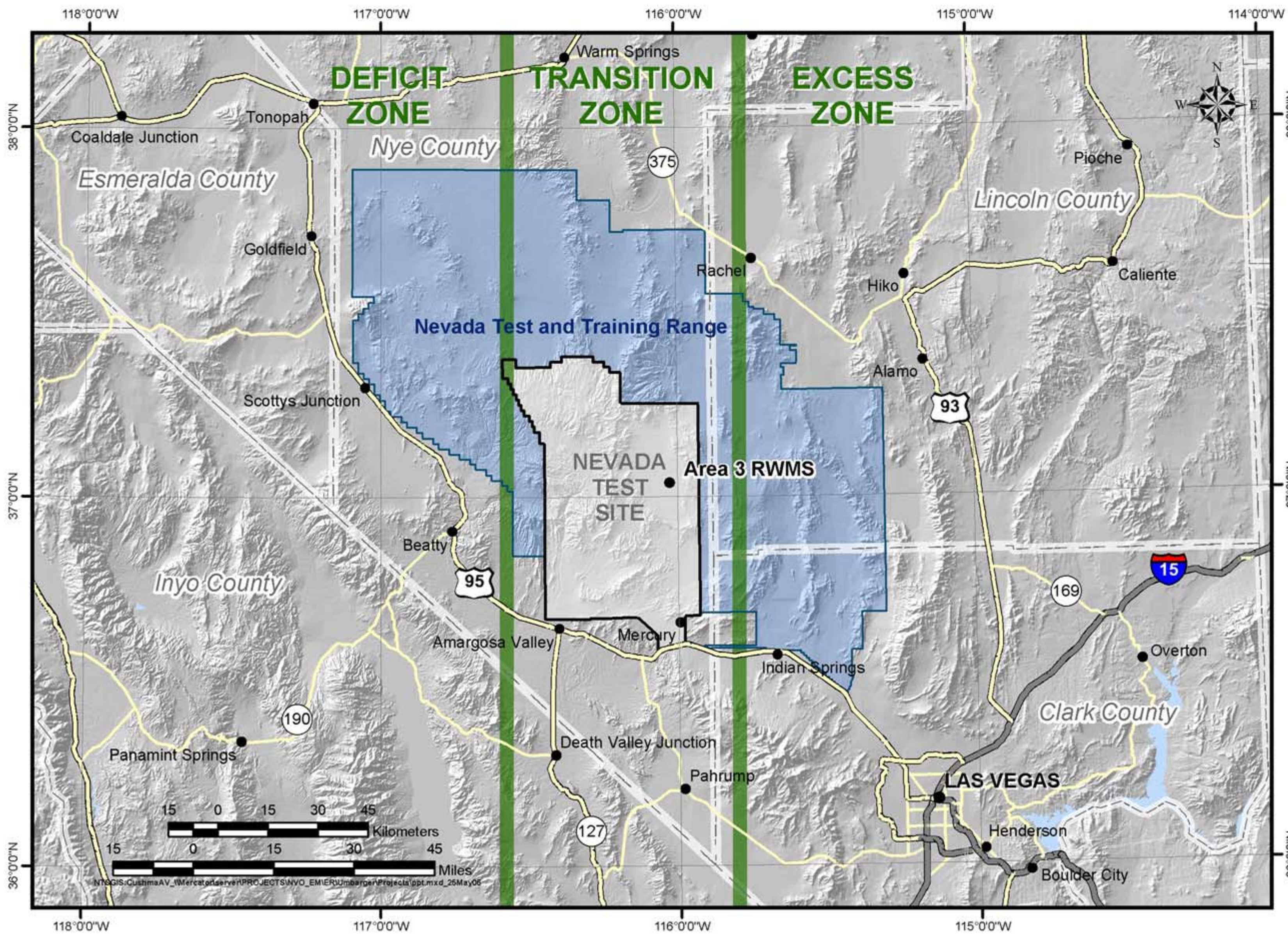
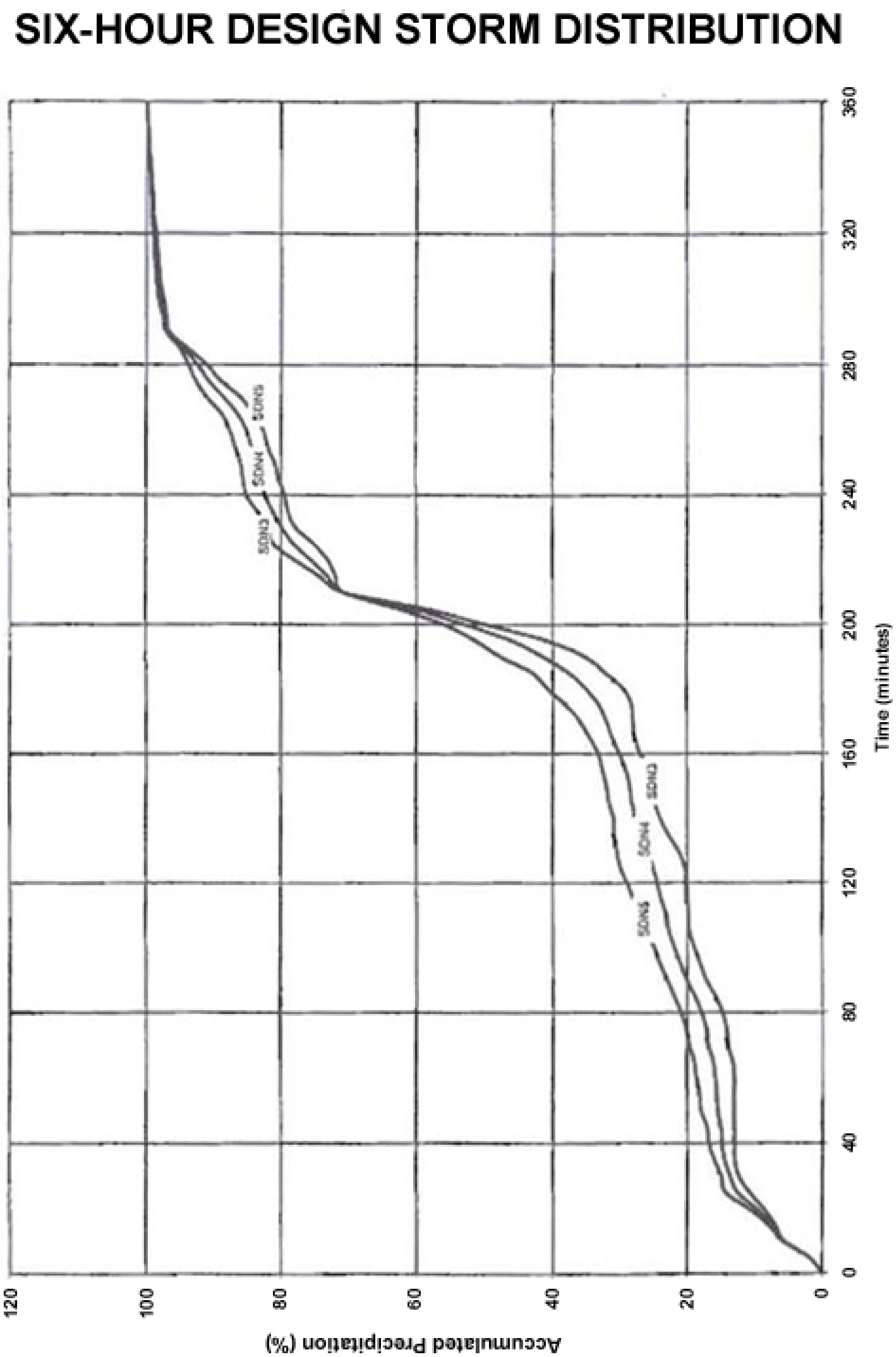


Figure 3-2. Hypothesized Zones of Precipitation in Southern Nevada (modified from French, 1983)



Notes:

1. SDN = Storm Distribution Number
2. For drainage areas less than 26 km^2 (10 mi^2), use SDN 3.
3. For drainage areas equal to or grater than 26 km^2 (10 mi^2), use SDN 5.

Figure 3-3. Storm Distribution Curves (Source: CCRFCD Manual, 1990)

Table 3-1. Six-Hour Precipitation Depth-Area Reduction Factors

		Point Precipitation Values (inches) for Given Return Intervals			
Drainage Area (mi^2)	Reduction Factor	100-Year	25-Year	10-Year	2-Year
.01	1.00	1.6	1.3	1.1	0.70
1	0.97	1.55	1.26	1.07	0.68
10	0.86	1.38	1.12	0.95	0.60
20	0.79	1.26	1.02	0.87	0.55
30	0.74	1.18	0.96	0.81	0.52
50	0.68	1.09	0.89	0.75	0.48

Table 3-2. Topographic Quadrangle Maps Used to Delineate the Yucca Flat Watershed and Four Subbasins for the Area 3 RWMS Flood Assessment

USGS Topographic Map Name and Publication Date	Area(s) Delineated [a]	USGS Topographic Map Name and Publication Date	Area(s) Delineated [a]
7.5-Minute Quadrangles			
Quartet Dome (1962)	YF	Plutonium Valley (1986)	YF
Mine Mountain (1986)	YF	Yucca Flat (1986)	YF, SB
Oak Spring (1986)	YF, SB	Oak Spring Butte (1962)	YF
Tippipah Spring (1952)	YF	Yucca Lake (1986)	YF
Paiute Ridge (1986)	YF, SB	Jangle Ridge (1986)	YF, SB
Rainier Mesa (1986)	YF		
30- × 60-Minute Topographic Quadrangles			
Indian Springs (1988)	YF	Beatty (1986)	YF
Pahute Mesa (1979)	YF	Pahranagat Ridge (1985)	YF

[a] YF = Yucca Flat Watershed
SB = Jangle Ridge, Paiute Ridge, Reitman Seep, and North Paiute Ridge Subbasins

3.1.3 Precipitation Losses

Precipitation losses were determined using the SCS curve number method and the applicable table from the CCRFCD Manual (1990) and reproduced in Table 3-3. The following information is required to determine a curve number for a specific subbasin:

- Hydrologic soil group
- Vegetation type
- Percent vegetation cover

Table 3-3. Runoff Curve Numbers for Semiarid Rangelands[a]

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	**Hydrologic Condition[b]**	**A[c]**	**B**	**C**	**D**
Herbaceous: Mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor	---	80	87	93
	Fair	---	71	81	89
	Good	---	62	74	85
Oak-aspen: Mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor	---	66	74	79
	Fair	---	48	57	63
	Good	---	30	41	48
Pinyon-juniper: Pinyon and/or juniper, grass understory	Poor	---	75	85	89
	Fair	---	58	73	80
	Good	---	41	61	71
Sagebrush: Sagebrush with grass understory	Poor	---	67	80	85
	Fair	---	51	63	70
	Good	---	35	47	55
Desert shrub: Major plants include saltbush, greasewood, creosote bush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

Modified from CCRFCD, 1990

[a] Average runoff condition, and Ia = 0.2S (where Ia = initial surface moisture storage capacity [inches]).

[b] Poor = <30 percent ground cover (litter, grass, and brush understory)
Fair = 30 to 70 percent ground cover
Good = >70 percent ground cover

[c] Curve numbers for Group A have been developed only for the desert shrub cover type.

The following procedures were used to obtain this information:

- The percent of bedrock and alluvium was determined for the subbasins using aerial photographs and geologic and topographic maps. Bedrock areas of the subbasins were assigned as Hydrologic Soil Group D. This soil group has high runoff potential and applies to areas with shallow soils or exposed bedrock. The alluvium is mostly sand and was assigned as Hydrologic Soil Group B based on field investigations.
- The vegetation cover type for the subbasins was determined to be desert shrub based on descriptions given in Table 3-3, field investigations, and study of both color and infrared aerial photographs.
- The hydrologic condition was determined to be poor, based on field investigations and study of color aerial photographs. Vegetation cover was estimated at less than 30 percent (Table 3-3). Because of the steep slopes and minimal or nonexistent soil, bedrock areas have less vegetation than alluvial areas; therefore the hydrologic condition of the bedrock areas was also classified as poor.

According to the CCRFCD Manual (1990), curve numbers for precipitation losses should be determined assuming an antecedent moisture condition (AMC) of II. AMC is dependent on antecedent rainfall, which is the amount of rainfall between 5 and 30 days preceding a flood-producing storm. AMC-I assumes the soil is dry; AMC-III assumes the soil is near or at saturation; AMC-II is halfway between the two. The CCRFCD Manual (1990) designates AMC-II because data required to determine the AMC for an entire area is not quantifiable.

Assuming AMC-II, curve numbers for the alluvium and bedrock were 77 and 88, respectively. A curve number of 83 (mean) was selected for areas with a thin mantle of alluvium overlying bedrock. The curve number for each subbasin was determined by taking the weighted average of the percentage of area covered by alluvium, a thin mantle of alluvium, and bedrock in each subbasin. Curve numbers for the subbasins are listed in Table 3-4. Hydrologic models in this study developed to estimate the 2-, 10-, and 25-year, 6-hour discharges assumed AMCs ranging from AMC-II to AMC-III. The 100-year, 6-hour hydrologic model developed for this study assumed AMC-III conditions. Results from all the models and the justification for varying the curve numbers per antecedent moisture conditions are addressed in Section 3.4, "Hydrology Discussion."

Table 3-4. Subbasin Curve Numbers

Subbasin Name	Subbasin Area mi^2 (km^2)	Curve Numbers for Model Discharges			
		100-Year, 6-Hour	25-Year, 6-Hour	10-Year, 6-Hour	2-Year, 6-Hour
PR1	1.8 (4.7)	93	90	89	88
PR2	2.3 (6.1)	91	88	87	86
PR3	0.4 (1.1)	92	89	88	87
PR4	0.2 (0.4)	91	88	887	86
PR5	0.2 (0.4)	92	89	88	87
PR6	1.9 (4.9)	84	81	79	77
NPR1	0.5 (1.2)	93	90	89	88
NPR2	3.2 (8.4)	84	81	79	77
RS1	1.3 (3.3)	88	85	83	81
RS2	3.1 (8.0)	86	83	81	79
RS3	2.1 (5.4)	86	83	81	79
JR1	0.7 (1.8)	93	90	89	88
JR2	3.2 (8.3)	91	88	87	86
JR3	1.7 (4.5)	91	88	87	86
JR4	2.2 (5.8)	92	89	88	87
JR5	1.7 (4.3)	91	88	87	86
JR6	0.9 (2.4)	91	88	87	86
JR7	0.4 (1.0)	90	87	85	83
JR8	0.2 (0.4)	92	89	88	87
JR9	7.7 (19.9)	84	81	79	77

3.1.4 Lag Time

In the SCS unit hydrograph method, only one input parameter, the lag time, is required. Lag time is calculated using one of two equations, depending on subbasin area. The CCRFCD Manual (1990) uses the lag time equation (English units) from the U.S. Bureau of Reclamation (Cudworth, 1989) for subbasins with areas greater than 2.6 km^2 (1 mi^2):

$$T_{lag} = 20K_n \left(\frac{LL_c}{S^{0.5}} \right)^{0.33}$$

where

T_{lag} = lag time (hours) between the center of mass of rainfall excess and the peak of the unit hydrograph

K_n = Manning roughness factor (dimensionless) for the basin channels

L = length of the longest watercourse (miles) within the subbasin

L_c = length along the longest watercourse (miles) measured upstream to a point opposite the centroid of the basin

S = average slope of the longest watercourse (feet per mile)

As indicated in the CCRFCD Manual (1990), the K_n factor is subjective. Therefore, criteria listed in the CCRFCD Manual (1990) are recommended and were used for this study (Table 3-5). Field investigations found that characteristics of the subbasins fall between the “n” value description for 0.030 and 0.050.

Table 3-5. Lag Equation Roughness Factors (Modified from CCRFCD Manual, 1990)

Watershed Characteristics	Roughness Factor, K_n
Urbanized Areas: Watercourses in the drainage area consist of street, storm sewer, and improved channels.	0.015
Natural Areas: Watercourses in the drainage area are well defined, unimproved channels or washes. Watershed has minimal vegetation.	0.030
Natural Areas: Watercourses in the drainage area are not well defined, and consist of many small rills and braided wash areas. Runoff from area combines slowly into channels. Includes mountainous channels with large boulders and flow restrictions.	0.050

The CCRFCD Manual (1990) uses the lag time equation (English units) from the U.S. Bureau of Reclamation (Cudworth, 1989) for subbasins with areas less than 2.6 km^2 (1 mi^2):

$$T_{lag} = 0.6\ (t_c)$$

$$t_i = \frac{1.8(1.1 - K_r)(L_o)^{0.6}}{(S)^{0.33}}$$

$$t_t = \left(L \big/ V \right)$$

where

$$t_c = t_i + t_t$$

T_{lag}	=	lag time (hours) between the center of mass of rainfall excess and the peak of the unit hydrograph
T_c	=	time of concentration (minutes)
T_i	=	initial time (minutes) to the channel
T_t	=	travel time in the channel (minutes)
K_r	=	flow resistance coefficient, where $K_r = 0.0139 \times CN - 0.32$
CN	=	curve number (Table 3-4)
L_o	=	length of overland flow (feet) (500 feet maximum)
S	=	average slope of the longest watercourse (feet per mile)
L	=	length of the longest watercourse (feet) within the subbasin
V	=	velocity (feet per second) as shown on Figure 602 of the CCRFCD Manual (1990)

Parameters used to determine the lag times for the subbasins are listed in Table 3-6. The L and S values for each subbasin were determined using a map wheel on the topographic maps. The L_c value was determined using a planimeter to find the centroid of each subbasin. A point on the longest watercourse of each subbasin that was closest to the respective centroid was selected. The L_o value was determined using a map wheel on the topographic maps. A maximum default value of 152.4 m (500 ft) was used if the measured L_o value was greater than 152.4 m (500 ft). The travel time V value was obtained from Figure 602 from the CCRFCD Manual (1990), using the curve labeled "Nearly Bare and Untilled (Overland Flow) & alluvial fans, Western Mountain Ranges."

The CCRFCD Manual (1990) suggests that Figure 602 be used for preliminary travel time calculations, and that subsequent calculations should be made using the hydraulic properties of the channel. However, field investigations showed that in most of the small subbasins defined in this study, it was difficult to discern when overland flow ceased and channelized flow began, as the channels were not easily differentiated. Also, these subbasins are relatively short, so a more detailed assessment of travel time required for longer basins is not necessary.

Table 3-6. Lag Time Parameters

Part A: Lag time parameters for subbasins with areas greater than 2.6 km^2 (1 mi^2)					
Subbasin	**L (miles)**	**L_c (miles)**	**K_r**	**S (feet/mile)**	**T_{lag} (hours)**
JR2	3.07	2.01	0.041	299.67	0.58
JR3	2.08	1.21	0.035	379.81	0.36
JR4	2.61	1.48	0.037	137.93	0.51
JR5	2.08	1.25	0.037	173.08	0.43
JR9	6.25	3.33	0.040	86.40	1.04
PR1	2.20	1.48	0.030	272.72	0.35
PR2	2.05	1.48	0.028	156.10	0.35
PR6	2.92	1.21	0.040	111.30	0.56
RS1	5.87	4.96	0.030	134.58	0.81
RS2	6.17	3.90	0.030	143.44	0.76
RS3	4.98	2.39	0.033	83.94	0.72
NPR2	4.05	2.50	0.040	113.58	0.79

Part B: Lag time parameters for subbasins with areas less than 2.6 km^2 (1 mi^2)						
Subbasin	**L (feet)**	**L_o (feet)**	**K_r**	**S (feet/mile)**	**V (feet/second)**	**T_{lag} (hours)**
JR1	6,019.2	500	0.77	219.3	2.1	0.50
JR6	8,025.6	500	0.75	144.74	1.7	0.82
JR7	5,174.4	500	0.71	183.67	1.8	0.51
JR8	4,012.8	500	0.76	157.89	1.7	0.42
PR3	5,386.6	500	0.76	218.75	2.0	0.47
PR4	3,220.8	500	0.75	155.29	1.7	0.36
PR5	2,798.0	500	0.76	320.75	2.5	0.21
NPR1	5.016.0	500	0.77	142.86	1.7	0.52

3.1.5 Channel Routing

The Muskingum channel routing method (McCarthy, 1938) was used for routing reaches. This routing method required three parameters: x, K, and the integer step. The weighting factor (x) expresses the amount of attenuation of the flood wave within the reach (Dunne and Leopold, 1978), and was determined using criteria cited by Cudworth (1989). The Muskingum coefficient (K) accounts for the translation of the peak flow for the entire channel reach. This coefficient is directly related to the length and the average velocity of the reach. The average channel velocity is determined using the Manning Equation. The Manning roughness coefficient was selected on the basis of field observations. Channel geometry was determined through field measurements. (The integer step and routing reach were determined so that the total travel time through the reach would be equal to K.) Eight reaches were routed in the models. Table 3-7 lists the routing parameters for these reaches.

Table 3-7. Routing Parameters Used in the Muskingum Routing Method

Reach Name	Integer Step [a]	Storage Constant [b] (K)	Weighting Factor [c] (x)
CPA to CPB	2	0.13	0.20
CPB to CPC	2	0.11	0.20
CPC to CPPRAF	11	0.86	0.20
NPR1 to CPD	17	1.39	0.20
JR1 to CPF	5	0.36	0.20
CPF to CPG	3	0.25	0.20
CPG to CPJRAF	12	0.99	0.20
CPJRAF to CPRWMS	4	0.28	0.20

[a] Integer Step: The integer step is the number of subreaches used in the Muskingum routing, and is dependent on the time interval specified in the model.

[b] Storage Constant (K): The Muskingum "K" coefficient is the travel time (hours) through the reach.

[c] Weighting Factor (x): The weighting factor expresses the amount of attenuation of the flood wave within the reach.

Transmission losses for the routing reaches are ignored in the models. Variability of infiltration rates along a channel reach can be extensive, making the losses over an entire reach difficult to quantify. Ignoring these losses adds conservatism to the model.

3.2 Hydrologic Models

Eleven hydrologic models were developed using the HEC-1 computer program (USACE, 1990a) to determine discharges for this flood assessment. The overall watershed that could impact the Area 3 RWMS was divided into 20 subbasins to provide discharges at key locations and concentration points. Figure 3-4 is a schematic showing how the subbasins were connected in the HEC-1 models. The model layout was the same for all models, as were the hydrologic parameters, with the exception of subbasin specific point precipitation values and curve numbers. Differences between models are explained in the model descriptions given in Table 3-8 and in Section 3.4, "Hydrology Discussion." Output details for the 11 hydrologic models are provided in Appendix A.

3.3 Hydrology Results

Discharges from the AR3100J, AR325F, AR310F, and AR32 models for the 100-, 25-, 10-, and 2-year, 6-hour storms, respectively, were used to analyze the flood hazard at the Area 3 RWMS. These models were generated by the HEC-1 model (USACE, 1990a) (Appendix A) and verified by a comparison of skew coefficients generated by the FEMA FAN model (1990) (Appendix B). The 500-year, 6-hour discharge was then extrapolated by the FEMA FAN model (1990) from the model-produced flood frequency curve. Justification for choosing these models is discussed in the following section.

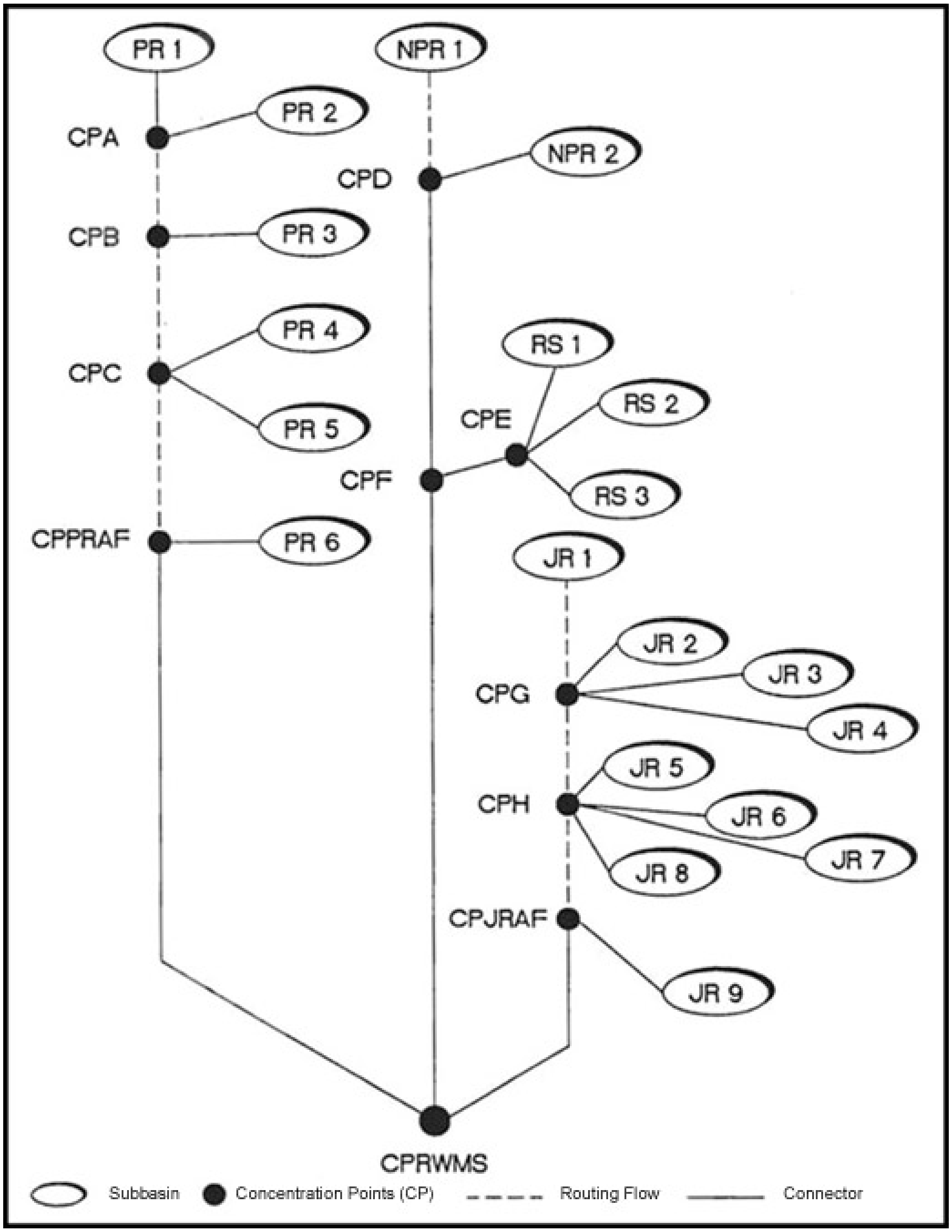


Figure 3-4. Schematic Diagram of the Area 3 Radioactive Waste Management Site Subbasin Network

Table 3-8. Hydrologic Model Descriptions

Model Name	Description
100-Year Hydrologic Models	
AR3100J	Model used for determining flood hazard at Area 3 RWMS. Curve numbers for bedrock- and alluvium-dominant subbasins were increased by 5 and 7, respectively. Point precipitation values were taken from NOAA Atlas 2, Volume VII (DOC, 1973).
AR3100F	Curve numbers for bedrock- and alluvium-dominant subbasins were increased by 4 and 7, respectively. Point precipitation values were taken from DOC (1973).
AR3100K	Curve numbers for bedrock- and alluvium-dominant subbasins were increased by 6 and 7, respectively. Point precipitation values were taken from DOC (1973).
AR3100	Model used as baseline subbasin delineation/curve number determination. No increases were made to curve numbers in any subbasins. Point precipitation values were taken from DOC (1973).
25-Year Hydrologic Models	
AR325F	Model used for determining flood hazard at Area 3 RWMS. Curve numbers for bedrock- and alluvium-dominant subbasins were increased by 2 and 4, respectively. Point precipitation values were taken from DOC (1973).
AR325D	Curve numbers for bedrock- and alluvium-dominant subbasins were increased by 1 and 3, respectively. Point precipitation values were taken from DOC (1973).
AR325	Model used as baseline subbasin delineation/curve number determination. No increases were made to curve numbers in any Subbasins. Point precipitation values were taken from DOC (1973).
10-Year Hydrologic Models	
AR310F	Model used for determining flood hazard at Area 3 RWMS. Curve numbers for bedrock- and alluvium-dominant subbasins were increased by 1 and 2, respectively. Point precipitation values were taken from DOC (1973).
AR310D	Curve numbers for bedrock- and alluvium-dominant subbasins were increased by 1. Point precipitation values were taken from DOC (1973).
AR310	Model used as baseline subbasin delineation/curve number determination. No increases were made to curve numbers in any subbasins. Point precipitation values were taken from DOC (1973).
2-Year Hydrologic Model	
AR32	Model used as baseline subbasin delineation/curve number determination. No increases were made to curve numbers in any subbasins. Point precipitation values were taken from DOC (1973).

3.4 Hydrology Discussion

The FEMA FAN model (1990) was used to verify the model-generated discharges for the 2-, 10-, 25-, and 100-year, 6-hour floods. Skew coefficients developed from model-generated discharges were compared with the regional skew coefficient (U.S. Water Resource Council Bulletin 17-B, 1981). If the hydrologic models are producing reasonable discharges, then the skew coefficients from these models should be close to the regional skew coefficient.

A major assumption in using skew coefficients is that the relationship between discharge and return period must follow a Log-Pearson Type III (LP3) probability distribution, as specified by WRC (1981). The FEMA FAN model (1990) contains a subroutine that calculates skew coefficients using a least-squares fit and an LP3 probability distribution. This program requires discharges from a minimum of three return periods to calculate the skew coefficient.

WRC Bulletin 17-B (1981) contains a map that shows the regional skew coefficients for the United States (reproduced here in Figure 3-5). According to information on this map, the skew coefficient for the washes on the NTS should be near zero. A zero skew coefficient means that if discharge were plotted against probability on log-probability paper, the flood frequency curve would plot as a log-normal distribution (straight line). Preliminary results from a study by the USGS using stream gage data gathered after 1981 also support a zero skew for this region (Hjalmarson, 1992).

A step-wise approach was taken to develop reasonable hydrologic models for the Area 3 RWMS subbasins. Using the HEC-1 model-generated 2-, 10-, 25-, and 100-year, 6-hour discharges, skew coefficient comparisons were made at the apexes of both the Jangle Ridge and Paiute Ridge alluvial fans. If the skew coefficients were not close to zero, modifications were made to the HEC-1 models, and the comparison made again. This iterative process continued until reasonable hydrologic models were developed. This same method was used to verify discharges at the concentration point at the Area 3 RWMS. Although this concentration point was not at the apex of an alluvial fan, the skew coefficient for discharges at the Area 3 RWMS should be close to the zero skew expected for the region.

Four model sets were evaluated using the skew coefficient comparison approach. Model Set 1 included the 2-, 10-, 25-, and 100-year, 6-hour models, (AR32, AR310, AR325, and AR3100, respectively). This model set was developed as a baseline using methods recommended in the CCRFCD Manual (1990). Discharges from both fan apexes in these models were entered into the FEMA FAN model (1990) to determine the skew coefficients (Appendix B). Skew coefficients corresponding to either apex (Table 3-9) were not close to zero; therefore discharges in Model Set 1 needed to be adjusted to move the skew coefficients closer to zero. Also, the skew coefficient corresponding to the discharges at the concentration point at the Area 3 RWMS was not close to zero, supporting the conclusion to modify the hydrologic models. The 2-year model was assumed to generate reasonable results; therefore, adjustments were made to the 10-, 25-, and 100-year, 6-hour models.

The 10-, 25-, and 100-year, 6-hour hydrologic models can be modified by adjusting curve numbers, depth of precipitation, or lag times. Of these three parameters, curve numbers show the widest variability because they are dependent on antecedent moisture conditions. Curve numbers for the subbasins in this study (Table 3-3) can range in the 50s and 60s under dry soil conditions (AMC-I) to the high 80s and low 90s (AMC-III) for saturated conditions.

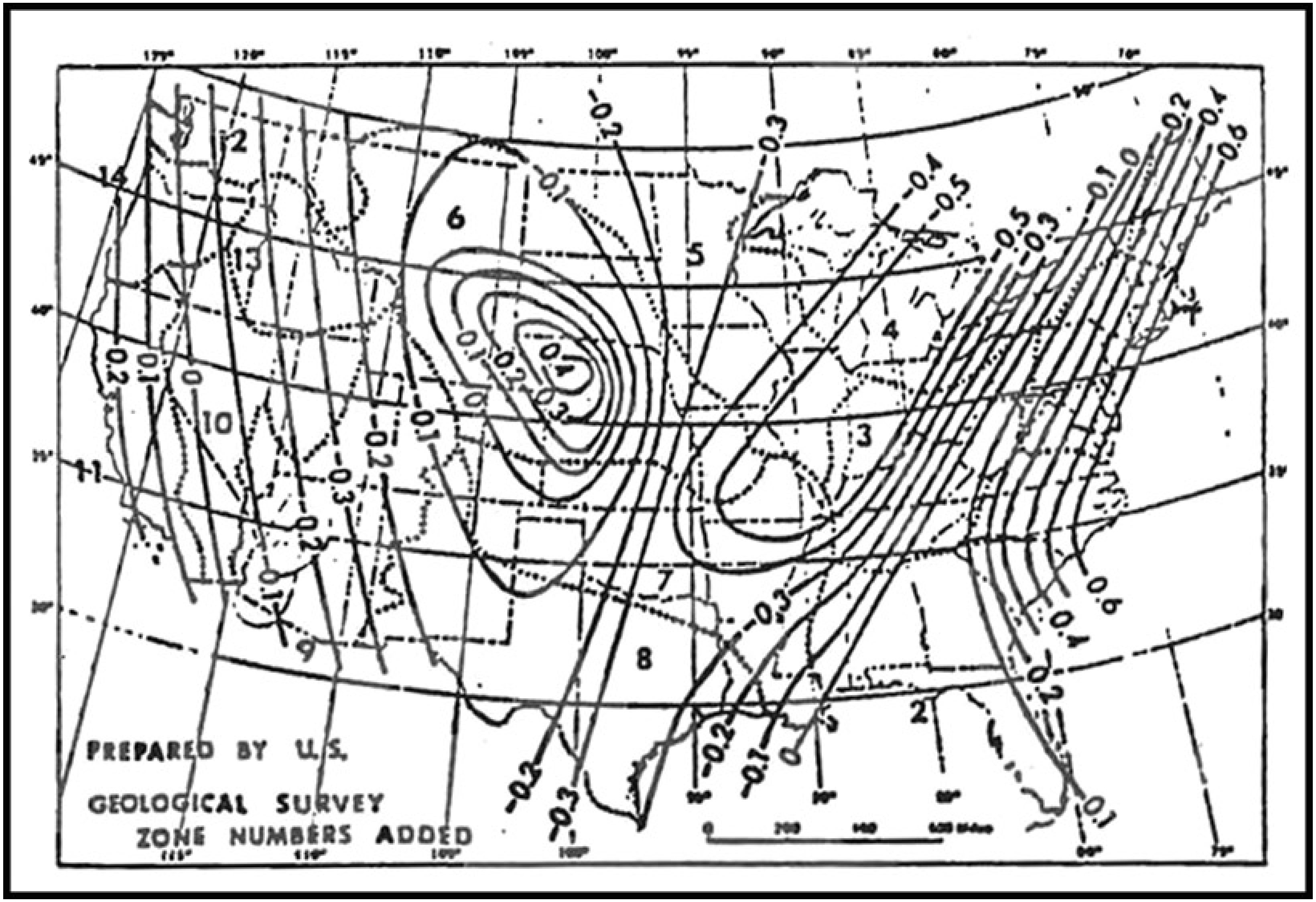


Figure 3-5. Generalized U.S. Skew Coefficients (WRC, 1981)

Table 3-9. Skew Coefficients from Different Model Sets (6-Hour Storms)

	Skew Coefficients			
Location	**Model Set 1**	**Model Set 2**	**Model Set 3**	**Model Set 4**
Paiute Ridge	-0.7	0.0	-0.3	-0.2
Jangle Ridge	-0.4	0.5	0.1	0.3
Area 3 RWMS	-0.3	0.5	0.0	0.2
Return Period	**Model Set 1**	**Model Set 2**	**Model Set 3**	**Model Set 4**
2-Year Model	AR32	AR32	AR32	AR32
10-Year Model	AR310	AR310D	AR310F	AR310F
25-Year Model	AR325	AR325D	AR325F	AR325F
100-Year Model	AR3100	AR3100F	AR3100J	AR3100K

The CCRFCD Manual (1990) assumes AMC-II because antecedent moisture conditions for a drainage basin are impossible to quantify and because a standard approach is required in Clark County to assure consistent analysis and design of drainage facilities and structures. The assumption of AMC-II may be reasonable for the 2-year flood events, as reflected in AR32, but may not be for the 10-, 25-, and 100-year flood events. For the 10-year or greater floods, the antecedent moisture condition, as well as rainfall, may contribute to flooding.

Precipitation depth and lag times are not as variable. Variation from the precipitation depths in DOC (1973) is not supportable because precipitation data in the study area (R.H. French, 1983; Barker, 1992) do not vary substantially from the values in DOC (1973). Variability in lag time is limited because three of the four parameters (L, L_c, and S) are measured from a topographic map, and significant variations in the K_n factor are not defendable using methods described in the CCRFCD Manual (1990) (Table 3-5). Therefore, curve numbers in the models were considered the most reasonable parameter to modify.

Modification of curve numbers was evaluated by first making adjustments similar to those used by Schmeltzer and others (1993). In this step, additional 10-, 25-, and 100-year, 6-hour models (AR310D, AR325D, and AR3100F, respectively) were created from the original models. In AR310D, curve numbers for alluvium-dominant subbasins were increased by 1; curve numbers for bedrock-dominant subbasins were not adjusted. In AR325D, curve numbers for bedrock- and alluvium-dominant subbasins were increased by 1 and 3, respectively. In AR3100F, curve numbers for bedrock- and alluvium-dominant subbasins were increased by 4 and 7, respectively.

Model Set 2 was developed using these modified models. The 2-, 10-, 25-, and 100-year, 6-hour discharges for Model Set 2 were entered into the FEMA FAN model (1990) to determine the skew coefficients (Appendix B). The skew coefficient for the Paiute Ridge alluvial fan apex was 0.0, corresponding to the appropriate regional skew coefficient. However, skew coefficients for the

Jangle Ridge alluvial fan apex and the concentration point at the Area 3 RWMS (Table 3-9) were both equal to 0.5; therefore, discharges in this set were again adjusted to move the skew coefficients closer to zero.

In this next step, additional 10-, 25-, and 100-year, 6-hour models (AR310F, AR325F, and AR3100J, respectively) were created. In AR310F, curve numbers for bedrock- and alluvium-dominant subbasins were increased by 1 and 2, respectively. In AR325F, curve numbers for bedrock- and alluvium-dominant subbasins were increased by 2 and 4, respectively. In AR3100J, curve numbers for bedrock- and alluvium-dominant subbasins were increased by 5 and 7, respectively.

Model Set 3 was developed using these modified models. The 2-, 10-, 25-, and 100-year, 6-hour discharges for Model Set 3 were entered into the FEMA FAN model (1990) to determine the skew coefficients (Appendix B). The skew coefficients corresponding to the Paiute Ridge alluvial fan apex, the Jangle Ridge alluvial fan apex, and the concentration point at the Area 3 RWMS were 0.3, 0.1, and 0.0, respectively.

In an attempt to generate skew coefficients closer to zero, an additional 100-year, 6-hour model, AR3100K, was created. In AR3100K, curve numbers for bedrock- and alluvium-dominant subbasins were increased by 6 and 7, respectively. Model Set 4, including AR32, AR310F, AR325F, and AR3100K, was thus developed. The 2-, 10-, 25-, and 100-year, 6-hour discharges for Model Set 4 were entered into the FEMA FAN model (1990) to determine the skew coefficients (Appendix B). Skew coefficients corresponding to the Paiute Ridge alluvial fan apex, the Jangle Ridge alluvial fan apex, and the Area 3 RWMS were -0.2, 0.3, and 0.2, respectively.

Review of these results indicated that Model Set 3 produced the most reasonable hydrologic models for the entire drainage basin impacting the Area 3 RWMS; therefore, the HEC-1 models in Model Set 3 were used to define the FEMA 100-year, 6-hour flood hazards in this flood assessment (Table 3-10). The FEMA FAN model (1990) uses skew coefficients to adjust the HEC-1 model-generated discharges to "best-fit discharges." Best-fit discharges would produce a zero skew coefficient, with the flood-frequency curve plotting as a log-normal distribution (a straight line on log-probability paper). From this flood-frequency curve, other return-period discharges can be interpolated or extrapolated. The FEMA FAN model (1990) automatically interpolates a 50-year discharge and extrapolates a 500-year discharge. Model Set 3 was used in the FEMA FAN model (1990) to develop the flood frequency curve used to extrapolate the 500-year, 6-hour discharges required in this flood assessment.

Table 3-10. HEC-1 Model-Generated Discharges at Key Locations

	Discharges (cubic feet per second) for Given Return Intervals				
Location	2-Year [a]	10-Year [a]	25-Year [a]	100-Year [a]	500-Year [b]
Paiute Ridge [c]	125	643	1,038	1,968	3,444
Jangle Ridge [d]	165	698	1,168	2,298	4,422
Area 3 RWMS [e]	122	732	1,492	3,313	7,272

[a] HEC-1 model-generated discharge

[b] Best fit discharge from flood frequency curve generated by FEMA FAN model (1990)

[c] Concentration point CPC

[d] Concentration point CPG

[e] Concentration point CPRWMS

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4.0 Hydraulics and Flood Hazard Determination

The Area 3 RWMS is located in an arid region where traditional approaches to define flood hazards (e.g., the hydraulic model HEC-2 [USACE, 1990b], which assumes a stable and fixed channel geometry), may not be appropriate for all types of flooding. Potential flooding of the Area 3 RWMS can occur as alluvial fan flooding and sheet flow. FEMA has developed methods to determine the 100-year flood hazards from these types of flooding.

This section includes the following:

- Brief description of the FEMA methods used to evaluate alluvial fan flooding and sheet flow.
- Results and discussion of the flood-hazard evaluation.
- Flood hazard maps.

4.1 Hydraulics and Flood Hazard Determination: Methods

4.1.1 Alluvial Fan Flooding

Flooding from the Jangle Ridge and Paiute Ridge alluvial fans could impact the Area 3 RWMS. Hydraulic processes on alluvial fans are different than in riverine channels. Alluvial fan flooding, as described by FEMA (1991), "...is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and unpredictable flowpaths." Channel geometry and direction on alluvial fans can change in direct response to a flood discharge. Field investigations and study of topographic maps and aerial photographs of the Jangle Ridge and Paiute Ridge alluvial fans support this description because flow paths are unpredictable, soil development is weak, and evidence of recent erosion and deposition is present.

FEMA (1991) states that if flow paths below the active apex cannot be predicted (as is the case for the Jangle Ridge and Paiute Ridge alluvial fans), the FEMA FAN model must be applied to evaluate the 100-year flood hazard. This model, which is a modification of the method proposed by Dawdy (1979), relates probability of discharges at the apex, as discussed below.

According to Dawdy (1979), flood flow from the apex of a typical alluvial fan does not spread evenly over the fan surface, but is instead confined to a surface or channel that carries flood waters from the apex to the toe of the fan (Figure 4-1). The active apex is selected at the point where the flow path becomes unpredictable, and flow is no more likely to follow an existing channel than to create a new path. In the upper region of an alluvial fan, flow is confined to a single channel where depth and width of the channel are functions of flow itself. In general, flow occurs at a critical depth and velocity is a result of steep slopes associated with this upper region. As slopes decrease towards the mid and distal parts of the fans, channel bifurcation can occur, resulting in a multiple-channel region. Dawdy (1979) did not incorporate a multiple-channel region into his method. FEMA (1991) modified the Dawdy method to address multiple-channel regions of alluvial fans.

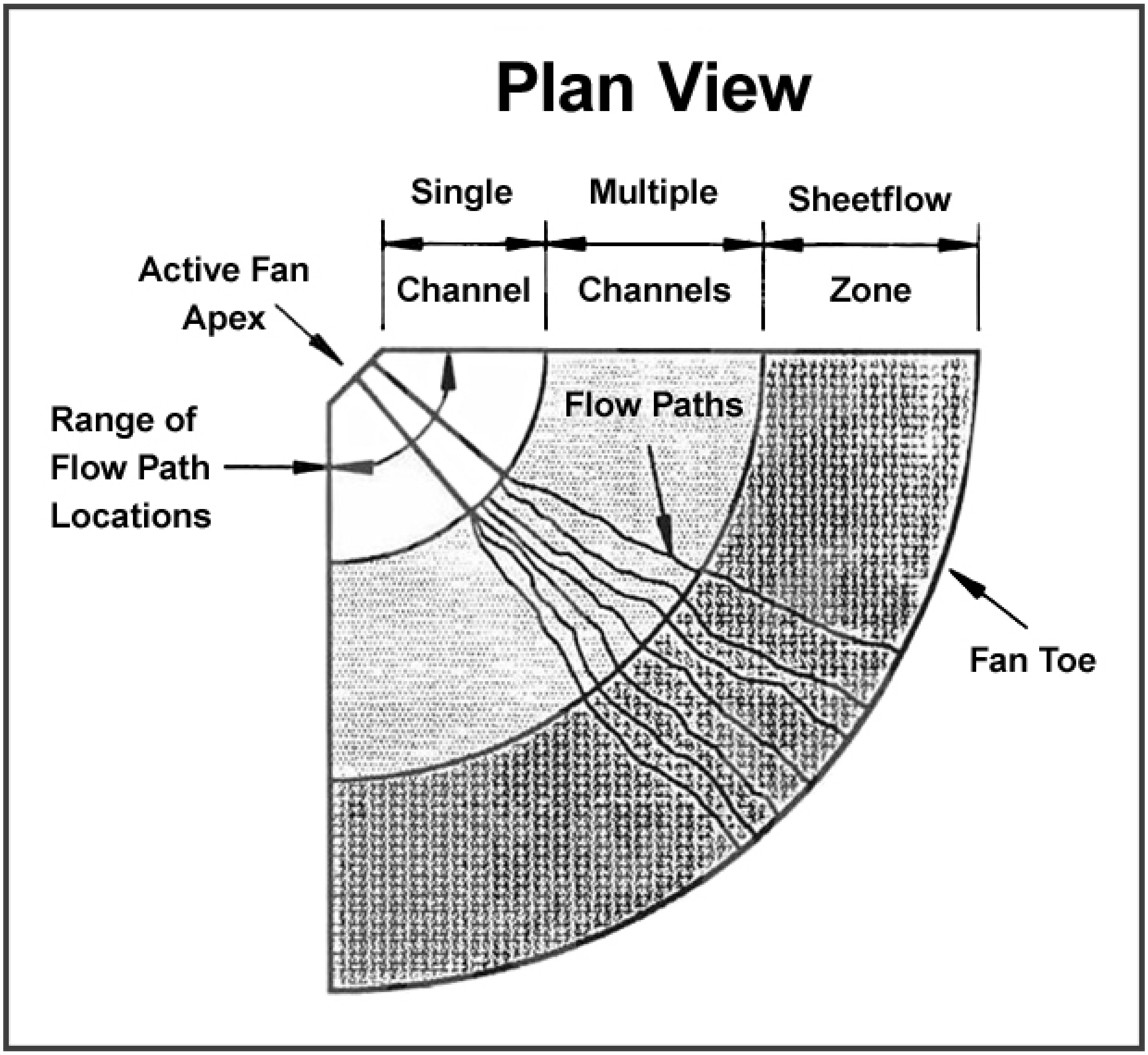

Figure 4-1. Plan View of an Alluvial Fan

Key assumptions of the FEMA model (R.H. French 1987):

- The location of the flood-event channel on the alluvial fan surface is random. A uniform probability is assumed, bounded by the edges of the alluvial fan. A channel passes through any given point on a contour of the alluvial fan.

–

- Flow occurs in flow-formed channels. Subsequent erosion results in these channels becoming well defined across the surface.
  - Incised channels do not exist prior to the flow event.
  - Existing channel capacity is not adequate to convey the flow, and overbank flooding occurs.

- The width and depth of the channel are a function of discharge.
- Transmission losses are not considered.
- On-fan precipitation (rainfall directly onto the alluvial fan surface) is not considered.
- The alluvial fan is active (net deposition is occurring in both time and space) and avulsions (channel migrations from one location to another during a single event) are occurring.
- An LP3 flood discharge frequency distribution is available at the alluvial fan apex.

Field observations, a study of topographic and geologic maps, aerial photographs, and examination of historic records were made during the flood assessment of these alluvial fans. Sources of flooding were defined, an apex was selected, active fan boundaries were delineated, entrenched reaches of channels were located and measured, and locations of flow obstructions were determined.

The method used for defining flood hazards on alluvial fans incorporates the FEMA FAN model (1990). Delineation of the 100-year flood hazard using the FEMA FAN model (1990) requires the following parameters and assumptions:

- Discharge information
- Apex location
- Fan boundaries and dimensions
- Potential flow obstructions and/or diversions
- Multiple channel region parameters. (Manning roughness coefficient and slope)

The FEMA FAN model (1990) requires that at least three discharges of different return periods be used to define flood-hazard zones. The 2-, 10-, 25-, and 100-year, 6-hour flood discharges for the Paiute Ridge and Jangle Ridge alluvial fans were taken from the HEC-1 models labeled AR3100J, AR325F, AR310F, and AR32, respectively, that were determined appropriate (see Section 3.4, “Hydrology Discussion”). Discharges used in the FEMA FAN model (1990) for Paiute Ridge alluvial fan were taken from the HEC-1 models at concentration point CPC. Discharges for Jangle Ridge alluvial fan were taken from the HEC-1 models at concentration point CPG (Table 3-10, Appendix A).

Apex locations and fan boundaries were determined from aerial photographs; available topographic, geologic, and surficial maps; and field investigations. Apexes were located using the FEMA definition of an active apex. Locations of the apexes for Jangle Ridge and Paiute Ridge alluvial fans are shown in Figure 2-1.

Potential flow obstructions and diversions such as roads, buildings, and other structures that can prevent flooding in some areas and increase flooding in others must be designated. In this flood assessment, all barriers, such as Road 3-03, secondary roads, geologic features, and all disturbed areas diverting flow away from the Area 3 RWMS were ignored, as quantification of the diversion would be difficult.

A Manning roughness coefficient of 0.040 was used for the multiple-channel regions of both fans. The Manning roughness coefficients for the multiple-channel regions of the fans were determined from field observations, and confirmed using descriptions and values found in tables developed by Chow (1959). Slope of the fans for the multiple-channel region parameters were determined from the Yucca Flat (1986) and Paiute Ridge (1986) 7.5-minute USGS topographic quadrangle maps.

4.1.2 Sheet Flow

The following quote from FEMA (1991) defines sheet flow:

> *[Sheetflow]. . . is the broad, relatively unconfined downslope movement of water across sloping terrain that results from . . . a channel that crosses a drainage divide, . . . and overflow from a perched channel onto . . . plains of lower elevations . . . [Sheetflow] is typical in areas of low topographic relief and poorly established drainage systems . . . Shallow flooding is often characterized by poorly defined channels and highly unpredictable flow direction because of low relief or shifting channels and debris loads. Where such conditions exist, the entire area susceptible to this unpredictable flow should be delineated as an area of equal risk. Small-scale topographic relief that is not evident on existing topographic mapping and that might lead to "islands" of one flood hazard zone within larger areas of another should be ignored.*

Sheet flow describes distal parts of the fans that drain from Jangle Ridge and Paiute Ridge toward the bottom of Yucca Flat. With current elevation information (6.1-m [20-ft] contour interval) on topographic maps, a detailed assessment of the sheet flow flood hazard was not possible because of the inability to distinguish channel and nonchannel regions. Therefore, per FEMA (1991), the 100-year flood hazard of this area was analyzed assuming that the entire area is prone to flooding and is delineated as an area of equal risk. Geomorphologic evidence gathered from analysis of color aerial photographs and field observations support this assumption because these areas have weak soil development and relatively few areas of relict deposits covered by desert pavement with desert varnish.

4.2 Results and Discussion of Flood Hazard Determination

Alluvial fan and sheet flow areas with 100-year flood depths greater than 0.3 m (1 ft) are designated as Zone AO by FEMA (1991). Zone AO is defined as the area of 100-year shallow flooding where average depths are between 0.3 and 1.0 m (1 and 3 ft). For alluvial fans anywhere throughout the zone, there is a probability of 0.01 that a channel can occur at the designated depth with flow at the designated velocity. Zone X represents areas outside the 100-year flood hazard or areas of 100-year shallow flooding (sheet flow) where average depths are less than 0.3 m (1 ft). A Zone X delineation does not mean that floods will not occur within this zone; therefore, flood hazard protection must be addressed.

Using methods described in Section 4.1, the 100-year flood hazard areas were defined on topographic maps (Figure 4-2). Zone AO and Zone X were used to denote the flood hazards in the vicinity of the Area 3 RWMS.

4.2.1 Alluvial Fan Flooding

The Area 3 RWMS is subject to flooding on the Jangle Ridge and Paiute Ridge alluvial fans. One-hundred-year flood-hazard zones for these fans are shown on Figure 4-2. The Area 3 RWMS is not within the boundaries of either alluvial fan as delineated in this study, and therefore is not within a FEMA-designated 100-year, 6-hour alluvial fan flood-hazard zone (Zone AO). However, flow from both fans still must be considered in mitigation design.

A delineated boundary of the Paiute Ridge alluvial fan is located just east of the facility. Review of aerial photographs shows that past flow paths of this alluvial fan extended beyond the present delineated fan boundary to the location of the Area 3 RWMS. To be conservative, flow from the Paiute Ridge alluvial fan was included in the total flow that must be considered in mitigation design.

The Jangle Ridge alluvial fan is north of the facility. Flow from this fan is intercepted at the bottom of Yucca Flat and drains southward along the basin bottom toward Yucca Lake. Aerial photographs and topographic maps show that the Area 3 RWMS is at or near the bottom of Yucca Flat. Aerial photographs also show past and present flow paths that extend over the location of the Area 3 RWMS. Although flow from all of the northern part of Yucca Flat watershed can drain along this flowpath, Jangle Ridge alluvial fan was assumed to be the most northern part of the watershed that presented a flood hazard to the Area 3 RWMS.

4.2.2 Sheet Flow

Sheet flow areas with 100-year flood depths less than 0.3 m (1 ft) are designated as Zone X by FEMA (1991). Calculated 100-year flow depths within the Area 3 RWMS vicinity are all less than 0.3 m (1 ft). Therefore, this facility is not located within a FEMA-designated 100-year, 6-hour flood-hazard zone from sheet flow (Figure 4-2). The calculated 500-year, 6-hour depth is also less than 0.3 m (1 ft). Therefore, the facility is not located within a 500-year, 6-hour flood-hazard zone from sheet flow. Appendix C contains calculations used to estimate the depth of flow in sheet flow regions.

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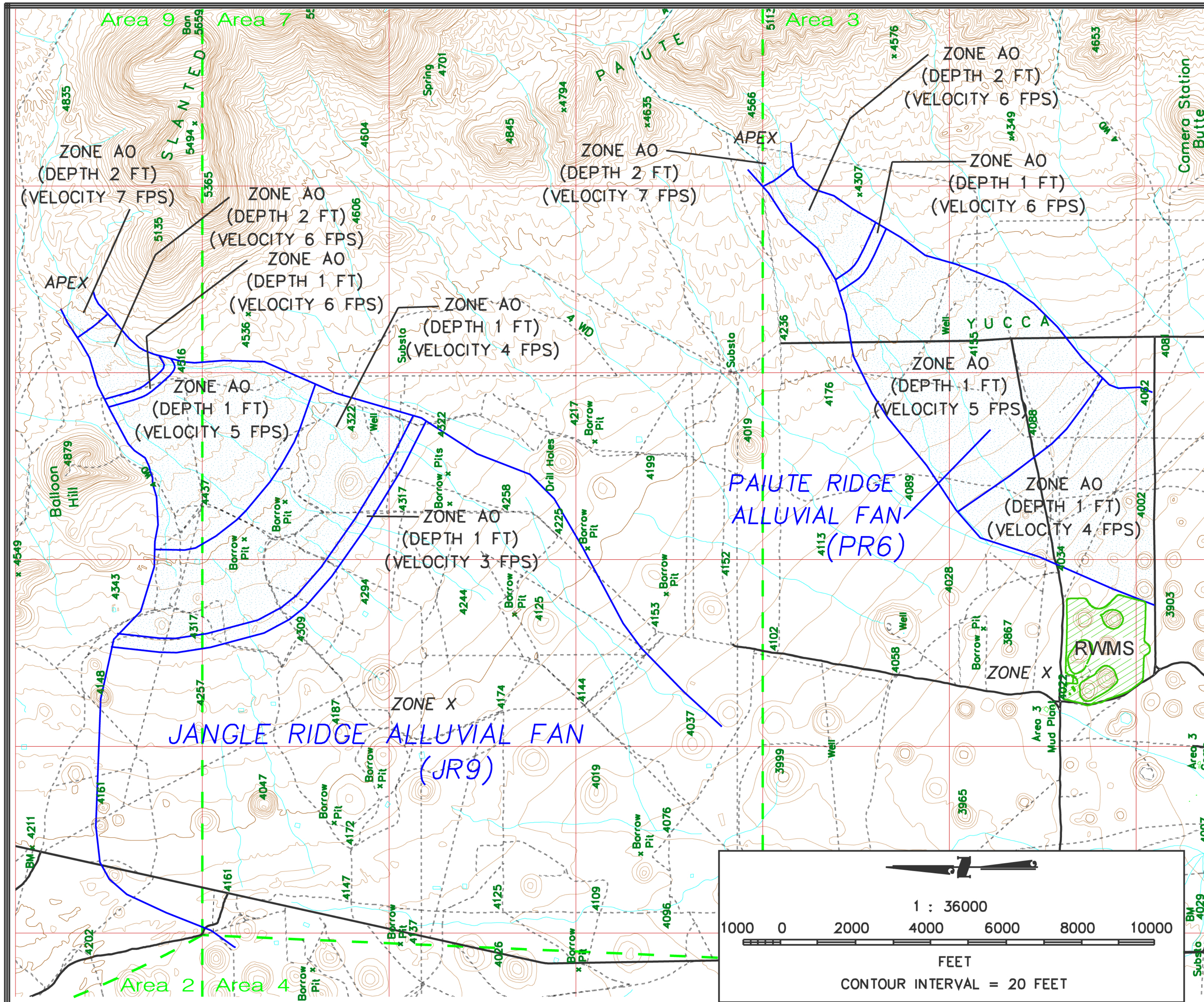

EXPLANATION

ALLUVIAL FAN BOUNDARY

NTS AREA BOUNDARY

ZONE AO (DEPTH 2 FT) (VELOCITY 5 FPS) — FEMA ALLUVIAL FAN 100-YEAR FLOOD ZONE DESIGNATION THAT CORRESPONDS TO AREAS OF 100-YEAR SHALLOW FLOODING WHERE AVERAGE DEPTHS ARE BETWEEN 1 AND 3 FEET. ANYWHERE THROUGHOUT THE ZONE THERE IS AN EQUALLY LIKELY CHANCE THAT A CHANNEL CAN OCCUR OF THE DESIGNATED DEPTH WITH A FLOW OF THE DESIGNATED VELOCITY.

ZONE X — FEMA FLOOD ZONE DESIGNATION THAT CORRESPONDS TO AREAS OUTSIDE THE 100-YEAR ALLUVIAL FAN FLOOD HAZARD AND TO AREAS OF 100-YEAR SHEETFLOW FLOODING WHERE AVERAGE DEPTHS ARE LESS THAN 1 FOOT.

RWMS — AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE (RWMS).

MAP INFORMATION

BASE MAP FROM USGS QUADRANGLES (1:24,000), OAK SPRING (1986), PAIUTE RIDGE (1986), YUCCA FLAT (1986), AND JANGLE RIDGE (1986), NYE COUNTY, NEVADA.

NOTES:
FT = FEET
FPS = FEET PER SECOND
USGS = US GEOLOGICAL SURVEY
4100 = ELEVATION IN FEET
(JR9) = SUB-BASIN SYMBOL

STATE OF NEVADA

LOCATION MAP

Figure 4–2

100–YEAR 6–HOUR FLOOD ZONE DELINEATION MAP OF THE AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE

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5.0 Summary

A flood assessment was conducted for the Area 3 RWMS at the NTS to determine whether the facility is located within a 100-year flood hazard as defined by FEMA, and to provide both 100-year and 500-year discharges for design of flood protection.

Potential flooding of the Area 3 RWMS can occur as alluvial fan flooding and sheet flow. Methods developed by FEMA (1991) to determine the 100-year flood hazard from these types of flooding were used to provide hydrologic and hydraulic information for design of flood protection structures for the facility.

The study area encompasses the approximately 780-km^2 (300 mi^2) Yucca Flat watershed; however, review of topographic maps and aerial photographs of Yucca Flat, in addition to field investigations, indicated that only a portion of this region, approximately 94 km^2 (36 mi^2) in size, could directly impact the Area 3 RWMS. This smaller drainage area encompasses portions of the Halfpint Range, including Paiute Ridge, Jangle Ridge, Carbonate Ridge, Slanted Buttes, Cockeyed Ridge, and Banded Mountain. The Area 3 RWMS is located on coalescing alluvial fans emanating from this drainage area.

In the arid Southwest, rainfall-runoff models are typically used to estimate flood discharges. Rainfall-runoff models were developed for the Area 3 RWMS flood assessment using the HEC-1, Flood Hydrograph Package (USACE, 1990a). Peak discharges generated by the HEC-1 model were incorporated into the FEMA FAN model (FEMA, 1990) to define flood hazards on identified alluvial fans within the study area. The HEC-1 model-generated discharges were also used to calculate sheet flow depths where appropriate.

Based on analyses described in this report, the Area 3 RWMS is not located within the FEMA-designated 100-year, 6-hour flood-hazard zone of either the Jangle Ridge or Paiute Ridge alluvial fans. Calculated 100-year sheet flow depths within the Area 3 RWMS vicinity are less than 0.3 m (1 ft). Therefore, the Area 3 RWMS is not located within a 100-year, 6-hour flood-hazard zone from sheet flow.

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6.0 References

Bull, W. B., 1964. History and Causes of Channel Entrenching, Western Fresno County, CA. American Journal of Science, v. 262, p. 249-258.

CCRFCD, see Clark county Regional Flood Control District.

Chow, V. T., 1959. Open Channel Hydraulics. McGraw-Hill Book Company, New York, NY.

Christenson, R. C., and N. E. Spahr, 1980. *Flood Potential of Topopah Wash and Tributaries, Eastern Part of Jackass Flats, Nevada Test Site, Southern Nevada*. U.S. Geological Survey Open-File Report 80-963, 22 pp.

Clark County Regional Flood Control District (CCRFCD), 1990. *Hydrologic Criteria and Drainage Design Manual*. WRC Engineering, Inc., Las Vegas, NV.

Cudworth, A. G., Jr., 1989. Flood Hydrology Manual (First Edition). U.S. Bureau of Reclamation, 243 pp.

Dawdy, D. R., 1979. *Flood Frequency Estimates on Alluvial Fans*. Journal of the Hydraulics Division, American Society of Civil Engineers, v. 105, n. HY-11, p. 1,407-1,413.

DOC, sees U.S. Department of Commerce.

Dunne, T., and L. B. Leopold, 1978. Water in Environmental Planning. W. H. Freeman and Company, San Francisco, CA, 818 pp.

EPA, see U.S. Environmental Protection Agency.

Executive Order 11988, Floodplain Management, 1977. Federal Register, Chapter 40, Protection of Environment, 42 FR 26951, 3 CFR, 1977 Comp., p. 117, May 24, 1977

FEMA, see Federal Emergency Management Agency.

Federal Emergency Management Agency, 1990. FAN: An Alluvial Fan Flooding Computer Program - User's Manual. U.S. Government Printing Office, Washington, D.C.

Federal Emergency Management Agency, 1991. Flood Insurance Study: Guidelines and Specifications for Study Contractors. U.S. Government Printing Office, Washington, D.C., 100 pp.

French, R. H., 1983. *Precipitation in Southern Nevada*. Journal of Hydraulic Engineering, American Society of Civil Engineers, v. 109, n. 7, p. 1,023-1,036.

French, R. H., 1987. Hydraulic Processes on Alluvial Fans. Elsevier, Amsterdam. 243 pp.

McCarthy, G. T. , 1938. "The Unit Hydrograph and Flood Routing", *Conf. North Atlantic Div*., U. S. Corps of Engineers, New London, Conn. 1938, *in* Maidment, David R., "Handbook of Hydrology," 1992: McGraw-Hill.

Schmeltzer, J. S., J. J. Miller, and D. L. Gustafson, 1993. Written communication. Subject: *Flood Assessment at the Area 5 Radioactive Waste Management Site, Nye County, Nevada*. Raytheon Services Nevada, Las Vegas, NV.

USACE, see U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers, September 1990a. Flood Hydrograph Package (HEC-1 Computer Program, Version 4.0). Davis, CA.

U.S. Army Corps of Engineers, September 1990b. *Water Surface Profiles (HEC-2 Computer Program)*. Davis, CA.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), 1973. NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume VII. Silver Spring, MD.

U. S. Environmental Protection Agency, 1980, Code of Federal Regulations (CFR) Title 44: Emergency management and Assistance: Chapter 1 - Federal Emergency Management Agency, Department of Homeland Security, Subchapter A – General, Part 9, Floodplain Management and Protection of Wetlands, [45 FR 59526, September 9, 1980, as amended at 49 FR 33879, August 27, 1984].

U.S. Environmental Protection Agency, 1982, Code of Federal Regulations (CFR) Title 10: Energy: Part 1022—*Compliance With Floodplain And Wetland Environmental Review Requirements* [42 U.S.C. 7101 et seq.; 50 U.S.C. 2401 et seq.; E.O. 11988, 42 FR 26951, 3 CFR, 1977 Comp., p. 117; E.O. 11990, 42 FR 26961, 3 CFR, 1977 Comp., p. 121; E.O. 12372, 47 FR 30959, 3 CFR, 1982 Comp., p. 197]

U.S. Environmental Protection Agency, 1983, Code of Federal Regulations (CFR) Title 40: Protection of Environment: Chapter 1 - Environmental Protection Agency, Subchapter I – Solid Wastes, Part 270 *EPA Administered Permit Programs: The Hazardous Waste Permit Program*, Part 270.14, *General Requirements*, [48 FR 14228, April 1, 1983; 48 FR 30114, June 30, 1983]

U.S. Environmental Protection Agency, 1987, Code of Federal Regulations (CFR) Title40: Protection of Environment: Chapter 1 - Environmental Protection Agency, Subchapter I – Solid Wastes, Part 264.18, *Location Standards* [46 FR 2848, January 12, 1981, as amended at 47 FR 32350, July 26, 1982; 48 FR 14294, April 1, 1983; 48 FR 30115, June 30, 1983; 50 FR 4514, January 31, 1985; 50 FR 28746, July 15, 1985; 52 FR 46963, December 10, 1987]

U.S. Water Resources Council, 1981. Guidelines for Determining Flood Flow Frequency. Bulletin 17-B of the Hydrology Committee, Washington, D.C.

WRC, see U.S. Water Resources Council.

Zehr, R. M., and V. A. Meyers, 1984. Depth-Area Ratios in the Semiarid Southwest United States. U.S. Department of Commerce, Silver Spring, MD, 45 pp.