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# Site-Specific Probable Maximum Precipitation Study for the White Tanks #4 Drainage Basin

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## Executive Summary

Applied Weather Associates (AWA) has completed a site-specific Probable Maximum Precipitation (PMP) study for White Tanks #4 located in Maricopa County, Arizona. The purpose of the study is to determine PMP values specific to the drainage basin, taking into account topography, climate and storm types that affect this region.

The approach used in this study is basically the same as that used in the numerous site-specific and regional studies that AWA has completed in the last ten years. This is the storm-based approach used by the National Weather Service (NWS) in the development of the recent Hydrometeorological Reports (HMRs). The World Meteorological Organization (WMO) for PMP determination (WMO Operational Hydrology Report No.1, 1986) recommends this same approach. This approach identifies extreme rainfall events that have occurred in the Desert Southwest, extending from the southeastern deserts of California through southern Arizona south of the Mogollon Rim that have meteorological characteristics similar to extreme rainfall storms that could occur over the White Tanks #4 drainage basin. The largest of these rainfall events are selected for detailed analyses.

Twenty-eight extreme rainfall storm events are identified as rainfall centers having similar characteristics to extreme rainfall events that could potentially occur over the drainage basin. This includes twelve local convective storms, eight remnant tropical storms, and eight general storms. Each of these storms was analyzed using the Storm Precipitation Analysis System (SPAS), which produced Depth-Area-Duration (DAD) values, mass curves, and total storm isohyetals among many other products. National Weather Service Next Generation Weather Radar (NEXRAD) data are incorporated when available. Two of the remnant tropical storms (August 1951 and September 1970) had previously been analyzed by the Bureau of Reclamation as part of the study "Determination of an Upper Limit Design Rainstorm for the Colorado River Basin above Hoover Dam" (Bureau of Reclamation 1990).

Standard procedures for maximization, transposition, and elevation moisture adjustments are used. New techniques and databases are used in the study to increase accuracy and reliability, while adhering to the basic approach used in the HMRs and in the WMO Manual.

Maximization factors are computed for each of the twenty-eight storms using an updated dew point climatology representing the maximum moisture that could have been associated with the rainfall event. This climatology includes the average 3-, 12-, and 24-hour 100-year return frequency values. The most appropriate duration consistent with the duration of the storm rainfall is used. For one storm where the moisture source originated over the ocean, an updated sea surface temperature (SST) climatology using plus 2 sigma values is used. HYSPLIT model trajectories and SST data from the National Center for Atmospheric Research (NCAR) and National Oceanic and Atmospheric Association (NOAA) National Environmental Satellite, Data, & Information Service (NESDIS) are used in the storm adjustment procedures.

Each historic extreme rainfall storm was maximized, transpositioned and elevation adjusted to the White Tanks #4 drainage basin. Depth-Area (DA) plots were made for each duration period. For local convective storms, the durations are 1-, 2-, 3-, 4-, 5-, and 6-hours. For

remnant tropical and general storms, the durations are 1-, 6-, 12-, 24-, 36-, 48-, 72-hours. Enveloping curves were constructed. Depth-Duration (DD) plots were then made and enveloping curves constructed. These final enveloping curves provide PMP values for the drainage basin.

The site-specific PMP values for the White Tanks #4 location are provided in the tables below.

Site-specific PMP values for local storms

| White Tanks #4 Site-Specific PMP Local Storm Values in Inches | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Area/Duration** | ***1-Hour*** | ***2-Hour*** | ***3-Hour*** | ***4-Hour*** | ***5-Hour*** | ***6-Hour*** |
| **AWA Local Storm PMP values** | 1 | 5.4 | 7.6 | 9.2 | 10.3 | 10.9 | 11.1 |
| | 10 | 4.9 | 6.9 | 8.5 | 9.9 | 10.6 | 10.7 |
| | 50 | 4.0 | 6.1 | 7.6 | 8.9 | 9.5 | 9.5 |
| | 100 | 3.5 | 5.7 | 7.0 | 8.2 | 8.8 | 8.8 |
| | 200 | 3.0 | 5.3 | 6.4 | 7.4 | 7.9 | 7.9 |
| | 500 | 2.4 | 4.5 | 5.4 | 6.1 | 6.6 | 6.6 |
| | 1000 | 1.9 | 3.6 | 4.3 | 4.8 | 5.2 | 5.4 |
| | 2000 | 1.4 | 2.8 | 3.4 | 3.8 | 4.1 | 4.3 |
| | 5000 | 0.8 | 1.5 | 1.9 | 2.2 | 2.4 | 2.6 |

Site-specific PMP values for remnant tropical storms

| White Tanks #4 Site-Specific PMP Tropical Storm Values in Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Area/Duration** | ***1-Hour*** | ***6-Hour*** | ***12-Hour*** | ***24-Hour*** | ***36-Hour*** | ***48-Hour*** | ***72-Hour*** |
| **AWA Tropical Storm PMP values** | 1 | 5.2 | 8.5 | 13.1 | 16.0 | 16.1 | 16.1 | 16.1 |
| | 10 | 5.0 | 7.8 | 12.0 | 14.5 | 14.6 | 14.6 | 14.6 |
| | 50 | 3.9 | 6.2 | 9.1 | 11.2 | 11.4 | 11.6 | 12.2 |
| | 100 | 3.3 | 5.5 | 7.8 | 9.9 | 10.1 | 10.4 | 11.2 |
| | 200 | 2.7 | 4.8 | 6.7 | 8.6 | 9.0 | 9.5 | 10.5 |
| | 500 | 2.1 | 4.0 | 5.7 | 7.1 | 8.2 | 8.9 | 9.9 |
| | 1000 | 1.7 | 3.4 | 5.1 | 6.3 | 7.6 | 8.4 | 9.5 |
| | 2000 | 1.3 | 3.0 | 4.5 | 5.7 | 7.2 | 7.9 | 9.1 |
| | 5000 | 0.8 | 2.4 | 3.6 | 4.9 | 6.6 | 7.4 | 8.3 |
| | 10000 | 0.6 | 1.9 | 2.7 | 4.2 | 6.0 | 6.8 | 7.6 |

Site-specific PMP values for general frontal storms

| White Tanks #4 Site-Specific PMP General Storm Values in Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Area/Duration** | ***1-Hour*** | ***6-Hour*** | ***12-Hour*** | ***24-Hour*** | ***36-Hour*** | ***48-Hour*** | ***72-Hour*** |
| **AWA General Storm PMP values** | 1 | 1.0 | 3.7 | 4.6 | 6.8 | 8.0 | 9.1 | 11.4 |
| | 10 | 1.0 | 3.6 | 4.5 | 6.7 | 7.8 | 9.0 | 11.3 |
| | 100 | 1.0 | 3.2 | 3.9 | 5.8 | 6.4 | 7.2 | 9.3 |
| | 200 | 0.9 | 3.0 | 3.7 | 5.5 | 6.0 | 6.6 | 8.4 |
| | 500 | 0.8 | 2.8 | 3.5 | 5.0 | 5.5 | 5.9 | 7.2 |
| | 1000 | 0.8 | 2.5 | 3.3 | 4.5 | 5.0 | 5.4 | 6.2 |
| | 2000 | 0.8 | 2.2 | 3.0 | 4.0 | 4.3 | 4.9 | 5.4 |
| | 5000 | 0.6 | 1.8 | 2.6 | 3.3 | 3.5 | 4.0 | 4.4 |
| | 10000 | 0.5 | 1.6 | 2.2 | 2.8 | 2.8 | 3.2 | 3.7 |
| | 20000 | 0.4 | 1.4 | 1.8 | 2.3 | 2.2 | 2.5 | 2.7 |

Comparison of the White Tanks #4 drainage basin site-specific PMP values at the 20-square mile area size for each storm type by duration

| ***Storm Duration*** | ***AWA Local Storm PMP Values 20sqmi*** | ***AWA Tropical Storm PMP Values 20sqmi*** | ***AWA General Storm PMP Values 20sqmi*** |
|---|---|---|---|
| ***1 Hour*** | **4.5** | **4.5** | **1.0** |
| ***2 Hours*** | **6.6** | | |
| ***3 Hours*** | **8.1** | | |
| ***4 Hours*** | **9.4** | | |
| ***5 Hours*** | **10.2** | | |
| ***6 Hours*** | **10.3** | **7.1** | **3.4** |
| ***12 Hours*** | | **10.8** | **4.3** |
| ***24 Hours*** | | **13.0** | **6.3** |
| ***36 Hours*** | | **13.1** | **7.3** |
| ***48 Hours*** | | **13.2** | **8.3** |
| ***72 Hours*** | | **13.5** | **10.8** |

## GLOSSARY

**Adiabat:** Curve of thermodynamic change taking place without addition or subtraction of heat. On an adiabatic chart or pseudo-adiabatic diagram, a line showing pressure and temperature changes undergone by air rising or condensation of its water vapor; a line, thus, of constant potential temperature.

**Adiabatic:** Referring to the process described by adiabat.

**Advection:** The process of transfer (of an air mass property) by virtue of motion. In particular cases, advection may be confined to either the horizontal or vertical components of the motion. However, the term is often used to signify horizontal transfer only.

**Air mass:** Extensive body of air approximating horizontal homogeneity, identified as to source region and subsequent modifications.

**Barrier:** A mountain range that partially blocks the flow of warm humid air from a source of moisture to the basin under study.

**Basin centroid:** The point at the exact center of the drainage basin as determined through geographical information systems calculations using the basin outline.

**Basin shape:** The physical outline of the basin as determined from topographic maps, field survey, or GIS.

**Cirrus shield:** In this study, the area of cirrus cloud that covers a mesoscale convective complex.

**Cirrus anvil:** The cirrus cloud that is advected downwind from the top of a cumulonimbus cloud.

**Cold front:** Front where relatively colder air displaces warmer air.

**Convective rain**: Rainfall caused by the vertical motion of an ascending mass of air that is warmer than the environment and typically forms a cumulonimbus cloud. The horizontal dimension of such a mass of air is generally of the order of 12 miles or less. Convective rain is typically of greater intensity than either of the other two main classes of rainfall (cyclonic and orographic) and is often accompanied by thunder. The term is more particularly used for those cases in which the precipitation covers a large area as a result of the agglomeration of cumulonimbus masses.

**Convergence:** Horizontal shrinking and vertical stretching of a volume of air, accompanied by net inflow horizontally and internal upward motion.

**Cooperative station:** A weather observation site where an unpaid observer maintains a climatological station for the National Weather Service.

**Cyclone:** A distribution of atmospheric pressure in which there is a low central pressure relative to the surroundings. On large-scale weather charts, cyclones are characterized by a system of closed constant pressure lines (isobars), generally approximately circular or oval in form, enclosing a central low-pressure area. Cyclonic circulation is counterclockwise in the northern hemisphere and clockwise in the southern. (That is, the sense of rotation about the local vertical is the same as that of the earth's rotation.)

**Depth-Area curve:** Curve showing, for a given duration, the relation of maximum average depth to size of area within a storm or storms.

**Depth-Area-Duration:** The precipitation values derived from Depth-Area and Depth-Duration curves at each time and area size increment analyzed for a PMP evaluation.

**Depth-Area-Duration Curve:** A curve showing the relation between an averaged areal rainfall depth and the area over which it occurs, for a specified time interval, during a specific rainfall event.

**Depth-Area-Duration values:** The combination of depth-area and duration-depth relations. Also called depth-duration-area.

**Depth-Duration curve:** Curve showing, for a given area size, the relation of maximum average depth of precipitation to duration periods within a storm or storms.

**Dew point:** The temperature to which a given parcel of air must be cooled at constant pressure and constant water vapor content for saturation to occur.

**Effective Barrier Height:** The height of a barrier determined from elevation analysis that reflects the effect of the barrier on the precipitation process for a storm event. The actual barrier height may be either higher or lower than the effective barrier height.

**Envelopment:** A process for selecting the largest value from any set of data. In estimating PMP, the maximum and transposed rainfall data are plotted on graph paper, and a smooth curve is drawn through the largest values.

**Explicit Transposition:** The movement of the rainfall amounts associated with a storm within boundaries of a region throughout which a storm may be transposed with only relatively minor modifications of the observed storm rainfall amounts. The area within the transposition limits has similar, but not identical, climatic and topographic characteristics throughout.

**First-order NWS station:** A weather station that is either automated, or staffed by employees of the National Weather Service and records observations on a continuous basis.

**Front:** The interface or transition zone between two air masses of different parameters. The parameters describing the air masses are temperature and dew point.

**General storm:** A storm event, that produces precipitation over areas in excess of 500 square miles, has a duration longer than 6 hours, and is associated with a major synoptic weather feature.

**Gulf Stream Current:** A warm, well-defined, swift, relatively narrow, ocean current in the western North Atlantic that originates where the Florida Current and the Antilles Current begin to curve eastward from the continental slope of Cape Hatteras, North Carolina. East of the Grand Banks, the Gulf Stream meets the cold Labrador Current, and the two flow eastward separated by the cold wall.

**HYSPLIT:** HYbrid Single-Particle Lagrangian Integrated Trajectory. A complete system for computing parcel trajectories to complex dispersion and deposition simulations using either puff or particle approaches. Gridded meteorological data, on one of three conformal (Polar, Lambert, or Mercator latitude-longitude grid) map projections, are required at regular time intervals. Calculations may be performed sequentially or concurrently on multiple meteorological grids, usually specified from fine to coarse resolution.

**Implicit Transpositioning:** The process of applying regional, areal, or durational smoothing to eliminate discontinuities resulting from the application of explicit transposition limits for various storms.

**Isohyets:** Lines of equal value of precipitation for a given time interval.

**Isoheytal Pattern:** The pattern formed by the isohyets of an individual storm.

**Isohyetal orientation:** The term used to define the orientation of precipitation patterns of major storms when approximated by elliptical patterns of best fit. It is also the orientation (direction from north) of the major axis through the elliptical PMP storm pattern.

**Jet Stream:** A strong, narrow current concentrated along a quasi-horizontal axis (with respect to the earth's surface) in the upper troposphere or in the lower stratosphere, characterized by strong vertical and lateral wind shears. Along this axis it features at least one velocity maximum (jet streak). Typical jet streams are thousands of kilometers long, hundreds of kilometers wide, and several kilometers deep. Vertical wind shears are on the order of 10 to 20 mph per kilometer of altitude and lateral winds shears are on the order of 10 mph per 100 kilometer of horizontal distance.

**Local storm:** A storm event that occurs over a small area in a short time period. Precipitation rarely exceeds 6 hours in duration and the area covered by precipitation is less than 500 square miles. Frequently, local storms will last only 1 or 2 hours and precipitation will occur over areas of up to 200 square miles. Precipitation from local storms will be isolated from general-storm rainfall. Often these storms are thunderstorms.

**Low Level Jetstream:** A band of strong winds at an atmospheric level well below the high troposphere as contrasted with the jet streams of the upper troposphere.

**Mass curve:** Curve of cumulative values of precipitation through time.

**Mesoscale Convective Complex (MCC):** For the purposes of this study, a heavy rain-producing storm with horizontal scales of 10 to 1000 kilometers (6 to 625 miles) which includes significant, heavy convective precipitation over short periods of time (hours) during some part of its lifetime.

**Mesoscale Convective System (MCS):** A complex of thunderstorms which becomes organized on a scale larger than the individual thunderstorms, and normally persists for several hours or more. MCSs may be round or linear in shape, and include systems such as tropical cyclones, squall lines, and MCCs (among others). MCS often is used to describe a cluster of thunderstorms that does not satisfy the size, shape, or duration criteria of an MCC.

**Mid-latitude frontal system:** An assemblage of fronts as they appear on a synoptic chart north of the tropics and south of the polar latitudes. This term is used for a continuous front and its characteristics along its entire extent, its variations of intensity, and any frontal cyclones along it.

**Moisture maximization:** The process of adjusting observed precipitation amounts upward based upon the hypothesis of increased moisture inflow to the storm.

**Observational day:** The 24-hour time period between daily observation times for two consecutive days at cooperative stations, e.g., 6:00PM to 6:00PM.

**One-hundred year rainfall event:** The point rainfall amount that has a one-percent probability of occurrence in any year. Also referred to as the rainfall amount that on the average occurs once in a hundred years or has a 1 percent chance of occurring in any single year.

**Polar front:** A semi-permanent, semi-continuous front that separates tropical air masses from polar air masses.

**Precipitable water:** The total atmospheric water vapor contained in a vertical column of unit cross-sectional area extending between any two specified levels in the atmosphere; commonly expressed in terms of the height to which the liquid water would stand if the vapor were completely condensed and collected in a vessel of the same unit cross-section. The total precipitable water in the atmosphere at a location is that contained in a column or unit cross-section extending from the earth's surface all the way to the "top" of the atmosphere. The 30,000 foot level (approximately 300mb) is considered the top of the atmosphere in this study.

**Persisting dew point:** The dew point value at a station that has been equaled or exceeded throughout a period. Commonly durations of 12 or 24 hours are used, though other durations may be used at times.

**Probable maximum precipitation (PMP):** Theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of the year.

**Pseudo-adiabat:** Line on thermodynamic diagram showing the pressure and temperature changes undergone by saturated air rising in the atmosphere, without ice-crystal formation and without exchange of heat with its environment, other than that involved in removal of any liquid water formed by condensation.

**Pseudo-adiabatic:** Referring to the process described by the pseudo-adiabat.

**Rainshadow:** The region, on the lee side of a mountain or mountain range, where the precipitation is noticeably less than on the windward side.

**PMP storm pattern:** The isohyetal pattern that encloses the PMP area, plus the isohyets of residual precipitation outside the PMP portion of the pattern.

**Saturation:** Upper limit of water-vapor content in a given space; solely a function of temperature.

**Spatial distribution:** The geographic distribution of precipitation over a drainage according to an idealized storm pattern of the PMP for the storm area.

**Storm transposition:** The hypothetical transfer, or relocation of storms, from the location where they occurred to other areas where they could occur. The transfer and the mathematical adjustment of storm rainfall amounts from the storm site to another location is termed "explicit transposition." The areal, durational, and regional smoothing done to obtain comprehensive individual drainage estimates and generalized PMP studies is termed "implicit transposition" (WMO, 1986).

**Synoptic:** Showing the distribution of meteorological elements over an area at a given time, e.g., a synoptic chart. Use in this report also means a weather system that is large enough to be a major feature on large-scale maps (e.g., of the continental U.S.).

**Temperature Inversion:** An increase in temperature with an increase in height.

**Temporal distribution:** The time order in which incremental PMP amounts are arranged within a PMP storm.

**Tropical Storm:** A cyclone of tropical origin that derives its energy from the ocean surface.

**Total storm area and total storm duration:** The largest area size and longest duration for which depth-area-duration data are available in the records of a major storm rainfall.

**Transposition limits:** The outer boundaries of the region surrounding an actual storm location that has similar, but not identical, climatic and topographic characteristics throughout. The storm can be transpositioned within the transposition limits with only relatively minor modifications to the observed storm rainfall amounts.

**Undercutting:** The process of placing an envelopment curve somewhat lower than the highest rainfall amounts on depth-area and depth-duration plots.

**Warm front:** Front where relatively warmer air replaces colder air.

**Warm sector:** Sector of warm air bounded on two sides by the cold and warm fronts extending from a center of low pressure.

# 1. Introduction

This study defines the site-specific probable maximum precipitation (PMP) for use in the computation of the probable maximum flood (PMF) for the White Tanks #4 drainage basin in Maricopa County, Arizona.

## 1.1 Background

Definitions of probable maximum precipitation (PMP) are found in most of the Hydrometeorological Reports (HMRs) issued by the National Weather Service (NWS). The definition used in the most recently published HMR is "theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year." (HMR 59, p. 5). Since the mid-1940s or earlier, several government agencies have been developing methods to calculate PMP in various regions of the United States. The National Weather Service (formerly the U.S. Weather Bureau) and the Bureau of Reclamation have been the primary agencies involved in this activity. PMP estimates derived in accord with their reports are used to calculate the PMF, which, in turn, is often used for the design of significant hydraulic structures.

The generalized PMP studies currently in use in the conterminous United States include HMR 49 (1977) for the Colorado River and Great Basin drainage; HMRs 51 (1978), 52 (1982) and 53 (1980) for the U.S. east of the 105th meridian; HMR 55A (1988) for the area between the Continental Divide and the 103rd meridian; HMR 57 (1994) for the Columbia River Drainage; and HMR 58 (1998) and 59 (1999) for California. The White Tanks #4 drainage basin is located in the HMR 49 domain.

In addition to these HMRs, numerous Technical Papers and Reports deal with specific subjects concerning precipitation (NOAA Tech. Report NWS 25, 1980 and NOAA Tech. Memorandum NWS HYDRO 45, 1995). Topics include maximum observed rainfall amounts; return periods for various rainfall amounts, and specific storm studies. Climatological Atlases (Technical Paper No. 40, 1961 and NOAA Atlas 2, 1973, NOAA Atlas 14, 2004) are available for use in determining precipitation return periods. A number of specialized and regional studies (Harriman Dam Study, 1987; Tomlinson, 1993; Tomlinson et al, 2002; Tomlinson et al 2003, and Tomlinson et al, 2008) augment generalized PMP reports for specific regions included in the large area addressed by HMRs 49 and 51. AWA has also recently completed several site-specific PMP projects within the domain covered by HMR 49. These have shown series errors and outdated procedures used in the development of HMR 49 and its subsequent PMP values. The PMP results from this project gives values that ranged replace values derived from HMR 49 or any other previous PM P studies.

# HMR 49 Boundary

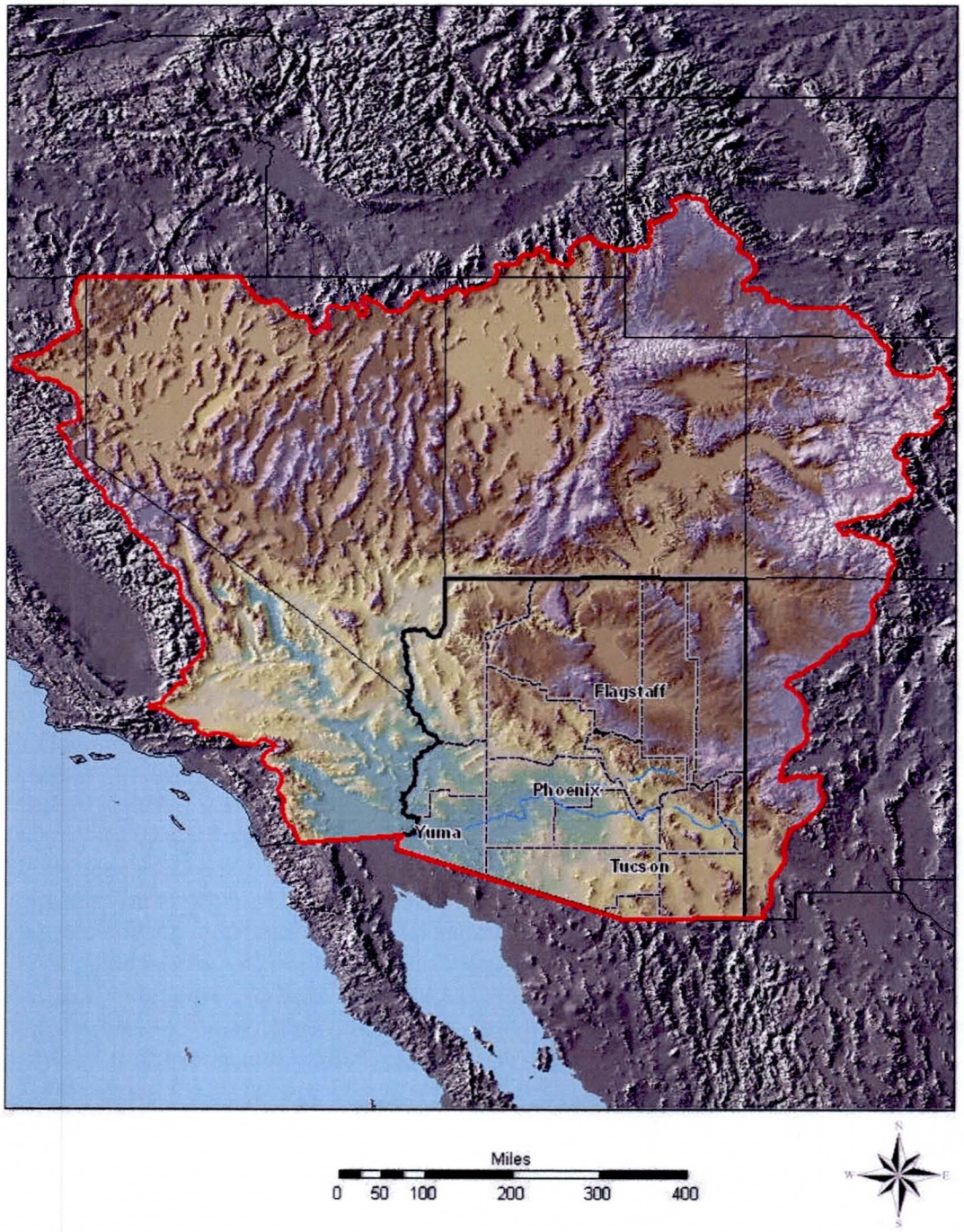



Figure 1.1 Domain covered by HMR 59 (Hansen et al, 1977)

As Figure 1.1 displays, HMR 49 covers a large area of the Intermountain West and Desert Southwest, including the entire state of Arizona, where climate and terrain vary greatly. Because of the distinctive climate regions and significant topography, it is difficult for PMP values to accurately account for the complexity of the meteorology and terrain throughout the state. HMR 49 is the oldest of the current HMR series. Several major issues have been identified with HMR 49. Among these is the lack of analyzed storm events, the age of the document, and the procedures used to derive and calculate PMP.

Previous site-specific and region PMP projects completed by AWA provide good examples of PMP studies that explicitly consider the topography of the basins and characteristics of historic extreme storms over climatically similar regions surrounding the basins. These site-specific PMP studies have received extensive review and the results have been used in computing the PMF for the watersheds. This study follows the same procedure used in these studies to determine site-specific PMP values for the White Tanks #4 drainage basin.

## 1.2 Objective

The objective of this study was to perform a site-specific study to determine reliable estimates of PMP values for the White Tanks #4 in Maricopa County, Arizona, west of Phoenix. The most reliable methods and data currently available have been used and are updates to the methods used in HMR 49.

## 1.3 Approach

The approach used in this study follows the same procedures that were used in the development of the HMRs 51, 57, and 59, with updated procedures implemented where appropriate and more recent updates AWA has performed during several PMP projects recently completed. These procedures were applied considering the site-specific characteristics of the White Tanks #4 drainage basin. The weather and climate of the region are discussed in Section 2. The effects of barrier to inflow moisture are detailed in Section 3. The initial step of identifying extreme storms is discussed in Section 5. Procedures used to analyze storms are discussed in Section 4 and 6. Adjustments for storm maximization, storm transpositioning, and elevation moisture depletion are presented in Sections 3, 4, 7, and 8. The final procedure of developing PMP values from the adjusted rainfall amounts is provided in Section 9. Results are presented in Section 10. Discussions on sensitivities are provided in Section 11 and the recommendations for application are provided in Section 12.

A goal of this study was to maintain as much consistency as possible with the general methods used in recent HMRs, the WMO manual for PMP, and the previous PMP studies completed by AWA. Deviations were incorporated when justified by developments in meteorological analyses and available data. The basic approach identifies major storms that occurred within the Desert Southwest region south of the first major upslopes of the Mogollon Rim through northern Mexico and from the southeastern

deserts of southern California through southwestern New Mexico. Each of the main storm types which produce extreme rainfalls were investigated. This includes local convective storms, remnant tropical storms, and general frontal storms. The moisture content of each of these storms is maximized to provide worst case rainfall estimation for each storm at the location where it occurred. The storms are then transpositioned to White Tanks #4 drainage basin to the extent supportable by similarity of topographic and meteorological conditions.

Advanced computer-based technologies, Weather Service Radar WSR-88D NEXt generation RADar (NEXRAD), and HYSPLIT model trajectories were used for storm analyses along with new meteorological data sources. New technology and data were incorporated into the study when they provided improved reliability, while maintaining as much consistency as possible with previous studies. This includes an updated dew point climatology where average dew points for durations consistent with the actual storm duration were developed. The dew point climatologies were 3-hour, 12-hour, and 24-hour 100-year return frequency average dew points and varies from the HMR 49 12-hour persisting local and general dew point climatologies. This approach provides the most complete scientific application compatible with the engineering requirements of consistency and reliability for credible PMP estimates.

For some applications, this study applied standard methods (e.g. WMO Operational Hydrology Report No. 1, 1986), while for other applications, new techniques were developed. Moisture analyses have historically used monthly maximum observed 12-hour persisting dew points (for Arizona as published in HMR 50 (1980). For this project a new dew point climatology was developed to better represent the storm types and durations that affect the region. This includes local convective, remnant tropical, and general frontal storms. Dew point climatologies representing the 3-hour, 12-hour, and 24-hour average return frequency values at 100-year intervals were derived and replace the 12-hour persisting values used in HMR 50. This data set better replicated the physical processes that are trying to be evaluated by associated moisture with each storm that is representative of the environment that actually led to the rainfall and could produce extreme rainfall events. Further, this data set used the most up to date period of record, increasing the previous work with over 20 years of data.

In a few cases (remnant tropical and general frontal) the moisture inflow vector source originated over the Gulf of California and/or the Eastern Pacific Ocean. In these cases, sea surface temperatures (SSTs) were used as a surrogate for surface dew point data. To accomplish this, a sea surface temperature (SST) procedure was used which follows the same procedure used in HMR 57 and HMR 59. However, an updated SST climatology was developed, replacing the Marine Climate Atlas of the World (U.S. Navy, 1981) used in HMR 59. This updated climatology dataset included monthly mean and 2-sigma maps for the eastern Pacific Ocean from the coastline of the United States and Mexico to 180W and from 15N to 55N (NOAA, Kent et al 2007, Reynolds et al 2007, and Worley et al 2005). In conjunction with the climatology maps, daily SST maps based on ship and buoy reports, as well as satellite data (after 1979), were produced and used in deriving the storm representative SST values for each short list storm event.

Finally, ESRI ArcView Geographic Information System (GIS) software was used extensively in the study to evaluate topography, delineate the characteristics of the White Tanks #4 drainage basin, evaluate upwind moisture barriers, and identify unique characteristics and terrain features of the region. The Storm Precipitation Analysis System (SPAS) used gridded storm analysis techniques to provide both spatial and temporal analyses for recent extreme storm events (see Appendix G for a complete description of SPAS).

## 1.4 Basin Location and Description

The drainage basin for White Tanks #4 is located in Maricopa County, AZ approximately 25 miles west of Phoenix. The center of the basin is 33.50° north latitude and 112.52° west longitude. The area of the drainage basin is approximately 19.7 square miles. The average elevation within the basin is 1577 feet and varies from 1028 feet at the eastern foot to 3655 feet along the crest of the White Tank Mountains, although other point just outside of the watershed are slightly higher. Figure 1.2 shows the basin location and surrounding topography. Figure 1.3 shows the topography within the basin.

## White Tanks #4 Drainage Basin
## Regional Location

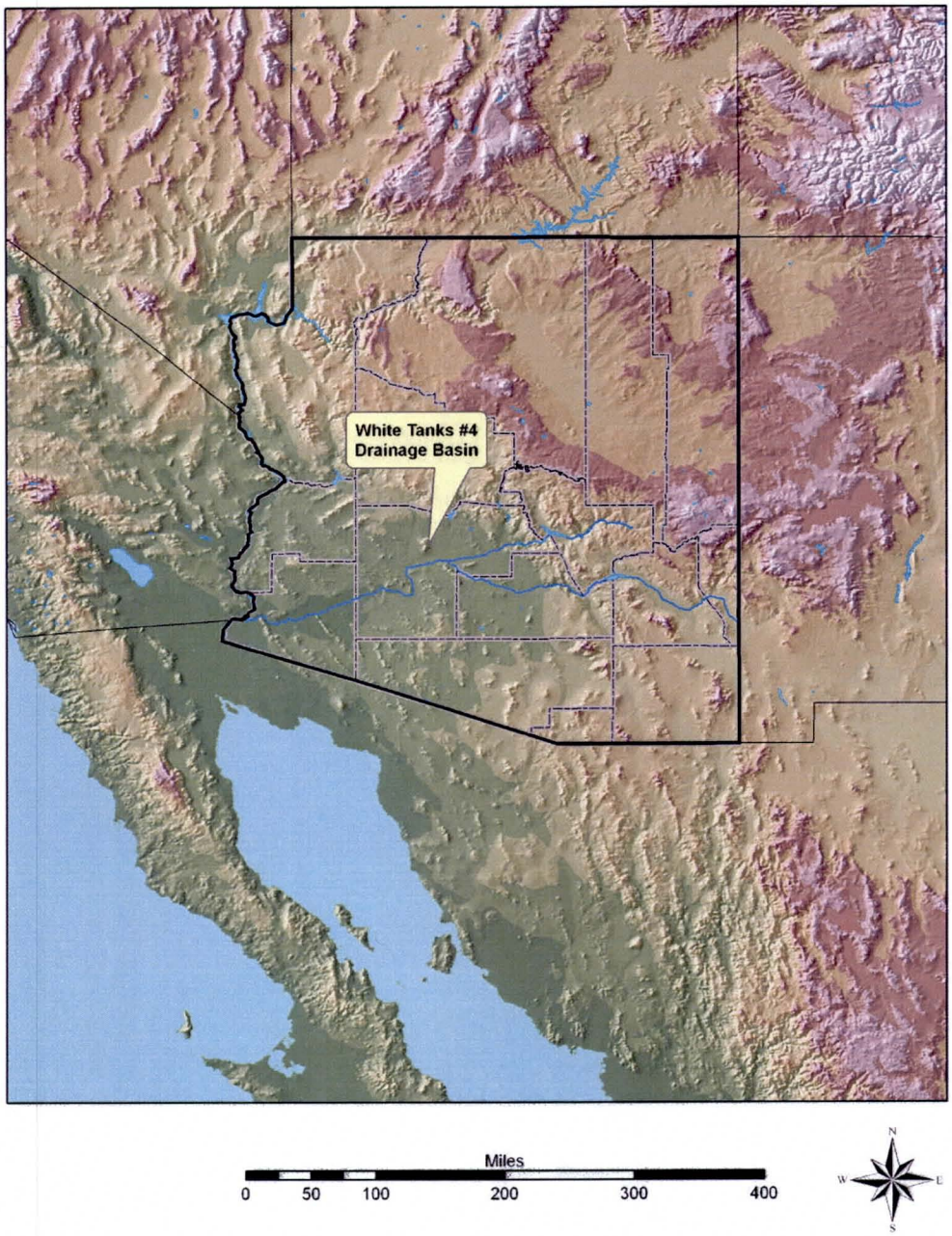



Figure 1.2 White Tanks #4 drainage basin regional location and topography

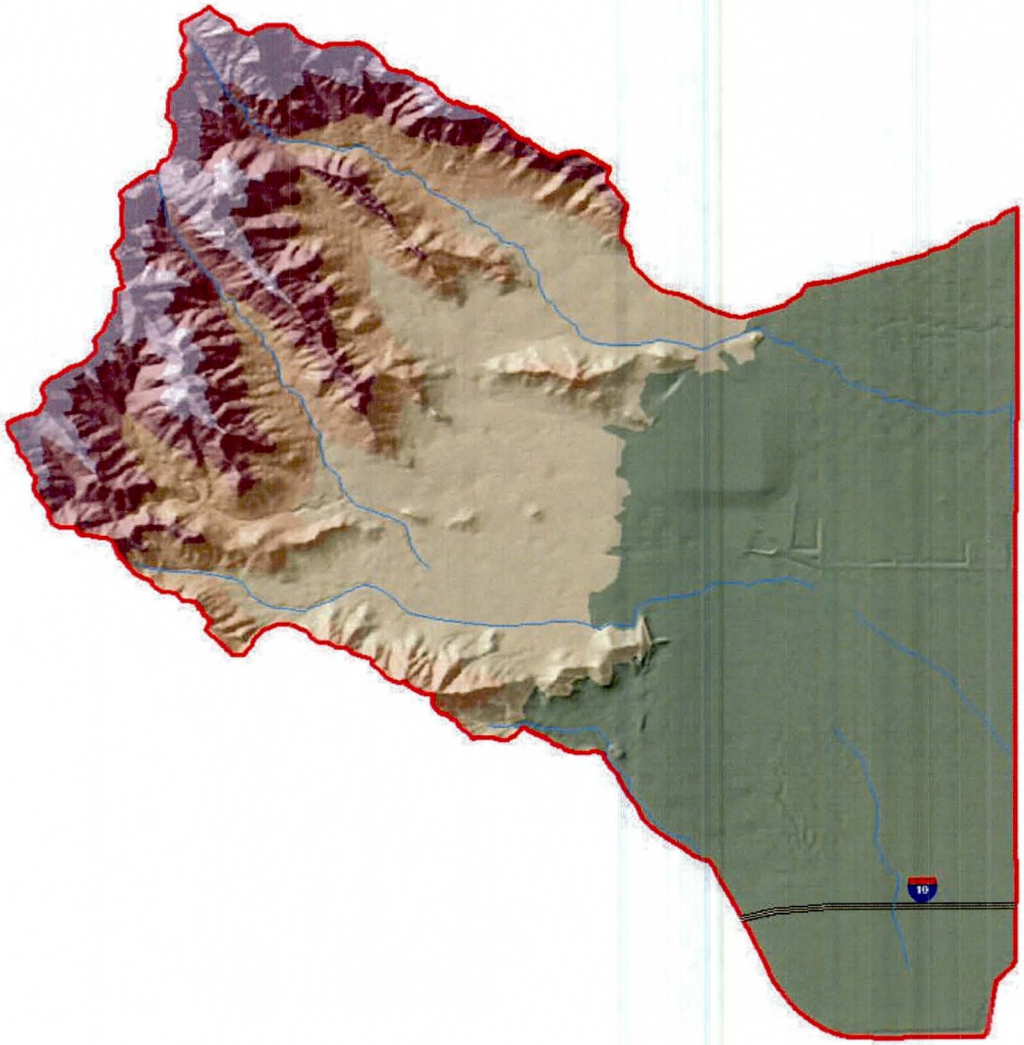



Figure 1.3 White Tanks #4 drainage basin

# 2. Weather and Climate of the White Tanks Region

## 2.1 General Climate of the White Tanks Drainage Basin

Exposure to Gulf of California moisture surges, Eastern Pacific tropical systems, and mid latitude winter storms interacting with the transition zone from the southern deserts to the Mogollon Rim create a unique and varying weather pattern across the region. There is a distinct bi-model precipitation regime for White Tanks, where general frontal winter storms bring rainfall from November through early March. These large scale storms bring rain and snow to much of Arizona over periods of several days. Once the jet stream begins to lift further north during the spring, almost no precipitation occurs from April through late June. Then the North American Monsoon System (NAM) sets up (for description of the NAM see Grantz et al. 2007, Higgins et al. 2003, Higgins et al. 1999, Adams and Comrie 1997, Higgins et al. 1997, Douglas 1995, Douglas 1993, Smith 1989, Carlton 1987, Carlton 1986, Hales 1972).

The weather patterns in the region are characterized by desert conditions. For the year as a whole, evaporation far exceeds rainfall leading to an ever-present surface water deficit. High pressure, clear skies, and low humilities are prevalent for the majority of the year, with the exception during the Monsoon and with the passage of a winter frontal system. This climate is most directly influenced by the basin's southerly latitude and inland location.

The region is directly influenced by the NAM, which transports high amounts of moisture into the otherwise arid region. This pattern shift usually takes place in late June or early July and is signaled by a steady increase in dew point temperatures and thunderstorm activity. The pattern normally lasts through September, sometimes extending into October. This coincides with the most likely time to experience extreme rainfall that would cause a PMP type event in and around the White Tanks #4 drainage basin.

On rare occasions this monsoon pattern can be enhanced by the passage of a decaying tropical system that moves out of the Eastern Pacific and north over the Gulf of California. This type of storm is responsible for the most extreme rainfalls on the synoptic scales (24 hours or longer covering large regions of 500 square miles or more). Some of the most notable of these events occurred in 1906, 1911, 1925, 1939, 1951, 1970, and 1997. All produced extreme rainfalls throughout the Southwest.

## 2.2 North American Monsoon Climatology

In June the 500 mb subtropical ridge (at approximately 18,000 feet above sea level) is located over northwest Mexico (Figure 2.1). As a result, the flow across Arizona is usually from the southwest. The hot and dry weather conditions experienced across Arizona during the month of June are a direct result of the position of the 500 mb subtropical ridge and dry southwest flow.

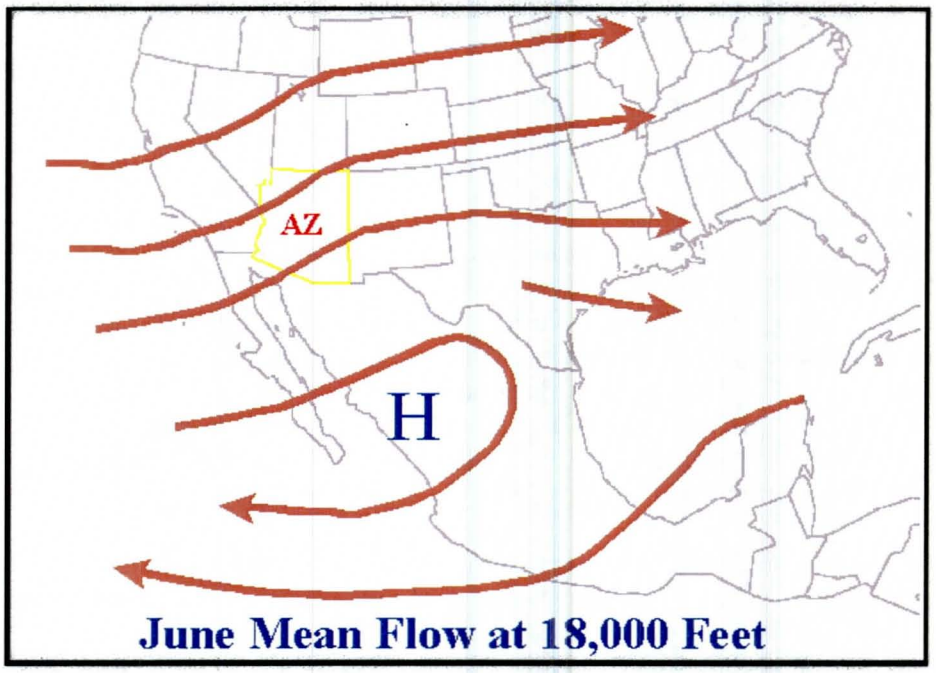



Figure 2.1 June Mean Flow at 500mb (18,000 feet) over the Southwest

By July the 500 mb subtropical ridge normally shifts northward with the center of circulation located over west Texas and New Mexico (Figure 2.2). As a result easterly flow develops over northwest Mexico in the mid-levels, while hot temperatures over the continent result in a general onshore (southerly) flow in the low-levels. The shift in the 500 mb subtropical ridge is followed by a dramatic increase in thunderstorm activity over northwest Mexico. Arizona lies on the northern fringes of this area of enhanced thunderstorm activity. It is during this time that Arizona experiences periodic increases in moisture originating from the Gulf of California (Gulf Surges) and the eastern tropical Pacific that often produce thunderstorms (Douglas 1993, Carlton 1986, Hales, 1972).

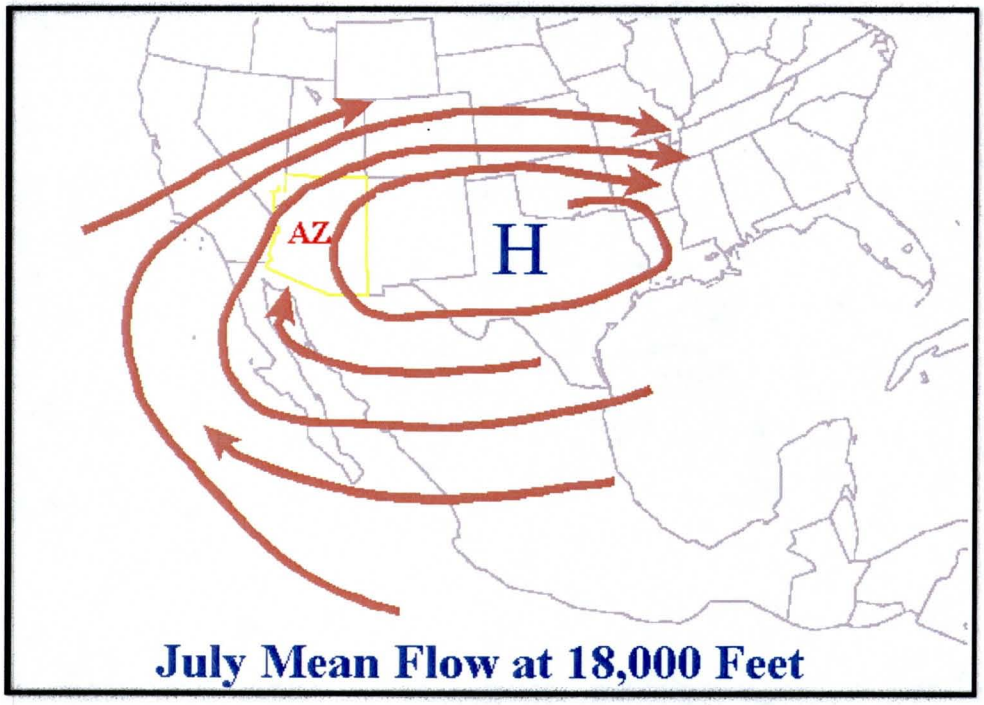



Figure 2.2 July Mean Flow at 500mb (18,000 feet) over the Southwest

Figure 2.3 shows the generalized surface synoptic conditions that are found during the NAM season. Notice the positioning of the areas of high and low pressure and the attendant circulations around these features. This leads to an average wind inflow from the south/southwest, up the Gulf of California and into Arizona thereby supplying the low level moisture necessary to fuel the intense thunderstorms activity during the NAM season.

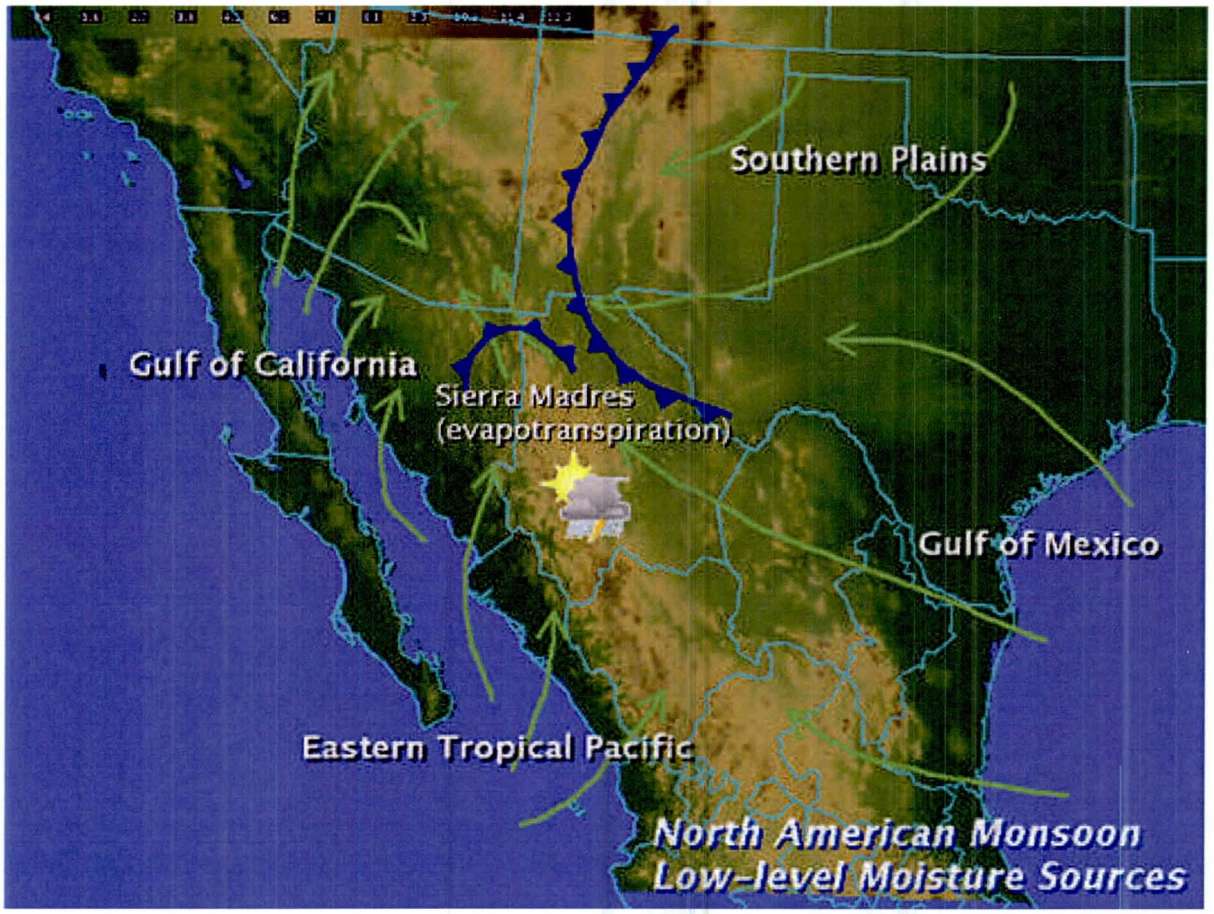



Figure 2.3 Generalized surface synoptic patterns associated with the NAM season

## 2.3 Representative Climate Stations

The most representative official weather station near the basin is Phoenix, AZ. There are several other stations near the drainage basin as well, all of which show the same general precipitation patterns. Figures 2.4 through 2.6 display the annual precipitation in the immediate vicinity of the basin[1]. Notice the bi-model precipitation pattern at all three stations with a maximum from late June through September and a secondary maximum from December through March. The monthly maximum of precipitation occurs in August as the convective potential in the atmosphere coincides with high levels of moisture associated with the influx of tropical moisture from the Gulf of California during the height of the NAM season. The most common type of heavy rain producing events occur as thunderstorms develop over the elevated terrain near the basin

[1] http://www.wrcc.dri.edu/summary/Climsmaz.html

during the afternoon, then migrate over the area during the evening and overnight hours (see Section 3 for more details on storm types).

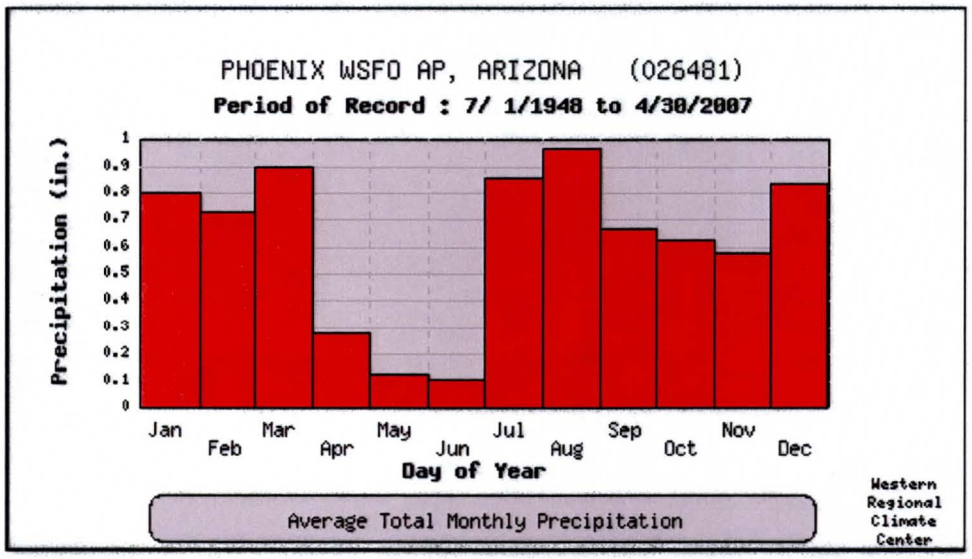



Figure 2.4 Average monthly precipitation at Phoenix, AZ 1948-2007 (Western Regional Climate Center)

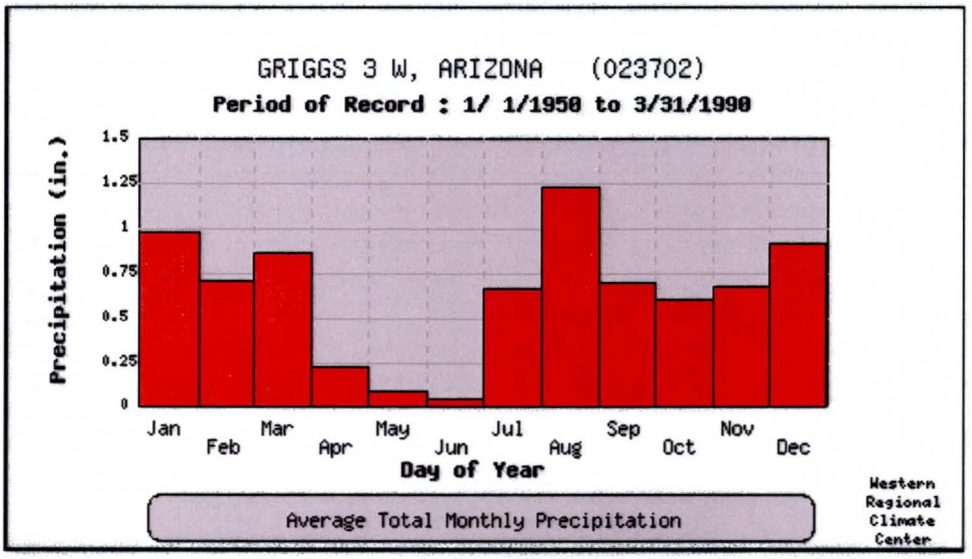



Figure 2.5 Average monthly precipitation at Griggs 3 W, AZ 1950-1990 (Western Regional Climate Center)

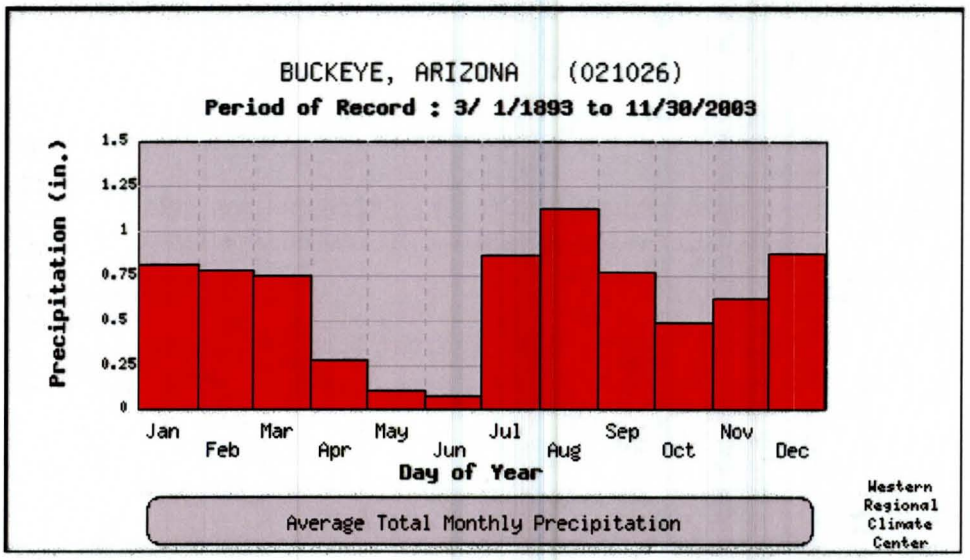



Figure 2.6 Average monthly precipitation at Buckeye, AZ 1893-2003 (Western Regional Climate Center)

## 2.4 White Tanks #4 Drainage Basin PMP Storm Type

### 2.4.1 Local Convective Storms

Thunderstorms are an almost daily occurrence once the NAM season sets in, usually starting in late June or early July (see Section 2.2). Often, the first indicator that severe convective weather will soon develop is the presence of a "Gulf Surge" of low level moisture which often precedes storm development by several hours (Green 2003). Most of the storms have a life cycle of less than three hours and produce more wind than rain in and around the drainage basin. Storm initiation generally occurs over the elevated terrain surrounding the basin. Storms then move west and south reaching the lower deserts by early evening. Additionally, drainage winds and outflow boundaries associates with terrain and thunderstorm activity converge with hot, moist, and unstable air to initiate thunderstorms over the lower elevations (Wallace 1999). In environments where atmospheric moisture levels that are exceptionally high combine with added lift from a short wave trough moving through the region, storms can last longer and produce large amounts of rain (1-2 inches per hour) over the region.

#### 2.4.1.1 Mesoscale Convective Systems

Mesoscale Convective Systems (MCS) are capable of producing extreme amounts of precipitation at short durations and over small area sizes. Although the storm types are not common in the region, they can and do occur. The terrain in the region plays an important role in thunderstorm initiation and propagation during an event (McCollum

1995). Generally, MCSs in Arizona occur with much less frequency and are of shorter duration, producing less rainfall than their Midwestern counterparts.

The current name of MCS was applied in the late 1970's to these type of "flood producing", strong thunderstorm complexes (Maddox 1980). For Arizona, the term MCS refers to any precipitation system with a spatial scale of 10-350 miles that include deep convection during part of its life-cycle (Zipser 1982). Mesoscale systems are so named because they are small in areal extent (10s to 100s of square miles), whereas synoptic storm events are 100s to 1000s of square miles. The MCSs also exhibit a distinctive signature on satellite imagery where they show rapidly growing cirrus shields with very high cloud tops. Further, MCS usually take on a nearly circular pattern with constantly regenerating thunderstorms fed by moist low-level jet inflow.

Climatologically, MCSs primarily form during the NAM months from late June through September, becoming most common around the drainage basin from mid-July through mid-August.

### 2.4.2 Remnant Tropical Storms

On rare occasions decaying tropical storms have directly affected the region around White Tanks #4 drainage basin. By the time this type of storm moves this far inland away from its energy source (the Gulf of California and the eastern tropical Pacific), it has lost many of its tropical characteristics, but the heavy rainfall associated with the storm is often present (see section 2.0 in HMR 50). Remnant moisture from these decaying tropical systems has produced some of the largest rainfalls of record throughout Arizona. A classic example of this storm type is Norma which brought torrential rains across much of the Four Corners region from September 4-7, 1970. This storm event produced 11.40 inches of rainfall in 24-hours at Workman Creek, AZ which nearly doubled the previous state 24-hour rainfall record (Hansen 1981). A more recent example was the remnants of Nora, which produced the new 24-hour state record rainfall for Arizona on September 1, 1997 at Harquahala Mountain just to the west/northwest of White Tanks #4. This storm was analyzed in conjunction with the project using the SPAS program. Details of this storm analysis are given in Appendix F.

### 2.4.3 General Frontal Systems

The polar front and jet stream, which separate cool, dry Canadian air to the north from warm, moist air to the south, sometimes produces wet weather in the region. The frontal systems contribute large amounts of energy and storm dynamics to storms that move through the region. These features are strongest and most active over the region from late fall through early spring.

This type of storm environment (general frontal) will usually not produce high rainfall rates over short durations, but instead can lead to flooding situations as heavy to moderate rain continues to fall over the same regions for an extended period of time. The series of storm systems that led to record flooding on several rivers throughout the region

during January and February of 1993 are an excellent example of this type of storm environment (House 1997). However, the local convective and remnant tropical storms are more significant for determining PMP values for the White Tanks #4 drainage basin.

## 2.5 Seasonality of Extreme Storm Events

Once the monsoon pattern sets up, rainfall can be a daily occurrence through the end of summer. In July and August alone, up to one third of the annual precipitation over and around the White Tanks #4 drainage basin accumulates. Figures 2.7a, 2.7b, and 2.7c show the seasonality associated with the extreme rainfall events identified in this study. The long list of storms included all significant rainfall events that could possibly affect the development of PMP values for the White Tanks #4 location.

Note the bimodal seasonality of the storm occurrences, with almost all of the NAM local convective storms occurring in July, August, and September and almost all of the general frontal storms occurring from December through March.

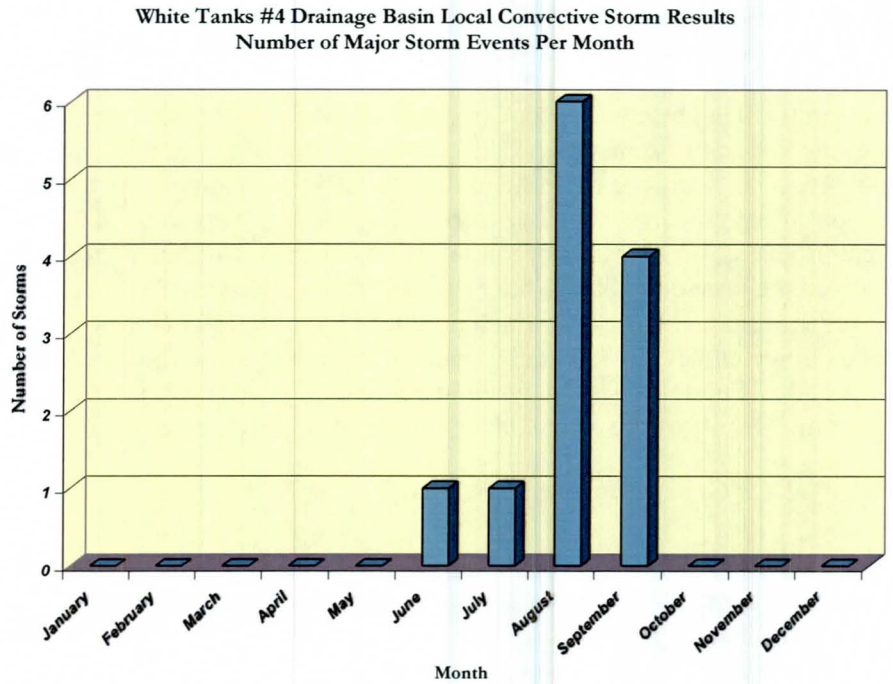



Figure 2.7a Local convective storm seasonality of the storms analyzed for White Tanks

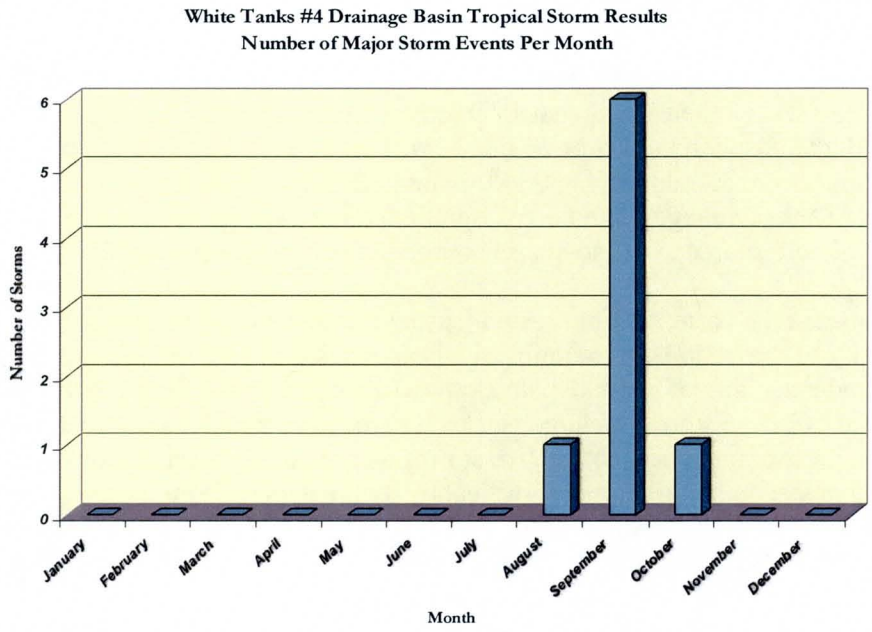



Figure 2.7b Remnant tropical storm seasonality of the storms analyzed for White Tanks

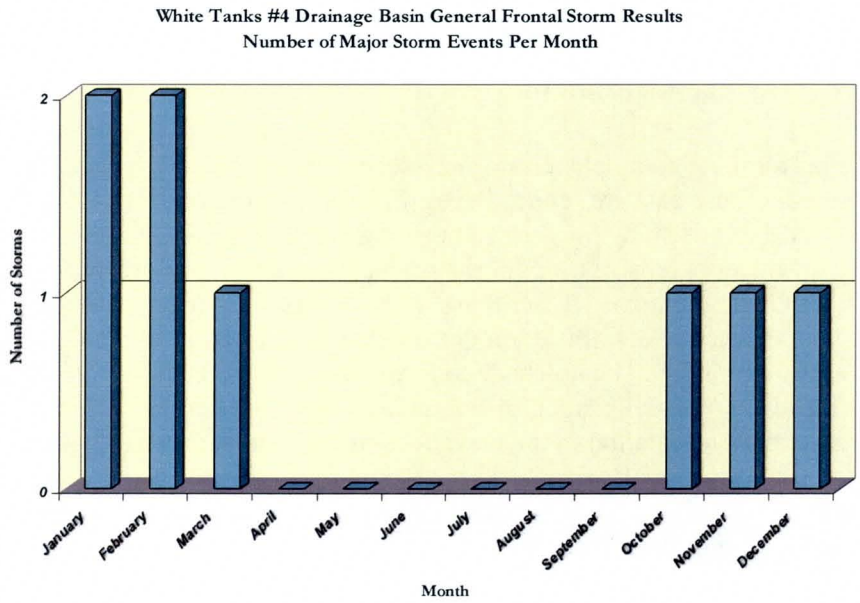



Figure 2.7c General frontal storm seasonality of the storms analyzed for White Tanks

# 3. Topographic Effects

The terrain within the White Tanks drainage basin varies in elevation from 1028 feet to 3,655 feet. When a basin has intervening elevated terrain features that deplete some of the atmospheric moisture available to storms before reaching the basin, these must be taken into account during the storm maximization process. However, because the White Tanks drainage basin has no significant intervening terrain barriers between it and its moisture source to the south, no barrier analysis was necessary for the basin.

Instead the basin itself acts as a focusing mechanism for rainfall and the topography of the basin helps to define the isohyetal storm patterns that occur. However, current understanding of storm dynamics shows that underlying terrain only has a substantial effect on storms on larger scales (i.e. remnant tropical and general frontal storms). For example, local convective storms do not last long enough or cover a large enough area size to be influenced significantly by the underlying terrain (see Section 9.7 HMR 59 for further discussion). Therefore, in the analysis and storm maximization process described later in this report, no elevation consideration were used in analyzing local convective events, while standard elevation adjustments were used for remnant tropical and general frontal storms. One exception was made to the use of elevation for the storm analysis, which followed the unique characteristics of the White Tanks basin. This was to use the highest elevation within the basin for the basin elevation instead of the average basin elevation. This was done to best replicate how the topography of the With Tanks #4 drainage basin actually interacts with remnant tropical and general storm events that affect the region.

## 3.1 GIS Preparation of Terrain Data for Analysis

To perform the complete terrain analyses for White Tanks #4, digital terrain data were collected. These data are referred to as digital elevation model (DEM) data. The DEM grids used in this study for general mapping purposes are based on a 30-meter pixel size with a 10-meter pixel size used for the basin. The terrain data are available from the United States Geologic Survey (USGS) and were downloaded from the USGS EROS website. The Mosaic to New Raster model was run from ESRI ArcCatalog to build one seamless elevation raster. The hillshade tool was run on the DEMs to give depth appearance and aid with delineation of ridgelines. The 30-meter resolution terrain data provided a good representation of the elevations of the mountain ranges surrounding the basin and within the state of Arizona. These terrain data provide an appropriate representation of the elevation of the mountain barriers that could potentially influence moisture transport into the basin.

All data is in North_America_GCS_1983 coordinate system. This choice was made to facilitate the project by requiring the fewest projection conversions which have potential to alter the accuracy of the data. The Xtools Plus third party extension was used to convert distances from decimal degrees to miles when necessary.

## 3.2 Barrier Moisture Depletion

Terrain features have significant effects on the broad scale flow of atmospheric moisture as it encounters and flows around and over mountain barriers. This study follows the same approach, but not exactly the same procedure, used in recent Hydrometeorological Reports 57 and 59 (Hansen, 1994; Corrigan, 1999) for evaluating barrier heights in orographic regions. In this study, mean barrier elevations are determined using GIS and then adjusted to provide effective barrier heights. The principal use of these effective barrier heights is to make adjustments to atmospheric moisture and storm precipitation. These adjustments are necessary since the air mass feeding the storm loses atmospheric moisture as it traverses over the barriers. The result is an increase in precipitation on the windward side of the barriers and decreased rainfall downwind of the barriers. The region of decreased rainfall downwind of barriers is often referred to as a rainshadow region (see Glossary).

As a storm moves across elevated terrain, the atmospheric moisture in the portion of the storm below the terrain elevation is assumed to precipitate out on the windward side of the barrier. As a result, that moisture is not available for rainfall production over locations downwind of the barrier. This does not mean that no rain falls over the rainshadow region, but the amount of rainfall is decreased and in some cases significantly.

The barrier analysis was limited to only those moisture inflow directions associated with PMP-type storm events for the basin. In this study, west through south directions were evaluated. However, since the White Tanks #4 has no barriers to the west through the south that would act to remove moisture from storms affecting the basin no further barriers analysis was completed.

# 4. HYSPLIT, Average Dew Point Climatology, and Sea Surface Temperatures

This study incorporates updated procedures and data analysis methods used in other PMP studies completed by AWA but not in the development of the HMRs. For previously completed AWA PMP studies, no significant deviations from the approaches and data were applied. However, there were some modest improvements made over earlier studies through the addition of new data sets and new techniques described below.

## 4.1 New Data Sets

Several new data sets not used in the development of HMRs 49 and 50 were identified. These data were used for storm maximization and transpositioning in this study. The identification and use of these data sets provide a significant improvement in storm adjustments, especially relating to the determination of each storm's moisture source and derivation of appropriate maximization factors.

### 4.1.1 HYSPLIT Trajectory Model

The HYSPLIT trajectory model (Draxler 2003) was used to evaluate moisture inflow vectors for all of the short list storms that occurred after 1947. Use of a trajectory model provides increased confidence for determining inflow vectors and storm representative dew points/SSTs. The HYSPLIT model trajectories have been used to analyze the moisture inflow vectors in other PMP studies such as the Magma FRS, the Blenheim Gilboa and the statewide Nebraska studies. During these analyses, the model trajectory results were verified and the utility explicitly evaluated (Tomlinson et al 2007, Tomlinson et al 2008).

HYSPLIT was used during the analysis of each of the rainfall events analyzed using SPAS and used for determination of PMP for the basin. Instead of subjectively determining the moisture inflow trajectory, the trajectory software was used to determine the trajectory of the moisture inflow, both location and altitude, for various levels in the atmosphere associated with the storm's rainfall production. The HYSPLIT software was run for trajectories at several levels of the lower atmosphere to capture the moisture source for each storm event. These included 700mb (approximately 10,000 feet altitude), 850mb (approximately 5,000 feet), and storm center location surface elevation. For the majority of the analyses, the surface and 850mb levels were determined to be most appropriate for use in evaluation of the upwind moisture source location. It is important to note that the resulting HYSPLIT model trajectories are only used as a general guide of where to evaluate the moisture source for storms. The final determination of the storm representative dew point/SST and it location is determined following the standard procedures used by AWA in previous PMP studies and as outlined in the HMRs and WMO manuals. Appendix F of this report (separate binding) lists each of the HYSPLIT trajectories analyzed as part of this study for each storm. As an example, Figures 4.1-4.3

show the HYSPLIT trajectory model results used to analyze the inflow vector from the remnant tropical event of Nora September, 1997.

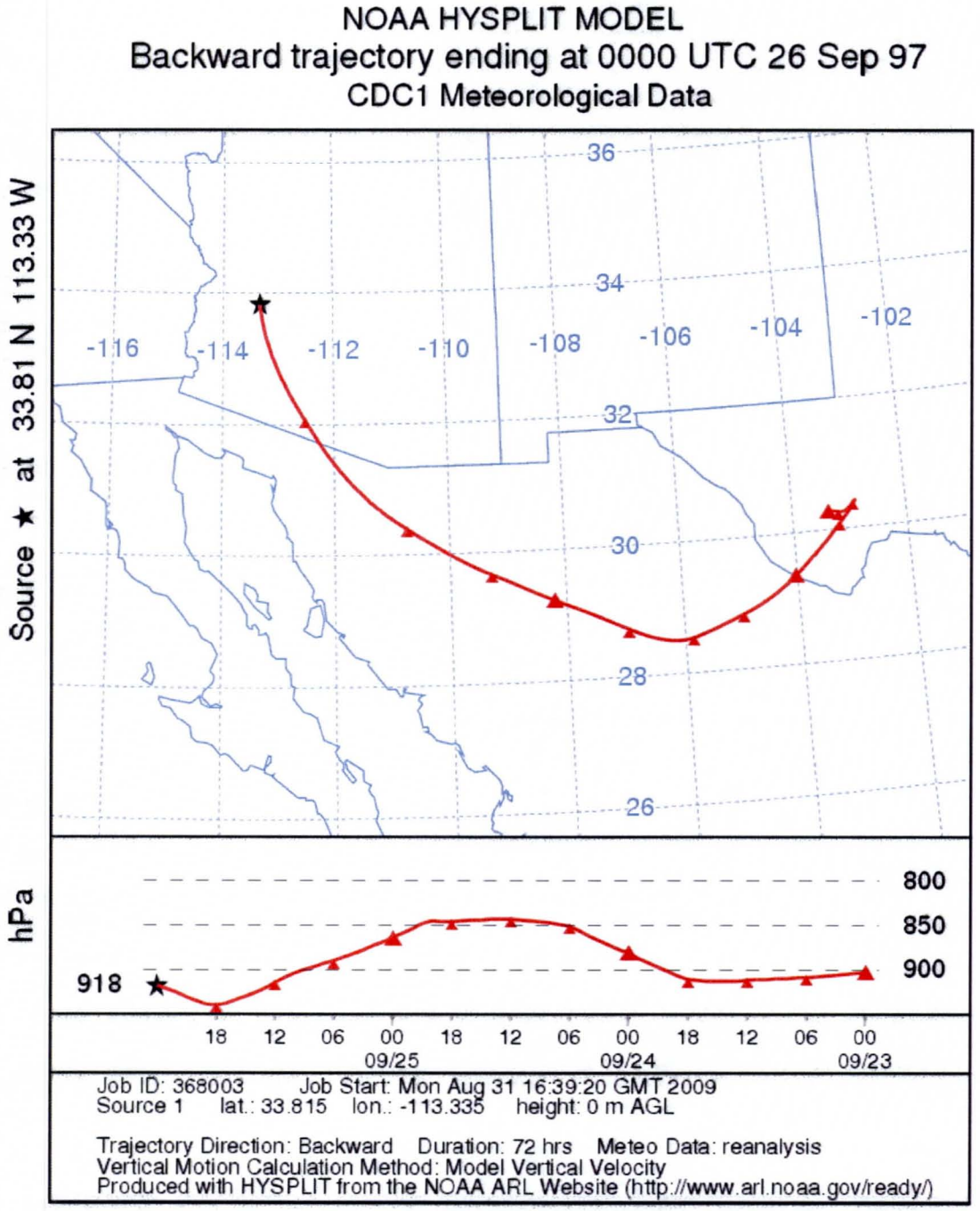



Figure 4.1 Surface HYSPLIT trajectory model results

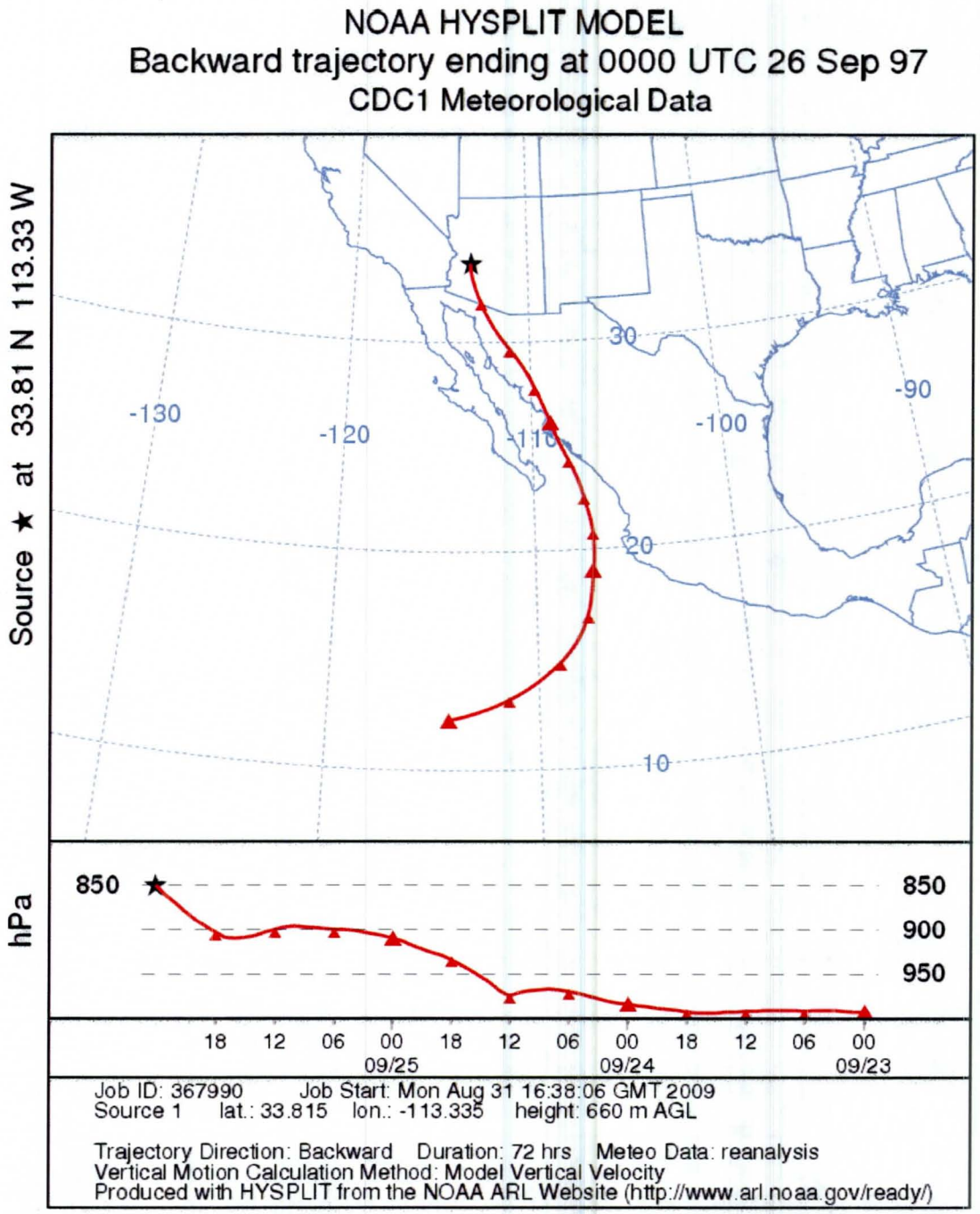



Figure 4.2 850mb HYSPLIT trajectory model results

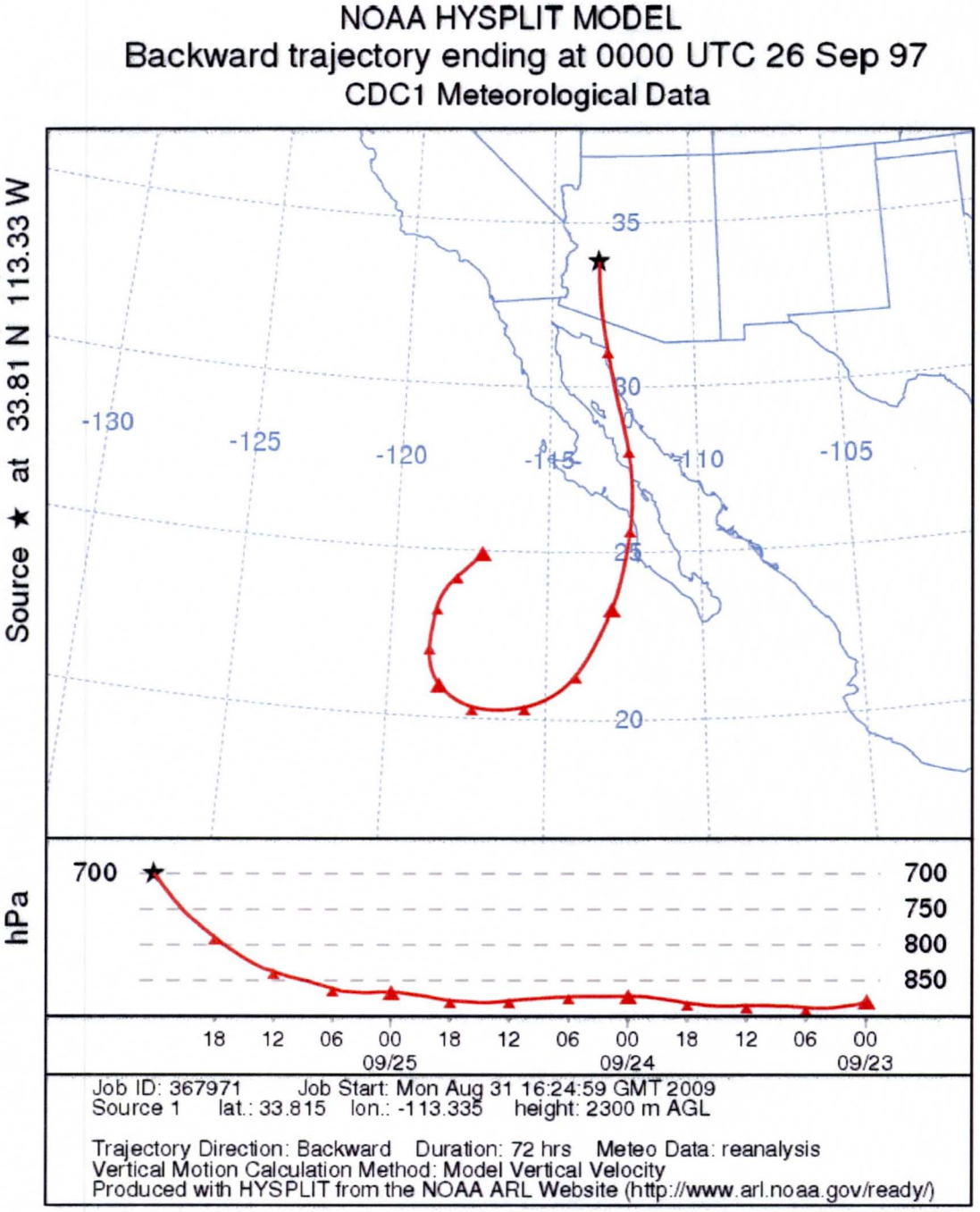



Figure 4.3 700mb HYSPLIT trajectory model results

An evaluation of the use of inflow vectors for determining the moisture source for local storms was completed. It is stated in HMRs 57 and 59 that inflow vectors are not representative of local storm environments and instead the closest dew point data from

any direction should be used. This assumption has validity for typical isolated convective storms. However, Arizona local storms, especially extreme rainfall producing events, are atypical from those described in HMRs 57 and 59 in that they are fed by the Gulf Surge events which are akin to the low-level jets that feed Midwestern United States thunderstorm complexes. Because of this, it is appropriate to define an inflow vector for local storms to capture and quantify the source of the low level moisture feeding an extreme rainfall event and more accurately determine the storm representative dew point value associated with the rainfall event.

### 4.1.2 Average Dew Point Climatology Methodology

An updated dew point climatology was derived and used in the storm maximization process as part of the statewide PMP study for Arizona. Initially, a search of the National Climatic Data Center (NCDC) hourly stations that record hourly dew point temperature data within a defined search domain surrounding Arizona was completed (Figure 4.4).

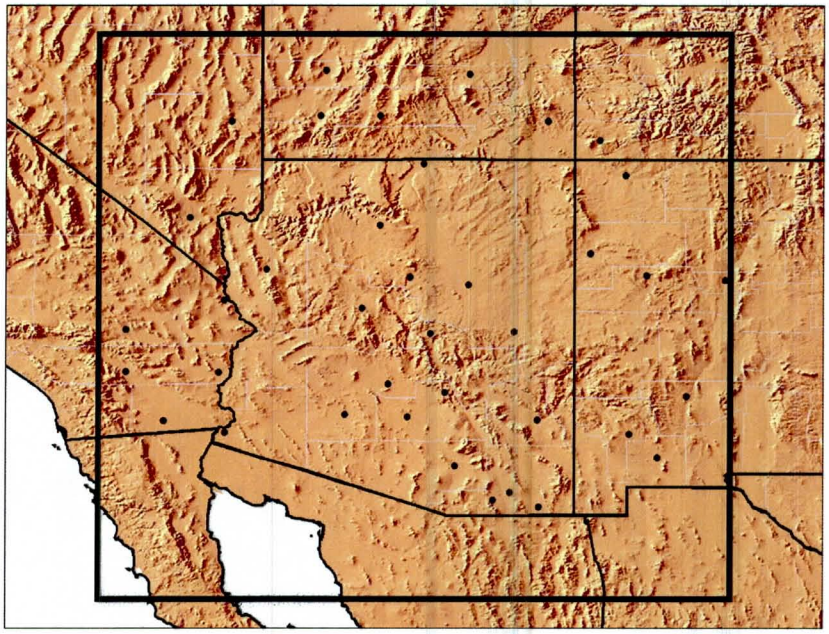


Figure 4.4 Hourly dew point station locations used for this analysis

Once these stations were identified, AWA searched for and extracted the archived NCDC hourly datasets for the maximum average 3-hr, 12-hr, and 24-hr dew point temperatures for each reporting station within the define search box (see Figure 4.4). A total of ninety-two hourly stations were within the search domain (Table 4.0). Initial quality control limited stations to 30-years or greater period-of-record; five stations with less than 30-years were included to help fill in spatial gaps. After this initial QC, thirty-

eight hourly stations were used for the dew point temperature analysis. A program was written and used for quality control (QC) to extract each station's monthly maximum dew point temperatures for each year, known as the annual maximum series (AMS). The AMS for each month, at each station, served as input to an R-statistical script that calculated L-moment statistics. Using the generalized-extreme-value (GEV) distribution, the 20-yr, 50-yr, and 100-yr dew point temperature values were calculated for each month for each station. The 20-year, 50-year, and 100-year dew point values were extracted for each station. The extracted dew point data were adjusted to represent the $15^{th}$ of each month and adjusted to represent 1,000 mb dew point values.

Table 4.0 Stations used to derive the dew point climatology for Arizona

| ID | Name | State | Latitude | Longitude | Elevation | POR |
|---|---|---|---|---|---|---|
| 4BL | BLANDING | UT | 37.6167 | -109.4670 | 6132 | 31 |
| 4HV | HANKSVILLE | UT | 38.3667 | -110.7170 | 4311 | 31 |
| ABQ | ALBUQUERQUE | NM | 35.0844 | -106.6501 | 5314 | 60 |
| BCE | BRYCE CANYON | UT | 37.7022 | -112.1540 | 7584 | 60 |
| BLH | BLYTHE | CA | 33.6186 | -114.7140 | 390 | 31 |
| CDC | CEDAR CITY | UT | 37.7000 | -113.1000 | 5618 | 60 |
| CEZ | CORTEZ | CO | 37.3000 | -108.6330 | 5916 | 31 |
| CGZ | CASA GRANDE | AZ | 32.9000 | -111.7000 | 1462 | 16 |
| DMN | DEMING | NM | 32.2597 | -107.7200 | 4300 | 31 |
| DUG | DOUGLAS | AZ | 31.4667 | -109.6000 | 4097 | 31 |
| EED | NEEDLES | CA | 34.7667 | -114.6170 | 887 | 31 |
| FHU | FT HUACHUCA | AZ | 31.5833 | -110.3330 | 4685 | 31 |
| FLG | FLAGSTAFF | AZ | 35.1333 | -111.6670 | 7018 | 58 |
| FMN | FARMINGTON | NM | 36.7500 | -108.2330 | 5502 | 59 |
| GBN | GILA BEND | AZ | 32.9333 | -112.7000 | 866 | 31 |
| GCN | GRAND CANYON | AZ | 35.9500 | -112.1500 | 6972 | 31 |
| GNT | GRANTS | NM | 35.1667 | -107.9000 | 6519 | 31 |
| GUP | GALLUP | NM | 35.5083 | -108.7930 | 6464 | 35 |
| IGM | KINGMAN | AZ | 35.2667 | -113.9500 | 3389 | 31 |
| INW | WINSLOW | AZ | 35.0167 | -110.7330 | 4883 | 31 |
| IPL | IMPERIAL | CA | 32.8344 | -115.5750 | -58 | 31 |
| LAS | LAS VEGAS | NV | 36.0833 | -115.1670 | 2180 | 60 |
| MLF | MILFORD | UT | 38.4333 | -113.0170 | 5033 | 60 |
| NXP | 29 PALMS | CA | 34.2962 | -116.1620 | 2051 | 21 |
| OE4 | PAYSON | AZ | 34.2333 | -111.3330 | 4915 | 22 |
| OMA3 | TOMBSTONE | AZ | 31.7053 | -110.058 | 4610 | 31 |
| P38 | CALIENTE | NV | 37.6167 | -114.5170 | 4380 | 25 |
| PGA | PAGE | AZ | 36.9333 | -111.4500 | 4278 | 31 |
| PHX | PHOENIX | AZ | 33.4333 | -112.0170 | 1107 | 60 |
| PIA3 | SUPERIOR | AZ | 33.3008 | -111.097 | 2860 | 31 |
| PRC | PRESCOTT | AZ | 34.6500 | -112.4330 | 5053 | 60 |
| SAD | SAFFORD | AZ | 32.8500 | -109.6330 | 3176 | 31 |
| SOW | SHOW LOW | AZ | 34.2667 | -110.0000 | 6411 | 31 |
| SVC | SILVER CITY | NM | 32.6333 | -108.1670 | 5443 | 31 |
| TCS | TRTH OR CON | NM | 33.2333 | -107.2670 | 4858 | 58 |
| TRM | THERMAL | CA | 33.6319 | -116.1640 | -112 | 31 |
| TUS | TUCSON | AZ | 32.1167 | -110.9330 | 2555 | 62 |
| YUM | YUMA | AZ | 32.6566 | -114.6060 | 216 | 29 |

#### 4.1.2.1 15th of the Month Adjustment Procedures

The station data were corrected to the 15th of each month using a linear relationship between the previous month, current month, and the next month. Steps are listed below:

1) Calculated the difference in days between the observed average date and the 15th.
2) Depending whether the difference in step 1 is positive or negative (direction of adjustment) calculate the ratio/difference between the non-adjusted dew point temperature (for the months of interest) and the number of days between the dates.
3) Applied the ratio calculated in step 2 to the difference calculated in step 1.
4) Checked the adjusted dew point value with the previous and next month values, and the other two durations
5) Calculated the difference between the original dew point value and the adjusted dew point value.
6) Created station plots of the duration and frequency for additional QC measure.
7) Created a list of the adjusted dew point values for each station in a GIS format

The 15th adjustment were performed using a series of Excel macros.

#### 4.1.2.2 1000mb Adjustment Procedures

A moist lapse rate (2.7°F/1000 ft) was used to adjust the dew point temperature (15th), at the stations elevation, to 1,000 mb which was assumed to be an elevation of zero. A linear relationship between elevation and lapse rate was created and applied to each station. The June 3-hr dew point data for Phoenix, AZ are shown in Table 4.1 below, the table shows the original station data, the data adjusted to the 15th, and the data adjusted to 1,000 mb.

Table 4.1 Original dew point data, adjusted dew point data (to the 15th), and the 1000mb dew point data for 20-yr, 50-yr, and 100-yr frequencies at Phoenix, AZ

| | 20-year | 50-year | 100-year |
|---|---|---|---|
| Station Data | 69.90 | 71.38 | 72.16 |
| 15th Data | 68.81 | 70.27 | 71.03 |
| 1000 mb Data | 71.80 | 73.26 | 74.02 |

#### 4.1.2.3 Spatial Interpolation of Data

Maximum and minimum monthly dew point temperature PRISM grids were downloaded for the continental United States for the time period of 1971-2000. PRISM grids were used to calculate the mean monthly dew point temperature $\overline{td}_m$ for this time period:

$$\overline{td}_m = \frac{\sum_{i=1}^{n} x_i}{n}$$

where $m$ is the month of interest, $n$ is the number months and $x_i$ are the monthly dew temperature values. The PRISM data were converted from degrees Celsius to degrees Fahrenheit. The mean monthly PRISM dew point data were extracted for each of the thirty-eight dew point stations.

The PRISM dew point grids did not cover the entire Arizona domain. In order to address spatial dew point estimates in Mexico, pseudo monthly dew point grids were created based on dew point elevation relationships. These new dew point grids covered the entire domain except for the southwest corner (see Figure4.5a and b). The terrain and pseudo basemap calculations in the southwest domain were not representative and were not included in the analysis. The steps for derivation of the monthly pseudo basemaps are listed below:

1) Calculated monthly ratio between dew point and elevation, created monthly ratio grids.
2) Grew the monthly ratio grids until entire domain was covered.
3) Estimated monthly dew point grid, multiple grown ratio grid by the elevation.
4) Created a mask (based on PRISM dew point grids).
5) Patched the estimated monthly dew point grids with the PRISM dew point grids. Estimated dew point is only used were PRISM data not available.
6) Smoothed the final dew point grids. These are the grids used for spatial interpolation methods.

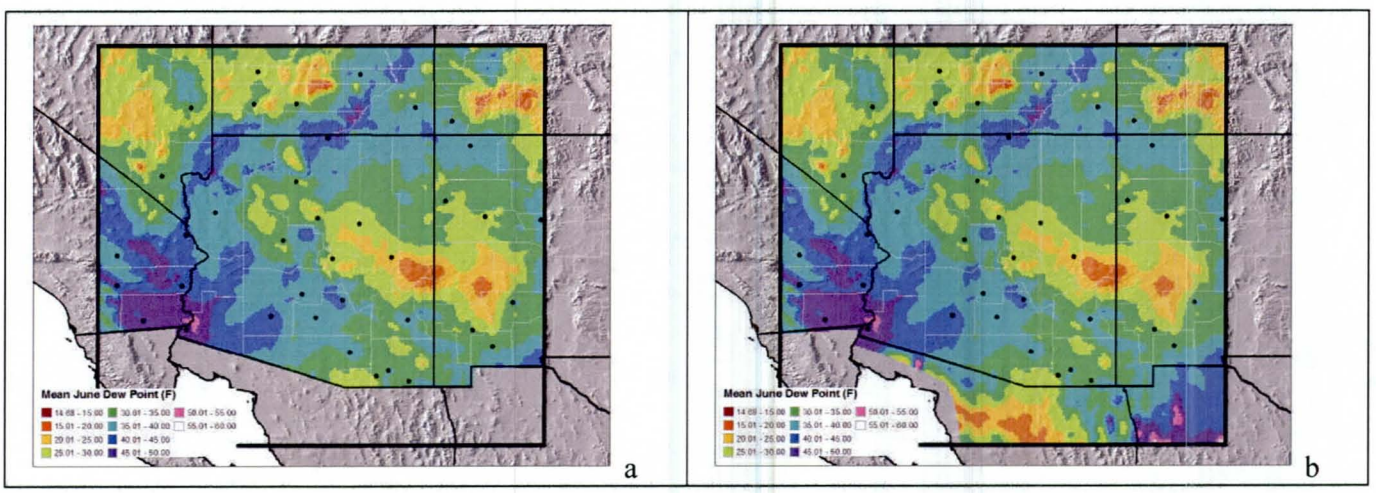



Figure 4.5 Mean June dew point (°F). a) June mean PRISM dew point b) June estimated mean pseudo dew point.

Linear relationships between PRISM data (described above) and the station dew point temperature data (1,000 mb) for each duration (3, 12, and 24 hour) and frequency (20, 50, and 100 year) were calculated, where *y* equals the stations dew point temperature (°F) value, and *x* equals the stations mean monthly PRISM dew point temperature (°F) value. An example of the linear relationships between mean monthly PRISM dew point data and the 100-year 24-hour dew point data for June, July, August, and September are shown in Figure 4.6.

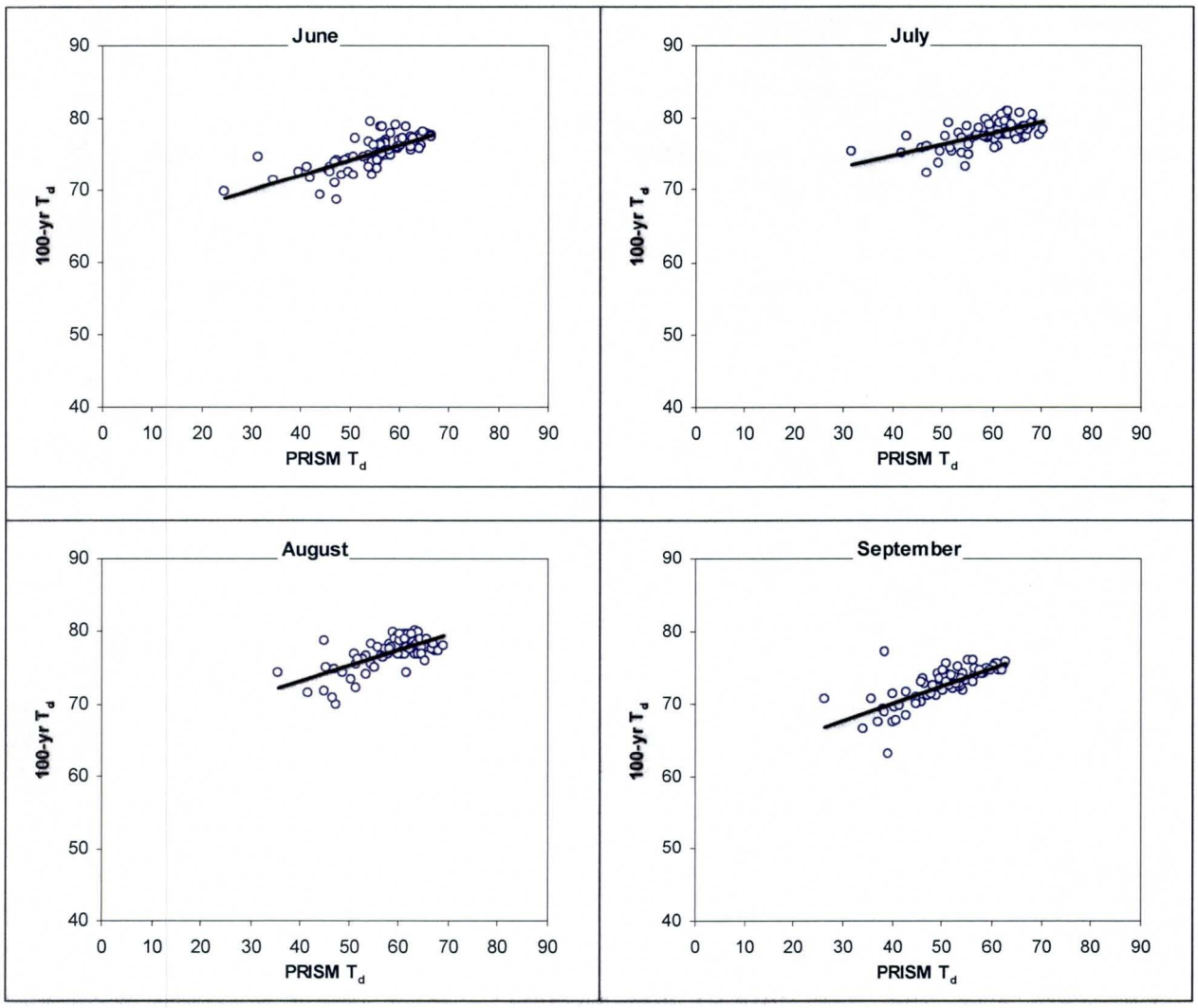



Figure 4.6 Linear relationships between mean monthly PRISM dew point data and the 100-year 24-hour dew point data for June, July, August, and September

The derived linear relationships were applied to the mean monthly dew point PRISM grids, which provided a first estimate of the dew point temperature spatial distribution. Residuals (actual – predicted) between the station and the first estimate

were calculated at each station. The 100-year 24-hour dew point residuals for June, July, August, and September are shown in Figure 4.7.

The residuals were spatially distributed across the search domain using an inverse-distance algorithm. The spatially distributed residual grids were smoothed to reduce bulls-eye effects. The smoothed residual grid was added to the first estimate grid to create the second estimate grid. The second estimate grids were smoothed in order to further reduce bulls-eye effects. The smoothed second estimate grids represent the final dew point temperature distribution.

The spatial interpolation method was tested and applied for the Nebraska statewide study. Perl and R-statistical programs were used to automate the process within GRASS GIS environment. The GRASS GIS script also created 1°F dew point contours from the final interpolated dew point grids. The GRASS GIS dew point analysis and 0.5°F contours for the June, July, August, and September 100-year 24-hour are shown in Figure 4.8 a, b, c and d. The GRASS GIS dew point rasters and contour shapefiles were exported from the GRASS GIS environment to an ArcGIS environment for creation of the final dew point map layouts.

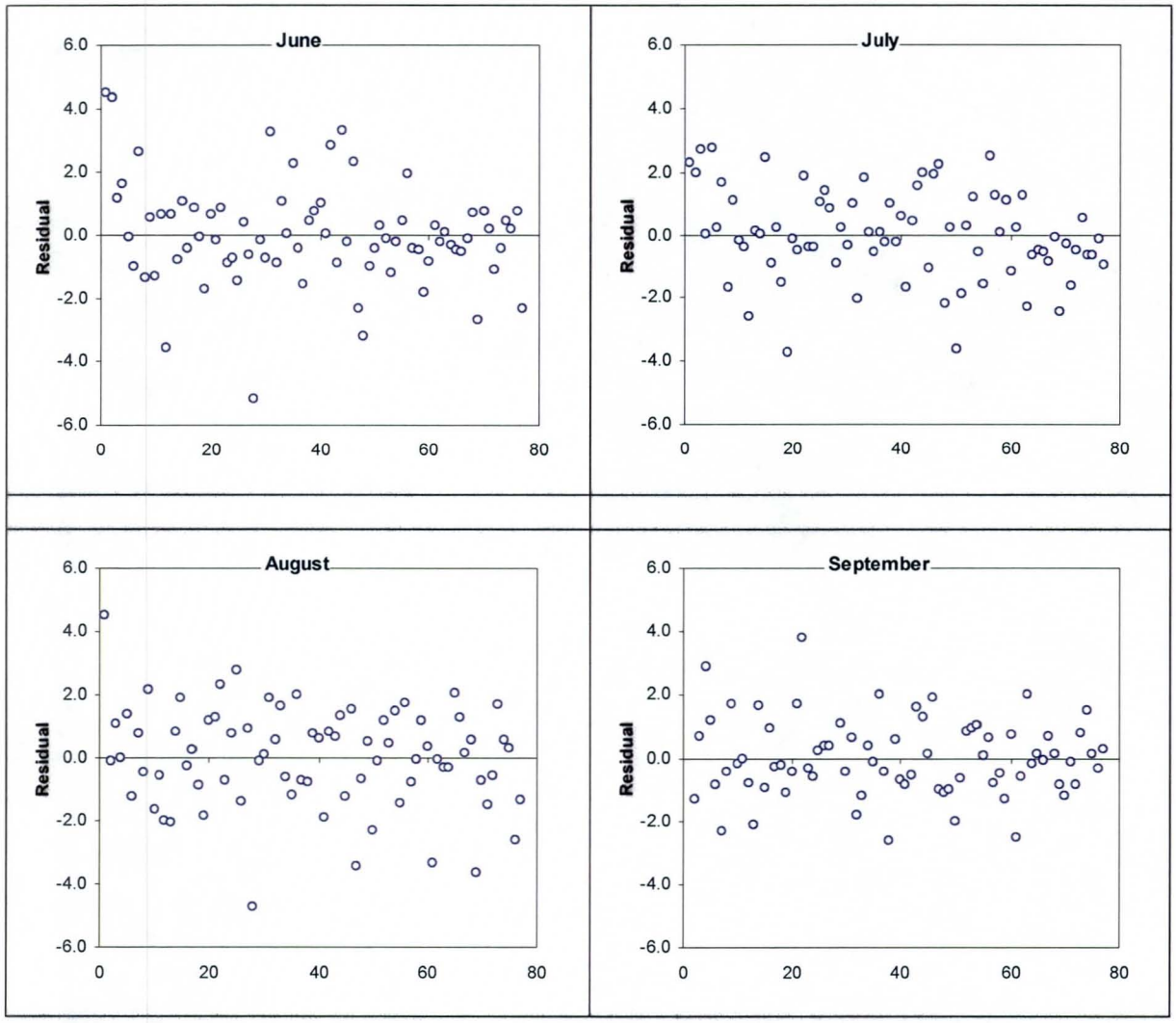



Figure 4.7 Calculated residuals between mean monthly PRISM dew point data and the 100-year 24-hour dew point data for June, July, August, and September

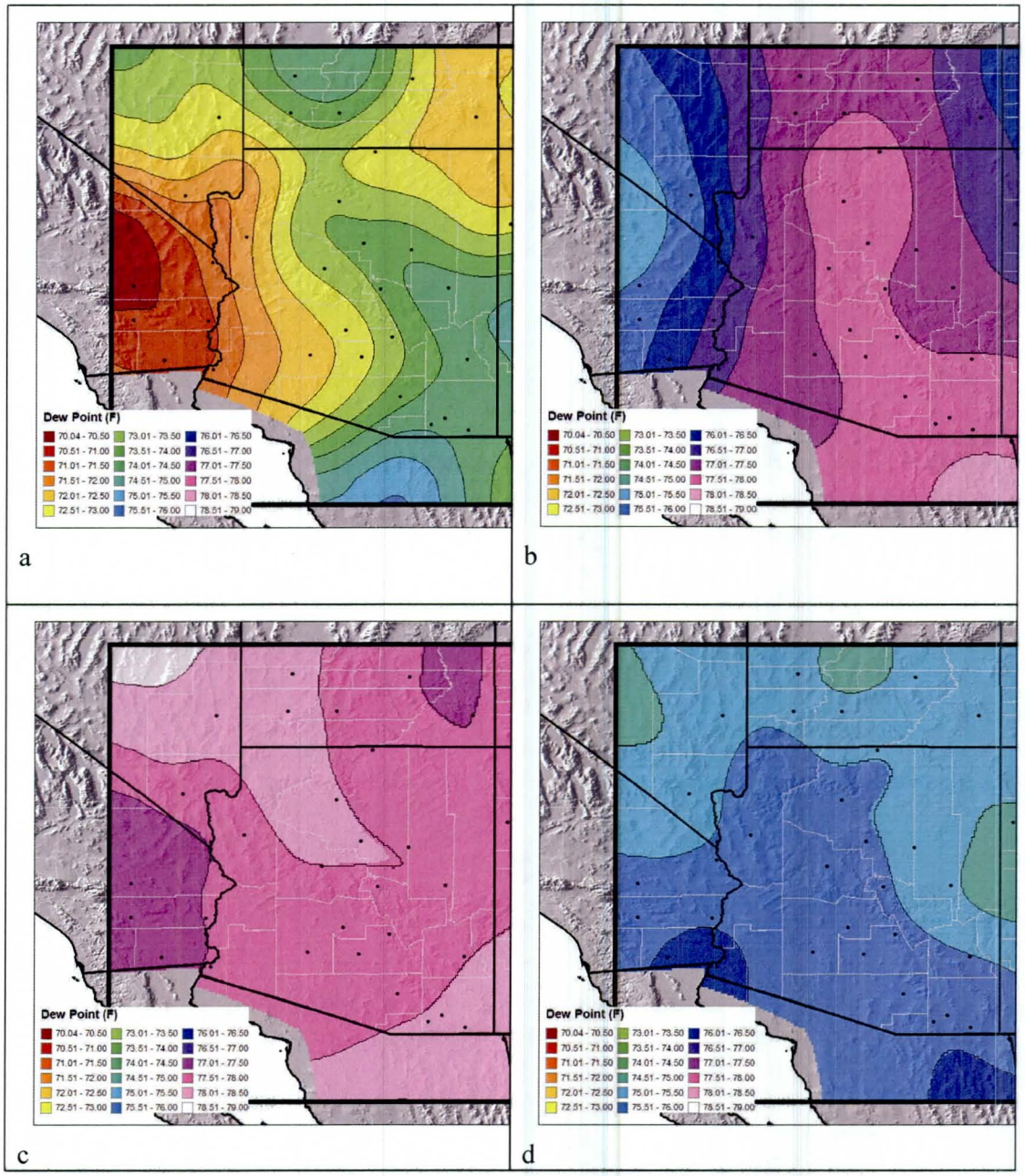



Figure 4.8 Dew point analysis, contours are at 0.5°F intervals. a) June 100-year 24-hour dew point b) July 100-year 24-hour dew point
c) August 100-year 24-hour dew point d) September 100-year 24-hour dew point.

Creation of the final dew point maps used in this project was completed after three more rounds of manually interpretation of the automated contours and meteorological analysis by AWA. During this manual analysis inconstancies were removed and smoothing was applied where meteorological, climatological, and topographical factors warranted such actions. Further, expertise was used to compensate

for the lack of spatial coverage in some sections of Arizona and to ensure continuity between months and durations. Figures 4.9-4.11 display examples of the final dew point maps and Appendix A displays all the maps derived as part of this PMP analysis and Appendix A discusses in detail the need to develop the updated dew point climatology for Arizona.

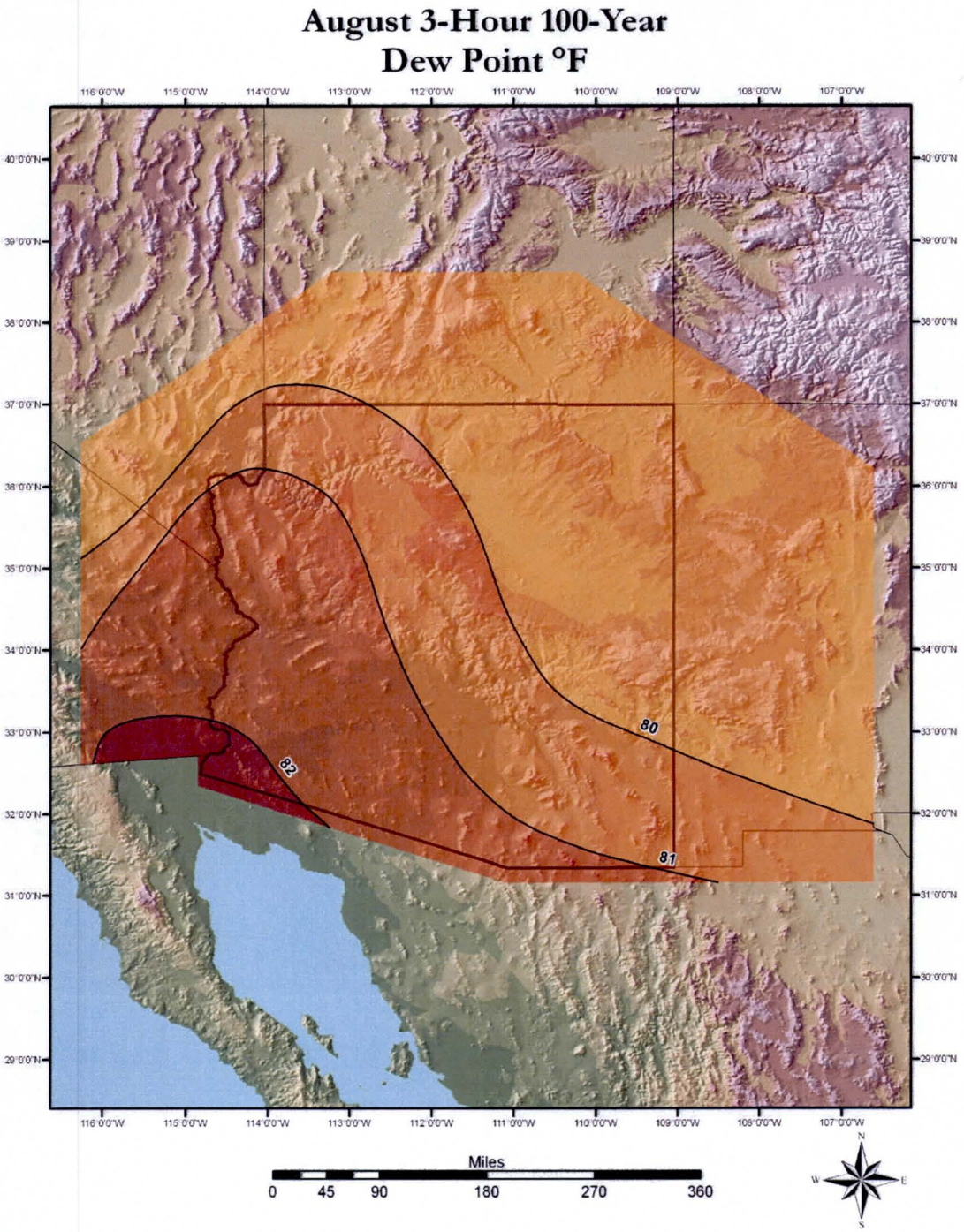



Figure -4.9 August 3-hour 100year return frequency dew point map

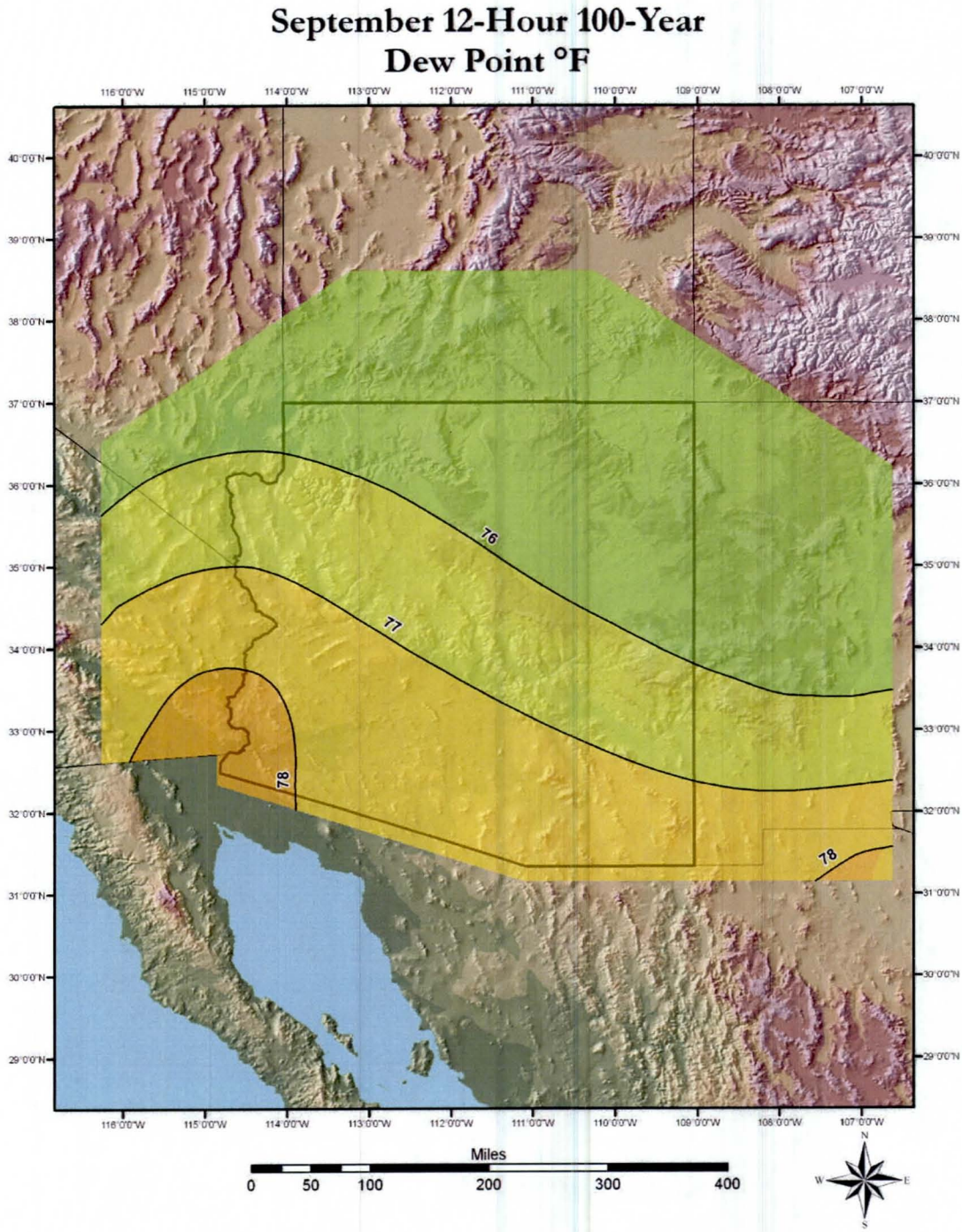



Figure 4.10 September 12-hour 100-year return frequency dew point map

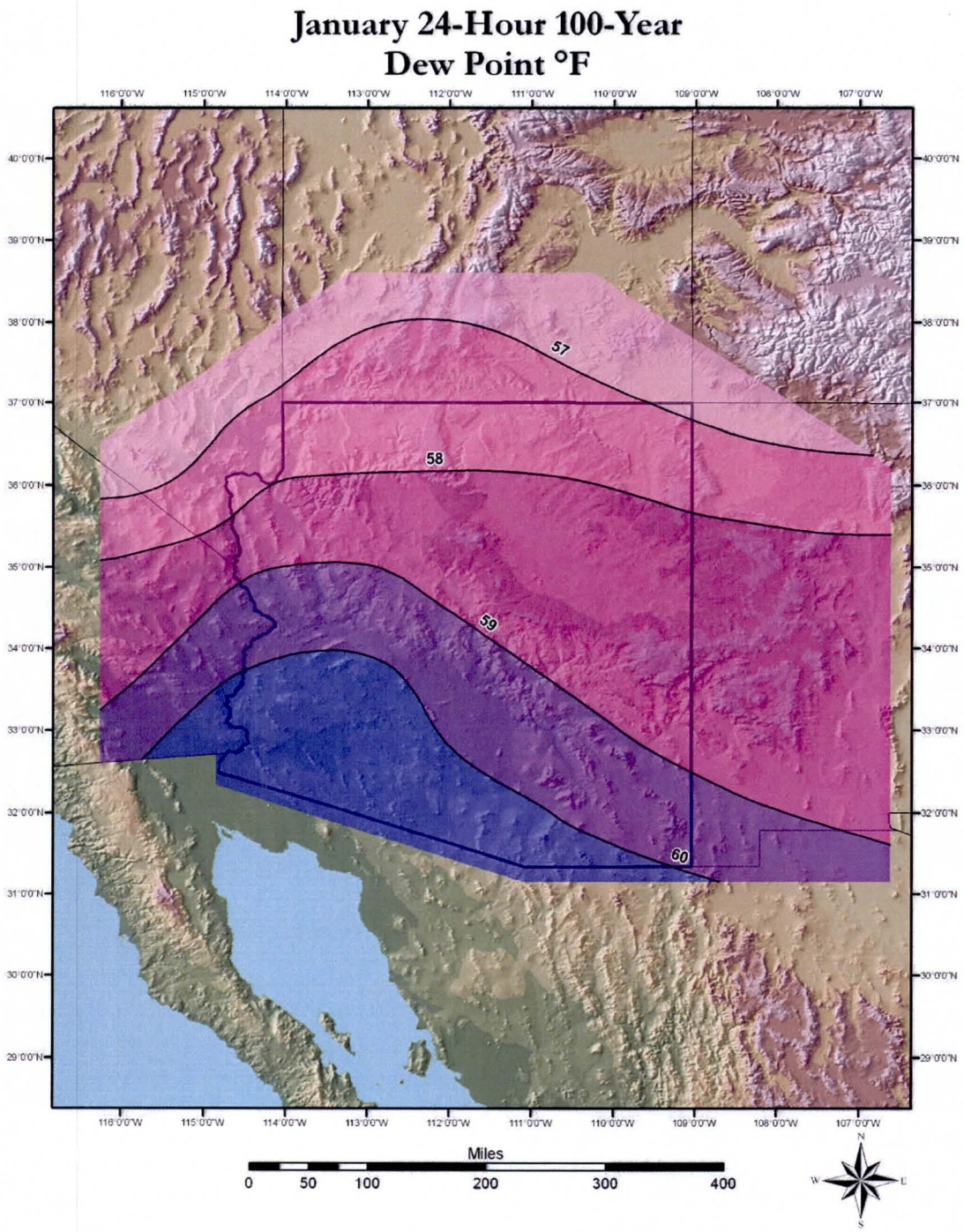



Figure 4.11 January 24-hour 100-year return frequency dew point map

### 4.1.3 Sea Surface Temperatures (SSTs)

The second data set used in storm analyses contained sea surface temperatures (SSTs) derived from the various databases available from NOAA. Daily values were generated from the following sources:

1985 – Present: http://dss.ucar.edu/datasets/ds277.7/
1985 - 1946: http://dss.ucar.edu/datasets/ds195.1/
Prior to 1946: http://dss.ucar.edu/datasets/ds540.0/

Observations were taken from ships, buoys (moored and drifting), automated coastal fixed platforms and drilling rigs, and satellite observations of SSTs. Analyses are archived to the nearest 0.02 degrees C, with a spatial resolution of one degree in both latitude and longitude. For storm analyses, daily SSTs were used.

For computing the maximization factors, a climatology of SSTs was computed for every one-degree latitude and longitude, based on twenty-five years of data. The standard deviation for each cell was calculated and two standard deviations were added to the monthly mean SST values for each cell. Monthly maps were produced to provide spatial analyses of the mean plus two sigma (two standard deviations warmer than the mean) SSTs. Use of the mean plus two sigma SSTs is consistent with the NWS procedure used in HMRs 57 and 59.

The monthly data sets were derived from the following sources:

1981-Present: SST fields:
http://www.emc.ncep.noaa.gov/research/cmb/sst_analysis/
1854-1981:
http://www.ncdc.noaa.gov/oa/climate/research/sst/ersstv3.php

The NWS states in HMR 57 that the two standard deviations warmer values are approximately equal to a 0.02 probability of occurrence. Specifically, Section 4.3, pp 43-44, states that two standard deviations represent about 98 percent of normally distributed values and this "...places the magnitude of this parameter at about the level of other estimates used in this study, e.g. the 100-year frequency values." For the 2-sigma probability, there is 0.05 out of 1.00 that is not included under the normal distribution curve. The 0.05 is divided between the extremes on the upper and lower ends of the normal distribution curve. Since only the high end (i.e. SST plus two standard deviations warmer) is used, only half of the 0.05 is excluded from under the normal distribution curve, i.e. 0.025. Hence 0.975 or 97.5% is included under the normal distribution curve. Figure 4.4 shows the normal distribution curve with the +1 sigma and +2-sigma values.

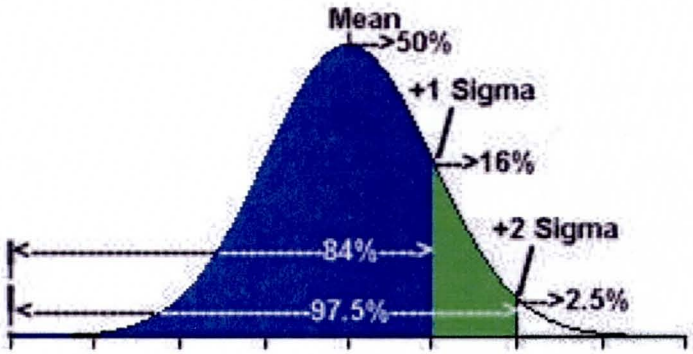



Figure 4.12 Normal distribution curve with +1 sigma and +2-sigma values shown

It appears that the NWS keeps rounding up until they conclude that the value is the 100-year frequency value (0.975 rounded up to 0.98 rounded up to 0.99). Without rounding 0.975 is about a 40-year return frequency value.

## 4.2 New Procedures

The HYSPLIT trajectory model provides detailed analyses for determining the upwind trajectories of atmospheric moisture that was advected into the storm systems. Using these trajectories, the moisture source locations are determined. The procedures followed are similar to the approach used in HMRs 57 and 59. However, by utilizing the HYSPLIT model trajectories, much of the subjectivity is eliminated. Further, details of each evaluation can be explicitly provided and the results are reproducible. For inflow vectors which originated over the ocean, the trajectories extend over coastal ocean currents to the warmer regions of the ocean that provide the atmospheric moisture that is later converted to rainfall by the storm system. The FPL study (Tomlinson et al, 2002) defined a procedure that was used for all storms to provide objectivity and reproducibility for the analyses.

Using SSTs for in-place maximization and storm transpositioning followed a similar procedure to that used with dew points. A detailed discussion is provided in Appendix C. Use of the HYSPLIT trajectory model provided a significant improvement in determining the inflow wind vectors compared to older methods of extrapolating coastal wind observations and estimating moisture advection from synoptic features over the ocean. The more objective procedure is especially useful for situations where a long distance is involved to reach warmer ocean regions. Timing is not as critical for inflow wind vectors extending over the oceans since SSTs change very slowly with time compared to dew point values over land. What is important is the changing wind direction, especially for situations where there is curvature in the wind fields. Any changes in wind curvature and variations in timing are inherently captured in the HYSPLIT model reanalysis fields, thereby eliminated another subjective and often unknown parameter.

Timing of rainfall is determined using the rainfall mass curves from the region of maximum rainfall. The location of the storm representative SST was determined when the SSTs are changing less than 1° F in a degree latitude and/or longitude distance following the inflow upwind. This procedure was developed to identify the homogeneous (or near homogeneous) region of SSTs associated with the atmospheric moisture source for the storms. The value from the SST daily analysis for that location was used for the storm representative SST. The storm representative SST was used in place of the storm representative dew point in the maximization procedure.

The value for the maximum SST was determined using the mean plus two sigma (two standard deviations warmer than the mean) SST for that location (see discussion on 2-sigma SST in Section 4.1.3). The storm representative SST and the mean plus 2-sigma SST were used in the same manner as the storm representative dew point and the maximum dew point in the maximization and transpositioning procedure discussed in Sections 8 and 9.

# 5. Extreme Storm Identification

## 5.1 Storm Search Area

A storm search was conducted for this study based on previous storm search results from the Magma FRS PMP and Safford PMP projects, as well as an expanded domain to capture all storms that could potentially affect PMP values within the state of Arizona This includes all storms in HMR 49 and those in HMR 59 that occurred in a meteorological and topographically homogenous region (i.e. the southeastern deserts of California). The primary search area includes all geographic locations where extreme rainfall storms similar to those that could occur over the White Tanks #4 may have been observed. The search area extended from southern Nevada and Utah to northern Mexico and from southeastern California eastward to the continental divide of Colorado and New Mexico (Figure 5.1). This insured a large enough area was analyzed to capture all significant storms that could influence the final PMP values for the basin.

## 5.2 Data Sources

The storm search was conducted using a database of rainfall data from several sources. The primary data sources are listed below:

1. Cooperative Summary of the Day / TD3200 through 2000. These data are published by the National Climatic Data Center (NCDC).
2. Hourly Weather Observations published by NCDC, U.S. Environmental Protection Agency, and Forecast Systems Laboratory (now National Severe Storms Laboratory).
3. NCDC Recovery Disk
4. Hydrometeorological Reports
5. Corps of Engineers Storm Studies
6. Other data published by state climate offices
7. Reports and discussion from Maricopa County FCD
8. American Meteorological Society journals

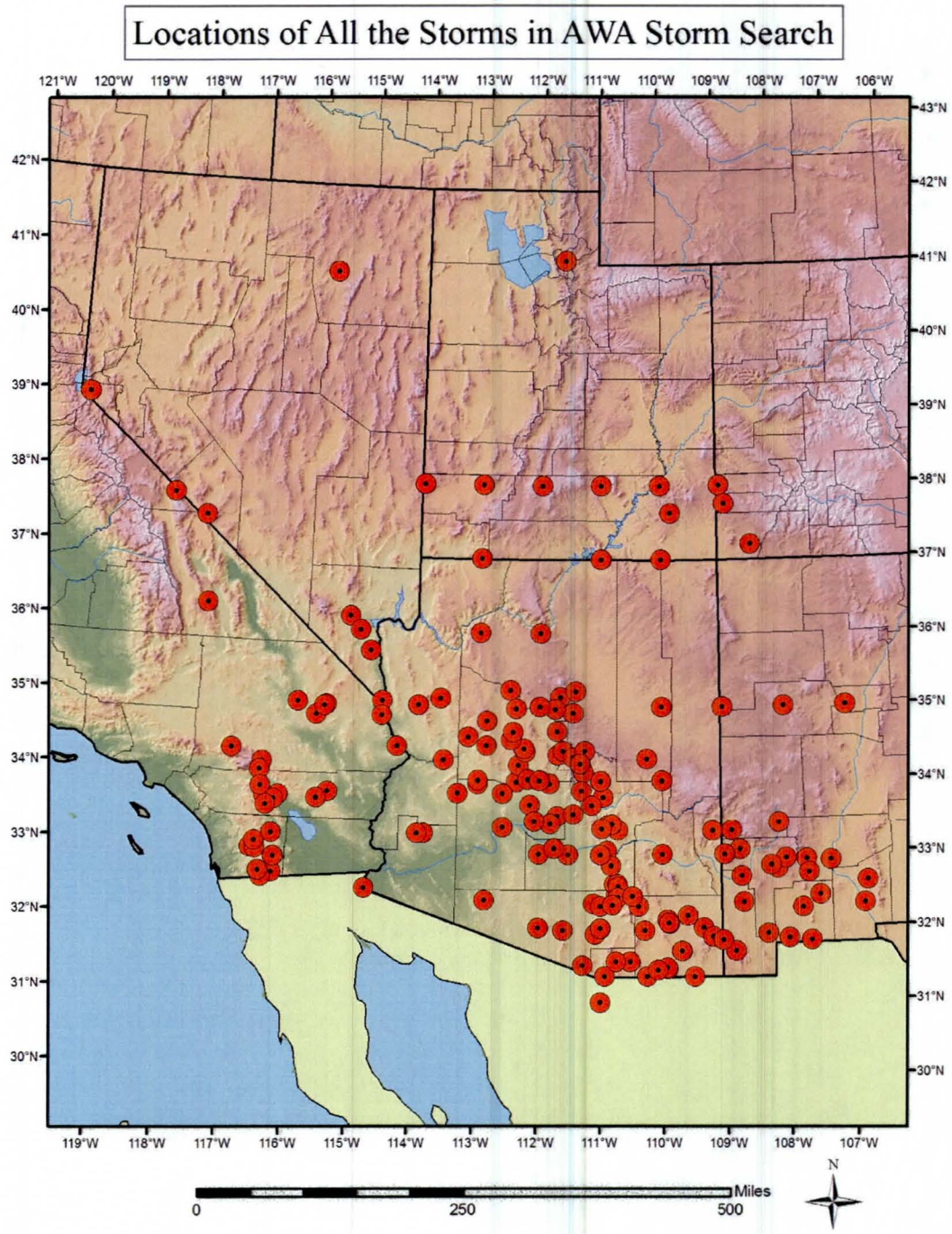



Figure 5.1 Storm locations for storms on the long storm list

## 5.3 Storm Search Method

The primary search began with identifying hourly and daily stations that have reliable rainfall data within the storm search area described previously. These stations were evaluated to identify the largest precipitation totals associated with the three storms types; local convective, remnant tropical, and general frontal. Other reference sources such as Hydrometeorological Reports, USGS reports, Flood Control District reports, and climate center reports were reviewed to identify other dates with large rainfall amounts for locations within the storm search domain. The initial cut-off for storms to make the initial list of significant storms (referred to as the long storm list) were events that exceeded the 100-year return frequency value for the specified duration and location.

The resulting long storm list was extensively quality controlled to ensure that only the highest storm rainfall values for each event were selected. Storms were then grouped by storm type and duration for further analysis.

These storms were plotted on a GIS map to ensure they occurred over similar meteorological and topographic regions as the White Tanks #4 drainage basin (Figure 5.1). From this initial long storm list, the potential storms to analyze list was derived. This list was developed after extensive communication with the statewide PMP review board as well as other stakeholders in the project. Each storm was also investigated for references in literature (NWS offices, USGS reports, flood report, HMRs, AMS journals, etc) to determine its significance in the storm and flood history of Arizona. Table 5.1 lists the storms identified in the storm search and included in the potential storms to analyze list.

Table 5.1 Potential storms to analyze list produced from the initial storm search. Maximum rainfall values shown are point values in inches. Storms are listed in reverse chronological order.

| Storm Location | State | Year | Month | Day | lat | lon | Precip |
|---|---|---|---|---|---|---|---|
| TUSCON | AZ | 1878 | 7 | 11 | 32.220 | -110.970 | 5.10 |
| STATEWIDE-FARLEY'S CAMP-SPAS 1148 | AZ | 1891 | 2 | 15 | 34.020 | -112.180 | 7.38 |
| PINAL RANCH | AZ | 1905 | 1 | 9 | 33.350 | -110.983 | 8.45 |
| YARNELL | AZ | 1905 | 11 | 26 | 34.222 | -112.747 | 4.80 |
| CASA GRANDE RUINS | AZ | 1906 | 8 | 1 | 33.000 | -111.533 | 5.40 |
| CLIFTON-1136 | AZ | 1906 | 12 | 4 | 33.051 | -109.296 | 10.00 |
| BISBEE | AZ | 1910 | 7 | 22 | 31.450 | -109.917 | 4.25 |
| PHOENIX | AZ | 1911 | 7 | 1 | 33.420 | -111.570 | 4.98 |
| SAN JUAN MTNS-SPAS 1107 | AZ | 1911 | 10 | 4 | 37.663 | -106.938 | 7.88 |
| MT ORD-SPAS 1144 | AZ | 1916 | 1 | 14 | 33.904 | -111.413 | 10.63 |
| CROWN KING | AZ | 1917 | 4 | 16 | 34.206 | -112.339 | 8.16 |
| CAVE CREEK | AZ | 1921 | 8 | 21 | 33.835 | -111.951 | 6.00 |
| KANAB | UT | 1925 | 10 | 4 | 37.047 | -112.525 | 2.80 |
| HEREFORD-SPAS 1099 | AZ | 1926 | 9 | 26 | 31.439 | -110.098 | 8.15 |
| CROWN KING | AZ | 1927 | 8 | 11 | 34.206 | -112.339 | 4.90 |
| PRESCOTT-SPAS 1079 | AZ | 1927 | 2 | 14 | 34.611 | -112.547 | 8.10 |
| WILLIAMS | AZ | 1928 | 11 | 25 | 35.233 | -112.183 | 10.35 |
| ESCALANTE | UT | 1932 | 7 | 12 | 37.767 | -111.600 | 3.24 |
| SIERRA ANCHA | AZ | 1933 | 9 | 10 | 33.800 | -110.967 | 4.28 |
| WIKIEUP | AZ | 1934 | 7 | 3 | 34.733 | -113.617 | 5.00 |
| RAMAH | NM | 1936 | 8 | 1 | 35.133 | -108.467 | 4.05 |
| PRESCOTT | AZ | 1937 | 2 | 6 | 34.611 | -112.547 | 4.90 |
| JUNIPINE-SPAS 1080 | AZ | 1938 | 3 | 1 | 34.611 | -112.547 | 6.00 |
| PIMA | AZ | 1939 | 8 | 2 | 32.850 | -110.830 | 3.10 |
| THATCHER-SPAS 1061 | AZ | 1939 | 9 | 17 | 32.763 | -109.829 | 4.18 |
| INDIO USDA-SPAS 1065 | CA | 1939 | 9 | 24 | 33.733 | -116.250 | 6.45 |
| SIERRA ANCHA | AZ | 1939 | 8 | 5 | 33.800 | -110.967 | 5.02 |
| CROSSMAN PEAK-SPAS 1077 | AZ | 1939 | 9 | 4 | 34.546 | -114.196 | 9.65 |
| FREDONIA | AZ | 1939 | 9 | 11 | 36.950 | -112.533 | 3.63 |
| PINAL RANCH | AZ | 1941 | 3 | 13 | 33.350 | -110.983 | 6.19 |
| BEAVER DAM St PK-SPAS 1082 | NV | 1946 | 10 | 27 | 37.524 | -114.072 | 7.50 |
| CROWN KING | AZ | 1948 | 8 | 5 | 34.206 | -112.339 | 6.17 |
| SAFFORD-SPAS 1153 | AZ | 1949 | 1 | 13 | 32.855 | -109.637 | 8.00 |
| PHOENIX | AZ | 1951 | 8 | 26 | 33.420 | -111.570 | 4.18 |
| CROWN KING-SPAS 1076 | AZ | 1951 | 8 | 24 | 34.204 | -112.354 | 14.99 |
| QUEEN CREEK-SPAS 1096 | AZ | 1954 | 8 | 18 | 33.203 | -111.145 | 8.06 |
| GLOBE-SPAS 1069 | AZ | 1954 | 7 | 28 | 33.330 | -110.720 | 3.50 |
| CANELO RANGE | AZ | 1955 | 8 | 26 | 31.550 | -110.517 | 6.39 |
| WELLTON 15WSW-SPAS 1064 | AZ | 1955 | 8 | 23 | 32.579 | -114.338 | 6.49 |
| MT TRUMBULL | AZ | 1955 | 7 | 24 | 36.417 | -113.300 | 4.37 |
| PAYSON | AZ | 1956 | 7 | 17 | 34.233 | -111.333 | 2.87 |
| ORACLE 4 SE | AZ | 1957 | 10 | 27 | 32.567 | -110.717 | 10.54 |
| TUCSON WSO AP | AZ | 1958 | 7 | 29 | 32.183 | -110.917 | 3.66 |
| TROUT CREEK | AZ | 1958 | 4 | 16 | 34.883 | -113.650 | 11.64 |
| SANTA RITA EXP RANGE-SPAS 1071 | AZ | 1959 | 6 | 29 | 31.767 | -110.850 | 4.50 |
| HORSESHOE DAM-SPAS 1154 | AZ | 1959 | 10 | 29 | 33.938 | -111.736 | 10.86 |
| ARIZONA SENORA DESERT MUSEUM-SPA | AZ | 1962 | 9 | 25 | 32.179 | -111.388 | 7.16 |
| COCHISE 4 SSE | AZ | 1963 | 8 | 26 | 32.059 | -109.891 | 3.54 |
| GLENDALE-SPAS 1123 | AZ | 1963 | 8 | 16 | 33.539 | -112.186 | 6.00 |
| CROWN KING-SPAS 1164 | AZ | 1963 | 8 | 16 | 34.200 | -112.333 | 13.09 |
| PERKINSVILLE-SPAS 1144 | AZ | 1963 | 7 | 31 | 34.900 | -112.200 | 3.59 |
| COPPER MINE TRADING-SPAS 11289 | AZ | 1963 | 7 | 10 | 36.633 | -111.417 | 4.40 |
| PRESCOTT-SPAS 1165 | AZ | 1963 | 8 | 16 | 34.611 | .-112.547 | 6.00 |
| PAGE-SPAS 1130 | AZ | 1963 | 8 | 30 | 36.917 | -111.450 | 2.03 |
| SAHUARITA-SPAS 1059 | AZ | 1964 | 9 | 9 | 32.006 | -110.904 | 6.77 |
| NORTH TUSCON-SPAS 1060 | AZ | 1964 | 9 | 6 | 32.304 | -111.004 | 5.28 |
| CASA GRANDE RUINS | AZ | 1964 | 8 | 12 | 33.000 | -111.533 | 3.08 |
| PHOENIX | AZ | 1964 | 9 | 14 | 33.435 | -112.014 | 1.25 |
| FLAGSTAFF WSO AP-SPAS 1127 | AZ | 1964 | 7 | 30 | 35.133 | -111.667 | 3.00 |

Table 5.1 Potential storms to analyze list produced from the initial storm search. Maximum rainfall values shown are point values in inches. Storms are listed in reverse chronological order (continued).

| Storm Location | State | Year | Month | Day | lat | lon | Precip |
|---|---|---|---|---|---|---|---|
| SANDERS 11 ESE | AZ | 1964 | 7 | 30 | 35.167 | -109.167 | 2.11 |
| BAGDAD 2 E-SPAS 1140 | AZ | 1965 | 3 | 16 | 34.583 | -113.167 | 9.04 |
| YOUNG-SPAS 1137 | AZ | 1965 | 11 | 22 | 34.000 | -111.000 | 11.59 |
| CROWN KING | AZ | 1965 | 12 | 22 | 34.204 | -112.354 | 15.00 |
| CASTLE HOT SPRINGS | AZ | 1966 | 9 | 12 | 33.983 | -112.367 | 6.53 |
| JUNIPINE-SPAS 1141 | AZ | 1966 | 12 | 4 | 34.611 | -112.547 | 9.57 |
| NORTH RIM ENTRANCE | AZ | 1966 | 12 | 3 | 36.335 | -112.116 | 14.00 |
| BLUFF | UT | 1966 | 7 | 29 | 37.283 | -109.550 | 3.60 |
| WALNUT GULCH-SPAS 1068 | AZ | 1967 | 9 | 10 | 31.700 | -110.083 | 3.45 |
| JAKES CORNER-SPAS 1133 | AZ | 1967 | 12 | 17 | 34.021 | -111.379 | 10.02 |
| SAN LUIS-SPAS 1081 | MX | 1967 | 11 | 26 | 32.500 | -114.800 | 7.64 |
| WELLTON-SPAS 1100 | AZ | 1967 | 9 | 1 | 32.617 | -114.333 | 4.39 |
| APACHE LAKE-SPAS 1124 | AZ | 1967 | 8 | 18 | 33.553 | -111.246 | 5.00 |
| APACHE LAKE | AZ | 1967 | 8 | 18 | 33.553 | -111.246 | 5.00 |
| CEDAR CITY FAA AP | UT | 1967 | 9 | 22 | 37.700 | -113.100 | 4.19 |
| BLANDING-SPAS 1162 | UT | 1968 | 8 | 1 | 37.625 | -109.478 | 6.00 |
| GLOBE-SPAS 1163 | AZ | 1968 | 8 | 3 | 33.330 | -110.720 | 3.30 |
| TEMPE-SPAS 1072 | AZ | 1969 | 9 | 13 | 33.367 | -111.967 | 3.52 |
| MARQUEZ | NM | 1969 | 10 | 21 | 35.300 | -107.300 | 4.10 |
| KITT PEAK | AZ | 1970 | 9 | 3 | 31.964 | -111.600 | 8.00 |
| WORKMAN CREEK-SPAS 1075 | AZ | 1970 | 9 | 4 | 33.820 | -110.721 | 12.13 |
| SELIGMAN-SPAS 1118 | AZ | 1970 | 7 | 21 | 35.317 | -112.883 | 4.84 |
| BUG POINT | UT | 1970 | 9 | 5 | 37.633 | -109.833 | 6.50 |
| DOVE CREEK | CO | 1970 | 9 | 5 | 37.750 | -108.917 | 6.00 |
| BRONCO CREEK-SPAS 1067 | AZ | 1971 | 8 | 19 | 34.676 | -113.679 | 3.00 |
| CEDAR POINT | UT | 1971 | 10 | 17 | 37.717 | -109.083 | 2.79 |
| PHOENIX-SPAS 1062 | AZ | 1972 | 6 | 22 | 33.517 | -112.023 | 5.63 |
| JUNIPINE-SPAS 1152 | AZ | 1972 | 10 | 19 | 34.611 | -112.547 | 7.19 |
| JOANNE-SPAS 1102 | AZ | 1972 | 10 | 4 | 33.821 | -110.921 | 11.66 |
| TRUXTON CANYON | AZ | 1972 | 8 | 12 | 35.388 | -113.659 | 2.70 |
| NOGALES | AZ | 1974 | 10 | 6 | 31.339 | -110.935 | 8.30 |
| SAFFORD-SPAS 1106 | AZ | 1974 | 7 | 17 | 32.834 | -109.707 | |
| LAKE HAVASU CITY-SPAS 1066 | AZ | 1974 | 7 | 19 | 34.433 | -114.333 | 4.50 |
| LAS VEGAS-SPAS 1143 | NV | 1975 | 7 | 3 | 36.131 | -115.181 | 3.00 |
| SEDONA-SPAS 1073 | AZ | 1975 | 7 | 13 | 34.930 | -111.770 | 3.50 |
| KOFA MINE-SPAS 1121 | AZ | 1976 | 10 | 23 | 33.267 | -113.867 | 5.60 |
| KOFA MOUNTAINS-SPAS 1101 | CA | 1976 | 9 | 24 | 33.300 | -113.980 | 6.33 |
| NOGALES-SPAS 1097 | AZ | 1977 | 10 | 6 | 31.339 | -110.935 | 14.00 |
| YUMA VALLEY-SPAS 1042 | AZ | 1977 | 8 | 13 | 32.611 | -114.631 | 6.85 |
| BIGHORN BASIN-HMR 59 1017-SPAS 1103 | CA | 1977 | 8 | 15 | 34.830 | -115.683 | 6.24 |
| BEAR SPRING-SPAS 1150 | AZ | 1978 | 2 | 27 | 34.038 | -111.488 | 15.52 |
| HELMET PEAK | AZ | 1978 | 10 | 21 | 31.917 | -111.083 | 5.50 |
| BROWNS PEAK-SPAS 1134 | AZ | 1978 | 12 | 17 | 33.675 | -111.335 | 10.37 |
| JUNIPINE | AZ | 1978 | 11 | 10 | 34.611 | -112.547 | 5.27 |
| CROWN KING-SPAS 1138 | AZ | 1980 | 2 | 13 | 34.221 | -112.346 | 17.63 |
| ALAMO-SPAS 1135 | NV | 1981 | 8 | 10 | 37.362 | -115.196 | 6.50 |
| VALLEY OF FIRE-SPAS 1119 | NV | 1981 | 8 | 11 | 36.433 | -114.517 | 3.05 |
| SEARCHLIGHT | NV | 1982 | 8 | 13 | 35.466 | -114.922 | 3.60 |
| COLORADO CITY | AZ | 1982 | 8 | 2 | 37.000 | -112.983 | 3.20 |
| REDINGTON | AZ | 1983 | 10 | 2 | 32.433 | -110.483 | 5.45 |
| MT GRAHAM-SPAS 1074 | AZ | 1983 | 9 | 28 | 33.247 | -109.198 | 12.00 |
| PRESCOTT-SPAS 1063 | AZ | 1983 | 9 | 23 | 34.621 | -112.554 | 17.95 |
| PHOENIX | AZ | 1983 | 8 | 16 | 33.510 | -112.117 | 1.14 |
| RED ROCK CANYON SP | NV | 1983 | 8 | 17 | 36.083 | -115.450 | 6.17 |
| SACATON | AZ | 1984 | 7 | 23 | 33.083 | -111.750 | 4.45 |
| MITCHELL CAVERNS-HMR 59 1018 | CA | 1984 | 7 | 27 | 34.970 | -115.520 | 5.05 |
| HARQUAHALA VALLEY-SPAS 1122 | AZ | 1984 | 9 | 2 | 33.488 | -113.254 | 8.00 |
| BISBEE 2 WNW | AZ | 1986 | 7 | 14 | 31.467 | -109.933 | 5.19 |
| VULTURE MINE ROAD | AZ | 1986 | 7 | 21 | 33.945 | -112.769 | 4.41 |

Table 5.1 Potential storms to analyze list produced from the initial storm search. Maximum rainfall values shown are point values in inches. Storms are listed in reverse chronological order (continued).

| Storm Location | State | Year | Month | Day | lat | lon | Precip |
|---|---|---|---|---|---|---|---|
| FLAGSTAFF WSO AP | AZ | 1986 | 8 | 13 | 35.133 | -111.667 | 2.94 |
| RED ROCK CANYON SP-SPAS 1159 | NV | 1986 | 3 | 10 | 36.083 | -115.450 | 5.38 |
| TUCSON | AZ | 1990 | 7 | 24 | 32.183 | -110.917 | 3.55 |
| WHITERIVER | AZ | 1991 | 8 | 27 | 33.833 | -109.967 | 3.30 |
| GLENDALE | AZ | 1992 | 7 | 23 | 33.510 | -112.118 | 6.25 |
| PHOENIX | AZ | 1992 | 7 | 24 | 33.510 | -112.117 | 6.25 |
| KNOLES HOLE SPRING-SPAS 1139 | AZ | 1993 | 1 | 5 | 33.829 | -110.913 | 13.36 |
| CROWN KING-SPAS 1078 | AZ | 1993 | 2 | 7 | 34.200 | -112.333 | 6.09 |
| FLAGSTAFF WSO AP-SPAS 1160 | AZ | 1993 | 2 | 19 | 35.133 | -111.667 | 4.48 |
| NOGALES 2 N-SPAS 1098 | AZ | 1993 | 8 | 25 | 31.350 | -110.933 | 6.31 |
| CAVE CREEK | AZ | 1993 | 8 | 31 | 33.834 | -111.951 | 6.00 |
| SIERRA VISTA 12S-SPAS 1132 | AZ | 1994 | 11 | 11 | 31.380 | -110.306 | 4.74 |
| TUCSON-SPAS 1086 | AZ | 1996 | 9 | 3 | 32.390 | -110.800 | 7.37 |
| HARQUAHALA MOUNTAIN-SPAS 1084 | AZ | 1997 | 9 | 25 | 33.815 | -113.335 | 12.13 |
| JOSEPH CITY-SPAS 1115 | AZ | 1998 | 7 | 31 | 34.956 | -110.335 | 3.23 |
| COLORADO CITY | AZ | 1998 | 9 | 9 | 37.000 | -112.983 | 4.85 |
| SABINO CAYNON-1087 | AZ | 1999 | 7 | 15 | 32.385 | -110.705 | 7.87 |
| GLOBE-SPAS 1008 | AZ | 1999 | 7 | 27 | 33.394 | -110.786 | 3.00 |
| PINE | AZ | 1999 | 8 | 30 | 34.385 | -111.456 | 3.00 |
| MIAMI | AZ | 2000 | 8 | 26 | 33.400 | -110.883 | 3.00 |
| JACKRABBIT WASH-SPAS 1126 | AZ | 2000 | 10 | 27 | 33.841 | -113.021 | 4.76 |
| NEW RIVER-SPAS 1095 | AZ | 2000 | 8 | 17 | 33.915 | -112.138 | 1.00 |
| SOLS WASH-SPAS 1048 | AZ | 2000 | 8 | 29 | 34.130 | -113.080 | 4.70 |
| OVERGAARD-SPAS 1111 | AZ | 2000 | 8 | 25 | 34.391 | -110.554 | 2.25 |
| VEYO POWERHOUSE | UT | 2000 | 8 | 29 | 37.352 | -113.667 | 3.18 |
| LINDEN | AZ | 2001 | 8 | 29 | 34.285 | -110.157 | 1.88 |
| OVERGAARD-SPAS 1110 | AZ | 2001 | 7 | 29 | 34.391 | -110.554 | 3.95 |
| BLUFF-SPAS 1131 | UT | 2001 | 8 | 14 | 37.283 | -109.550 | 3.50 |
| ELFRIDA-SPAS 1104 | AZ | 2002 | 7 | 21 | 31.690 | -109.350 | 4.70 |
| CIRCLE CITY-SPAS 1094 | AZ | 2003 | 8 | 26 | 33.950 | -112.340 | 10.17 |
| PHOENIX-long list | AZ | 2003 | 8 | 28 | 33.450 | -112.067 | 4.00 |
| ROOSEVELT LAKES-SPAS 1109 | AZ | 2003 | 9 | 6 | 33.596 | -110.996 | 9.50 |
| PAYSON | AZ | 2003 | 8 | 26 | 34.231 | -111.325 | 2.30 |
| VERNON | AZ | 2003 | 7 | 20 | 34.258 | -109.639 | 1.00 |
| WILLIAMS-SPAS 1117 | AZ | 2003 | 8 | 26 | 35.250 | -112.191 | 2.30 |
| SAFFORD | AZ | 2004 | 8 | 17 | 32.834 | -109.707 | 2.00 |
| QUEEN VALLEY-JAVIER-SPAS 1088 | AZ | 2004 | 9 | 18 | 34.730 | -113.020 | 10.10 |
| VULTURE MINE ROAD-SPAS 1093 | AZ | 2004 | 8 | 15 | 33.945 | -112.769 | 4.00 |
| COLORADO CITY | AZ | 2004 | 10 | 20 | 37.000 | -112.983 | 3.91 |
| DUNCAN | AZ | 2005 | 2 | 12 | 32.721 | -109.105 | 7.80 |
| BIG PINE FLAT-SPAS 1147 | AZ | 2005 | 2 | 10 | 33.685 | -111.325 | 8.72 |
| THATCHER | AZ | 2005 | 5 | 28 | 32.850 | -109.100 | 1.00 |
| CAMP CREEK-SPAS 1092 | AZ | 2005 | 8 | 9 | 33.918 | -111.821 | 4.50 |
| CAMP CREEK-SPAS 1091 | AZ | 2005 | 9 | 3 | 34.380 | -111.180 | 4.93 |
| PINETOP-SPAS 1151 | AZ | 2005 | 8 | 11 | 34.155 | -109.973 | 5.00 |
| TUCSON | AZ | 2006 | 7 | 26 | 32.183 | -110.917 | 11.10 |
| CEDAR CITY 5 E-SPAS 1120 | UT | 2006 | 7 | 31 | 37.650 | -113.000 | 3.83 |
| BOULDER-SPAS 1146 | UT | 2006 | 10 | 5 | 37.917 | -111.417 | 3.68 |
| MIAMI | AZ | 2007 | 7 | 15 | 33.400 | -110.883 | 2.75 |
| CAVE BUTTES-SPAS 1090 | AZ | 2007 | 7 | 31 | 33.726 | -112.468 | 3.00 |
| COOKS MESA-SPAS 1149 | AZ | 2007 | 11 | 30 | 34.460 | -111.230 | 8.60 |
| SAINT JOHNS-SPAS 1112 | AZ | 2007 | 8 | 2 | 34.500 | -109.367 | 3.02 |
| PETRIFIED FOREST-SPAS 1113 | AZ | 2007 | 7 | 27 | 34.800 | -109.867 | 3.29 |
| MANNING CAMP-SPAS 1105 | AZ | 2008 | 7 | 3 | 32.209 | -110.554 | 4.49 |
| MAGMA-SPAS 1051 | AZ | 2008 | 7 | 10 | 33.194 | -111.347 | 3.89 |
| PHOENIX-SPAS 1089 | AZ | 2008 | 7 | 29 | 33.420 | -111.570 | 1.20 |
| WENDEN | AZ | 2008 | 7 | 26 | 33.823 | -113.542 | 4.00 |
| WENDEN-BOUSE-SPAS 1085 | AZ | 2008 | 8 | 26 | 33.823 | -113.542 | 4.82 |
| HAVASUPAI-SPAS 1128 | AZ | 2008 | 8 | 15 | 35.802 | -112.426 | 6.00 |
| WAGON BOW-SPAS 1166 | AZ | 2009 | 7 | 3 | 34.865 | -113.455 | 7.67 |

## 5.4 Developing the Short List of Extreme Storms

The long storm list was very extensive containing 548 storms. The multiple step process described in the previous section was followed to determine a list of storms that was comprehensive enough to ensure that major events were identified but eliminating smaller events that would not be significant for determining PMP values at any area size or duration after standard adjustments were applied. This produced the potential storms to analyze list.

The next step was to determine which of these storms would ultimately need to be fully analyzed. Several steps were taken to compare each of the events on the potential storms to analyze list. Storms were sorted by storm type and location as an initial level of comparison. This helped eliminate several storms that which occurred in the same climate region but were of significant less magnitude than others. The remaining storms were further investigated from the various flood reports, discussions with scientists and personal familiar with the storm events, and examination of the synoptic environment surrounding the event. The storms which made it through these final analyses were then place on the storms to analyze list. This list contains all the storms that AWA deems necessary to be analyzed to derive valid PMP values without leaving out any potentially significant events. This list contains 105 storms (see Table 5.2). This list was then scrutinized again and each storm was ranked a high, medium, or low priority. These rankings were based on availability of data, storm location, storm type, and magnitude of event. For the White Tanks #4 drainage basin, 28 storm events were analyzed using the SPAS software program (see Table 5.2).

Figures 5.2 through 5.6 show the locations of all the storms contained on the storms to analyze list. Figure 5.2 shows the location of all the storms, Figure 5.3 shows the locations of all the local storms, Figure 5.4 shows the locations of all the remnant tropical storms, and Figure 5.5 shows the locations of all the general frontal storms. Finally, Figure 5.6 shows the storm information for all the storms that were analyzed and considered in the derivation of the PMP values for White Tanks.

Table 5.2 Storms to analyze list sorted by priority, then storm type

| Priority | Storm Number | Storm Type | Storm Location | State | lat | lon | Day | Year | Month | Precip |
|---|---|---|---|---|---|---|---|---|---|---|
| HIGH | 1133 | general | JAKES CORNER | AZ | 34.021 | -111.379 | 1967 | 12 | 17 | 10.02 |
| HIGH | 1134 | general | BIG PINE FLAT | AZ | 33.675 | -111.335 | 1978 | 12 | 16 | 10.37 |
| HIGH | 1137 | general | YOUNG | AZ | 34.000 | -111.000 | 1965 | 11 | 22 | 11.59 |
| HIGH | 1138 | general | CROWN KING | AZ | 34.221 | -112.346 | 1980 | 2 | 13 | 17.63 |
| HIGH | 1139 | general | KNOLES HOLE SPRING | AZ | 33.829 | -110.913 | 1993 | 1 | 5 | 13.36 |
| HIGH | 1140 | general | BAGDAD 2E | AZ | 34.583 | -113.167 | 1965 | 3 | 16 | 9.04 |
| HIGH | 1141 | general | JUNIPINE | AZ | 34.611 | -112.547 | 1966 | 12 | 4 | 9.57 |
| HIGH | 1144 | general | MT ORD | AZ | 33.904 | -111.413 | 1916 | 1 | 14 | 10.63 |
| HIGH | 1147 | general | BIG PINE FLAT | AZ | 33.685 | -111.325 | 2005 | 2 | 10 | 8.72 |
| HIGH | 1149 | general | COOKS MESA | AZ | 34.460 | -111.230 | 2007 | 11 | 30 | 8.60 |
| HIGH | 1150 | general | BEAR SPRING | AZ | 34.038 | -111.488 | 1978 | 2 | 27 | 15.52 |
| HIGH | 1078 | general | NE-S-SE ARIZONA | AZ | 34.204 | 112.354 | 1993 | 2 | 7 | 6.09 |
| HIGH | 1154 | general | HORSESHOE DAM | AZ | 33.938 | -111.736 | 1959 | 10 | 27 | 10.86 |
| HIGH | 1160 | general | CENTRAL ARIZONA | AZ | 34.204 | 112.354 | 1993 | 2 | 19 | 4.48 |
| HIGH | 1059 | local | SAHUARITA | AZ | 32.006 | -110.904 | 1964 | 9 | 9 | 6.77 |
| HIGH | 1060 | local | NORTH TUCSON | AZ | 32.304 | -111.004 | 1964 | 9 | 5 | 5.28 |
| HIGH | 1061 | local | THATCHER | AZ | 32.763 | -109.829 | 1939 | 9 | 16 | 4.18 |
| HIGH | 1062 | local | PHEONIX | AZ | 33.517 | -112.023 | 1972 | 6 | 21 | 5.63 |
| HIGH | 1063 | local | PRESCOTT | AZ | 34.621 | -112.554 | 1983 | 9 | 23 | 17.95 |
| HIGH | 1064 | local | WELLTON | AZ | 32.579 | -114.338 | 1955 | 8 | 22 | 6.49 |
| HIGH | 1065 | local | INDIO | CA | 33.733 | -116.250 | 1939 | 9 | 23 | 6.45 |
| HIGH | 1066 | local | LAKE HAVASU CITY | AZ | 34.433 | -114.333 | 1974 | 7 | 18 | 4.50 |
| HIGH | 1068 | local | WALNUT GULCH | AZ | 31.700 | -110.083 | 1967 | 9 | 9 | 3.45 |
| HIGH | 1069 | local | GLOBE | AZ | 33.330 | -110.720 | 1954 | 7 | 28 | 3.50 |
| HIGH | 1070 | local | CASA GRANDE RUINS | AZ | 33.000 | -111.533 | 1906 | 7 | 31 | 5.40 |
| HIGH | 1071 | local | SANTA RITA EX RANGE | AZ | 31.767 | -110.850 | 1959 | 6 | 28 | 4.65 |
| HIGH | 1073 | local | SEDONA | AZ | 34.930 | -111.770 | 1975 | 7 | 13 | 3.50 |
| HIGH | 1085 | local | WENDEN & BOUSE | AZ | 33.915 | -113.905 | 2008 | 8 | 26 | 4.82 |
| HIGH | 1086 | local | TUCSON | AZ | 32.390 | -110.800 | 1996 | 9 | 3 | 7.37 |
| HIGH | 1087 | local | SABINO CANYON | AZ | 32.385 | -110.705 | 1999 | 7 | 14 | 7.87 |
| HIGH | 1091 | local | CAMP CREEK | AZ | 34.380 | -111.180 | 2005 | 9 | 3 | 4.93 |
| HIGH | 1094 | local | CIRCLE CITY | AZ | 33.950 | -112.340 | 2003 | 8 | 26 | 10.17 |
| HIGH | 1096 | local | QUEEN CREEK | AZ | 33.203 | -111.145 | 1954 | 8 | 18 | 8.06 |
| HIGH | 1106 | local | SAFFORD | AZ | 32.834 | -109.707 | 1974 | 7 | 17 | 4.00 E |
| HIGH | 1109 | local | ROOSEVELT LAKE | AZ | 33.596 | -110.996 | 2003 | 9 | 6 | 9.50 |
| HIGH | 1110 | local | OVERGAARD | AZ | 34.391 | -110.554 | 2001 | 7 | 29 | 3.95 |
| HIGH | 1113 | local | PETRIFIED FOREST | AZ | 34.800 | -109.867 | 2007 | 7 | 27 | 3.29 |
| HIGH | 1115 | local | JOSEPH CITY | AZ | 34.956 | -110.335 | 1998 | 7 | 31 | 3.23 |
| HIGH | 1118 | local | SELIGMAN | AZ | 35.317 | -112.883 | 1970 | 7 | 21 | 4.84 |
| HIGH | 1119 | local | VALLEY OF FIRE SP | NV | 36.433 | -114.517 | 1981 | 8 | 11 | 3.05 |
| HIGH | 1120 | local | CEDAR CITY 5E | UT | 37.650 | -113.000 | 2006 | 7 | 31 | 3.83 |
| HIGH | 1121 | local | KOFA MINE | AZ | 33.267 | -113.867 | 1976 | 10 | 23 | 5.60 |
| HIGH | 1122 | local | HARQUAHALA VALLEY | AZ | 33.488 | -113.254 | 1984 | 9 | 2 | 8.00 |
| HIGH | 1127 | local | FLAGSTAFF | AZ | 35.133 | -111.667 | 1964 | 7 | 30 | 3.00 |
| HIGH | 1128 | local | HAVASUPAI | AZ | 35.802 | -112.426 | 2008 | 8 | 15 | 6.00 |
| HIGH | 1129 | local | COPPER MINE | AZ | 36.633 | -111.417 | 1963 | 7 | 10 | 4.40 |
| HIGH | 1130 | local | PAGE | AZ | 36.917 | -111.450 | 1963 | 8 | 30 | 2.03 |
| HIGH | 1131 | local | BLUFF | UT | 37.283 | -109.550 | 2001 | 8 | 14 | 3.50 |
| HIGH | 1135 | local | ALAMO | NV | 37.362 | -115.196 | 1981 | 8 | 10 | 6.50 |
| HIGH | 1162 | local | BLANDING | UT | 37.625 | -109.478 | 1968 | 8 | 1 | 6.00 |
| HIGH | 1166 | local | WAGON BOW | AZ | 34.865 | -113.455 | 2009 | 7 | 2 | 7.67 |

Table 5.2 Storms to analyze list sorted by priority, then storm type (continued)

| Priority | Storm Number | Storm Type | Storm Location | State | Year | Month | Day | lat | lon | Precip |
|---|---|---|---|---|---|---|---|---|---|---|
| HIGH | 1074 | tropical | MT GRAHAM | AZ | 33.247 | -109.198 | 1983 | 10 | 1 | 12.00 |
| HIGH | 1075 | tropical | WORKMAN CREEK | AZ | 33.820 | -110.721 | 1970 | 9 | 4 | 12.13 |
| HIGH | 1076 | tropical | Crown King | AZ | 34.204 | 112.354 | 1951 | 8 | 26 | 14.99 |
| HIGH | 1077 | tropical | CROSSMAN PEAK | AZ | 34.546 | 114.196 | 1939 | 9 | 4 | 9.65 |
| HIGH | 1083 | tropical | SONORA DESERT MUSEUM | AZ | 32.179 | -111.388 | 1962 | 9 | 25 | 7.16 |
| HIGH | 1084 | tropical | HARQUAHALA MOUNTAIN | AZ | 33.815 | -113.335 | 1997 | 9 | 25 | 12.13 |
| HIGH | 1088 | tropical | JAVIER | AZ | 34.730 | -113.020 | 2004 | 9 | 18 | 10.10 |
| HIGH | 1097 | tropical | NOGALES | AZ | 31.339 | -110.935 | 1977 | 10 | 6 | 14.00 |
| HIGH | 1101 | tropical | KOFA MOUNTAIN | AZ | 33.300 | -113.980 | 1976 | 9 | 24 | 6.33 |
| HIGH | 1102 | tropical | JOANNE | AZ | 33.821 | -110.921 | 1972 | 10 | 4 | 11.66 |
| HIGH | 1107 | tropical | SAN JUAN MOUNTAINS | CO | 37.663 | -106.938 | 1911 | 10 | 4 | 7.88 |
| HIGH | 1152 | tropical | JUNIPINE | AZ | 34.611 | -112.547 | 1972 | 10 | 19 | 7.19 |
| MEDIUM | 1079 | general | PRESCOTT | AZ | 34.611 | -112.547 | 1927 | 2 | 11 | 8.10 |
| MEDIUM | 1081 | general | SAN LUIS | MX | 32.500 | -114.800 | 1967 | 11 | 24 | 7.64 |
| MEDIUM | 1082 | general | BEAVER DAM SP | NV | 37.524 | -114.072 | 1946 | 10 | 25 | 7.50 |
| MEDIUM | 1136 | general | CLIFTON | AZ | 33.051 | -109.296 | 1906 | 12 | 4 | 10.00 |
| MEDIUM | 1146 | general | BOULDER | UT | 37.917 | -111.417 | 2006 | 10 | 5 | 3.68 |
| MEDIUM | 1148 | general | FARLEY'S CAMP | AZ | 34.020 | -112.180 | 1891 | 2 | 15 | 7.38 |
| MEDIUM | 1159 | general | RED ROCK CANYON SP | NV | 36.083 | -115.450 | 1986 | 3 | 10 | 5.38 |
| MEDIUM | 1164 | general | Crown King | AZ | 34.204 | 112.354 | 1963 | 8 | 16 | 13.09 |
| MEDIUM | 1067 | local | BRONCO CREEK | AZ | 34.676 | -113.679 | 1971 | 8 | 18 | 3.00 |
| MEDIUM | 1072 | local | TEMPE | AZ | 33.367 | -111.967 | 1969 | 9 | 13 | 3.52 |
| MEDIUM | 1089 | local | PHEONIX | AZ | 33.420 | -111.570 | 2008 | 7 | 29 | 1.20 |
| MEDIUM | 1092 | local | CAMP CREEK | AZ | 33.918 | -111.821 | 2005 | 8 | 9 | 4.50 |
| MEDIUM | 1093 | local | VULTURE MINE ROAD | AZ | 33.945 | -112.769 | 2004 | 8 | 15 | 4.00 |
| MEDIUM | 1095 | local | NEW RIVER | AZ | 33.915 | -112.138 | 2000 | 8 | 17 | 1.00 |
| MEDIUM | 1100 | local | WELLTON | AZ | 32.617 | -114.333 | 1967 | 9 | 1 | 4.39 |
| MEDIUM | 1104 | local | EFRIDA | AZ | 31.690 | -109.350 | 2002 | 7 | 21 | 4.70 |
| MEDIUM | 1112 | local | SAINT JOHNS | AZ | 34.500 | -109.367 | 2007 | 8 | 2 | 3.02 |
| MEDIUM | 1114 | local | PERKINSVILLE | AZ | 34.900 | -112.200 | 1963 | 7 | 31 | 3.59 |
| MEDIUM | 1117 | local | WILLIAMS | AZ | 35.250 | -112.191 | 2003 | 8 | 26 | 2.30 |
| MEDIUM | 1123 | local | GLENDALE | AZ | 33.539 | -112.186 | 1963 | 8 | 16 | 6.00 |
| MEDIUM | 1124 | local | APACHE LAKE | AZ | 33.553 | -111.246 | 1967 | 8 | 18 | 5.00 |
| MEDIUM | 1126 | local | JACKRABBIT WASH | AZ | 33.841 | -113.021 | 2000 | 10 | 27 | 4.76 |
| MEDIUM | 1151 | local | PINETOP | AZ | 34.155 | -109.973 | 2005 | 8 | 11 | 5.00 |
| MEDIUM | 1163 | local | GLOBE | AZ | 33.394 | -110.786 | 1968 | 8 | 3 | 3.30 |
| MEDIUM | 1165 | local | PRESCOTT | AZ | 34.611 | .-112.547 | 1963 | 8 | 16 | 6.00 |
| MEDIUM | 1099 | tropical | HEREFORD | AZ | 31.439 | -110.098 | 1926 | 9 | 26 | 8.15 |
| LOW | 1080 | general | JUNIPINE | AZ | 34.611 | -112.547 | 1938 | 2 | 27 | 6.00 |
| LOW | 1132 | general | SIERRA VISTA | AZ | 31.380 | -110.306 | 1994 | 11 | 11 | 4.74 |
| LOW | 1145 | general | MT TRUMBULL | AZ | 36.417 | -113.300 | 1955 | 7 | 24 | 4.37 |
| LOW | 1153 | general | SAFFORD | AZ | 32.855 | -109.637 | 1949 | 1 | 13 | 8.00 |
| LOW | 1155 | general | JUNIPINE | AZ | 34.611 | -112.547 | 1978 | 11 | 10 | 5.27 |
| LOW | 1161 | general | CENTRAL ARIZONA | AZ | 34.204 | 112.354 | 1993 | 1 | 13 | 8.00 |
| LOW | 1090 | local | CAVE BUTTES | AZ | 33.726 | -112.468 | 2007 | 7 | 31 | 3.00 |
| LOW | 1105 | local | MANNING CAMP | AZ | 32.209 | -110.554 | 2008 | 7 | 3 | 4.49 |
| LOW | 1108 | local | GLOBE | AZ | 33.394 | -110.786 | 1999 | 7 | 27 | 3.00 |
| LOW | 1111 | local | OVERGAARD | AZ | 34.391 | -110.554 | 2000 | 8 | 25 | 2.25 |
| LOW | 1116 | local | MITCHELL CAVERNS-HMR 59 1018 | CA | 34.970 | -115.520 | 1984 | 7 | 27 | 5.05 |
| LOW | 1143 | local | LAS VEGAS | NV | 36.131 | -115.181 | 1975 | 7 | 3 | 3.00 |
| LOW | 1098 | tropical | NOGALES 2 N | AZ | 31.350 | -110.933 | 1993 | 8 | 25 | 6.31 |
| LOW | 1103 | tropical | BIGHORN BASIN-HMR 59 1017 | CA | 34.830 | -115.683 | 1977 | 8 | 15 | 6.24 |

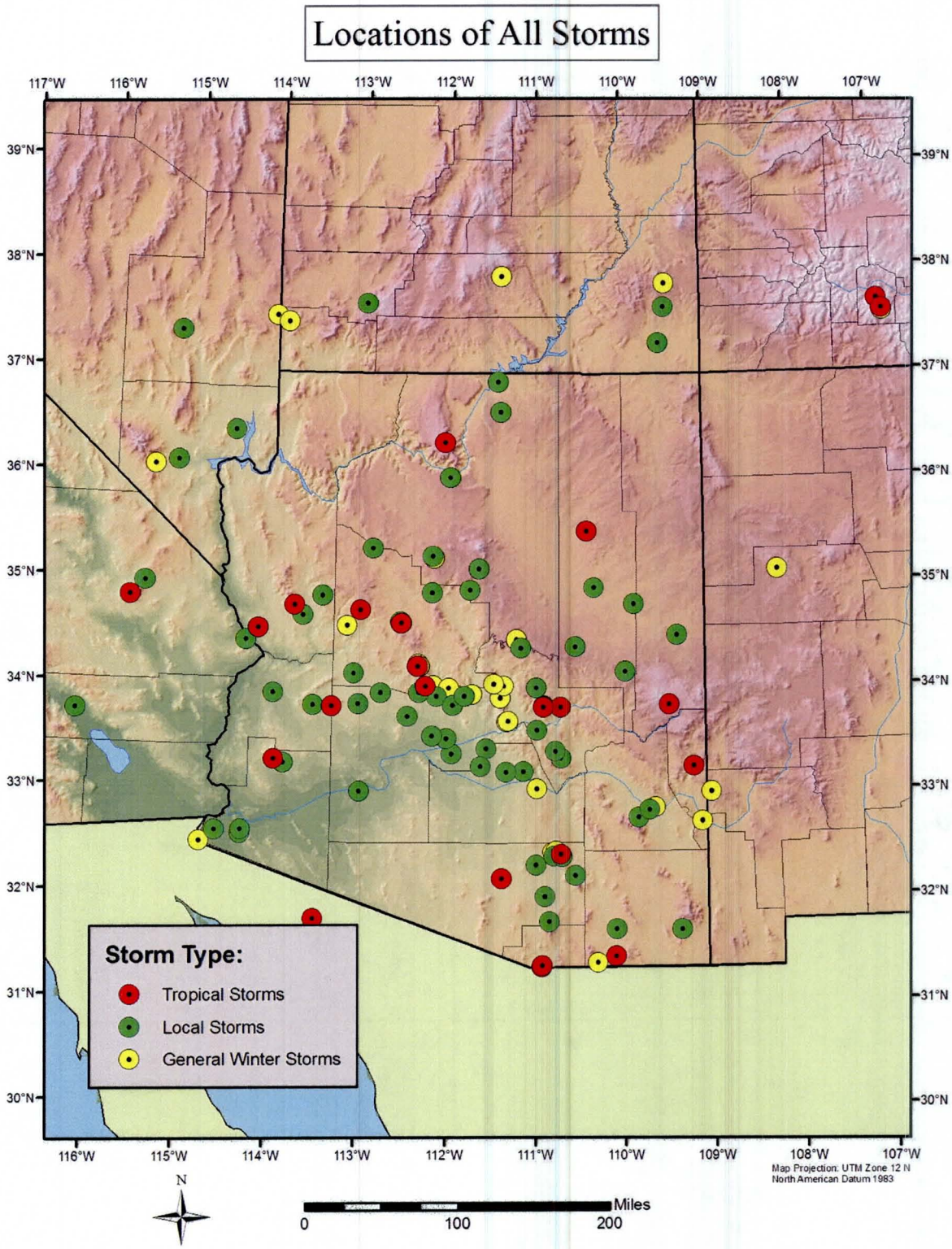



Figure 5.2 Storm locations for storms on the storms to analyze list

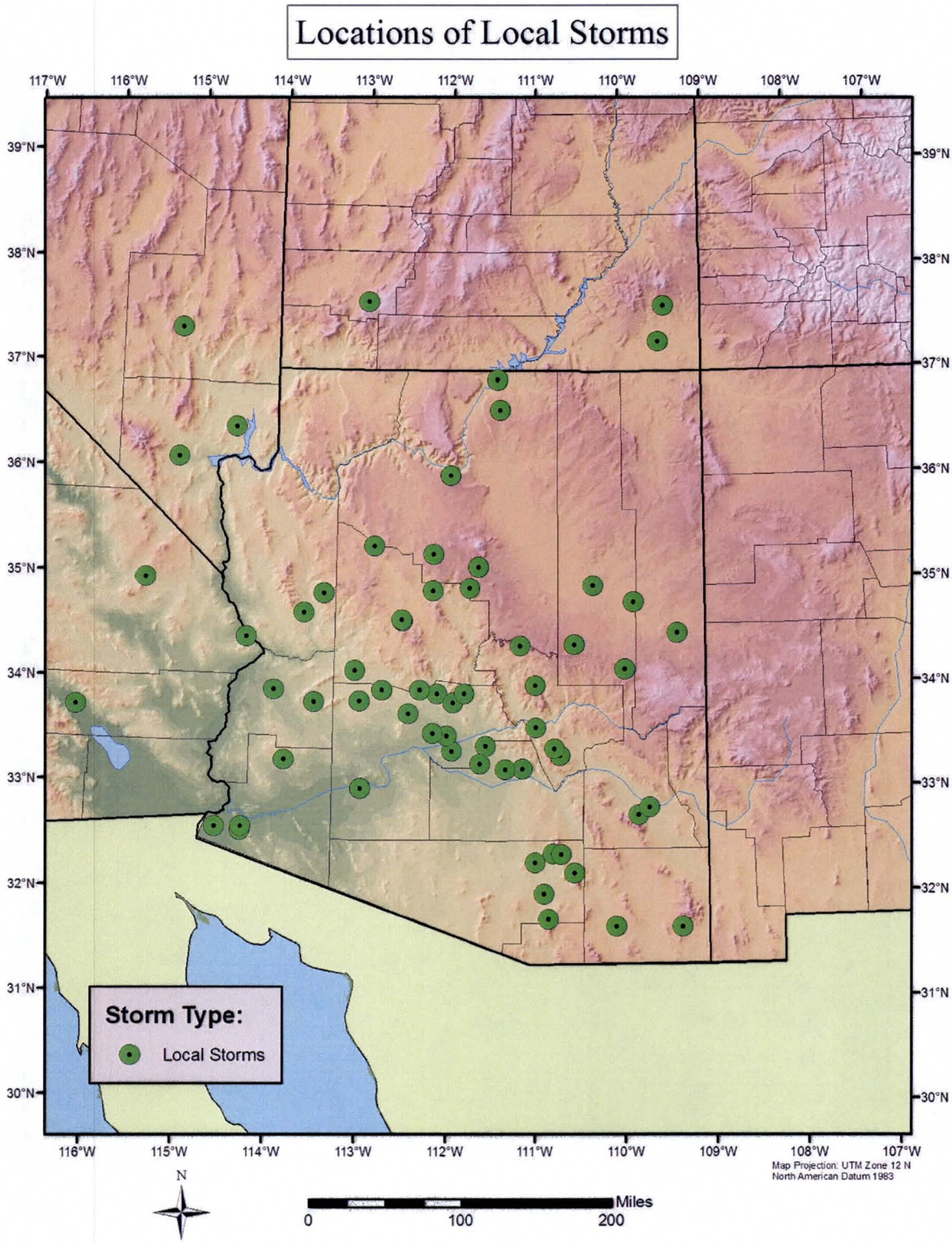



Figure 5.3 Storm locations for local storms on the storms to analyze list

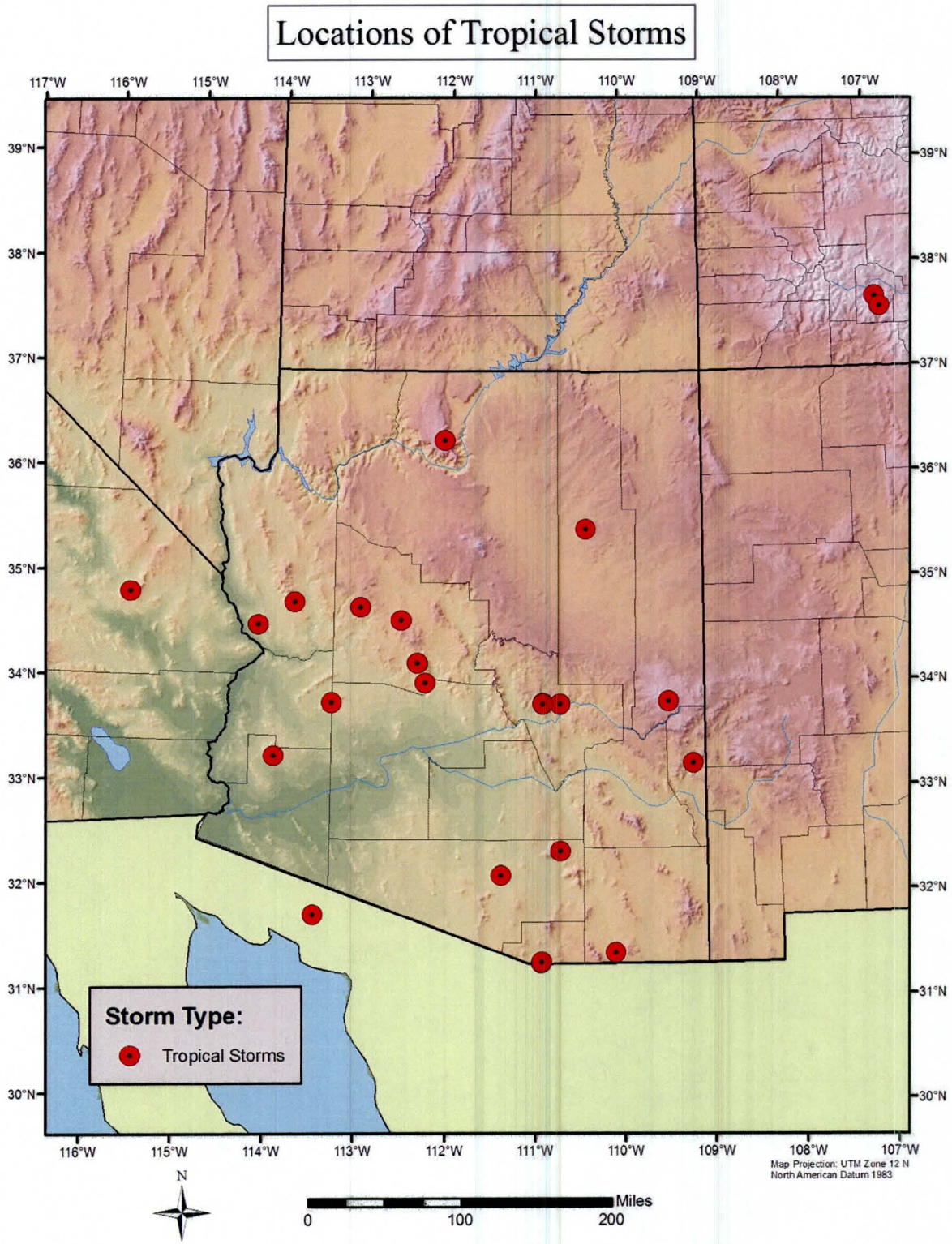



Figure 5.4 Storm locations for tropical storms on the storms to analyze list

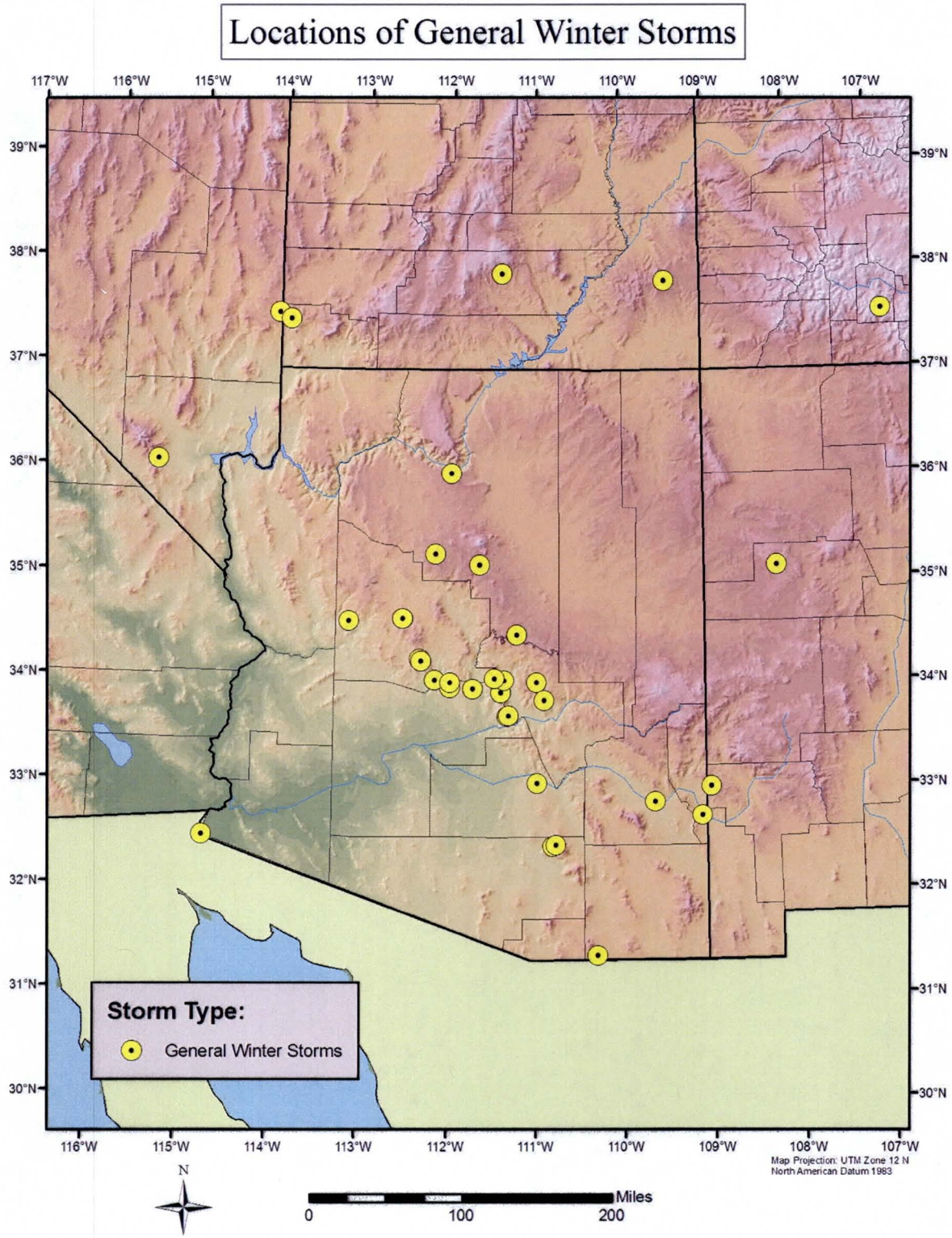



Figure 5.5 Storm locations for tropical storms on the storms to analyze list

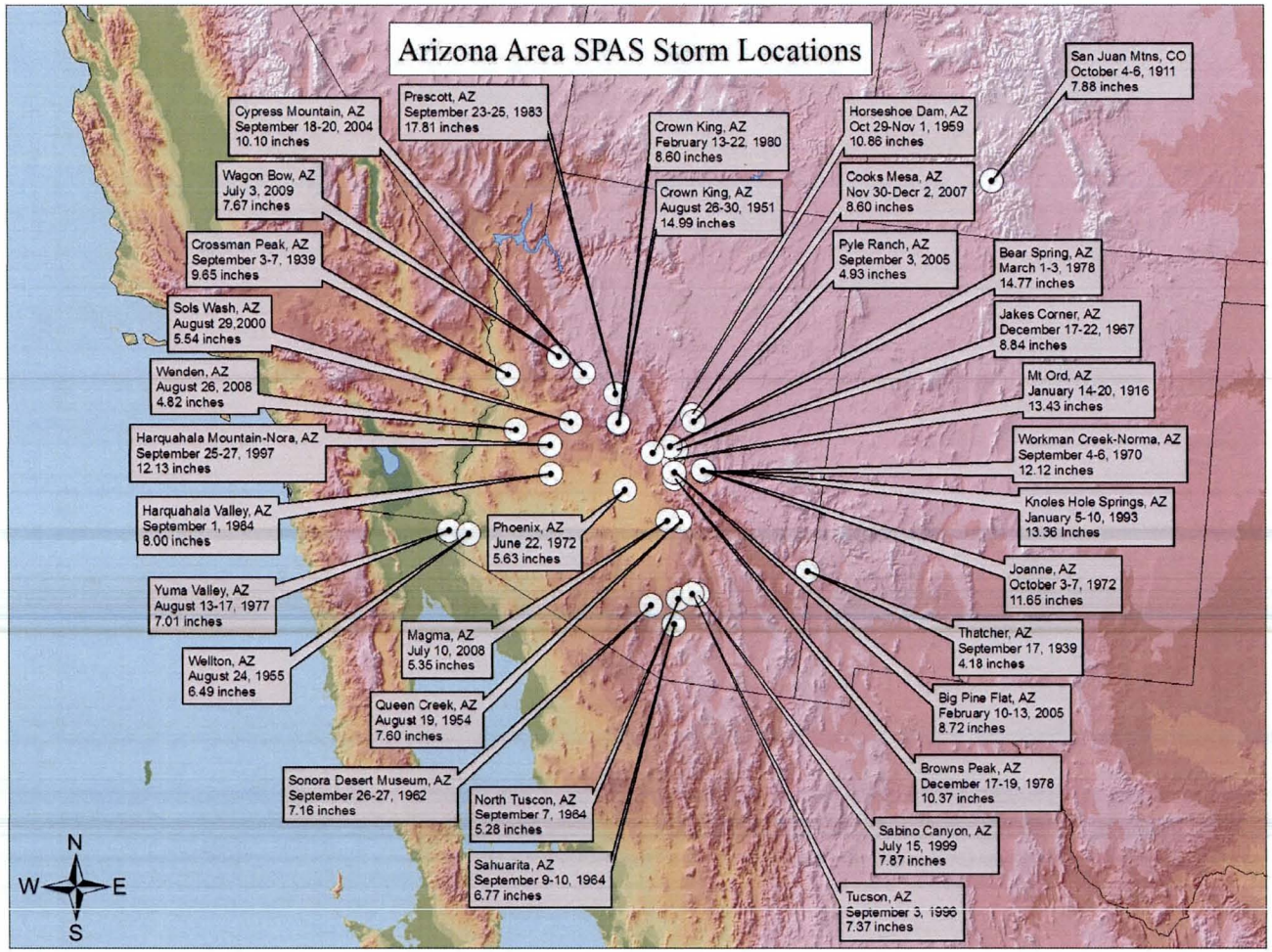



Figure 5.6 Storms analyzed using SPAS to derive the PMP values for Arizona; a subset of twenty-eight of these storms was used for White Tanks #4

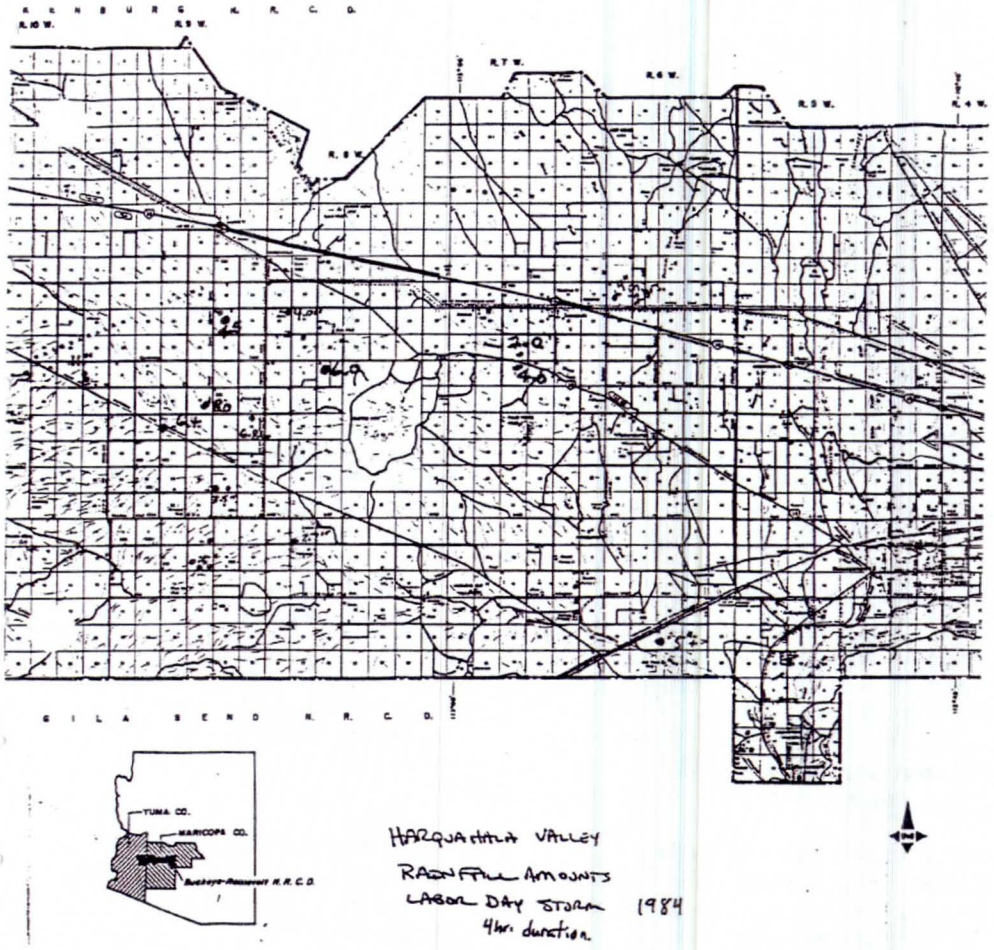
### 5.4.1 Reanalysis of the Harquahala Valley 1984 storm

Rainfall information for this storm was taken from the SCS Engineering Report, dated February 1987. This report primarily addresses damage to the Harquahala Valley Watershed Saddleback Diversion from the September 1-2, 1984 storm. This 71-page report includes information on design, flows and damage including pictures of damages that resulted from the flooding. Appendix A from that report contains the following two paragraphs along with two figures associated with the rainfall, a map with plotted reported rainfall values and recorder charts:

Rainfall

Figure 1 shows the rainfall amounts reported at locations near the watershed. The red values were obtained by work unit staff, the green during the study. Reported amounts range from 2 to 11 inches. There are no residences in the drainage area of Saddleback diversion, thus no rainfall information was available there. It appears, however, that the most intense part of the storm traveled from NW to SE and traversed the central and lower portion of the diversion watershed. High water marks at FRS 1 showed that the maximum stage was 4.8 feet over the principal spillway crest. The total capacity at this stage is 1732 acre-feet or .32 inches runoff from the watershed. The sediment pool capacity is 424 acre-feet or .08 inches. Because of the short duration of the storm, and small principal spillway capacity of FRS 1, rainfall above the site was not used in the Saddleback Diversion Study.

The storm distribution was taken from the recorder chart (Figure 2). The tabulated values were used because it was not possible to accurately read shorter time increments from the chart. It is probable that more intensive rainfall occurred during shorter time increments.




BUCKEYE-ROOSEVELT
NATURAL RESOURCE CONSERVATION DISTRICT
MARICOPA AND YUMA COUNTIES, ARIZONA

OCTOBER 1976

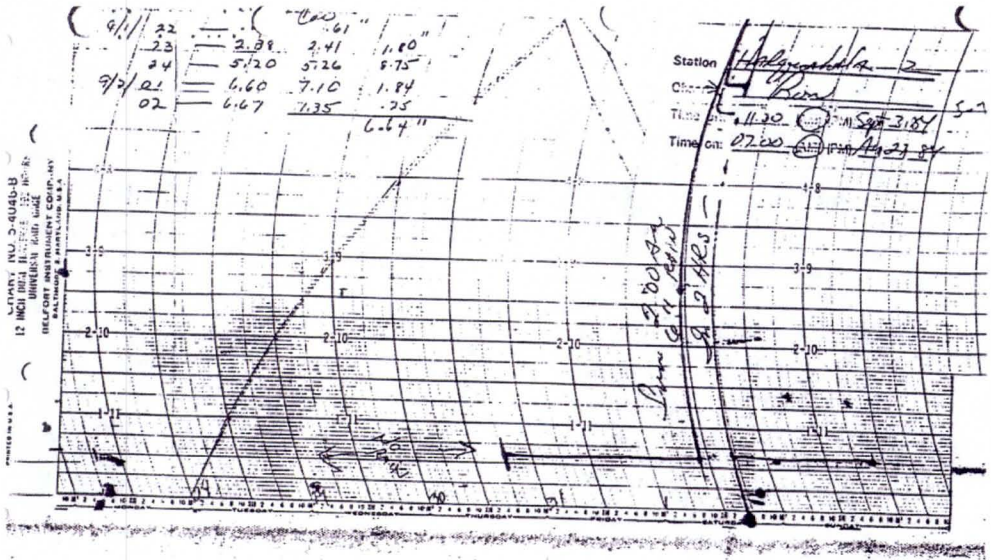
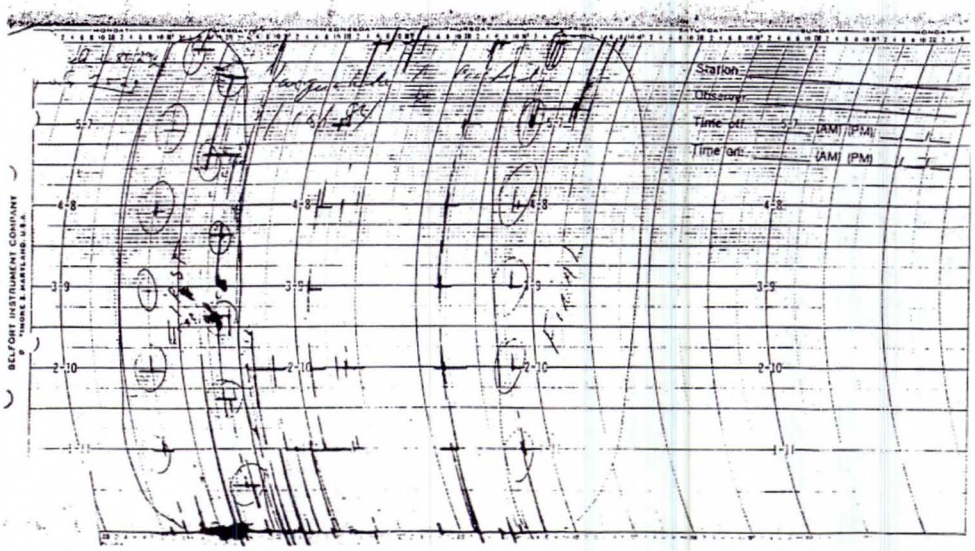

Station
Time on: 11:20 Sept 3 1984
Time on: 07:00 Aug 27 84
12 INCH DISC CHART
BELFORT INSTRUMENT COMPANY
BALTIMORE, MARYLAND, U.S.A.

Figure 2


Station
Observer
Time off
(AM) (PM)
Time on
(AM) (PM)
BELFORT INSTRUMENT COMPANY

Amir Motamedi from the Flood Control District of Maricopa County completed some investigation on available supporting materials regarding the storm event as a results of discussions during the second Arizona statewide PMP Review Committee meeting. He located a file at the Flood Control District with some information collected after the storm. Of particular interest is the notation of 11.00" followed by "Ron Howe, foreman at ranch." A copy of the sheets with the reported rainfall notation is shown below:

Verification: 9 + 5 total point

11.00" Ron Howe - foreman at ranch
Wallis - 978-3008

6.9 — lady on property
4.0" — Charlie Nye - Big Horn ranch foreman
< 2 hr.
4.5" — Tom Sykes - Silver Dollar - Green Farm
< 2 hr.
8.0 — F. Rogers - F.D.O maybe
6.0 + — Steve Palisch injured

Phone conversation with Nancy Wilson
7/29/86

① Lady on 481st said they had gage ~~in~~
; She was in Calif when storm came other
members of family said 6"

② 4" Charlie Nye - Big Horn Ranch
491st Farm Manager - 4" in less than
2 hours - Occurred at Midnight
Had rain about week before.

③ 4.5" Tom Sikes in less than 2 hrs
511st Dadly Greer Farm

4. Mr Rogers - Had rain about 10 days before
3 borrell set Water Office - Caught 8"
Thinks rained more in Sta - than on
Mountain.

5. Steve Toocle Hdg 4"
Vineyard

The notations above appear to be the source of rainfall information plotted on the map in the SCS report. How the reported rainfall amounts were obtained is not documented. The 11.00" value has what appears to be a telephone number suggesting that possibly the report was obtained via telephone conversation. Another notation indicates a phone conversation with another individual.

These reported rainfall amounts are the sole source of rainfall information for this storm with the exception of the recorder chart traces. Reports such as these are often referred to as "bucket survey" reports. Historically, the Weather Bureau, now renamed the National Weather Service, has made extensive use of bucket survey rainfall observations obtained from unofficial

sources. However, before a bucket survey rainfall report was accepted, the site was visited by someone familiar with rainfall observation criteria and evaluated for reliability. If the evaluation indicated that the reported rainfall was collected in an acceptable container that was sited appropriately and the timing of measurements was well documented, the reported rainfall was used in the storm rainfall analysis.

There is no documentation that the reported rainfall amounts provided in the SCS report or in the District notes were subjected to any quality control evaluations. This does not prove that they are not reliable but the important issue is that the reports were not evaluated by qualified personnel for reliability, a procedure normally followed by the National Weather Service before the reports are included in official storm rainfall analyses. There are several possibilities that could lead to erroneous reports. This includes that the container was not empty at the beginning of the rainfall, the site of the container was too close to a roof or other obstruction, or the sides of the container were sloped. Another possibility is that estimates of rainfall amounts have been reported as measured, e.g. a six inch deep container filled and overflowed so maybe twice the amount collected was reported in a well meaning effort to quantify the rainfall.

After further discussions with the Review Board as well as the NRCS (the original agency responsible for the report and storm information), it was agreed that the 11" rainfall value not be considered valid for use. The storm instead has been reanalyzed using only the remaining values, as these are considered reasonable based on the amount recorded on an official trace recorder and the number of other similar amounts reported between 4-8 inches. Complete details on this storm can be found in Appendix F.

# 6. Storm Depth-Area-Duration (DAD) Analyses of Storms

For all storms identified as part of this study, DADs needed to be computed. The Storm Precipitation Analysis System (SPAS) was used to compute DADs for these storms.

There are two main steps in the SPAS DAD analysis: 1) The creation of high-resolution hourly precipitation grids and 2) the computation of depth-area rainfall amounts for various durations. The reliability of the results from step 2) depends on the accuracy of step 1). Historically the process has been very labor intensive. SPAS utilizes Geographic Information Systems (GIS) concepts to create spatially-oriented and accurate results in an efficient manner (step 1). Furthermore, the availability of NEXRAD (NEXt generation RADar) data allows SPAS to better account for the spatial and temporal variability of storm precipitation for events occurring since the early 1990s. Prior to NEXRAD, the National Weather Service (NWS) developed and used a method based on Weather Bureau Technical Paper No. 1. Because this process has been the standard for many years and holds merit, the DAD analysis process developed for this study attempts to mimic the NWS procedure as much as possible. See Appendix G for a full description of SPAS. By adopting this approach, some level of consistency between the newly analyzed storms and the hundreds of storms already analyzed by the NWS can be achieved. Comparisons between the NWS DAD results and those computed using the new method for two storms (Westfield, MA 1955 and Ritter, IA 1953) indicated very similar results (see Appendix G for complete discussion, comparisons, and results).

## 6.1 Data Collection

The areal extent of a storm's rainfall is evaluated using existing maps and documents along with plots of total storm rainfall. Based on the storm's spatial domain (longitude-latitude box), hourly and daily rain gauge data are extracted from the database for the specified area, dates, and times. To account for the temporal variability in observation times at daily stations, the extracted hourly data must capture the entire observational period of all extracted daily stations. For example, if a station takes daily observations at 8:00 AM local time, then the hourly data needs to be complete from 8:00 AM local time the day prior. As long as the hourly data are sufficient to capture all of the daily station observations, the hourly variability in the daily observations can be properly addressed.

The daily observations database contains data from National Climatic Data Center (NCDC) TD-3206 (pre-1948) and TD-3200 (generally 1948-present) data sets. The hourly observations database contains from NCDC TD-3240 data set. The daily supplemental database is largely comprised of data from "bucket surveys", local rain gauge networks (e.g. ALERT, USGS, etc.) and daily gauges with accumulated rainfall data.

## 6.2 Mass Curves

The most complete rainfall observational dataset available is compiled for each storm. To obtain temporal resolution to the nearest hour in the final DAD results, it is necessary to distribute the daily precipitation observations (at daily stations) into hourly bins. This process has traditionally been accomplished by anchoring each of the daily stations to a single hourly station for

timing. However, this may introduce biases and may not correctly represent hourly precipitation at locations between hourly observation stations. A preferred approach is to anchor the daily station to some set of nearest hourly stations. This is accomplished using a spatially based approach called the spatially based mass curve (SMC) process (see Appendix B).

## 6.3 Hourly or Sub-hourly Precipitation Maps

At this point, SPAS can either operate in its standard mode or in NEXRAD-mode to create high resolution hourly or sub-hourly (for NEXRAD storms) grids. In practice both modes are run when NEXRAD data are available so that a comparison can be made between the methods. Regardless of the mode, the resulting grids serve as the basis for the DAD computations.

### 6.3.1 Standard SPAS mode

The standard SPAS mode requires a full listing of all the observed hourly rainfall values, as well as the newly created estimated hourly data from daily and daily supplemental stations. This is done by creating an hourly file that contains the newly created hourly mass curve precipitation data (from the daily and supplemental stations) and the "true" hourly mass curve precipitation. If not using a base map, the individual hourly precipitation values are simply plotted and interpolated to a raster with an inverse distance weighting (IDW) interpolation routine in a GIS.

### 6.3.2 NEXRAD mode

Radar has been in use by meteorologists since the 1960s to estimate rainfall depth. In general, most current radar-derived rainfall techniques rely on an assumed relationship between radar reflectivity and rainfall rate. This relationship is described by the equation (1) below:

(1) $Z = aR^b$

where Z is the radar reflectivity, measured in units of dBZ, R is the rainfall rate, $a$ is the "multiplicative coefficient" and $b$ is the "power coefficient". Both $a$ and $b$ are related to the drop size distribution (DSD) and the drop number distribution (DND) within a cloud (Martner et al 2005).

The National Weather Service (NWS) uses this relationship to estimate rainfall through the use of their network of Doppler radars (NEXRAD) located across the United States. A standard default Z-R algorithm of $Z = 300R^{1.4}$ is the primary algorithm used throughout the country and has proven to produce highly variable results. The variability in the results of Z vs. R is a direct result of differing DSD and DND, and differing air mass characteristics across the United States (Dickens 2003). The DSD and DND are determined by a complex interaction of microphysical processes in a cloud. They fluctuate hourly, daily, seasonally, regionally, and even within the same cloud (see Appendix G for a more detailed description).

Using the technique described above, NEXRAD rainfall depth and temporal distribution estimates are determined for the area in question.

## 6.4 Depth-Area-Duration (DAD) Program

The DAD extension of SPAS runs from within a GRASS 6.2 GIS environment and utilizes many of the built-in functions for calculation of area sizes and average depths. The following is the general outline of the procedure:

1. Given a duration (e.g. x-hours) and cumulative precipitation, sum up the appropriate hourly or sub-hourly precipitation grids to obtain an x-hour total precipitation grid starting with the first x-hour moving window.

2. Determine x-hour precipitation total and its associated areal coverage. Store these values. Repeat for various lower rainfall thresholds. Store the average rainfall depths and area sizes.

3. The result is a table of depth of precipitation and associated area sizes for each x-hour window location. Summarize the results by moving through each of the area sizes and choosing the maximum precipitation amount. A log-linear plot of these values provides the depth-area curve for the x-hour duration.

4. Based on the log-linear plot of the rainfall depth-area curve for the x-hour duration, determine rainfall amounts for the standard area sizes for the final DAD table. Store these values as the rainfall amounts for the standard sizes for the x-duration period. Determine if the x-hour duration period is the longest duration period being analyzed. If it is not, analyze the next longest duration period and return to step 1.

5. Construct the final DAD table with the stored rainfall values for each standard area for each duration period.

# 7. Storm Maximization

Storm maximization is the process of increasing rainfall associated with an observed extreme storm under the potential condition that additional moisture could have been available to the storm for rainfall production. This is accomplished by increasing the surface dew points (or SSTs) to some climatological maximum and calculating the enhanced rainfall amounts that could potentially have been produced. An additional consideration is usually applied that selects the climatological maximum dew point or SSTs for a date two weeks towards the warm season from the date that the storm actually occurred. This procedure assumes that the storm could have occurred two weeks earlier or later in the year when maximum dew points or SSTs are higher.

## 7.1 Use of Dew Point Temperatures

HMR and WMO procedures for storm maximization use a representative storm dew point as the parameter to represent available moisture to a storm. Storm precipitation amounts are maximized using the ratio of precipitable water for the maximum dew point to precipitable water for the observed storm representative dew point. A more detailed discussion, along with examples of this procedure, is provided in Appendix C.

The storm representative dew point was derived for each storm event analyzed. Once the general upwind location was determined using the processes described in Section 4, the hourly surface observations were analyzed for all available stations within the vicinity of the inflow vector. From this data, the appropriate durational dew point value was averaged for each station (3-hour, 12-hour, or 24-hour depending on storm type). These values were then taken to 1000mb and the appropriate storm representative dew point and location derived. The information used and values derived for each storm are included as part of Appendix F.

## 7.2 Use of Sea Surface Temperatures (SSTs)

Dew point observations are not generally available over ocean regions. When the source region of atmospheric moisture feeding an extreme rainfall event is over the ocean, a substitute for dew points observations is required. The NWS has adopted a procedure for using sea surface temperatures (SSTs) as surrogates for dew points over the ocean. The value used as the maximum SST in the PMP calculations is determined using the SSTs, two standard deviations warmer than the mean SST. This provides a value for the maximum SST that has a probability of occurrence of about 0.025, i.e. about the 40-year return frequency value (see Section 4.1.3 for more detail).

Storm representative SSTs were substituted for dew points for only one storm in this study-the December 1978 general frontal storm-SPAS 1134. These SST values are then treated the same as dew points and the same process is followed for storm maximization as if the SST values were dew point values were taken from land based stations. A more detailed discussion, along with examples of this procedure, is provided in Appendix C.

Using SSTs for in-place maximization and storm transpositioning follows a similar procedure to that used with dew points. The HYSPLIT trajectory model provide a significant improvement in determining the inflow wind vector as compared to older methods. This is

particularly significant when extrapolating coastal wind observations over long distances to reach warmer ocean regions. Timing is not as critical for inflow wind vectors extending over the oceans, since SSTs change very slowly compared to dew point values over land. What is important is the changing wind direction for situations where there is curvature in the wind fields as the inflow wind vector is followed upwind for hundreds of miles.

As is the case for the storm representative dew point analysis, timing of the rainfall is determined using the rainfall mass curves from the region of maximum rainfall. The wind speed and direction are determined using NCEP reanalysis wind fields incorporated into the HYSPLIT program to identify source regions for atmospheric moisture over the warmer ocean areas. The location of the storm representative SST was determined when SSTs are changing less than one degree F in a degree latitude and/or longitude distance following the inflow wind vector upwind. Values from the NOAA SST analysis for that location were used to determine the storm representative SST.

For storm maximization, the value for the maximum SST is determined using the mean plus two sigma SST for that location for a date two weeks before or after the storm date (which ever represents the climatologically warmer period). Storm representative SSTs and the mean plus two sigma SSTs are used in the same manner as storm representative dewpoints and maximum dewpoints in the maximization and transpositioning procedure.

# 8. Storm Transpositioning

Extreme rain events in a meteorologically homogeneous region surrounding a watershed are a very important part of the historical evidence on which a PMP estimate for the drainage basin is based. Since most basin locations have a limited period of record for rainfall data collected within the basin boundaries, the number of extreme storms that have been observed over the basin is limited. Storms that have been observed within similar climate and topographic regions are analyzed and adjusted to provide information describing the storm rainfall, as if that storm had occurred over the basin being studied. Transfer of a storm from where it occurred to a location that is meteorologically and geographically similar is called storm transpositioning. The underlying assumption is that storms transposed to the basin could occur over the basin under similar meteorological conditions. To properly relocate such storms, it is necessary to address issues of similarity as they relate to meteorological conditions and topography.

The search for extreme rainfall events identified storms that occurred throughout Arizona south of the Mogollon Rim south and east through Tucson and to northern Mexico. This region was considered meteorologically and geographically homogenous and therefore the climatological settings of the basin and the locations of each of the transposed storms are similar. Further analysis of storm patterns on both a temporal and spatial scale within this region revealed that only storms that were not influenced extensively by orographic enhancement were considered to have similar enough storm dynamics to be transpositionable to the drainage basin (this excluded storms that were centered over the Mt Lemmon area).

## 8.1 Use of Maximum Dew Point and SST Climatologies

The procedure for storm maximization has been discussed in Section 7. The same maps used for maximum dew points/SSTs are used in the storm transpositioning procedure. The wind inflow vector connecting the storm location with the storm representative dew point/SST location was transpositioned to the basin location. Figure 8.1 shows an example of vector transpositioning. The upwind end of the vector identifies the transpositioned location for the transposition maximum dew point/SST. The value of the maximum dew point/SST at that location provided the transpositioned maximum dew point/SST value used to compute the transposition adjustment for relocating the storm. The primary effect of storm transpositioning is to adjust storm rainfall amounts to account for enhanced or reduced atmospheric moisture made available to the storm at the transposed location. A more detailed discussion of this procedure is provided in Appendix C.

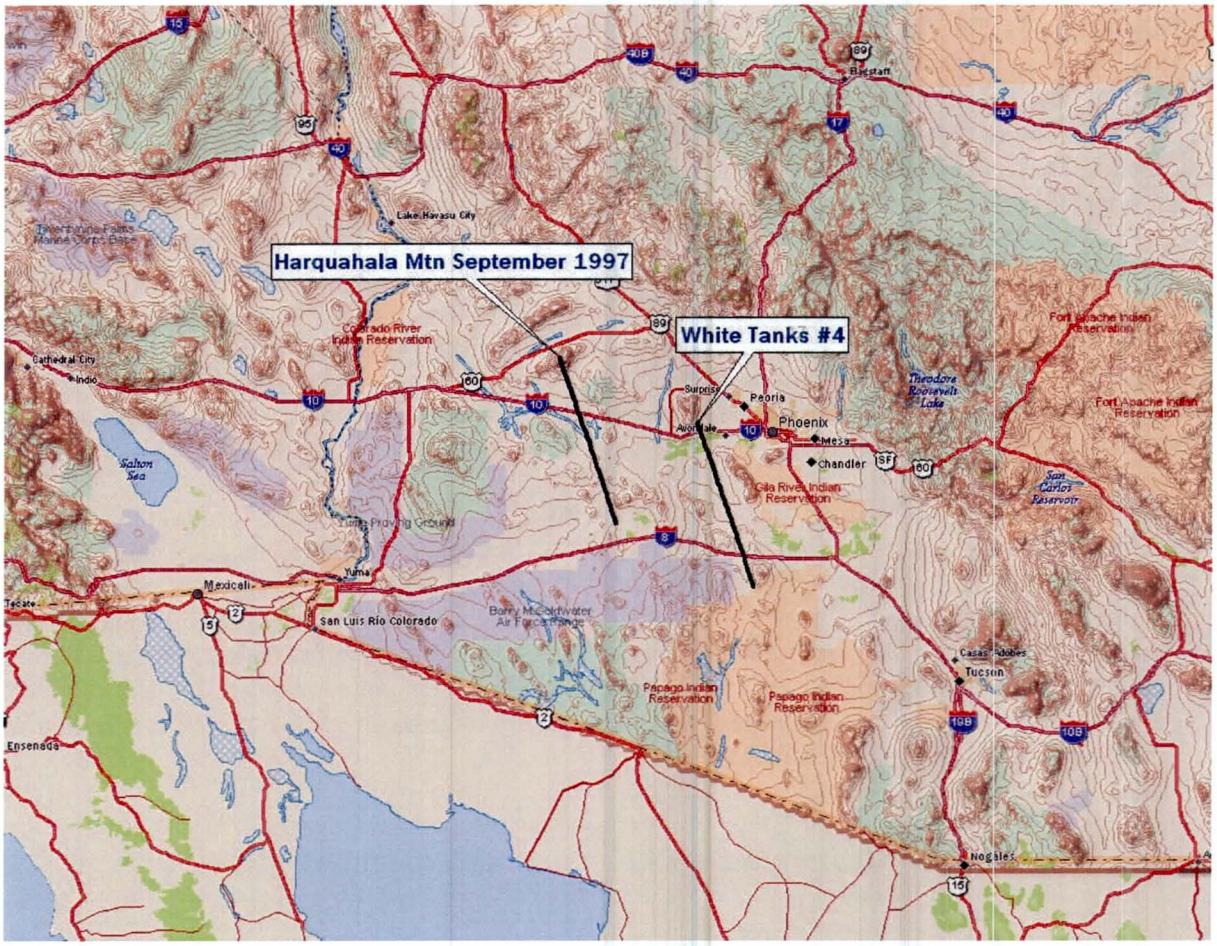



Figure 8.1 An example of inflow wind vector transpositioning for the Harquahala Mountain-Nora September 1997 storm. The storm representative dew point location is 60 miles south/southeast of the storm location.

# 9. Development of PMP Values from Adjusted Storm DADs

Storm maximization and transposition provide an indication of the maximum amount of precipitation that a particular storm could have produced over the White Tanks #4 drainage basin. Use of these values alone does not ensure that PMP values are provided for all area sizes and durations since some of the maximized and transpositioned values could be less than the PMP. By enveloping the rainfall amounts from all the major storms, rainfall values indicative of the PMP magnitude are produced (WMO, 1986).

Enveloping is a process for selecting the largest value from a set of data (see Glossary). This technique provides continuous smooth curves based on the largest precipitation values from the set of maximized and transposed storm rainfall values. The largest precipitation amounts provide guidance for drawing the curves.

During the enveloping process, values which are not consistent (are either high or low) are re-evaluated to insure reliability. High values are enveloped unless an explanation can be provided to justify undercutting the value. Low values are also re-evaluated for reliability and then enveloped to maintain consistency with surrounding values. This enveloping procedure addresses the possibility that for certain area sizes and durations, no significantly large storms have been observed that provide large enough values after being maximized and transposed to represent the PMP. The result of this procedure is a set of smooth curves that maintain continuity among temporal periods and areal sizes.

The envelopment process was used twice in PMP determination for this study. The first application was in determining the depth-area curves for each duration period. Curves for each storm were drawn using the adjusted storm values. An enveloping curve using all of the storm curves was drawn for each duration period. Although there were some situations that required enveloping, there were no cases that involved undercutting, primarily because the maximized and transposed data points were adequately consistent. The envelopment procedure was performed to provide smooth depth-area curves with continuity among area sizes. The curves were constructed in such a way to ensure that, for a given duration, the depth for any area did not exceed the depth for a smaller area.

The second application of the envelopment process was used in determining the depth-duration curves. Curves for each of the area sizes were constructed using results from the depth-area analysis. Enveloping curves were drawn to produce smooth curves that provide continuity in time.

The final set of curves defines PMP values for the site-specific study. The envelopment of the adjusted storms together with the curve smoothing process insured that all storm data were included and that the resulting set of PMP values provides rainfall values that are consistent spatially and temporally (see Appendix E for the full set of curves).

# 10. Results

## 10.1 Site-Specific PMP Values

This site-specific PMP study has produced PMP values for use in computing the PMF for the White Tanks #4 drainage basin. The site-specific values are listed below by storm type in Tables 10.1-10.3:

Table 10.1 Site-specific PMP values for local storms

| White Tanks #4 Site-Specific PMP Local Storm Values in Inches | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Area/Duration** | ***1-Hour*** | ***2-Hour*** | ***3-Hour*** | ***4-Hour*** | ***5-Hour*** | ***6-Hour*** |
| **AWA Local Storm PMP values** | 1 | 5.4 | 7.6 | 9.2 | 10.3 | 10.9 | 11.1 |
| | 10 | 4.9 | 6.9 | 8.5 | 9.9 | 10.6 | 10.7 |
| | 50 | 4.0 | 6.1 | 7.6 | 8.9 | 9.5 | 9.5 |
| | 100 | 3.5 | 5.7 | 7.0 | 8.2 | 8.8 | 8.8 |
| | 200 | 3.0 | 5.3 | 6.4 | 7.4 | 7.9 | 7.9 |
| | 500 | 2.4 | 4.5 | 5.4 | 6.1 | 6.6 | 6.6 |
| | 1000 | 1.9 | 3.6 | 4.3 | 4.8 | 5.2 | 5.4 |
| | 2000 | 1.4 | 2.8 | 3.4 | 3.8 | 4.1 | 4.3 |
| | 5000 | 0.8 | 1.5 | 1.9 | 2.2 | 2.4 | 2.6 |

Table 10.2 Site-specific PMP values for remnant tropical storms

| White Tanks #4 Site-Specific PMP Tropical Storm Values in Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Area/Duration** | ***1-Hour*** | ***6-Hour*** | ***12-Hour*** | ***24-Hour*** | ***36-Hour*** | ***48-Hour*** | ***72-Hour*** |
| **AWA Tropical Storm PMP values** | 1 | 5.2 | 8.5 | 13.1 | 16.0 | 16.1 | 16.1 | 16.1 |
| | 10 | 5.0 | 7.8 | 12.0 | 14.5 | 14.6 | 14.6 | 14.6 |
| | 50 | 3.9 | 6.2 | 9.1 | 11.2 | 11.4 | 11.6 | 12.2 |
| | 100 | 3.3 | 5.5 | 7.8 | 9.9 | 10.1 | 10.4 | 11.2 |
| | 200 | 2.7 | 4.8 | 6.7 | 8.6 | 9.0 | 9.5 | 10.5 |
| | 500 | 2.1 | 4.0 | 5.7 | 7.1 | 8.2 | 8.9 | 9.9 |
| | 1000 | 1.7 | 3.4 | 5.1 | 6.3 | 7.6 | 8.4 | 9.5 |
| | 2000 | 1.3 | 3.0 | 4.5 | 5.7 | 7.2 | 7.9 | 9.1 |
| | 5000 | 0.8 | 2.4 | 3.6 | 4.9 | 6.6 | 7.4 | 8.3 |
| | 10000 | 0.6 | 1.9 | 2.7 | 4.2 | 6.0 | 6.8 | 7.6 |

Table 10.3 Site-specific PMP values for general frontal storms

| White Tanks #4 Site-Specific PMP General Storm Values in Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Area/Duration** | ***1-Hour*** | ***6-Hour*** | ***12-Hour*** | ***24-Hour*** | ***36-Hour*** | ***48-Hour*** | ***72-Hour*** |
| **AWA General Storm PMP values** | 1 | 1.0 | 3.7 | 4.6 | 6.8 | 8.0 | 9.1 | 11.4 |
| | 10 | 1.0 | 3.6 | 4.5 | 6.7 | 7.8 | 9.0 | 11.3 |
| | 100 | 1.0 | 3.2 | 3.9 | 5.8 | 6.4 | 7.2 | 9.3 |
| | 200 | 0.9 | 3.0 | 3.7 | 5.5 | 6.0 | 6.6 | 8.4 |
| | 500 | 0.8 | 2.8 | 3.5 | 5.0 | 5.5 | 5.9 | 7.2 |
| | 1000 | 0.8 | 2.5 | 3.3 | 4.5 | 5.0 | 5.4 | 6.2 |
| | 2000 | 0.8 | 2.2 | 3.0 | 4.0 | 4.3 | 4.9 | 5.4 |
| | 5000 | 0.6 | 1.8 | 2.6 | 3.3 | 3.5 | 4.0 | 4.4 |
| | 10000 | 0.5 | 1.6 | 2.2 | 2.8 | 2.8 | 3.2 | 3.7 |
| | 20000 | 0.4 | 1.4 | 1.8 | 2.3 | 2.2 | 2.5 | 2.7 |

## 10.2 Comparison of the Site-Specific PMP Values with 24-Hour 100-Year Rainfall Values

PMP values were compared with 100-year rainfall values as a general check for reasonableness. The ratio of the 1-square mile 24-hour PMP to 24-hour 100-year return period rainfall amounts is generally expected to range between two and four, with values as low as 1.7 and as high as 5.5 found in HMRs 57 and 59 (Hansen et al. 1977; Reidel and Schreiner 1980, Hansen et al. 1988, Hansen et al. 1994). Further, as stated in HMR 59 "*...the comparison indicates that larger ratios are in lower elevations where short-duration, convective precipitation dominates, and smaller ratios in higher elevations where general storm, long duration precipitation is prevalent*" (Corrigan 1999). Therefore, it would be reasonable to expect the ratios for White Tanks #4 to be in the higher end of the range. The 100-year 24-hour return frequency rainfall values were derived from NOAA Atlas 14 for the White Tanks basin. Comparisons of the 1-square mile, 1-hour value for local convective PMP and the 10-square mile 24-hour value for remnant tropical/general frontal PMP to the 100-year 10-square mile, 24-hour rainfall return frequency values were made (Tables 10.4a and b).

Comparison of PMP values with rainfall frequencies is generally made for point locations, i.e., individual locations. Sufficient data are not available to make the comparison at other area sizes. For example, comparison for the 20-square mile area size would be more useful for this study, but return frequency statistics are not available for spatial scales larger than point locations.

Data from NOAA Atlas 14 found on the NOAA's Hydrometeorological Design Center web interface for Arizona (http://hdsc.nws.noaa.gov/hdsc/pfds/sa/az_pfds.html) were used to determine 100-year return frequency value for the White Tanks #4 basin, 33.55447°N latitude and 112.5511°W longitude. The site-specific 1-square mile, 1-hour and 10-square mile 24-hour PMP values were divided by the appropriate 100-year 24-hour values. The ratio from NOAA Atlas 14 for 1-square mile at 1-hour is 2.4 and for 10-square miles at 24-hours is 3.4.

Table 10.4a Comparison of Site-Specific PMP with 1-hour 100-Year Rainfall Frequency

| | |
|---|---|
| 1-square mile 1-hour PMP: | 5.4 inches |
| NOAA Atlas 14 100-year 1-hour 1-square mile rainfall: | 2.26 inches |
| Ratio of PMP to the 100-year rainfall: | 2.4 |

Table 10.4b Comparison of Site-Specific PMP with 24-hour 100-Year Rainfall Frequency

| | |
|---|---|
| 10-square mile 24-hour PMP: | 14.5 inches |
| NOAA Atlas 14 100-year 1-hour 1-square mile rainfall: | 4.24 inches |
| Ratio of PMP to the 100-year rainfall: | 3.4 |

## 10.3 Comparison of the Site-Specific PMP Values by Storm Type and Duration

This site-specific PMP study provided PMP values for durations from 1-hour through 72-hours and area sizes from 1-square mile to 20,000-square miles. However, for the White Tanks #4 drainage basin, values for the 20-square mile area size are most relevant. Table 10.5 shows the values for each storm type and provides a comparison between each storm type to determine which type of storm is most important for producing PMP at each durational increment.

Table 10.5 Comparison of the White Tanks #4 drainage basin site-specific PMP values at the 20-square mile area size for each storm type by duration

| Storm Duration | AWA Local Storm PMP Values 20sqmi | AWA Tropical Storm PMP Values 20sqmi | AWA General Storm PMP Values 20sqmi |
|---|---|---|---|
| 1 Hour | 4.5 | 4.5 | 1.0 |
| 2 Hours | 6.6 | | |
| 3 Hours | 8.1 | | |
| 4 Hours | 9.4 | | |
| 5 Hours | 10.2 | | |
| 6 Hours | 10.3 | 7.1 | 3.4 |
| 12 Hours | | 10.8 | 4.3 |
| 24 Hours | | 13.0 | 6.3 |
| 36 Hours | | 13.1 | 7.3 |
| 48 Hours | | 13.2 | 8.3 |
| 72 Hours | | 13.5 | 10.8 |

# 11. Sensitivity Analysis

In the process of deriving site-specific PMP values, various assumptions were made and explicit procedures were adopted for use. Additionally, various parameters and derived values are used in the calculations. It is of interest to assess the sensitivity of PMP values to assumptions that were made and to the variability of parameter values.

## 11.1 Assumptions

### 11.1.1 Saturated Storm Atmospheres

The atmospheric air masses that provide available moisture to both the historic storm and the PMP storm are assumed to be saturated through the entire depth of the atmosphere and to contain the maximum moisture possible based on the surface dew point. This assumes moist pseudo-adiabatic temperature profiles for both the historic storm and the PMP storm. Limited evaluation of this assumption in the EPRI Michigan/Wisconsin PMP study and the Blenheim Gilboa study indicated that historic storm atmospheric profiles are generally not entirely saturated and contain somewhat less precipitable water than is assumed in the PMP procedure. It follows that the PMP storm (if it were to occur) would also have somewhat less precipitable water available than the assumed saturated PMP atmosphere would contain. What is used in the PMP procedure is the *ratio* of precipitable water associated with each storm. If the precipitable water values for each storm are both slightly overestimated, the ratio of these values will be essentially unchanged. For example, consider the case where instead of a historic storm with a storm representative dew point of 70° F degrees having 2.25 inches of precipitable water assuming a saturated atmosphere, it actually had 90% of that value or about 2.02 inches. The PMP procedure assumes the same type of storm with similar atmospheric characteristics for the maximized storm but with a higher dew point, say 76° F degrees. The maximized storm, having similar atmospheric conditions, would have about 2.69 inches of precipitable water instead of the 2.99 inches associated with a saturated atmosphere with a dew point of 76° F degrees. The maximization factor computed using the assumed saturated atmospheric values would be 2.99/2.25 = 1.33. If both storms were about 90% saturated instead, the maximization factor would be 2.69/2.02 = 1.33. Therefore potential inaccuracy of assuming saturated atmospheres (whereas the atmospheres may be somewhat less than saturated) should have a minimal impact on storm maximization and subsequent PMP calculations.

### 11.1.2 Maximum Storm Efficiency

The assumption is made that if a sufficient period of record is available for rainfall observations, at least a few storms would have been observed that attained or came close to attaining the maximum efficiency possible in nature for converting atmospheric moisture to rainfall for regions with similar climates and topography. The further assumption is made that if additional atmospheric moisture had been available, the storm would have maintained the same efficiency for converting atmospheric moisture to rainfall. The ratio of the maximized rainfall

amounts to the actual rainfall amounts would be the same as the ratio of the precipitable water in the atmospheres associated with each storm.

There are two issues to be considered. First is the assumption that a storm has occurred that has a rainfall efficiency close to the maximum possible. Unfortunately, state-of-the-science in meteorology does not support a theoretical evaluation of storm efficiency. However, if the period of record is considered (generally over 100 years), along with the extended geographic region with transpositionable storms, it is accepted that there should have been at least one storm with dynamics that approach the maximum efficiency for rainfall production.

The other issue is the assumption that storm efficiency does not change if additional atmospheric moisture is available. Storm dynamics could potentially become more efficient or possibly less efficient depending on the interaction of cloud microphysical processes with the storm dynamics. Offsetting effects could indeed lead to the storm efficiency remaining essentially unchanged. For the present, the assumption of no change in storm efficiency is accepted.

## 11.2 Parameters

### 11.2.1 Storm Representative Dew Point and Maximum Dew Point, and Storm Representative SST and 2-sigma SST

This discussion applied to both dew points and SSTs although only dew points will be addressed. SSTs are used as substitutes for dew points for all storms in this study for inflow vectors that originate over ocean regions and have the same sensitivity considerations.

The maximization factor depends on the determination of storm representative dew points, along with maximum historical dew point values. The magnitude of the maximization factor varies depending on the values used for the storm representative dew point and the maximum dew point. Holding all other variables constant, the maximization factor is smaller for higher storm representative dew points as well as for lower maximum dew point values. Likewise, larger maximization factors result from the use of lower storm representative dew points and/or higher maximum dew points. The magnitude of the change in the maximization factor varies depending on the dew point values. For the range of dew point values used in most PMP studies, the maximization factor for a particular storm will change about 5% for every $1^{\circ}$ F difference between the storm representative and maximum dew point values. The same sensitivity applies to the transposition factor, with about a 5% change for every $1^{\circ}$ F change in either the in-place maximum dew point or the transposition maximum dew point.

For example, consider the following case:

| | | | |
|---|---|---|---|
| Storm representative dew point: | 75 ° F | Precipitable water: | 2.85 " |
| Maximum dew point: | 79 ° F | Precipitable water: | 3.44" |

Maximization factor = 3.44"/2.85" = 1.21

If the storm representative dew point were 74 ° F with precipitable water of 2.73",
Maximization factor = 3.44"/2.73" = 1.26 (an increase of approximately 4%)

If the maximum dew point were 78 ° F with precipitable water of 3.29",
Maximization factor = 3.29"/2.85" = 1.15 (a decrease of approximately 5%)

### 11.2.2 Sensitivity of the Elevation Adjustment Factor to Changes in Storm Elevation

Elevated topographic features remove atmospheric moisture from an air mass as it moves over the terrain. When storms are transpositioned, the elevation of the original storm is used in this study to compute the amount of atmospheric moisture depleted from or added to the storm atmosphere. The absolute amount of moisture depletion or addition is somewhat dependent on the dew point values, but is primarily dependent on the elevation at the original storm location and the elevation of the study basin. The elevation adjustment is slightly less than 1% for every 100 feet of elevation change between the original storm location and the study basin elevation.

For example, consider the following case:

| | |
|---|---|
| Maximum dew point: | 79 ° F |
| Study basin elevation: | 100 feet |
| Historic storm location elevation: | 500 feet |
| Precipitable water between 1000-mb and the top of the atmosphere: | 3.44 inches |
| Precipitable water between 1000-mb and 100': | 0.03 inches |
| Precipitable water between 1000-mb and 500': | 0.15 inches |

Elevation Adjustment Factor = (3.44"-0.03")/(3.44-0.15") = 1.04 (about 1% per 100 feet)

If the historic storm location elevation were 1,000', the precipitable water between 1000mb and 1,000' is 0.28"
Elevation Adjustment Factor = (3.44"-0.03")/(3.44"-0.28") = 1.08 (about 1% per 100 feet)

# 12. Recommendations for Application

## 12.1 Site-Specific PMP Applications

Site-specific PMP values have been computed that provide rainfall amounts for use in computing the Probable Maximum Flood (PMF). The study addressed several issues that could potentially affect the magnitude of the PMP storm over the White Tanks #4 drainage basin.

The storm search and selection of storms to be analyze emphasized storms with the largest rainfall values that occurred over areas that are both meteorologically and topographically similar to the White Tanks #4 drainage basin. Each storm type that occurs over the region was analyzed. This included local convective, remnant tropical, and general frontal storms. Results of this study should not be used for watersheds where meteorological and/or topographical parameters are different from the White Tanks #4 drainage basin without further evaluation.

## 12.2 Temporal Distribution of precipitation for Local, Tropical, and General Storms

Understanding and quantifying how rainfall associated with the PMP storm would fall temporally is very important to the modeling of the PMF. To determine the temporal distribution of rainfall, storms that were used to derive PMP for White Tanks #4 were analyzed. Storms were grouped by type; local, tropical, and general. Local storms were analyzed from 1-6 hours, with an additional analysis completed for sub-hourly intervals (15-minutes for the first hour). Tropical and general storms were analyzed on an hourly basis from 1 through 72 hours.

A total of thirty-two SPAS storms were used for temporal distribution analysis, including 16–local, 7-tropical, and 9-general. The location of the storm center, for each storm analysis, was used for the temporal distribution calculations. A script was written to determine the maximum precipitation accumulations for the duration of interest (6-hr, 24-hr, and 72-hr) and the average for each hour analyzed. The initial analysis for the 1 through 6 hour local storm analysis (the most relevant for PMP at White Tanks #4) included normalizing the data to the PMP values for the basin. This was accomplished by dividing the adjusted 1 hour amount for each storm into the 6 hour PMP value for the basin the multiplying this value by the 1 hour adjusted value of the particular storm by its adjusted 6 hour value. From this a set of curves was derived for each storm for 1 through 6 hours that represents each storm's percent of rainfall compared to PMP at that particular hour. This set of curves was then enveloped to produce a storm based temporal distribution for local storm from 1 through 6 hours using two different distributions (Table 12.1). One was for a front loaded storm where all the precipitation falls within the first 3-hours of the 6-hour storm and one where the precipitation falls over a 5-hour period (following the Queen Creek depth-are analysis). AWA also analyzed the 1 through 6-hour data using 15-minute increments to determine if this would more accurately represent the temporal patterns of the local storm rainfall as it accumulates from hours 1 through 6. The results of this analysis showed no

significant improvement over using a linear interpolation between each of the hours 1 through 6 for the local storm temporal analysis and therefore were not included.

Table 12.1 Timing of 1 through 6-hour local storm data in 1-hour sequential increments, a) shows the front loaded 6-hour storm distribution and b) shows the 6-hour storm distribution related to the Queen Creek storm distribution

**Sequential Hourly Timing-Front Loaded**

| *1 Hour* | *2 Hours* | *3 Hours* | *4 Hours* | *5 Hours* | *6 Hours* |
|---|---|---|---|---|---|
| **40%** | **60%** | **85%** | **100%** | **100%** | **100%** |

**Sequential Hourly Timing-Queen Creek**

| *1 Hour* | *2 Hours* | *3 Hours* | *4 Hours* | *5 Hours* | *6 Hours* |
|---|---|---|---|---|---|
| **15%** | **30%** | **60%** | **80%** | **100%** | **100%** |

These data were then broken down into sub-hourly percentages for the first hour only. The data (0 miinutes-60 minutes) was evaluated in 15-minute increments, with results showing the percentage of rainfall at each 15-minute interval out of total amount for the 1-hour period. The accumulations were converted into a ratio of the cumulative precipitation to the maximum accumulated precipitation for that duration, and a ratio of the cumulative time to the total time (Figure 12.2). This same analysis was completed using a 5-minute incremental window as well. However, this showed no improvement over the 15-minute increments and therefore was not included in this report. For sub-hourly data, gridded precipitation data were used that incorporated NEXRAD radar data (7 storm events). Again, two distributions are given, one representing a front loaded storm where all the rainfall for the 1-hour period falls within the first 45 minutes and the second distribution which shows a more constant set of values for each15-minute increment (this was the average of the 7 events).

Table 12.2 Timing of sub-hourly rainfall in 15-minute sequential increments, a) is the front loaded distribution and b) is the average distribution

**Sub-Hourly Timing First Hour Only-Front Loaded**

| *15 Minutes* | *30 Minutes* | *45 Minutes* | *1 Hour* |
|---|---|---|---|
| **61%** | **98%** | **100%** | **100%** |

**Sub-Hourly Timing First Hour Only-Average**

| *15 Minutes* | *30 Minutes* | *45 Minutes* | *1 Hour* |
|---|---|---|---|
| **30%** | **59%** | **82%** | **100%** |

For the hourly analysis of the tropical and general storms, gridded precipitation data were used for all SPAS storms (16 total storms). The maximum precipitation accumulations per duration were based on gridded precipitation at the storm center. Each of the storms was analyzed by hour as a percentage of the total storm amount for both the 24-hour and 72-hour durations to equal 100%. The data represent a sequential hourly temporal distribution starting at hour 1 and ending at hour 24 or 72 (Figures 12.3-12.6).

Table 12.3 Timing of 1- through 24-hour tropical storm data in sequential 1-hour increments, a) is a front loaded event, b) is a middle loaded event, and c) is back loaded

**Sequential Hourly Timing-Front Loaded**

| 1 Hour | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 7 Hours | 8 Hours | 9 Hours | 10 Hours | 11 Hours | 12 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 3% | 5% | 7% | 9% | 14% | 22% | 53% | 69% | 75% | 79% | 81% |
| **13 Hours** | **14 Hours** | **15 Hours** | **16 Hours** | **17 Hours** | **18 Hours** | **19 Hours** | **20 Hours** | **21 Hours** | **22 Hours** | **23 Hours** | **24 Hours** |
| 83% | 85% | 86% | 87% | 88% | 90% | 91% | 92% | 93% | 95% | 98% | 100% |

**Sequential Hourly Timing-Middle Loaded**

| 1 Hour | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 7 Hours | 8 Hours | 9 Hours | 10 Hours | 11 Hours | 12 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0% | 0% | 0% | 0% | 1% | 4% | 9% | 18% | 26% | 37% | 47% |
| **13 Hours** | **14 Hours** | **15 Hours** | **16 Hours** | **17 Hours** | **18 Hours** | **19 Hours** | **20 Hours** | **21 Hours** | **22 Hours** | **23 Hours** | **24 Hours** |
| 56% | 62% | 69% | 76% | 83% | 86% | 88% | 91% | 96% | 99% | 100% | 100% |

**Sequential Hourly Timing-Back Loaded**

| 1 Hour | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 7 Hours | 8 Hours | 9 Hours | 10 Hours | 11 Hours | 12 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0% | 0% | 0% | 0% | 0% | 1% | 2% | 4% | 6% | 8% | 14% |
| **13 Hours** | **14 Hours** | **15 Hours** | **16 Hours** | **17 Hours** | **18 Hours** | **19 Hours** | **20 Hours** | **21 Hours** | **22 Hours** | **23 Hours** | **24 Hours** |
| 25% | 50% | 59% | 68% | 86% | 91% | 95% | 98% | 99% | 99% | 99% | 100% |

Table 12.4 Timing of 1- through 72-hour tropical storm data in sequential 1-hour increments, a) shows the 72-hour storm distribution where the rainfall accumulates in a nearly linear fashion throughout and b) shows the 72-hour storm distribution where the rainfall is back loaded, with most of the rainfall accumulating in the final 24-hours

**Sequential Hourly Timing-Average**

| 1 Hour | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 7 Hours | 8 Hours | 9 Hours | 10 Hours | 11 Hours | 12 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0% | 0% | 1% | 2% | 4% | 7% | 10% | 12% | 15% | 17% | 19% |
| 13 Hours | 14 Hours | 15 Hours | 16 Hours | 17 Hours | 18 Hours | 19 Hours | 20 Hours | 21 Hours | 22 Hours | 23 Hours | 24 Hours |
| 21% | 23% | 25% | 26% | 27% | 28% | 29% | 30% | 31% | 32% | 33% | 34% |
| 25 Hours | 26 Hours | 27 Hours | 28 Hours | 29 Hours | 30 Hours | 31 Hours | 32 Hours | 33 Hours | 34 Hours | 35 Hours | 36 Hours |
| 35% | 36% | 38% | 40% | 42% | 44% | 46% | 48% | 50% | 51% | 52% | 53% |
| 37 Hours | 38 Hours | 39 Hours | 40 Hours | 41 Hours | 42 Hours | 43 Hours | 44 Hours | 45 Hours | 46 Hours | 47 Hours | 48 Hours |
| 54% | 56% | 58% | 60% | 61% | 62% | 63% | 63% | 63% | 64% | 65% | 66% |
| 49 Hours | 50 Hours | 51 Hours | 52 Hours | 53 Hours | 54 Hours | 55 Hours | 56 Hours | 57 Hours | 58 Hours | 59 Hours | 60 Hours |
| 67% | 68% | 69% | 70% | 71% | 72% | 73% | 75% | 78% | 82% | 86% | 92% |
| 61 Hours | 62 Hours | 63 Hours | 64 Hours | 65 Hours | 66 Hours | 67 Hours | 68 Hours | 69 Hours | 70 Hours | 71 Hours | 72 Hours |
| 96% | 98% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

**Sequential Hourly Timing-Back Loaded**

| 1 Hour | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 7 Hours | 8 Hours | 9 Hours | 10 Hours | 11 Hours | 12 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0% | 1% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 3% |
| 13 Hours | 14 Hours | 15 Hours | 16 Hours | 17 Hours | 18 Hours | 19 Hours | 20 Hours | 21 Hours | 22 Hours | 23 Hours | 24 Hours |
| 4% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 6% | 6% | 6% | 6% |
| 25 Hours | 26 Hours | 27 Hours | 28 Hours | 29 Hours | 30 Hours | 31 Hours | 32 Hours | 33 Hours | 34 Hours | 35 Hours | 36 Hours |
| 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% |
| 37 Hours | 38 Hours | 39 Hours | 40 Hours | 41 Hours | 42 Hours | 43 Hours | 44 Hours | 45 Hours | 46 Hours | 47 Hours | 48 Hours |
| 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 8% |
| 49 Hours | 50 Hours | 51 Hours | 52 Hours | 53 Hours | 54 Hours | 55 Hours | 56 Hours | 57 Hours | 58 Hours | 59 Hours | 60 Hours |
| 12% | 15% | 21% | 26% | 30% | 34% | 40% | 45% | 51% | 62% | 68% | 76% |
| 61 Hours | 62 Hours | 63 Hours | 64 Hours | 65 Hours | 66 Hours | 67 Hours | 68 Hours | 69 Hours | 70 Hours | 71 Hours | 72 Hours |
| 82% | 92% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

Table 12.5 Timing of 1- through 24-hour general storm data in sequential 1-hour increments, a) is a middle loaded event, b) is a nearly constant rainfall over the 24-hour period

**Sequential Hourly Timing-Middle Loaded**

| *1 Hour* | *2 Hours* | *3 Hours* | *4 Hours* | *5 Hours* | *6 Hours* | *7 Hours* | *8 Hours* | *9 Hours* | *10 Hours* | *11 Hours* | *12 Hours* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1% | 1% | 7% | 16% | 30% | 42% | 55% | 68% | 78% | 83% | 86% | 89% |
| *13 Hours* | *14 Hours* | *15 Hours* | *16 Hours* | *17 Hours* | *18 Hours* | *19 Hours* | *20 Hours* | *21 Hours* | *22 Hours* | *23 Hours* | *24 Hours* |
| 93% | 96% | 97% | 97% | 97% | 97% | 98% | 98% | 99% | 99% | 100% | 100% |

**Sequential Hourly Timing-Average**

| *1 Hour* | *2 Hours* | *3 Hours* | *4 Hours* | *5 Hours* | *6 Hours* | *7 Hours* | *8 Hours* | *9 Hours* | *10 Hours* | *11 Hours* | *12 Hours* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1% | 1% | 7% | 16% | 32% | 42% | 55% | 68% | 78% | 83% | 86% | 89% |
| *13 Hours* | *14 Hours* | *15 Hours* | *16 Hours* | *17 Hours* | *18 Hours* | *19 Hours* | *20 Hours* | *21 Hours* | *22 Hours* | *23 Hours* | *24 Hours* |
| 93% | 96% | 96% | 97% | 97% | 97% | 98% | 98% | 99% | 99% | 100% | 100% |

Table 12.6 Timing of 1- through 72-hour general storm data in sequential 1-hour increments, a) shows the 72-hour storm distribution where the rainfall accumulates in a front loaded storm b) shows the 72-hour storm distribution where the rainfall is middle loaded

**Sequential Hourly Timing-Front Loaded**

| 1 Hour | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 7 Hours | 8 Hours | 9 Hours | 10 Hours | 11 Hours | 12 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0% | 0% | 2% | 3% | 5% | 7% | 9% | 11% | 13% | 14% | 15% |
| 13 Hours | 14 Hours | 15 Hours | 16 Hours | 17 Hours | 18 Hours | 19 Hours | 20 Hours | 21 Hours | 22 Hours | 23 Hours | 24 Hours |
| 16% | 17% | 18% | 20% | 22% | 24% | 26% | 27% | 28% | 29% | 31% | 33% |
| 25 Hours | 26 Hours | 27 Hours | 28 Hours | 29 Hours | 30 Hours | 31 Hours | 32 Hours | 33 Hours | 34 Hours | 35 Hours | 36 Hours |
| 36% | 39% | 42% | 45% | 49% | 53% | 58% | 64% | 69% | 74% | 81% | 86% |
| 37 Hours | 38 Hours | 39 Hours | 40 Hours | 41 Hours | 42 Hours | 43 Hours | 44 Hours | 45 Hours | 46 Hours | 47 Hours | 48 Hours |
| 92% | 94% | 95% | 96% | 97% | 97% | 97% | 97% | 97% | 97% | 97% | 97% |
| 49 Hours | 50 Hours | 51 Hours | 52 Hours | 53 Hours | 54 Hours | 55 Hours | 56 Hours | 57 Hours | 58 Hours | 59 Hours | 60 Hours |
| 97% | 97% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% |
| 61 Hours | 62 Hours | 63 Hours | 64 Hours | 65 Hours | 66 Hours | 67 Hours | 68 Hours | 69 Hours | 70 Hours | 71 Hours | 72 Hours |
| 99% | 99% | 99% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

**Sequential Hourly Timing-Middle Loaded**

| 1 Hour | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 7 Hours | 8 Hours | 9 Hours | 10 Hours | 11 Hours | 12 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% |
| 13 Hours | 14 Hours | 15 Hours | 16 Hours | 17 Hours | 18 Hours | 19 Hours | 20 Hours | 21 Hours | 22 Hours | 23 Hours | 24 Hours |
| 3% | 4% | 4% | 4% | 4% | 5% | 5% | 5% | 6% | 6% | 6% | 7% |
| 25 Hours | 26 Hours | 27 Hours | 28 Hours | 29 Hours | 30 Hours | 31 Hours | 32 Hours | 33 Hours | 34 Hours | 35 Hours | 36 Hours |
| 8% | 9% | 10% | 11% | 13% | 15% | 16% | 18% | 20% | 22% | 26% | 30% |
| 37 Hours | 38 Hours | 39 Hours | 40 Hours | 41 Hours | 42 Hours | 43 Hours | 44 Hours | 45 Hours | 46 Hours | 47 Hours | 48 Hours |
| 37% | 44% | 50% | 55% | 60% | 65% | 70% | 75% | 79% | 82% | 85% | 89% |
| 49 Hours | 50 Hours | 51 Hours | 52 Hours | 53 Hours | 54 Hours | 55 Hours | 56 Hours | 57 Hours | 58 Hours | 59 Hours | 60 Hours |
| 93% | 95% | 97% | 99% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% |
| 61 Hours | 62 Hours | 63 Hours | 64 Hours | 65 Hours | 66 Hours | 67 Hours | 68 Hours | 69 Hours | 70 Hours | 71 Hours | 72 Hours |
| 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

## 12.3 Climate Change Assumptions

Climate change has occurred in the past, is now occurring, and undoubtedly will continue in the future. This is and has always been a natural part of Earth's cycles. How the climate will change and how this will affect the number and intensity of extreme rainfall events over the basin is unknown as of the date of this report.

With a warming of the atmosphere, there can potentially be an increase in the available atmospheric moisture for storms to convert to rainfall. However, storm dynamics play a significant role in that conversion process and the result of a warming or cooling climate on storm dynamics is not well understood. A warmer or cooler climate may lead to a change in the frequency of storms and/or a change in the intensity of storms, but there is no definitive evidence to indicate the trend or the magnitude of potential changes (Taylor 2008).

AWA recognizes that the climate is in a constant state of change. However, the current scientific consensus and understanding cannot agree how climate is changing and more importantly what those changes will be for the region (www.icecap.us). Therefore, one cannot say whether White Tanks #4 will be wetter or drier, warmer or colder and/or experience more or less extreme precipitation events with any quantitative and statistically significant certainty. Further, most projects of this type have a projected life between 50 to 100 years before they are redeveloped. In general, most projected changes that *may* occur within the Earth's climate system would be unlikely to significantly affect the project's hydrology beyond the bounds of the PMP values derived as part of this project during its useful life. Based on these discussions, it is apparent that the current practice of PMP determination should *not* be modified in an attempt to address potential changes associated with climate change. This study has continued the practice of assuming no climate change, as climate trends are not considered when preparing PMP estimates (WMO, Section 1.1.1).

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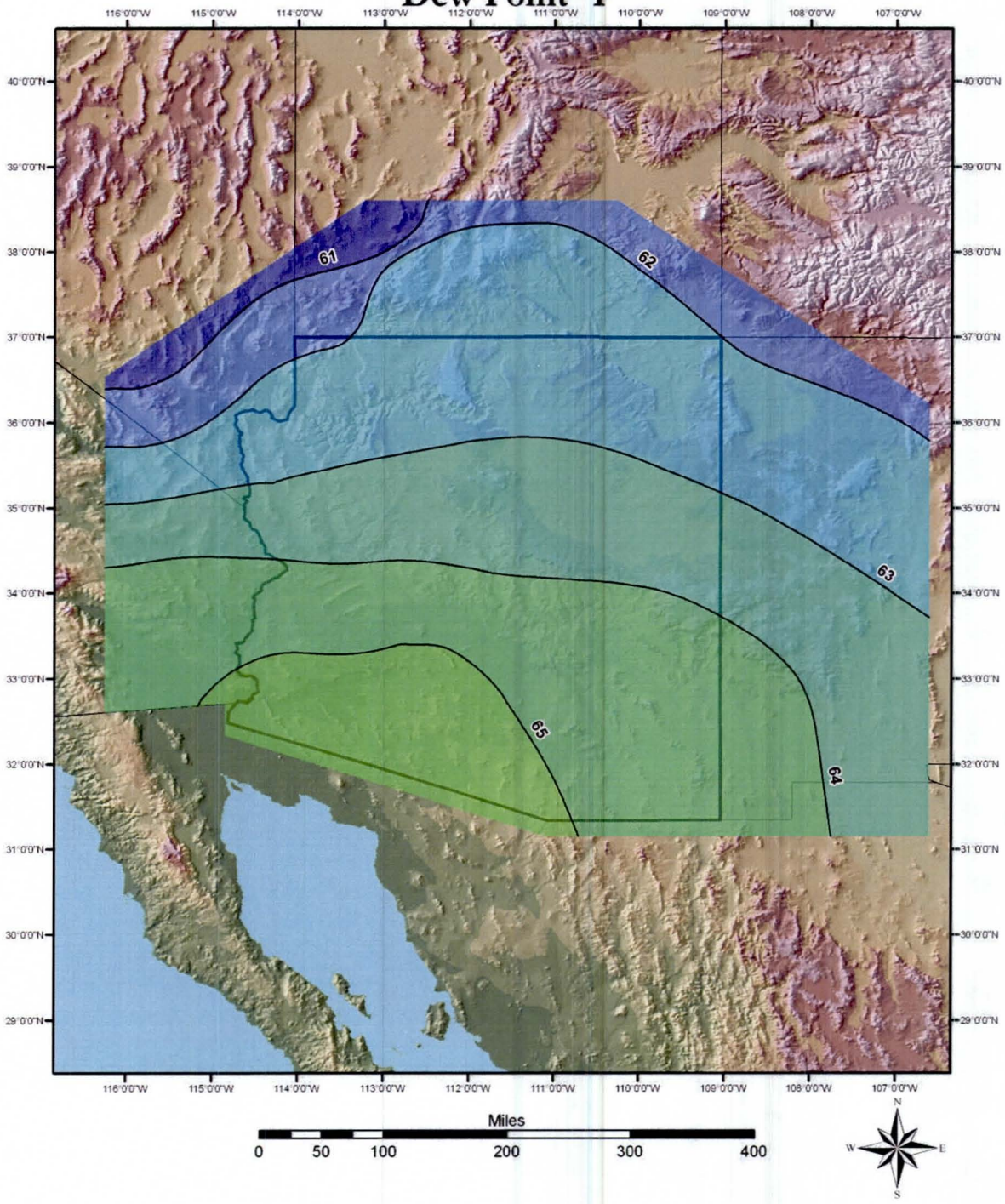
# Appendix A

# Average Dew Point Maps for 3-hour, 12-hour, 24-hour 100-year Return Frequencies

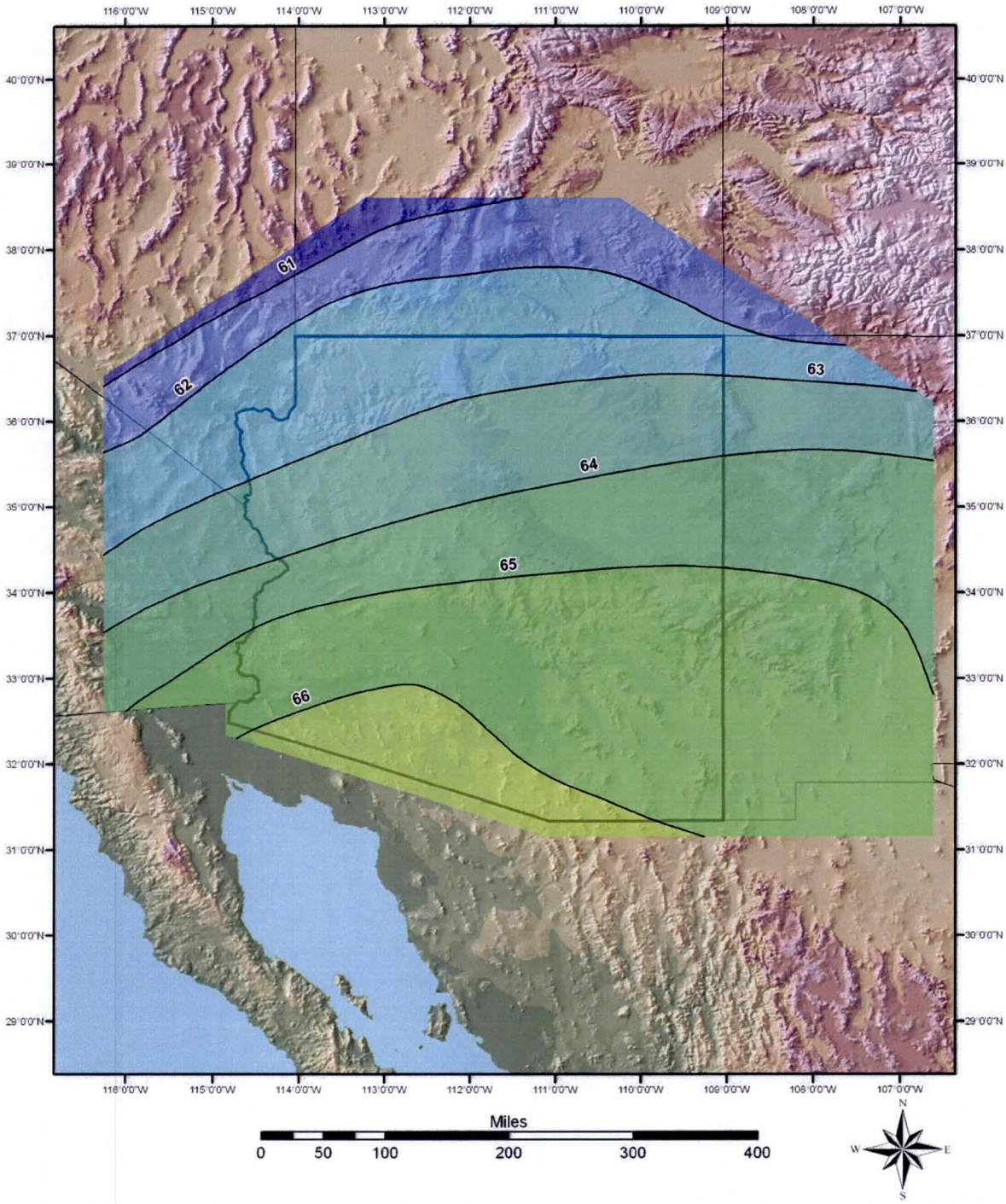
# And

# Plus 2 sigma Sea Surface Temperatures Maps

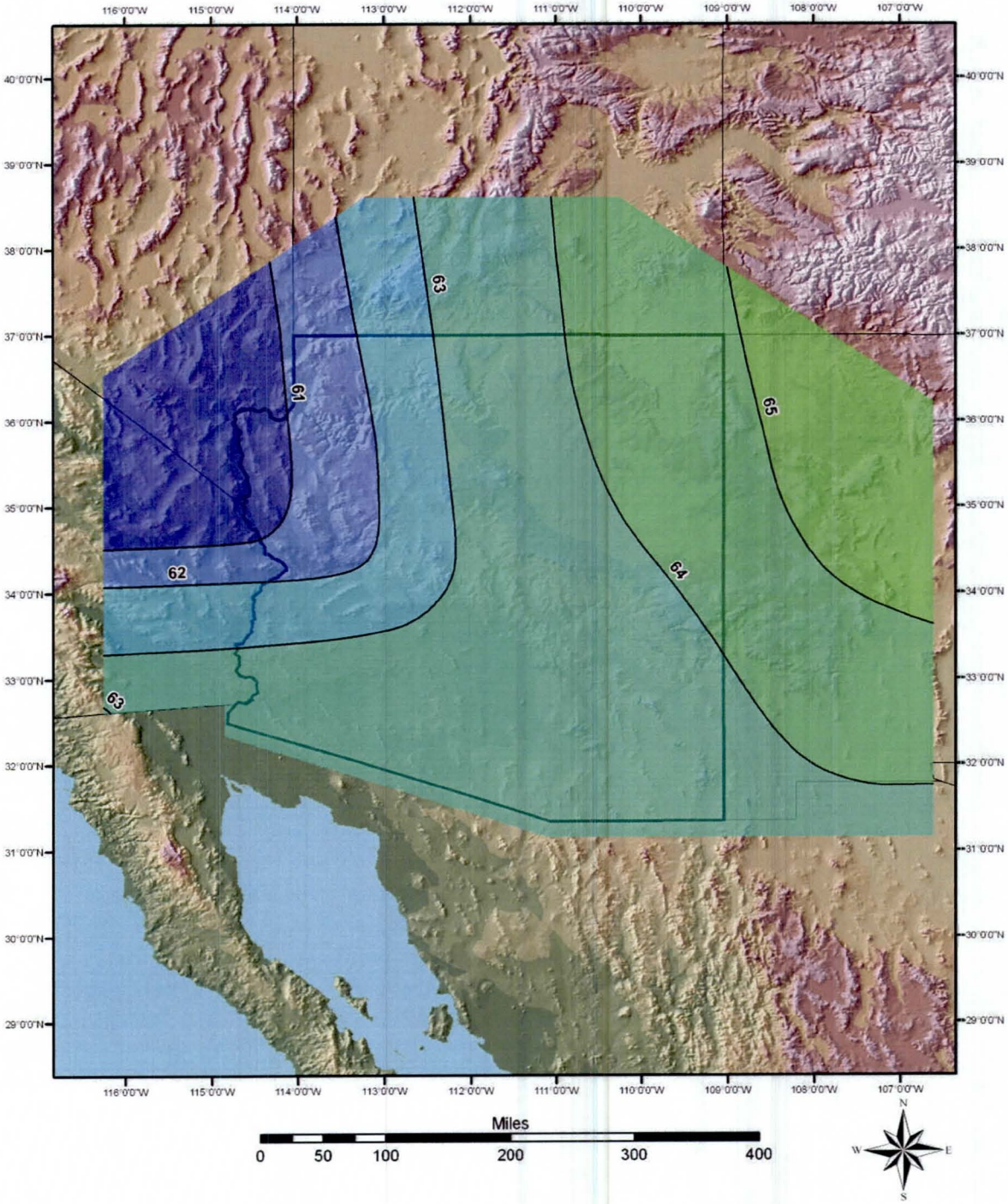
# January 3-Hour 100-Year Dew Point °F



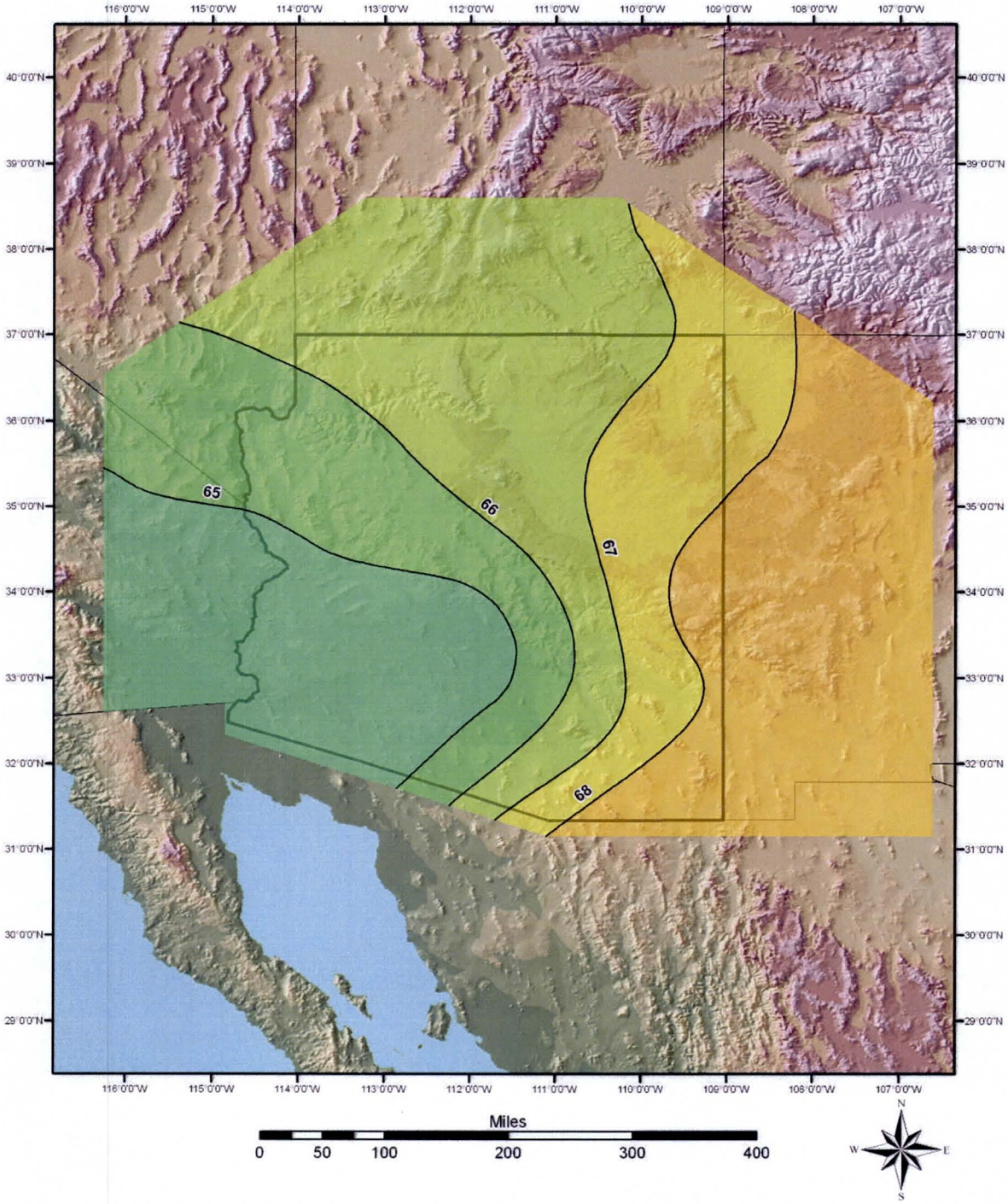
# February 3-Hour 100-Year
# Dew Point °F



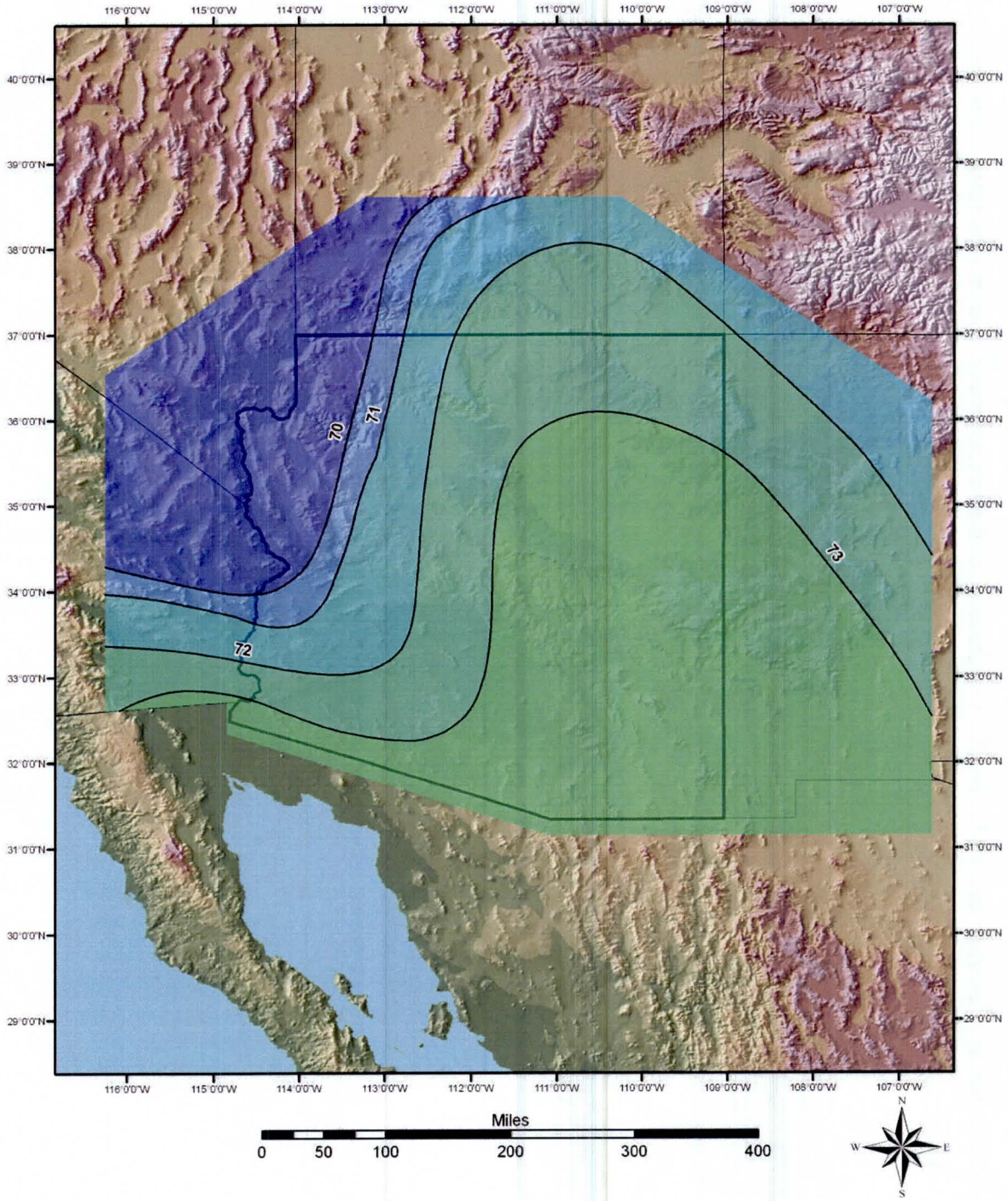
# March 3-Hour 100-Year
# Dew Point °F



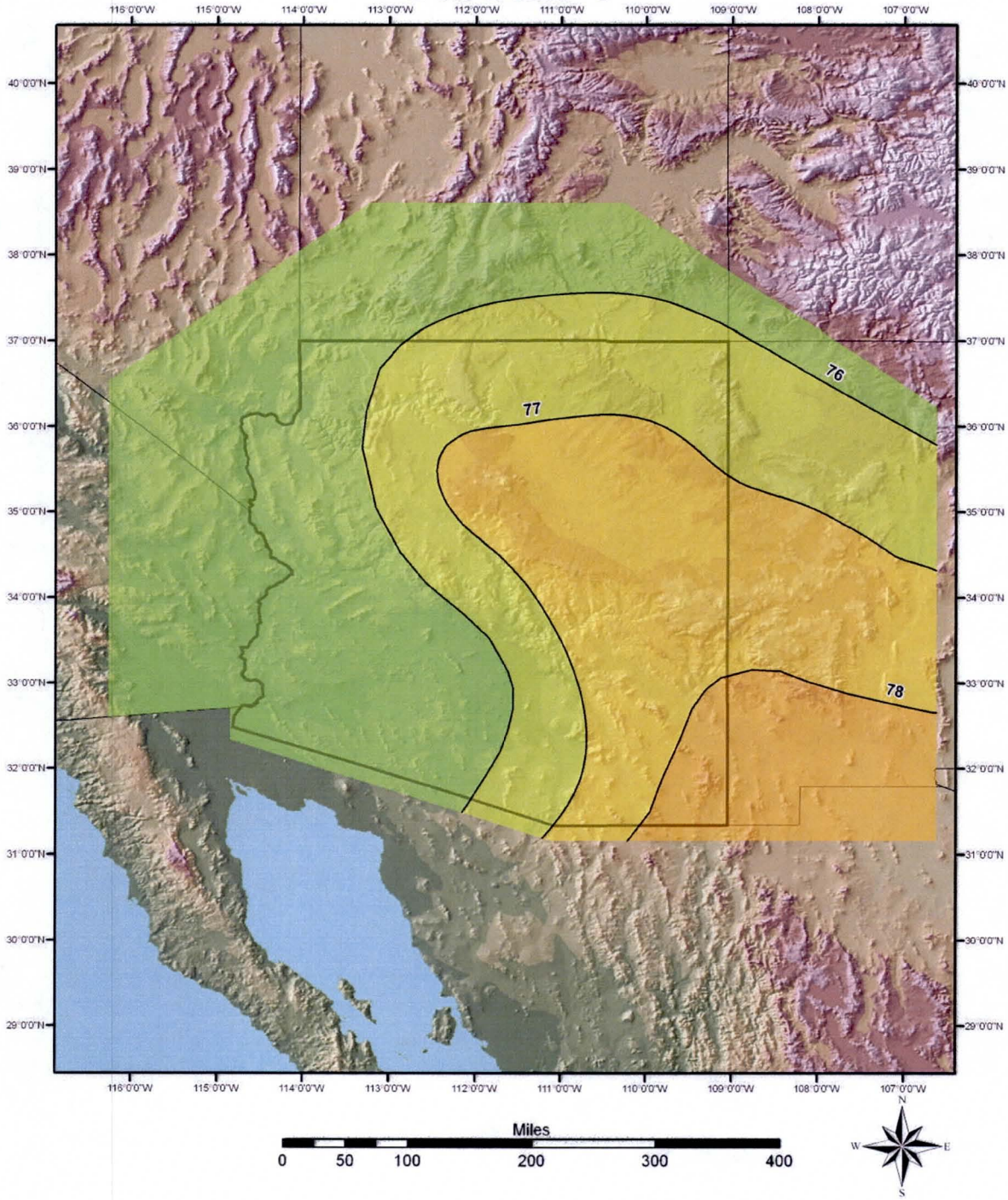
# April 3-Hour 100-Year
# Dew Point °F



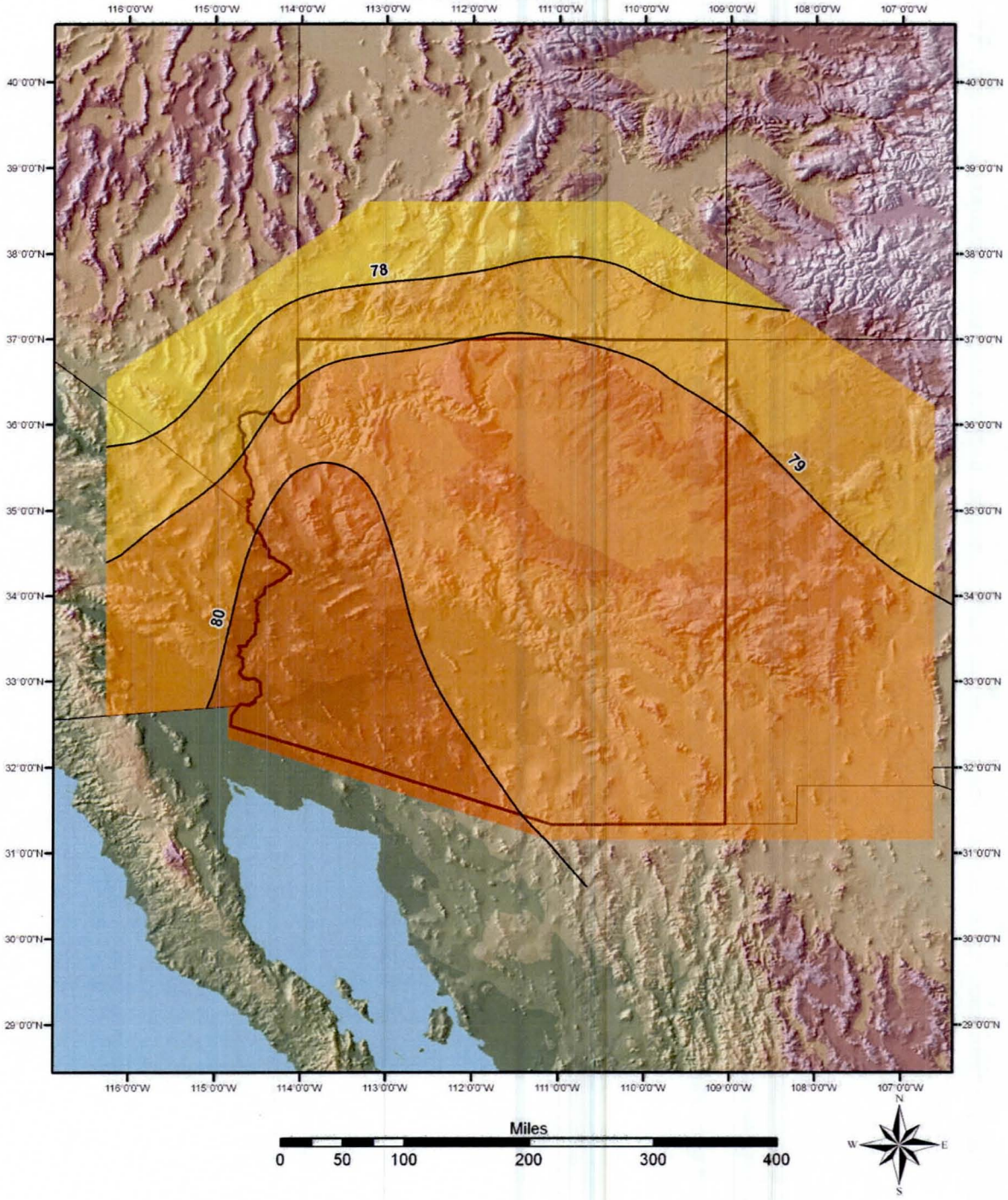
# May 3-Hour 100-Year
# Dew Point °F



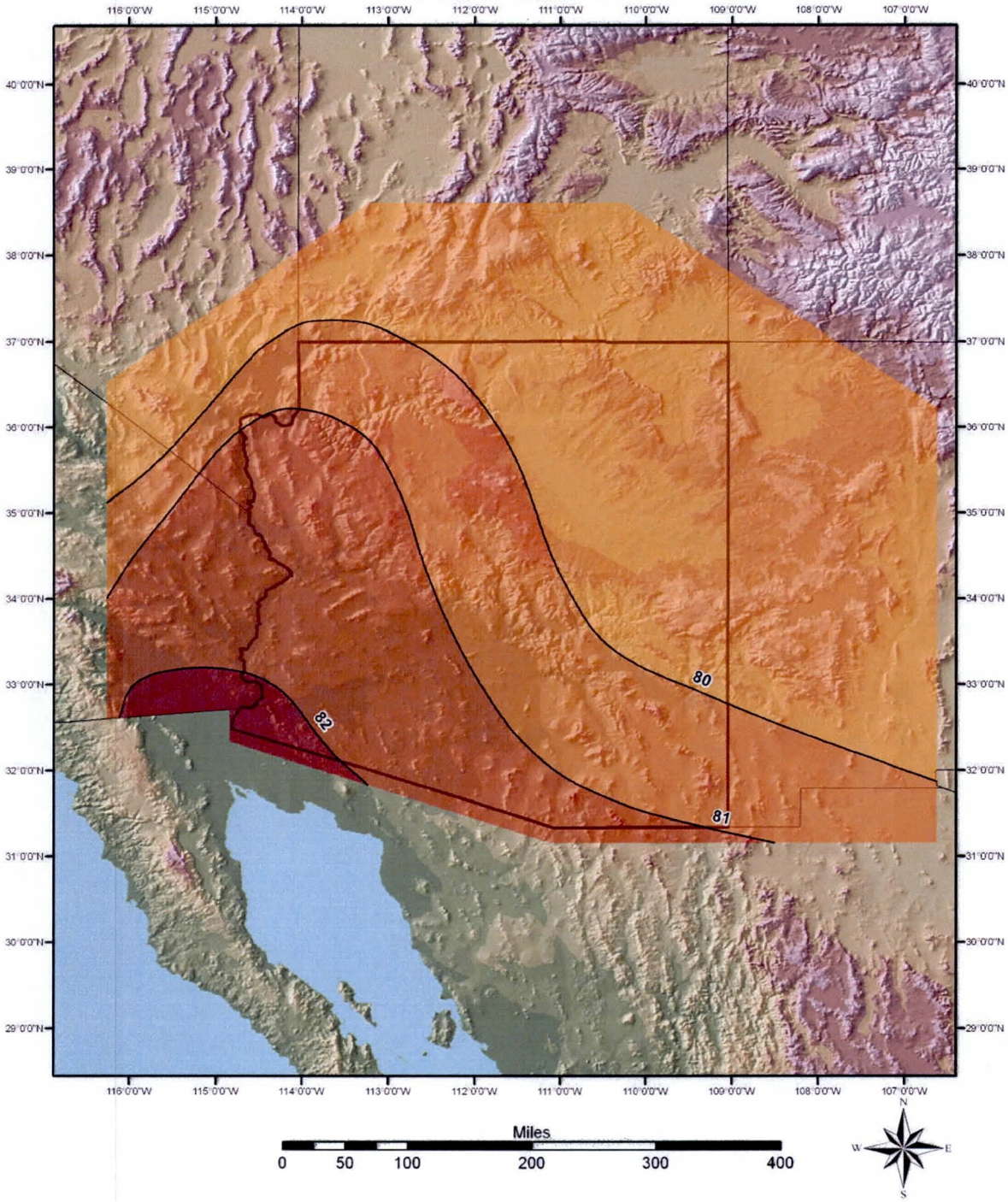
# June 3-Hour 100-Year
# Dew Point °F



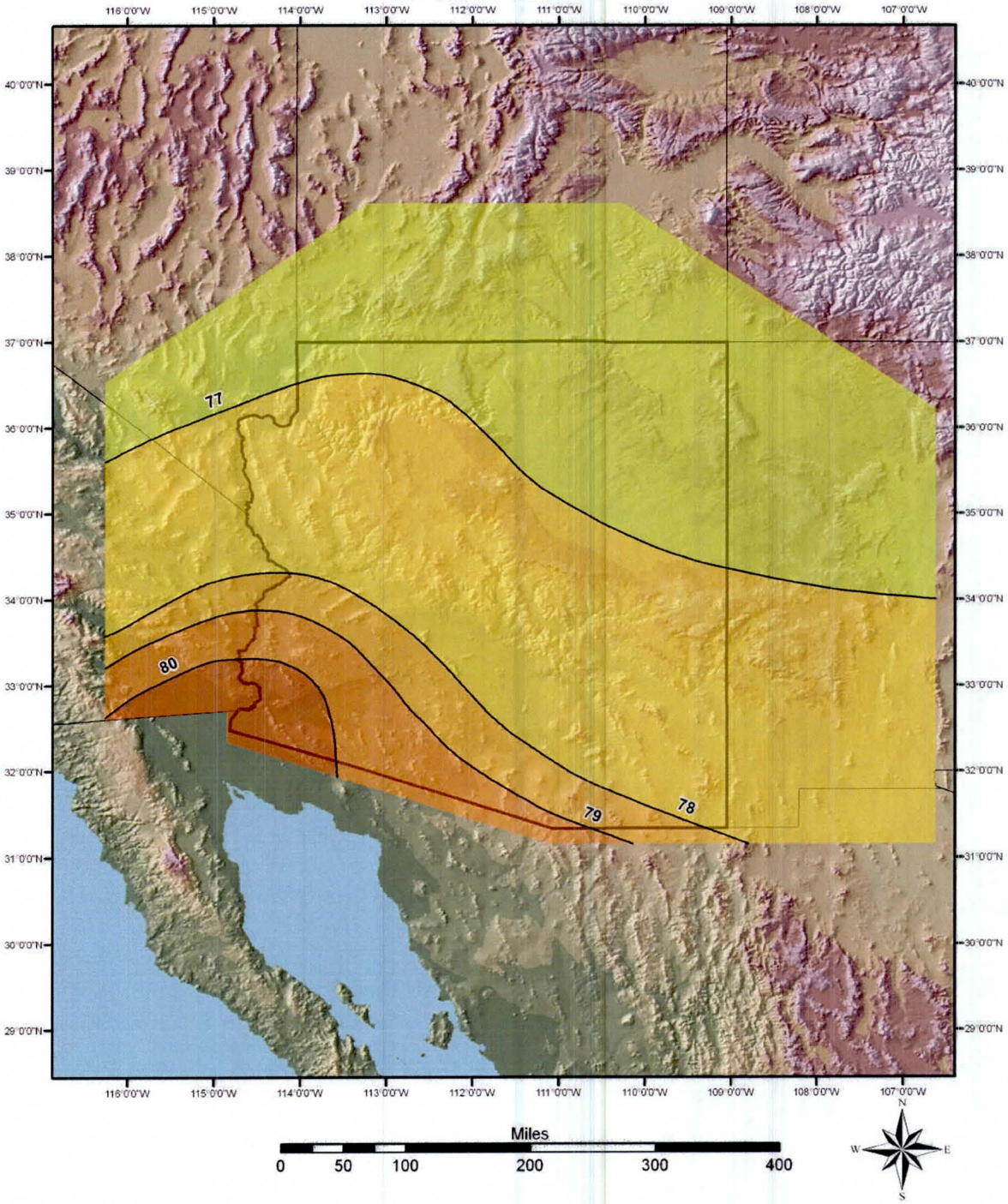
# July 3-Hour 100-Year
# Dew Point °F



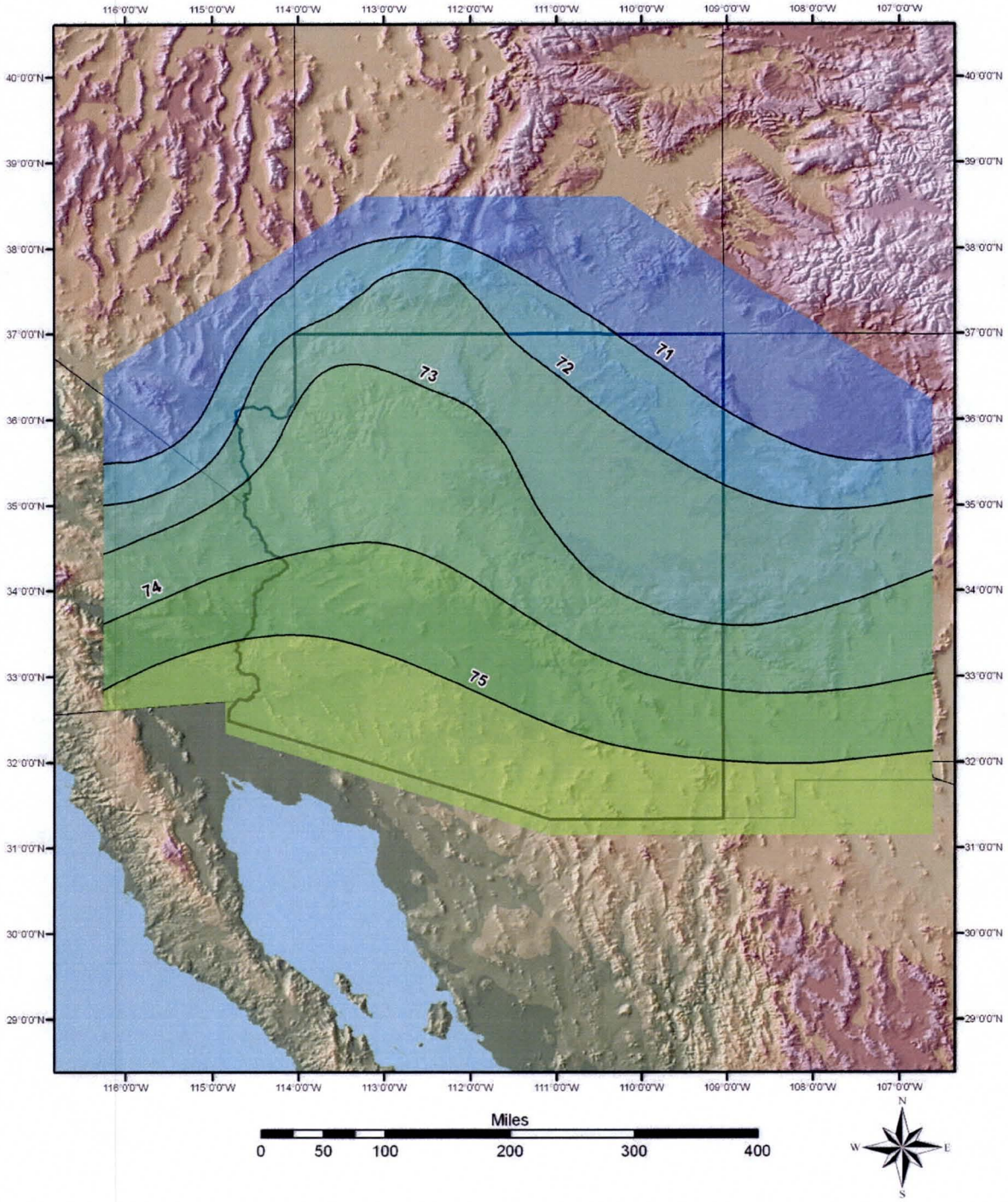
# August 3-Hour 100-Year Dew Point °F



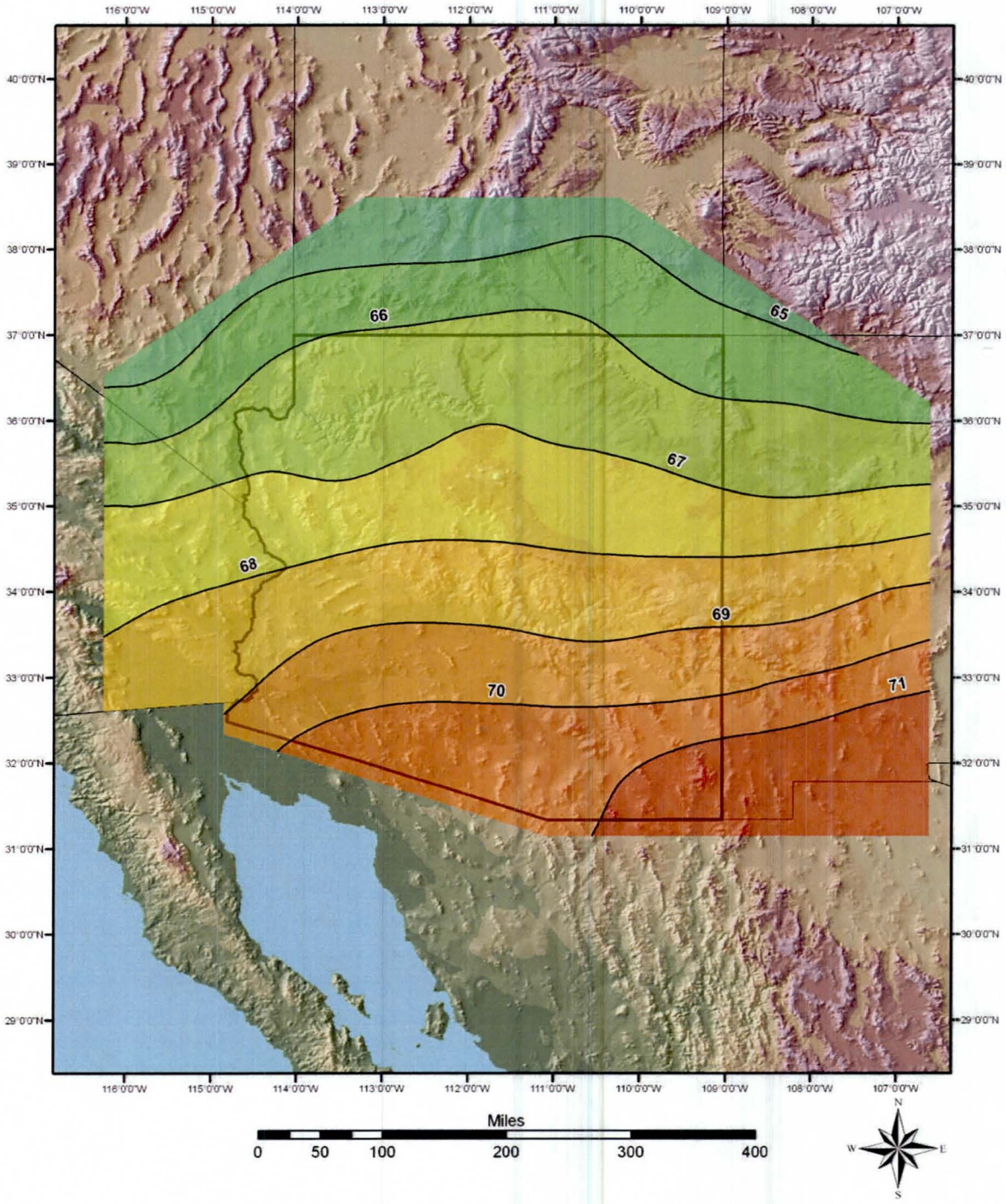
# September 3-Hour 100-Year Dew Point °F



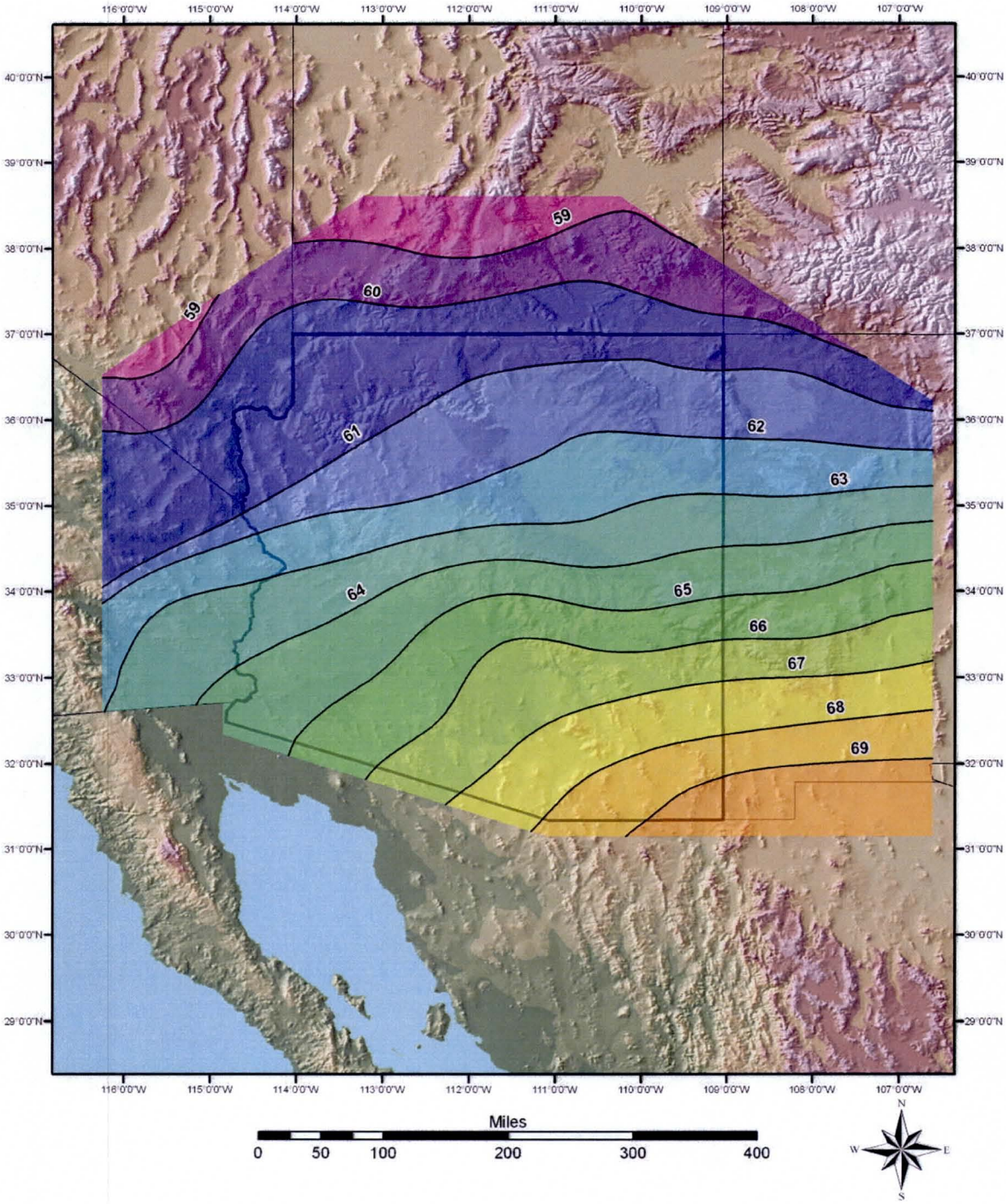
# October 3-Hour 100-Year
# Dew Point °F



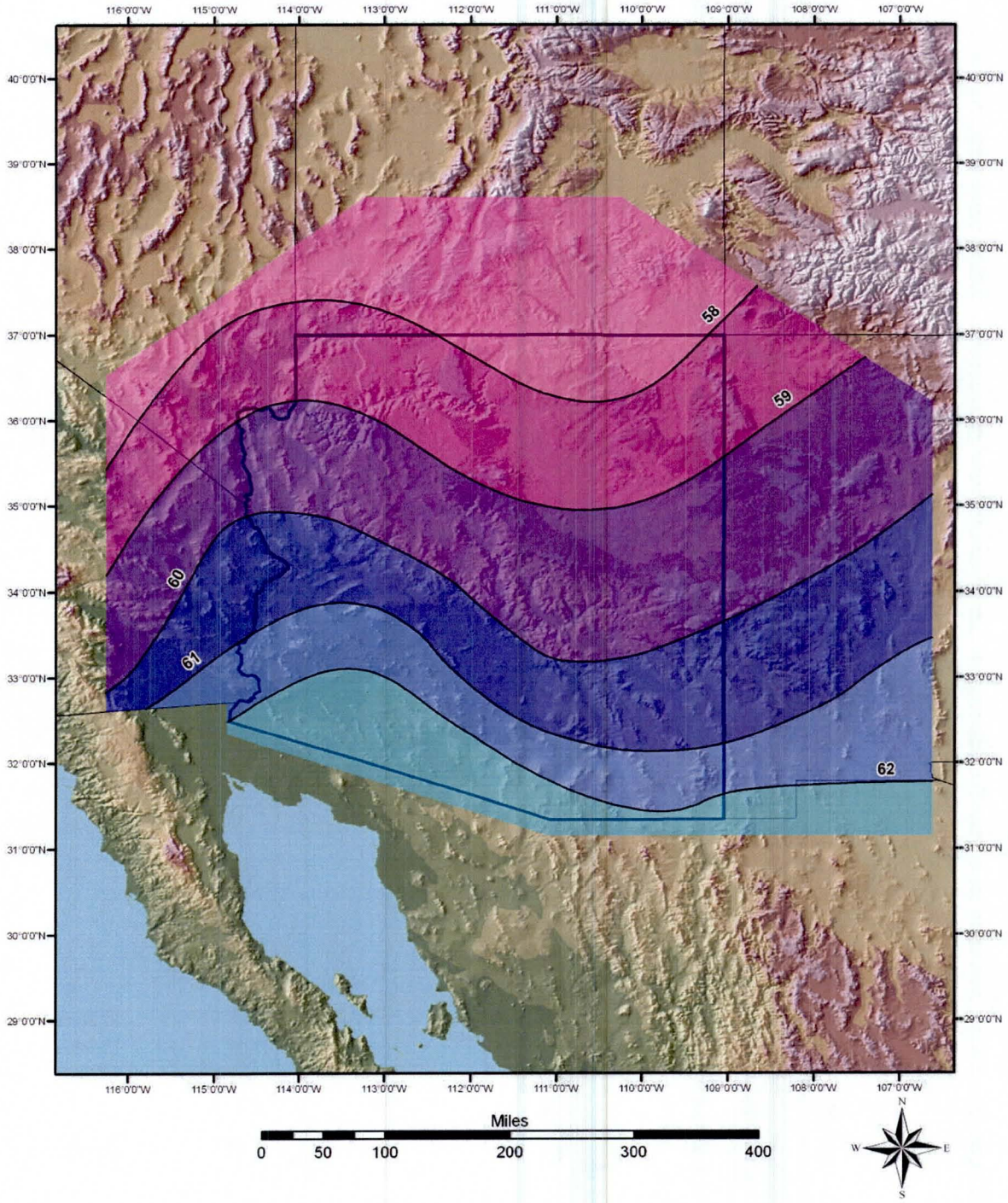
# November 3-Hour 100-Year
# Dew Point °F



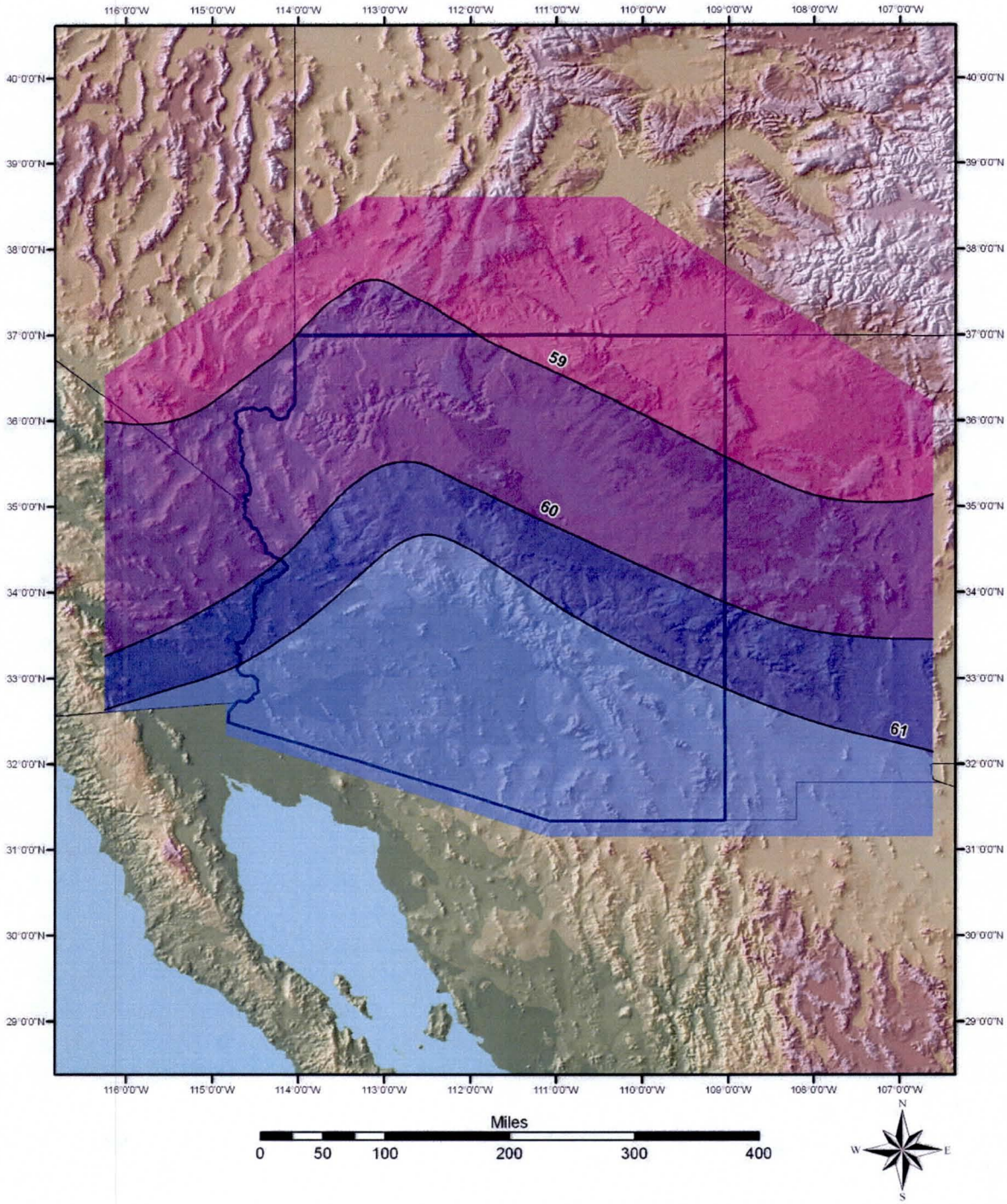
# December 3-Hour 100-Year
# Dew Point °F



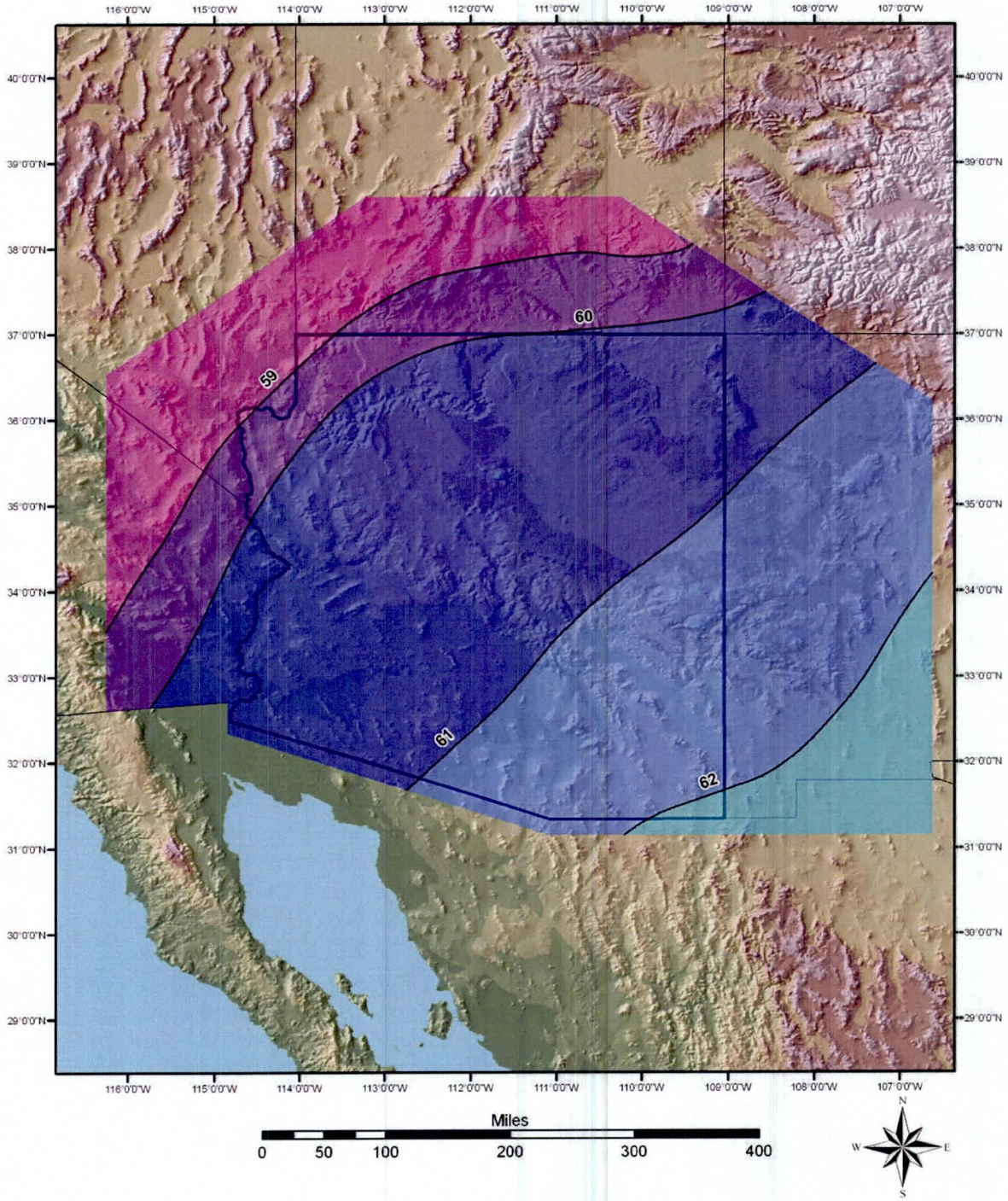
# January 12-Hour 100-Year
# Dew Point °F



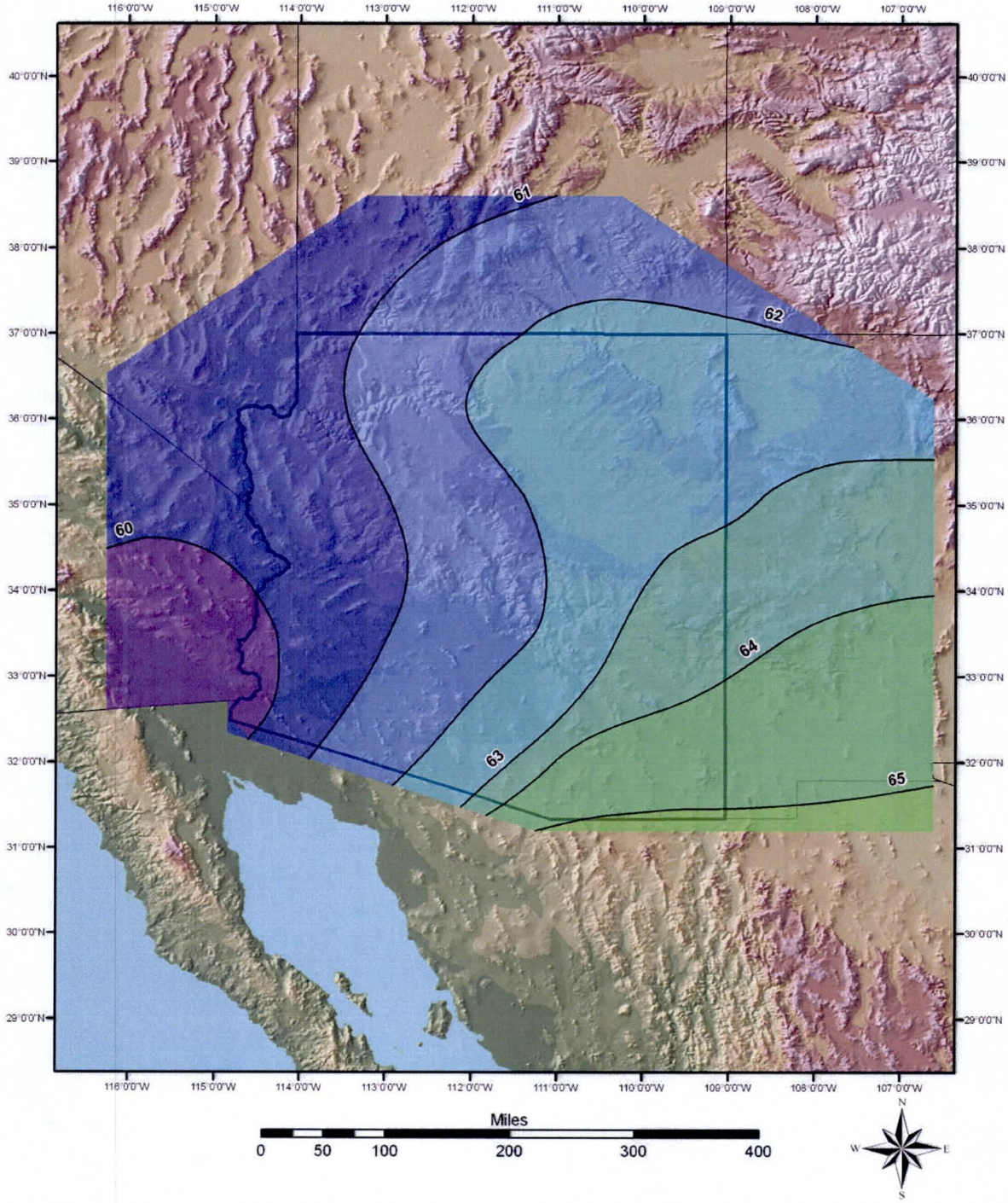
# February 12-Hour 100-Year Dew Point °F



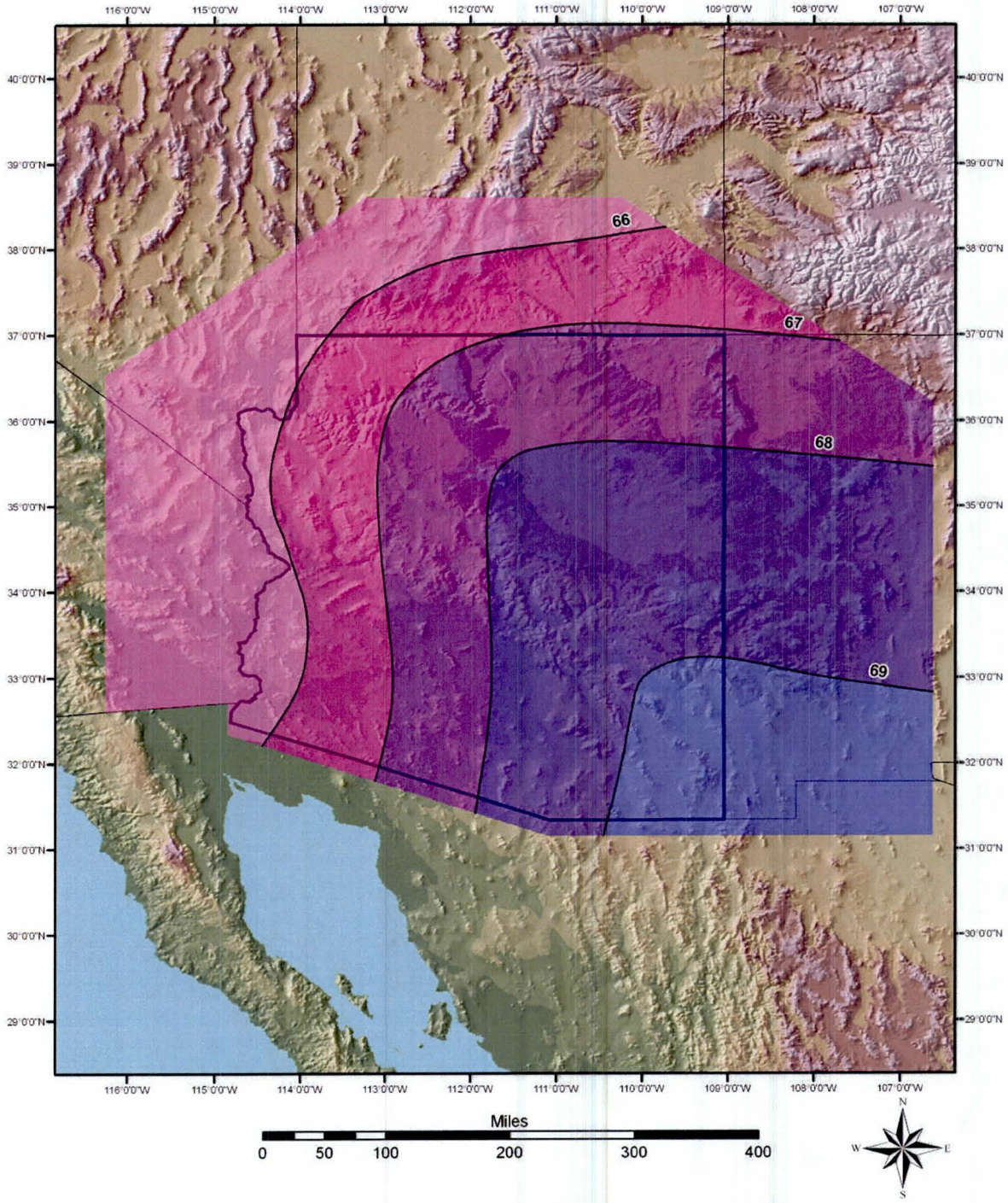
# March 12-Hour 100-Year
# Dew Point °F



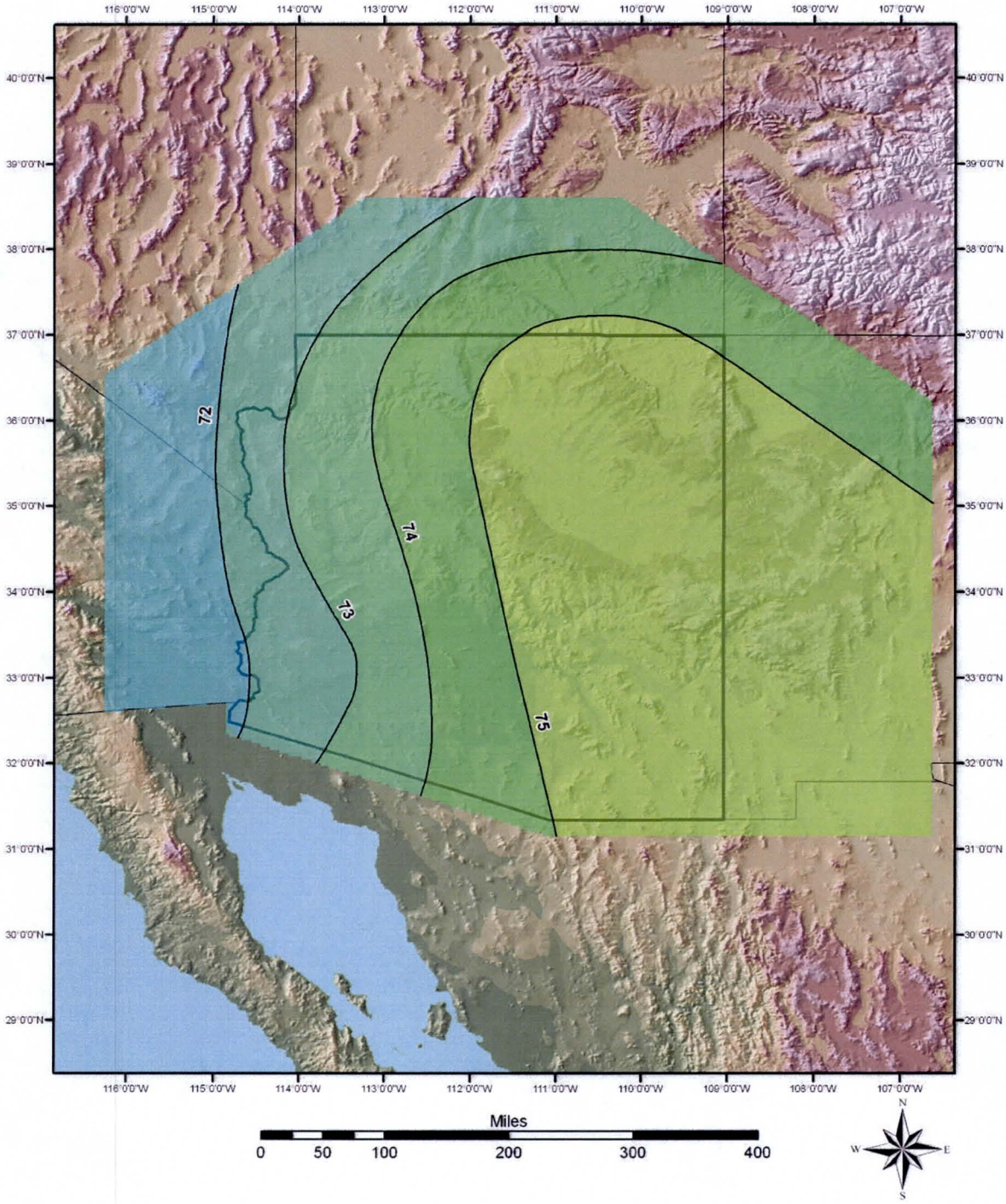
# April 12-Hour 100-Year
# Dew Point °F



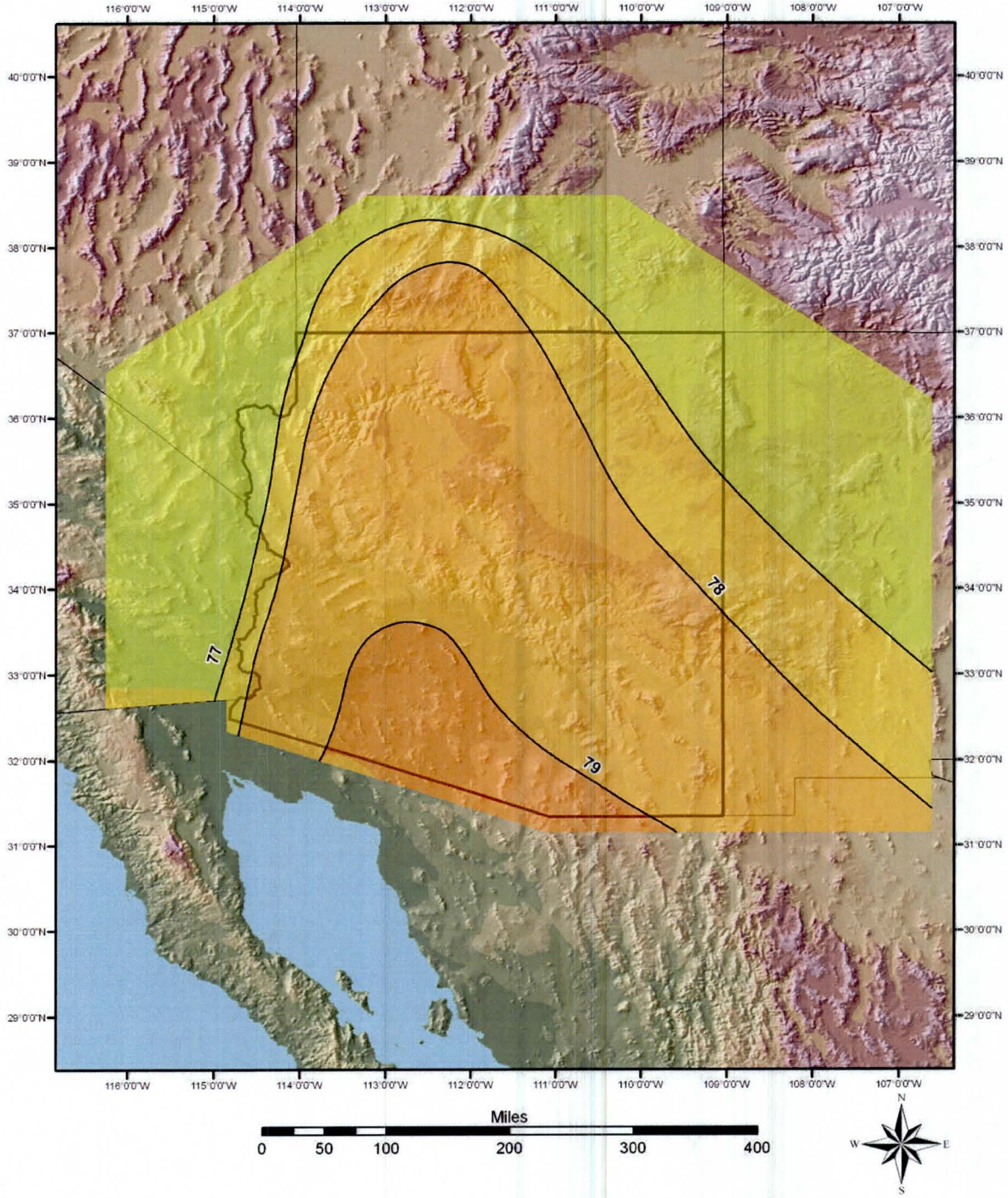
# May 12-Hour 100-Year
# Dew Point °F



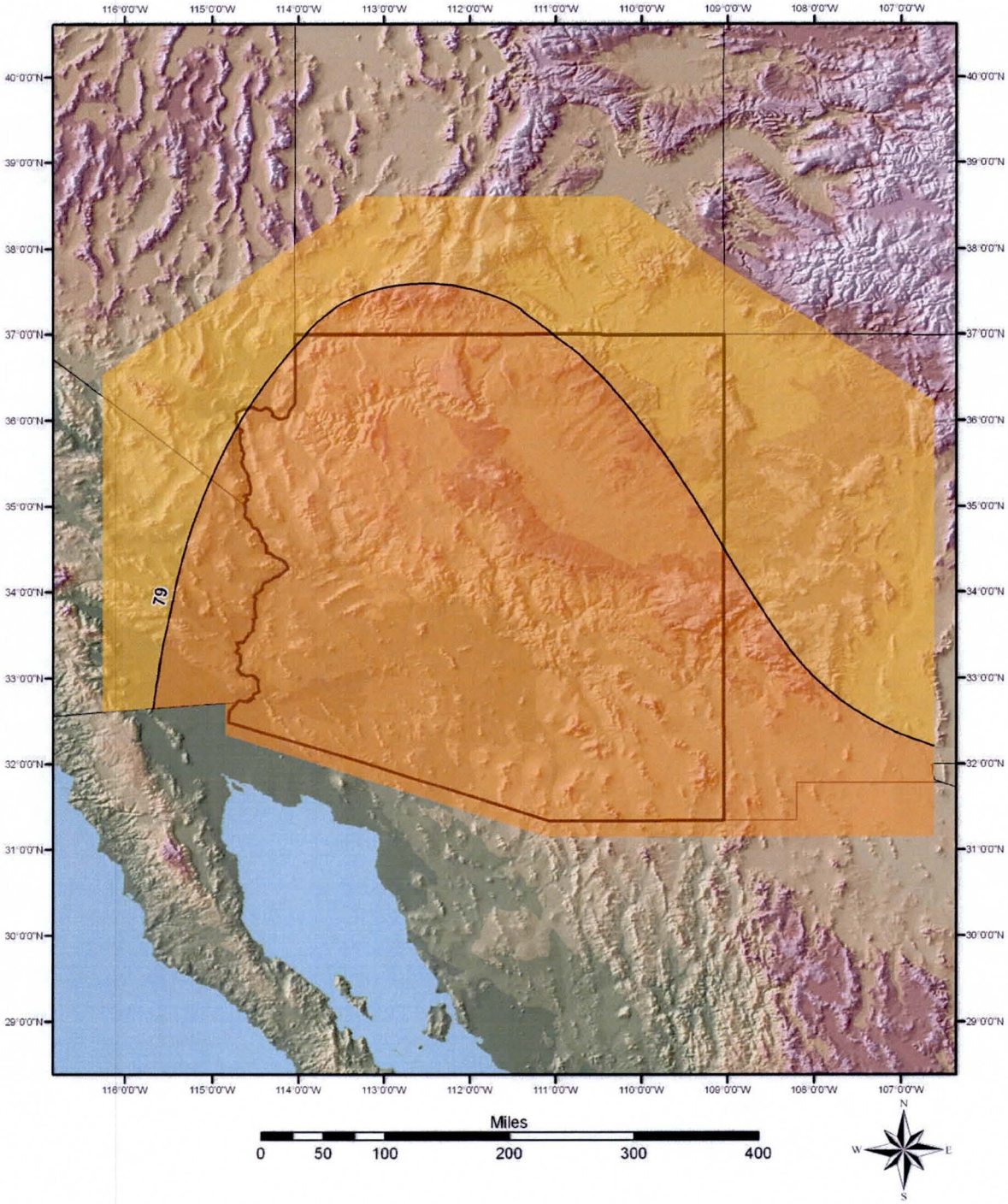
# June 12-Hour 100-Year
# Dew Point °F



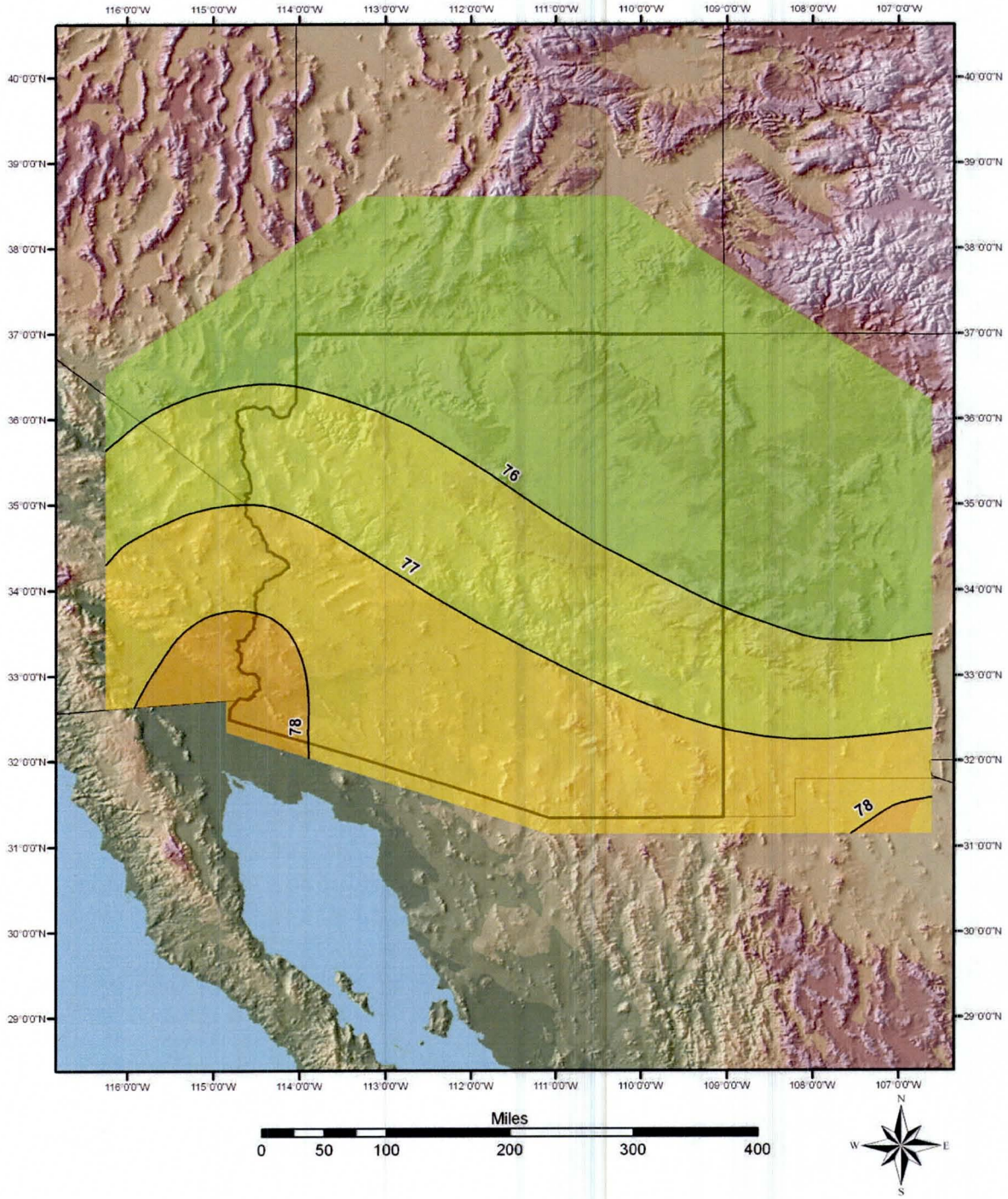
# July 12-Hour 100-Year
# Dew Point °F



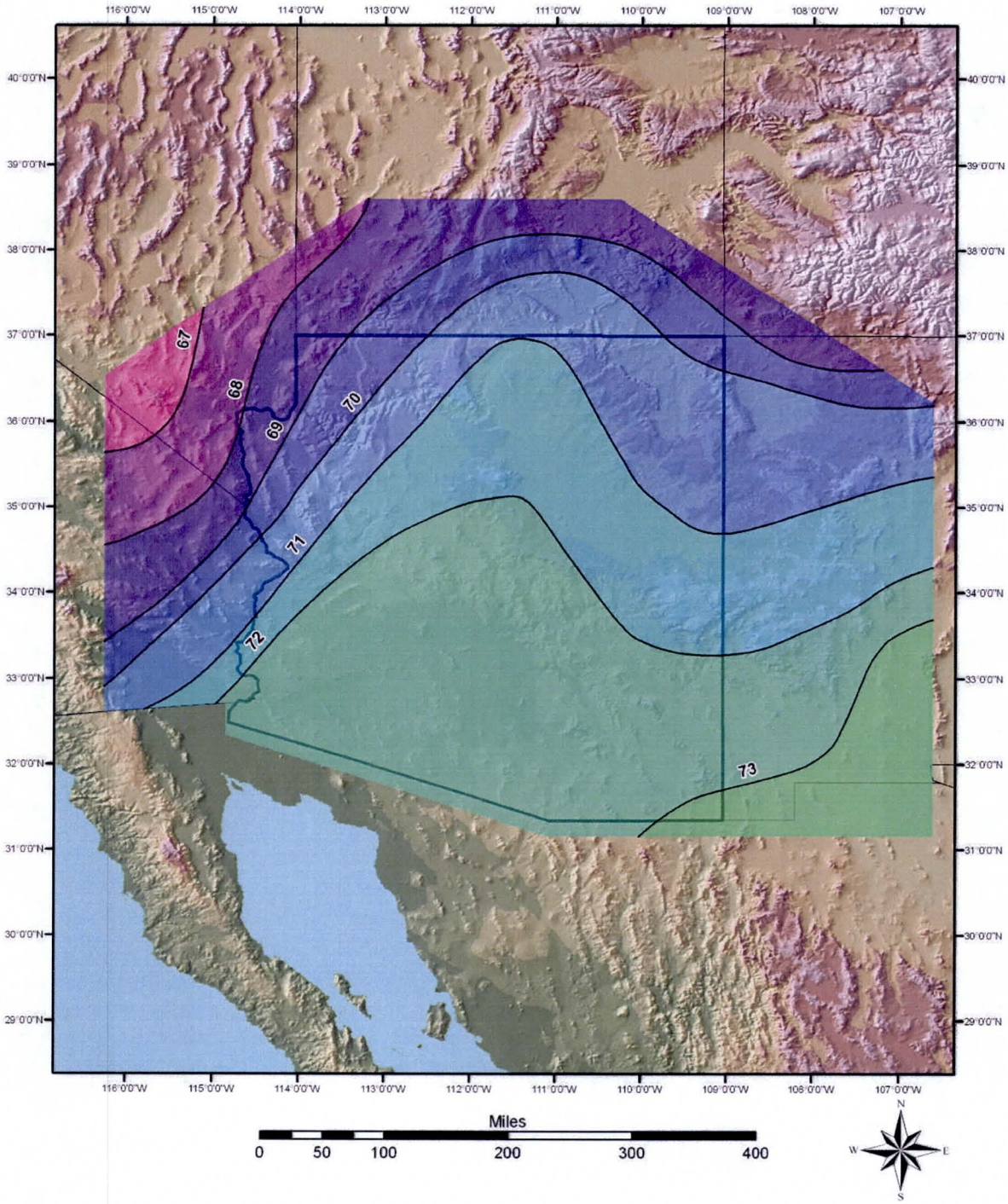
# August 12-Hour 100-Year
# Dew Point °F



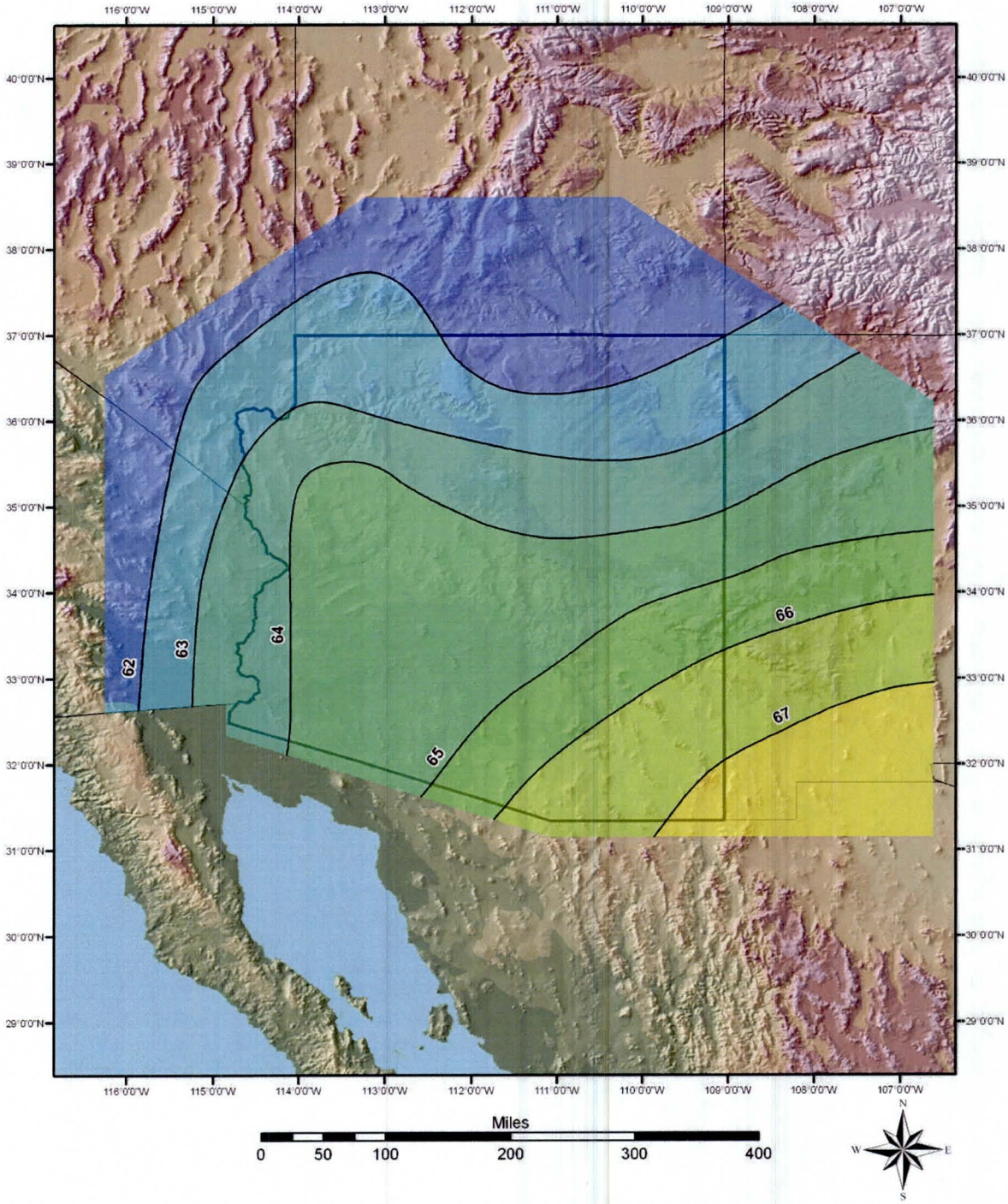
# September 12-Hour 100-Year
# Dew Point °F



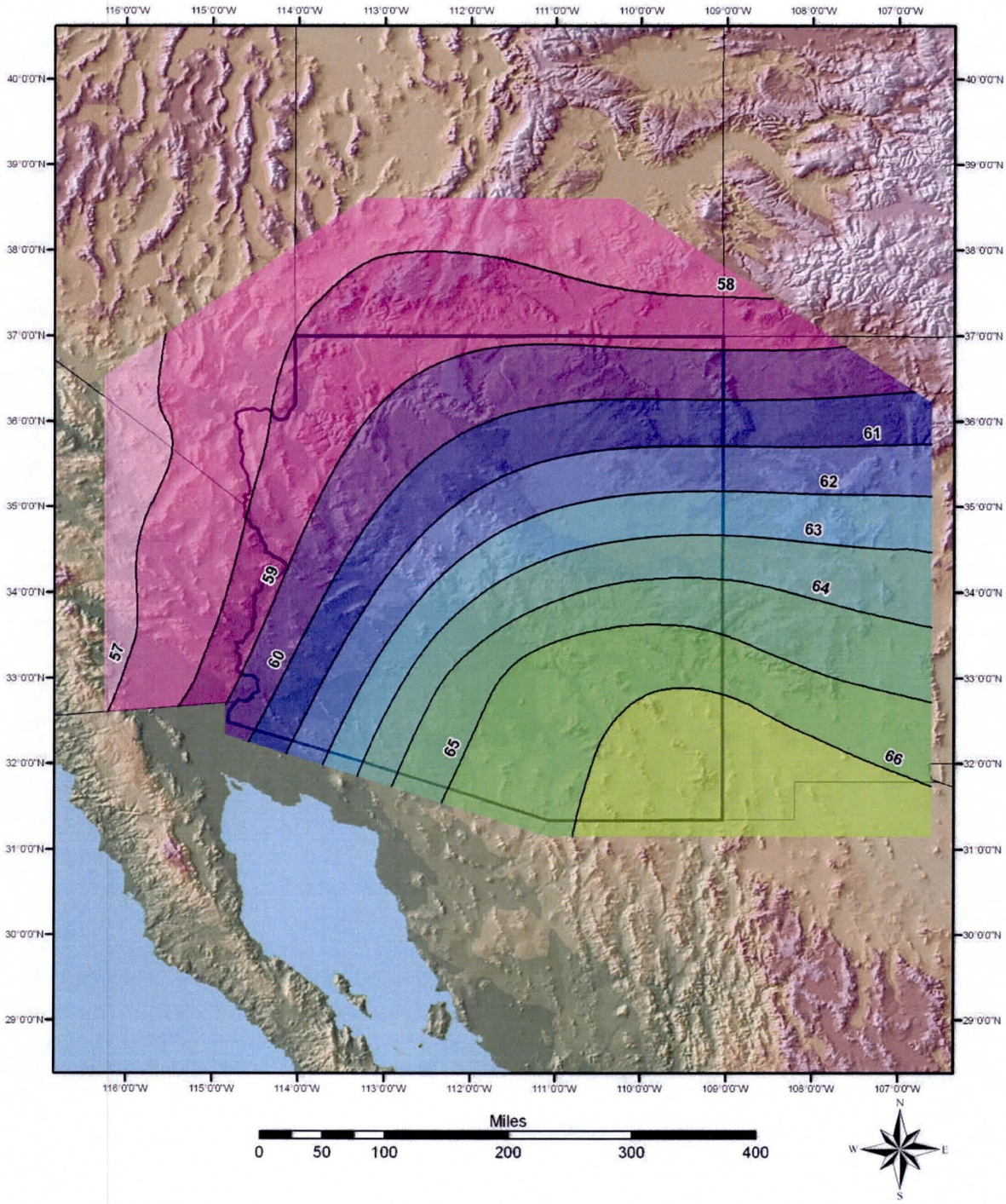
# October 12-Hour 100-Year
# Dew Point °F



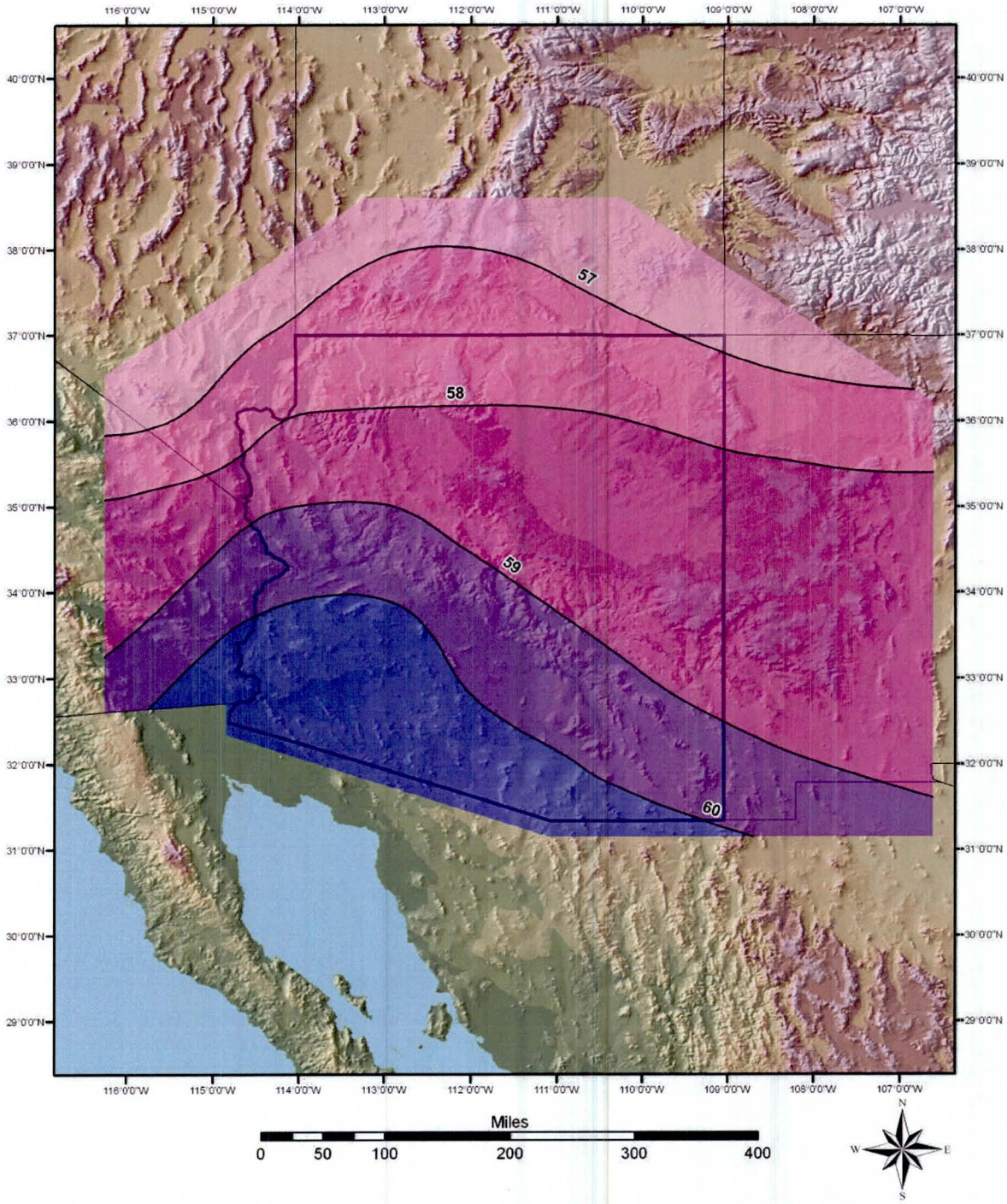
# November 12-Hour 100-Year
# Dew Point °F



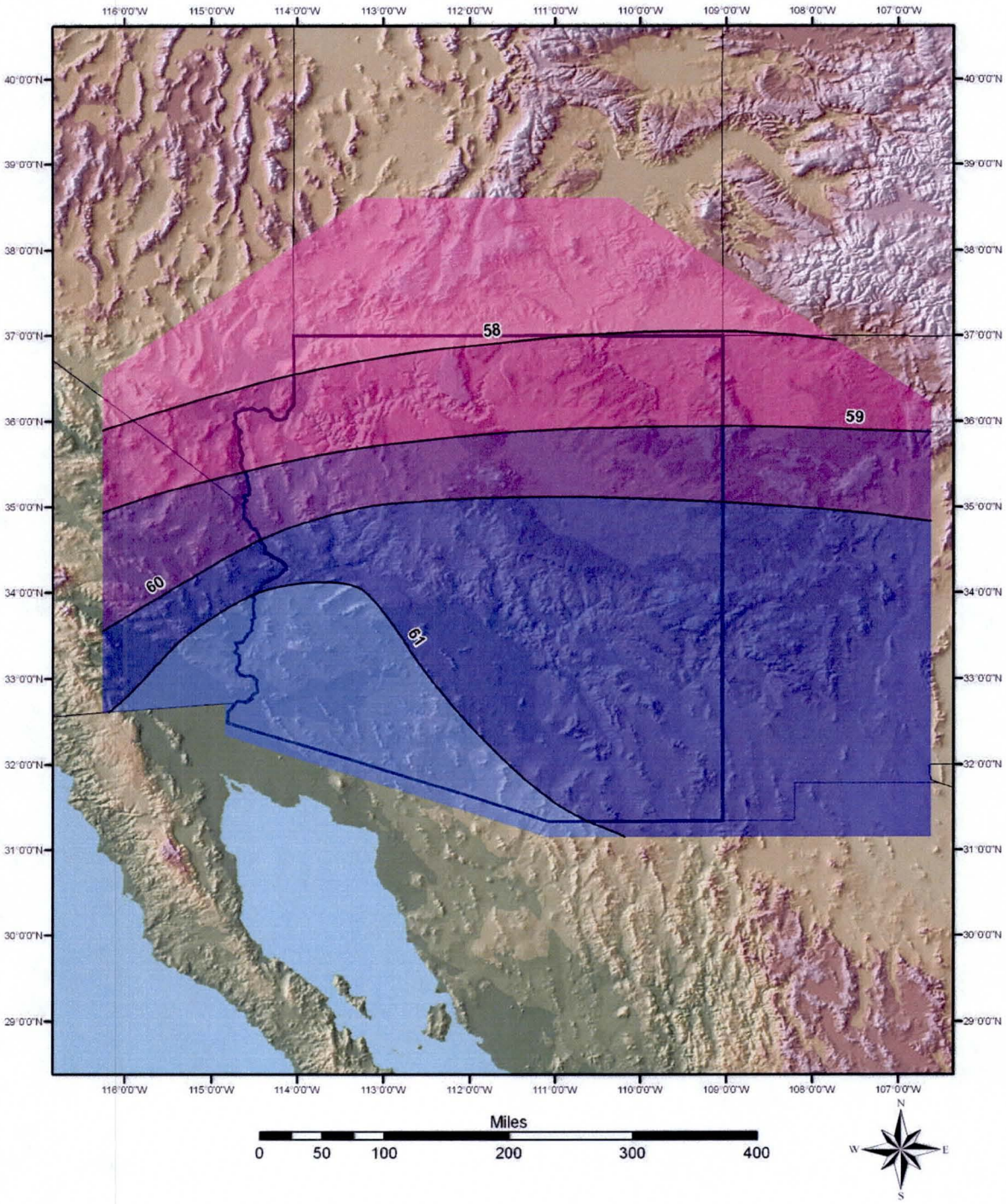
# December 12-Hour 100-Year
# Dew Point °F



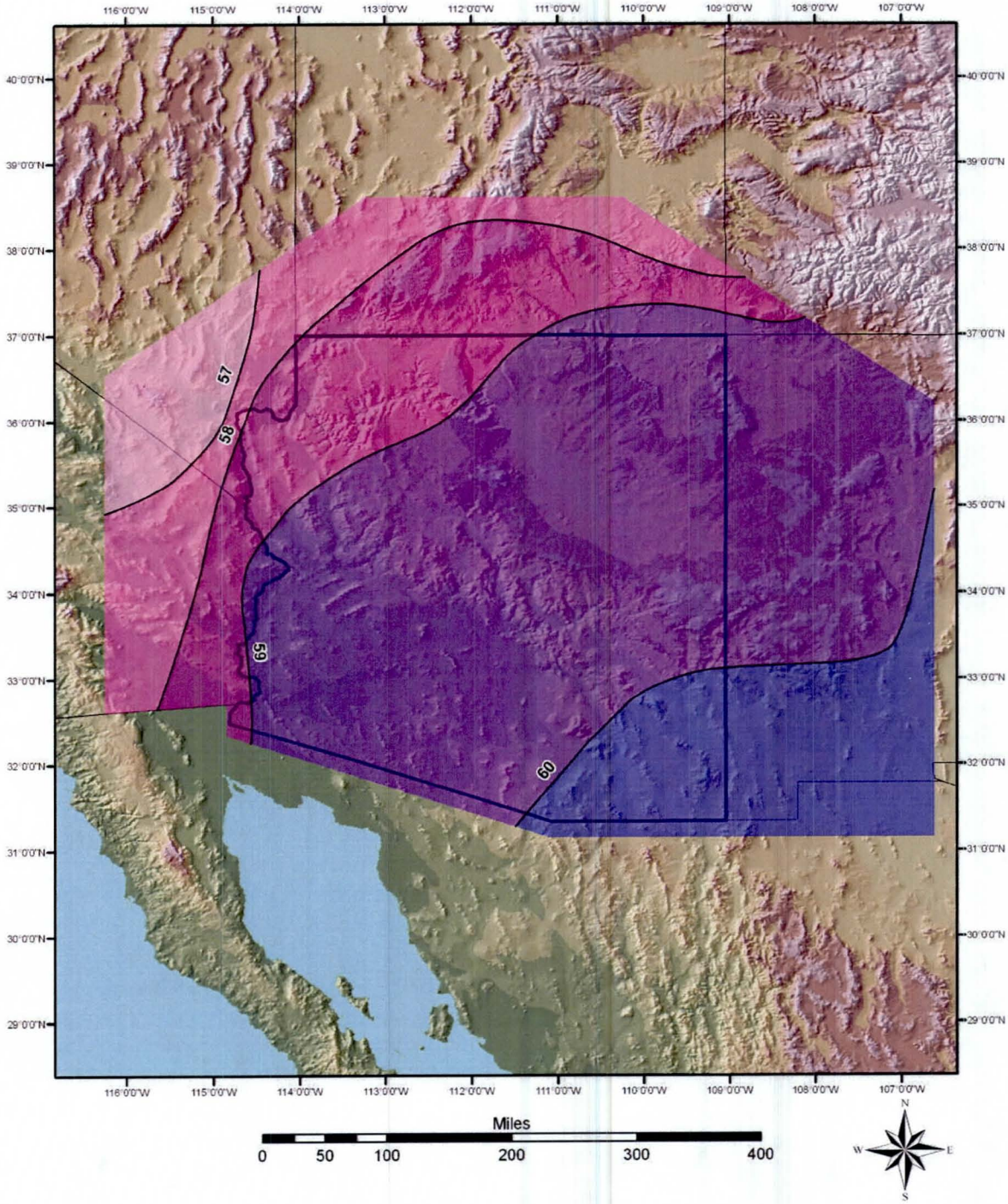
# January 24-Hour 100-Year
# Dew Point °F



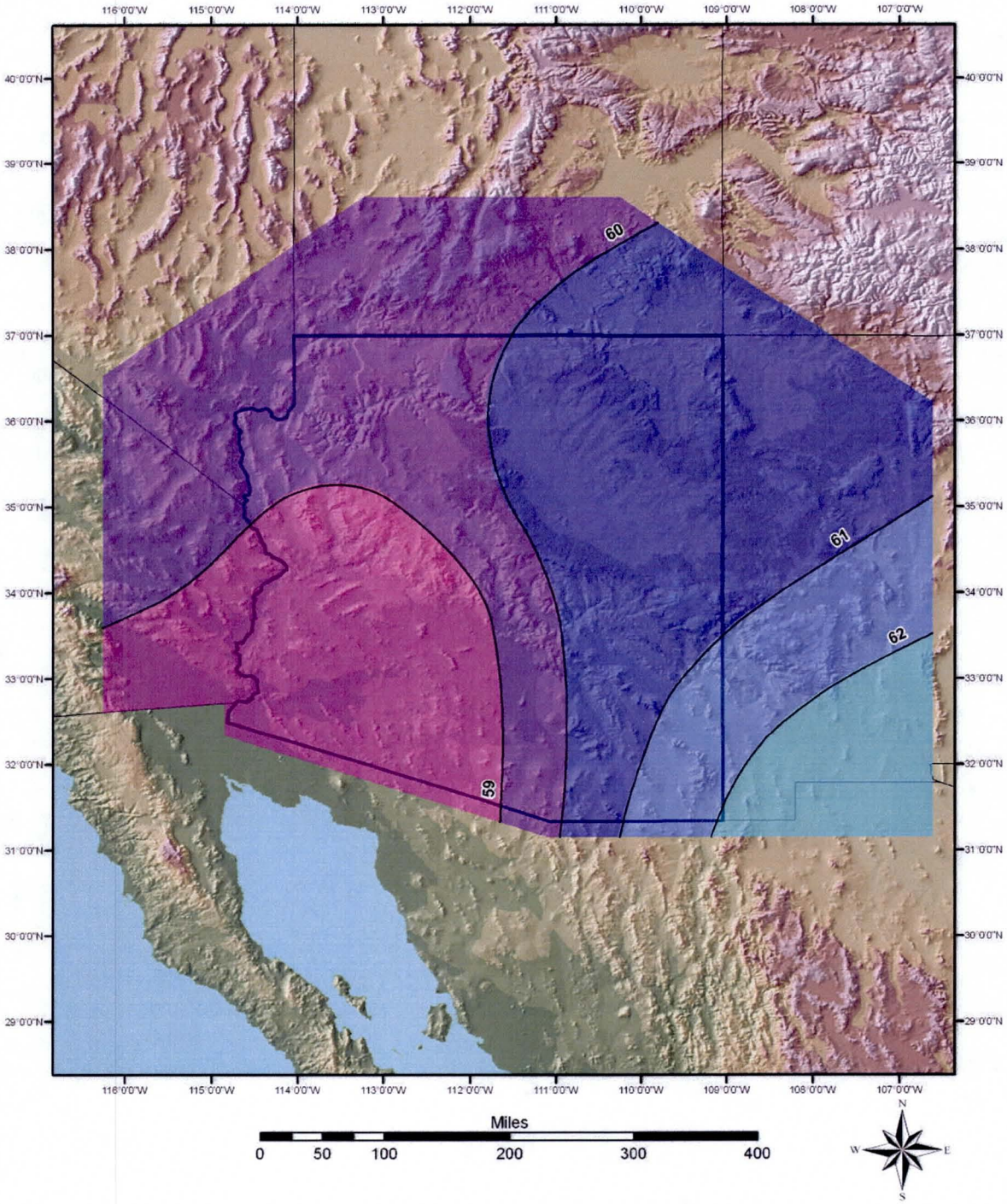
# February 24-Hour 100-Year
# Dew Point °F



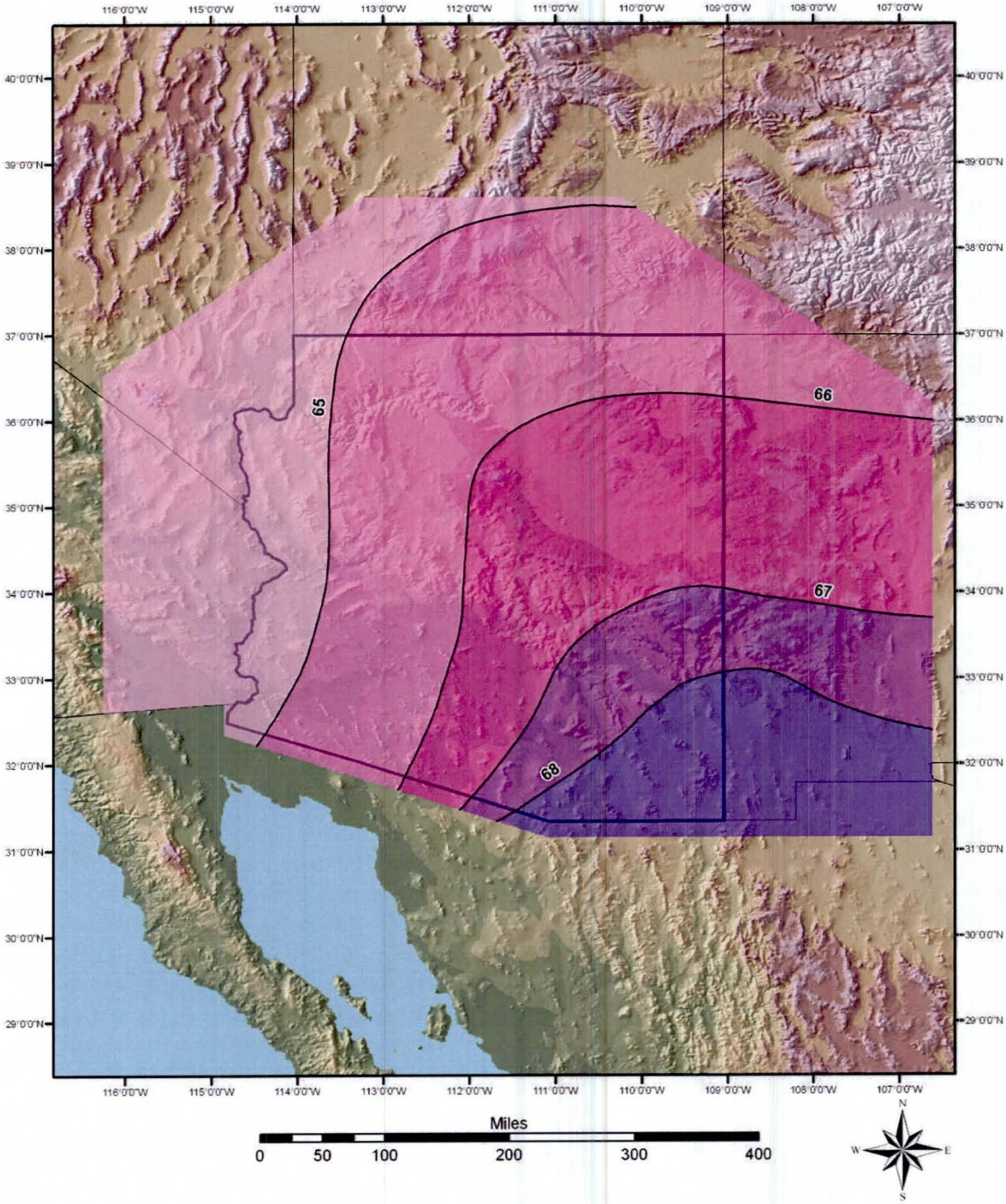
# March 24-Hour 100-Year
# Dew Point °F



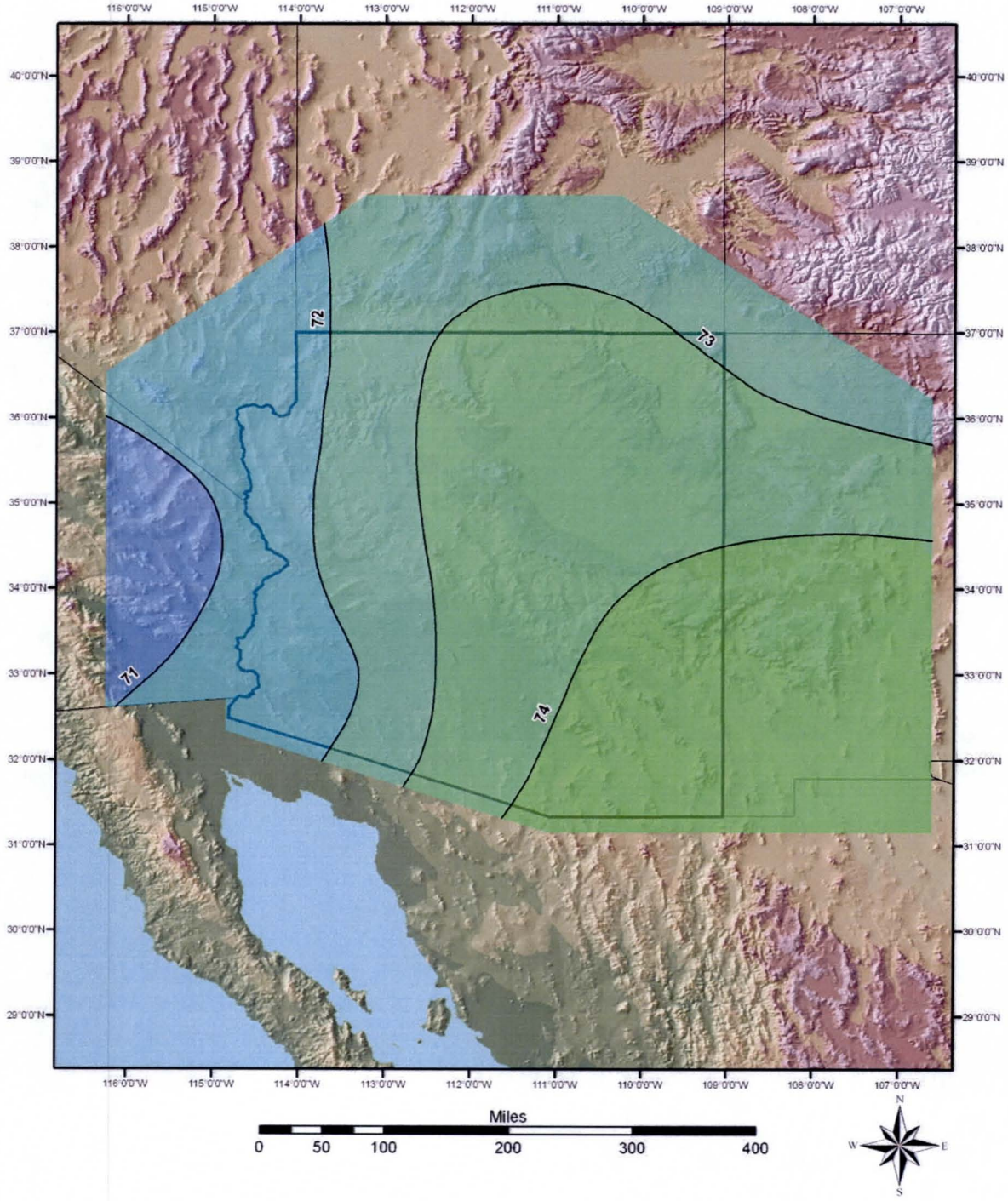
# April 24-Hour 100-Year
# Dew Point °F



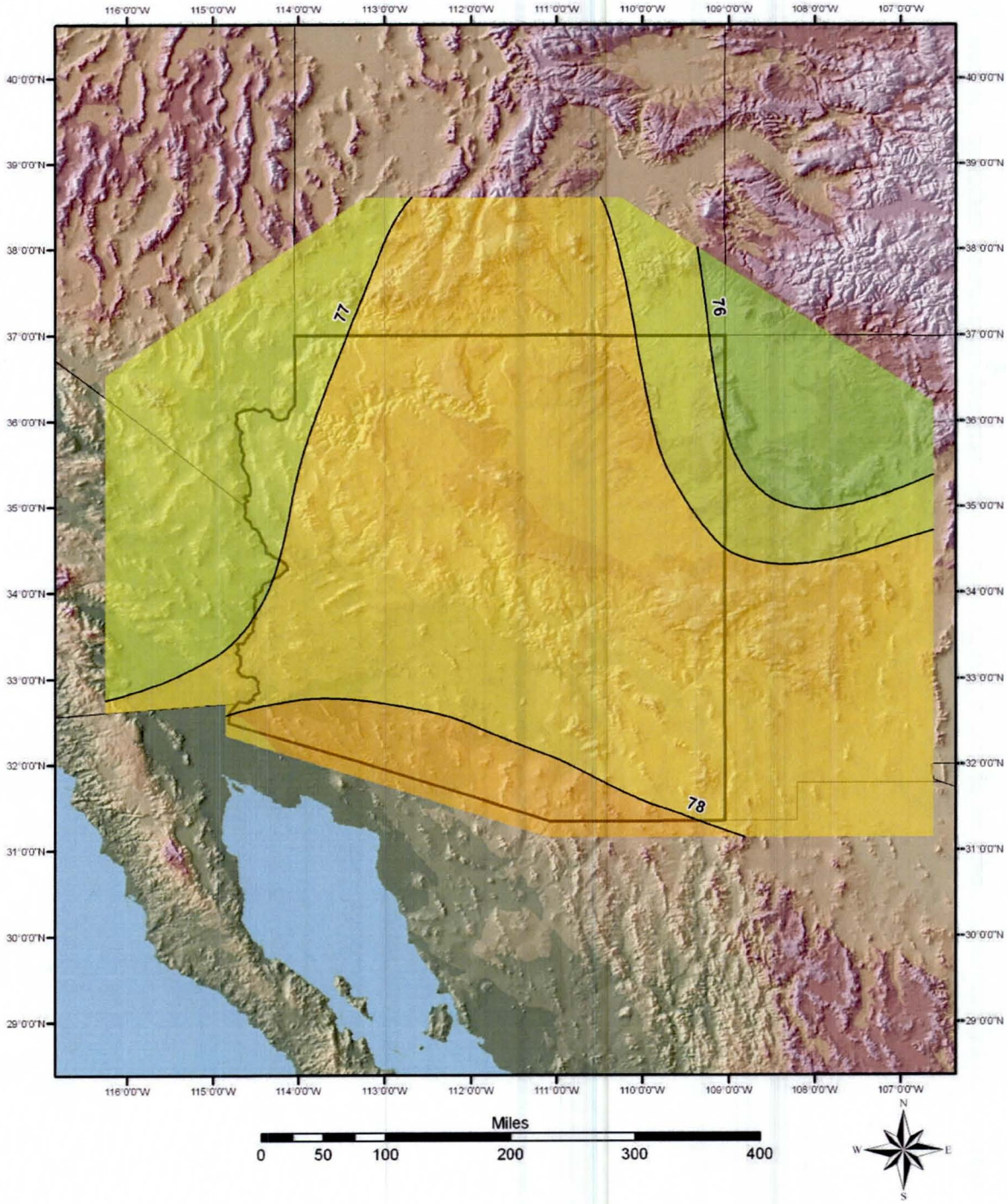
# May 24-Hour 100-Year
# Dew Point °F



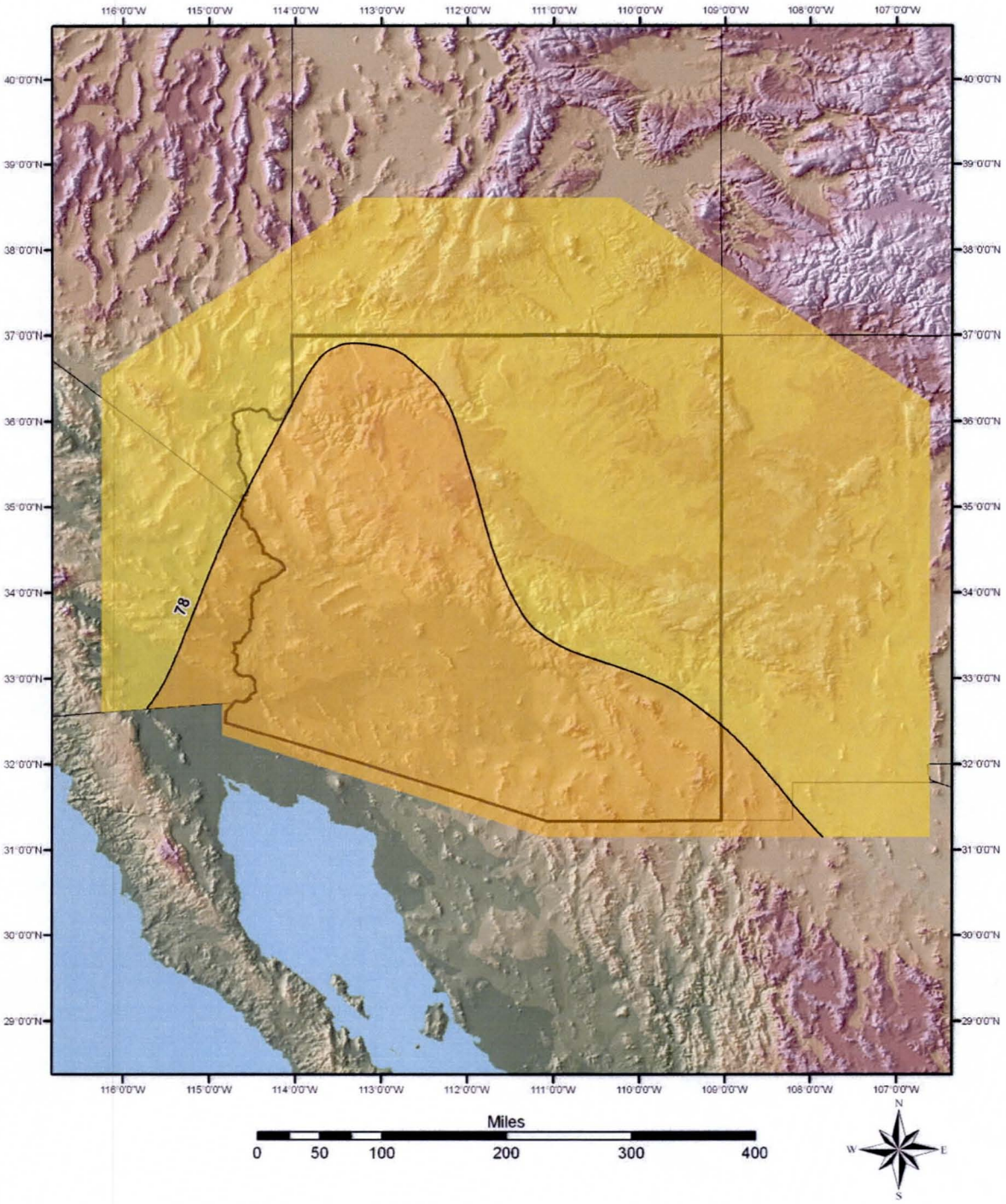
# June 24-Hour 100-Year
# Dew Point °F



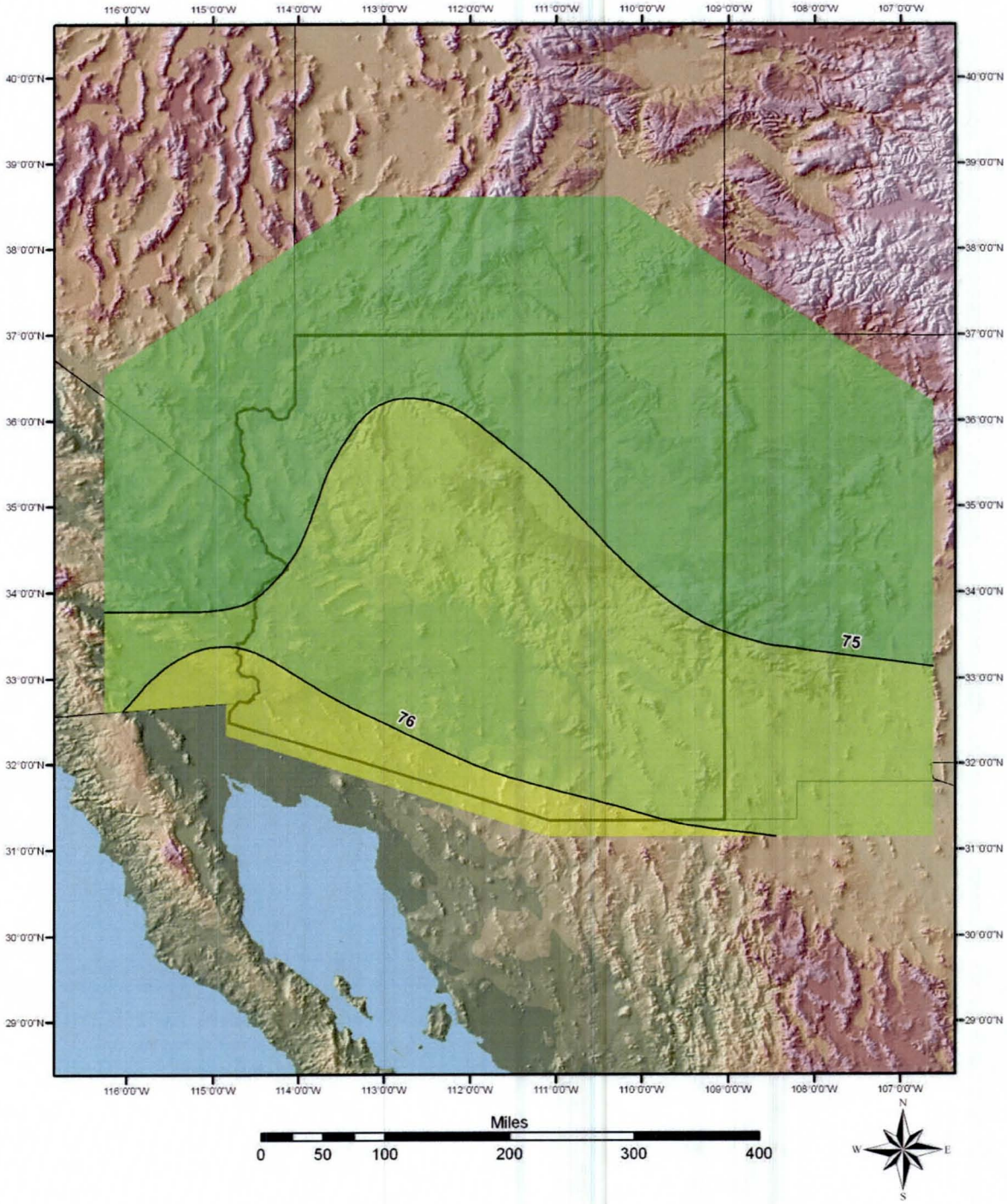
# July 24-Hour 100-Year
# Dew Point °F



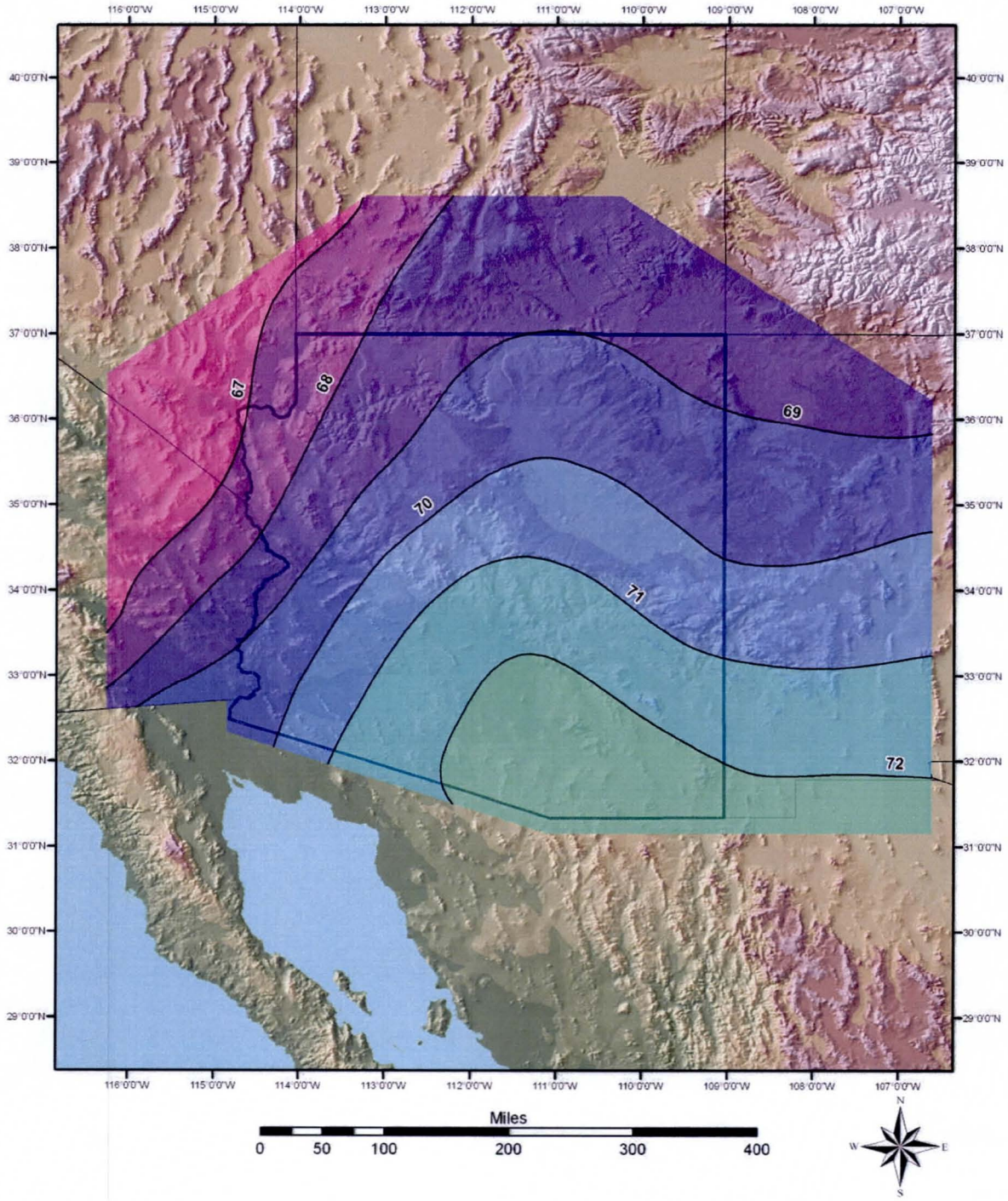
# August 24-Hour 100-Year
# Dew Point °F



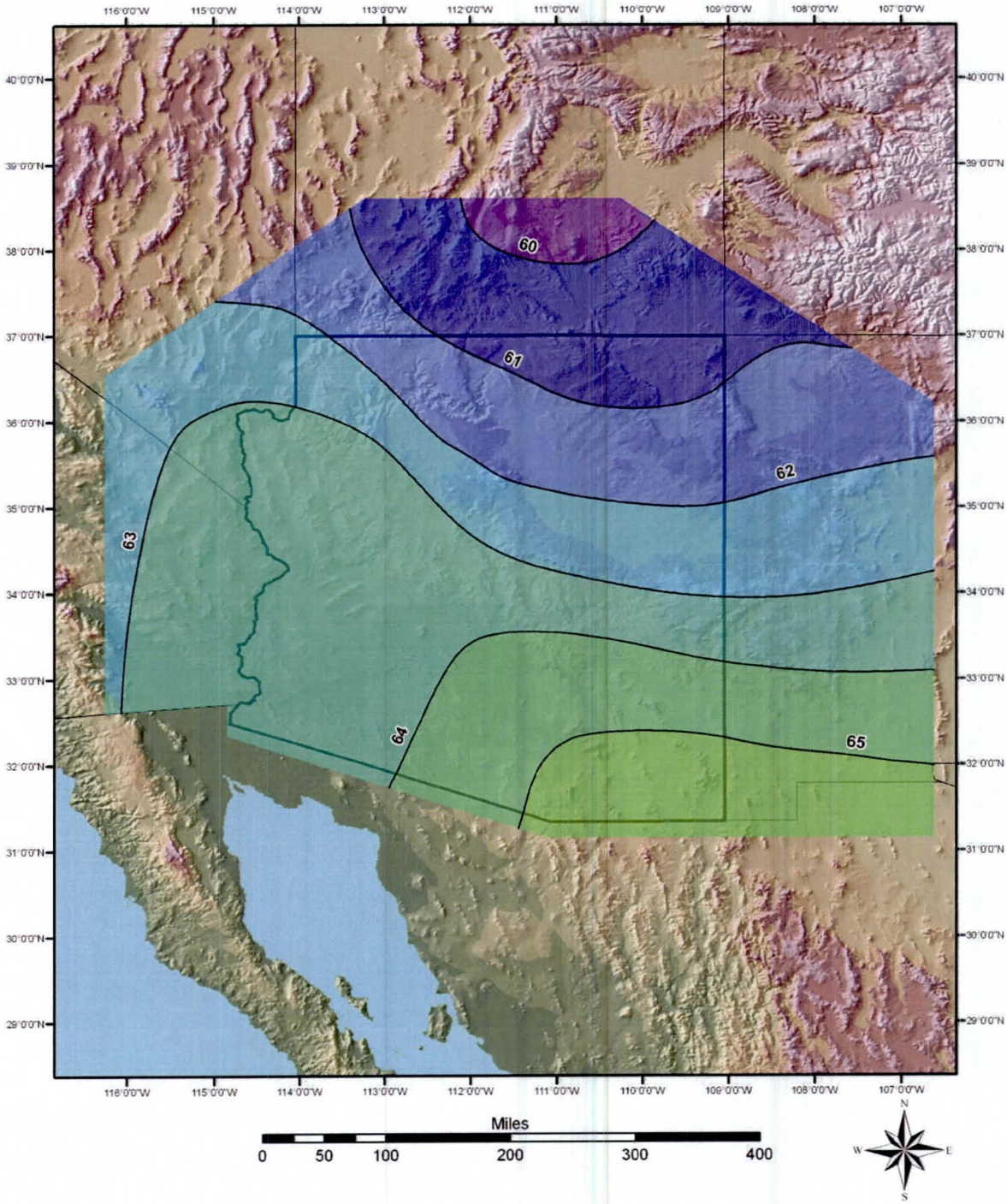
# September 24-Hour 100-Year
# Dew Point °F



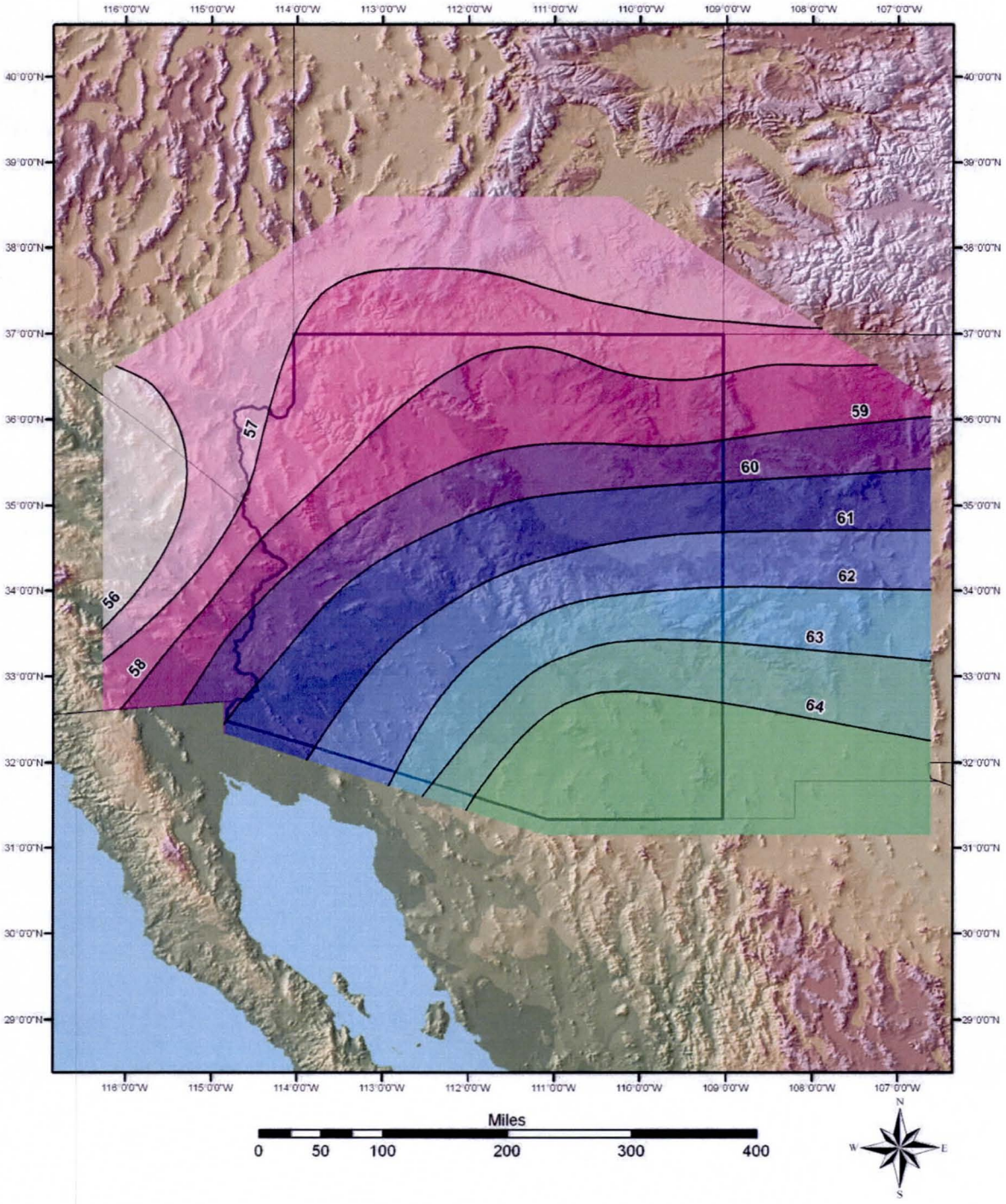
# October 24-Hour 100-Year
# Dew Point °F



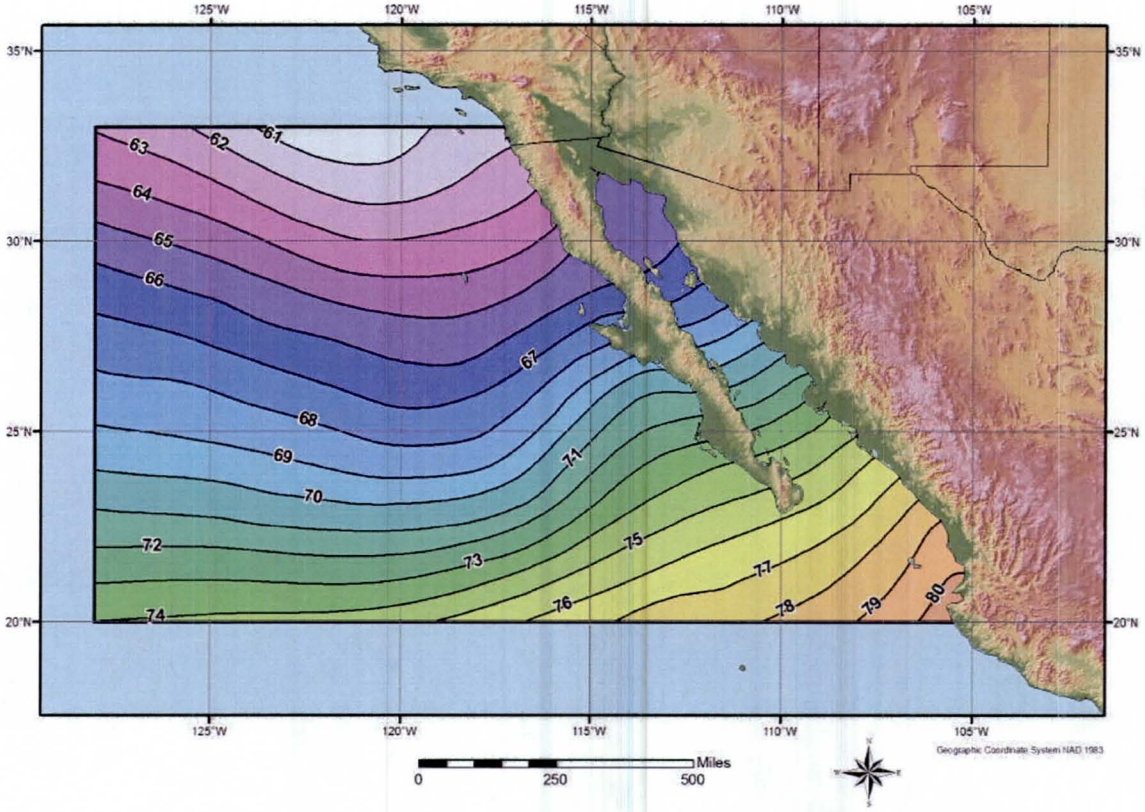
# November 24-Hour 100-Year
# Dew Point °F



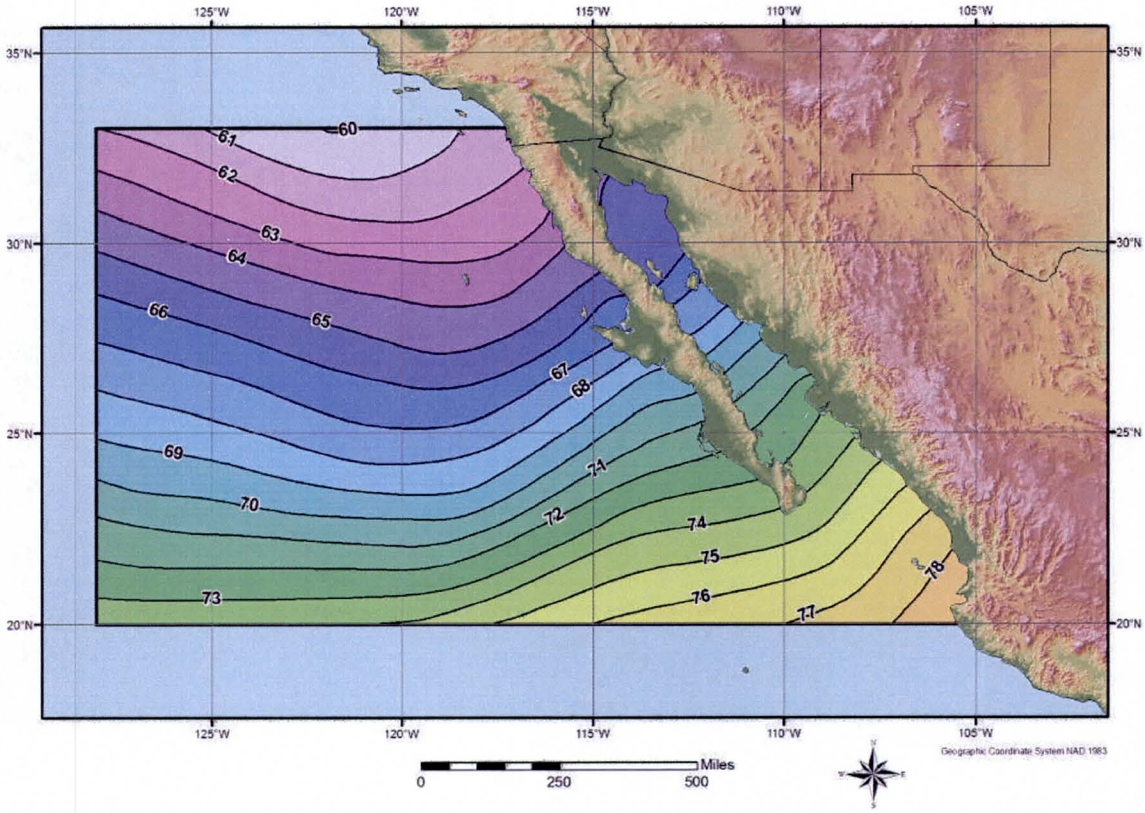
# December 24-Hour 100-Year
# Dew Point °F



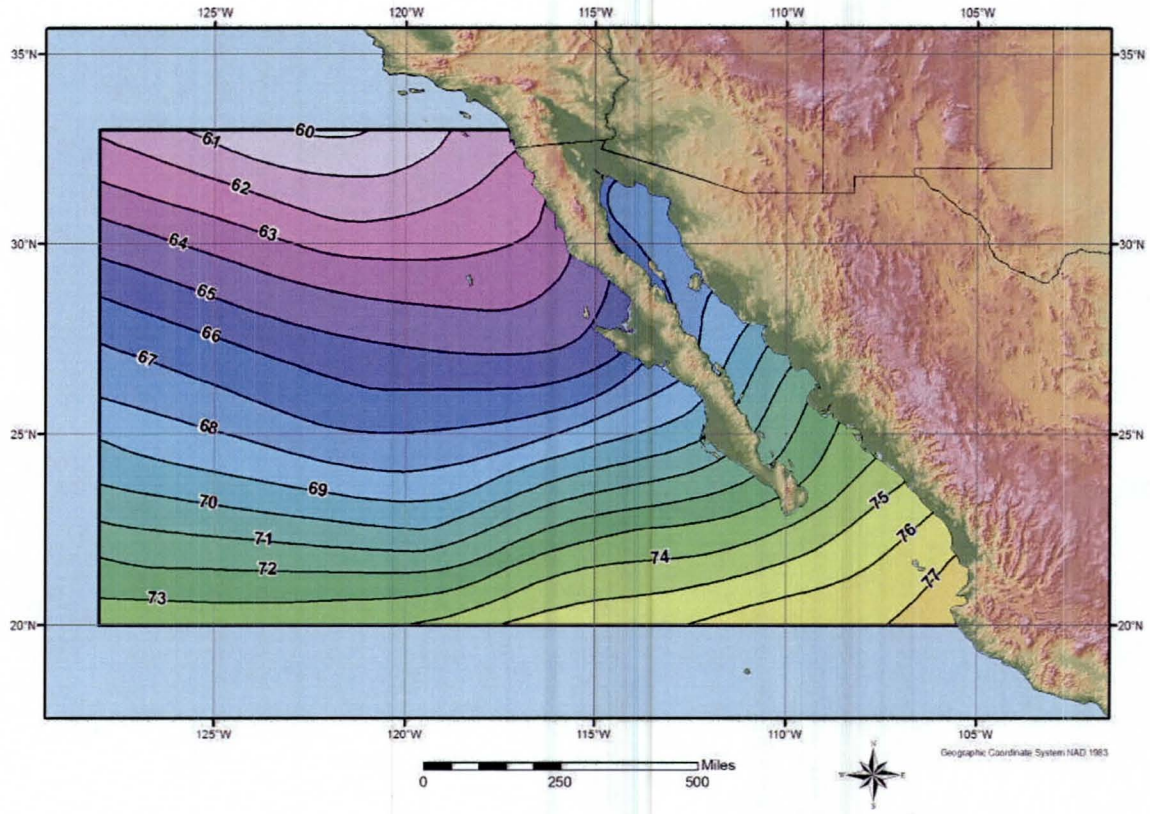
# January 2 Sigma SST °F



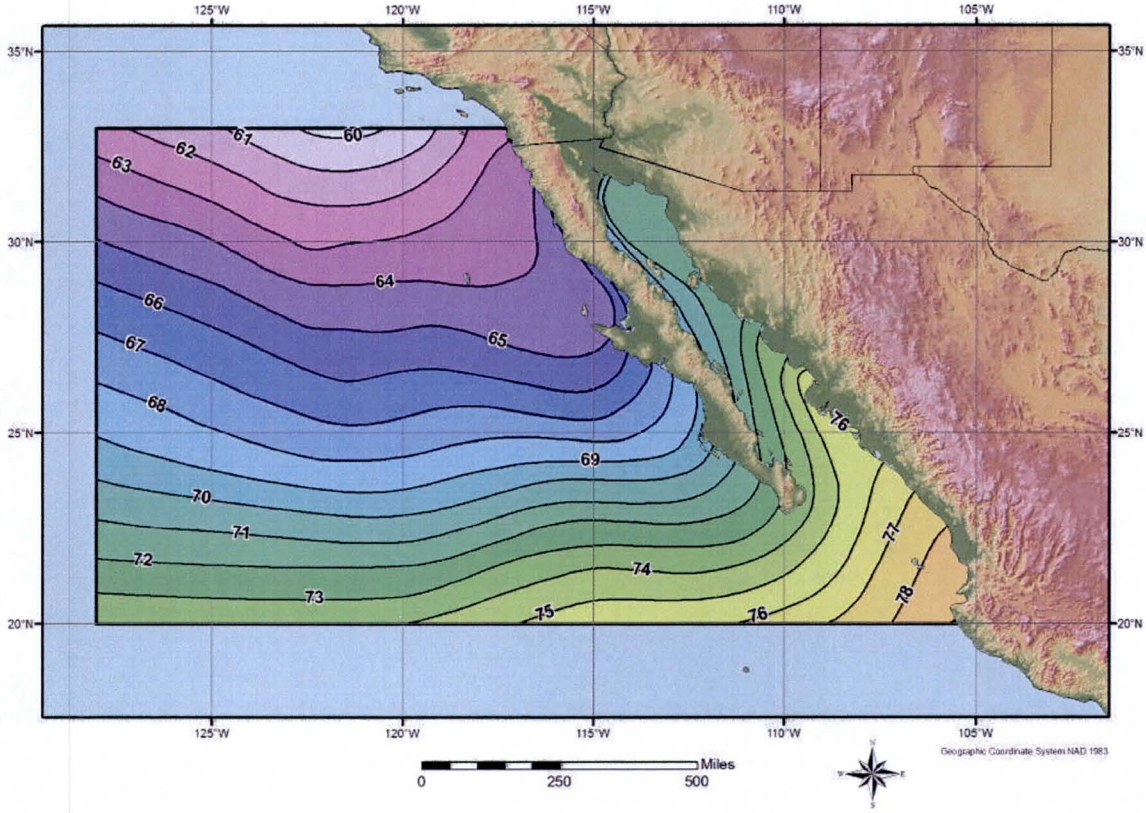
# February 2 Sigma SST °F



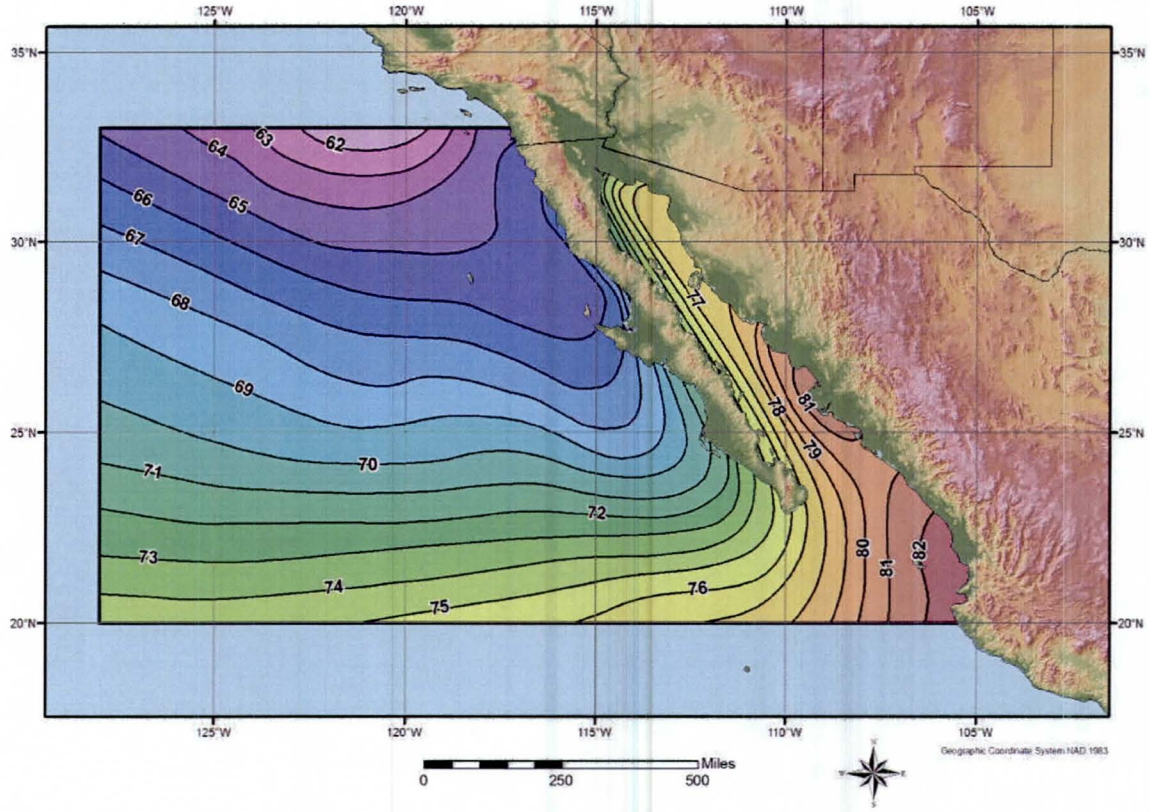
# March 2 Sigma SST °F



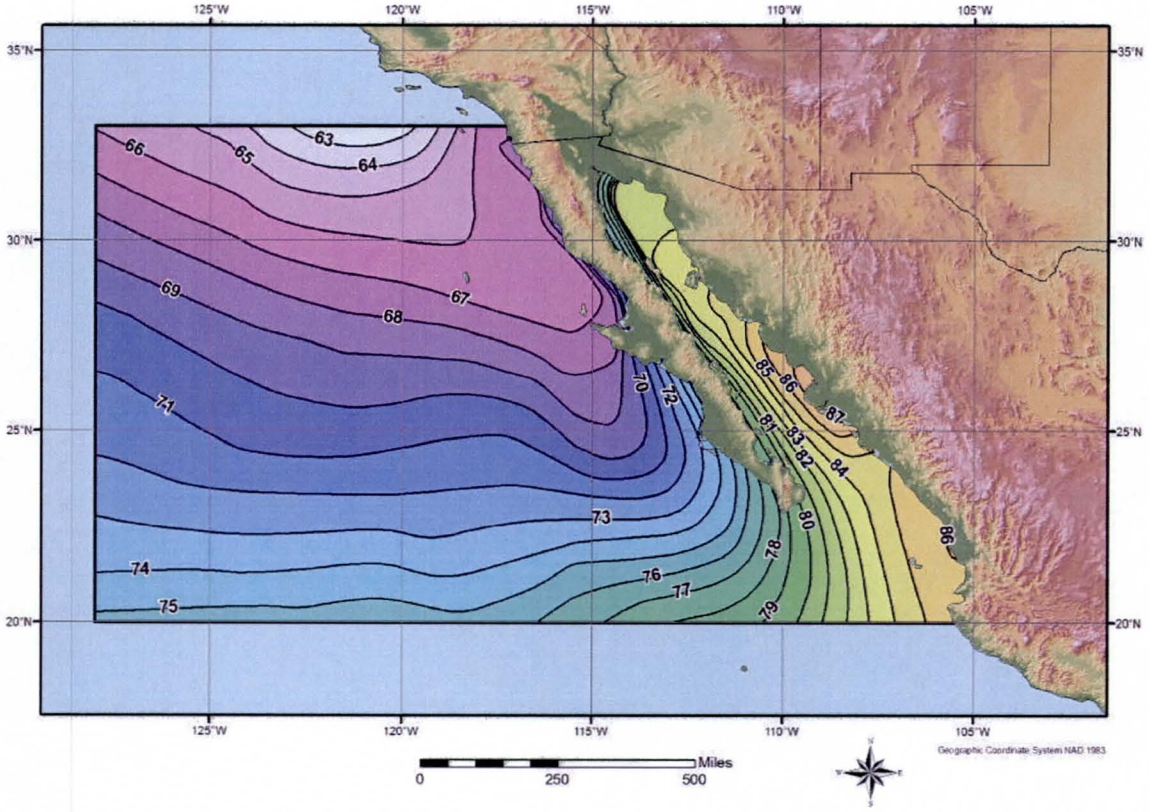
# April 2 Sigma SST °F



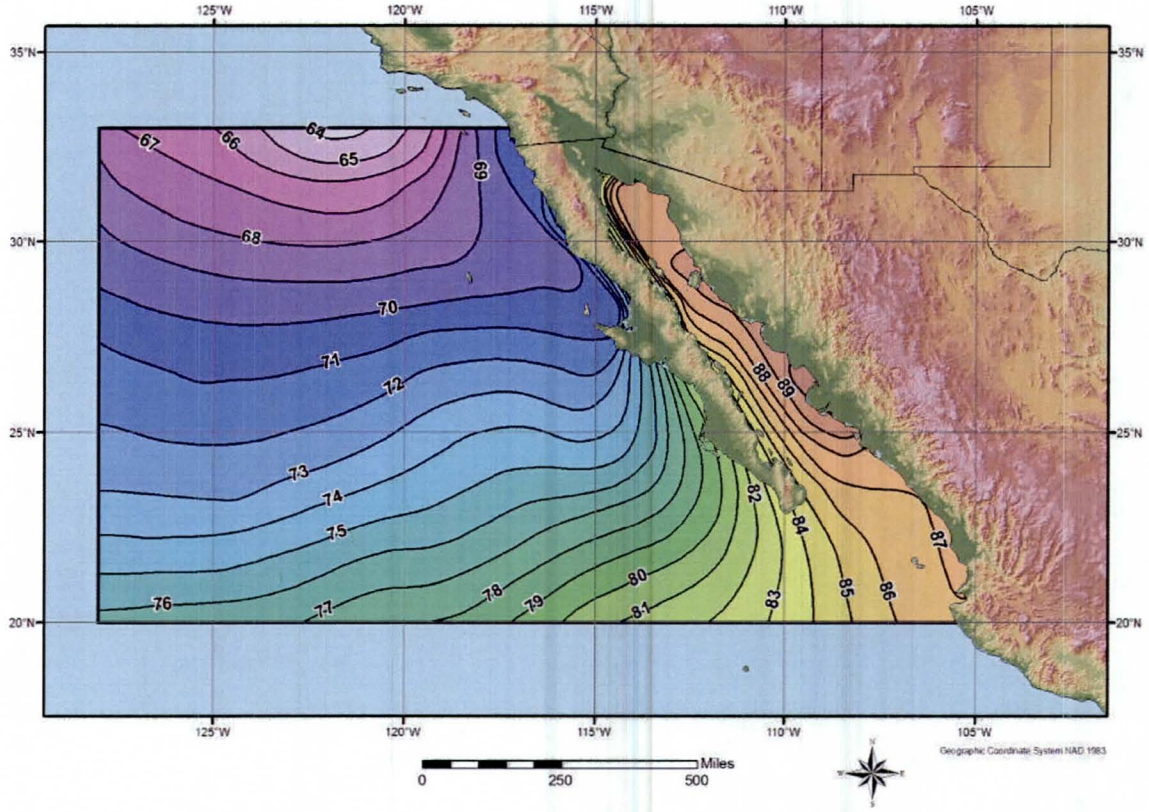
# May 2 Sigma SST °F



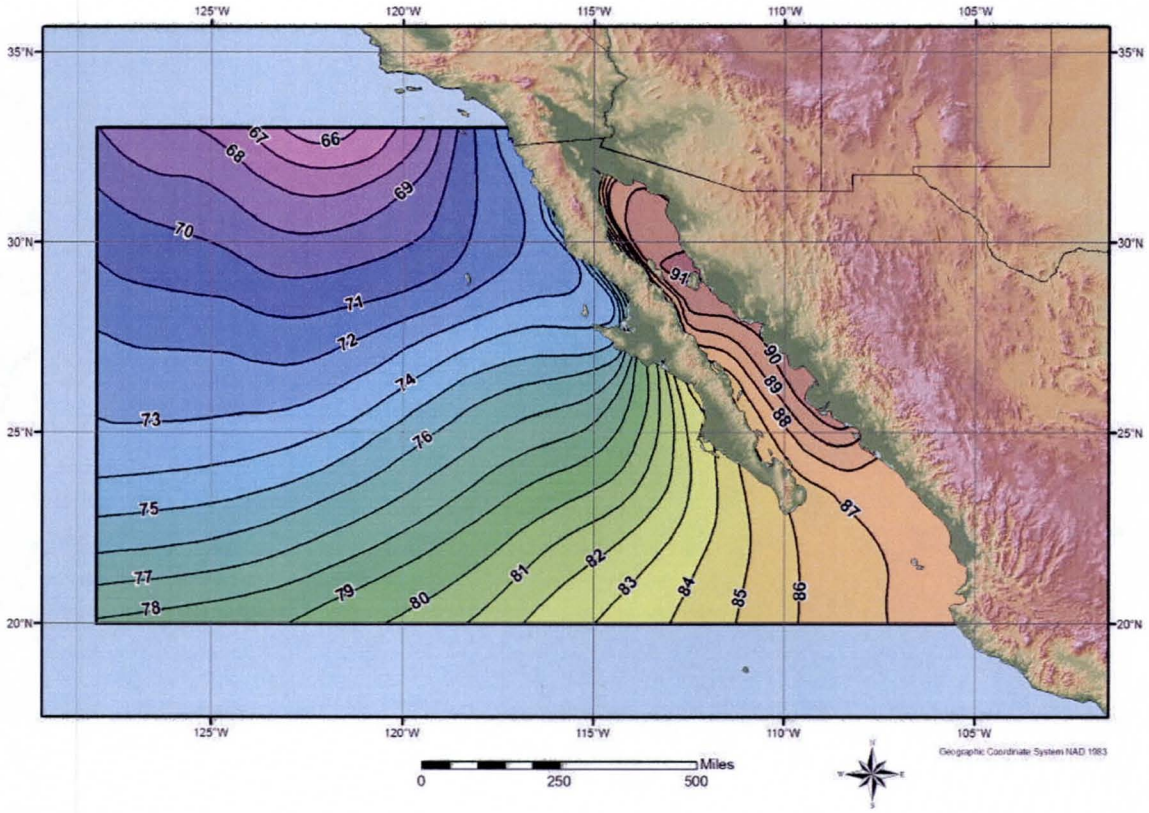
# June 2 Sigma SST °F



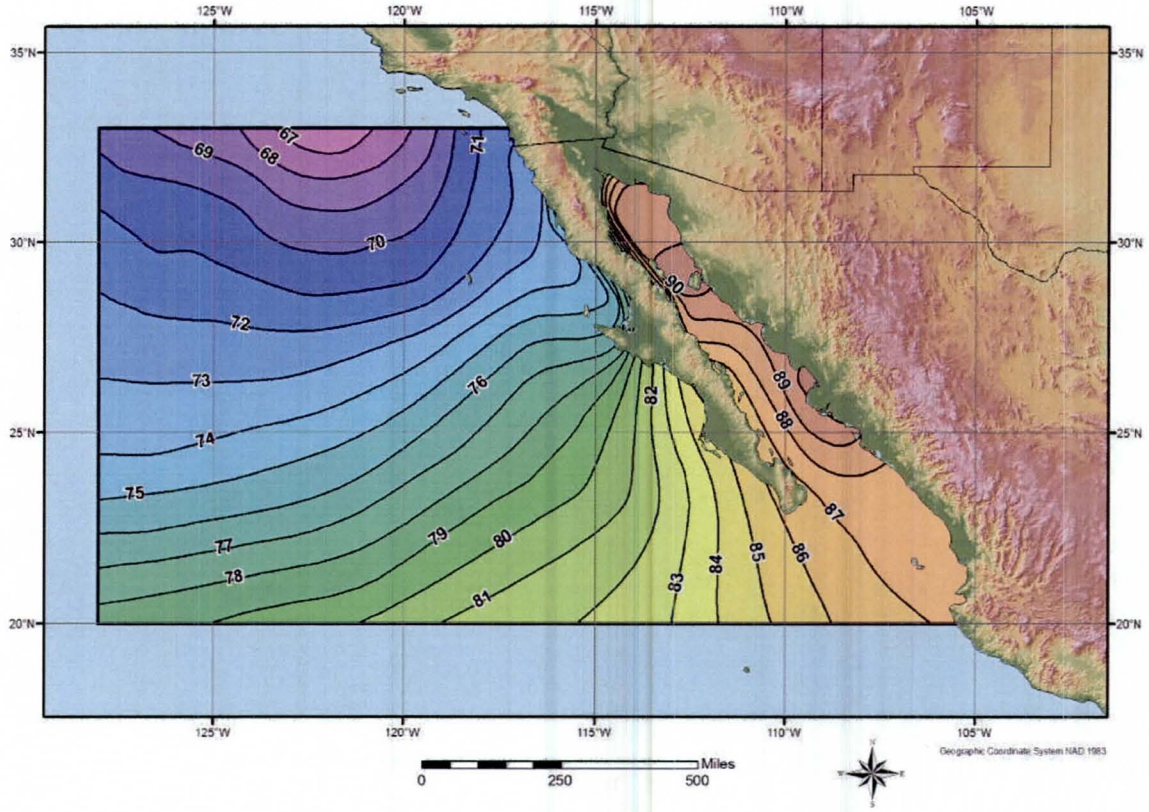
# July 2 Sigma SST °F



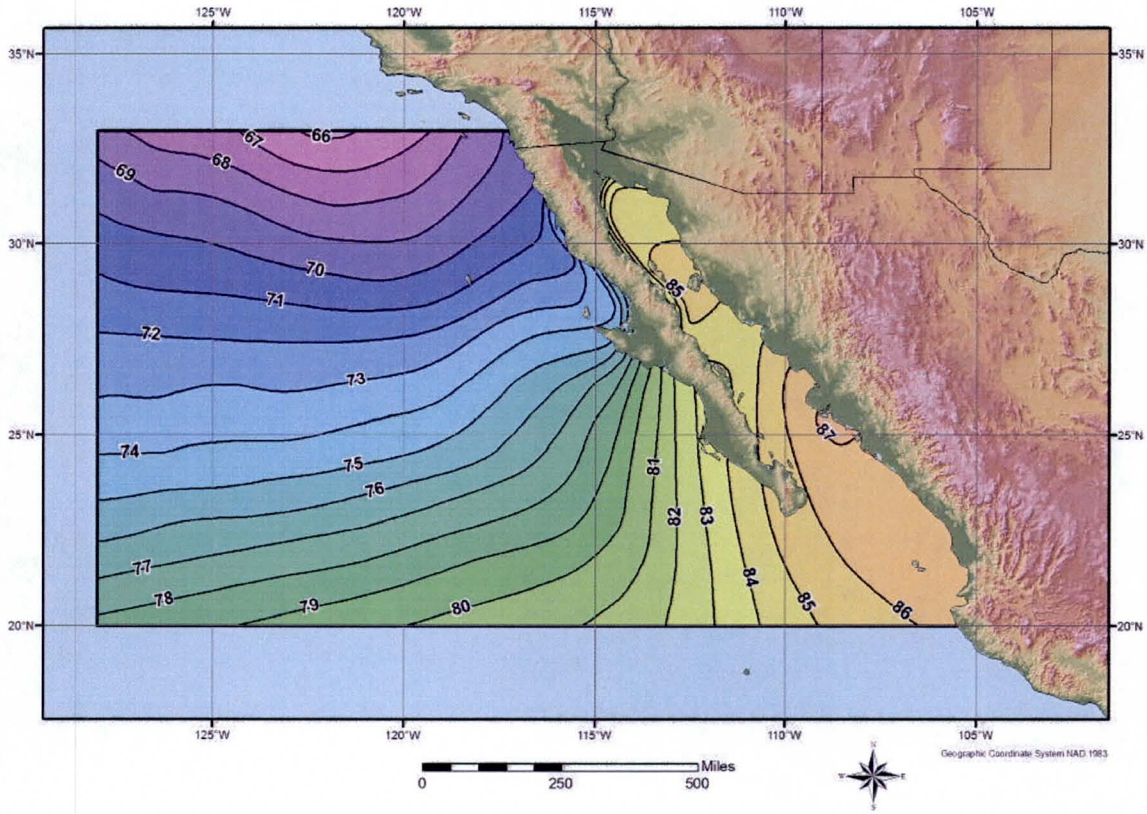
# August 2 Sigma SST °F



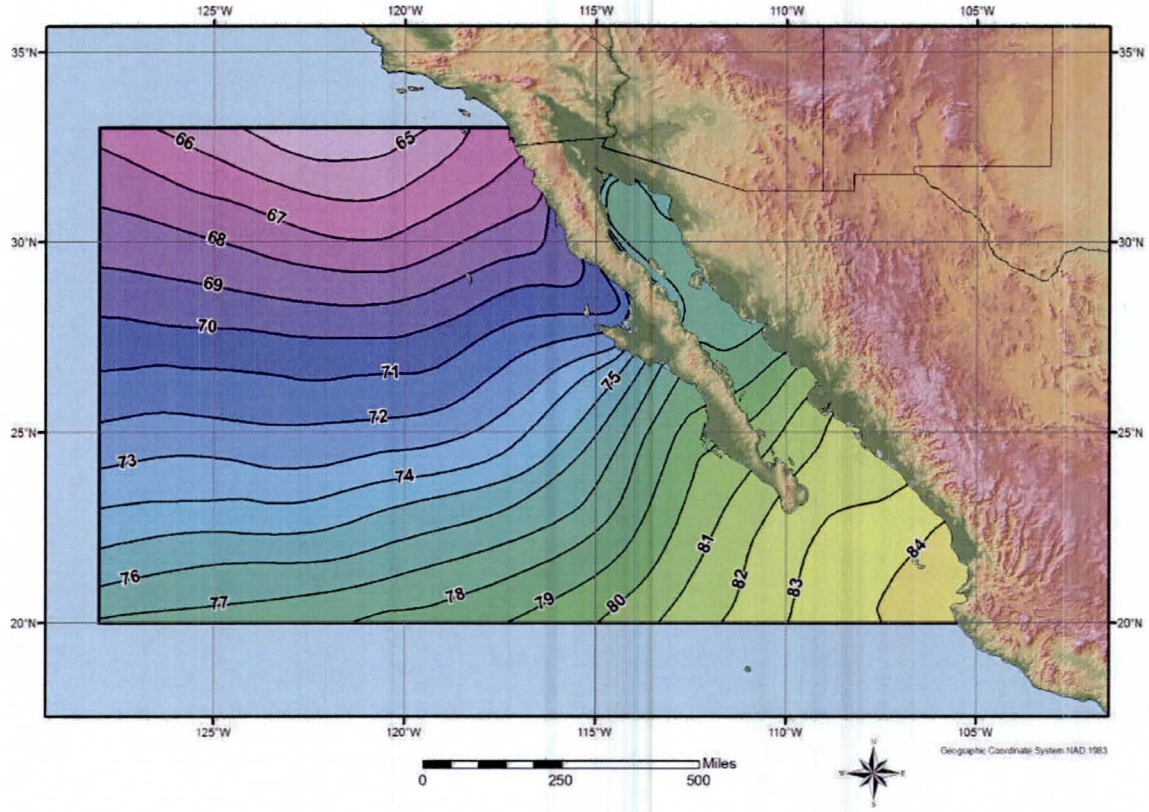
# September 2 Sigma SST °F



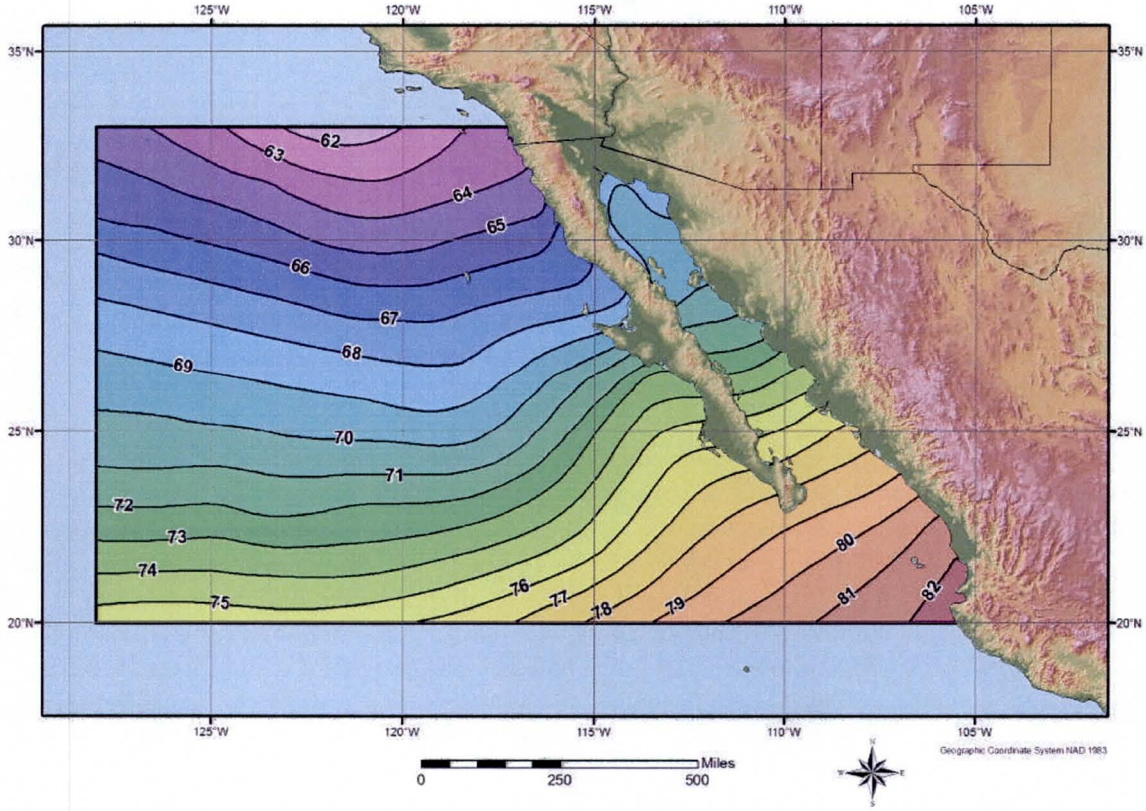
# October 2 Sigma SST °F



# November 2 Sigma SST °F



# December 2 Sigma SST °F



# Appendix B

# Discussion on Average vs Persisting Dew Point and Errors with HMR 49/50 Dew Point Climatologies

A major issue associated with the determination of dew point values are the use by the NWS of persisting dew points. Historically, 12-hour persisting dew point values have been used in the development and storm maximization in the HMRs. A 12-hour persisting dew point is defined as the highest dew point value that persists for a 12 hour period. In reality, it is the lowest of 12 hours of observed dew point values. It should be remembered that the dew point values are supposed to be representative of the moisture in the air mass associated with the rainfall. Using the lowest observed dew point vs. the average dew point may not be appropriate. Further, using a 12-hour duration vs. 3-hour or 24-hour duration more representative of the actual storm event may not be appropriate. NWS has in HMRs 57 and 59 used 3-hour and 12-hour durations but continues to use persisting dew point values. Other site-specific and regional PMP studies have adopted the use of 6-, 12-, and 24-hour dew point values that use average vs. persisting dewpoint values to better quantify the atmospheric moisture associated with the rainfall production (Tomlinson 1993, Tomlinson et al 2007, Tomlinson et al 2008).

HMR 50 (a companion document to HMR 49) provides maximum dew point maps. There are two sets of maps, one for use with local storms and one for use with general storms. Both use 12-hour persisting dew points. An explicit discussion on how these maps were derived as well as the data sets used is not provided nor are discussions related to the differences in the values between local and general storm dew point values. There is a statement made that "considerations of local and general storm situations suggested a difference of 2° to 3°". The authors of HMR 50 did give a high level overview of the processes and stations used to develop their dew point climatology (HMR 50 Section 4.3), but it is greatly lacking in detail and therefore cannot be verified or replicated.

Table 4.1 of HMR 50 Section 4.2.2.1.1 lists the four highest warm season 12-hour 1000-mb dew point situations at Phoenix. AWA attempted to verify these values and then compare the 3-hour, 12-hour and 24-hour average dew point values for the same periods with the 12-hour persisting values using the historic dew point observations at Phoenix. This analysis revealed several issues with the HMR 50 dew point data as presented. The most significant being that we could not replicate the values as presented in the table, either using the actual station data or adjusting the observations to 1000-mb (Table 4.0).

For this comparison, AWA used the hourly observations from the Phoenix Weather Bureau station location for the dates presented in HMR 50 Table 4.1 for a 72-hour period starting

the day previous to the date listed and ending the following day. This ensured all the data that could have potentially been used to determine their 12-hour 1000-mb dew point value were evaluated. Unfortunately, the author's of HMR 50 did not explicitly identify the 12-hour period used to determine the listed dew point value. AWA used the 12-hour period within the 72-hour window that produced the highest 12-hour persisting value since the values listed in HMR 50 Table 4.1 were identified as the highest warm season values at Phoenix. Observational data for Phoenix from AWA's in-house data server (data acquired from the National Weather Service National Climatic Data Center) were used since the Phoenix observational data were not include in HMR 50 for the dates listed in Table 4.1.

The analysis shows that the values listed in Table 4.1 of HMR 50 are not reproducible based on the hourly dew point observations from Phoenix. The values are listed as the highest 12-hour 1000-mb persisting dew points for the dates provided. The HMR 50 Table 4.1 values and results of the AWA analysis are shown in Table B.1 below.

Table B.1 Comparison of HMR 50 Table 4.1 persisting 12-hour 1000-mb dew point values and the AWA analyzed persisting 12-hour 1000-mb dew point values for Phoenix[2]

| HMR 50 Dew Point Date | HMR 50 Dew Point Adjusted to 1000-mb | AWA Dew Point Adjusted to 1000-mb |
|---|---|---|
| August 3, 1951 | 73° | 75.5° |
| August 4, 1954 | 72° | 73.5° |
| August 13, 1955 | 73° | 74.5° |
| August 1, 1964 | 73° | 73.5° |
| August 1, 1980 | 73° | 65.5° |

No consistent bias is observed. From this analysis, it is unknown how the HMR 50 values were determined but using the Phoenix observations for the dates provided, the HMR 50 Table 4.1 values could not be reproduced.

Using the HMR 50 dew point values listed in Table B.1 above, comparisons were made with the HMR 50 maximum dewpoint maps for July and August for both local and general storms, Figures 4.22 – 4.25. The map values for the Phoenix location are approximately 5° F higher than the HMR 50 Table 4.1 values for the local storm and 2.5° F higher for the general storm. The seasonal plot shown in HMR 50 Figures 4.9 does not seem to have all four values from Table 4.1 plotted. Additionally, there are some return frequency values plotted for the 50% and 1% probability levels. These are determined applying the normal distribution to a series of monthly maxima using 21 years of data. There are a couple of issues with this statistical analysis. The first is that maximum dew point observations are not well represented by the normal distribution, GEV currently is considered the best distribution to use. The second is the use of 21 years of data to determine a 1% probability value (one in a hundred years). The curves developed in HMR 50 for other individual stations were developed similar to the plot in Figure 4.9 for Phoenix using both maximum observed and return frequency values. However, HMR 50 states that "An iterative process was carried out until realistic and compatible single station

[2] The date of 8/1/1980 listed in HMR 50 Table 4.1 appears to be in error. In the text describing the table, the author's of HMR 50 mention August 1, 1964 as the appropriate date and after analyzing the dew point observations for the two dates, it seems reasonable that 1964 is the appropriate date to use.

curves and regional analyses were completed." Therefore it is not surprising that the adopted curves do not consistently represent the maximum dew point data used in the analyses. Given that adopted curves for the seasonal local storm maximum dew point were developed subjectively (see previous quote from HMR 50), a comparison of the August maximum local storm value from Figure 4.9 was compared to the value from the August local storm map, Figure 4.24, for the Phoenix location. The map value is 78° F whereas the curve value is 76° F. Somewhere between the adopted local storm curve in Figure 4.9 and the construction of the maximum dew point local storm map, the maximum dew point value for Phoenix increased 2° F. It is important to note that a change of 1° F in the dew point value equates to approximate a 5% change in the maximization factor for individual storms. Since the maximization factor is a linear multiplier in the PMP determination process, the resulting change in rainfall amounts is 5%. Any errors in the development of the maximum dew point maps reflect directly on the reliability of the resulting PMP values.

A comparison was completed using this same data set used to evaluate the maximum dew point values in HMR 50 Table 4.1 to determine the 3-hour, 12-hour, and 24-hour *average* dew point values (these values have been used in the most recent site-specific PMP reports). This analysis compared variable duration average dew point values to the HMR 50 12-hour 1000-mb persisting and AWA 12-hour 1000-mb persisting dew points. Tables B.2A-B.2C show the difference between the HMR 50 12-hr 1000-mb persisting dew point values versus the 3-hour, 12-hour, and 24-hour average dew points.

Table B.2A Comparison of HMR 50 12-hour 1000-mb ***persisting*** dew point versus AWA analyzed 3-hour ***average*** 1000-mb dewpoints

| HMR 50 Dew Point Date | HMR 50 Dew Point Adjusted to 1000-mb | AWA 3-hour Average Dew Point Adjusted to 1000-mb |
|---|---|---|
| August 3, 1951 | 73° | 77.5° |
| August 4, 1954 | 72° | 76.5° |
| August 13, 1955 | 73° | 77.5° |
| August 1, 1964 | 73° | 76.5° |

Table B.2B Comparison of HMR 50 12-hour 1000-mb ***persisting*** dew poin versus AWA analyzed 12-hour ***average*** 1000-mb dewpoints

| HMR 50 Dew Point Date | HMR 50 Dew Point Adjusted to 1000-mb | AWA 12-hour Average Dew Point Adjusted to 1000-mb |
|---|---|---|
| August 3, 1951 | 73° | 76.5° |
| August 4, 1954 | 72° | 75° |
| August 13, 1955 | 73° | 76.5° |
| August 1, 1964 | 73° | 75.5° |

Table B.2C Comparison of HMR 50 12-hour 1000-mb ***persisting*** dew point versus AWA analyzed 24-hour ***average*** 1000-mb dewpoints

| HMR 50 Dew Point Date | HMR 50 Dew Point Adjusted to 1000-mb | AWA 24-hour Average Dew Point Adjusted to 1000-mb |
|---|---|---|
| August 3, 1951 | 73° | 75.5° |
| August 4, 1954 | 72° | 74° |
| August 13, 1955 | 73° | 75° |
| August 1, 1964 | 73° | 75.5° |

Tables B.3A-B.3C show the difference between the AWA analyzed 12-hour 1000-mb persisting dew point values versus the 3-hour, 12-hour, and 24-hour average dew points.

Table B.3A Comparison of AWA 12-hour 1000-mb ***persisting*** dew point versus AWA analyzed 3-hour ***average*** 1000-mb dewpoints

| HMR 50 Dew Point Date | AWA Dew Point Adjusted to 1000-mb | AWA 3-hour Average Dew Point Adjusted to 1000-mb |
|---|---|---|
| August 3, 1951 | 75.5° | 77.5° |
| August 4, 1954 | 74° | 76.5° |
| August 13, 1955 | 74.5° | 77.5° |
| August 1, 1964 | 74° | 76.5° |

Table B.3B Comparison of AWA 12-hour 1000-mb ***persisting*** dew point versus AWA analyzed 12-hour ***average*** 1000-mb dewpoints

| HMR 50 Dew Point Date | AWA Dew Point Adjusted to 1000-mb | AWA 12-hour Average Dew Point Adjusted to 1000-mb |
|---|---|---|
| August 3, 1951 | 75.5° | 76.5° |
| August 4, 1954 | 74° | 75° |
| August 13, 1955 | 74.5° | 76.5° |
| August 1, 1964 | 74° | 75.5° |

Table B.3C Comparison of AWA 12-hour 1000-mb ***persisting*** dew point versus AWA analyzed 24-hour ***average*** 1000-mb dewpoints

| HMR 50 Dew Point Date | AWA Dew Point Adjusted to 1000-mb | AWA 24-hour Average Dew Point Adjusted to 1000-mb |
|---|---|---|
| August 3, 1951 | 75.5° | 75.5° |
| August 4, 1954 | 74° | 74° |
| August 13, 1955 | 74.5° | 75° |
| August 1, 1964 | 74° | 75.5° |

In all cases, the average dew point values are higher than the 12-hour persisting values given by the author's of HMR 50 and in all but two of the 24-hour values analyzed by AWA. These differences are most pronounced at the 3-hour duration and become smaller from 12-hours to 24-hours. This same occurrence was found and adjusted for in previous site-specific PMP studies (Tomlinson 1993, Tomlinson et al 2007, Tomlinson et al 2008) and referenced but not implemented in HMR 57. The authors of the most recent HMRs (HMR 57 and HMR 59)

recognized that using a 12-hour persisting dew point value may not accurately represent the moisture that fed the storm event being analyzed. This is especially true for local storms where the moisture tongue which fed the storm was of short duration and/or occurred within a limited spatial extent. Therefore, using the average dew point values for periods of time consistent with the rainfall duration better represents the storm environment and as such, should be the preferred way to analyze the moisture associated with a storm event and develop storm maximization values.

It is very important to have confidence that the climatological maximum dew point maps be reliable in providing appropriate dew point values for use in both the maximization and transpositioning process. For some recent PMP studies, e.g. the statewide PMP study for Nebraska (Tomlinson et al 2008), return frequency analyses of maximum average dew point values for various durations have been completed. These return frequency maps for durations appropriate for various storm types provide reliable climatological maps for use in PMP studies.

# Appendix C

## Procedure for using Dew Point Temperatures and Sea Surface Temperatures (SSTs) for Storm Maximization and Transposition

Maximum dew point temperatures (hereafter referred to as dew points) have historically been used for two primary purposes in the PMP computation process:

1. To increase the observed rainfall amounts to a maximum value based on a potential increase in atmospheric moisture available to the storm.
2. To adjust the available atmospheric moisture to account for any increases or decreases associated with the maximized storm potentially occurring at another location within the transposition limits for that storm.

HMR and WMO procedures for storm maximization use a representative storm dew point as the parameter to represent available moisture to a storm. Prior to the mid-1980s, maps of maximum dew point values from the *Climatic Atlas of the United States*, Environmental Data Services, Department of Commerce (1968), were the source for maximum dew point values. HMR 55 published in 1984 updated maximum dew point values for a portion of the United States from the Continental Divide eastward into the central plains. A regional PMP study for Michigan and Wisconsin produced return frequency maps using the L-moments method (Tomlinson 1993). The Review Committee for that study included representatives from NWS, FERC, Bureau of Reclamation, and others. They agreed that the 50-year return frequency values were appropriate for use in PMP calculations. HMR 57 was published in 1994 and HMR 59 in 1999. These latest NWS publications also update the maximum dew point climatology but use maximum observed dew points instead of return frequency values. This study used an updated sea surface temperature (SST) climatology for use in storm maximization and transpositioning.

The procedure for determining a storm representative dew point begins with the determination of the inflow wind vector (direction and magnitude) for the air mass that contains the atmospheric moisture available to the storm. Beginning and ending times of the rainfall event at locations of the most extreme rainfall amounts are determined using rainfall mass curves from those locations.

The storm inflow wind vector is determined using available wind data and the HYSPLIT trajectory model. The HYSPLIT trajectory model data are available back to 1948. Use of these reanalysis fields provides much improved reliability in the determination of the storm inflow wind vectors. The program is available through an online interface through the Air Resources

Laboratory section of NOAA and is called HYSPLIT. Users are able to enter in specific parameters that then output a wind inflow from a starting point going backwards (or forwards) for a specified amount of time. Users can define variables such as the starting point (using latitude and longitude or a map interface), the date and time to start the trajectory, the length of time to run the trajectory, and the pressure level at which to delineate the inflow vector. Figures C.1 to C.3 show example inflow vectors generated by HYSPLIT at three levels; 700mb, 850mb, surface for the Harquahala Mountain-Hurricane Nora September 1997 extreme rainfall event. Each of these three levels were evaluated for each storm that occurred from 1948 through present. The data generated from the HYSPLIT runs is then used in conjunction with standard methods to help delineate the source region of the air mass responsible for the storm precipitation.

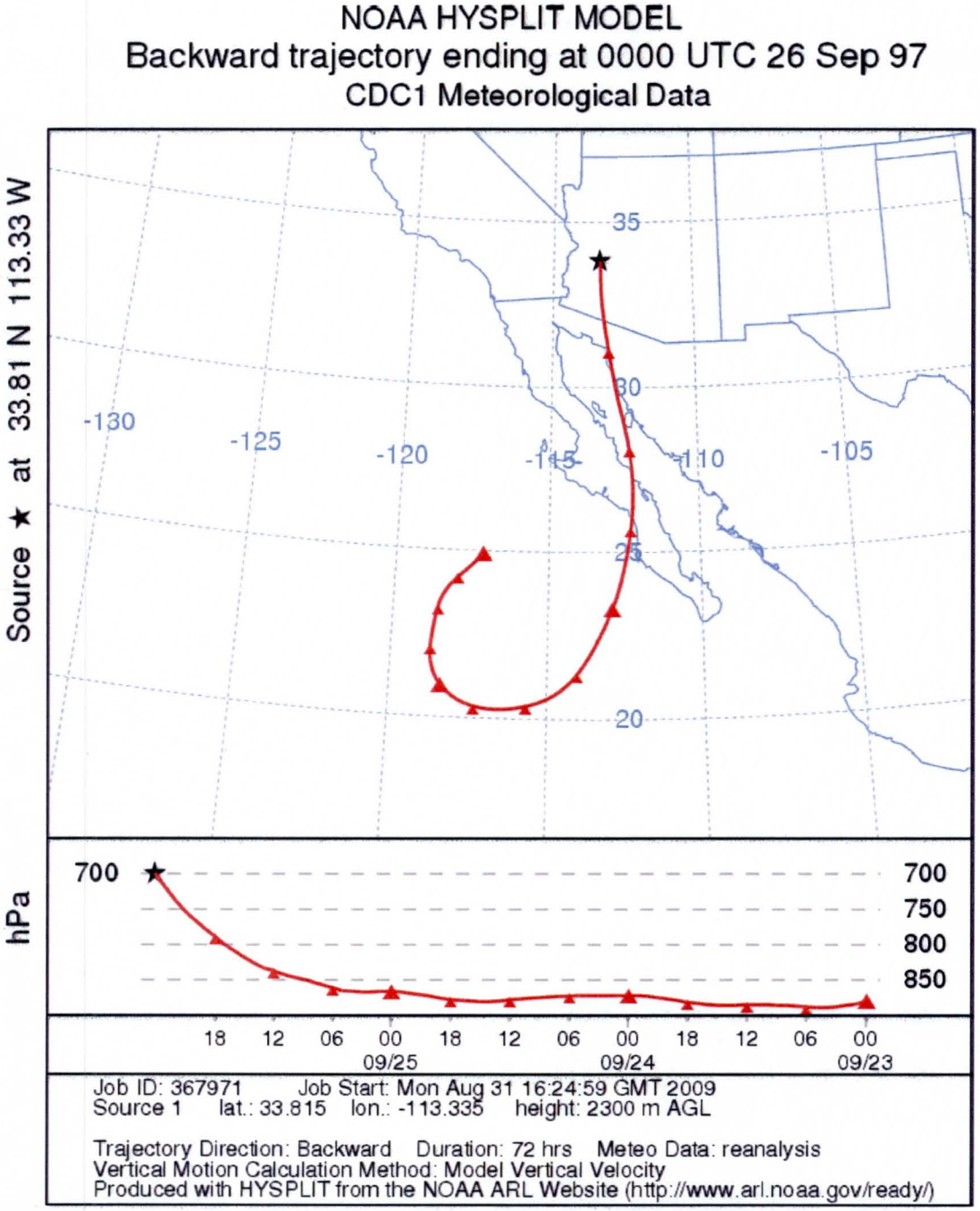



Figure C.1 HYSPLIT model results for 700mb Hurricane Nora September 1997

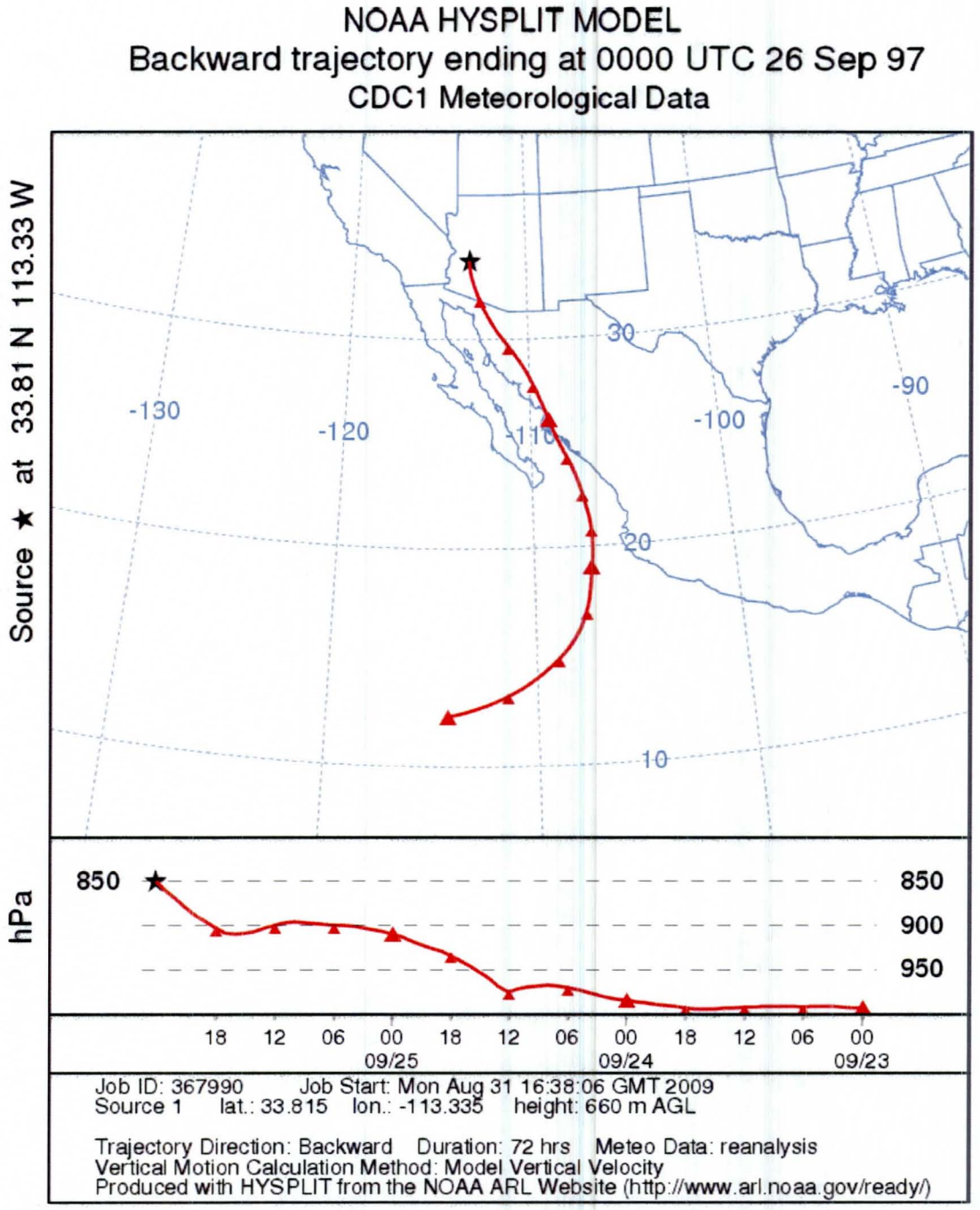



Figure C.2 HYSPLIT model results for 850mb Hurricane Nora September 1997

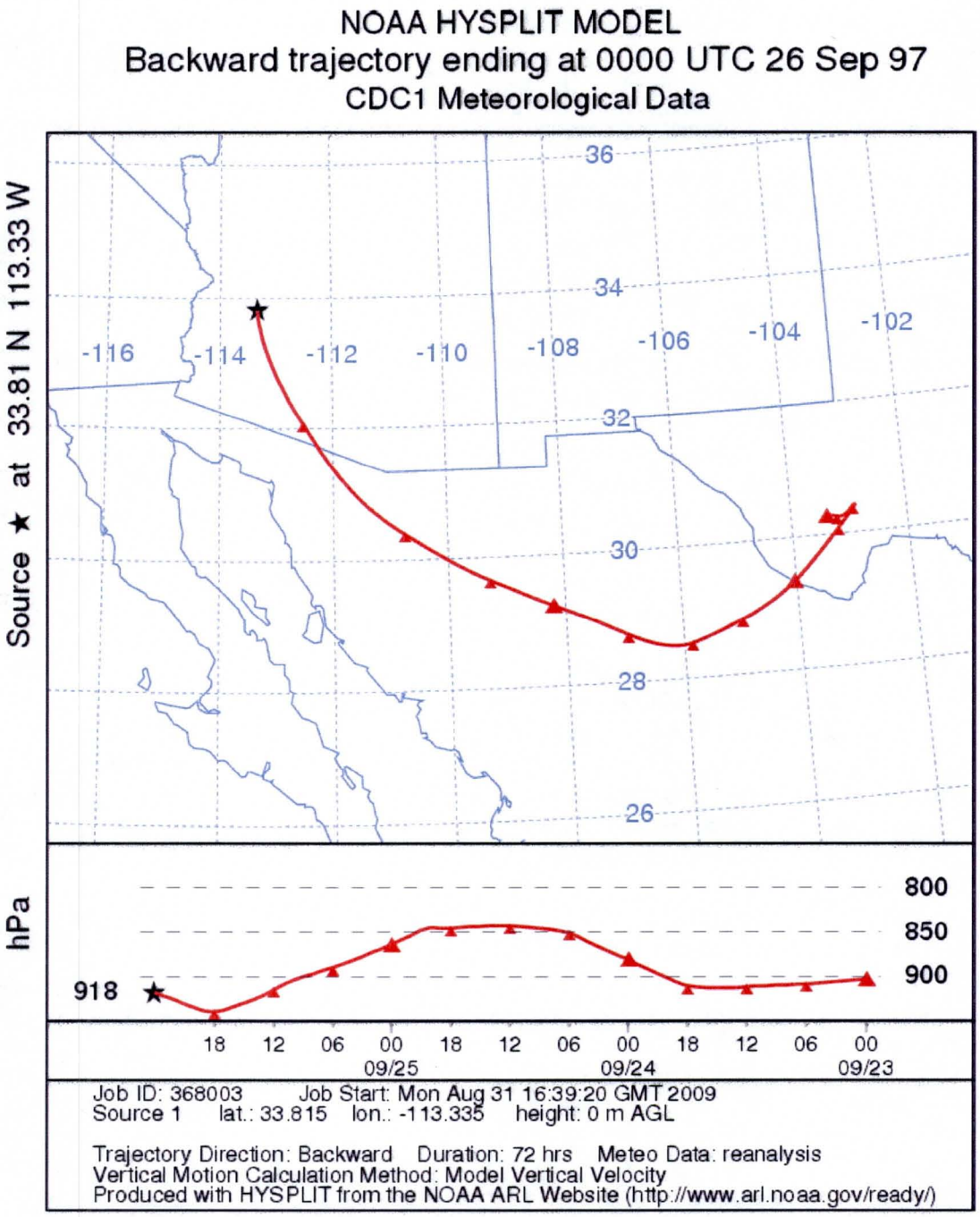



Figure C.3 HYSPLIT model results for surface Hurricane Nora September 1997

For moisture source regions over the oceans, dew point observations are not generally available with the exception of occasional ship reports. NWS has adopted a procedure for using sea surface temperatures (SSTs) as substitutes for dew points over the ocean. The best available observations are used to determine the storm representative dew point. This could be a dew

point values from a ship report, SST observation or daily SST analysis. The value used as the maximum SST value in PMP calculations is determined using the SST which is two standard deviations warmer than the mean SST. This provides a value for the maximum SST that has a probability of occurrence of about 0.05, i.e., about the 20-year return frequency value.

Using SSTs for in-place maximization and storm transpositioning follows a similar procedure to that used with dew points. The HYSPLIT trajectory model provide a significant improvement in determining the inflow wind vector as compared to older methods. This is particularly significant when extrapolating coastal wind observations over long distances to reach warmer ocean regions.

The inflow wind vector is followed upwind until a location is reached that is at the sea surface. A point which represents a blend of the 850mb and 700mb trajectories that have been in contact with the sea surface and/or boundary is chosen as representative to contributing the moisture to the storm. Once this general location is determine, the location of the storm representative SST was determined when the SSTs are changing less than 1° F in a half-degree latitude and/or longitude following the inflow upwind. This procedure was developed to identify the homogeneous (or near homogeneous) region of SSTs associated with the atmospheric moisture source for the storms. The value from the SST daily analysis for that location was used for the storm representative SST, which was used in place of the storm representative dew point in the maximization procedure.

Timing is not as critical for inflow wind vectors extending over the oceans since SSTs change very slowly with time compared to dew point values over land. What is important is the changing wind direction, especially for situations where there was curvature in the wind fields as the inflow wind vector was followed upwind. Any changes in wind curvature and variations in timing are inherently captured in the HYSPLIT model reanalysis fields, thereby eliminated another subjective and often unknown parameter.

The value for the maximum SST was determined using the mean plus two sigma (two standard deviations warmer than the mean) SST for that location (see discussion on 2-sigma SST in Section 5.1.3). The storm representative SST and the mean plus 2-sigma SST were used in the same manner as the storm representative dew point and the maximum dew point in the maximization and transpositioning procedure

The storm representative dew point determined from the SST observations is inherently corrected to the 1000mb level.

The procedure that computes the in-place maximized rainfall for a storm provides an estimate of the maximum amount of rainfall that could have been produced by the same storm at the same location if the maximum amount of atmospheric moisture had been available. This procedure requires that a maximum value for the storm representative dew point be determined. The maximum dew point value is selected at the same location where the storm dew point was determined using a maximum dew point climatology. The precipitable water in the atmosphere is determined using the storm representative and maximum dew point values. Precipitable water

is defined in this study as the total amount of moisture in a column of the atmosphere from sea level to 30,000 feet, assuming a vertically saturated atmosphere. Values of atmospheric precipitable water are determined using the moist pseudo-adiabatic assumption, i.e. assume that for the given 1000-mb dew point value, the atmosphere holds the maximum amount of moisture possible. The ratio of the precipitable water associated with the maximum 1000mb dew point to the precipitable water associated with the 1000-mb storm representative dew point is the maximization factor.

For example, consider the following case:

| | |
|---|---|
| 1000mb storm representative dew point: | 72°F |
| 1000mb maximum dew point: | 76°F |
| Precipitable water associated with a 1000mb dew point of 72°F: | 2.47 inches |
| Precipitable water associated with a 1000mb dew point of 76°F: | 2.99 inches |

Maximization factor: PW(76°F)/PW(72°F) = 2.99"/2.47" = 1.21

For transpositioning, the storm inflow vector (determined by connecting the storm representative dew point location with the location of maximum rainfall) is moved to the basin location being studied. The new location of the upwind end of the vector is determined. The maximum dew point associated with that location is then selected using the same maximum dew point climatology map used for in-place maximization. The transpositioning factor is the ratio of the precipitable water associated with the maximum 1000mb dew point value at the transpositioned location to the precipitable water associated with the maximum 1000mb dew point for the storm representative dew point location.

An example is provided.

| | |
|---|---|
| 1000mb maximum dew point at the storm representative dew point location: | 76°F |
| 1000mb maximum dew point at the transpositioned location: | 74°F |
| Precipitable water associated with a 1000mb dew point of 76°F: | 2.99 in |
| Precipitable water associated with a 1000mb dew point of 74°F: | 2.73 in |

Transposition factor: PW(74°F)/PW(76°F) = 2.73"/2.99" = 0.91

# Appendix D

## Procedure for Deriving PMP Values from Storm Depth-Area-Duration (DAD) Analyses

Although PMP rainfall amounts are theoretical values, there currently is no theoretical method for determining the values. The accepted procedure for determining PMP values begins with the largest identified historic observed rainfall amounts and applies the following procedures:

1. Increase the rainfall amounts to some maximized value (in-place maximization),
2. Adjust the "maximized" rainfall amounts to the potential situation where the historic storm occurs over the basin being studied (transposition),
3. Adjust the "maximized transpositioned" rainfall amounts for elevation changes.

The procedure begins with the depth-area-duration (DAD) analysis from the largest of the identified storms that have occurred over regions that are climatologically and topographically similar to the basin being studied. Identification of the largest rainfall events is relatively straightforward and is accomplished by identifying the largest station rainfall amounts and correlating the dates among adjacent stations to identify the areal extent of the heavy rainfall and the storm period. The DAD for each storm is computed using isohyetal analyses for each hour during the storm and determining the largest rainfall totals for each duration of interest over each area size of interest.

The US Army Corps of Engineers, the Bureau of Reclamation and the National Weather Service have performed storm studies and produced DADs for many storms. This study reviewed additional weather station data to identify extreme rainfall storms that had not been identified and studied previously. All storms used in this study are being analyzed with DADs for the first time[3]. This is because HMR 49 was the last HMR to not use a storm based DAD approach to derive PMP values. These DADs quantify the rainfall associated with each storm event, providing the largest rainfall amounts for each of the durations and area sizes used in this study.

Identification of storms that can be transpositioned to the White Tanks #4 drainage basin is largely based on subjective judgment. For a storm to be transpositionable, it should have occurred over a region that is climatologically and topographically similar to the basin being studied. Storms generally should not be transpositioned across significant topographic features

[3] A Bureau of Reclamation report "Determination of an Upper Limit Design rainstorm for the Colorado River Basin Above Hoover Dam (1990) did produce DADs for thirteen storm events considered in the statewide study. Further, HMR 59 includes DAD values for two storm used in the statewide study.

or into different climate regions (WMO, 1986). The largest rainfall events identified in the storm search generally occurred over locations south of the Mogollon Rim to the southeastern deserts of California and eastward to Tucson and the southern desert of Arizona. These storms usually had similar topographic features between the location of maximum rainfall and the moisture source for the storm.

Maximization of the storm DADs involves use of dew point temperatures and in one case the SSTs associated with the air mass that provided the moisture for the production of rainfall by the storm dynamics. To determine the storm dew point, winds coming into the storm are evaluated using the HYSPLIT trajectory model and hourly surface observations. The direction of the wind provides the direction to the region from which the air mass came and the speed provides the rate at which the air mass was transported into the storm. The procedure is to go upwind along the inflow wind direction until a position is found where which best represents the moisture source location. This location is chosen to ensure that the data represents the available moisture which can be converted into precipitation as part of the storm environment based on the dew point/SST values. Using this location, an inflow vector (direction and distance) is determined. The dew point/SST data are used to determine the dew point temperature for the storm. This dew point value is used together with some maximum dew point value to determine a maximization factor for the storm.

The maximum dew point represents the greatest amount of atmospheric moisture that potentially could have been available to the storm. Using a maximum dew point climatology (2-sigma SST temperatures at the same location), the maximum dew point is determined for the same location as was selected for the storm dew point. Precipitable water associated with each of these dew point values is used to determine the in-place maximization factor. This procedure assumes that the storm dynamics of the largest historic storms are very close to being as efficient as is physically possible and are representative of a PMP storm. The assumption is also made that if additional atmospheric moisture had been available to the storm, the storm rainfall would have increased by a ratio directly proportional to the increase in atmospheric moisture. Hence, once a dew point associated with the storm air mass is determined, the moisture in the actual storm air mass, referred to as the "in-place" storm precipitable water (storm PW), can be quantified. The moisture in an air mass with the maximum dew point for the same location, referred to as maximum precipitable water (maximum PW) can also be quantified. The ratio of maximum PW to storm PW is the in-place maximization factor.

The equation for this computation is as follows:

In-place maximization factor = (in-place maximum PW)/(in-place storm PW)

Unless the actual storm occurred within the boundaries of the basin under investigation, a transpositioning procedure is followed to adjust the maximized storm DAD for "moving" the storm to the study basin. i.e. determine the maximum potential rainfall if the same storm were to occur over the study basin. The storm inflow vector is moved to the study basin location and the location at the upwind end of the vector (the end away from the basin) is determined. Using that location and the maximum dew point (SST) climatology, a transpositioned maximum dew point

value is selected. The precipitable water values associated with the in-place maximum dew point and the transpositioned maximum dew point are used to compute the transposition factor.

The equation for this computation is as follows:

Transposition factor = (transpositioned maximum PW)/(in-place maximum PW)

For situations where there are changes in the elevations between the original storm location and the study basin, a procedure is applied to account for the loss of atmospheric moisture. However, for local convective storms used in the White Tanks #4 analysis, not elevation adjustments are considered below 6000 feet following guidance from HMRs 57 and 59. The adjustment factor uses precipitable water contained in the moisture maximized atmosphere above the basin elevation, i.e., the moisture contained in the entire depth of the moisture maximized atmosphere, minus the moisture contained in the moisture maximized atmosphere below the basin elevation. Also used is the precipitable water contained in the moisture maximized atmosphere above the storm elevation. The elevation adjustment factor is determined by computing the ratio of precipitable water in the moisture maximized atmosphere above the basin to the precipitable water in the entire depth of the moisture maximized atmosphere.

The equation for this computation is as follows:

For conditions where maximization, transpositioning and barrier depletion are all applied to a storm, the factors can be combined.

Total adjustment factor = (in-place maximum PW)/(in-place storm PW)
*Multiplied by*
(transpositioned maximum PW)/(in-place maximum PW)
*Multiplied by*
[(transpositioned maximized PW)/(transpositioned maximized PW)

Multiplication of these terms leads to a simplified computation where all the required adjustments are implicit in a single term.

Total adjustment factor =
(transpositioned maximized PW) x (in-place storm PW)

The total adjustment factor that includes maximization, transposition, and barrier moisture depletion (if applicable) uses only two computed values:

1) the maximum atmospheric moisture available to a historic storm if it were to occur within the study basin. This air mass is assumed to contain the maximum amount of moisture for the basin location that could be transported over any intervening barrier(s).
2) the atmospheric moisture available for the historic storm at the location where it occurred.

These adjustment factors are applied as a linear multiplier for each storm for all rainfall amounts in the storm DAD.

For this study, all computations associated with historic storms are computed at the 1000-mb level (approximately sea level). The elevation of the maximum rainfall location is used as the storm elevation. An adjustment is applied to the storm moisture to account for the elevation of the storm above sea level. For example, if the greatest rainfall occurred at an average elevation of 500 feet, the total atmospheric moisture (500 to 30,000 feet) is increased by the amount of moisture between sea level and 500 feet.

As an example, the DAD from the Harquahala Mountain-Nora-1997 SPAS 1184 storm center is transpositioned, maximized, and elevation adjusted for the basin. The following are values for the parameters used in computing the adjustments:

| | |
|---|---|
| Storm representative dew point: | 73.5.0° F |
| In-place maximum dew point: | 76.5° F |
| Transpositioned maximum dew point : | 76.5° F |
| Basin average elevation: | 3650' |
| Effective barrier height, South/Southeast inflow: | 0' |
| Storm elevation: | 4900' |

| | |
|---|---|
| Total atmospheric precipitable water for 73.5° F: | 2.67" |
| Total atmospheric precipitable water for 76.5° F: | 3.07" |
| Adjustment for storm elevation, 1000mb to 4900' at 73.5°F: | 1.02" |
| Adjustment for storm elevation, 1000mb to 4900' at 76.5°F: | 1.13" |
| Adjustment for basin elevation, 1000mb to 3650' at 76.5°F: | 0.88" |
| Adjustment for effective barrier, 1000mb to 3650' at 76.5°F: | 0.88" |

Total adjustment factor = (In-place max factor) (transpositioned to basin factor) (barrier adjustment factor

= (3.07-1.02 / (2.67-1.13) (3.07- 0.88 / 3.07-1.02) (3.07- 0.88 / 3.07-0.88) = (1.18)(1.13)(1.00)

= 1.33

To explicitly show how each adjustment factor (in-place maximization, transposition, barrier adjustment) affects the total adjustment, separate computation are provided.

<u>In-place maximization factor</u>

| | |
|---|---|
| Storm representative dew point: | 73.5° F |
| In-place maximum dewpoint: | 76.5° F |
| Storm atmospheric precipitable water for 73.5° F: | 2.67" |
| Maximum atmospheric precipitable water for 76.5° F: | 3.07" |
| Adjustment for storm elevation, 1000mb to 4900' at 73.5°F: | 2.67" |
| Adjustment for storm elevation, 1000mb to 4900' at 76.5°F: | 3.07" |

In-place maximization factor = (in-place maximum PW at storm elevation)/(in-place storm PW at storm elevation)

= (3.07-1.02 / (2.67-1.13)
= 1.18

Transposition factor

| | |
|---|---|
| In-place maximum dew point: | 76.5° F |
| Transpositioned maximum dew point: | 76.5° F |
| Maximum atmospheric precipitable water for 76.5° F: | 3.07" |
| Maximum atmospheric precipitable water for 76.5° F: | 3.07" |
| Adjustment for storm elevation, 1000mb to 4900' at 76.5°F: | 1.13" |
| Adjustment for basin elevation, 1000mb to 3650' at 76.5°F: | 0.88" |

Transposition factor = (transpositioned maximum PW at basin elevation)/(in-place maximum PW at storm elevation)

= (3.07- 0.88 / 3.07-1.02)
= 1.13

Barrier adjustment factor

| | |
|---|---|
| Transpositioned maximum dewpoint: | 76.5° F |
| Average basin elevation: | 36500' |
| Effective barrier height for the South inflow: | 3650' |
| Maximum atmospheric precipitable water for 76.5° F: | 0.88" |
| Adjustment for effective barrier, 76.5° F, 1000mb to 3650': | 0.88" |
| Adjustment for effective barrier, 76.5° F, 1000mb to 3650': | 0.88" |

Barrier adjustment factor = (transpositioned maximum PW at effective barrier height for the inflow direction)/( transpositioned maximum PW at basin elevation)

= (3.07- 0.88 / 3.07- 0.88)
= 1.00

Total adjustment factor = (In-Place maximization) X (Transposition) X (Barrier adjustment) X
= 1.18 X 1.13 X 1.00
= 1.33

This is the same total adjustment computed earlier (within round-off error) using the single equation to compute the total adjustment factor.

Since these procedures involve linear multiplication, Excel spread sheets are used to incorporate the storm DAD and apply the factors to compute the transpositioned, maximized, barrier and orographic adjusted DAD. In this study, this procedure is applied for each storm

transpositioned to the basin using Microsoft Excel and each of the computational storm spreadsheets is listed in Appendix F

Once the total adjustment factors are applied to all of the storms being considered, rainfall amounts from largest storms are plotted on a log-linear plot with rainfall depth plotted on the linear scale and area size plotted on the log scale. Appendix E contains examples of these plots. A separate graph is constructed for each duration period, e.g. 1-hour, 6-hour, 12-hour, etc. The graphs provide curves of the transpositioned, maximized, and barrier adjusted storm rainfall amounts for all area sizes. These depth-area curves represent the maximum rainfall potential based on standard procedure modifications of the largest observed historic storms in the region surrounding the basin. An enveloping curve is drawn through the largest rainfall values. All of the plotted rainfall amounts either lie on the enveloping curve or below it. The exception is in the case where there is reason to suspect that a value is larger than is reasonable and that rainfall value may be undercut, i.e. the envelop curve is drawn beneath the value. Undercutting should rarely be done and each case needs to be justified. No undercutting was done in the White Tanks #4 study. In general, the enveloping curve should provide a smooth transition among the maximum rainfall values for various area sizes. This process of enveloping depth-area plots provides continuity in space for the rainfall amounts among various area sizes.

After enveloping curves are completed for each of the duration periods, depth-duration curves are plotted on a linear-linear graph, with duration on one axis and depth on the other. Since there is only a single curve for each area size from the enveloped depth-area plots, all of depth-area curves can be plotted as a family of curves on a single graph. Enveloping curves are drawn for each area size. The enveloping curve should provide a smooth transition among the maximum rainfall values for various durations. This procedure of enveloping depth-duration plots provides continuity in time for the rainfall amounts among various durations.

The final envelopment curves provide the maximum rainfall amounts that represent PMP values for the basin. Rainfall amounts for each area size and each duration period are taken from the curves and used to construct the PMP DAD table.

# Appendix E

## Storm Depth-Area and Depth-Duration Plots

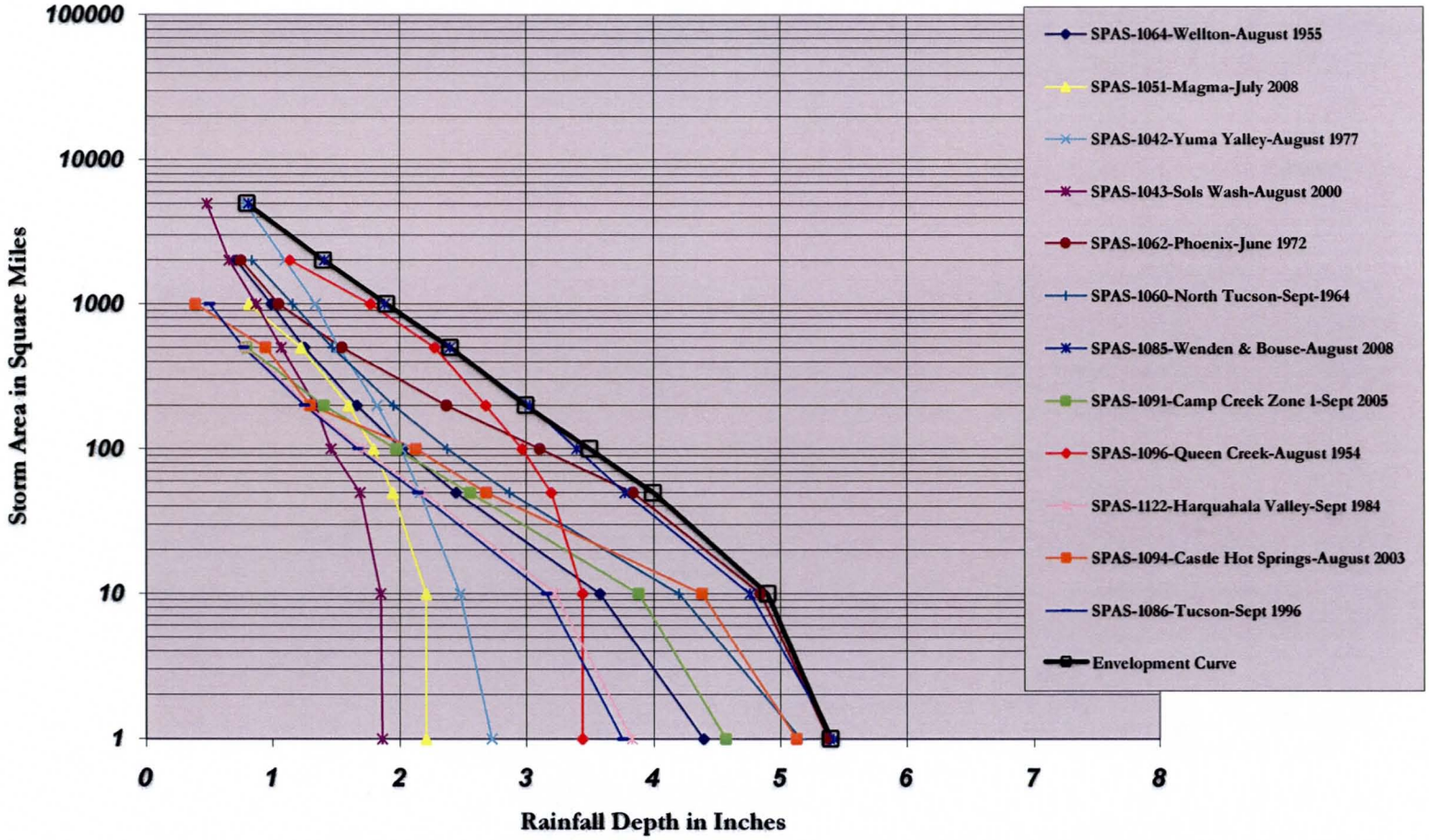
Adjustments to each of the storms on the short list were made using spreadsheets (Appendix F). The storm depth-area-duration (DAD) was entered along with the storm representative dew point, in-place maximum dew point, transposition maximum dew point, original storm elevation, appropriate barrier heights and orographic adjustment factors. All adjustments were computed within the spreadsheet and an adjusted DAD was produced. These adjusted DADs were used in the depth-area plots.

Rainfall amounts from the storms, after being adjusted to the White Tanks #4, were plotted on depth-area plots. Plots were made for each duration period. Enveloping curves were drawn using the maximum rainfall values and smoothing was applied to provide smooth transitions among area sizes.

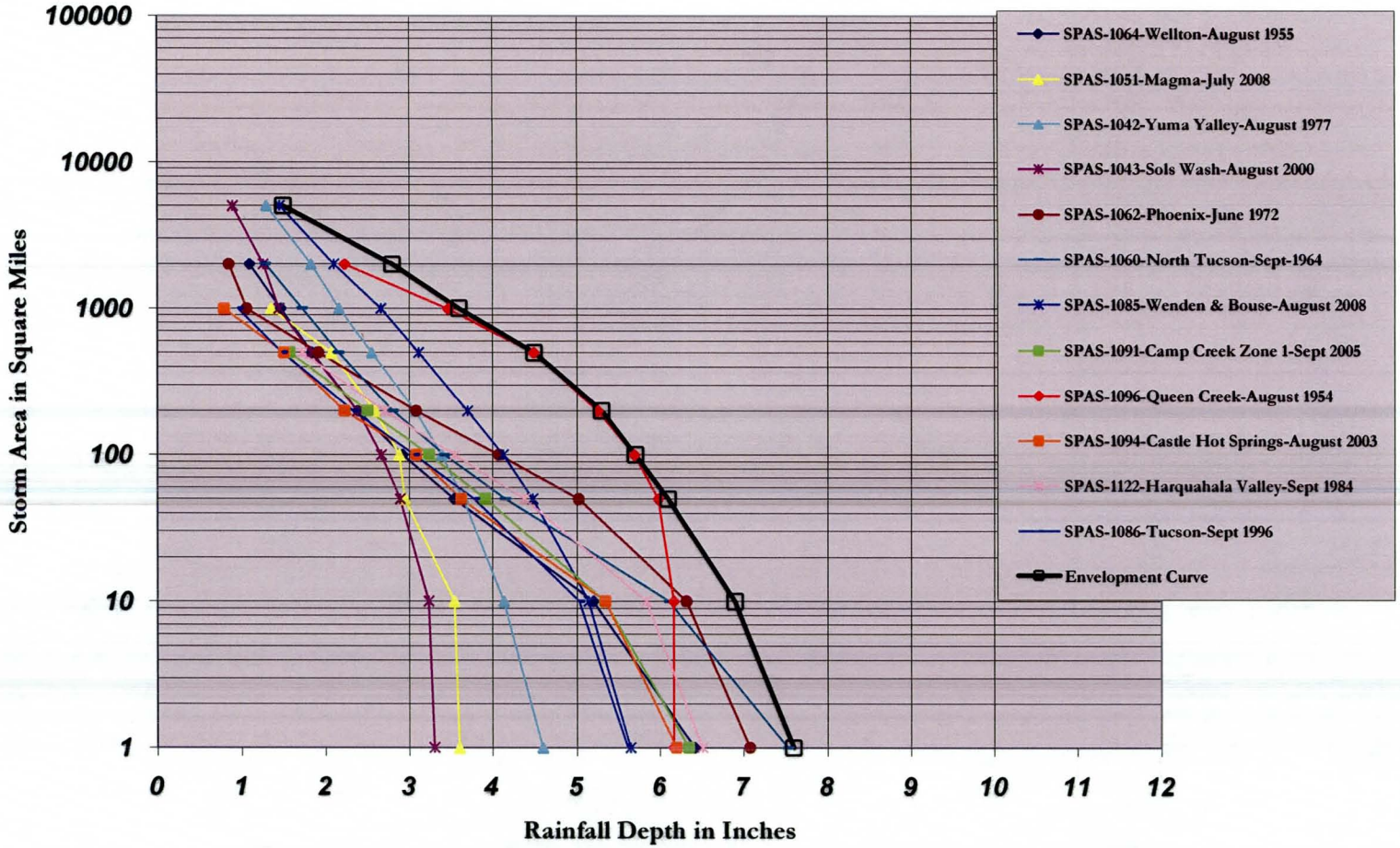
Enveloped rainfall values were taken from the depth-area plots and used to construct the depth-duration plots. A curve was constructed for each area size. Enveloping curves were drawn with smoothing to provide smooth transitions among duration periods.

This procedure of enveloping and smoothing produces maximum rainfall amounts that have continuity in both time and space. Final plots of the depth-area and depth-duration curves are provided in this appendix. The final PMP values for the study were taken from the depth-duration curves. Plots of the depth-area curves for each duration period and the depth-duration curves are provided in this appendix. The first set of depth-area curves are for the local convective storms and include the 1-, 2-, 3-, 4-, 5-, and 6- hours durations and are followed by the depth-duration plots for 1-, 10-, 50-, 100-, 200-, 500-, 1000-, 2000-, and 5000-square miles. The second set of depth-area curves are for the remnant tropical storms and include the 1-, 6-, 12-, 24-, 36-, 48-, and 72-hour durations and are followed by the depth-duration plots for 1-, 10-, 50-, 100-, 200-, 500-, 1000-, 2000-, 5000-, and 10000-square miles. The final set of depth-are curves are for the general frontal storms and include the 1-, 6-, 12-, 24-, 36-, 48-, and 72-hour durations and are followed by the depth-duration plots for 1-, 10-, 100-, 200-, 500-, 1000-, 2000-, 5000-, 10000-, and 20000-square miles.

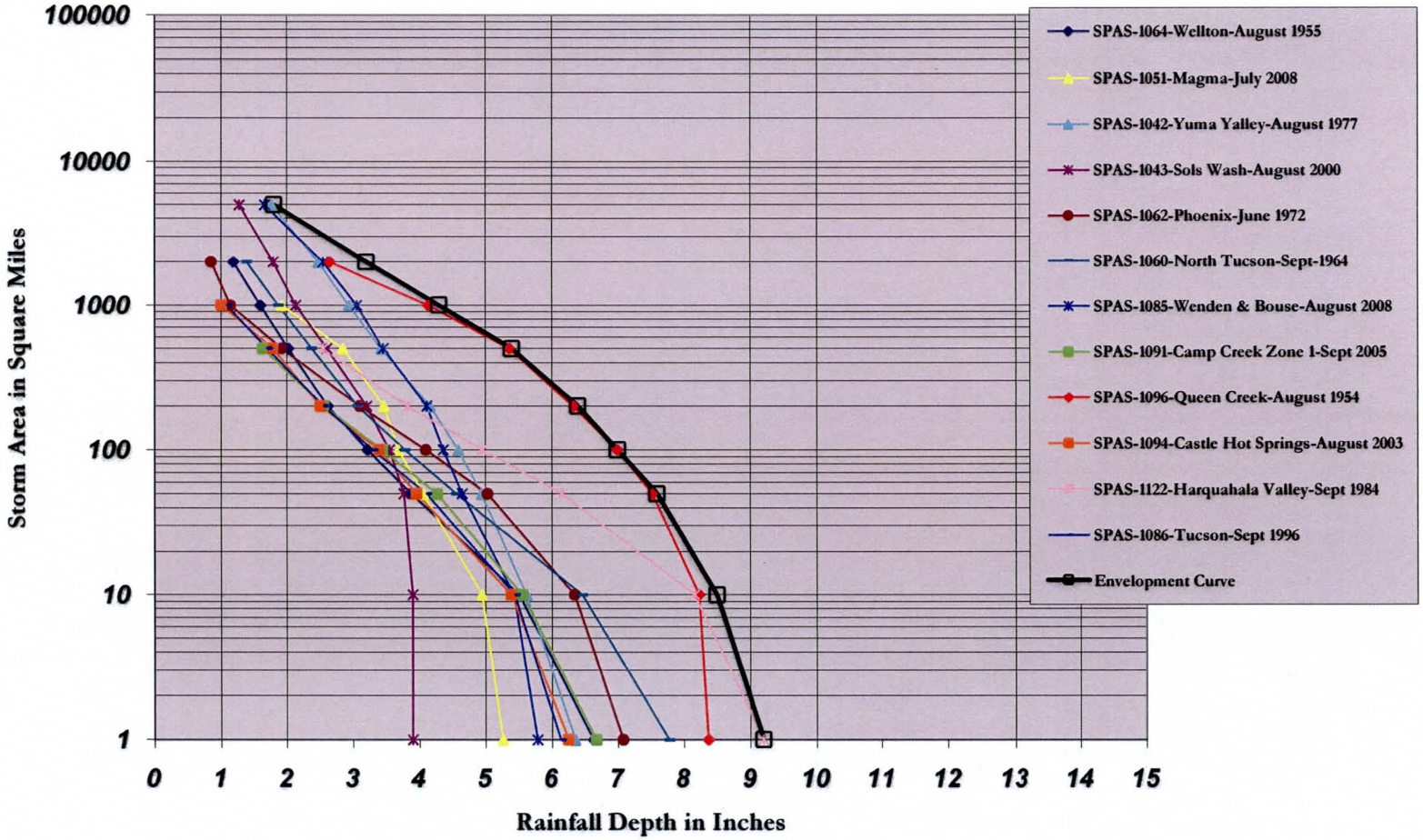
## 1-Hour Adjusted Local Storm Depth-Area Curves for White Tanks #4



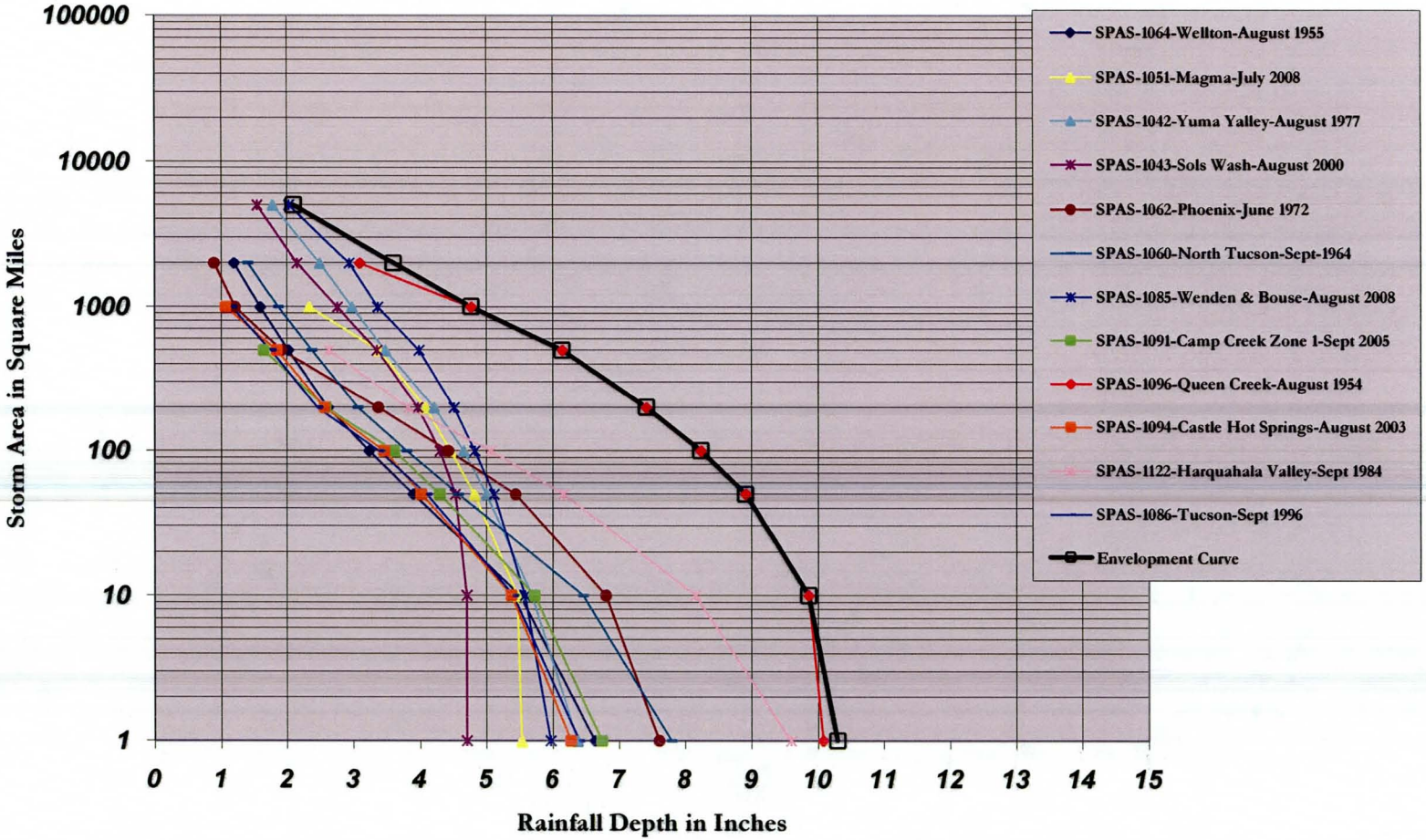
## 2-Hour Adjusted Local Storm Depth-Area Curves for White Tanks #4



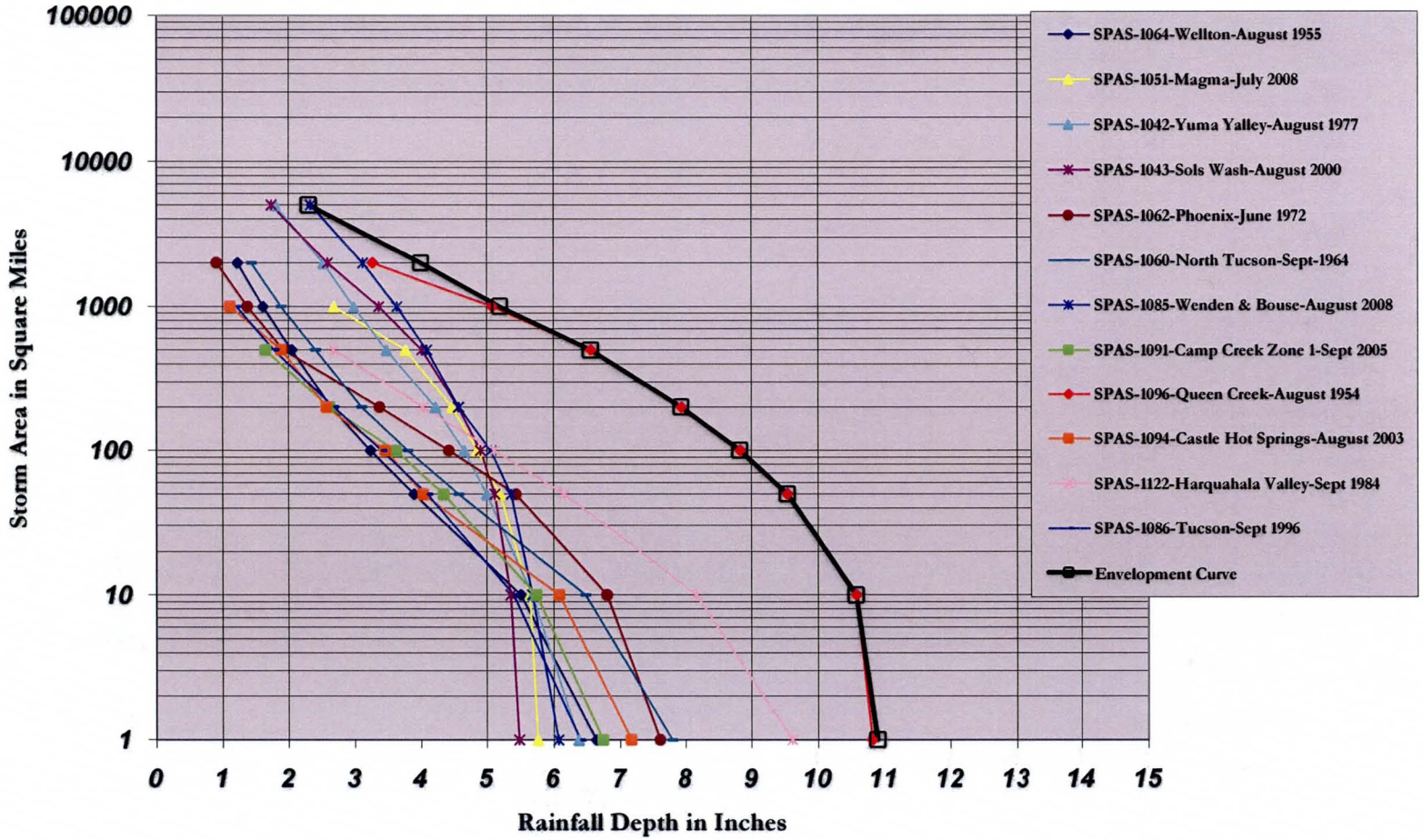
## 3-Hour Adjusted Local Storm Depth-Area Curves for White Tanks #4



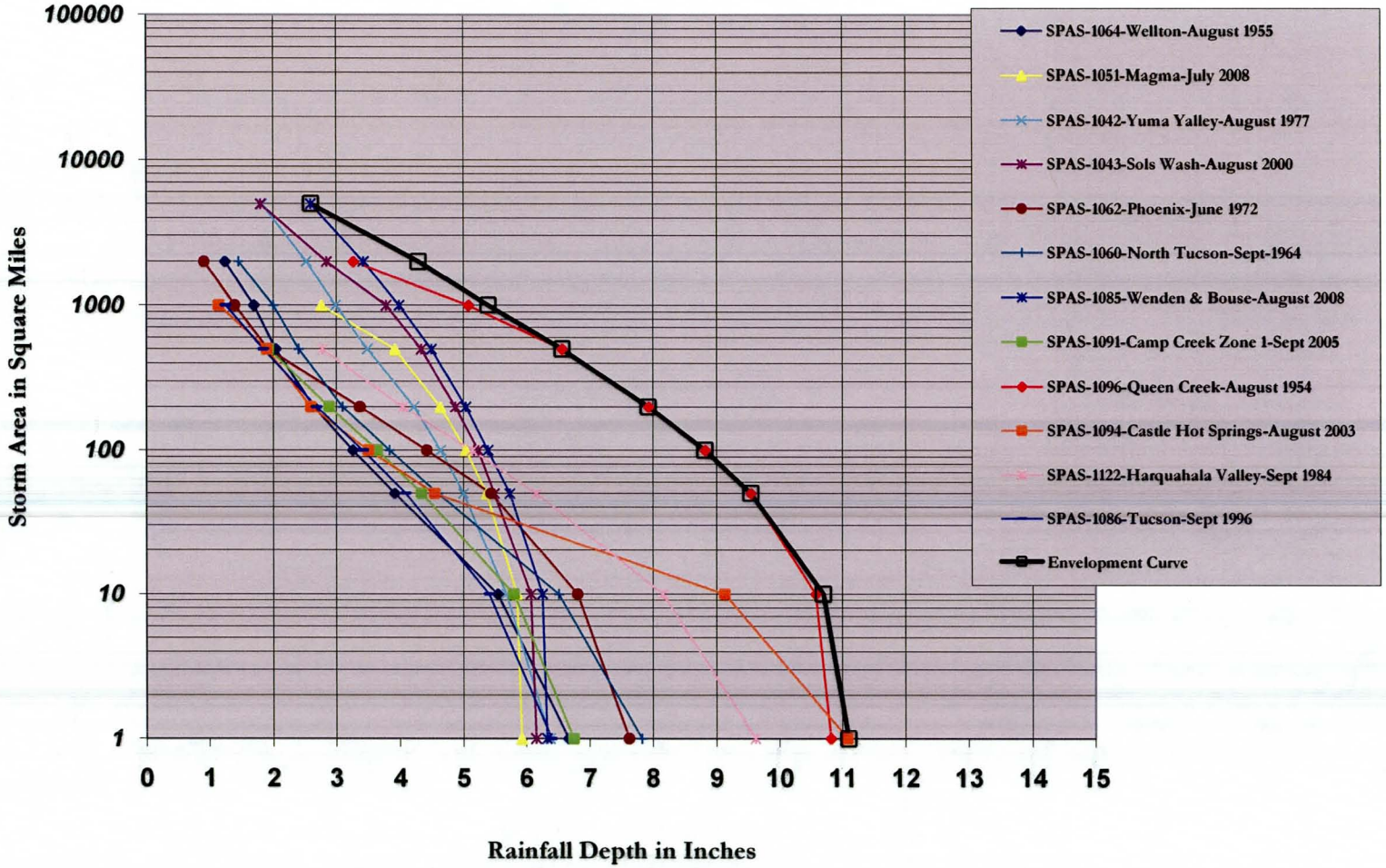
## 4-Hour Adjusted Local Storm Depth-Area Curves for White Tanks #4



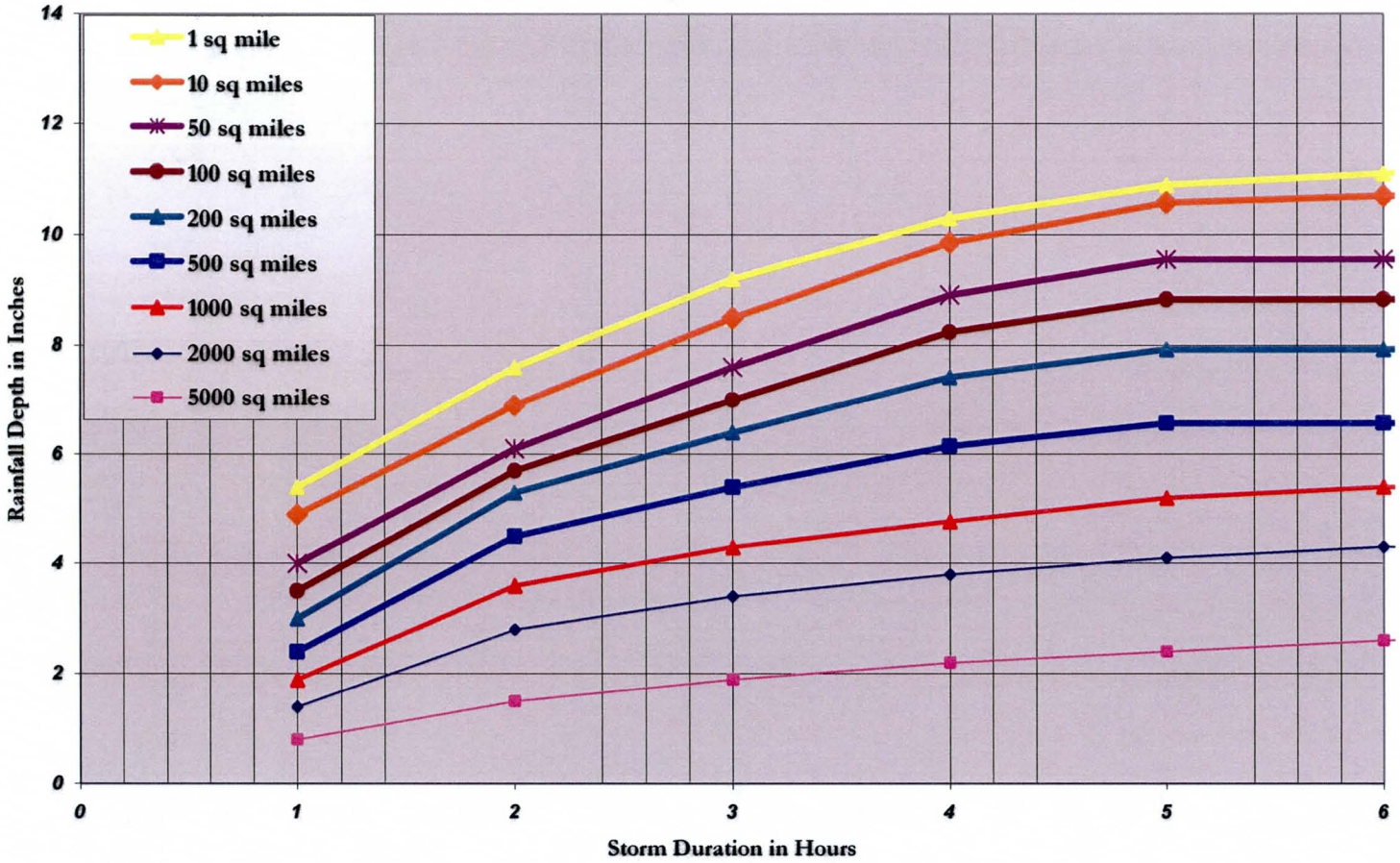
## 5-Hour Adjusted Local Storm Depth-Area Curves for White Tanks #4



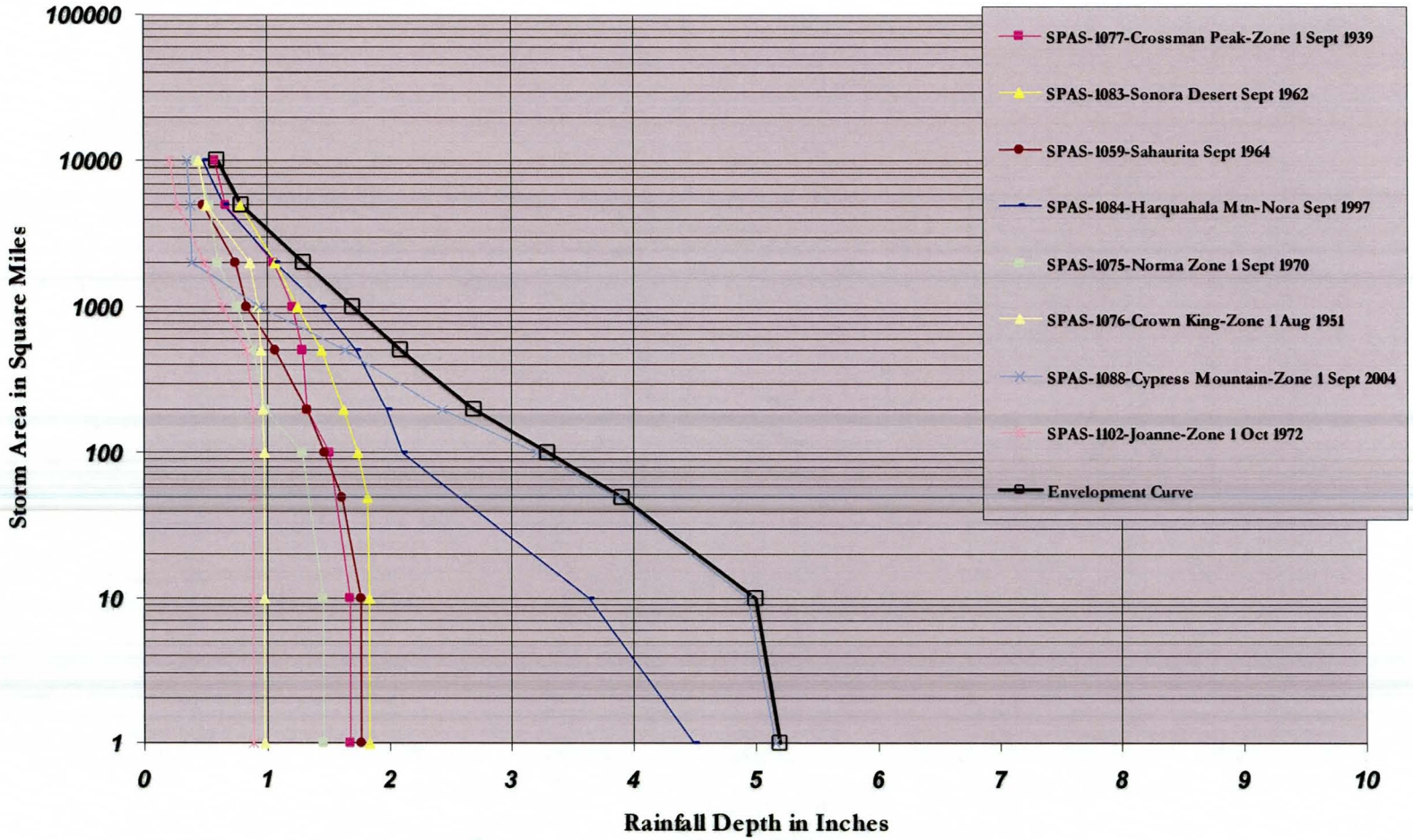
## 6-Hour Adjusted Local Storm Depth-Area Curves for White Tanks #4



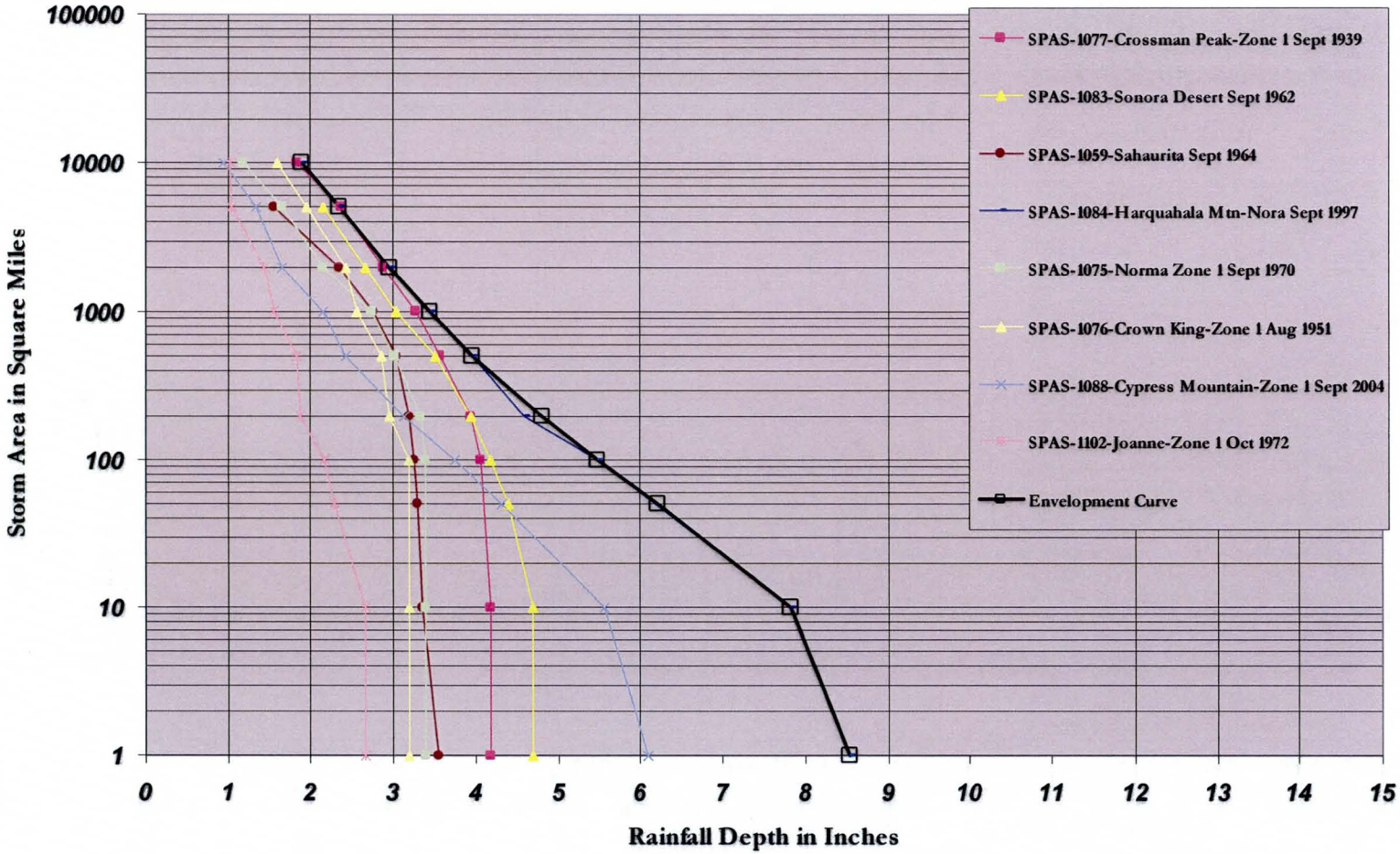
## Depth-Duration Chart of Enveloped Storm Data for White Tanks #4 Drainage Basin *updated 11/13/09*



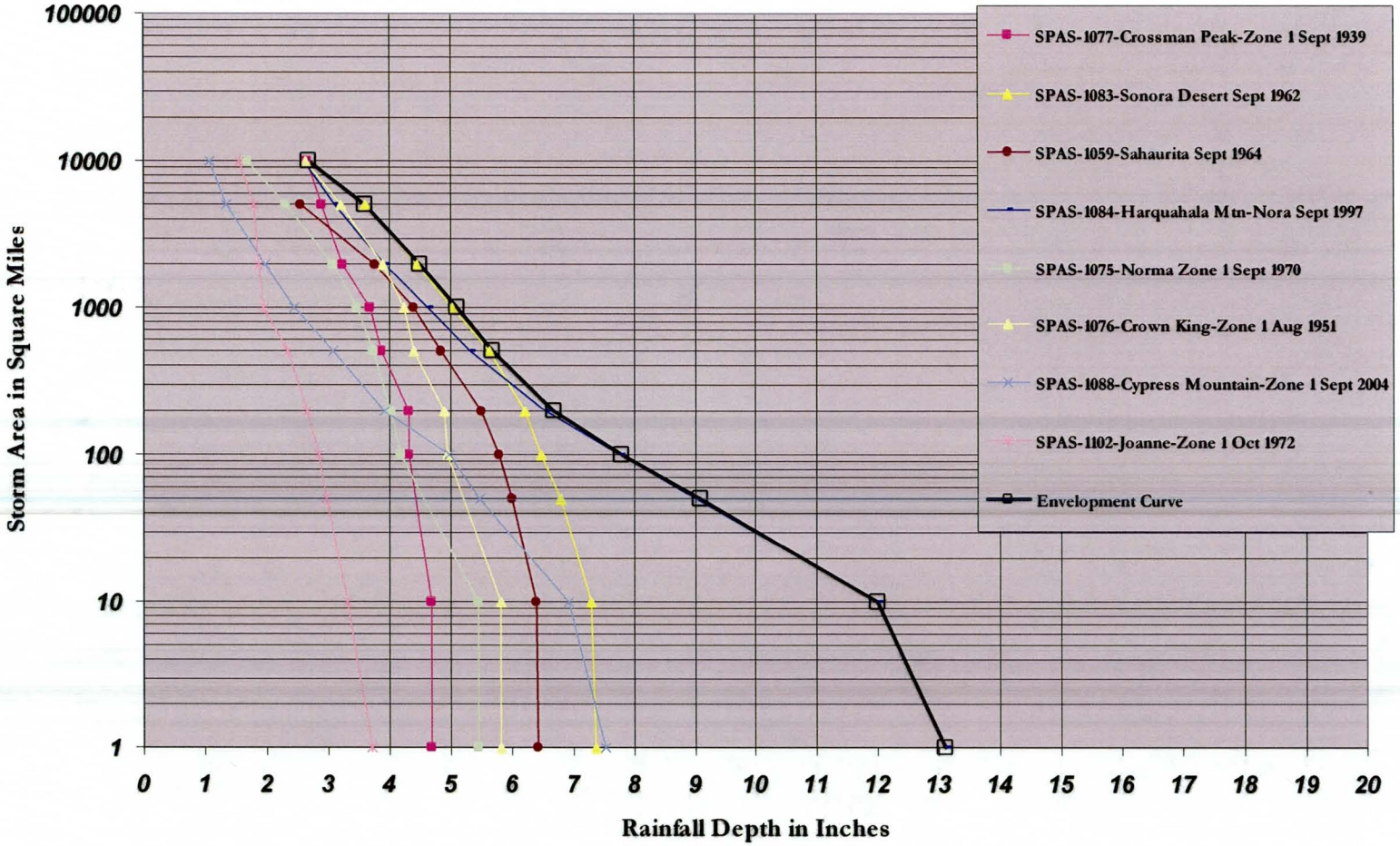
## 1-Hour Observed Tropical Storm Depth-Area Curves for White Tanks #4



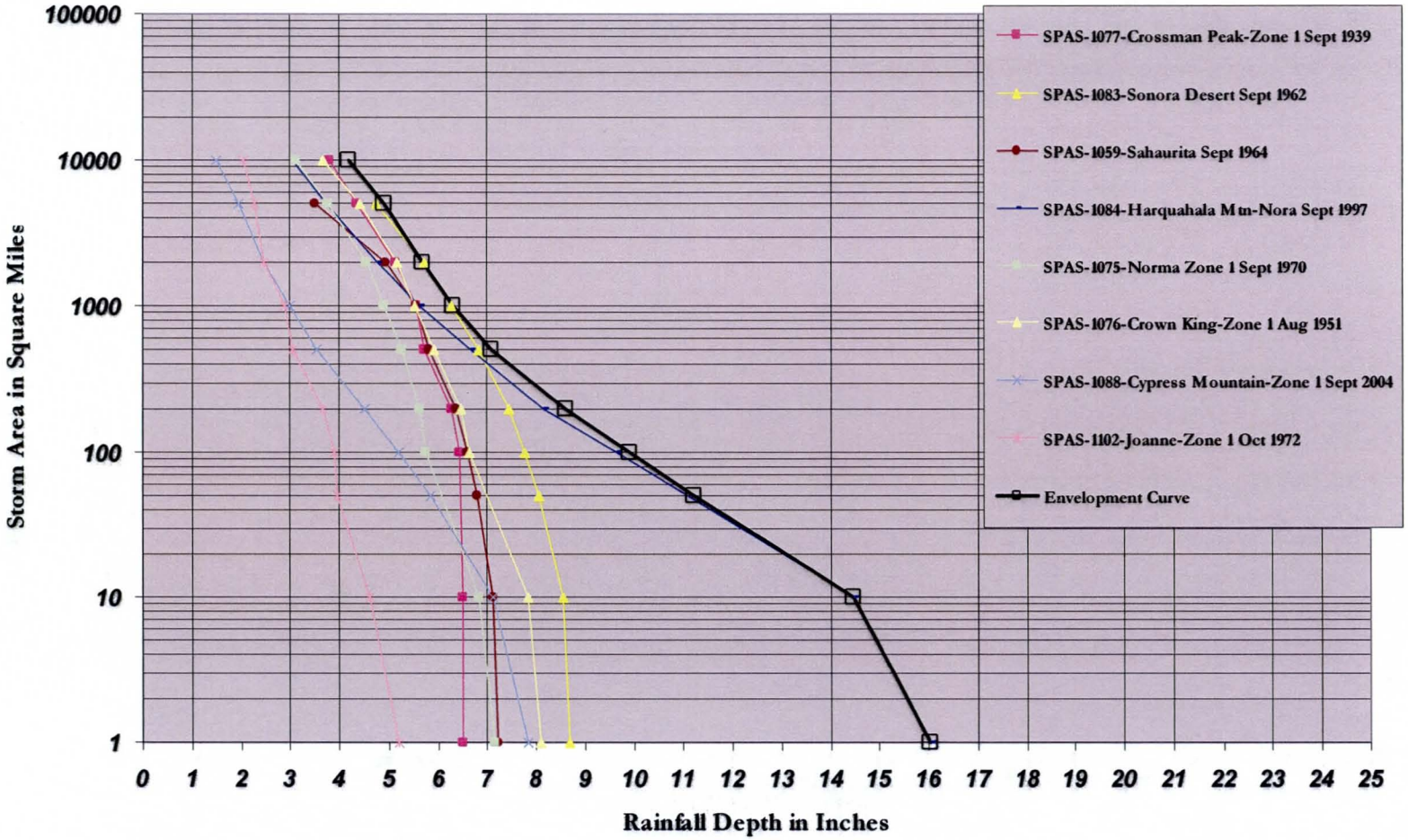
## 6-Hour Observed Tropical Storm Depth-Area Curves for White Tanks #4



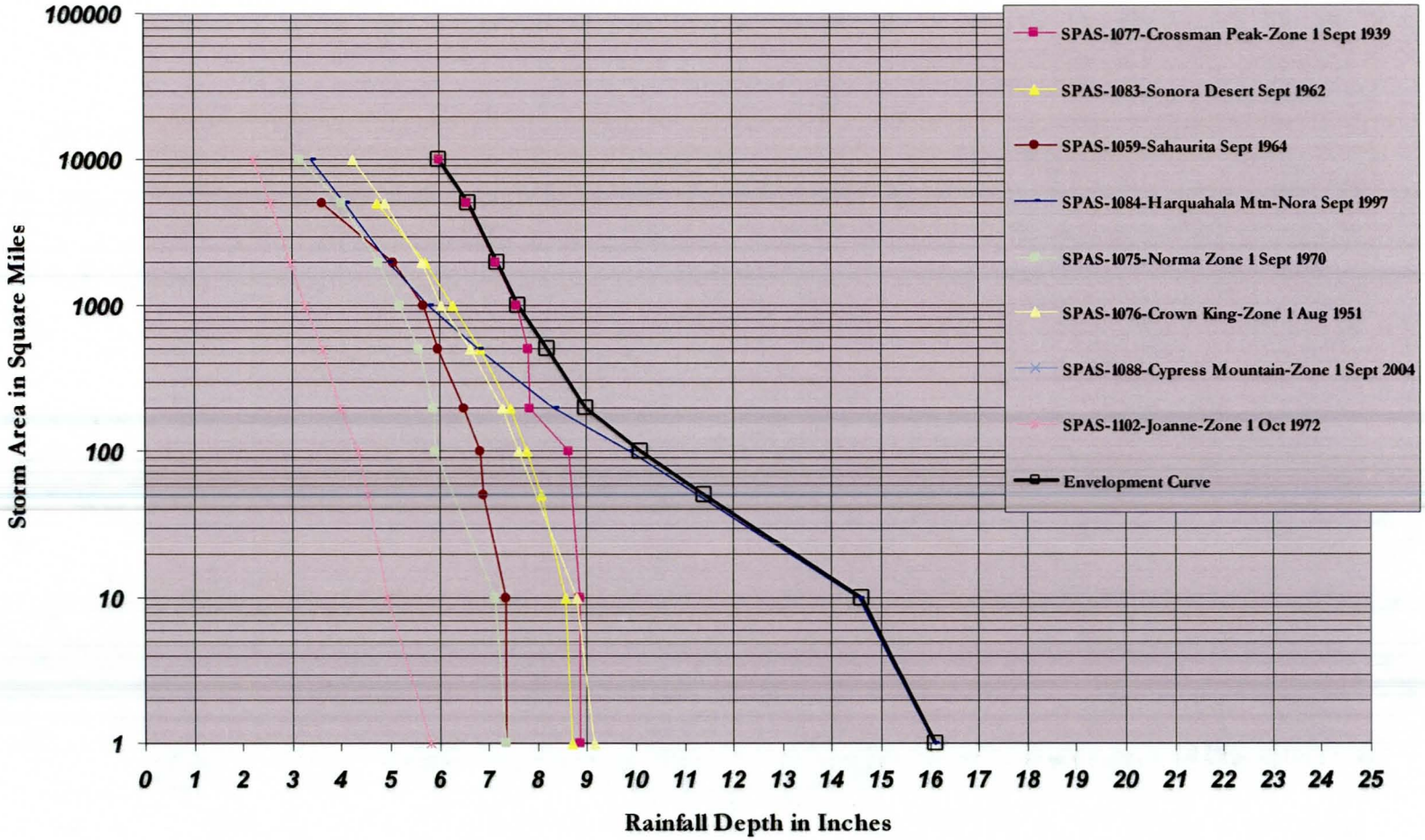
## 12-Hour Observed Tropical Storm Depth-Area Curves for White Tanks #4



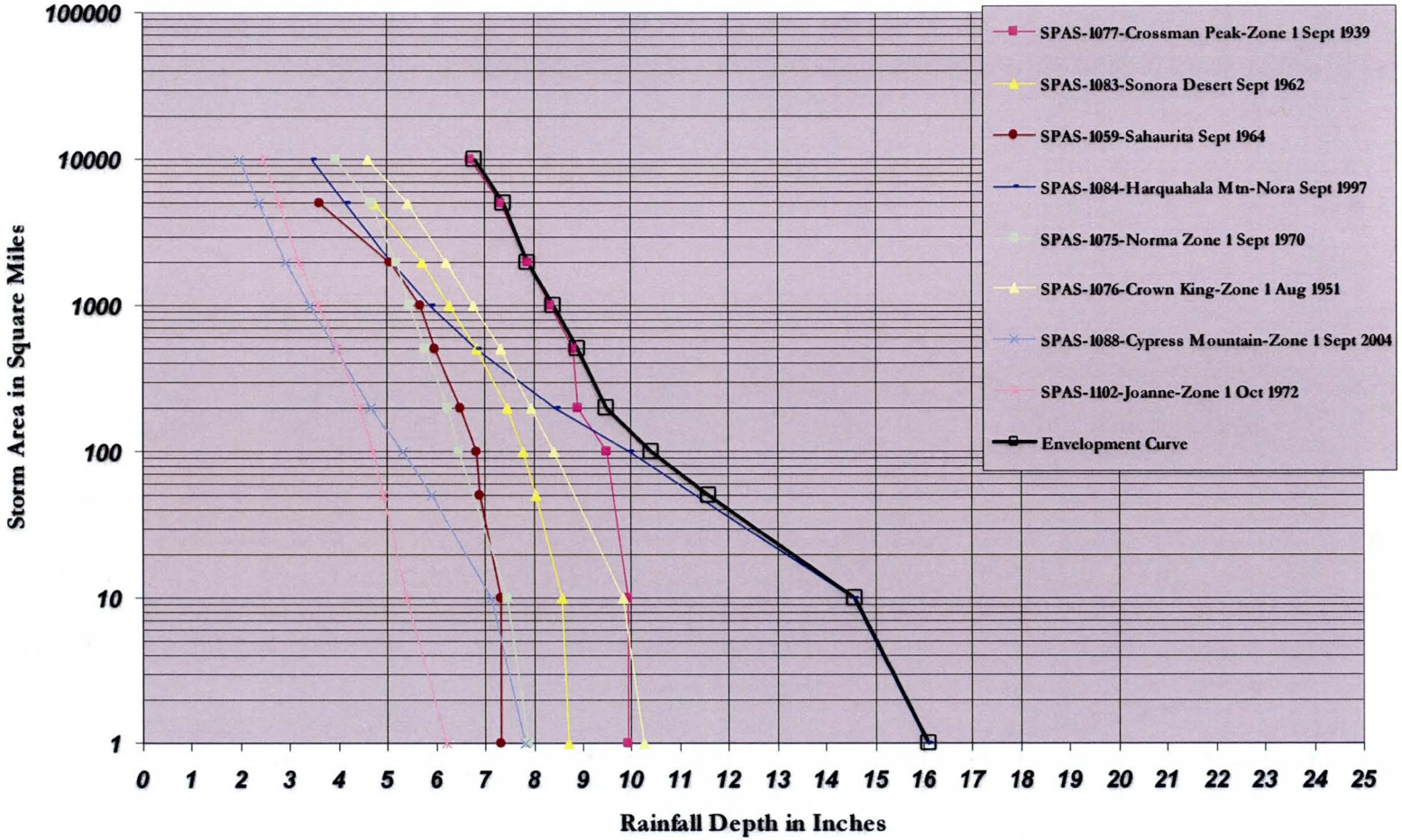
## 24-Hour Observed Tropical Storm Depth-Area Curves for White Tanks #4



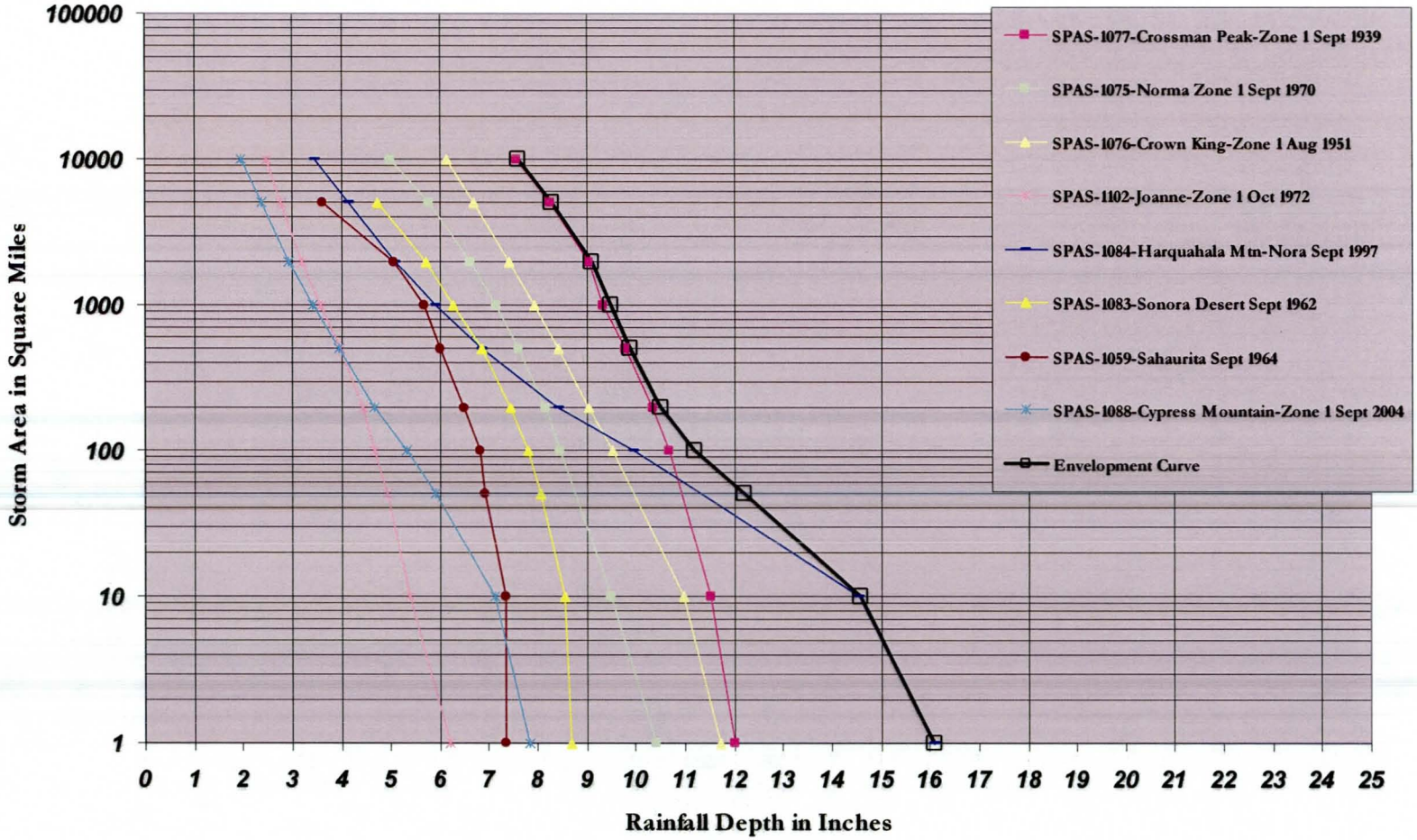
## 36-Hour Observed Tropical Storm Depth-Area Curves for White Tanks #4

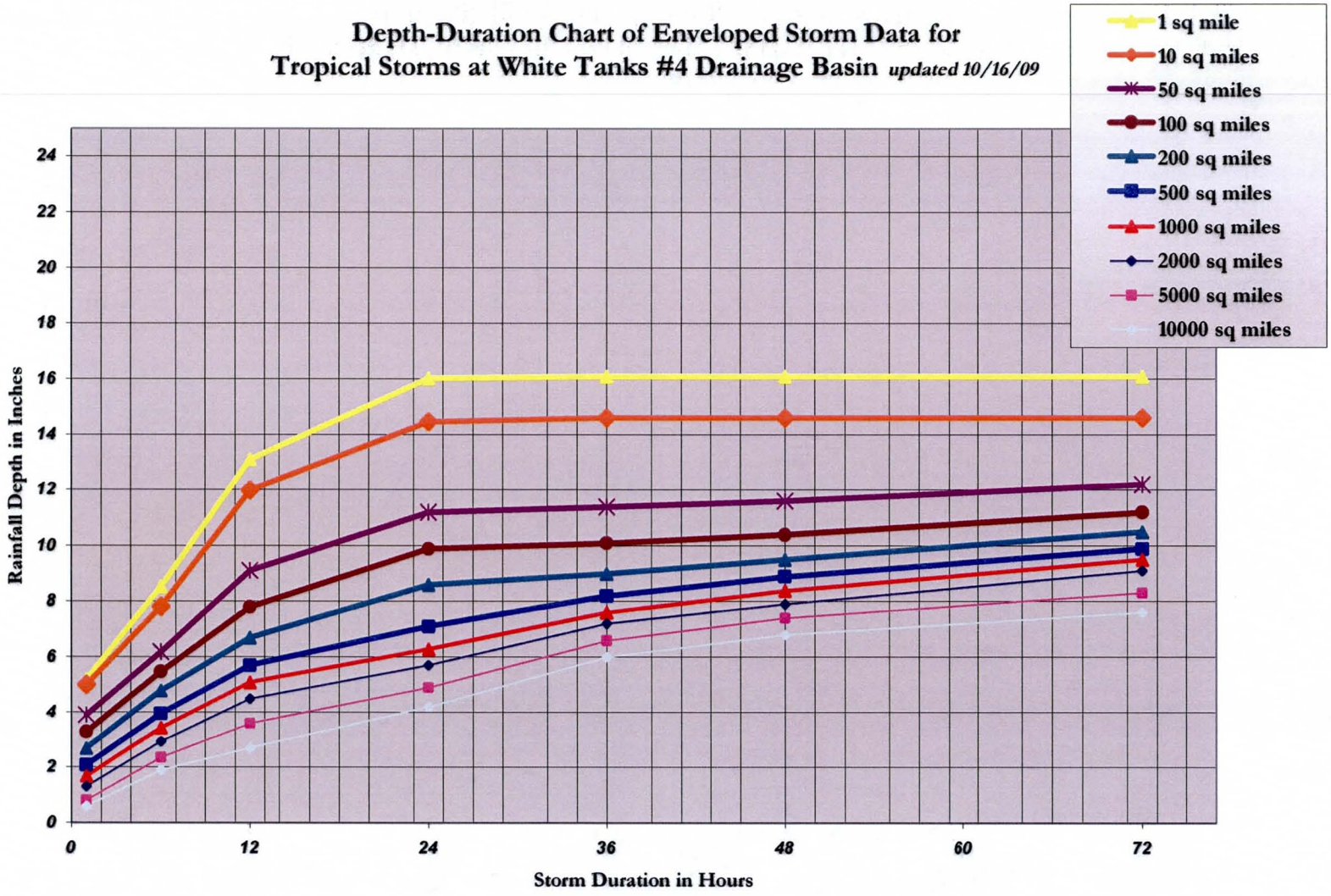


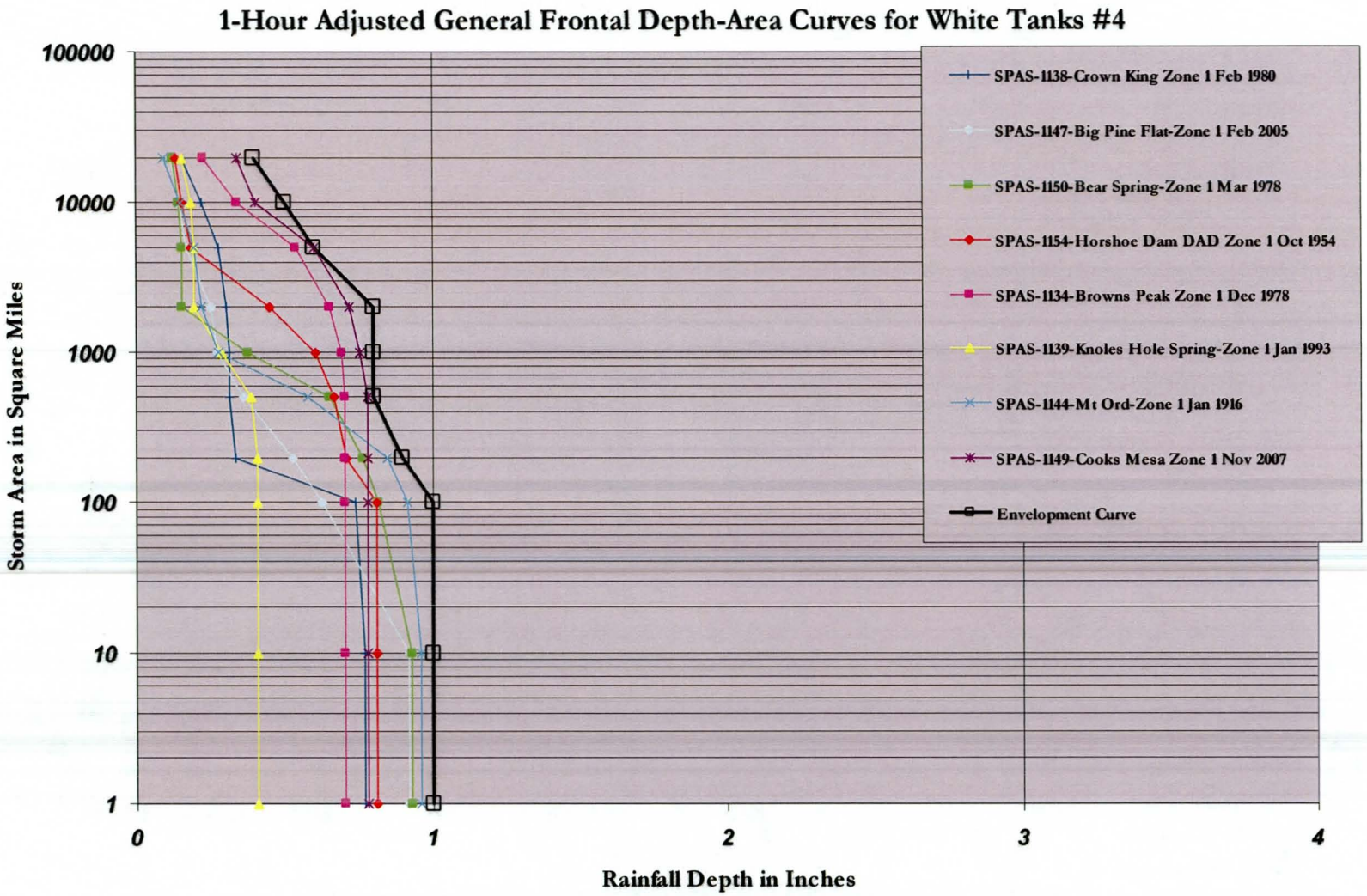
## 48-Hour Observed Tropical Storm Depth-Area Curves for White Tanks #4

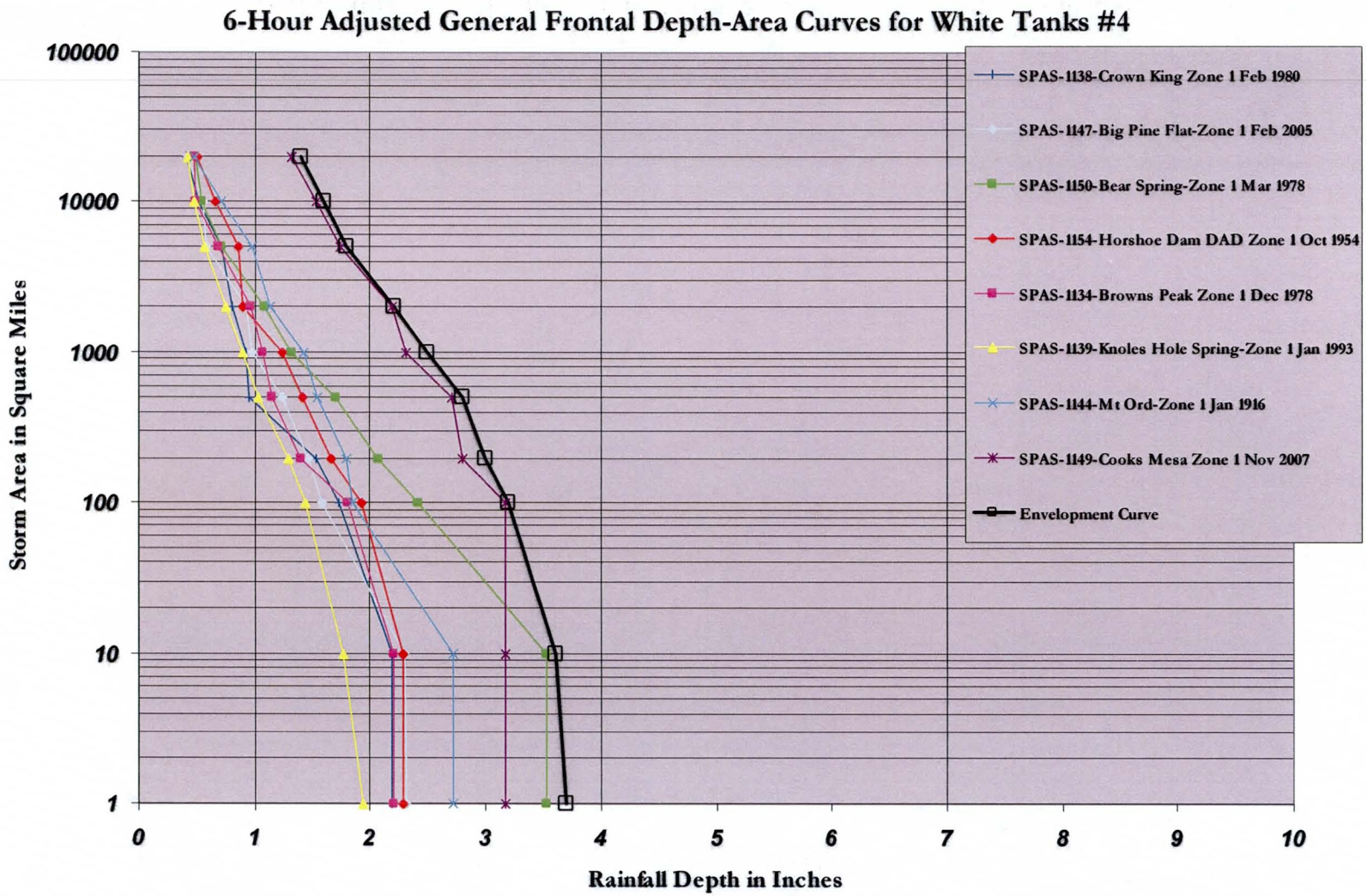


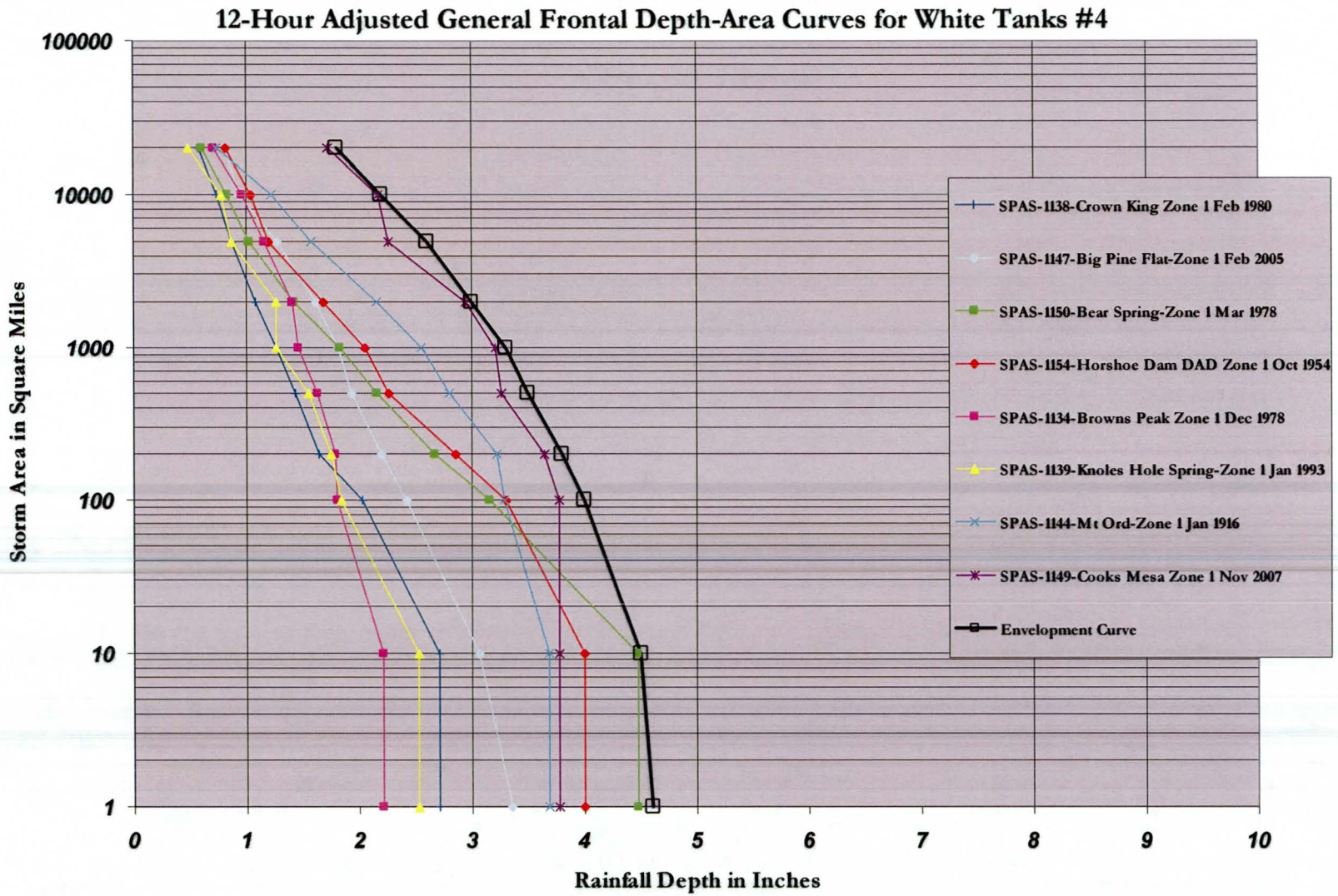
## 72-Hour Observed Tropical Storm Depth-Area Curves for White Tanks #4

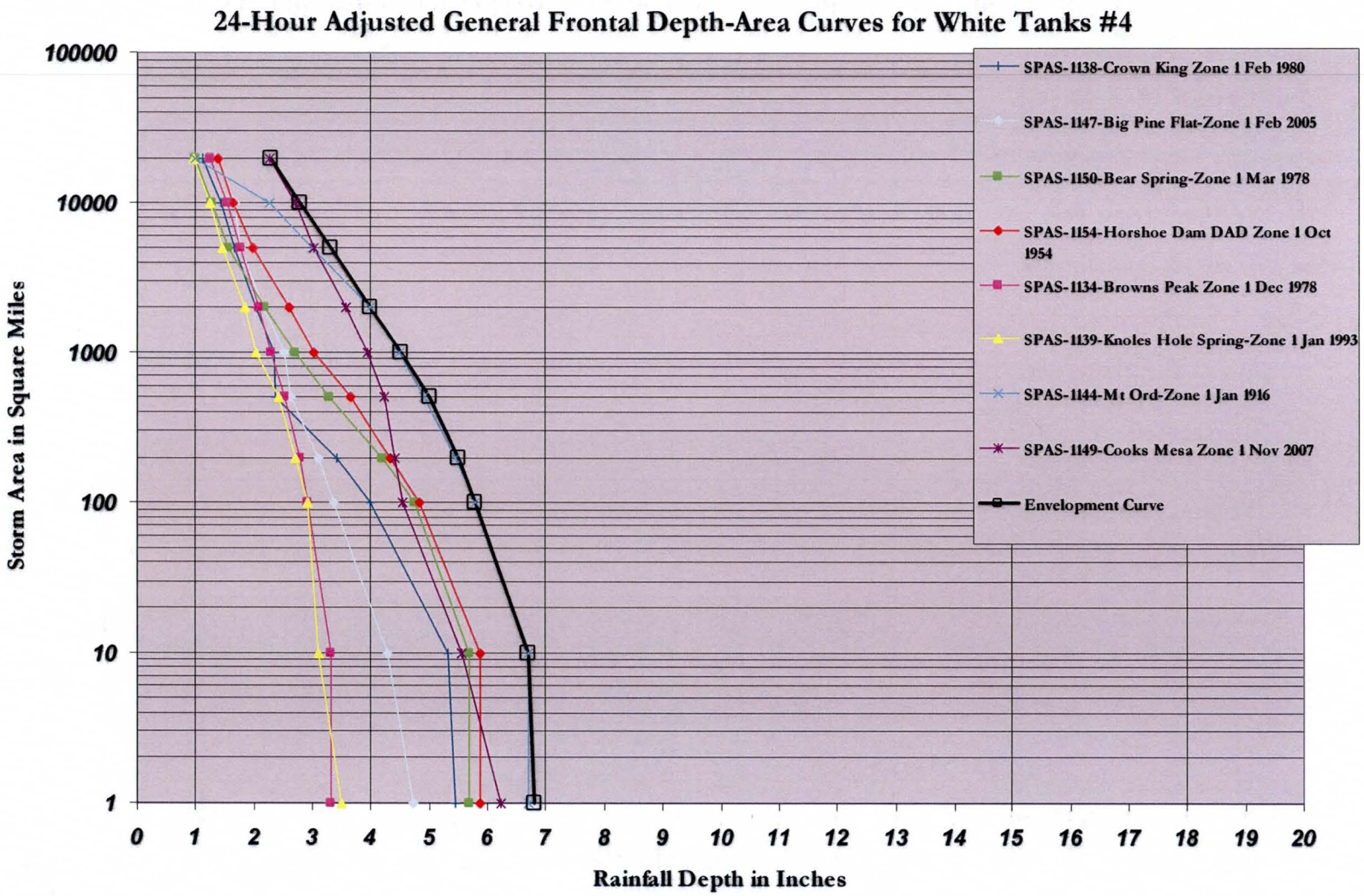



Depth-Duration Chart of Enveloped Storm Data for
Tropical Storms at White Tanks #4 Drainage Basin updated 10/16/09
1 sq mile
10 sq miles
50 sq miles
100 sq miles
200 sq miles
500 sq miles
1000 sq miles
2000 sq miles
5000 sq miles
10000 sq miles
Rainfall Depth in Inches
0
2
4
6
8
10
12
14
16
18
20
22
24
Storm Duration in Hours
0
12
24
36
48
60
72


1-Hour Adjusted General Frontal Depth-Area Curves for White Tanks #4
Storm Area in Square Miles
100000
10000
1000
100
10
1
0
1
2
3
4
Rainfall Depth in Inches
SPAS-1138-Crown King Zone 1 Feb 1980
SPAS-1147-Big Pine Flat-Zone 1 Feb 2005
SPAS-1150-Bear Spring-Zone 1 Mar 1978
SPAS-1154-Horshoe Dam DAD Zone 1 Oct 1954
SPAS-1134-Browns Peak Zone 1 Dec 1978
SPAS-1139-Knoles Hole Spring-Zone 1 Jan 1993
SPAS-1144-Mt Ord-Zone 1 Jan 1916
SPAS-1149-Cooks Mesa Zone 1 Nov 2007
Envelopment Curve


6-Hour Adjusted General Frontal Depth-Area Curves for White Tanks #4
Storm Area in Square Miles
100000
10000
1000
100
10
1
0
1
2
3
4
5
6
7
8
9
10
Rainfall Depth in Inches
SPAS-1138-Crown King Zone 1 Feb 1980
SPAS-1147-Big Pine Flat-Zone 1 Feb 2005
SPAS-1150-Bear Spring-Zone 1 Mar 1978
SPAS-1154-Horshoe Dam DAD Zone 1 Oct 1954
SPAS-1134-Browns Peak Zone 1 Dec 1978
SPAS-1139-Knoles Hole Spring-Zone 1 Jan 1993
SPAS-1144-Mt Ord-Zone 1 Jan 1916
SPAS-1149-Cooks Mesa Zone 1 Nov 2007
Envelopment Curve


12-Hour Adjusted General Frontal Depth-Area Curves for White Tanks #4
Storm Area in Square Miles
100000
10000
1000
100
10
1
0
1
2
3
4
5
6
7
8
9
10
Rainfall Depth in Inches
SPAS-1138-Crown King Zone 1 Feb 1980
SPAS-1147-Big Pine Flat-Zone 1 Feb 2005
SPAS-1150-Bear Spring-Zone 1 Mar 1978
SPAS-1154-Horshoe Dam DAD Zone 1 Oct 1954
SPAS-1134-Browns Peak Zone 1 Dec 1978
SPAS-1139-Knoles Hole Spring-Zone 1 Jan 1993
SPAS-1144-Mt Ord-Zone 1 Jan 1916
SPAS-1149-Cooks Mesa Zone 1 Nov 2007
Envelopment Curve


24-Hour Adjusted General Frontal Depth-Area Curves for White Tanks #4
Storm Area in Square Miles
100000
10000
1000
100
10
1
0
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7
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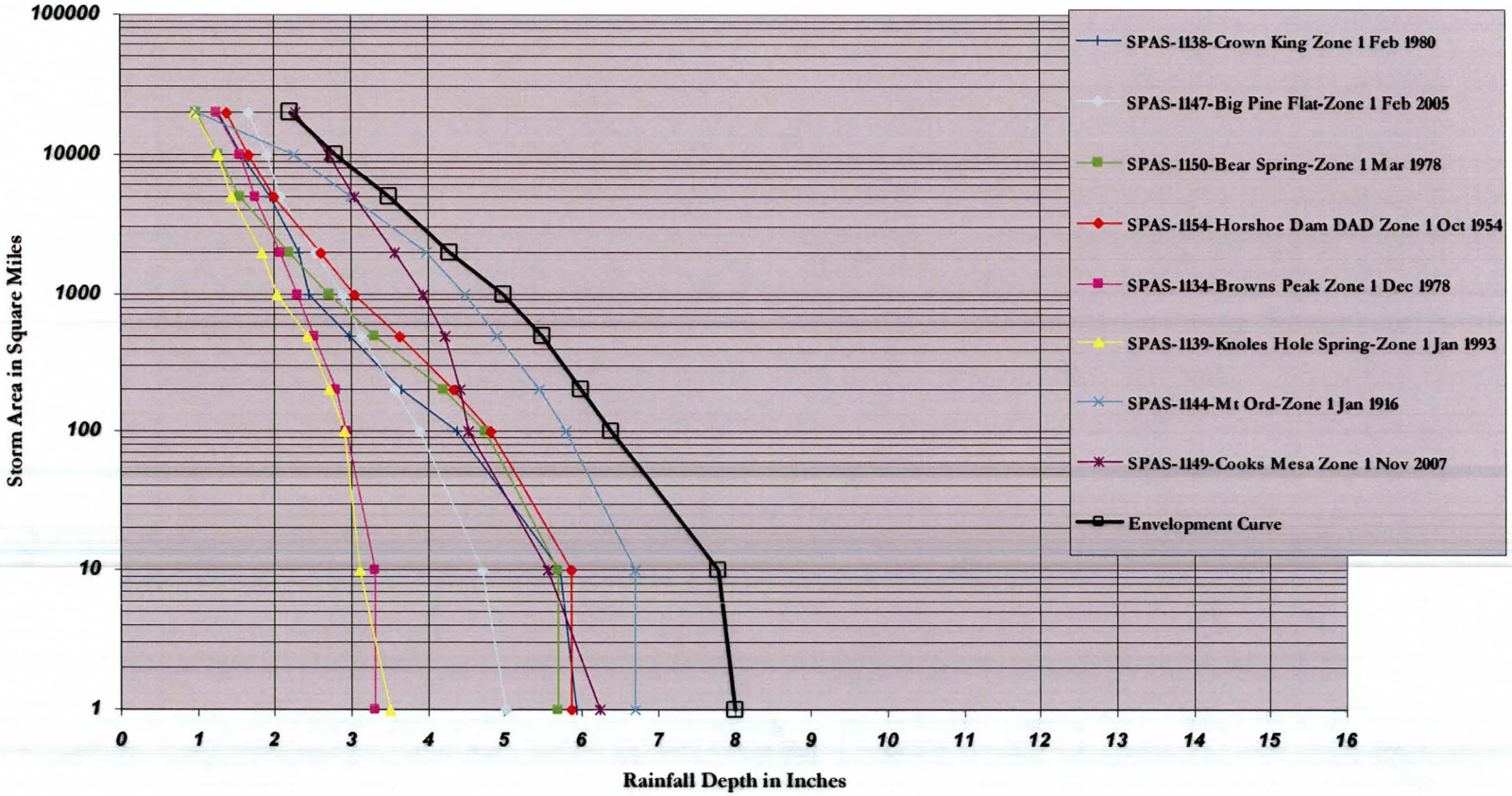
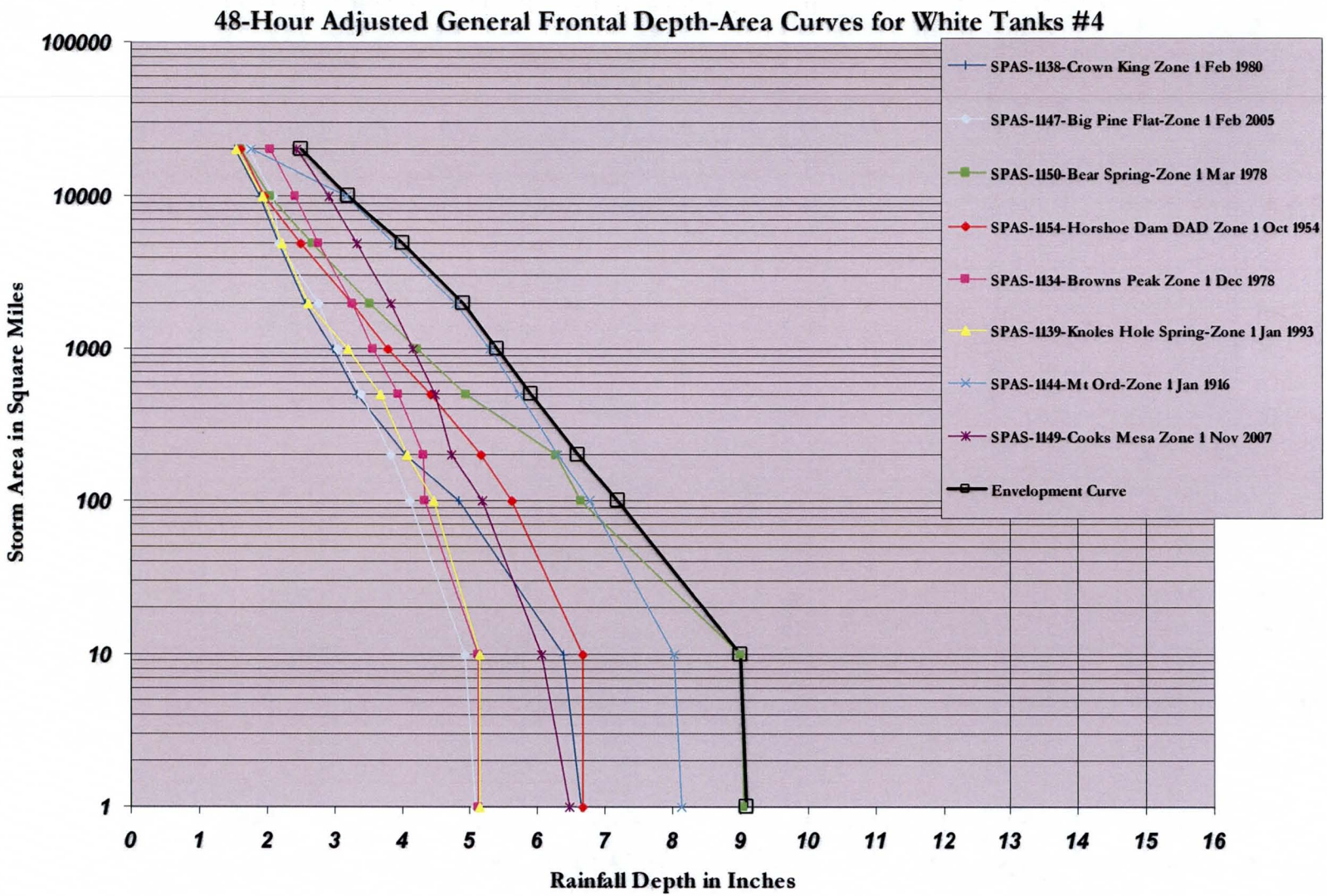
9
10
11
12
13
14
15
16
17
18
19
20
Rainfall Depth in Inches
SPAS-1138-Crown King Zone 1 Feb 1980
SPAS-1147-Big Pine Flat-Zone 1 Feb 2005
SPAS-1150-Bear Spring-Zone 1 Mar 1978
SPAS-1154-Horshoe Dam DAD Zone 1 Oct 1954
SPAS-1134-Browns Peak Zone 1 Dec 1978
SPAS-1139-Knoles Hole Spring-Zone 1 Jan 1993
SPAS-1144-Mt Ord-Zone 1 Jan 1916
SPAS-1149-Cooks Mesa Zone 1 Nov 2007
Envelopment Curve

## 36-Hour Adjusted General Frontal Depth-Area Curves for White Tanks #4




48-Hour Adjusted General Frontal Depth-Area Curves for White Tanks #4
Storm Area in Square Miles
100000
10000
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100
10
1
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7
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11
12
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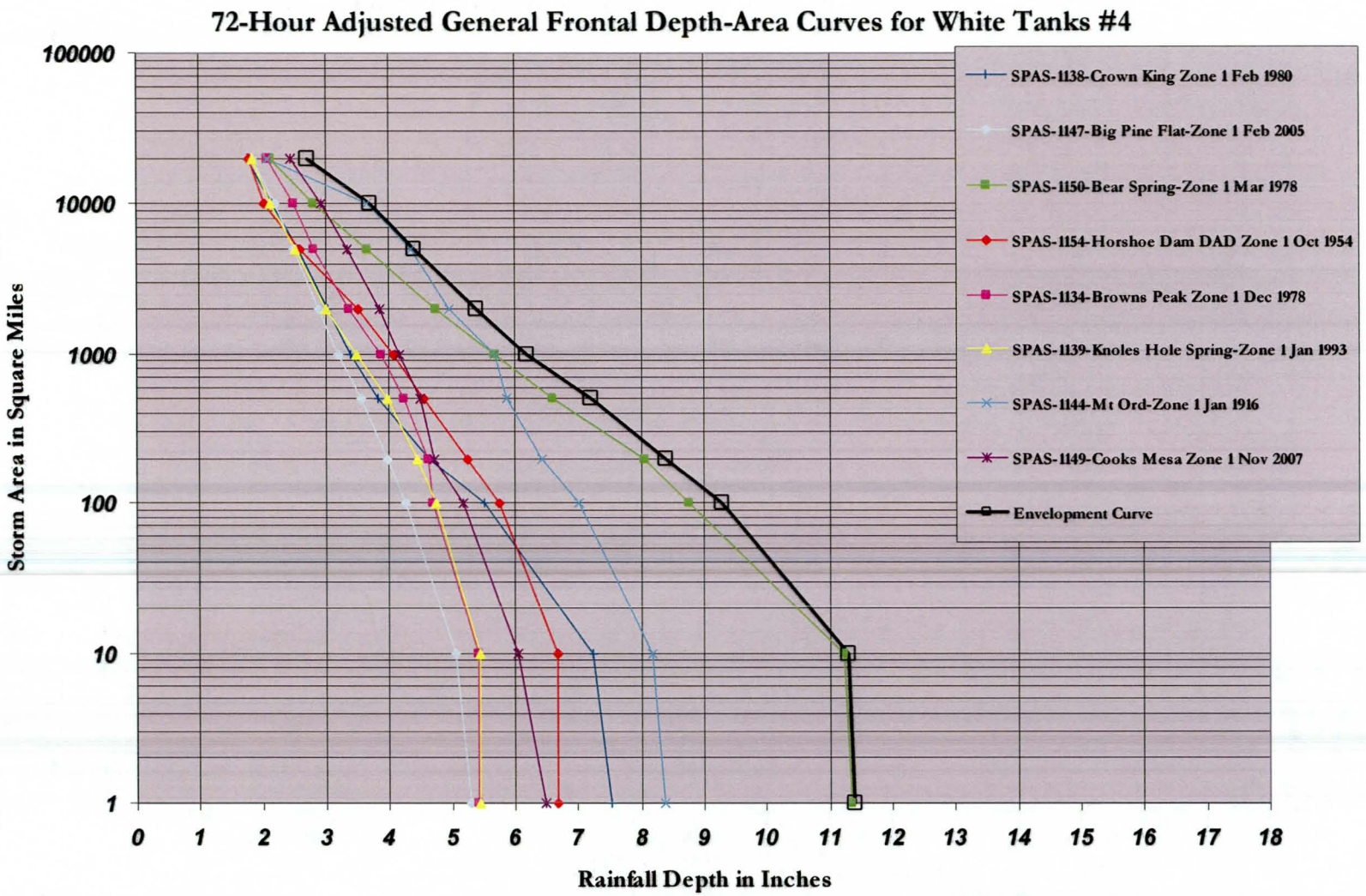
14
15
16
Rainfall Depth in Inches
SPAS-1138-Crown King Zone 1 Feb 1980
SPAS-1147-Big Pine Flat-Zone 1 Feb 2005
SPAS-1150-Bear Spring-Zone 1 Mar 1978
SPAS-1154-Horshoe Dam DAD Zone 1 Oct 1954
SPAS-1134-Browns Peak Zone 1 Dec 1978
SPAS-1139-Knoles Hole Spring-Zone 1 Jan 1993
SPAS-1144-Mt Ord-Zone 1 Jan 1916
SPAS-1149-Cooks Mesa Zone 1 Nov 2007
Envelopment Curve


72-Hour Adjusted General Frontal Depth-Area Curves for White Tanks #4
Storm Area in Square Miles
100000
10000
1000
100
10
1
0
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2
3
4
5
6
7
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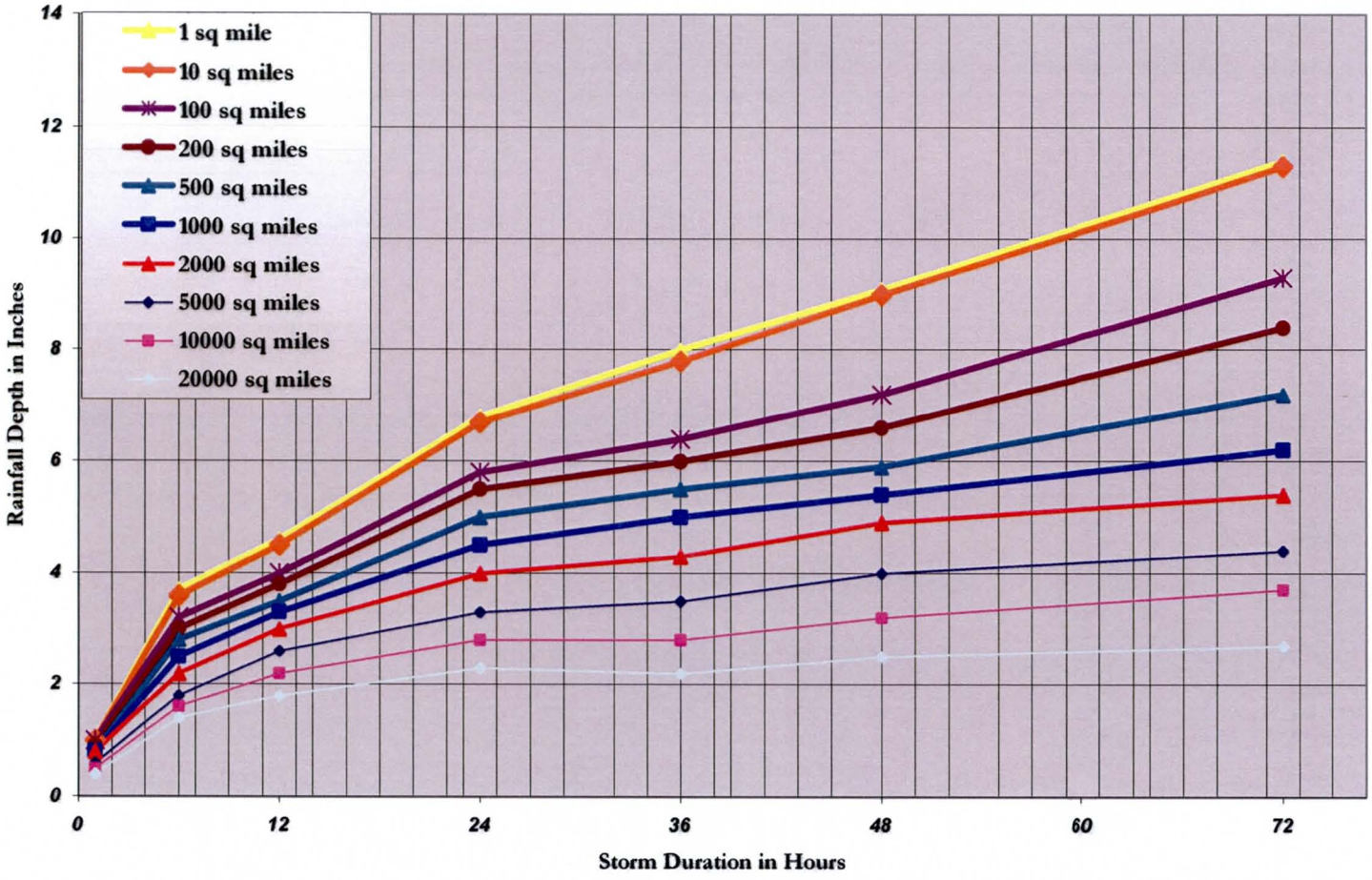
16
17
18
Rainfall Depth in Inches
SPAS-1138-Crown King Zone 1 Feb 1980
SPAS-1147-Big Pine Flat-Zone 1 Feb 2005
SPAS-1150-Bear Spring-Zone 1 Mar 1978
SPAS-1154-Horshoe Dam DAD Zone 1 Oct 1954
SPAS-1134-Browns Peak Zone 1 Dec 1978
SPAS-1139-Knoles Hole Spring-Zone 1 Jan 1993
SPAS-1144-Mt Ord-Zone 1 Jan 1916
SPAS-1149-Cooks Mesa Zone 1 Nov 2007
Envelopment Curve

**Depth-Duration Chart of Enveloped Storm Data for**
**General Frontal Storms at White Tanks #4 Drainage Basin** ***updated 11/18/09***



# Appendix F

# Short Storm List Storm Analysis

**See Separate Binding**

# Appendix G

# Storm Precipitation Analysis System (SPAS) Description

## Introduction

The Weather Bureau (currently the National Weather Service, or NWS) and the Corps of Engineers routinely performed detailed storm rainfall analyses until the 1950s. Since then, only a few selected storms have been analyzed. Using digital precipitation data now available, storm rainfall analysis procedures and software have been developed to provide detailed rainfall analyses using Geographical Information Systems (GIS). Hourly high spatial resolution rainfall analyses are produced to quantify the spatial and temporal distribution of storm rainfall over watersheds. Furthermore, the availability of NEXRAD (Next Generation Radar) data has allowed SPAS to better account for the spatial and temporal variability of storm precipitation for events occurring since the early 1990s.

Applied Weather Associates, LLC, Metstat, Inc and Genesis Weather Solutions, LLC have teamed to develop a rainfall analysis procedure for analyzing rainfall associated with extreme storms. The Storm Precipitation Analysis System (SPAS) applies the same basic approach used by the Weather Bureau and the Corps of Engineers, thereby achieving a level of consistency between the newly analyzed storms and the historic storms previously analyzed. However, more recent (i.e. post 1990) storms can be analyzed using NEXRAD data and a slightly different approach. The SPAS algorithms are a suite of UNIX-based programs that utilize the Geographic Resources Analysis Support System (GRASS) GIS engine to evaluate the spatial, temporal and depth-area characteristics of precipitation events. (1) For pre-NEXRAD storms, SPAS uses a spatial approach for allocating precipitation at the daily reporting stations into hourly rainfall values, thus creating high resolution precipitation maps for each hour of the rainfall event. Likewise, for post-NEXRAD storms SPAS utilizes the spatial and temporal information from radar data.

SPAS has been rigorously tested, both with a theoretical storm where the rainfall rates and spatial distribution are known exactly and with historic storms that have been previously analyzed by the Weather Bureau.

SPAS analyses have been completed for several recent extreme rainfall storms. These include Hurricane Floyd (1999) and two extreme rainfall events over northern Wisconsin (1978 and 2003). Results are presented for the test storm; two Weather Bureau analyzed storms (Westfield, MA 1955 and Ritter, IA 1953), Hurricane Floyd 1999, and the two more recent Wisconsin storm events. The SPAS analysis results compared very well with the theoretical storm rainfall amounts and timing. The SPAS storm-centered depth-area-duration (DAD)

analysis results were within 5% of the Weather Bureau results for Westfield 1955 and Ritter 1953 for most area sizes and durations. SPAS DADs for Hurricane Floyd have been used in a FERC approved site-specific PMP study in New York and several subsequent site-specific PMP studies and storm analyses. The SPAS analysis results are continually being incorporated into updated technology applications for PMP and PMF analyses.

## Background

The Weather Bureau and Corps of Engineers produced many storm studies for extreme rainfall events that occurred during the first half of the last century. The DADs from these studies were used to compare rainfall events and were used in Hydrometeorological Reports (HMRs) to determine PMP rainfall amounts. Objective procedures were used in these analyses augmented with subjective judgment by well qualified Hydrometeorologists. The SPAS analysis procedures incorporate many of the earlier procedures while providing updated techniques along with GIS and NEXRAD to improve the quality and speed of the analyses.

With SPAS, storms analyses (including storm-centered DADs and mass curves) can be efficiently completed much more quickly and with more detail than historic analyses. In the past, a detailed analysis of a storm's precipitation required a great deal of manual labor, hence making it time consuming and prone to human errors. SPAS is a largely automated system, yet it provides flexibility and several enhancements over the old storm analysis procedure. In the past, it was time and cost prohibitive to produce hourly precipitation maps, therefore assumptions had to be made in the computations of the DAD results. SPAS, however, does not have to make as many assumptions since it has the ability to mimic and resolve the storm's precipitation much better through the use of NEXRAD data and GIS algorithms. Table G.1 compares the procedures used historically by the Weather Bureau and SPAS.

Table G.1 Comparison between the Weather Bureau storm analysis method and SPAS.

| Topic | Weather Bureau | SPAS |
|---|---|---|
| Timing of daily stations | Mimics the hourly distribution of the nearest hourly station | Uses several representative hourly stations in an inverse distance weighting scheme |
| Pseudo-data | Did not use | Various options for use |
| Base map options | 100-year 24-hour or nothing | Multiple base map options |
| DAD calculations based on six hour duration analyses | The total storm, hand-analyzed isohyetal map | Based on hourly GIS-created precipitation grids |
| Automation | None | Largely automated |

**Storm Depth-Area-Duration (DAD) Analyses for New Storms**

For newly identified extreme rainfall events without published depth-area-duration (DAD) analyses, DADs needed to be computed. The Storm Precipitation Analysis System (SPAS) was used to compute DADs for these storms.

There are two main steps in a DAD analysis: 1) The creation of high-resolution hourly precipitation grids and 2) the computation of depth-area rainfall amounts for various durations. The reliability of the results from step 2) depend on the accuracy of step 1). Historically the process has been very labor intensive. SPAS utilizes Geographic Information Systems (GIS) concepts to create more spatially-oriented and accurate results in a more efficient manner (step 1). Furthermore, the availability of NEXRAD (NEXt Generation RADar) data allows SPAS to better account for the spatial and temporal variability of storm precipitation for events occurring since the early 1990s. Prior to NEXRAD, the National Weather Service (NWS) developed and used a method based on the research of several scientists. Because this process has been the standard for many years and holds merit, the DAD analysis process developed for this study attempts to mimic it as much as possible. See Appendix G for a full description of SPAS. By adopting this approach, some level of consistency between the newly analyzed storms and the hundreds of storms already analyzed can be achieved. Comparisons between the NWS DAD results and those computed using the new method for two storms (Westfield, MA 1955 and Ritter, IA 1953) indicated very similar results.

## Data Collection

The areal extent of a storm's rainfall is evaluated using existing maps and documents along with plots of total storm rainfall. Based on the storm's spatial domain (longitude-latitude box), hourly and daily data are extracted from the database for the specified area, date and time. To account for the temporal variability in observation times at daily stations, the extracted hourly data must capture the entire observational period of all extracted daily stations. For example, if a station takes daily observations at 8:00 AM local time, then the hourly data needs to be complete from 8:00 AM local time the day prior. As long as the hourly data are sufficient to capture all of the daily station observations, the hourly variability in the daily observations can be properly addressed.

The daily database is comprised of data from National Climatic Data Center (NCDC) TD-3206 (pre 1948) and TD-3200 (generally 1948 through present). The hourly database is comprised of data from NCDC TD-3240. The daily supplemental database is largely comprised of data from "bucket surveys," local rain gauge networks (e.g. ALERT, USGS, etc.) and daily gauges with accumulated data.

The various types of stations include:

1. Hourly complete
2. Hourly stations with reliable temporal precipitation data, but the magnitude is questionable in relation to co-located daily gauge
3. Daily complete
   Daily stations with complete data and known observation times

4. Daily supplemental
   Daily stations without known observation times

As part of the daily data extraction process, the time of observation – as indicted in NCDC TD-3200/3206 – is used. However, experience has indicated that the times in TD3200/3206 are not updated very frequently and are not reliable. Additional efforts are taken to insure the observation times are accurate. Hardcopy reports of "Climatological Data," scanned observational forms and/or station metadata forms have proven to be valuable and accurate resources for observation times. Furthermore, erroneous observation times and dates are identified in the mass-curve procedure and can be corrected at that point in the analysis procedure. For stations with an observation time that is undetermined, it is assumed to have an accurate storm total precipitation and is converted to a daily supplemental using the full tabulated time period of record as the observational period.

## Mass Curves

The most complete rainfall observational dataset available is compiled for each storm. To obtain temporal resolution to the nearest hour in the final DAD results, it is necessary to distribute the daily precipitation observations (at daily stations) into hourly bins. This process has traditionally been accomplished by anchoring each of the daily stations to a single hourly timer station. However, this may introduce biases and may not correctly represent hourly precipitation at locations between hourly stations. A preferred approach is to anchor the daily station to some set of the nearest hourly stations. This is accomplished using a spatially based approach that is called the spatially based mass curve (SMC) process. Steps involved in the SMC process are described below:

1. Evaluate and quality control (QC) hourly station data using synoptic maps, nearby stations, orographic effects, station history and other documentation on the storm. Resolve any problems with the hourly data as well as manually distributing accumulated hourly values. At this point in the process, pseudo (hourly) stations can be added to represent rainfall timing in topographically complex locations, areas with limited hourly data, and to capture the temporal variations of the precipitation. This is done by distributing the precipitation by hand at a co-located daily station or by creating a completely new pseudo station. In either case, the pseudo-station is flagged with a "P" so the software knows only to use it for timing and not its actual precipitation. A true hourly station is flagged "H" while daily and supplemental stations are flagged "D" and "S," respectively. If a daily station is used to create a pseudo-station, the pseudo-station is used in all of the subsequent mass-curve related products (i.e. grids and maps). This procedure is similar to the NWS approach. Like in the NWS procedure, care must be taken to insure hourly stations represent important physical and meteorological characteristics before being incorporated into the process. In general, use of pseudo-data is kept to a minimum. The importance of insuring the reliability of every hourly station cannot be over emphasized. Since the entire SMC process is based on them, it is important to collect as many accurate and representative hourly stations as possible. All

of the final hourly stations, including pseudos, are included in the master GIS hourly rainfall file.

2. Using the master GIS hourly file, actual hourly precipitation values are converted into percentages that are the actual individual hourly precipitation values divided by the total tabulated hourly precipitation for that station. The percentages are not a function of the core precipitation period (CPP), but rather a percentage based on the storm precipitation period (SPP). An hourly percent of total storm rainfall value is computed for the location of the daily reporting station for each hour of the storm. Adjustments are made to account for any differences in accumulated daily rainfall amounts between the sum of hourly rainfall values and the daily amounts reported at the daily reporting station. A GIS-ready x-y file is then constructed for each hour that contains the latitude, longitude and percent of precipitation for a particular hour. Using GIS (GRASS 6.2), an inverse-distance-weighting (IDW) interpolation technique is applied to each of the files. The result is a continuous grid with percentage values for the entire domain, keeping the grid cells on which the hourly station resides faithful to the observed/actual percentage. Because the percentages typically have a high degree of spatial autocorrelation, the spatial interpolation has skill in determining the percentages between stations, especially since the percentages are somewhat independent of the precipitation magnitude. The end result is a grid file for each hour that represents the percentage of the SPP precipitation that fell during that hour.

3. At this point another quality control procedure has been designed for the SMC process. Since the SMC process is spatially oriented, a tool was designed that allows the analyst to use a point-and-click interface to evaluate the hourly percentile maps. This is an effective way to immediately detect temporal and spatial problems with the hourly-based percentiles. Any problems identified are resolved and the process to this point is re-run.

4. After the hourly maps of percentages are generated and QC'd for the entire SPP, a program is executed that converts the daily station data into incremental hourly data. The timing at each of the daily stations is based on (1) the daily station observation and (2) the interpolated grid-cell hourly percentage of total storm precipitation. To make the daily accumulated mass curve data faithful to the daily observations (at daily stations), it is necessary to adjust the hourly percentages such that they add up to 100% and therefore account for 100% of the daily observed precipitation. To accomplish this, an adjustment factor is applied to each of the hourly values with greater than zero inches of precipitation.

5. A similar program is run that converts the supplemental daily stations (i.e. those stations with unknown or uneven observational periods and/or accumulated values) into incremental hourly data. In cases where the hourly grids/maps do not indicate any precipitation falling during the daily stations' observational period but the daily station reported precipitation, the daily total precipitation is evenly distributed throughout the hours that make up the observational period. This is the same procedure traditionally used by the NWS method in these cases. Another possible problem at this point is the

situation where the observational period at the daily station extends before or beyond that of the hourly data. The software is sensitive to this and forces an exit, then prompts the analyst with suggested changes to the raw data.

6. Similar to the NWS method, exhaustive quality control measures are taken at this point. The SMC procedure groups each station (regardless of type) and some number (user specified) of nearest stations (regardless of type) into a single file. These files are subsequently imported into graphing software (or a spreadsheet) for graphing and evaluation. Unusual characteristics in the mass curve are investigated and the station data corrected, if necessary. Once the final mass curve results are complete, the database is ready to create hourly precipitation maps.

## Hourly or Sub-hourly Precipitation Maps

At this point, SPAS can operate either in its standard mode or in NEXRAD-mode to create high resolution hourly or sub-hourly (for NEXRAD storms) grids. In practice both modes are run so that a comparison can be made between the methodologies. Regardless of the mode, the resulting grids serve as a basis for the DAD results.

### Standard SPAS mode

The standard SPAS mode requires a full listing of all the actual hourly precipitation values, as well as the newly created estimated hourly data from daily and daily supplemental stations (pseudo-stations are not included). This is done by creating an hourly file that contains the newly created hourly mass curve precipitation data (from the daily and supplemental stations) and the "true" hourly mass curve precipitation (not percent). If not using a base map, the individual hourly precipitation values are simply plotted and interpolated to a raster with an IDW interpolation routine in a GIS.

### NEXRAD mode

Radar has been in use by meteorologists since the 1960's to estimate rainfall depth. In general, most current radar-derived rainfall techniques rely on an assumed relationship between radar reflectivity and rainfall rate. This relationship is described by the equation (1) below:

(1) $Z = aR^b$

where Z is the radar reflectivity, measured in units of dBZ, R is the rainfall rate, $a$ is the "multiplicative coefficient" and $b$ is the "power coefficient". Both $a$ and $b$ are directly related to the drop size distribution (DSD) and the drop number distribution (DND) within a cloud (Martner et al 2005).

The National Weather Service (NWS) uses this relationship to estimate rainfall through the use of their network of Doppler radars (NEXRAD) located across the United States. A

standard default Z-R algorithm of $Z = 300R^{1.4}$ is the primary algorithm used throughout the country and has proven to produce highly variable results. The variability in the results of Z vs. R is a direct result of differing DSD and DND, and differing air mass characteristics across the United States (Dickens 2003). The DSD and DND are determined by a complex interaction of microphysical processes in a cloud. They fluctuate hourly, daily, seasonally, regionally, and even within the same cloud. Other factors that affect radar rainfall computations include occultation or blockage of the radar beam due to terrain features and range effects that are the result of the radar beam passing through the cloud at elevations too high in the cloud to observe the main precipitation portion of the cloud.

Using the technique described above, NEXRAD rainfall depth and temporal distribution estimates are determined for the area in question.

The methodology that is used to estimate the rainfall is described below.

1. Surface rainfall observations measured within the project area are obtained from multiple sources for the rainfall event. A Geographic Information System (GIS) layer containing the locations of these rainfall observations (Figure 1.0) is created using GIS software.

2. NEXRAD Level II data is obtained from the National Climatic Data Center (NCDC). Level II Base Reflectivity data, 0.50-degree beam angle (lowest beam angle), 124 km range, data resolution of 1 degree x 1.0 km (polar coordinates) and 0.50 dBZ data bin resolution is extracted from the Level II dataset (Figure 2.0).

3. The polar coordinate base reflectivity data (Z) is converted into Cartesian coordinate ESRI ASCII GIS files and combined with the rainfall observations GIS layer. The grid cells within the GIS grid have a resolution of approximately 1.00 $km^2$. A SPAS program is used to determine base reflectivity values (Z) over each grid cell, within the project area, for each base reflectivity time step.

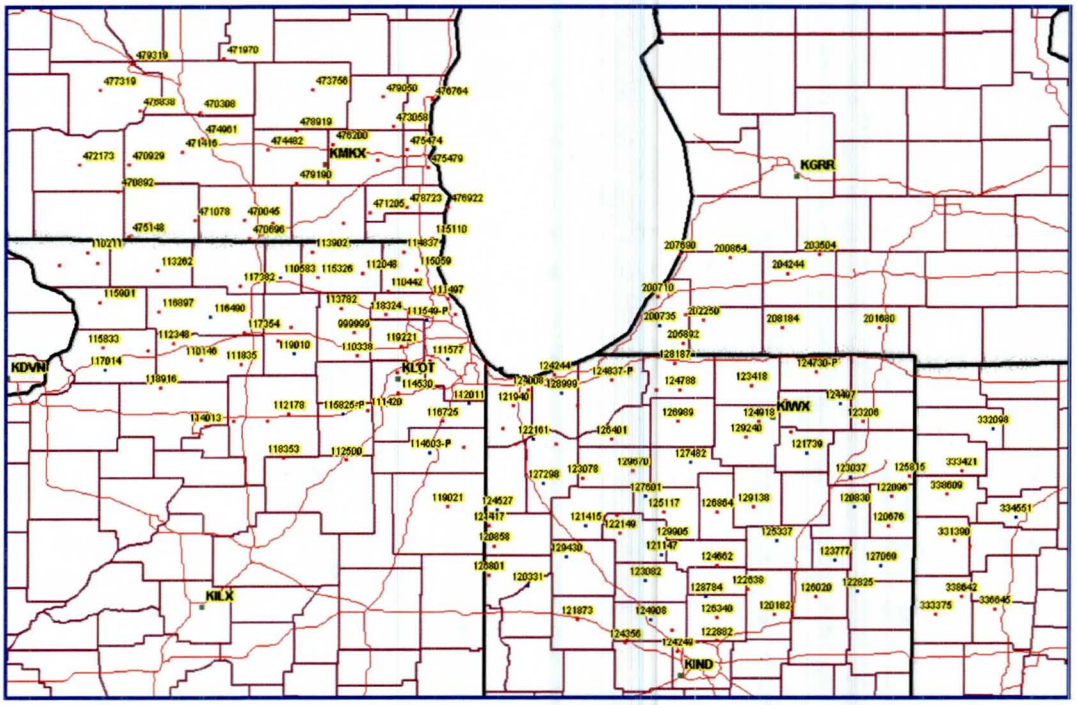



Figure G.1 Example rainfall calculation project area with rain gauge locations

4. A range correction scheme developed by the United States Bureau of Reclamation is applied to each grid cell.

   The range correction factor (CF) used was: $(1.04607 - 0.0029590)\,(r + 0.0000506)\,r^2$ where $r$ is the range (distance in km) from the radar (Hartzell and Super, 2000). The correction is applied to grid cells that are greater than 35 km beyond the radar site. The range correction corrects for rainfall underestimation due to the radar beam passing through an elevation too high in the cloud to observe the main precipitation portion of the cloud.

A procedure is used to calculate a "best-fit" Z-R algorithm for the project area. A "best-fit" Z-R algorithm is calculated on an hourly basis by using the least squares methodology.

Least squares is a mathematical optimization technique which, when given a series of observed data values, finds a function which closely approximates the data (a "best fit"). It attempts to minimize the sum of the squares of the differences between points generated by the function and corresponding points in the data.

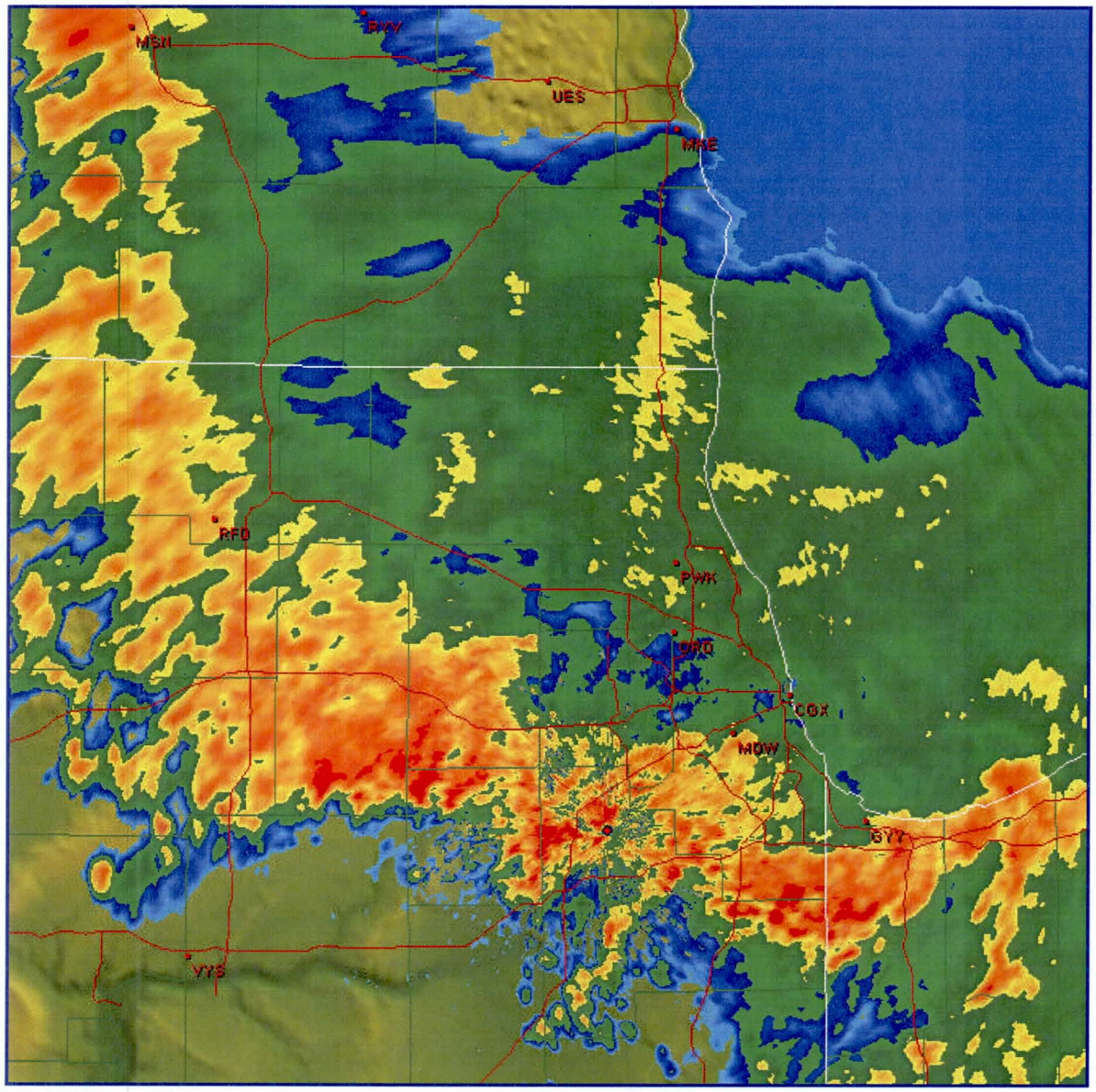



Figure G.2 Doppler radar Level II base reflectivity image

The calculated hourly "best-fit" Z-R algorithm is used to compute radar derived hourly rainfall depths for each hourly rain gauge location.

By comparing radar calculated rainfall (Rcalc) depths to observed point rainfall depths at the rainfall observation sites and calculating a ratio (Rcalc/Robs), it is determined how close a fit exists between the estimated rainfall depths and the observed point rainfall depths. This procedure yields areas where ratios are above 1.0 and areas where ratios are below 1.0. These differences in ratios can be partially contributed to convective rainfall and hail. This results in

vastly different DSD and DND being observed by the radar beams during each radar scan, producing some variability between the radar derived rainfall and the observed rainfall depths. Other issues that contribute are discussed in the next section.

Issues are sometimes encountered in the radar-rainfall calculation process that can contribute to a less than perfect correlation between radar rainfall depth calculations and rainfall depth observations at the rainfall observation sites. These issues include the following:

1. Area average radar-rainfall depth estimates versus observed point rainfall depths: A rain gauge observation represents a much smaller area than the area sampled by the radar. The area that the radar is sampling is approximately $1km^2$. The radar data provide the average reflectivity (Z) within the area being sampled. This average reflectivity is used to convert Z to Rcalc for the sample area. This radar derived rainfall value is compared to a point rainfall depth measured by a rain gauge located within the radar sample area. This area vs point issue contributes to correlations greater than or less than 1.0 within the project area.

2. Rain gauge catch: Precipitation gauges, shielded and unshielded, inherently underestimate total precipitation due to local airflow, wind undercatch, wetting, and evaporation. The wind undercatch errors are usually around 5% but can be as large as 40% in high winds. Tipping buckets miss a small amount of rainfall during each tip of the bucket due to the bucket travel and tip time. As rainfall intensities increase, the volumetric loss of rainfall due to tipping tends to increase. At rainfall intensities greater than 152 mm per hour, 1 mm tipping buckets will under report rainfall in the range of 0-5% depending on how the gauge was calibrated. Smaller tipping buckets can have higher volumetric losses due to higher tip frequencies.

3. Radar Calibration: NEXRAD radars calibrate reflectivity every volume scan, using an internally generated test. The test determines changes in internal variables such as beam power and path loss of the receiver signal processor since the last off-line calibration. If this value becomes large, it is likely that there is a problem with the calibration and precipitation estimates could be significantly in error. The calibration test is supposed to maintain a reflectivity precision of 1 dBZ. A 1 dBZ error results in an error of 17% in Rcalc, using the default Z-R relationship Z=3001.4. Higher calibration errors will result in higher Rcalc errors. However, by performing correlations each hour, the calibration issue is minimized.

4. Attenuation: Attenuation is the reduction in power of the radar beams energy as it travels from the antenna to the target and back and is caused by the absorption and the scattering of power from the beam by precipitation. Attenuation can result in errors in Z as large as 1 dBZ especially when the radar beam is sampling a large area of heavy precipitation, as was the case for this rainfall event.

5. Range effects: The curvature of the Earth and standard refraction result in the radar beam becoming more elevated above the surface with increasing range. With the

increased elevation of the radar beam comes a decrease in Z values due to the radar beam not sampling the main precipitation portion of the cloud. A correction scheme is used for this issue.

6. Radar Beam Occultation/Ground Clutter: Radar occultation (beam blockage) results when to the radar beam's energy intersects terrain features. The result is an increase in radar reflectivity values that can result in higher than normal rainfall estimates.

Using GIS, the radar reflectivity grids are converted into rainfall depths using Z-R equations. The equations were unique to defined "sectors" which exhibited similar DSD, reflectivity (Z) values and observed rainfall. After several iterations to account for changes in the sector boundaries, a final "radar reconstruction" (Rcalc) is completed for each radar site being utilized in the process.

If more than one radar site is being utilized the 5 or 6-minute rainfall grids from each radar site are mosaiced together to produce a seamless grid of precipitation for the storm domain. The complete grid is smoothed to remove extraneous noise. Additionally, the radar domain boundaries are subjected to additional smoothing to ensure a smooth spatial transition from one radar domain to the next and across sector boundaries. The mosaiced grids are then summed into hourly or sub-hourly intervals.

### Gridded Rainfall Quality Control

At this point, additional QC checks are completed on the resulting hourly or sub-hourly precipitation maps/grids for the SPP. Among the tools is a point-and-click graphical user interface used to evaluate the hourly precipitation grids. However, by this point error detection becomes much more difficult since the maps contain more data points and the data has been through several QC screening processes already. The total cumulative precipitation (or any combination of hours) and/or maximum 1-hour grids can be viewed to find gross errors. The end result is individual hourly or sub-hourly precipitation grids for the entire SPP.

## Depth-Area-Duration (DAD) Program

The DAD extension of SPAS runs from within a GRASS 6.2 GIS environment and utilizes many of the built-in functions for calculation of area sizes and average depths. The following is the general outline of the procedure:

1. Given a duration (e.g. x-hours) and cumulative precipitation, sum up the appropriate hourly or sub-hourly precipitation grids to obtain an x-hour total precipitation grid starting with the first x-hour moving window

2. Determine x-hour precipitation total and its associated areal coverage. Store these values. Repeat for various lower rainfall thresholds. Store the average rainfall depths and area sizes

a. Determine if the x-hour window includes the last hour of the CPP; if it does not move the x-hour window forward one hour and return to step 1.

3. The result is a table of depth of precipitation and associated area sizes for each x-hour window location. Summarize the results by moving through each of the area sizes and choosing the maximum precipitation amount. A log-linear plot of these values provides the depth-area curve for the x-hour duration.

4. Based on the log-linear plot of the rainfall depth-area curve for the x-hour duration, determine rainfall amounts for the standard area sizes for the final DAD table. Store these values as the rainfall amounts for the standard sizes for the x-duration period.
   a. Determine if the x-hour duration period is the longest duration period being analyzed; if it is not, analyze the next longest duration period and return to step 1.

5. Construct the final DAD table with the stored rainfall values for each standard area for each duration period.

## Test Cases

To check the accuracy of the DAD software, three test cases were evaluated.

### "Pyramidville" Storm

The first test was that of a theoretical storm with a pyramid shaped isohyetal pattern. This case was called the Pyramidville storm. It contained 361 hourly stations, each occupying a single grid cell. The configuration of the Pyramidville storm (see Figure G.3) allowed for uncomplicated and accurate calculation of the analytical depth-area truth independent of the DAD software. The main motivation of this case was to verify that the DAD software was properly computing the area sizes and average depths.

1. Storm center: 39°N 104°W
2. Duration: 10-hours
3. Maximum grid cell precipitation: 1.00" (see Figure 3.0)
4. Grid cell resolution: 0.06 sq.-miles (361 total cells)
5. Total storm size: 23.11 sq-miles
6. Distribution of precipitation:
   Hour 1: Storm drops 0.10" at center (area 0.06 sq-miles)
   Hour 2: Storm drops 0.10" over center grid cell AND over one cell width around hour 1 center
   Hours 3-10:
   1. Storm drops 0.10" per hour at previously wet area, plus one cell width around previously wet area
   2. Area analyzed at every 0.10"
   3. Analysis resolution:
      15-sec (~.25 sq-miles)

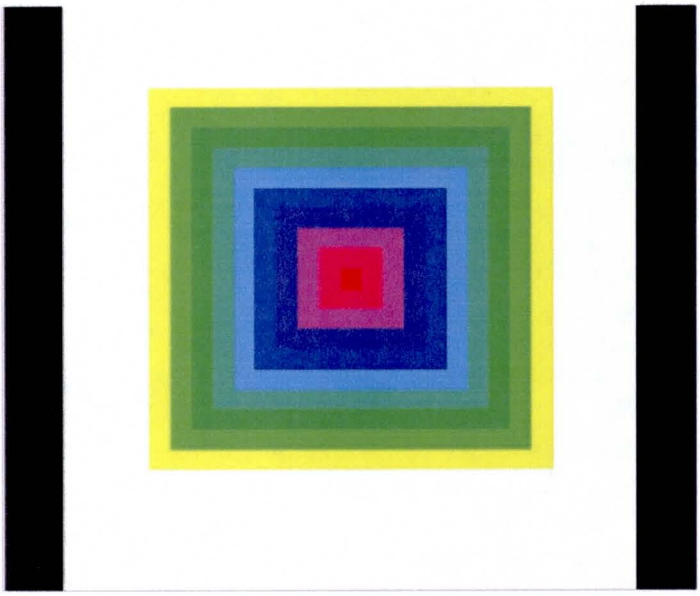


Figure G.3 "Pyramidville" Total precipitation. Center = 1.00", Outside edge = 0.10"

The analytical truth was calculated independent of the DAD software, and then compared to the DAD output. The DAD software results were equal to the truth, thus demonstrating that the depth-area estimates were properly calculated (Figure G.4).

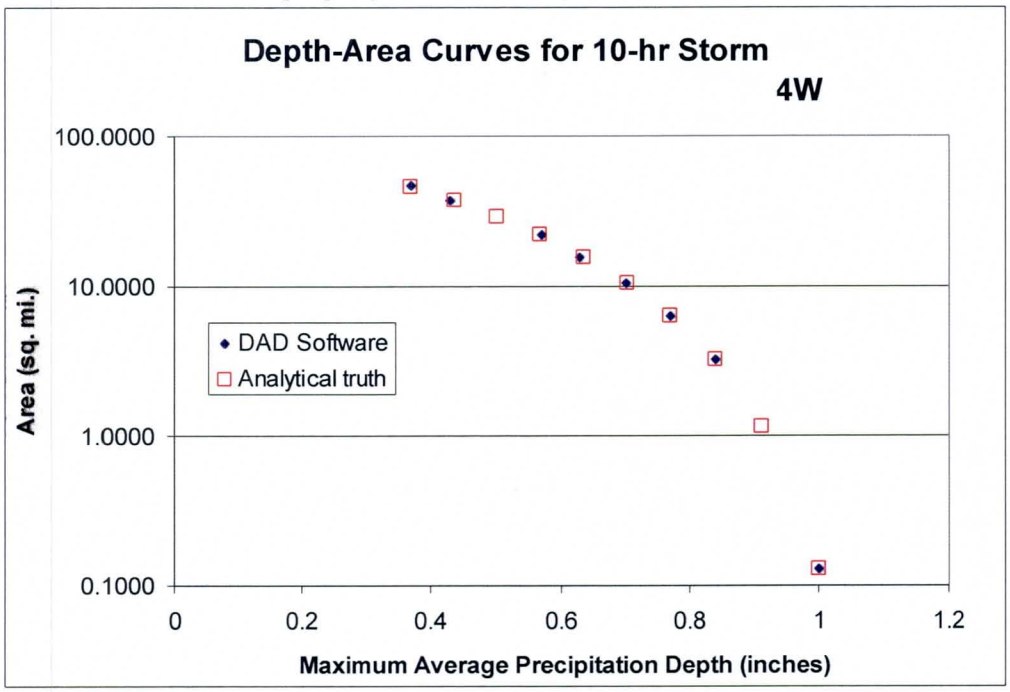



Figure G.4 10-hour depth-area results for "Pyramidville"; truth vs. output from DAD software

The Pyramidville storm was then changed such that the mass curve and spatial interpolation methods would be stressed. Test cases included:

- Two-centers, each center with 361 hourly stations
- A single center with 36 hourly stations, 0 daily stations
- A single center with 3 hourly stations and 33 daily stations

As expected, results began shifting from the 'truth,' but minimally and within the expected uncertainty.

### Ritter, Iowa Storm, June 7, 1953

Ritter, Iowa was chosen as a test case for a number of reasons. The NWS had completed a storm analysis, with available DAD values for comparison. The storm occurred over relatively flat terrain so orographics was not an issue. An extensive "bucket survey" provided a great number of additional observations from this event. Of the hundreds of additional reports, about 30 of the most accurate reports were included in the DAD analysis.

The DAD software results are very similar to the NWS DAD values (Table G.2).

Table G.2 The percent difference [(AWA-NWS)/NWS] between the AWA depth-area results and those published by the NWS for the 1953 Ritter, Iowa storm

**% Difference**

| | Duration (hours) | | | | |
|---|---|---|---|---|---|
| **Area (sq.mi.)** | | 6 | 12 | 24 | total |
| | | | | | |
| **10** | | -15% | -7% | 2% | 2% |
| **100** | | -7% | -6% | 1% | 1% |
| **200** | | 2% | 0% | 9% | 9% |
| **1000** | | -6% | -7% | 4% | 4% |
| **5000** | | -13% | -8% | 2% | 2% |
| **10000** | | -14% | -6% | 0% | 0% |

### Westfield, Massachusetts Storm, August 8, 1955

Westfield, Massachusetts was also chosen as a test case for a number of reasons. It is a probable maximum precipitation (PMP) driver for the northeastern United States. Also, the Westfield storm was analyzed by the NWS and the DAD values are available for comparison. Although this case proved to be more challenging than any of the others, the final results are very similar to those published by the NWS (Table G.3).

Table G.3 The percent difference [(AWA-NWS)/NWS] between the AWA depth-area results and those published by the NWS for the 1955 Westfield, Massachusetts storm.

**% Difference**

| | Duration (hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Area (sq. mi.)** | | 6 | 12 | 24 | 36 | 48 | 60 | total |
| | | | | | | | | |
| **10** | | 2% | 3% | 0% | 1% | -1% | 0% | 2% |
| **100** | | -5% | 2% | 4% | -2% | -6% | -4% | -3% |
| **200** | | -6% | 1% | 1% | -4% | -7% | -5% | -5% |
| **1000** | | -4% | -2% | 1% | -6% | -7% | -6% | -3% |
| **5000** | | 3% | 2% | -3% | -3% | -5% | -5% | 0% |
| **10000** | | 4% | 9% | -5% | -4% | -7% | -5% | 1% |
| **20000** | | 7% | 12% | -6% | -3% | -4% | -3% | 3% |

The principal components of SPAS are: storm search, data extraction, quality control (QC), conversion of daily precipitation data into estimated hourly data, hourly and total storm precipitation grids/maps and a complete storm-centered DAD analysis.

## Data

### Storm Search

A storm search is the first step in a SPAS run. A total storm map is created with readily available rainfall data to estimate the areal extent of the storm. Based on the initial storm map, a user-defined domain is established as the SPAS study area, typically a latitude-longitude box. The study area and storm dates are entered into software that extracts and formats all of the available hourly and daily precipitation data. For example, Hurricane Floyd produced heavy rain over many regions of the Atlantic seaboard. One of the SPAS analyses selected the rainfall center over northern New Jersey. The state of New Jersey along with portions of surrounding states was analyzed. Additionally, for a NEXRAD-based analysis radar sites are identified and the NEXRAD Level II is obtained from the National Climatic Data Center (NCDC). Level II Base Reflectivity data, 0.50-degree beam angle (lowest beam angle), 124 km range, data resolution of 1 degree x 1.0 km (polar coordinates) and 0.50 dBZ data bin resolution is extracted from the Level II dataset. In order to make the NEXRAD data compatible with SPAS, it is re-projected from its native polar coordinate system to a Cartesian coordinate system. Thereafter, the grids are converted into ESRI ASCII GIS files. The grid cells within the GIS grid have a resolution of approximately 1.00 $km^2$.

### Precipitation Data

SPAS has the ability to utilize a variety of different types of data to achieve the highest spatial and temporal resolution possible. The majority of data are obtained from digital archives provided by NCDC. These datasets represent official precipitation information and therefore provide the most critical precipitation input to SPAS. However, supplemental data from other sources can also be used to better resolve the storm's characteristics.

### *Hourly data*

Precipitation data that is reported every hour comes from a variety of sources. The base hourly data is from the NCDC dataset TD-3240, U.S. Control Cooperative Hourly Precipitation. This dataset provided hourly data sufficient for the Hurricane Floyd analysis. However, other hourly precipitation gauge data from Automated Local Evaluation in Real Time (ALERT) networks, Remote Automated Weather Stations (RAWS), NWS's Automated Surface Observing Systems (ASOS), municipal networks, etc. can also be used.

Quality control (QC) is an ongoing exercise in SPAS. The first QC takes place after the hourly data has been collected. The hourly station data are evaluated based on knowledge acquired from weather maps, nearby stations, known orographic effects, station history and other documentation on the storm. Any hourly data errors are resolved.

Observed hourly data governs the temporal characteristics of the storm and is also used in the radar calibration (for NEXRAD-based SPAS runs), so every attempt is made to restore incomplete or accumulated hourly data records. This is done using the same knowledge used to QC the data. Based on professional judgment and the level of restoration required, the restored hourly stations are flagged either as pseudo-hourly stations or as supplemental hourly stations. Supplemental hourly stations will be treated in SPAS just like a complete hourly station. Pseudo-hourly stations, on the other hand, are only utilized for timing considerations. Pseudo-hourly stations allow the SPAS meteorologist to add data to the analysis to better resolve physical and meteorological processes that would otherwise be ignored in a strict model. Creating pseudo hourly data is accomplished by manual distributing precipitation at a daily station into hourly estimates. This distribution is determined from nearby hourly stations and information from other sources such as radar or local storm reports. The Hurricane Floyd analysis did not require any pseudo-hourly stations since the precipitation and terrain were both relatively uniform. However, several hourly stations were flagged supplemental.

### *Daily data*

Daily precipitation data representing a 24-hour accumulation are more abundant than hourly precipitation data, and thus provide valuable spatial detail. Daily data are available from a number of sources, but the base data are from the NCDC datasets TD-3200, U.S. Cooperative Summary of Day, and TD-3206 U.S., Cooperative Summary of the Day – pre 1948. Additional supporting daily data is often obtained from other sources such as municipal networks, etc. In fact, for our Floyd analysis we obtained over 100 supplemental daily observations, taken by volunteer observers who belong to one or more of several networks across New Jersey, from the New Jersey State Climatologist Office.

An initial QC screening of the daily data is conducted at this point. The daily data are summed into storm totals and mapped to spatially identify gross errors. Also, the daily data are subjected to a threshold check that identifies all of the daily precipitation values that equal or exceed some threshold. The threshold is usually objectively based on the depth of precipitation

for a 50- or 100-year reoccurrence interval available from the current precipitation frequency atlases. For our Hurricane Floyd analysis, we used 7.50 inches, the average 100-year 24-hour precipitation in New Jersey from Technical Paper 40.

Once an initial QC pass is completed on all of the available data, SPAS begins its analysis of the hourly data in order to convert the daily data into estimated hourly amounts.

**Methodology**

Among one of most significant strengths of SPAS is its ability to convert daily measured precipitation into hourly precipitation – known as timing - utilizing several nearby hourly stations. In the past, timing of daily measured data was accomplished by associating each daily station with a nearby hourly station and distributing the daily precipitation exactly the same as that hourly station. SPAS, however, uses several hourly stations to time each of the daily stations, thereby allowing the hourly precipitation distribution to be unique at each daily station. If NEXRAD data are available, then it is also used for timing.

***Hourly Percentile Grids***

The hourly data serve as the basis for timing the daily stations. The first step involved with this transformation is converting each of the hourly precipitation depths into a percent of the total storm precipitation. The hourly percentages from each station are then plotted and spatially distributed for each hour of the storm. The percentages are spatially distributed to a uniform grid by applying an inverse-distance-weighting (IDW) algorithm, an exact interpolator where the grid cell values at stations are equal to the station value. Because the percentages typically have a high degree of spatial autocorrelation, the spatial interpolation carries skill in predicting the percentages between hourly stations, especially since the percentages are largely independent of the precipitation magnitude. For instance, an orographic flow over a mountain range will deposit more precipitation on the windward side and less on the lee side; however the timing of the precipitation across the mountain range will generally be the same. The end result is a grid for each hour of the storm, each representing the percentage of precipitation that fell during that hour (see Figure B.5.)

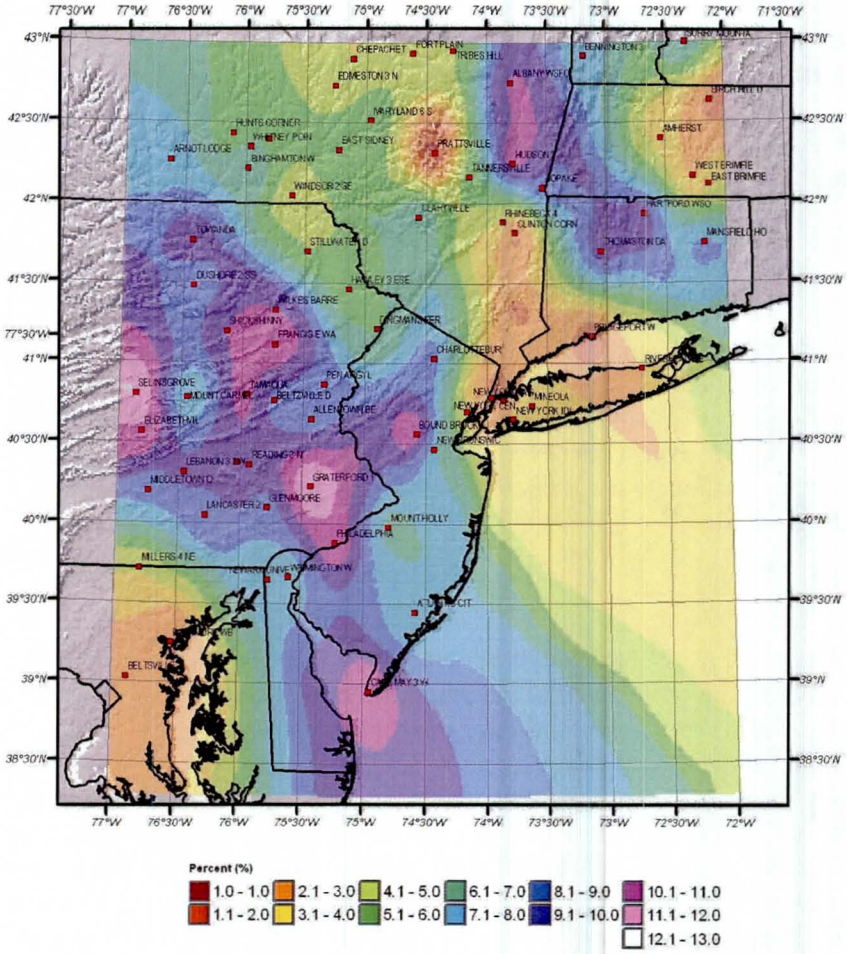



Figure G.5 An example of a percent of total precipitation map for a single hour during Hurricane Floyd. Each symbolized station represents an hourly station.

At this point, a point-and-click QC interface in a GIS is used to evaluate the hourly percentile grids. This has proven to be an effective way to immediately detect temporal and spatial problems with the hourly station data. After all problems have been resolved, the process is then re-run to this point.

### *Timing of Daily Data*

After the hourly percentile grids are finalized, they are used to create simulated hourly data for daily station data. The observation time and coordinates of the daily station are used to extract the appropriate percentile values from the appropriate hourly percentile grids and stored. To make the daily-accumulated hourly data faithful to the daily observations, it is necessary to adjust the hourly percentages such that they add up to 100% to account for all of the daily observed precipitation. To accomplish this, an adjustment factor is applied to each of the hourly values by multiplying the daily station observational day precipitation by the ratio of the actual

hourly percentage to the sum of percentages for that observational day. The daily precipitation amounts are then multiplied by the adjusted percentile values, resulting in a series of hourly precipitation estimates for the daily station (see Figure G.6).

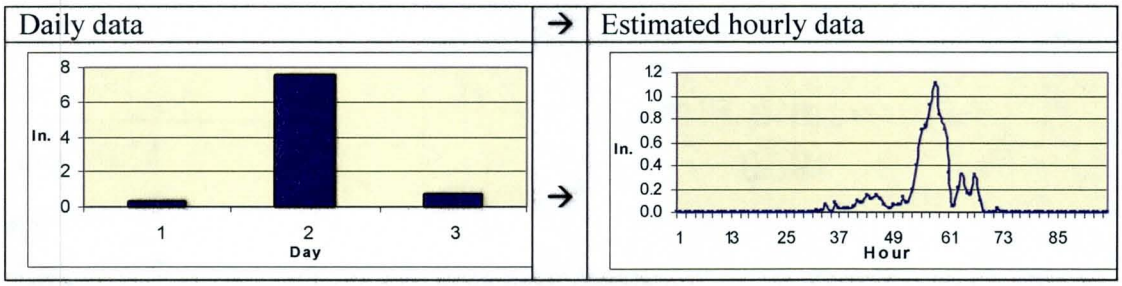



Figure G.6 An illustration of how SPAS converts three days of daily precipitation into estimated hourly amounts.

A similar procedure is used to convert the supplemental and pseudo-daily data (i.e. those stations with uneven observational periods and/or accumulated values) into hourly precipitation estimates. Since these stations do not always have a complete precipitation record for the entire storm period, their missing hours of precipitation are filled in with spatially interpolated estimates later in the SPAS process.

Once the daily data has been converted into hourly estimates, exhaustive and very effective QC measures are taken. Plots of the incrementally accumulated precipitation data (known as mass curves) are created for each daily station and then combined into a single plot with other nearby stations for evaluation. The most common QC issue detected at this stage is related to the observation time of the daily station. A suspect observation time will cause a shift in the distribution of precipitation in comparison to the other nearby stations. Any suspect observation times are corrected when possible. Otherwise, the station is converted to a supplemental station with the observational period set to the bounds of the storm period, hence making it unnecessary to know the daily stations' observation time(s). Once any and all timing issues are resolved, SPAS is re-run.

## Output

SPAS generates a number of products to aid in hydrologic modeling, Probable Maximum Precipitation (PMP) applications and other hydrologic studies. The SPAS output includes:

1. High resolution (user defined, but typically 30-seconds or about 0.5 miles) hourly precipitation grids and ArcView Shapefiles.
2. Mass curves for all of the stations (see Figure G.7)
3. A complete storm-centered DAD table and summary, including station density. (See Figure G.8 and G.9)
4. A complete station list.

5. Color cartographic total storm precipitation map (see Figure G.10)

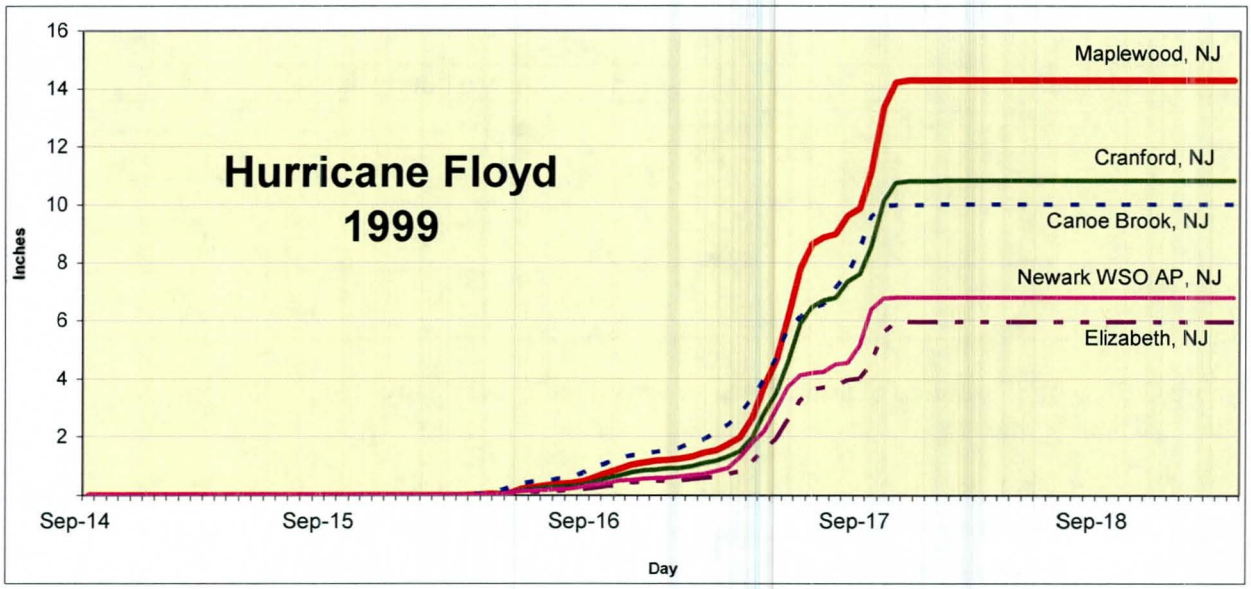



Figure G.7 Storm center mass curve for precipitation associated with Hurricane Floyd (September 14-18, 1999) in New Jersey.

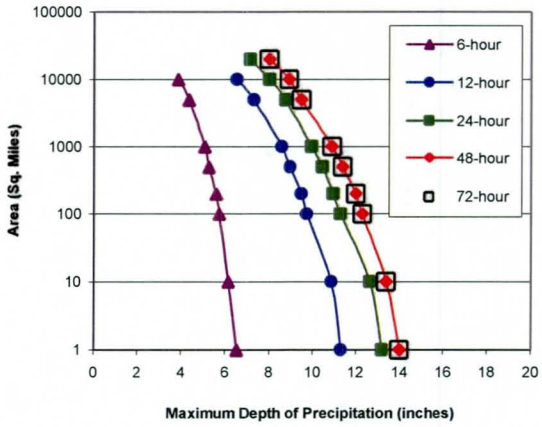



Figure G.8 Storm-centered DAD graph associated with the New Jersey rainfall from Hurricane Floyd (September 14-18, 1999).

| Area | Duration (hours) | | | | |
|---|---|---|---|---|---|
| (sq. mi.) | 6 | 12 | 24 | 48 | 72 |
| 1 | 6.5 | 11.3 | 13.2 | 14.0 | 14.0 |
| 10 | 6.1 | 10.9 | 12.7 | 13.4 | 13.4 |
| 100 | 5.7 | 9.8 | 11.3 | 12.3 | 12.3 |
| 200 | 5.6 | 9.5 | 11.0 | 12.0 | 12.0 |
| 500 | 5.3 | 9.0 | 10.5 | 11.4 | 11.4 |
| 1000 | 5.1 | 8.6 | 10.0 | 10.9 | 10.9 |
| 5000 | 4.4 | 7.3 | 8.8 | 9.5 | 9.5 |
| 10000 | 3.9 | 6.5 | 8.0 | 8.9 | 8.9 |
| 20000 | 3.3 | 5.6 | 7.1 | 8.0 | 8.0 |

Figure G.9 Storm-centered DAD table for the New Jersey rainfall from Hurricane Floyd (September 14-18, 1999).

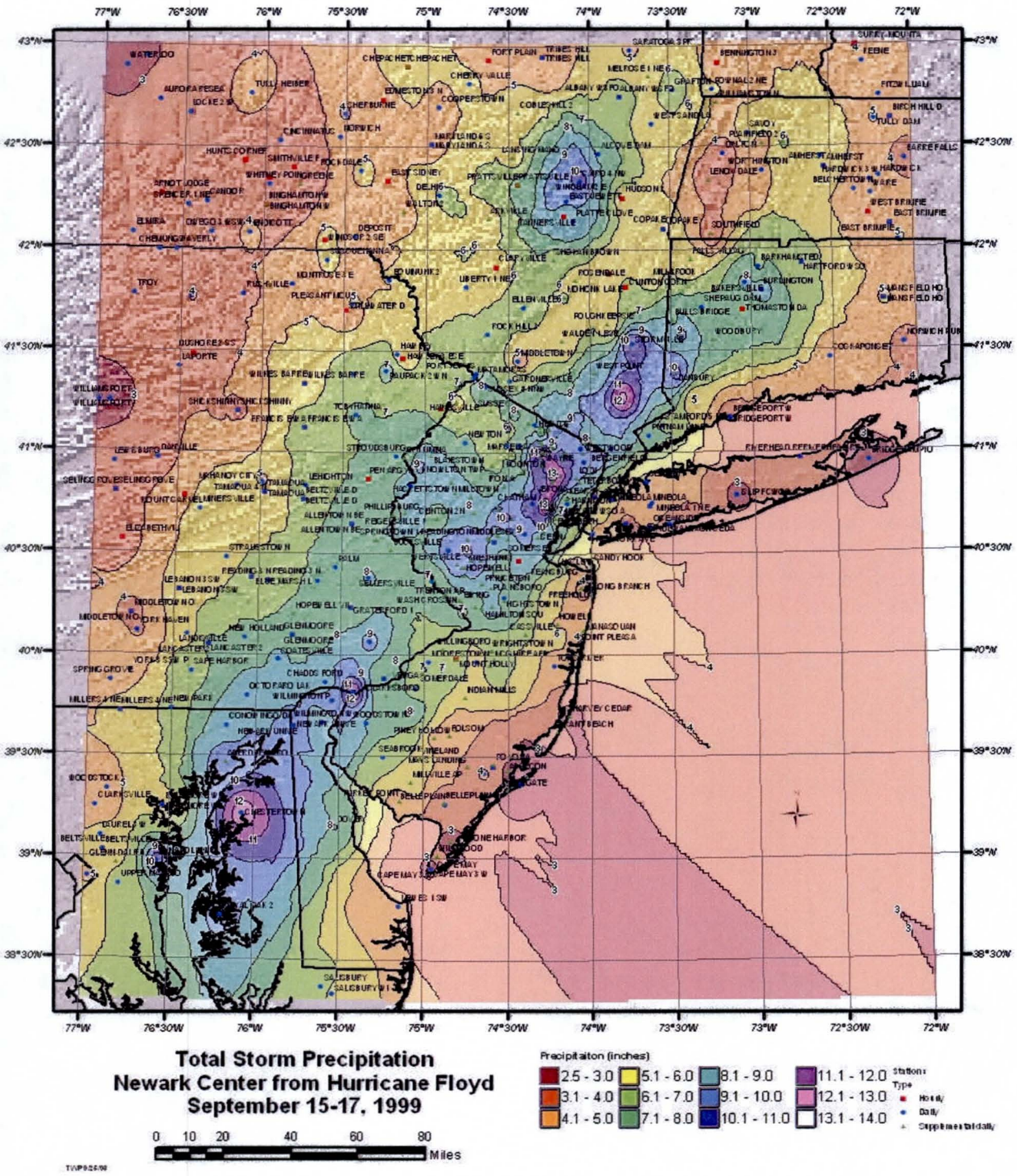



Figure G.10 Total storm (Hurricane Floyd) precipitation map for the New Jersey region during the period September 14-18, 1999 developed using SPAS.

## Summary

SPAS is based on the sound foundation of the storm analysis procedure used by the Weather Bureau, thereby providing consistency between storms already analyzed and those being analyzed today. However, SPAS has the ability to compute more precise and perhaps more accurate results by using a more sophisticated timing algorithm, a variety of base maps, a wider variety of data and fewer assumptions. Although largely automated, SPAS has been designed to be flexible such that it can be utilized for any storm situation. SPAS produces reproducible results and uses less subjectivity than previous storm analysis studies.

There is a very large backlog of extreme rainfall storm analyses that should be completed. With rare exception, extreme rainfall storms that have occurred in the last 50 years have not been analyzed. Without storm DADs, comparison of rainfall amounts from extreme rainfall storms for various area sizes and durations is not possible. The storm databases in most of the current HMRs are significantly out of date. For example, the most recent storm used in HMR 51 occurred in 1972. Using SPAS, this backlog in storm analyses can be addressed. Equally important, storm analyses can be provided in near real-time, utilizing rainfall observations that are not included in official archives. Analyses could provide emergency managers with some measure of how extreme storm rainfall amounts over various area sizes and for various durations were compared to other storms, to published return frequency values and to published PMP values.

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# Site-Specific Probable Maximum Precipitation Study for the White Tanks #4 Drainage Basin

## Appendix F Storm Analyses

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# Appendix F:

# List of Storms Analyzed

Storm files were made for the twenty-eight storms used to derive the site-specific PMP values for White Tanks #4 drainage basin. This includes twelve local convective storms, eight remnant tropical storms, and eight general frontal storms (Table F.1)

## Table F.1 White Tanks #4 Short Storm List (Chronological listing)

| SPAS Storm Number | Storm Type | Storm Location | State | Date | Lat | Lon | Precip |
|---|---|---|---|---|---|---|---|
| SPAS 1144 | General Frontal | Mt. Ord | AZ | 1/14-21/1916 | 33.754 | -111.563 | 7.85 |
| SPAS 1077 | Remnant Tropical | Crossman Creek | AZ | 9/3-7/1939 | 34.546 | -114.196 | 9.65 |
| SPAS 1076 | Remnant Tropical | Crown King | AZ | 8/26-30/1951 | 34.010 | -112.260 | 10.30 |
| SPAS 1096 | Local Convective | Queen Creek | AZ | 8/19/1954 | 33.203 | -111.145 | 8.06 |
| SPAS 1064 | Local Convective | Wellton | AZ | 8/24/1955 | 32.579 | -114.338 | 6.49 |
| SPAS 1154 | General Frontal | Horshoe Dam | AZ | 10/27-11/1/1959 | 33.040 | -111.000 | 6.70 |
| SPAS 1083 | Remnant Tropical | Sonora Desert Museum | AZ | 9/26-28/1962 | 32.179 | -111.388 | 7.16 |
| SPAS 1060 | Local Convective | North Tucson | AZ | 9/6-7/1964 | 32.304 | -111.004 | 5.28 |
| SPAS 1059 | Remnant Tropical | Sahuarita | AZ | 9/9-11/1964 | 32.006 | -110.904 | 6.77 |
| SPAS 1075 | Remnant Tropical | Norma | AZ | 9/4-7/1970 | 31.960 | -111.610 | 8.01 |
| SPAS 1062 | Local Convective | Phoenix | AZ | 6/22/1972 | 33.517 | -112.023 | 5.63 |
| SPAS 1102 | Remnant Tropical | Joanne | AZ | 10/3-7/1972 | 31.780 | -113.500 | 7.27 |
| SPAS 1042 | Local Convective | Yuma Valley | AZ | 8/15/1977 | 32.611 | -114.631 | 6.85 |
| SPAS 1150 | General Frontal | Bear Spring | AZ | 2/27-3/3/1978 | 33.500 | -111.600 | 12.04 |
| SPAS 1134 | General Frontal | Browns Peak | AZ | 12/17-19/1978 | 33.430 | -111.450 | 5.61 |
| SPAS 1138 | General Frontal | Crown King | AZ | 2/13-22/1980 | 34.010 | -112.260 | 11.10 |
| SPAS 1122 | Local Convective | Harquahala Valley | AZ | 9/1/1984 | 33.488 | -113.254 | 8.00 |
| SPAS 1139 | General Frontal | Knoles Hole Spring | AZ | 1/5-10/1993 | 33.038 | -111.004 | 7.99 |
| SPAS 1086 | Local Convective | Tucson | AZ | 9/3/1996 | 32.390 | -110.800 | 7.37 |
| SPAS 1084 | Remnant Tropical | Harquahala Mtn-Nora | AZ | 9/25-27/1997 | 33.815 | -113.335 | 12.13 |
| SPAS 1043 | Local Convective | Sols Wash | AZ | 8/29/2000 | 34.130 | -113.080 | 4.70 |
| SPAS 1094 | Local Convective | Castle Hot Springs | AZ | 8/27/2003 | 33.950 | -112.340 | 10.17 |
| SPAS 1088 | Remnant Tropical | Cypress Mountain | AZ | 9/18-20/2004 | 34.520 | -113.860 | 6.99 |
| SPAS 1147 | General Frontal | Big Pine Flat | AZ | 2/10-13/2005 | 33.360 | -111.330 | 6.06 |
| SPAS 1091 | Local Convective | Camp Creek | AZ | 9/3/2005 | 34.040 | -111.810 | 4.82 |
| SPAS 1149 | General Frontal | Cooks Mesa | AZ | 11/30-12/2/2007 | 35.410 | -114.160 | 5.57 |
| SPAS 1051 | Local Convective | Magma | AZ | 7/10/2008 | 33.194 | -111.347 | 4.89 |
| SPAS 1085 | Local Convective | Wenden Bouse | AZ | 8/26/2008 | 33.920 | -113.910 | 4.82 |

# Table of Contents
## (Chronological listing)


| | |
|---|---|
| Mt Ord, AZ January 14-21, 1916 | 1 |
| Crossman Creek, AZ September 3-7, 1939 | 7 |
| Crown King, AZ August 26-30, 1951 | 13 |
| Queen Creek, AZ August 19, 1954 | 19 |
| Wellton, AZ August 24, 1955 | 25 |
| Horshoe Dam, AZ October 27 – November 1, 1959 | 31 |
| Sonora Desert, AZ September 26-28, 1962 | 37 |
| North Tucson, AZ September 6-7, 1964 | 43 |
| Sahuarita, AZ September 9-11, 1964 | 49 |
| Norma, AZ September 4-7, 1970 | 55 |
| Phoenix, AZ June 22, 1972 | 61 |
| Joanne, AZ October 3-7, 1972 | 67 |
| Yuma Valley, AZ August 15, 1977 | 73 |
| Bear Spring, AZ February 27 – March 3, 1978 | 79 |
| Browns Peak, AZ December 17-19, 1978 | 85 |
| Crown King, AZ February 13-22, 1980 | 91 |
| Harquahala Valley, AZ September 1, 1984 | 97 |
| Knoles Hole Spring, AZ January 5-10, 1993 | 103 |
| Tucson, AZ September 3, 1996 | 109 |
| Harquahala Mountain-Nora, AZ September 25-27, 1997 | 115 |
| Sols Wash, AZ August 29, 2000 | 121 |
| Castle Hot Springs, AZ August 27, 2003 | 127 |
| Cypress Mountain, AZ September 18-20, 2004 | 133 |

Big Pine Flat, AZ February 10-13, 2005 139

Camp Creek, AZ September 3, 2005 145

Cooks Mesa, AZ November 30 – December 2, 2007 151

Magma, AZ July 10, 2008 157

Wenden Bouse, AZ August 26, 2008 163

# Mt Ord, AZ

**January 14-21, 1916**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1144-Mt Ord-Zone 1 |
| Storm Date: | 01/14-20/1916 |
| AWA Analysis Date: | 11/2/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 1-Feb

| | Lat | Long |
|---|---|---|
| Storm center location | 33.75 N | 111.56 W |
| Storm Rep dew point location | 33.20 N | 113.42 W |
| Transposition dewpoint location | 33.00 N | 114.44 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | WSW @ 11 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 3,200 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The storm representative dew point is | 57.0 F | with total precipitable water above sea level of | | | | 1.19 | inches. |
| The in-place maximum dew point is | 60.5 F | with total precipitable water above sea level of | | | | 1.42 | inches. |
| The transpositioned maximum dew point is | 60.5 F | with total precipitable water above sea level of | | | | 1.42 | inches. |
| The in-place storm elevation is | 3,200 | which subtracts | 0.40 | inches of precipitable water at | | 57.0 F | |
| The in-place storm elevation is | 3,200 | which subtracts | 0.45 | inches of precipitable water at | | 60.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.51 | inches of precipitable water at | | 60.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.51 | inches of precipitable water at | | 60.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.23 |
| The transposition/elevation factor is | 0.94 |
| The barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.16 |

Notes: 24hr ave from Yuma and Phoenix twice daily observations at 530am and 530pm on the 17th

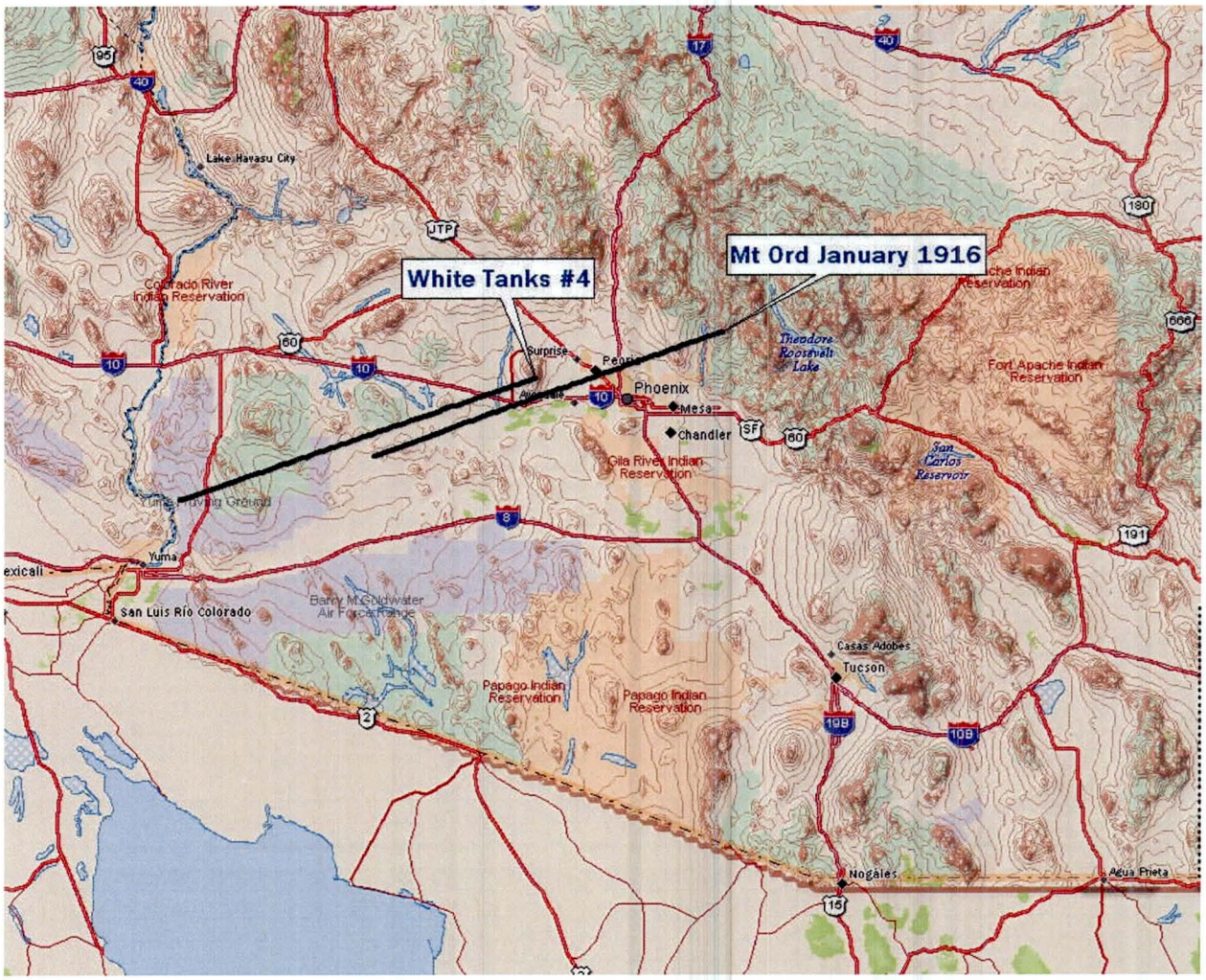
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.4 | 2.0 | 2.5 | - | 4.6 | - | - | 5.6 | - | 5.8 |
| 10 sq miles | 0.4 | 1.8 | 2.5 | - | 4.6 | - | - | 5.5 | - | 5.6 |
| 100 sq miles | 0.4 | 1.5 | 2.4 | - | 4.0 | - | - | 4.7 | - | 4.8 |
| 200 sq miles | 0.4 | 1.3 | 2.2 | - | 3.8 | - | - | 4.3 | - | 4.4 |
| 500 sq miles | 0.4 | 1.1 | 1.9 | - | 3.4 | - | - | 4.0 | - | 4.1 |
| 1000 sq miles | 0.3 | 0.9 | 1.8 | - | 3.1 | - | - | 3.7 | - | 3.9 |
| 2000 sq miles | 0.2 | 0.8 | 1.5 | - | 2.8 | - | - | 3.3 | - | 3.4 |
| 5000 sq miles | 0.2 | 0.6 | 1.1 | - | 2.1 | - | - | 2.7 | - | 3.0 |
| 10000 sq miles | 0.2 | 0.5 | 0.8 | - | 1.6 | - | - | 2.2 | - | 2.5 |
| 20000 sq miles | 0.2 | 0.4 | 0.5 | - | 0.7 | - | - | 1.2 | - | 1.4 |

**Adjusteded Storm Depth-Area-Duration**

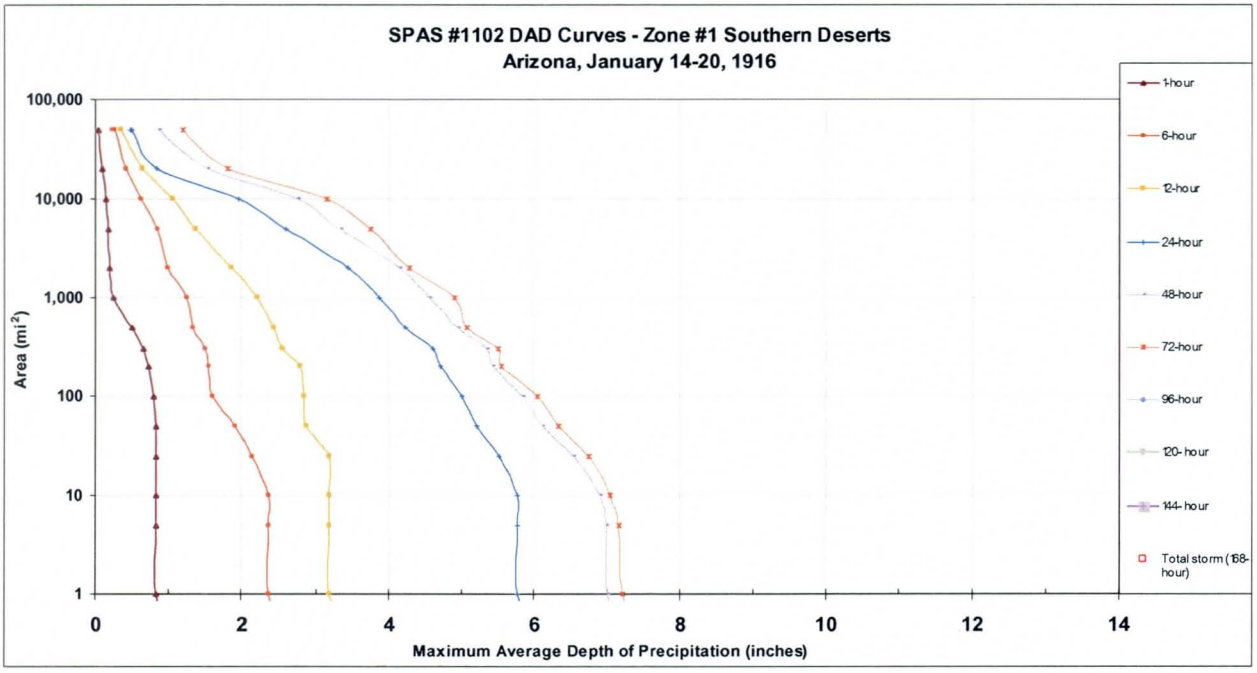
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.5 | 2.3 | 2.9 | - | 5.3 | - | - | 6.5 | - | 6.7 |
| 10 sq miles | 0.5 | 2.1 | 2.9 | - | 5.3 | - | - | 6.4 | - | 6.5 |
| 100 sq miles | 0.5 | 1.7 | 2.8 | - | 4.6 | - | - | 5.4 | - | 5.6 |
| 200 sq miles | 0.5 | 1.6 | 2.5 | - | 4.4 | - | - | 5.0 | - | 5.1 |
| 500 sq miles | 0.5 | 1.2 | 2.2 | - | 3.9 | - | - | 4.6 | - | 4.7 |
| 1000 sq miles | 0.3 | 1.1 | 2.1 | - | 3.6 | - | - | 4.3 | - | 4.5 |
| 2000 sq miles | 0.2 | 0.9 | 1.7 | - | 3.2 | - | - | 3.8 | - | 3.9 |
| 5000 sq miles | 0.2 | 0.7 | 1.3 | - | 2.4 | - | - | 3.1 | - | 3.5 |
| 10000 sq miles | 0.2 | 0.6 | 0.9 | - | 1.9 | - | - | 2.5 | - | 2.9 |
| 20000 sq miles | 0.2 | 0.5 | 0.6 | - | 0.8 | - | - | 1.4 | - | 1.6 |

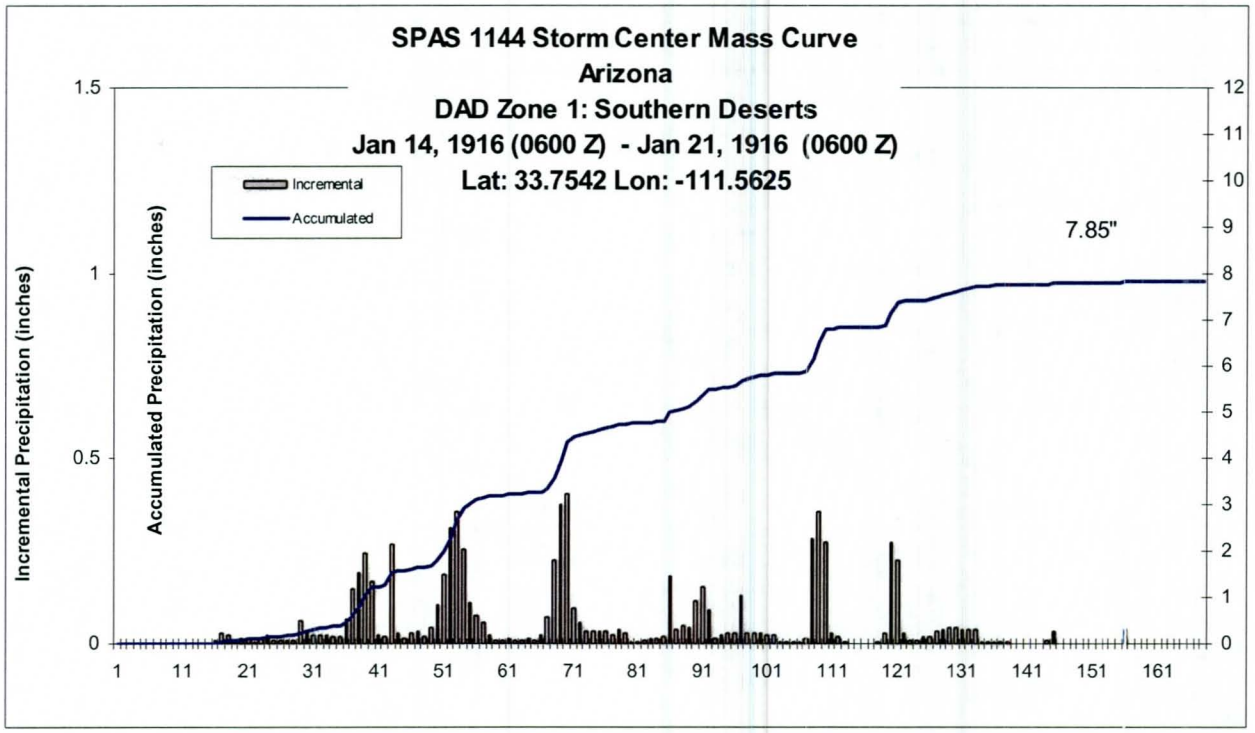
| | | | |
|---|---|---|---|
| Storm or Storm Center Name | SPAS-1144-Mt Ord-Zone 1 | | |
| Storm Date(s) | 01/14-20/1916 | | |
| Storm Type | General | | |
| Storm Location | 33.75 N | 111.56 W | |
| Storm Center Elevation | 3200 | orographic first upslopes east of Phoenix | |
| Precipitation Total & Duration (10 sq mi) | 7.85 inches 72 hours (SPAS 1144 DAD) | | |
| | | | |
| Storm Representative Dewpoint | 57.0 F | 24hr ave | KYUM KPHX |
| Storm Representative Dewpoint Location | 33.20 N | 113.42 W | |
| In-place Maximum Dewpoint | 60.5 F | | |
| Moisture Inflow Vector | WSW @ 114 | | |
| In-place Maximization Factor | | | |
| | | | |
| Temporal Transposition (Date) | 1-Feb | | |
| Transposition Dewpoint Location | 33.00 N | 114.44 W | |
| Transposition Maximum Dewpoint | 60.5 F | | |
| Transposition Adjustment Factor | | | |
| Average Basin Elevation | 3,650 | | |
| Highest Elevation in Basin | 3,655 | | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | | |
| Elevation Adjustment Factor | | | |

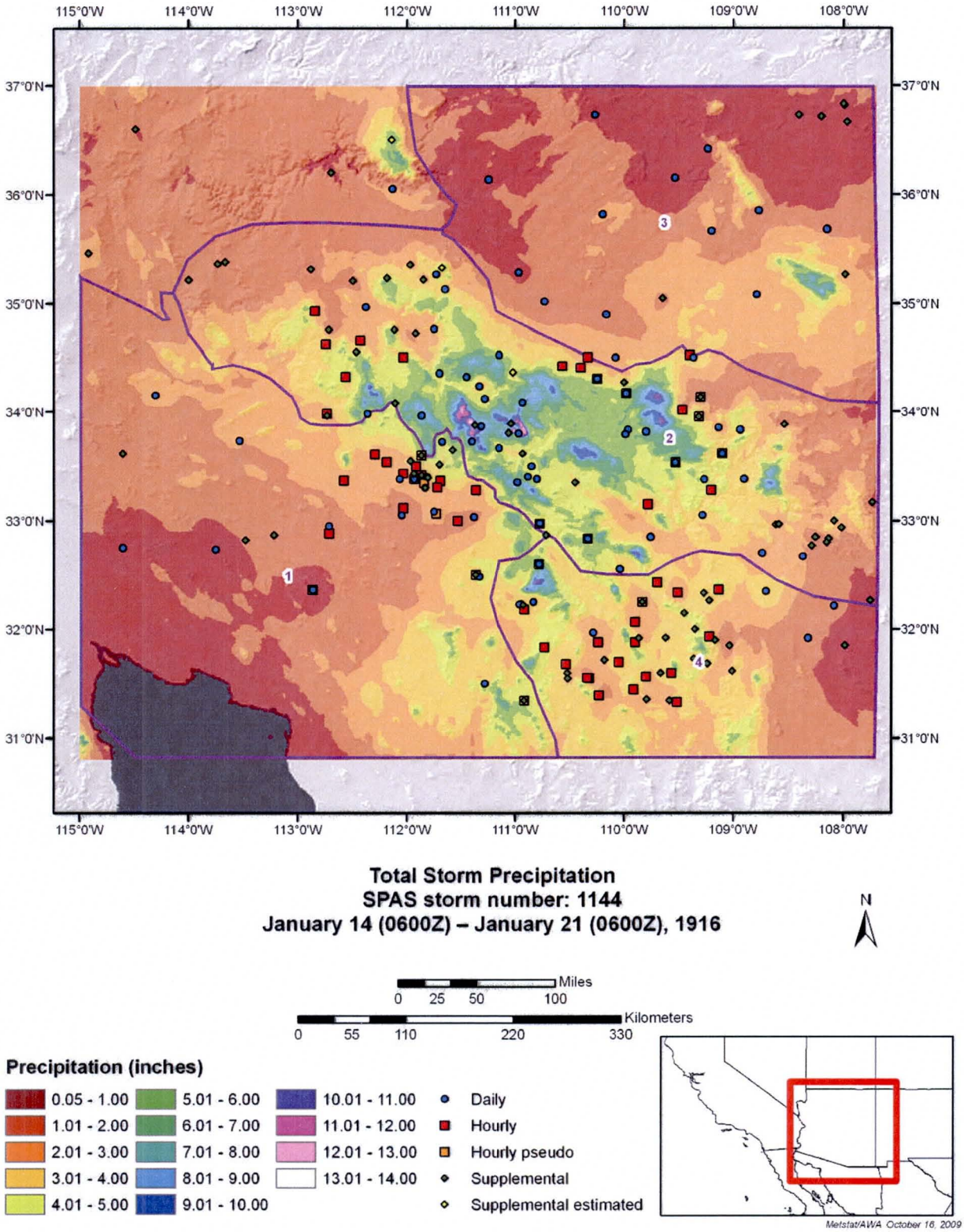

White Tanks #4
Mt Ord January 1916
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt Lake
Fort Apache Indian Reservation
San Carlos Reservoir
Yuma
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| | Duration (hours) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($mi^2$) | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | 120 | 144 | Total |
| 0.27 | 1.12 | | | | | 2.60 | 3.51 | | 6.12 | | 7.32 | 7.48 | | | | |
| 1 | 0.83 | | | | | 2.35 | 3.18 | | 5.78 | | 7.01 | 7.21 | | | | |
| 5 | 0.83 | | | | | 2.35 | 3.18 | | 5.78 | | 6.99 | 7.17 | | | | |
| 10 | 0.83 | | | | | 2.35 | 3.18 | | 5.78 | | 6.91 | 7.04 | | | | |
| 25 | 0.83 | | | | | 2.13 | 3.18 | | 5.52 | | 6.55 | 6.75 | | | | |
| 50 | 0.82 | | | | | 1.91 | 2.87 | | 5.21 | | 6.12 | 6.34 | | | | |
| 100 | 0.79 | | | | | 1.59 | 2.84 | | 5.00 | | 5.84 | 6.05 | | | | |
| 200 | 0.73 | | | | | 1.55 | 2.78 | | 4.70 | | 5.43 | 5.55 | | | | |
| 300 | 0.65 | | | | | 1.49 | 2.54 | | 4.60 | | 5.34 | 5.49 | | | | |
| 500 | 0.50 | | | | | 1.33 | 2.42 | | 4.22 | | 4.95 | 5.07 | | | | |
| 1000 | 0.24 | | | | | 1.23 | 2.20 | | 3.86 | | 4.56 | 4.90 | | | | |
| 2000 | 0.19 | | | | | 0.98 | 1.86 | | 3.44 | | 4.14 | 4.28 | | | | |
| 5000 | 0.17 | | | | | 0.84 | 1.36 | | 2.59 | | 3.34 | 3.75 | | | | |
| 10000 | 0.13 | | | | | 0.62 | 1.05 | | 1.95 | | 2.75 | 3.14 | | | | |
| 20000 | 0.08 | | | | | 0.41 | 0.64 | | 0.85 | | 1.53 | 1.80 | | | | |
| 50000 | 0.03 | | | | | 0.26 | 0.34 | | 0.49 | | 0.86 | 1.19 | | | | |
| 50001 | 0.03 | | | | | 0.23 | 0.34 | | 0.48 | | 0.86 | 1.19 | | | | |




SPAS 1144 Storm Center Mass Curve
Arizona
DAD Zone 1: Southern Deserts
Jan 14, 1916 (0600 Z) - Jan 21, 1916 (0600 Z)
Lat: 33.7542 Lon: -111.5625
Incremental
Accumulated
7.85"
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
1.5
1
0.5
0
12
11
10
9
8
7
6
5
4
3
2
1
0
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141
151
161


115°0'W
114°0'W
113°0'W
112°0'W
111°0'W
110°0'W
109°0'W
108°0'W
37°0'N
36°0'N
35°0'N
34°0'N
33°0'N
32°0'N
31°0'N
1
2
3
4
Total Storm Precipitation
SPAS storm number: 1144
January 14 (0600Z) – January 21 (0600Z), 1916
N
Miles
0 25 50 100
Kilometers
0 55 110 220 330
Precipitation (inches)
0.05 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00
13.01 - 14.00
Daily
Hourly
Hourly pseudo
Supplemental
Supplemental estimated
Metstat/AWA October 16, 2009

# Crossman Creek, AZ

**September 3-7, 1939**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| Storm Name: | SPAS-1077-Crossman Peak Sept 1 |
| Storm Date: | 9/3-7/1939 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 20-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 34.55 N | 114.20 W |
| Storm Rep dew point location | 33.21 N | 114.87 W |
| Transposition dewpoint location | 32.15 N | 113.18 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SSW @ 100 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 4,150 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 73.5 F | with total precipitable water above sea level of | | | 2.67 | inches. |
| The in-place maximum dew point is | 77.5 F | with total precipitable water above sea level of | | | 3.21 | inches. |
| The transpositioned maximum dew point is | 77.5 F | with total precipitable water above sea level of | | | 3.21 | inches. |
| The in-place storm elevation is | 4,150 | which subtracts | 0.885 | inches of precipitable water at | 73.5 F | |
| The in-place storm elevation is | 4,150 | which subtracts | 1.02 | inches of precipitable water at | 77.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.91 | inches of precipitable water at | 77.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.91 | inches of precipitable water at | 77.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.23 |
| The transposition/elevation factor is | 1.05 |
| The barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.29 |

Notes: 24hr average taken from the From 1001 reports at Needles, Blythe, and Yuma which reported every 6hrs. USGS WSP 1820, p123

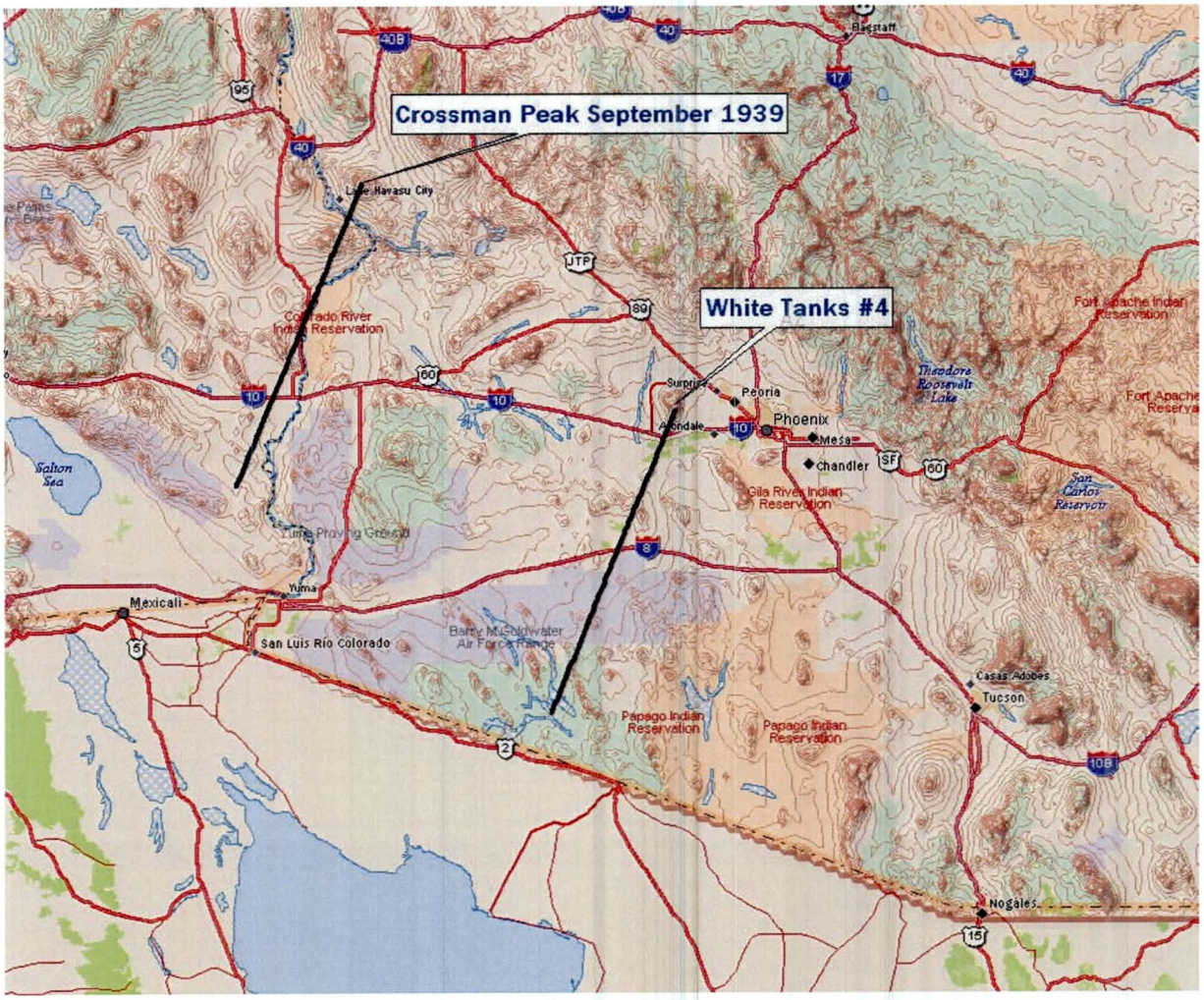
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.3 | 2.5 | 2.6 | 2.7 | 3.0 | 3.2 | 3.6 | 5.0 | 6.9 | 7.7 | 9.3 |
| 10 sq miles | 1.3 | 2.5 | 2.6 | 2.7 | 3.0 | 3.2 | 3.6 | 5.0 | 6.9 | 7.7 | 8.9 |
| 100 sq miles | 1.2 | 2.1 | 2.3 | 2.5 | 3.0 | 3.1 | 3.3 | 5.0 | 6.7 | 7.4 | 8.3 |
| 200 sq miles | 1.0 | 2.0 | 1.9 | 2.4 | 2.9 | 3.1 | 3.3 | 4.9 | 6.1 | 6.9 | 8.0 |
| 500 sq miles | 1.0 | 1.8 | 1.7 | 2.1 | 2.4 | 2.8 | 3.0 | 4.4 | 6.1 | 6.8 | 7.6 |
| 1000 sq miles | 0.9 | 1.6 | 1.7 | 1.7 | 2.3 | 2.5 | 2.9 | 4.3 | 5.9 | 6.5 | 7.2 |
| 2000 sq miles | 0.8 | 1.4 | 1.3 | 1.7 | 1.9 | 2.2 | 2.5 | 4.0 | 5.5 | 6.1 | 7.0 |
| 5000 sq miles | 0.5 | 1.1 | 1.1 | 1.3 | 1.7 | 1.8 | 2.3 | 3.4 | 5.1 | 5.7 | 6.4 |
| 10000 sq miles | 0.4 | 0.7 | 0.9 | 1.2 | 1.4 | 1.4 | 2.1 | 3.0 | 4.7 | 5.2 | 5.9 |
| 20000 sq miles | 0.3 | 0.5 | 0.7 | 0.9 | 1.0 | 1.1 | 1.7 | 2.4 | 3.9 | 4.4 | 5.1 |

**Adjusteded Storm Depth-Area-Duration**

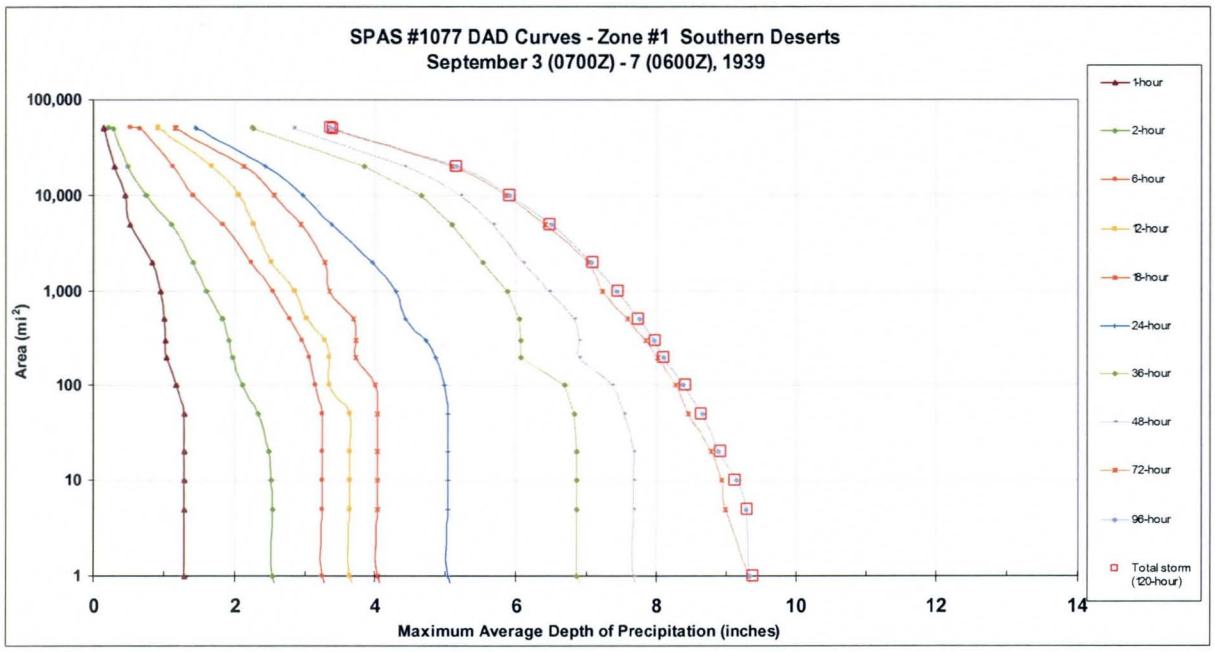
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.7 | 3.3 | 3.3 | 3.5 | 3.8 | 4.2 | 4.7 | 6.5 | 8.9 | 9.9 | 12.0 |
| 10 sq miles | 1.7 | 3.2 | 3.3 | 3.4 | 3.8 | 4.2 | 4.7 | 6.5 | 8.9 | 9.9 | 11.5 |
| 100 sq miles | 1.5 | 2.7 | 3.0 | 3.2 | 3.8 | 4.0 | 4.3 | 6.4 | 8.6 | 9.5 | 10.7 |
| 200 sq miles | 1.3 | 2.5 | 2.4 | 3.1 | 3.7 | 3.9 | 4.3 | 6.3 | 7.8 | 8.9 | 10.3 |
| 500 sq miles | 1.3 | 2.4 | 2.2 | 2.8 | 3.1 | 3.6 | 3.9 | 5.7 | 7.8 | 8.8 | 9.8 |
| 1000 sq miles | 1.2 | 2.1 | 2.2 | 2.2 | 2.9 | 3.3 | 3.7 | 5.5 | 7.6 | 8.3 | 9.3 |
| 2000 sq miles | 1.1 | 1.8 | 1.7 | 2.2 | 2.5 | 2.9 | 3.2 | 5.1 | 7.1 | 7.9 | 9.0 |
| 5000 sq miles | 0.7 | 1.4 | 1.4 | 1.6 | 2.1 | 2.4 | 2.9 | 4.4 | 6.5 | 7.3 | 8.3 |
| 10000 sq miles | 0.6 | 1.0 | 1.2 | 1.5 | 1.7 | 1.8 | 2.7 | 3.8 | 6.0 | 6.7 | 7.6 |
| 20000 sq miles | 0.4 | 0.6 | 0.8 | 1.1 | 1.3 | 1.4 | 2.2 | 3.1 | 5.0 | 5.7 | 6.6 |

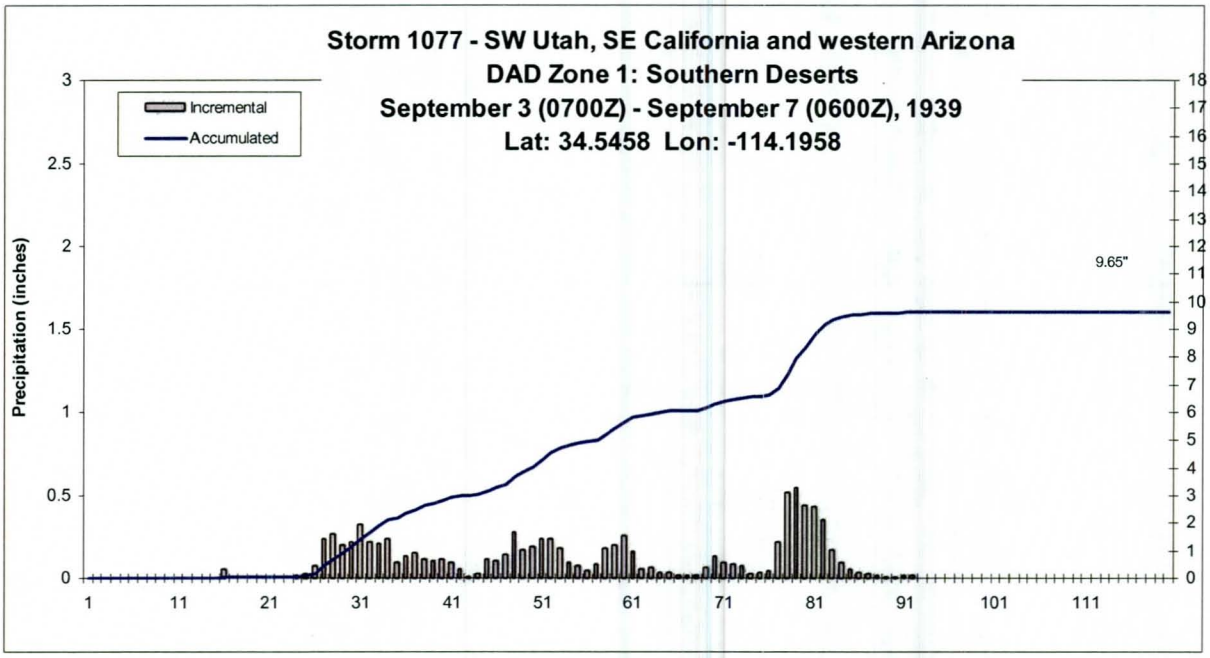
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1077-Crossman Peak Sept 1939-Zone 1 | |
| Storm Date(s) | 9/3-7/1939 | |
| Storm Type | Tropical | |
| Storm Location | 34.55 N | 114.20 W |
| Storm Center Elevation | 4150 | orographic Isolated Mtn outside of Lk Havasu City |
| Precipitation Total & Duration (10 sq mi) | 9.57 inches 72 hours 4.04" 12hrs (SPAS 1077 DAD) | |
| | | |
| Storm Representative Dewpoint | 73.5 F | 24hr ave of Needles, Blythe, Yuma |
| Storm Representative Dewpoint Location | 33.21 N | 114.87 W |
| In-place Maximum Dewpoint | 77.5 F | |
| Moisture Inflow Vector | SSW @ 100 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 20-Aug | |
| Transposition Dewpoint Location | 32.15 N | 113.18 W |
| Transposition Maximum Dewpoint | 77.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.29 | |

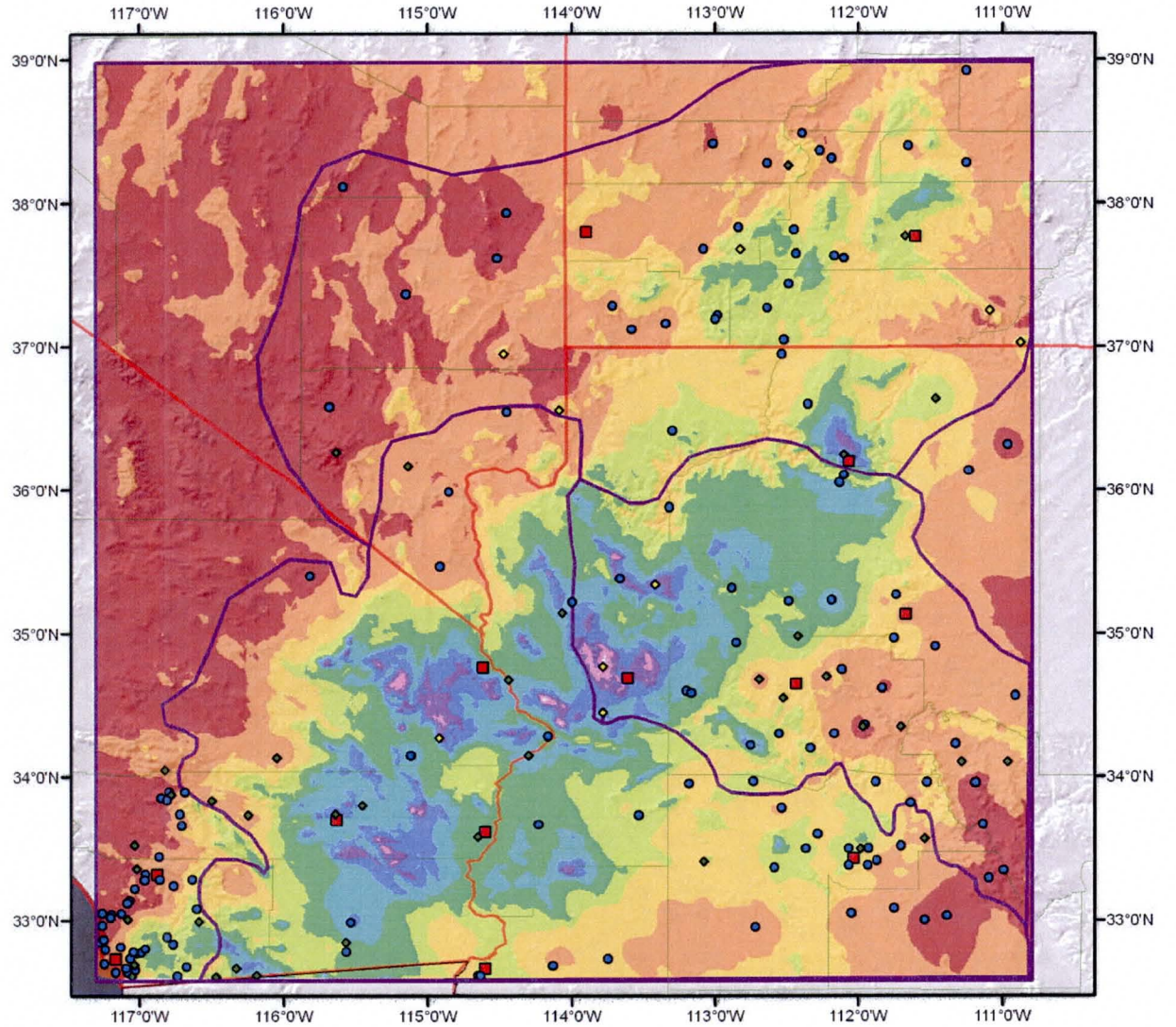

Crossman Peak September 1939
White Tanks #4
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Salton Sea
Yuma Proving Ground
Yuma
Mexicali
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Surprise
Peoria
Phoenix
Mesa
Chandler
Avondale
Gila River Indian Reservation
Theodore Roosevelt Lake
Fort Apache Indian Reservation
San Carlos Reservoir
Casas Adobes
Tucson
Papago Indian Reservation
Nogales

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| Area (mi²) | Duration (hours) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | Total |
| 0.27 | 1.67 | 2.77 | 2.94 | 2.97 | 3.34 | 3.63 | 4.04 | 4.42 | 5.43 | 7.24 | 7.97 | 9.57 | 9.65 | 9.65 |
| 1 | 1.30 | 2.54 | 2.55 | 2.70 | 2.96 | 3.24 | 3.63 | 4.04 | 5.04 | 6.87 | 7.68 | 9.31 | 9.33 | 9.38 |
| 5 | 1.30 | 2.54 | 2.55 | 2.70 | 2.96 | 3.24 | 3.63 | 4.04 | 5.04 | 6.87 | 7.68 | 8.98 | 9.27 | 9.30 |
| 10 | 1.30 | 2.52 | 2.55 | 2.66 | 2.96 | 3.24 | 3.63 | 4.04 | 5.04 | 6.87 | 7.68 | 8.93 | 9.14 | 9.12 |
| 20 | 1.30 | 2.48 | 2.54 | 2.64 | 2.96 | 3.24 | 3.63 | 4.04 | 5.04 | 6.87 | 7.68 | 8.77 | 8.88 | 8.92 |
| 50 | 1.29 | 2.33 | 2.45 | 2.58 | 2.96 | 3.24 | 3.63 | 4.04 | 5.04 | 6.83 | 7.54 | 8.44 | 8.65 | 8.63 |
| 100 | 1.17 | 2.10 | 2.30 | 2.48 | 2.96 | 3.14 | 3.34 | 4.00 | 4.99 | 6.69 | 7.37 | 8.27 | 8.38 | 8.41 |
| 200 | 1.03 | 1.96 | 1.85 | 2.38 | 2.85 | 3.05 | 3.34 | 3.73 | 4.86 | 6.07 | 6.89 | 8.02 | 8.10 | 8.10 |
| 300 | 1.02 | 1.91 | 1.75 | 2.30 | 2.74 | 2.95 | 3.27 | 3.72 | 4.73 | 6.07 | 6.89 | 7.85 | 7.96 | 7.98 |
| 500 | 1.00 | 1.83 | 1.73 | 2.14 | 2.38 | 2.77 | 3.01 | 3.69 | 4.43 | 6.06 | 6.83 | 7.59 | 7.76 | 7.74 |
| 1000 | 0.94 | 1.61 | 1.67 | 1.72 | 2.27 | 2.54 | 2.85 | 3.34 | 4.30 | 5.88 | 6.46 | 7.23 | 7.43 | 7.44 |
| 2000 | 0.82 | 1.42 | 1.33 | 1.67 | 1.94 | 2.23 | 2.51 | 3.27 | 3.97 | 5.54 | 6.11 | 7.01 | 7.07 | 7.08 |
| 5000 | 0.51 | 1.10 | 1.10 | 1.25 | 1.65 | 1.83 | 2.25 | 2.93 | 3.38 | 5.08 | 5.68 | 6.41 | 6.50 | 6.49 |
| 10000 | 0.44 | 0.74 | 0.90 | 1.17 | 1.35 | 1.42 | 2.06 | 2.56 | 2.96 | 4.65 | 5.20 | 5.86 | 5.92 | 5.92 |
| 20000 | 0.29 | 0.49 | 0.65 | 0.85 | 1.00 | 1.12 | 1.68 | 2.12 | 2.43 | 3.85 | 4.41 | 5.09 | 5.15 | 5.16 |
| 50000 | 0.14 | 0.27 | 0.41 | 0.49 | 0.58 | 0.65 | 0.92 | 1.16 | 1.46 | 2.25 | 2.82 | 3.34 | 3.38 | 3.39 |
| 50368 | 0.13 | 0.21 | 0.32 | 0.40 | 0.45 | 0.52 | 0.92 | 1.15 | 1.45 | 2.24 | 2.82 | 3.34 | 3.36 | 3.37 |




Storm 1077 - SW Utah, SE California and western Arizona
DAD Zone 1: Southern Deserts
September 3 (0700Z) - September 7 (0600Z), 1939
Lat: 34.5458 Lon: -114.1958
Incremental
Accumulated
Precipitation (inches)
9.65"
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
11
21
31
41
51
61
71
81
91
101
111




**Storm #1077**
**Wikieup, AZ**
**Sept 4-7, 1939**

Miles
0 35 70 140

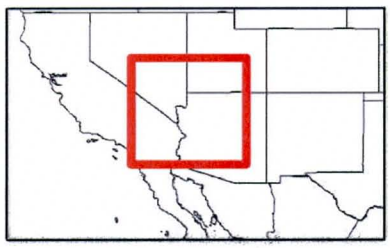
Kilometers
0 20 40 80 120

**Precipitation (inches)**

- 0.01 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00
- 6.01 - 7.00
- 7.01 - 8.00
- 8.01 - 9.00
- 9.01 - 10.00

- Daily
- Hourly
- Supplemental
- Supplemental estimated
- dadzones_1077

N



*Metstat/AWA July 20, 2009*

# Crown King, AZ

**August 26-30, 1951**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| Storm Name: | SPAS-1076-Crown King-Zone 1 |
| Storm Date: | 8/26-30/1951 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 15-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 34.01 N | 112.26 W |
| Storm Rep dew point location | 32.46 N | 112.35 W |
| Transposition dewpoint location | 31.95 N | 112.60 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 120 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,900 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 73.5 F | with total precipitable water above sea level of | | | 2.67 | inches. |
| The in-place maximum dew point is | 78.0 F | with total precipitable water above sea level of | | | 3.29 | inches. |
| The transpositioned maximum dew point is | 78.0 F | with total precipitable water above sea level of | | | 3.29 | inches. |
| The in-place storm elevation is | 2,900 | which subtracts | 0.65 | inches of precipitable water at | 73.5 F | |
| The in-place storm elevation is | 2,900 | which subtracts | 0.75 | inches of precipitable water at | 78.0 F | |
| Basin elevation at | 3,650 | which subtracts | 0.93 | inches of precipitable water at | 78.0 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.93 | inches of precipitable water at | 78.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.26 |
| The transposition/elevation factor is | 0.93 |
| The barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.17 |

Notes: 24 hour average from KPHX and KTUS

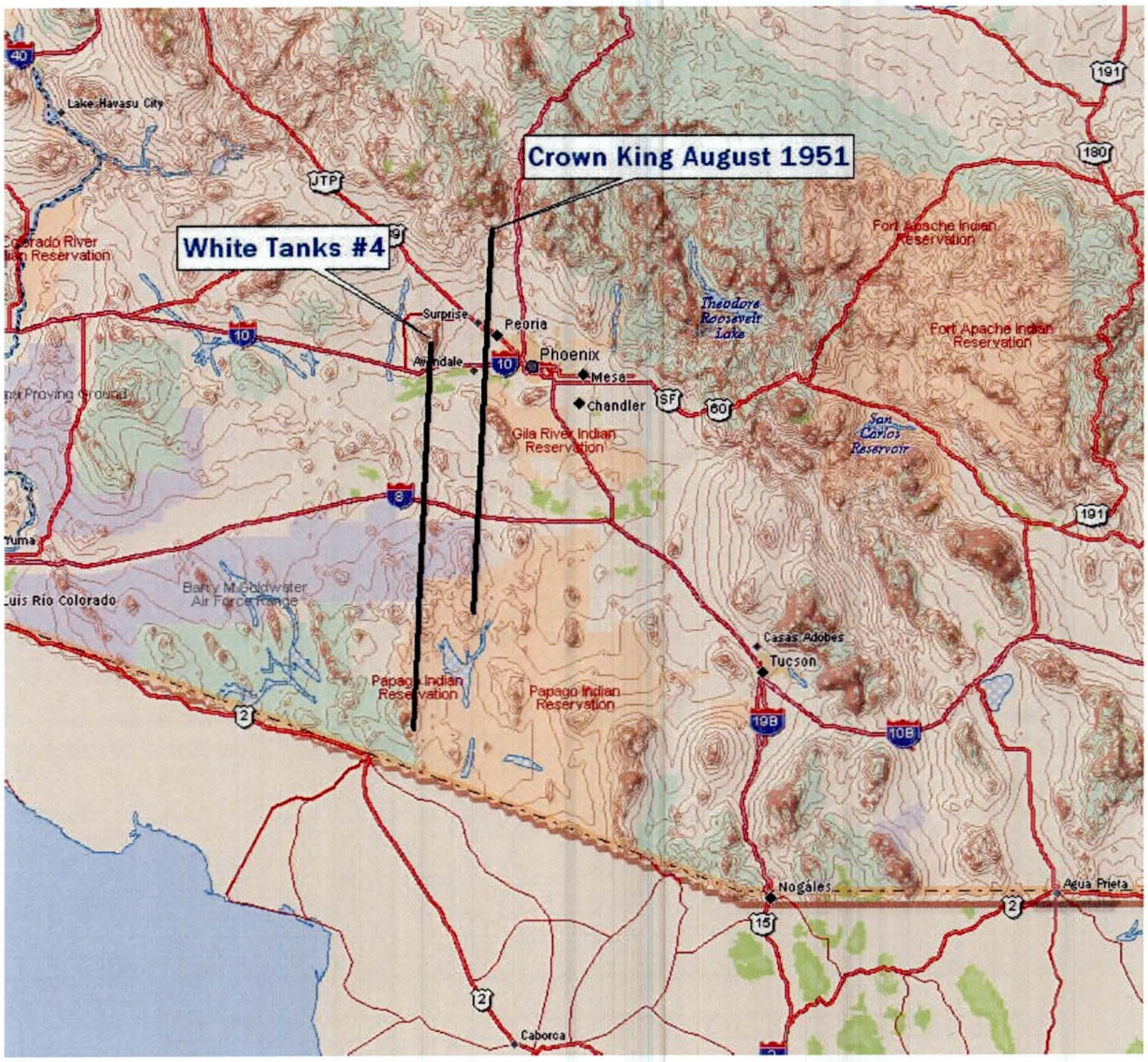
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.8 | 1.8 | 2.4 | 2.6 | 2.7 | 2.7 | 5.0 | 6.9 | 7.8 | 8.8 | 10.0 |
| 10 sq miles | 0.8 | 1.8 | 2.4 | 2.6 | 2.7 | 2.7 | 5.0 | 6.7 | 7.5 | 8.4 | 9.4 |
| 100 sq miles | 0.8 | 1.8 | 2.4 | 2.6 | 2.7 | 2.7 | 4.2 | 5.7 | 6.5 | 7.2 | 8.1 |
| 200 sq miles | 0.8 | 1.8 | 2.4 | 2.5 | 2.5 | 2.5 | 4.2 | 5.5 | 6.2 | 6.8 | 7.7 |
| 500 sq miles | 0.8 | 1.8 | 2.3 | 2.4 | 2.5 | 2.5 | 3.8 | 5.1 | 5.7 | 6.3 | 7.2 |
| 1000 sq miles | 0.8 | 1.6 | 2.1 | 2.2 | 2.2 | 2.2 | 3.6 | 4.7 | 5.2 | 5.8 | 6.8 |
| 2000 sq miles | 0.7 | 1.4 | 1.9 | 2.0 | 2.1 | 2.1 | 3.3 | 4.4 | 4.8 | 5.3 | 6.3 |
| 5000 sq miles | 0.4 | 1.0 | 1.5 | 1.5 | 1.5 | 1.7 | 2.8 | 3.8 | 4.2 | 4.6 | 5.7 |
| 10000 sq miles | 0.4 | 0.7 | 0.9 | 1.1 | 1.2 | 1.4 | 2.3 | 3.2 | 3.6 | 3.9 | 5.2 |
| 20000 sq miles | 0.2 | 0.5 | 0.7 | 0.7 | 0.9 | 1.0 | 1.7 | 2.5 | 2.9 | 3.5 | 4.6 |

**Adjusteded Storm Depth-Area-Duration**

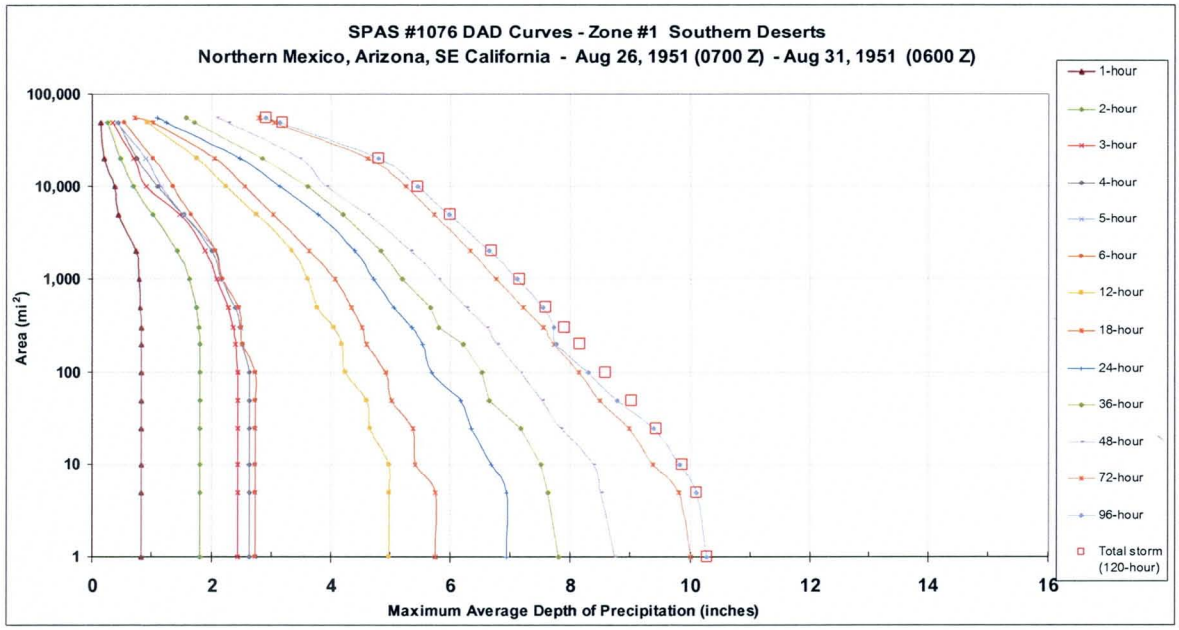
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.0 | 2.1 | 2.8 | 3.1 | 3.2 | 3.2 | 5.8 | 8.1 | 9.1 | 10.2 | 11.7 |
| 10 sq miles | 1.0 | 2.1 | 2.8 | 3.1 | 3.2 | 3.2 | 5.8 | 7.8 | 8.8 | 9.8 | 11.0 |
| 100 sq miles | 1.0 | 2.1 | 2.8 | 3.1 | 3.2 | 3.2 | 5.0 | 6.7 | 7.6 | 8.4 | 9.5 |
| 200 sq miles | 1.0 | 2.1 | 2.8 | 2.9 | 3.0 | 3.0 | 4.9 | 6.5 | 7.3 | 7.9 | 9.0 |
| 500 sq miles | 0.9 | 2.0 | 2.7 | 2.8 | 2.9 | 2.9 | 4.4 | 5.9 | 6.6 | 7.3 | 8.4 |
| 1000 sq miles | 0.9 | 1.9 | 2.4 | 2.5 | 2.5 | 2.6 | 4.2 | 5.5 | 6.1 | 6.8 | 7.9 |
| 2000 sq miles | 0.9 | 1.7 | 2.2 | 2.3 | 2.4 | 2.4 | 3.9 | 5.2 | 5.7 | 6.2 | 7.4 |
| 5000 sq miles | 0.5 | 1.2 | 1.7 | 1.8 | 1.8 | 1.9 | 3.2 | 4.4 | 4.9 | 5.4 | 6.7 |
| 10000 sq miles | 0.4 | 0.8 | 1.1 | 1.3 | 1.4 | 1.6 | 2.6 | 3.7 | 4.2 | 4.6 | 6.1 |
| 20000 sq miles | 0.2 | 0.6 | 0.8 | 0.9 | 1.1 | 1.2 | 2.0 | 2.9 | 3.3 | 4.1 | 5.4 |

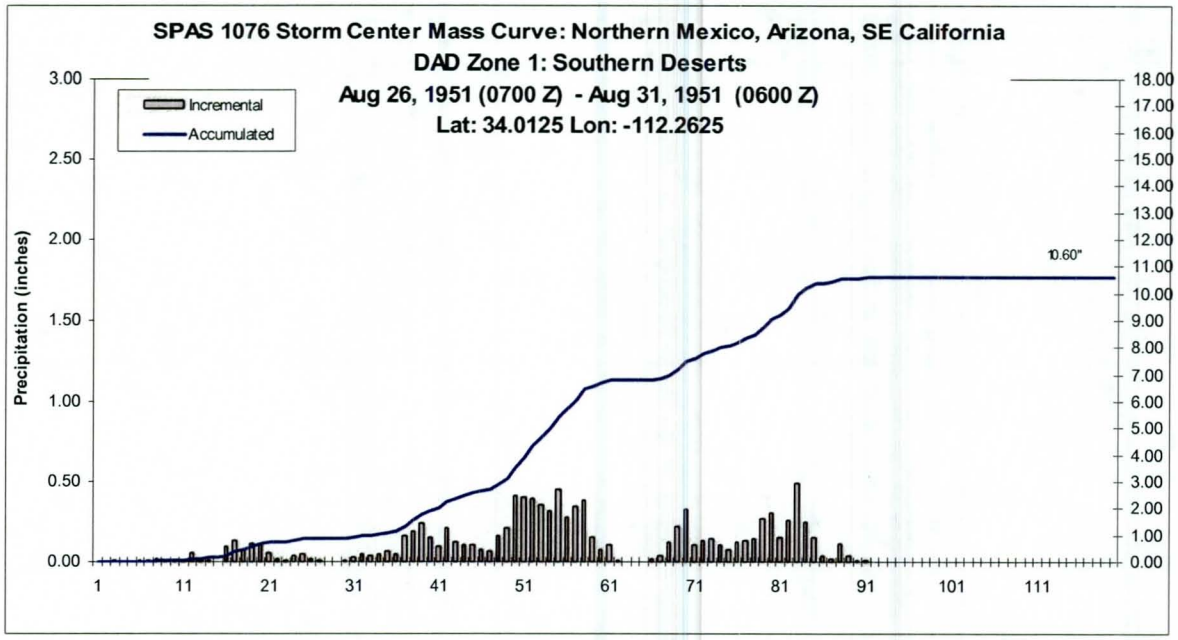
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1076-Crown King-Zone 1 | |
| Storm Date(s) | 8/26-30/1951 | |
| Storm Type | Tropical | |
| Storm Location | 34.01 N | 112.26 W |
| Storm Center Elevation | 2900 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 10.30 inches 72 hours (SPAS 1076 DAD) | |
| | | |
| Storm Representative Dewpoint | 73.5 F | 24hr ave KPHX, KTUS |
| Storm Representative Dewpoint Location | 32.46 N | 112.35 W |
| In-place Maximum Dewpoint | 78.0 F | |
| Moisture Inflow Vector | S @ 120 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 31.95 N | 112.60 W |
| Transposition Maximum Dewpoint | 78.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

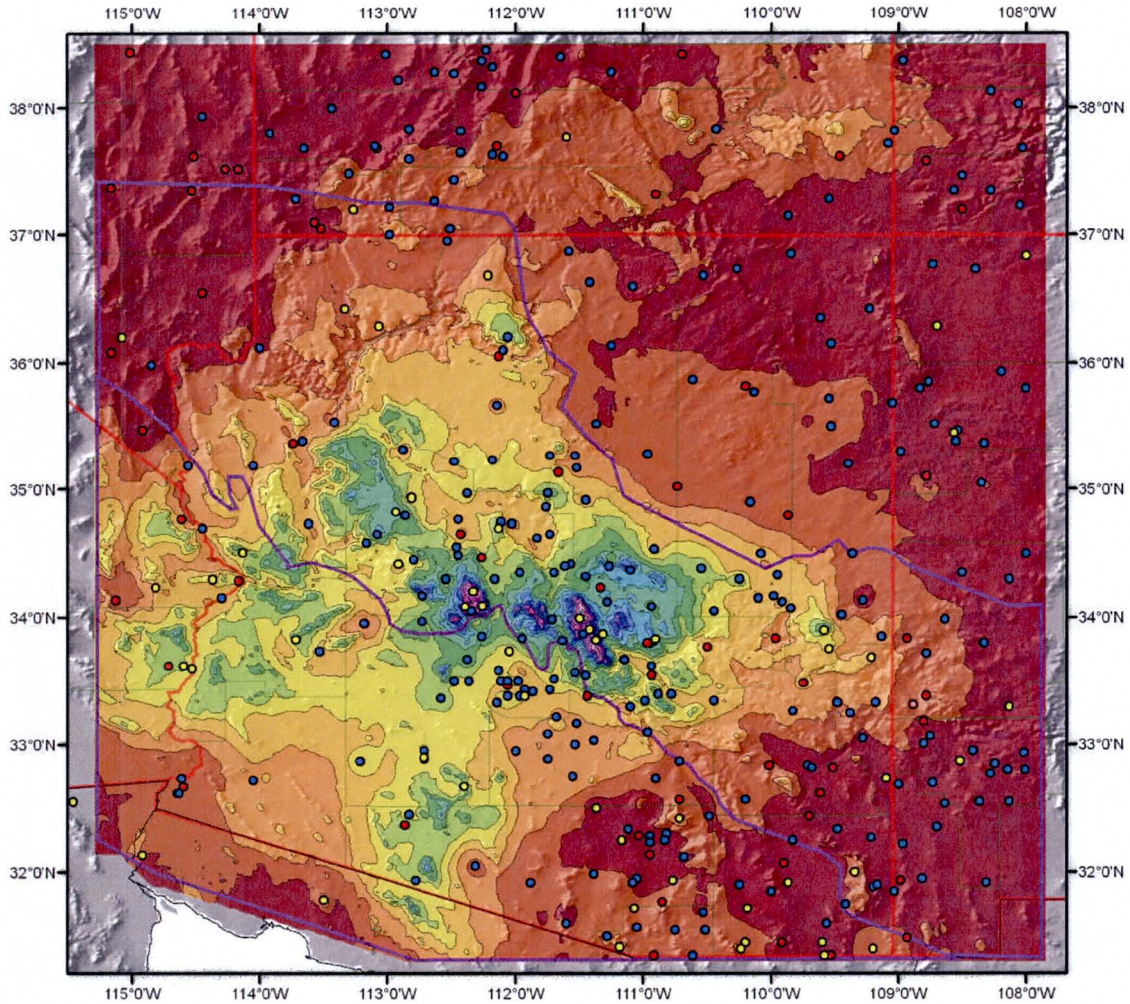

Crown King August 1951
White Tanks #4
Lake Havasu City
Surprise
Peoria
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
Fort Apache Indian Reservation
Gila River Indian Reservation
San Carlos Reservoir
Casas Adobes
Tucson
Papago Indian Reservation
Nogales
Agua Prieta
Caborca

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| | Duration (hours) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($mi^2$) | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | 120 | Total |
| **0.27** | 1.22 | 2.15 | 2.81 | 3.01 | 3.14 | 3.14 | 5.29 | 6.04 | 7.24 | 8.06 | 9.05 | 10.30 | 10.60 | 10.60 | 10.60 |
| **1** | 0.83 | 1.81 | 2.43 | 2.63 | 2.73 | 2.73 | 4.98 | 5.73 | 6.93 | 7.81 | 8.75 | 10.01 | 10.28 | 10.28 | 10.28 |
| **5** | 0.83 | 1.81 | 2.43 | 2.63 | 2.73 | 2.73 | 4.98 | 5.73 | 6.93 | 7.63 | 8.51 | 9.80 | 10.10 | 10.11 | 10.11 |
| **10** | 0.83 | 1.81 | 2.43 | 2.63 | 2.73 | 2.73 | 4.98 | 5.40 | 6.69 | 7.50 | 8.40 | 9.38 | 9.82 | 9.87 | 9.87 |
| **25** | 0.83 | 1.81 | 2.43 | 2.63 | 2.73 | 2.73 | 4.66 | 5.37 | 6.35 | 7.17 | 7.84 | 8.98 | 9.40 | 9.44 | 9.44 |
| **50** | 0.83 | 1.81 | 2.43 | 2.63 | 2.73 | 2.73 | 4.60 | 5.01 | 6.18 | 6.65 | 7.52 | 8.50 | 8.78 | 9.03 | 9.03 |
| **100** | 0.83 | 1.81 | 2.43 | 2.63 | 2.73 | 2.73 | 4.24 | 4.92 | 5.68 | 6.52 | 7.18 | 8.14 | 8.30 | 8.59 | 8.59 |
| **200** | 0.82 | 1.81 | 2.40 | 2.51 | 2.52 | 2.52 | 4.18 | 4.60 | 5.52 | 6.22 | 6.79 | 7.72 | 7.76 | 8.15 | 8.15 |
| **300** | 0.82 | 1.79 | 2.36 | 2.47 | 2.49 | 2.50 | 4.05 | 4.52 | 5.35 | 5.80 | 6.60 | 7.54 | 7.73 | 7.91 | 7.91 |
| **500** | 0.81 | 1.75 | 2.28 | 2.40 | 2.45 | 2.45 | 3.77 | 4.34 | 5.05 | 5.67 | 6.27 | 7.21 | 7.54 | 7.59 | 7.59 |
| **1,000** | 0.79 | 1.63 | 2.08 | 2.17 | 2.17 | 2.19 | 3.62 | 4.07 | 4.72 | 5.18 | 5.79 | 6.77 | 7.11 | 7.15 | 7.15 |
| **2,000** | 0.73 | 1.43 | 1.88 | 2.00 | 2.07 | 2.07 | 3.34 | 3.63 | 4.41 | 4.83 | 5.32 | 6.33 | 6.65 | 6.68 | 6.68 |
| **5,000** | 0.43 | 1.02 | 1.47 | 1.54 | 1.54 | 1.66 | 2.75 | 3.03 | 3.79 | 4.20 | 4.62 | 5.72 | 5.98 | 6.00 | 6.00 |
| **10,000** | 0.38 | 0.69 | 0.90 | 1.10 | 1.16 | 1.36 | 2.25 | 2.56 | 3.15 | 3.62 | 3.93 | 5.24 | 5.44 | 5.44 | 5.44 |
| **20,000** | 0.19 | 0.47 | 0.68 | 0.74 | 0.91 | 1.02 | 1.74 | 2.04 | 2.48 | 2.85 | 3.47 | 4.62 | 4.79 | 4.79 | 4.79 |
| **50,000** | 0.13 | 0.26 | 0.34 | 0.44 | 0.42 | 0.54 | 0.92 | 1.02 | 1.26 | 1.71 | 2.28 | 3.04 | 3.15 | 3.18 | 3.18 |
| **56,112** | | | | | | | | 0.70 | 1.11 | 1.57 | 2.09 | 2.80 | 2.91 | 2.91 | 2.91 |




SPAS 1076 Storm Center Mass Curve: Northern Mexico, Arizona, SE California
DAD Zone 1: Southern Deserts
Aug 26, 1951 (0700 Z) - Aug 31, 1951 (0600 Z)
Lat: 34.0125 Lon: -112.2625
Incremental
Accumulated
Precipitation (inches)
10.60"
3.00
2.50
2.00
1.50
1.00
0.50
0.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1
11
21
31
41
51
61
71
81
91
101
111




**Storm #1076**
**Hurricane Remnants**
**Aug 26, 1951 (0700 Z) - Aug 31, 1951 (0600 Z)**

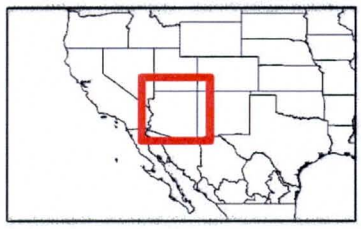
Miles
0 25 50 100
Kilometers
0 30 60 120 180

**Precipitation (inches)**

| | | |
|---|---|---|
| 0.00 - 1.00 | 5.01 - 6.00 | 10.01 - 11.00 |
| 1.01 - 2.00 | 6.01 - 7.00 | 11.01 - 12.00 |
| 2.01 - 3.00 | 7.01 - 8.00 | 12.01 - 13.00 |
| 3.01 - 4.00 | 8.01 - 9.00 | 13.01 - 14.00 |
| 4.01 - 5.00 | 9.01 - 10.00 | 14.01 - 15.00 |

**Station Type**
- Daily
- Hourly
- Hourly estimated
- Hourly pseudo
- Supplemental

N



*Coordinate system: GCS North American 1983*
Metstat/AWA May 27, 2009

# Queen Creek, AZ

**August 19, 1954**

**Storm Type: Local Convective**

| | |
|---|---|
| **Storm Name:** | **SPAS-1096-Queen Creek** |
| **Storm Date:** | **August 19, 1954** |
| **AWA Analysis Date:** | **10/15/2009** |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** **15-Aug**

| | Lat | Long |
|---|---|---|
| **Storm center location** | **33.20 N** | **111.15 W** |
| **Storm Rep dew point location** | **32.74 N** | **112.61 W** |
| **Transposition dewpoint location** | **33.05 N** | **113.98 W** |
| **Basin location** | **33.55 N** | **112.55 W** |

| | | |
|---|---|---|
| **Moisture Inflow Direction:** | **WSW @ 90** | miles |
| **Basin Elevation** | **3,650** | feet |
| **Storm Elevation** | **3,500** | feet |
| **Effective Barrier Height** | **3,650** | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | **74.0 F** | with total precipitable water above sea level of | | | **2.73** | inches. |
| The in-place maximum dew point is | **81.5 F** | with total precipitable water above sea level of | | | **3.84** | inches. |
| The transpositioned maximum dew point is | **82.0 F** | with total precipitable water above sea level of | | | **3.92** | inches. |
| The in-place storm elevation is | **0** | which subtracts | **0.00** | inches of precipitable water at | **74.0 F** | |
| The in-place storm elevation is | **0** | which subtracts | **0.00** | inches of precipitable water at | **81.5 F** | |
| Basin elevation at | **0** | which subtracts | **0.00** | inches of precipitable water at | **82.0 F** | |
| The inflow barrier height/basin elevation is | **0** | which subtracts | **0.00** | inches of precipitable water at | **82.0 F** | |

| | |
|---|---|
| The in-place maximization factor is | **1.41** |
| The transposition factor is | **1.02** |
| The elevation/barrier adjustment factor is | **1.00** |
| The total adjustment factor is | **1.44** |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. 3hr average from KPHX and KYUM.

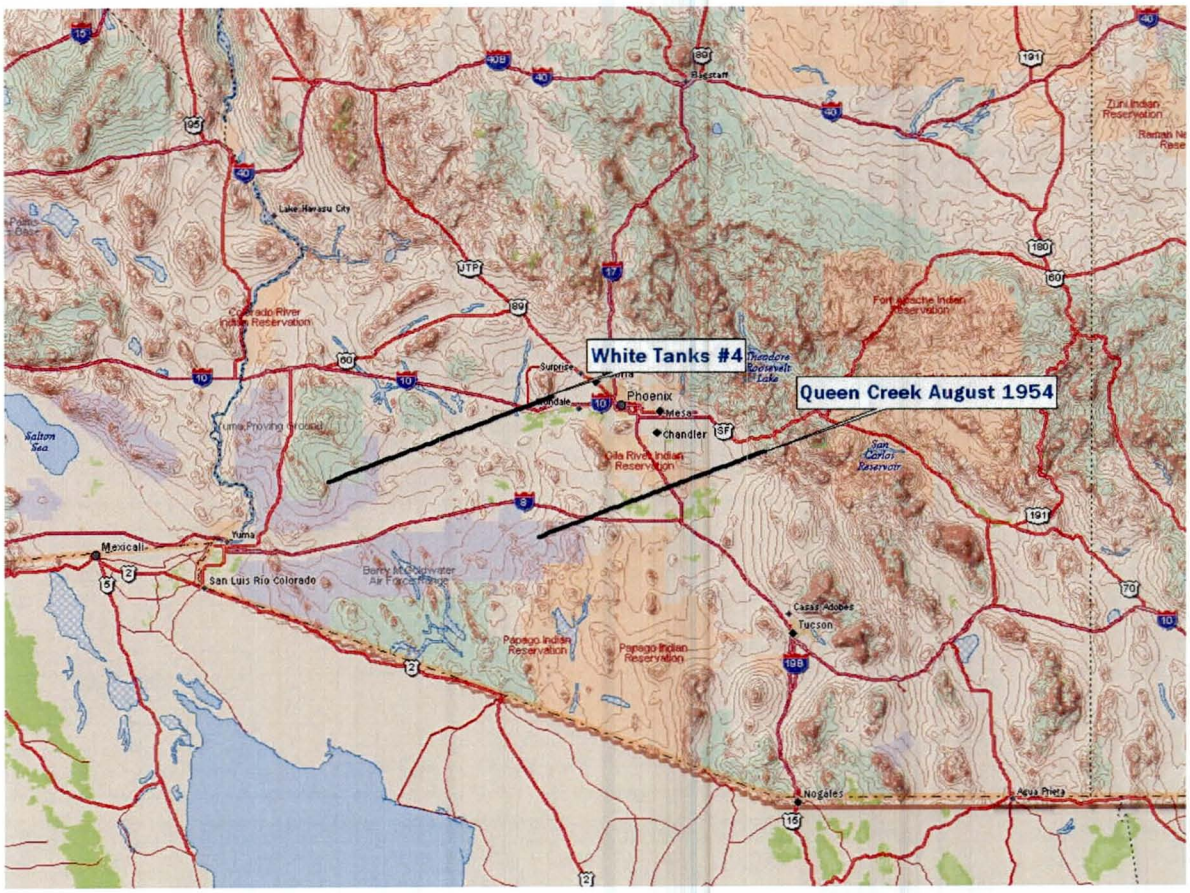
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **2.4** | **4.3** | **5.8** | **7.0** | **7.5** | **7.5** | **7.5** | **7.5** | **7.8** | - |
| 10 sq miles | **2.4** | **4.3** | **5.7** | **6.9** | **7.4** | **7.4** | **7.4** | **7.4** | **7.6** | - |
| 50 sq miles | **2.2** | **4.2** | **5.2** | **6.2** | **6.6** | **6.6** | **6.6** | **6.6** | **6.9** | - |
| 100 sq miles | **2.1** | **4.0** | **4.9** | **5.7** | **6.1** | **6.1** | **6.1** | **6.1** | **6.5** | - |
| 200 sq miles | **1.9** | **3.7** | **4.4** | **5.2** | **5.5** | **5.5** | **5.5** | **5.5** | **5.9** | - |
| 500 sq miles | **1.6** | **3.1** | **3.7** | **4.3** | **4.6** | **4.6** | **4.6** | **4.6** | **5.1** | - |
| 1000 sq miles | **1.2** | **2.4** | **2.9** | **3.3** | **3.5** | **3.5** | **3.5** | **3.5** | **4.0** | - |
| 2000 sq miles | **0.8** | **1.6** | **1.8** | **2.2** | **2.3** | **2.3** | **2.3** | **2.3** | **2.8** | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

**Adjusted Storm Depth-Area-Duration**

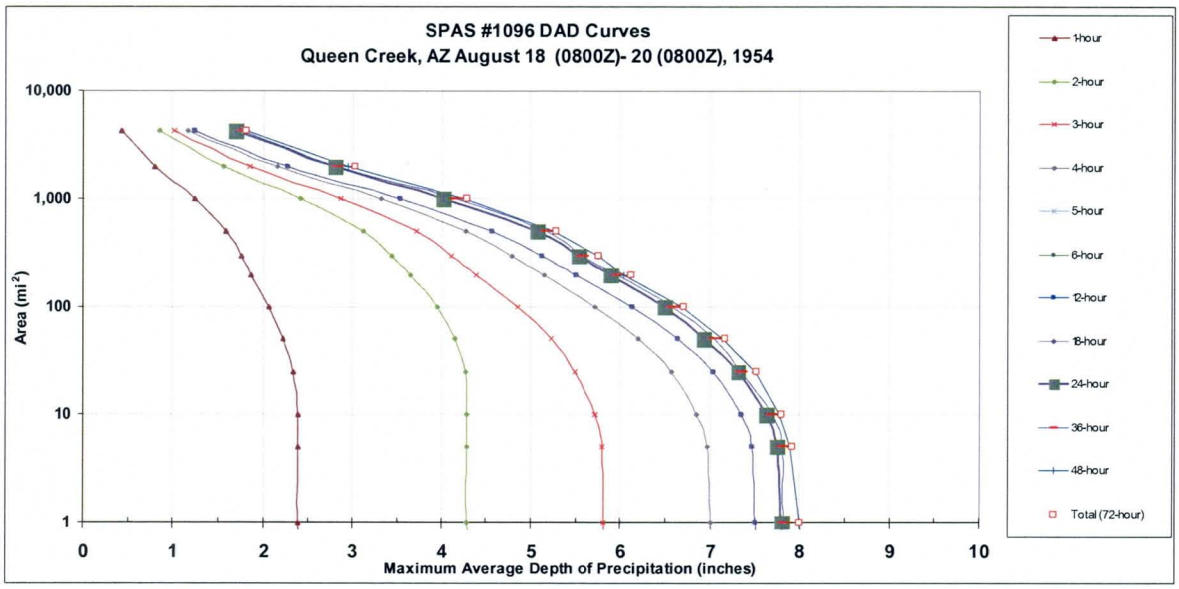
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **3.4** | **6.1** | **8.3** | **10.1** | **10.8** | **10.8** | **10.8** | **10.8** | **11.2** | - |
| 10 sq miles | **3.4** | **6.1** | **8.2** | **9.8** | **10.6** | **10.6** | **10.6** | **10.6** | **11.0** | - |
| 50 sq miles | **3.2** | **6.0** | **7.5** | **8.9** | **9.5** | **9.5** | **9.5** | **9.5** | **9.9** | - |
| 100 sq miles | **3.0** | **5.7** | **7.0** | **8.2** | **8.8** | **8.8** | **8.8** | **8.8** | **9.3** | - |
| 200 sq miles | **2.7** | **5.2** | **6.3** | **7.4** | **7.9** | **7.9** | **7.9** | **7.9** | **8.5** | - |
| 500 sq miles | **2.3** | **4.5** | **5.3** | **6.1** | **6.5** | **6.5** | **6.5** | **6.5** | **7.3** | - |
| 1000 sq miles | **1.8** | **3.5** | **4.1** | **4.8** | **5.1** | **5.1** | **5.1** | **5.1** | **5.8** | - |
| 2000 sq miles | **1.1** | **2.2** | **2.6** | **3.1** | **3.3** | **3.3** | **3.3** | **3.3** | **4.0** | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

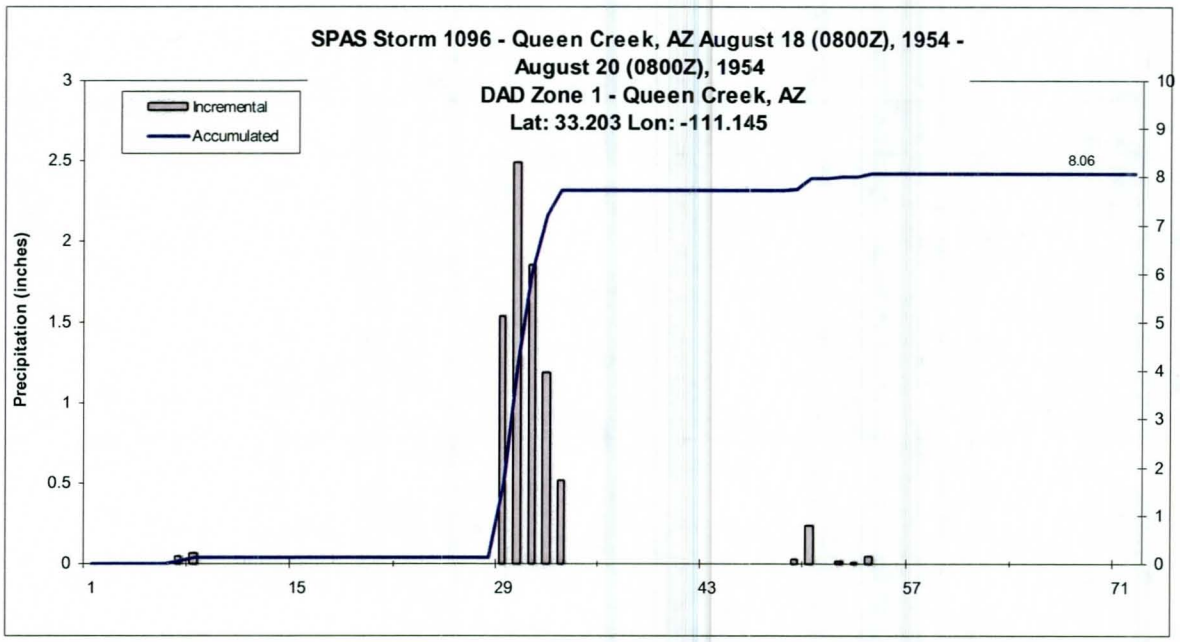
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1096-Queen Creek** | |
| Storm Date(s) | 8/19/54 | |
| Storm Type | Local Storm | |
| Storm Location | 33.20 N | 111.15 W |
| Storm Center Elevation | 3500 | |
| Precipitation Total & Duration (10 sq mi) | 5.88 inches in 3hrs (SPAS 1096 DAD) | |
| | | |
| Storm Representative Dewpoint | 74.0 F | 3rh ave KPHX, KYUM |
| Storm Representative Dewpoint Location | 32.74 N | 112.61 W |
| In-place Maximum Dewpoint | 81.5 F | |
| Moisture Inflow Vector | WSW @ 90 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 33.05 N | 113.98 W |
| Transposition Maximum Dewpoint | 82.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.44 | |

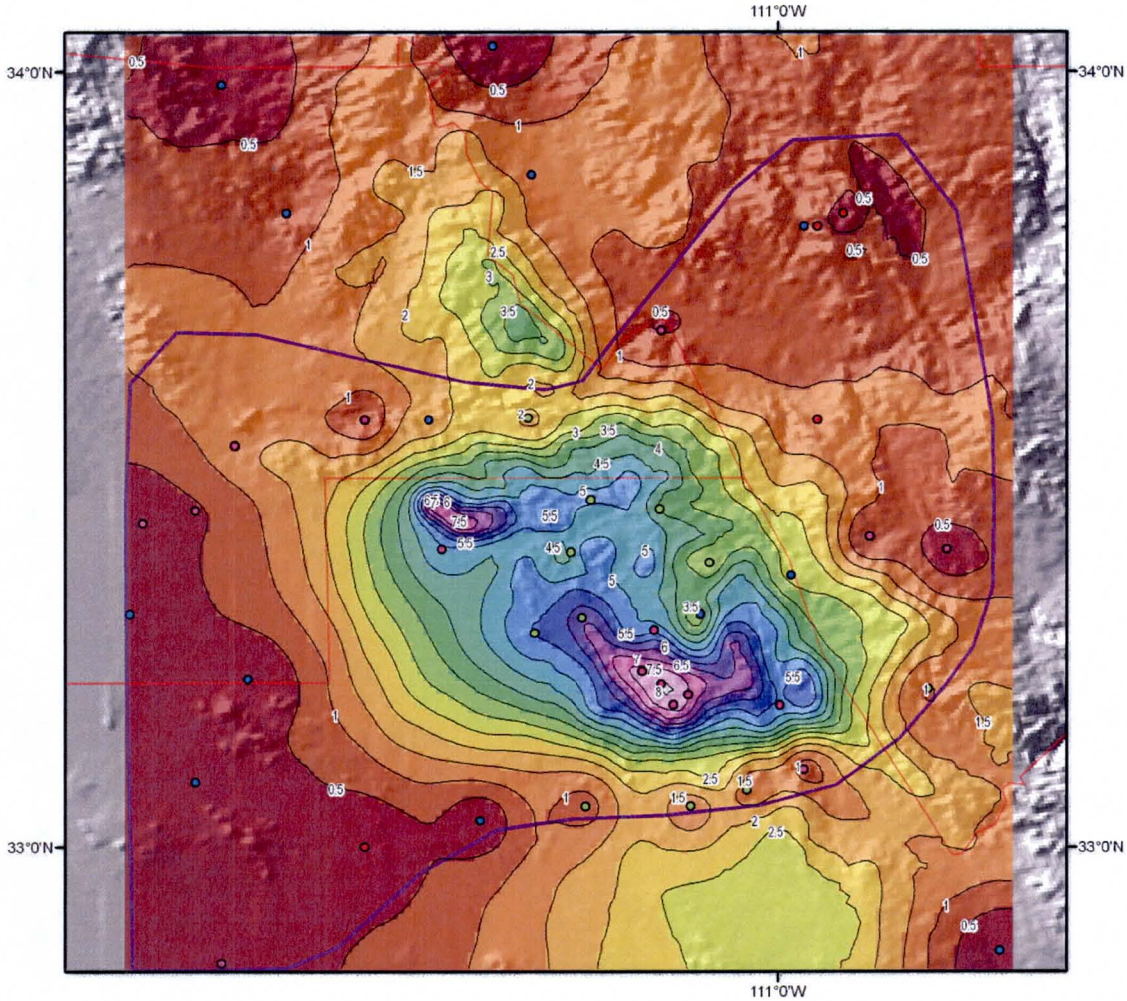

White Tanks #4
Queen Creek August 1954
Phoenix
Mesa
Chandler
Tucson
Yuma
Mexicali
San Luis Rio Colorado
Nogales
Flagstaff
Lake Havasu City
Salton Sea
Colorado River Indian Reservation
Gila River Indian Reservation
Papago Indian Reservation
Zuni Indian Reservation
Fort Apache Indian Reservation
Theodore Roosevelt Lake
San Carlos Reservoir
Casas Adobes
Surprise
Goodyear

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | total |
| **0.28** | 2.49 | 4.40 | 5.88 | 7.08 | 7.60 | 7.60 | 7.60 | 7.60 | 7.88 | 7.95 | 8.06 | 8.06 |
| **1** | 2.39 | 4.28 | 5.81 | 7.00 | 7.51 | 7.51 | 7.51 | 7.51 | 7.80 | 7.82 | 8.00 | 8.00 |
| **5** | 2.39 | 4.28 | 5.80 | 6.96 | 7.47 | 7.47 | 7.47 | 7.47 | 7.75 | 7.81 | 7.89 | 7.92 |
| **10** | 2.39 | 4.28 | 5.71 | 6.85 | 7.35 | 7.35 | 7.35 | 7.35 | 7.63 | 7.69 | 7.77 | 7.80 |
| **25** | 2.34 | 4.27 | 5.49 | 6.56 | 7.03 | 7.03 | 7.03 | 7.03 | 7.31 | 7.35 | 7.51 | 7.52 |
| **50** | 2.22 | 4.15 | 5.22 | 6.19 | 6.63 | 6.63 | 6.63 | 6.63 | 6.92 | 7.04 | 7.13 | 7.16 |
| **100** | 2.06 | 3.95 | 4.86 | 5.72 | 6.13 | 6.13 | 6.13 | 6.13 | 6.48 | 6.58 | 6.69 | 6.70 |
| **200** | 1.86 | 3.65 | 4.39 | 5.15 | 5.51 | 5.51 | 5.51 | 5.51 | 5.89 | 5.97 | 6.04 | 6.11 |
| **300** | 1.75 | 3.44 | 4.11 | 4.79 | 5.12 | 5.12 | 5.12 | 5.12 | 5.53 | 5.57 | 5.75 | 5.76 |
| **500** | 1.58 | 3.12 | 3.72 | 4.27 | 4.56 | 4.56 | 4.56 | 4.56 | 5.06 | 5.17 | 5.25 | 5.28 |
| **1,000** | 1.23 | 2.41 | 2.87 | 3.31 | 3.53 | 3.53 | 3.53 | 3.53 | 4.02 | 4.16 | 4.26 | 4.28 |
| **2,000** | 0.79 | 1.55 | 1.84 | 2.15 | 2.27 | 2.27 | 2.27 | 2.27 | 2.80 | 2.82 | 2.94 | 3.02 |
| **4,181** | 0.43 | 0.85 | 1.01 | 1.16 | 1.24 | 1.24 | 1.24 | 1.24 | 1.68 | 1.76 | 1.81 | 1.81 |




SPAS Storm 1096 - Queen Creek, AZ August 18 (0800Z), 1954 - August 20 (0800Z), 1954
DAD Zone 1 - Queen Creek, AZ
Lat: 33.203 Lon: -111.145
Incremental
Accumulated
Precipitation (inches)
8.06
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
9
10
1
15
29
43
57
71



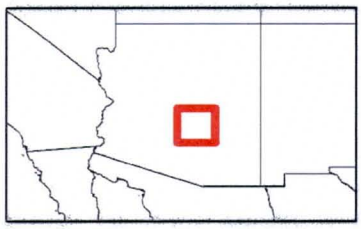

**Storm #1096**
**Queen Creek 1954**
**August 18-20, 1954**

Miles
0 4 8 16
Kilometers
0 4 8 16 24

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.04 - 0.50 | 3.01 - 3.50 | 6.01 - 6.50 | Daily |
| 0.51 - 1.00 | 3.51 - 4.00 | 6.51 - 7.00 | Hourly |
| 1.01 - 1.50 | 4.01 - 4.50 | 7.01 - 7.50 | Hourly pseudo |
| 1.51 - 2.00 | 4.51 - 5.00 | 7.51 - 8.00 | Supplemental |
| 2.01 - 2.50 | 5.01 - 5.50 | 8.01 - 8.50 | Supplemental estimated |
| 2.51 - 3.00 | 5.51 - 6.00 | | dadzones_1096 |

N



*Coordinate system: GCS North American 1983*
*Metstat/AWA June 3, 2009*

# Wellton, AZ

**August 24, 1955**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| **Storm Name:** | **SPAS-1064-Wellton** |
| **Storm Date:** | **August 24, 1955** |
| **AWA Analysis Date:** | **10/15/2009** |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** **15-Aug**

| | Lat | Long |
|---|---|---|
| **Storm center location** | **32.58 N** | **114.34 W** |
| **Storm Rep dew point location** | **32.65 N** | **114.60 W** |
| **Transposition dewpoint location** | **33.58 N** | **112.79 W** |
| **Basin location** | **33.55 N** | **112.55 W** |

| | | |
|---|---|---|
| **Moisture Inflow Direction:** | **WNW @ 20** | miles |
| **Basin Elevation** | **3,650** | feet |
| **Storm Elevation** | **1,650** | feet |
| **Effective Barrier Height** | **3,650** | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | **75.0 F** | with total precipitable water above sea level of | | | **2.85** | inches. |
| The in-place maximum dew point is | **82.0 F** | with total precipitable water above sea level of | | | **3.92** | inches. |
| The transpositioned maximum dew point is | **81.0 F** | with total precipitable water above sea level of | | | **3.76** | inches. |
| The in-place storm elevation is | **0** | which subtracts | **0.00** | inches of precipitable water at | **75.0 F** | |
| The in-place storm elevation is | **0** | which subtracts | **0.00** | inches of precipitable water at | **82.0 F** | |
| Basin elevation at | **0** | which subtracts | **0.00** | inches of precipitable water at | **81.0 F** | |
| The inflow barrier height/basin elevation is | **0** | which subtracts | **0.00** | inches of precipitable water at | **81.0 F** | |

| | |
|---|---|
| The in-place maximization factor is | **1.38** |
| The transposition factor is | **0.96** |
| The elevation/barrier adjustment factor is | **1.00** |
| The total adjustment factor is | **1.32** |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. KTUS sfc obs for the 22nd 3hr ave 75°, ESE @ 200, PHX HYSPLIT going forward to 25th 6Z to 12Z 74°, Daily SST 70.5, and monthly mean SST using 24th 00Z HYSPLIT trajectory location

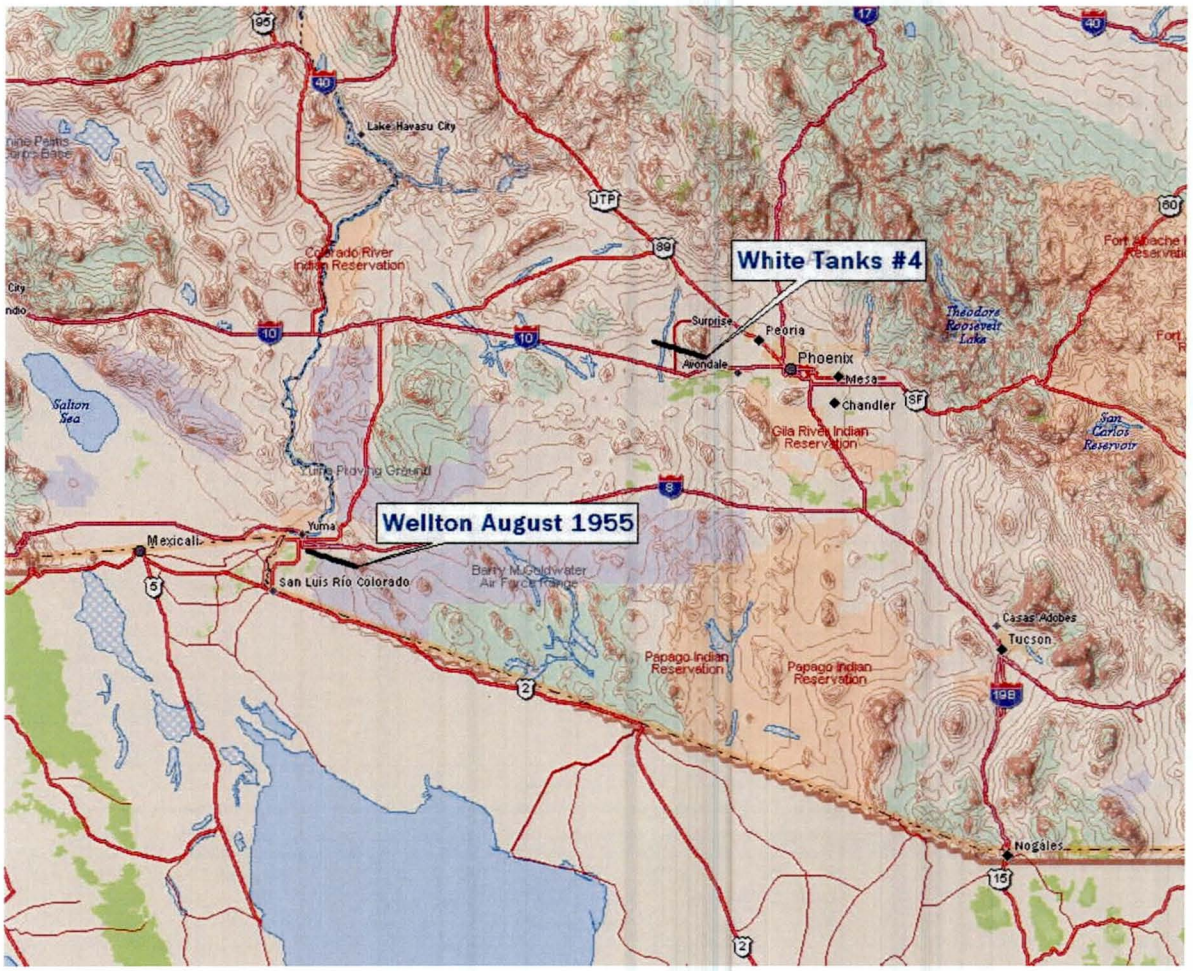
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **3.3** | **4.9** | **5.0** | **5.0** | **5.0** | **5.1** | **5.1** | **5.1** | | |
| 10 sq miles | **2.7** | **3.9** | **4.2** | **4.2** | **4.2** | **4.2** | **4.3** | **4.3** | | |
| 50 sq miles | **1.9** | **2.7** | **2.9** | **3.0** | **3.0** | **3.0** | **3.1** | **3.1** | | |
| 100 sq miles | **1.5** | **2.2** | **2.4** | **2.5** | **2.5** | **2.5** | **2.5** | **2.6** | | |
| 200 sq miles | **1.3** | **1.8** | **2.0** | **2.0** | **2.0** | **2.0** | **2.1** | **2.1** | | |
| 500 sq miles | **1.0** | **1.4** | **1.5** | **1.5** | **1.6** | **1.6** | **1.6** | **1.7** | | |
| 1000 sq miles | **0.8** | **1.1** | **1.2** | **1.2** | **1.2** | **1.3** | **1.4** | **1.4** | | |
| 2000 sq miles | **0.5** | **0.8** | **0.9** | **0.9** | **0.9** | **0.9** | **1.1** | **1.1** | | |
| 5000 sq miles | | | | | | | | | | |

**Adjusted Storm Depth-Area-Duration**

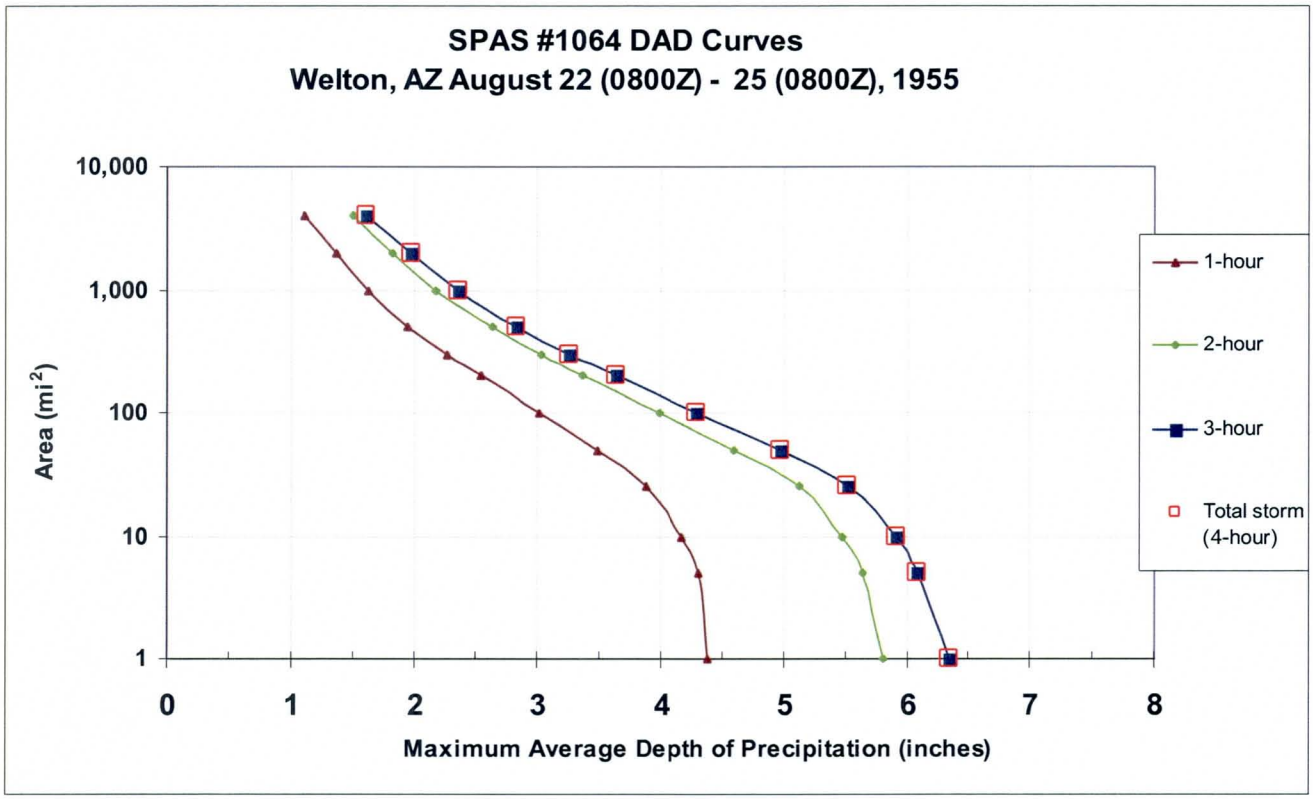
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **4.4** | **6.4** | **6.6** | **6.6** | **6.6** | **6.7** | **6.8** | **6.8** | | |
| 10 sq miles | **3.6** | **5.2** | **5.5** | **5.5** | **5.5** | **5.5** | **5.7** | **5.7** | | |
| 50 sq miles | **2.4** | **3.5** | **3.9** | **3.9** | **3.9** | **3.9** | **4.0** | **4.0** | | |
| 100 sq miles | **2.0** | **2.9** | **3.2** | **3.2** | **3.2** | **3.3** | **3.3** | **3.4** | | |
| 200 sq miles | **1.7** | **2.4** | **2.6** | **2.6** | **2.6** | **2.6** | **2.8** | **2.8** | | |
| 500 sq miles | **1.3** | **1.8** | **2.0** | **2.0** | **2.0** | **2.0** | **2.1** | **2.2** | | |
| 1000 sq miles | **1.0** | **1.5** | **1.6** | **1.6** | **1.6** | **1.7** | **1.8** | **1.8** | | |
| 2000 sq miles | **0.7** | **1.1** | **1.2** | **1.2** | **1.2** | **1.2** | **1.4** | **1.4** | | |
| 5000 sq miles | | | | | | | | | | |

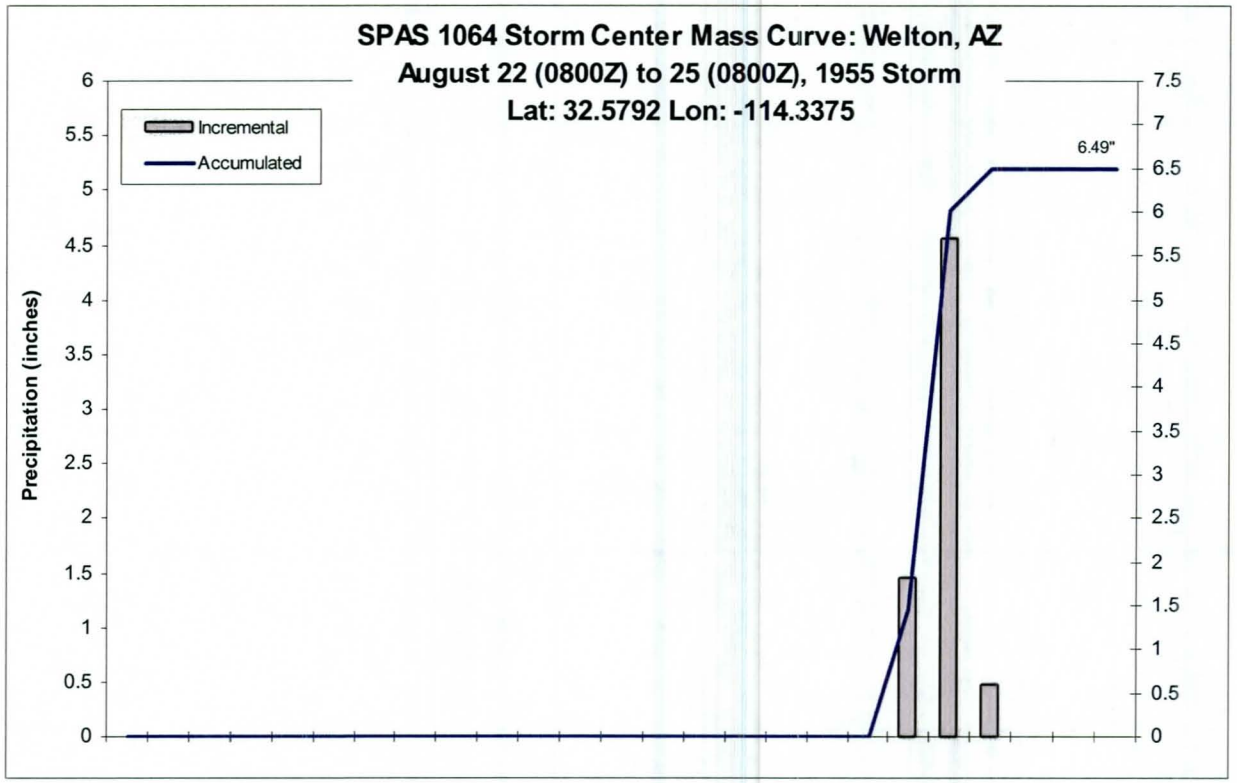
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1064-Wellton** | |
| Storm Date(s) | 8/24/55 | |
| Storm Type | Local Storm | |
| Storm Location | 32.58 N | 114.34 W |
| Storm Center Elevation | 1650 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 6.49 inches 3 hours 4.56" in 1hr and 6.01" in 2hrs (SPAS 1064 DAD) | |
| | | |
| Storm Representative Dewpoint | 75.0 F | 3rh ave-KYUM |
| Storm Representative Dewpoint Location | 32.65 N | 114.60 W |
| In-place Maximum Dewpoint | 82.0 F | |
| Moisture Inflow Vector | WNW @ 20 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 33.58 N | 112.79 W |
| Transposition Maximum Dewpoint | 81.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.32 | |

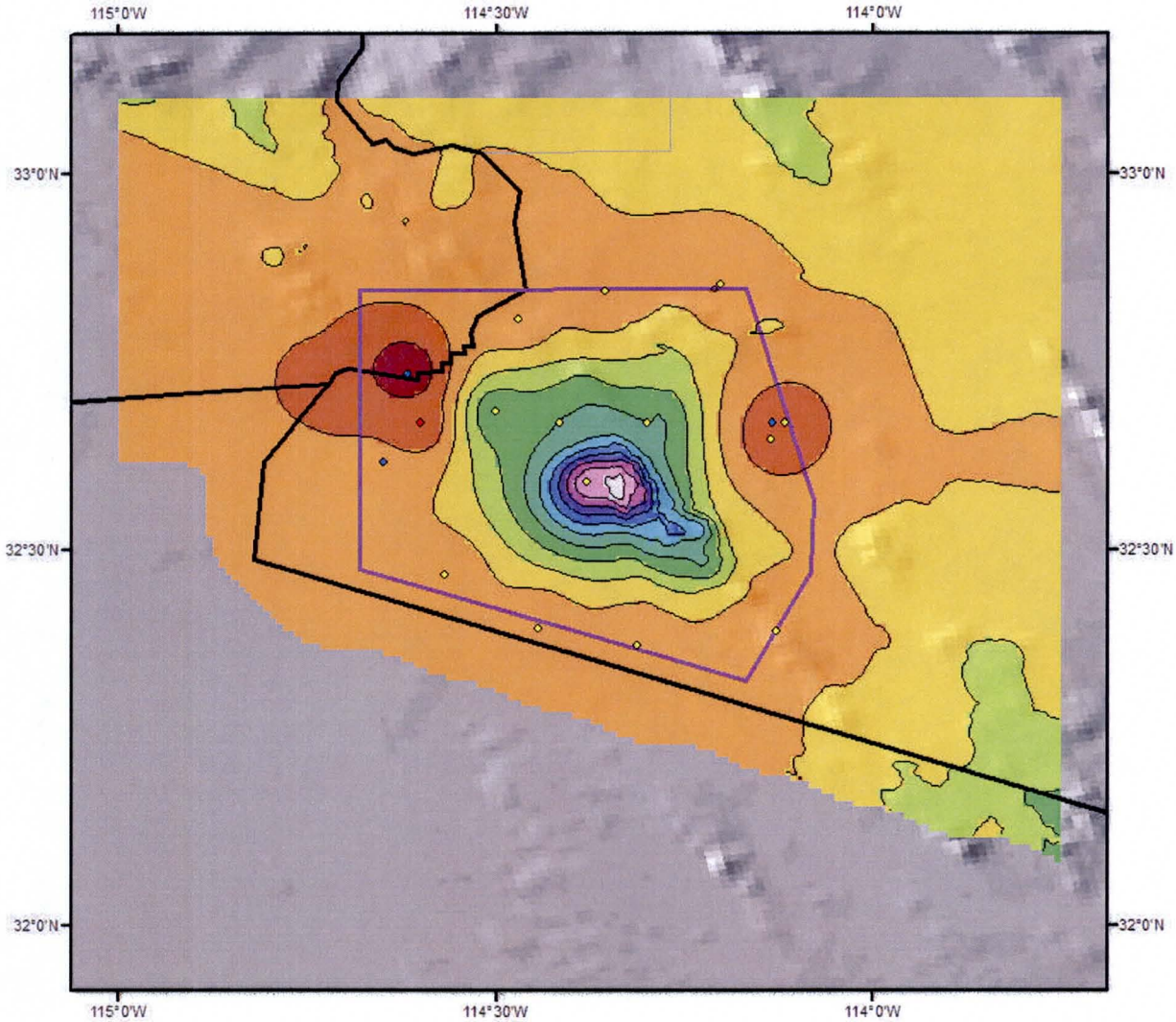

White Tanks #4
Wellton August 1955
Lake Havasu City
Colorado River Indian Reservation
Salton Sea
Yuma Proving Ground
Yuma
Mexicali
San Luis Río Colorado
Surprise
Peoria
Avondale
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
Gila River Indian Reservation
San Carlos Reservoir
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Papago Indian Reservation
Casas Adobes
Tucson
Nogales

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) 1 | 2 | 3 | 4 | 5 | 6 | 12 | total |
|---|---|---|---|---|---|---|---|---|
| **0.28** | 4.56 | 6.01 | 6.49 | 6.49 | - | - | - | 6.49 |
| **1** | 4.38 | 5.81 | 6.34 | 6.34 | - | - | - | 6.34 |
| **5** | 4.30 | 5.64 | 6.09 | 6.09 | - | - | - | 6.09 |
| **10** | 4.16 | 5.48 | 5.92 | 5.92 | - | - | - | 5.92 |
| **25** | 3.88 | 5.12 | 5.52 | 5.52 | - | - | - | 5.52 |
| **50** | 3.48 | 4.60 | 4.97 | 4.97 | - | - | - | 4.97 |
| **100** | 3.01 | 3.98 | 4.29 | 4.29 | - | - | - | 4.29 |
| **200** | 2.54 | 3.36 | 3.63 | 3.63 | - | - | - | 3.63 |
| **300** | 2.27 | 3.02 | 3.25 | 3.25 | - | - | - | 3.25 |
| **500** | 1.95 | 2.63 | 2.83 | 2.83 | - | - | - | 2.83 |
| **1,000** | 1.62 | 2.18 | 2.36 | 2.36 | - | - | - | 2.36 |
| **2,000** | 1.37 | 1.83 | 1.97 | 1.97 | - | - | - | 1.97 |
| **4,060** | 1.11 | 1.50 | 1.61 | 1.61 | - | - | - | 1.61 |




SPAS 1064 Storm Center Mass Curve: Welton, AZ
August 22 (0800Z) to 25 (0800Z), 1955 Storm
Lat: 32.5792 Lon: -114.3375
Incremental
Accumulated
6.49"
Precipitation (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
7
7.5




**Total Rainfall (72-hours)**
**Welton, AZ 1955 Storm**
**Storm #1064 August 22 (0800 Z) to 25 (0800 Z), 1955**

**Gauging Stations**

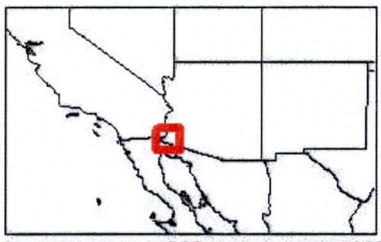
- Daily
- Hourly
- Supplemental

Miles: 0 4.5 9 18
Kilometers: 0 5 10 20 30 40

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.13 - 0.50 | 2.01 - 2.50 | 4.01 - 4.50 | 6.01 - 6.50 |
| 0.51 - 1.00 | 2.51 - 3.00 | 4.51 - 5.00 | |
| 1.01 - 1.50 | 3.01 - 3.50 | 5.01 - 5.50 | |
| 1.51 - 2.00 | 3.51 - 4.00 | 5.51 - 6.00 | |

N



*Coordinate system: GCS North American 1983*
*Scale: 1:821,805*
*Metstat/AWA April 28, 2009*

# Horshoe Dam, AZ

**October 27 – November 1, 1959**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1154-Horshoe Dam DAD Zo |
| Storm Date: | 10/29-11-1/1954 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 15-Oct

| | Lat | Long |
|---|---|---|
| Storm center location | 33.04 N | 111.00 W |
| Storm Rep dew point location | 32.22 N | 111.04 W |
| Transposition dewpoint location | 32.68 N | 112.56 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 60 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,750 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 69.5 F | with total precipitable water above sea level of | | | 2.20 | inches. |
| The in-place maximum dew point is | 72.0 F | with total precipitable water above sea level of | | | 2.47 | inches. |
| The transpositioned maximum dew point is | 71.5 F | with total precipitable water above sea level of | | | 2.47 | inches. |
| The in-place storm elevation is | 2,750 | which subtracts | 0.540 | inches of precipitable water at | 69.5 F | |
| The in-place storm elevation is | 2,750 | which subtracts | 0.59 | inches of precipitable water at | 72.0 F | |
| Basin elevation at | 3,650 | which subtracts | 0.740 | inches of precipitable water at | 71.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.740 | inches of precipitable water at | 71.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.13 |
| The transposition factor is | 0.92 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.04 |

Notes: 24hr average from KDMA 27th 7LST-28th 4LST (6 obs), KFHU 28th (6obs), KLUF 27th 9LST-28th 21LST (6obs)

**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.8 | 2.2 | 3.8 | - | 5.6 | - | - | 6.4 | - | 6.4 |
| 10 sq miles | 0.8 | 2.2 | 3.8 | - | 5.6 | - | - | 6.4 | - | 6.4 |
| 100 sq miles | 0.8 | 1.9 | 3.2 | - | 4.6 | - | - | 5.4 | - | 5.5 |
| 200 sq miles | 0.7 | 1.6 | 2.7 | - | 4.2 | - | - | 5.0 | - | 5.0 |
| 500 sq miles | 0.6 | 1.4 | 2.2 | - | 3.5 | - | - | 4.3 | - | 4.4 |
| 1000 sq miles | 0.6 | 1.2 | 2.0 | - | 2.9 | - | - | 3.7 | - | 3.9 |
| 2000 sq miles | 0.4 | 0.9 | 1.6 | - | 2.5 | - | - | 3.1 | - | 3.4 |
| 5000 sq miles | 0.2 | 0.8 | 1.2 | - | 1.9 | - | - | 2.4 | - | 2.5 |
| 10000 sq miles | 0.2 | 0.6 | 1.0 | - | 1.6 | - | - | 1.9 | - | 2.0 |
| 20000 sq miles | 0.1 | 0.5 | 0.8 | - | 1.3 | - | - | 1.6 | - | 1.7 |

**Adjusteded Storm Depth-Area-Duration**

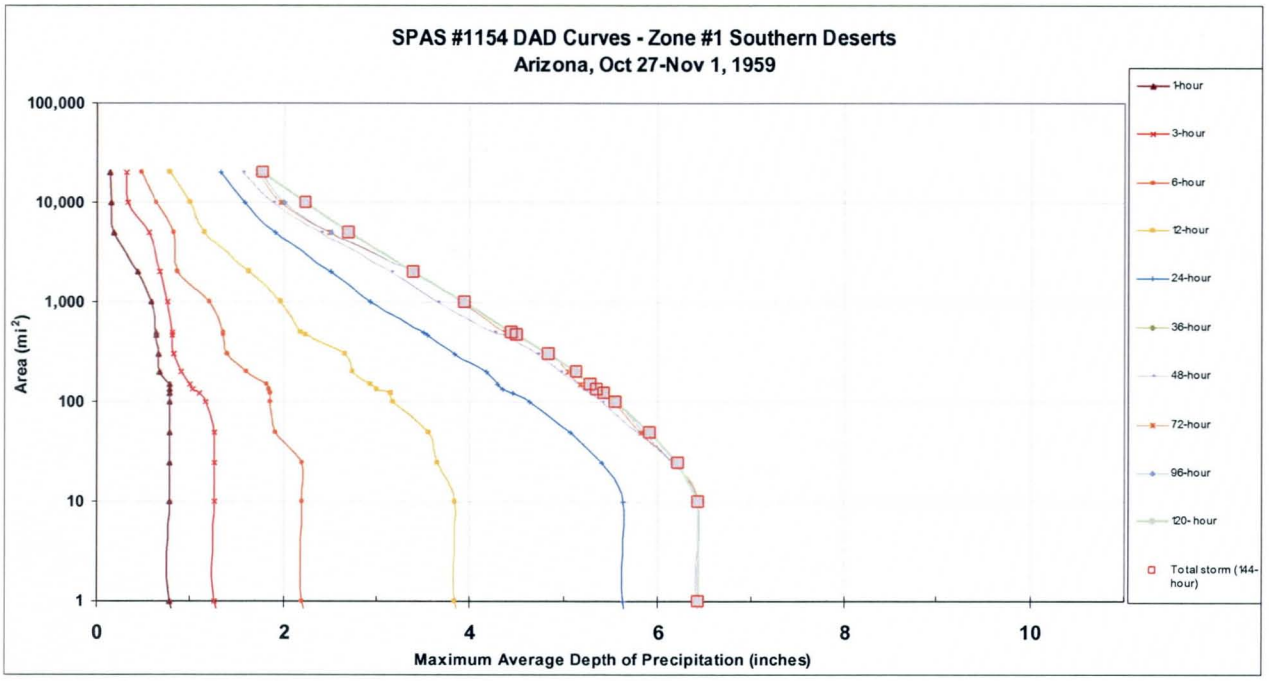
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.8 | 2.3 | 4.0 | - | 5.9 | - | - | 6.7 | - | 6.7 |
| 10 sq miles | 0.8 | 2.3 | 4.0 | - | 5.9 | - | - | 6.7 | - | 6.7 |
| 100 sq miles | 0.8 | 1.9 | 3.3 | - | 4.8 | - | - | 5.6 | - | 5.8 |
| 200 sq miles | 0.7 | 1.7 | 2.9 | - | 4.3 | - | - | 5.2 | - | 5.3 |
| 500 sq miles | 0.7 | 1.4 | 2.3 | - | 3.6 | - | - | 4.4 | - | 4.6 |
| 1000 sq miles | 0.6 | 1.3 | 2.1 | - | 3.0 | - | - | 3.8 | - | 4.1 |
| 2000 sq miles | 0.4 | 0.9 | 1.7 | - | 2.6 | - | - | 3.3 | - | 3.5 |
| 5000 sq miles | 0.2 | 0.9 | 1.2 | - | 2.0 | - | - | 2.5 | - | 2.6 |
| 10000 sq miles | 0.2 | 0.7 | 1.0 | - | 1.7 | - | - | 2.0 | - | 2.0 |
| 20000 sq miles | 0.1 | 0.5 | 0.8 | - | 1.4 | - | - | 1.6 | - | 1.8 |

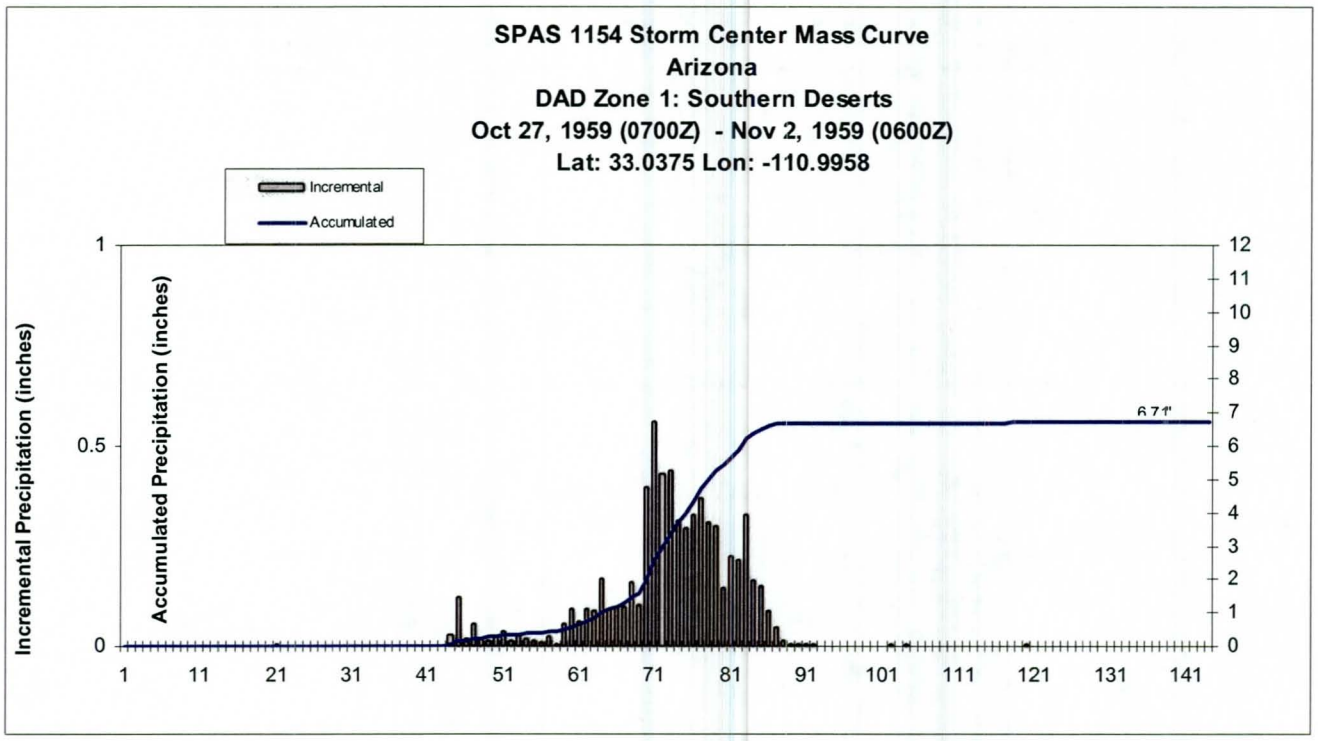
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1154-Horshoe Dam DAD Zone 1** | |
| Storm Date(s) | 10/29-11-1/1954 | |
| Storm Type | General | |
| Storm Location | 33.04 N | 111.00 W |
| Storm Center Elevation | 2750 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 6.70 inches 72 hours (SPAS 1134 DAD Zone 1) | |
| | | |
| Storm Representative Dewpoint | 69.5 F | 24hr ave KLUF, KDMA, KFHU |
| Storm Representative Dewpoint Location | 32.22 N | 111.04 W |
| In-place Maximum Dewpoint | 72.0 F | |
| Moisture Inflow Vector | S @ 60 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Oct | |
| Transposition Dewpoint Location | 32.68 N | 112.56 W |
| Transposition Maximum Dewpoint | 71.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

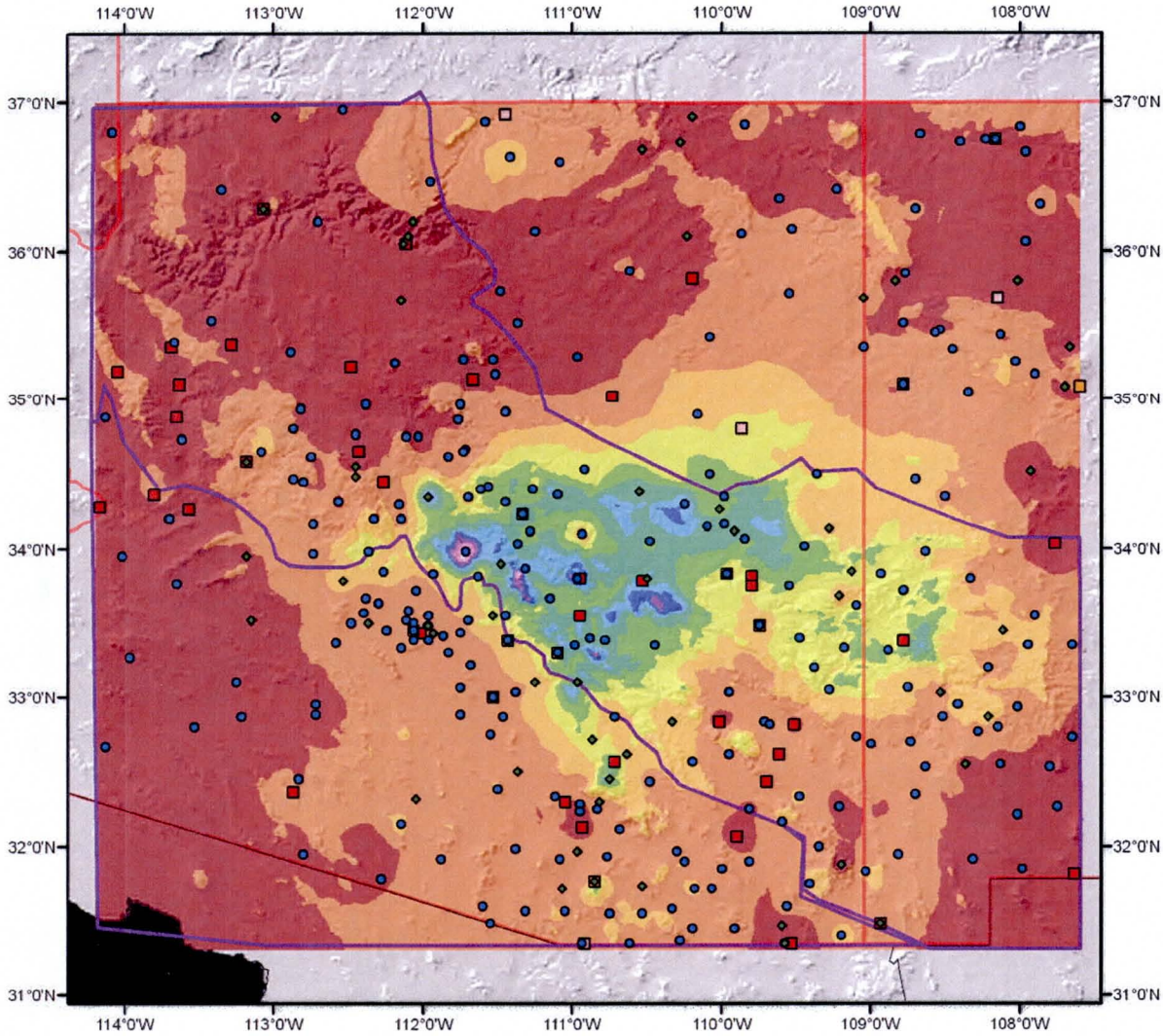
White Tanks #4
Horshoe Dam Zone 1 October 1959
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt
San Carlos Reservoir
Fort Apache Indian Reservation
Ramah Navajo Indian Reservation
Yuma Proving Ground
Yuma
San Luis Rio Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta
Caborca
Gulf of

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| | Duration (hours) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($mi^2$) | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | 120 | Total (144-hr |
| 0.27 | 1.15 | | 1.57 | | | 2.46 | 4.13 | | 5.88 | | 6.68 | 6.70 | 6.71 | 6.71 | 6.71 |
| 1 | 0.78 | | 1.26 | | | 2.20 | 3.84 | | 5.63 | | 6.42 | 6.43 | 6.44 | 6.44 | 6.44 |
| 10 | 0.78 | | 1.26 | | | 2.20 | 3.84 | | 5.63 | | 6.42 | 6.43 | 6.44 | 6.44 | 6.44 |
| 25 | 0.78 | | 1.26 | | | 2.20 | 3.64 | | 5.41 | | 6.17 | 6.18 | 6.17 | 6.22 | 6.22 |
| 50 | 0.78 | | 1.26 | | | 1.91 | 3.55 | | 5.06 | | 5.80 | 5.83 | 5.86 | 5.92 | 5.92 |
| 100 | 0.78 | | 1.16 | | | 1.86 | 3.17 | | 4.63 | | 5.40 | 5.54 | 5.55 | 5.55 | 5.55 |
| 121 | 0.78 | | 1.10 | | | 1.85 | 3.14 | | 4.46 | | 5.30 | 5.42 | 5.42 | 5.43 | 5.43 |
| 135 | 0.78 | | 1.03 | | | 1.84 | 3.00 | | 4.35 | | 5.20 | 5.33 | 5.34 | 5.34 | 5.35 |
| 150 | 0.78 | | 1.00 | | | 1.82 | 2.92 | | 4.30 | | 5.16 | 5.18 | 5.28 | 5.28 | 5.29 |
| 200 | 0.68 | | 0.91 | | | 1.60 | 2.74 | | 4.17 | | 4.96 | 5.04 | 5.12 | 5.12 | 5.13 |
| 300 | 0.67 | | 0.83 | | | 1.39 | 2.65 | | 3.83 | | 4.72 | 4.83 | 4.83 | 4.84 | 4.84 |
| 475 | 0.64 | | 0.81 | | | 1.36 | 2.23 | | 3.54 | | 4.38 | 4.49 | 4.49 | 4.5 | 4.5 |
| 500 | 0.64 | | 0.81 | | | 1.36 | 2.18 | | 3.50 | | 4.25 | 4.37 | 4.45 | 4.45 | 4.45 |
| 1000 | 0.58 | | 0.76 | | | 1.20 | 1.97 | | 2.92 | | 3.65 | 3.90 | 3.92 | 3.93 | 3.94 |
| 2000 | 0.43 | | 0.68 | | | 0.87 | 1.62 | | 2.51 | | 3.14 | 3.37 | 3.37 | 3.38 | 3.39 |
| 5000 | 0.18 | | 0.56 | | | 0.82 | 1.15 | | 1.91 | | 2.40 | 2.49 | 2.50 | 2.69 | 2.7 |
| 10000 | 0.15 | | 0.32 | | | 0.63 | 1.00 | | 1.59 | | 1.88 | 1.96 | 2.01 | 2.23 | 2.23 |
| 20,000 | 0.13 | | 0.31 | | | 0.48 | 0.79 | | 1.33 | | 1.56 | 1.72 | 1.76 | 1.77 | 1.78 |




SPAS 1154 Storm Center Mass Curve
Arizona
DAD Zone 1: Southern Deserts
Oct 27, 1959 (0700Z) - Nov 2, 1959 (0600Z)
Lat: 33.0375 Lon: -110.9958
Incremental
Accumulated
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
6.71"
1
0.5
0
12
11
10
9
8
7
6
5
4
3
2
1
0
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141

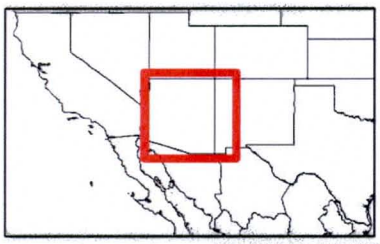



**Total Precipitation**
**SPAS storm 1154**
**10/27/1959 - 11/01/1959**

Miles
0 15 30 60

**Stations**

| | | | | |
|---|---|---|---|---|
| 0.00 - 1.00 | 4.01 - 5.00 | 8.01 - 9.00 | Daily | |
| 1.01 - 2.00 | 5.01 - 6.00 | 9.01 - 10.00 | Hourly | |
| 2.01 - 3.00 | 6.01 - 7.00 | 10.01 - 11.00 | Hourly estimated | |
| 3.01 - 4.00 | 7.01 - 8.00 | | Hourly pseudo | |
| | | | Supplemental | |



Metstat/AWA August 19, 2009

# Sonora Desert, AZ

**September 26-28, 1962**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| Storm Name: | SPAS-1083-Sonora Desert Museun |
| Storm Date: | 9/26-27/1962 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 10-Sep

| | Lat | Long |
|---|---|---|
| Storm center location | 32.18 N | 111.39 W |
| Storm Rep dew point location | 32.12 N | 110.93 W |
| Transposition dewpoint location | 33.04 N | 112.05 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | ESE @ 25 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 3,200 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 72.5 F | with total precipitable water above sea level of | | | 2.54 | inches. |
| The in-place maximum dew point is | 77.5 F | with total precipitable water above sea level of | | | 3.21 | inches. |
| The transpositioned maximum dew point is | 78.0 F | with total precipitable water above sea level of | | | 3.21 | inches. |
| The in-place storm elevation is | 3,200 | which subtracts | 0.68 | inches of precipitable water at | 72.5 F | |
| The in-place storm elevation is | 3,200 | which subtracts | 0.805 | inches of precipitable water at | 77.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.93 | inches of precipitable water at | 78.0 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.93 | inches of precipitable water at | 78.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.29 |
| The transposition/elevation factor is | 0.95 |
| The barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.23 |

Notes: USGS WSP 1820, p123, Storm rep taken at KTUS, KDMA, KFHU, however rain was falling during the 12hr window 01Z-12Z on the 26th at KTUS

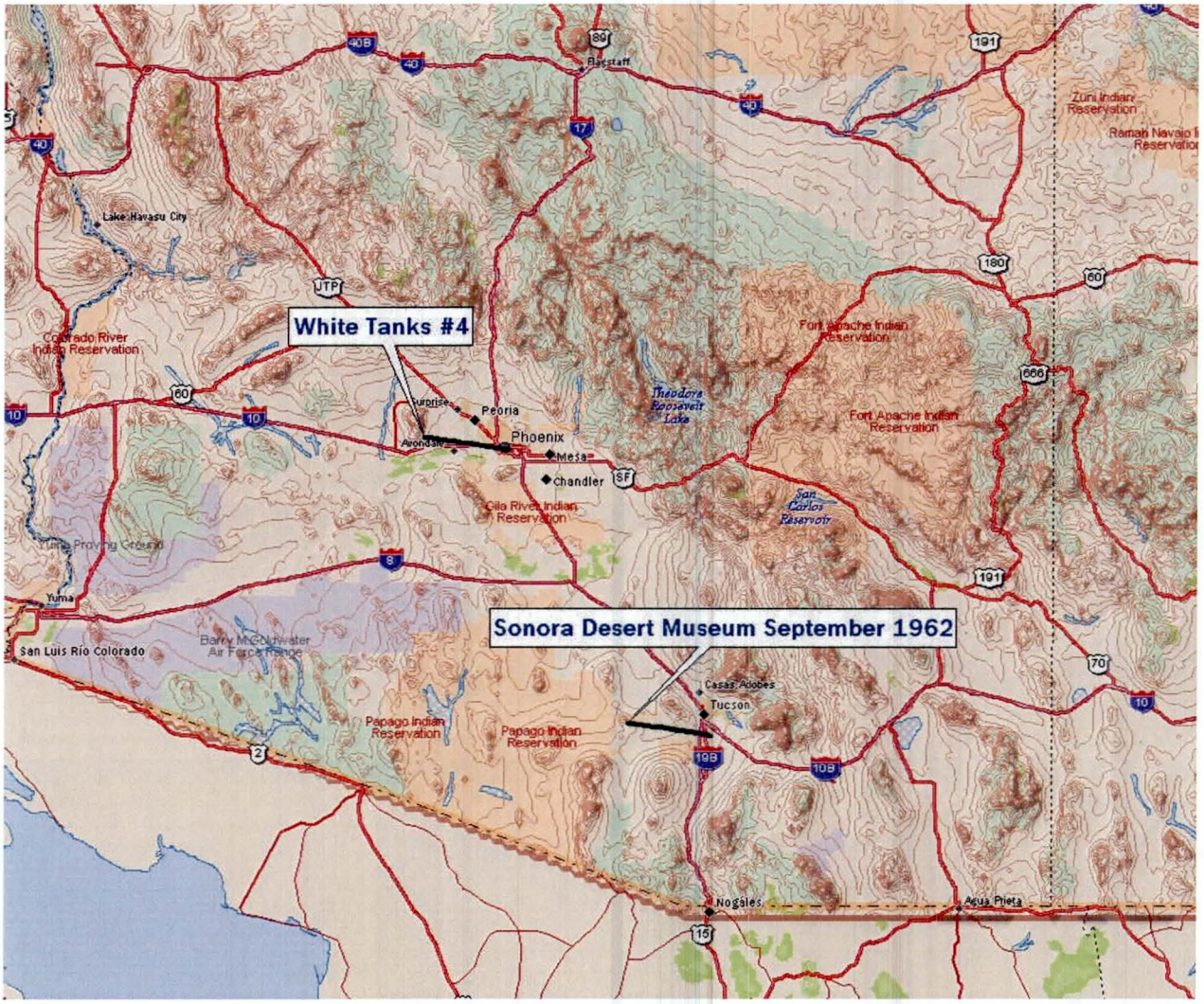
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.5 | 1.9 | 2.1 | 2.4 | 3.3 | 3.8 | 6.0 | 7.1 | | |
| 10 sq miles | 1.5 | 1.9 | 2.1 | 2.4 | 3.3 | 3.8 | 5.9 | 7.0 | | |
| 50 sq miles | 1.5 | 1.8 | 2.0 | 2.3 | 3.1 | 3.6 | 5.5 | 6.6 | | |
| 100 sq miles | 1.4 | 1.7 | 1.9 | 2.2 | 2.9 | 3.4 | 5.3 | 6.3 | | |
| 200 sq miles | 1.3 | 1.6 | 1.9 | 2.1 | 2.8 | 3.2 | 5.1 | 6.1 | | |
| 500 sq miles | 1.2 | 1.4 | 1.6 | 1.9 | 2.5 | 2.9 | 4.6 | 5.6 | | |
| 1000 sq miles | 1.0 | 1.3 | 1.5 | 1.6 | 2.2 | 2.5 | 4.1 | 5.1 | | |
| 2000 sq miles | 0.9 | 1.1 | 1.4 | 1.4 | 1.9 | 2.2 | 3.6 | 4.6 | | |
| 5000 sq miles | 0.6 | 0.8 | 1.1 | 1.2 | 1.5 | 1.8 | 2.9 | 3.9 | | |

**Adjusted Storm Depth-Area-Duration**

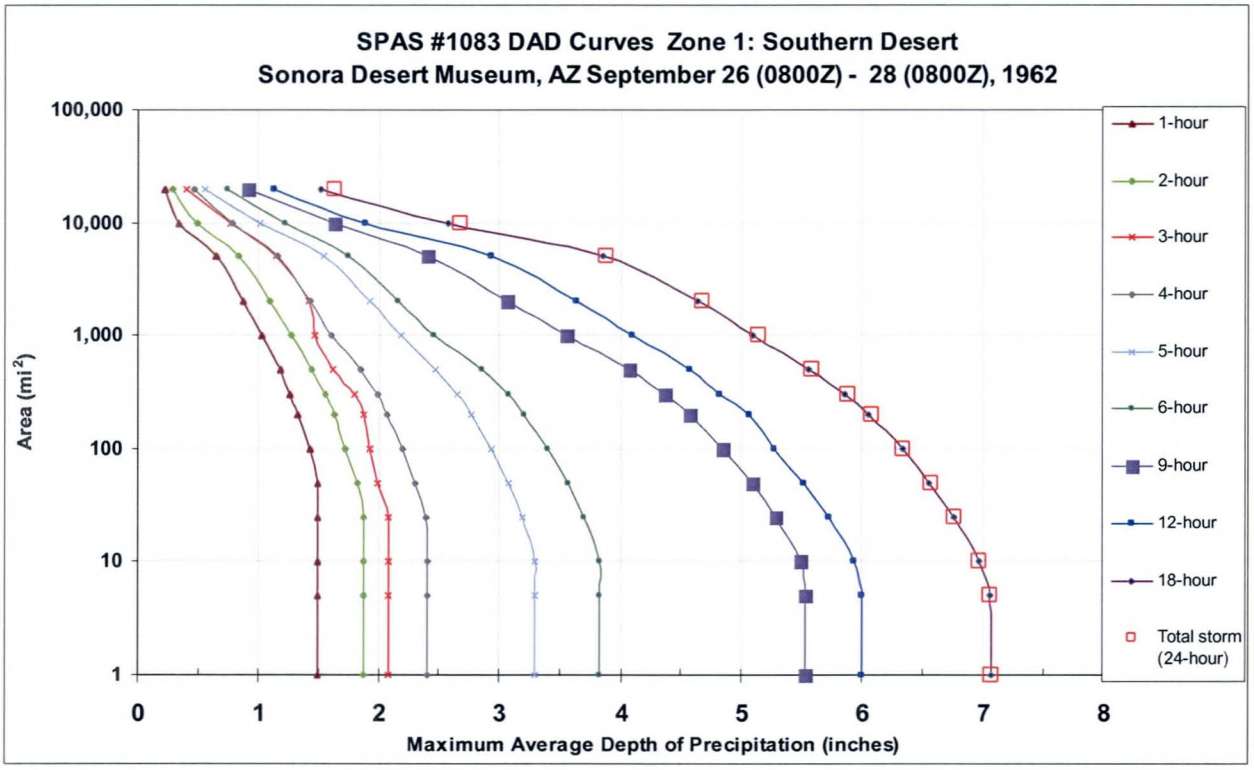
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.8 | 2.3 | 2.6 | 2.9 | 4.0 | 4.7 | 7.4 | 8.7 | | |
| 10 sq miles | 1.8 | 2.3 | 2.6 | 2.9 | 4.0 | 4.7 | 7.3 | 8.6 | | |
| 50 sq miles | 1.8 | 2.2 | 2.4 | 2.8 | 3.8 | 4.4 | 6.8 | 8.0 | | |
| 100 sq miles | 1.7 | 2.1 | 2.4 | 2.7 | 3.6 | 4.2 | 6.5 | 7.8 | | |
| 200 sq miles | 1.6 | 2.0 | 2.3 | 2.5 | 3.4 | 3.9 | 6.2 | 7.4 | | |
| 500 sq miles | 1.4 | 1.8 | 2.0 | 2.3 | 3.0 | 3.5 | 5.6 | 6.8 | | |
| 1000 sq miles | 1.3 | 1.6 | 1.8 | 2.0 | 2.7 | 3.0 | 5.0 | 6.3 | | |
| 2000 sq miles | 1.1 | 1.3 | 1.7 | 1.7 | 2.4 | 2.7 | 4.5 | 5.7 | | |
| 5000 sq miles | 0.8 | 1.0 | 1.4 | 1.4 | 1.9 | 2.1 | 3.6 | 4.7 | | |

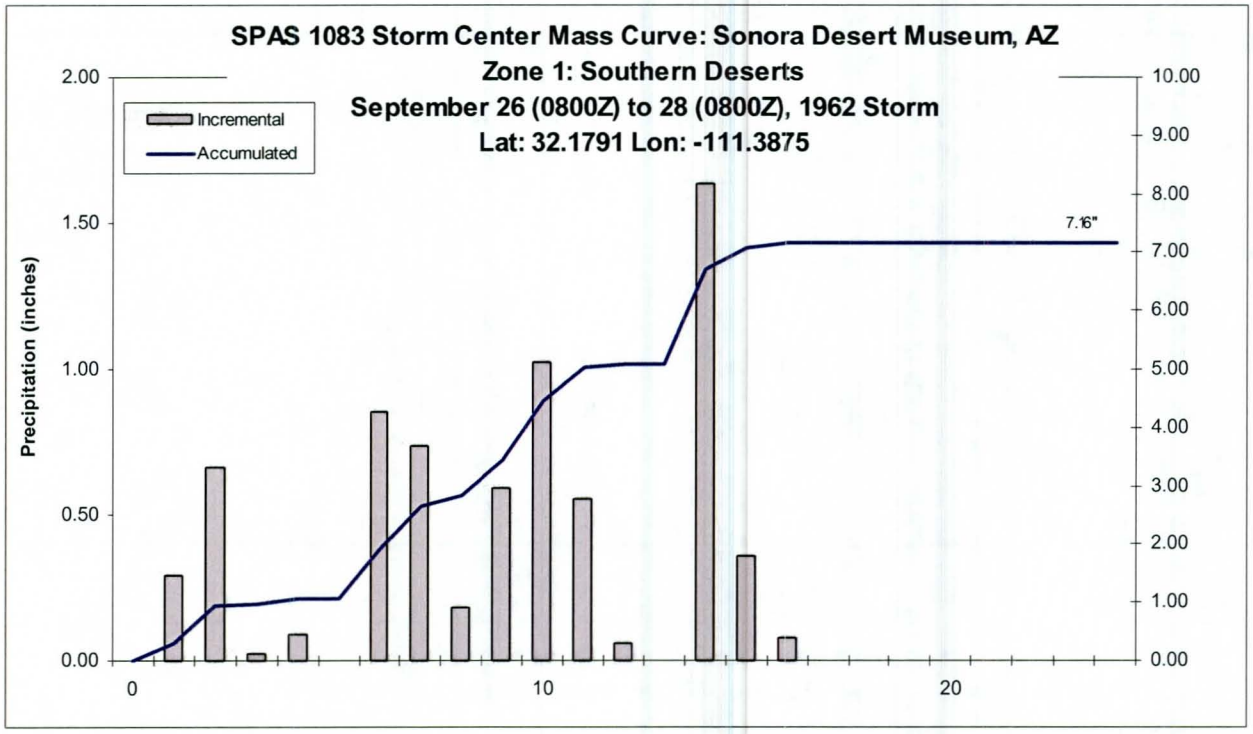
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1083-Sonora Desert Museum** | |
| Storm Date(s) | 9/26-27/1962 | |
| Storm Type | Local-Tropical | |
| Storm Location | 32.18 N | 111.39 W |
| Storm Center Elevation | 3200 | non-orogra 1k relief desert floor to isolated mtns at storm center |
| Precipitation Total & Duration (10 sq mi) | 7.16 inches 18 hours 3.94" 6hrs (SPAS 1083 DAD) | |
| | | |
| Storm Representative Dewpoint | 72.5 F | 12hr ave KTUS, KDMA, KFHU |
| Storm Representative Dewpoint Location | 32.12 N | 110.93 W |
| In-place Maximum Dewpoint | 77.5 F | |
| Moisture Inflow Vector | ESE @ 25 | based on HYSPLIT |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 10-Sep | |
| Transposition Dewpoint Location | 33.04 N | 112.05 W |
| Transposition Maximum Dewpoint | 78.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.23 | |

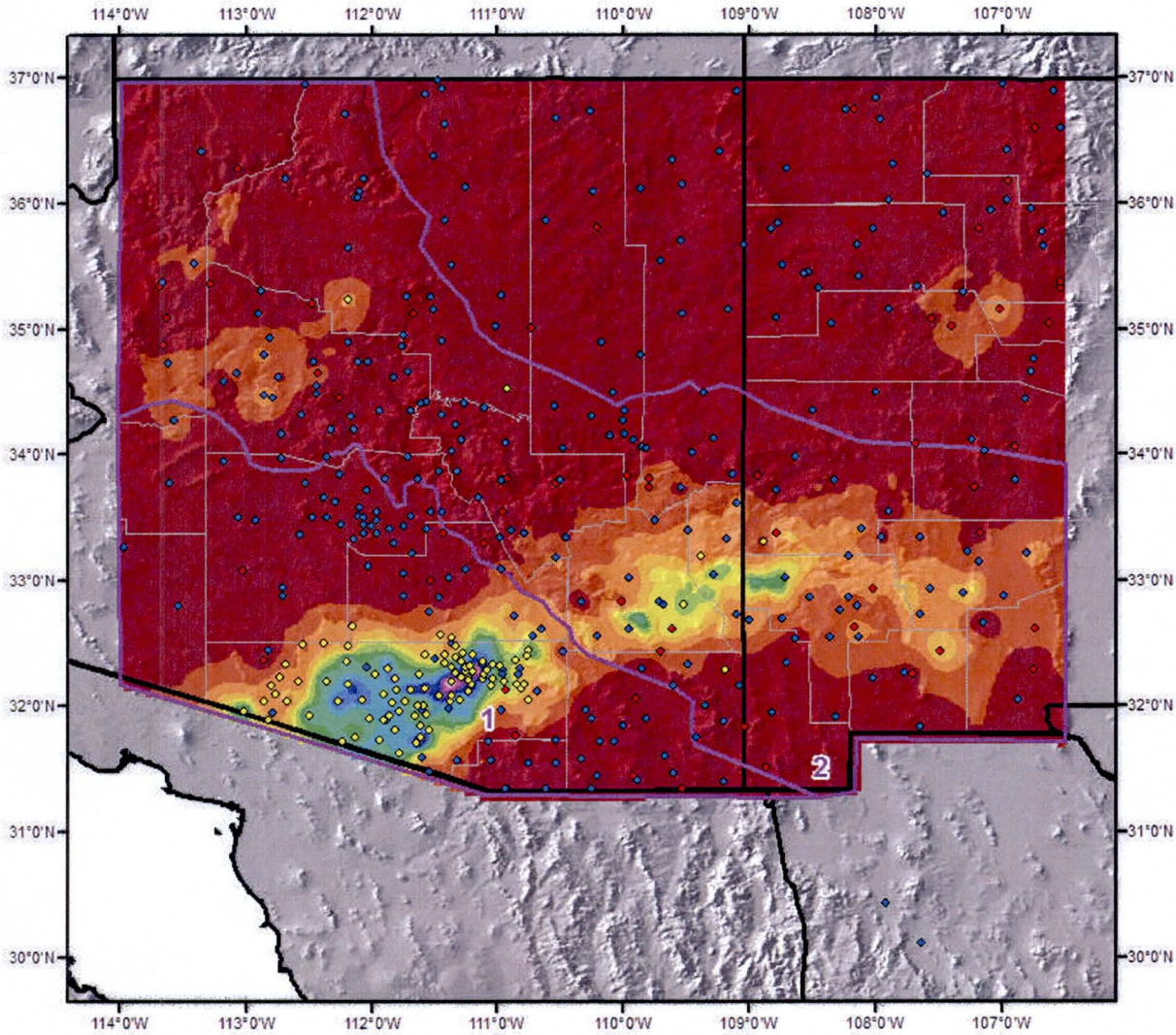

White Tanks #4
Sonora Desert Museum September 1962
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Theodore Roosevelt Lake
Fort Apache Indian Reservation
Zuni Indian Reservation
Gila River Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
San Luis Rio Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area (mi$^2$) | Duration (hours) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 9 | 12 | 18 | total |
| **0.28** | 1.64 | 2.00 | 2.21 | 2.53 | 3.39 | 3.94 | 5.64 | 6.09 | 7.16 | 7.16 |
| **1** | 1.49 | 1.88 | 2.08 | 2.40 | 3.29 | 3.82 | 5.53 | 6.00 | 7.07 | 7.07 |
| **5** | 1.49 | 1.88 | 2.08 | 2.40 | 3.29 | 3.82 | 5.53 | 6.00 | 7.06 | 7.06 |
| **10** | 1.49 | 1.88 | 2.08 | 2.40 | 3.29 | 3.82 | 5.49 | 5.93 | 6.96 | 6.96 |
| **25** | 1.49 | 1.88 | 2.08 | 2.39 | 3.19 | 3.70 | 5.29 | 5.72 | 6.76 | 6.76 |
| **50** | 1.48 | 1.82 | 1.99 | 2.30 | 3.07 | 3.57 | 5.09 | 5.52 | 6.55 | 6.56 |
| **100** | 1.42 | 1.72 | 1.92 | 2.20 | 2.94 | 3.40 | 4.85 | 5.27 | 6.33 | 6.33 |
| **200** | 1.32 | 1.63 | 1.87 | 2.07 | 2.77 | 3.21 | 4.57 | 5.06 | 6.05 | 6.07 |
| **300** | 1.26 | 1.55 | 1.80 | 1.99 | 2.65 | 3.07 | 4.37 | 4.82 | 5.86 | 5.88 |
| **500** | 1.17 | 1.44 | 1.62 | 1.85 | 2.47 | 2.86 | 4.07 | 4.58 | 5.56 | 5.58 |
| **1,000** | 1.02 | 1.27 | 1.46 | 1.60 | 2.18 | 2.46 | 3.55 | 4.10 | 5.09 | 5.14 |
| **2,000** | 0.87 | 1.09 | 1.41 | 1.42 | 1.92 | 2.16 | 3.06 | 3.63 | 4.64 | 4.68 |
| **5,000** | 0.64 | 0.83 | 1.14 | 1.15 | 1.54 | 1.75 | 2.41 | 2.93 | 3.85 | 3.88 |
| **10,000** | 0.34 | 0.49 | 0.76 | 0.77 | 1.01 | 1.22 | 1.63 | 1.89 | 2.57 | 2.68 |
| **20,000** | 0.22 | 0.28 | 0.40 | 0.46 | 0.56 | 0.74 | 0.90 | 1.12 | 1.51 | 1.63 |




SPAS 1083 Storm Center Mass Curve: Sonora Desert Museum, AZ
Zone 1: Southern Deserts
September 26 (0800Z) to 28 (0800Z), 1962 Storm
Lat: 32.1791 Lon: -111.3875
Incremental
Accumulated
Precipitation (inches)
2.00
1.50
1.00
0.50
0.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
7.16"
0
10
20




**Total Rainfall (24-hours)**
**Sonora Desert Museum, AZ 1962 Storm**
**Storm #1083 September 26 (0800 Z) to 28 (0800 Z), 1962**

**Gauging Stations**

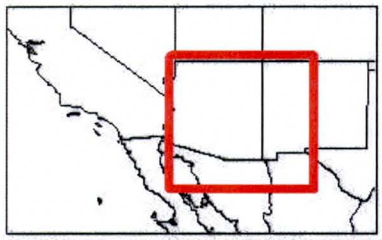
- Daily
- Hourly
- Hourly Pseudo
- Supplemental

Miles: 0 25 50 100
Kilometers: 0 45 90 180 270

N

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.00 - 0.50 | 2.01 - 2.50 | 4.01 - 4.50 | 6.01 - 6.50 |
| 0.51 - 1.00 | 2.51 - 3.00 | 4.51 - 5.00 | 6.51 - 7.00 |
| 1.01 - 1.50 | 3.01 - 3.50 | 5.01 - 5.50 | 7.01 - 7.50 |
| 1.51 - 2.00 | 3.51 - 4.00 | 5.51 - 6.00 | |



*Coordinate system: GCS North American 1983*
*Scale: 1:4,980,531*

MetstatAWA May 22, 2009

# North Tucson, AZ

**September 6-7, 1964**

**Storm Type: Local Convective**

| | |
|---|---|
| **Storm Name:** | **SPAS-1060-North Tucson** |
| **Storm Date:** | **9/6-7/1964** |
| **AWA Analysis Date:** | **10/15/2009** |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** **20-Aug**

| | Lat | Long |
|---|---|---|
| **Storm center location** | **32.30 N** | **111.00 W** |
| **Storm Rep dew point location** | **32.17 N** | **110.93 W** |
| **Transposition dewpoint location** | **33.37 N** | **112.45 W** |
| **Basin location** | **33.55 N** | **112.55 W** |

| | | |
|---|---|---|
| **Moisture Inflow Direction:** | **SSE @ 10** | miles |
| **Basin Elevation** | **3,650** | feet |
| **Storm Elevation** | **2,250** | feet |
| **Effective Barrier Height** | **3,650** | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | **71.5 F** | with total precipitable water above sea level of | | | **2.42** | inches. |
| The in-place maximum dew point is | **80.5 F** | with total precipitable water above sea level of | | | **3.68** | inches. |
| The transpositioned maximum dew point is | **80.5 F** | with total precipitable water above sea level of | | | **3.68** | inches. |
| The in-place storm elevation is | **0** | which subtracts | **0.000** | inches of precipitable water at | **71.5 F** | |
| The in-place storm elevation is | **0** | which subtracts | **0.000** | inches of precipitable water at | **80.5 F** | |
| Basin elevation at | **0** | which subtracts | **0.000** | inches of precipitable water at | **80.5 F** | |
| The inflow barrier height/basin elevation is | **0** | which subtracts | **0.000** | inches of precipitable water at | **80.5 F** | |

| | |
|---|---|
| The in-place maximization factor is | **1.50** |
| The transposition factor is | **1.00** |
| The elevation/barrier adjustment factor is | **1.00** |
| The total adjustment factor is | **1.50** |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. 3hr average taken from KTUS and KDMA. Calculated in-place maxization iis 1.52, held to 1.50.

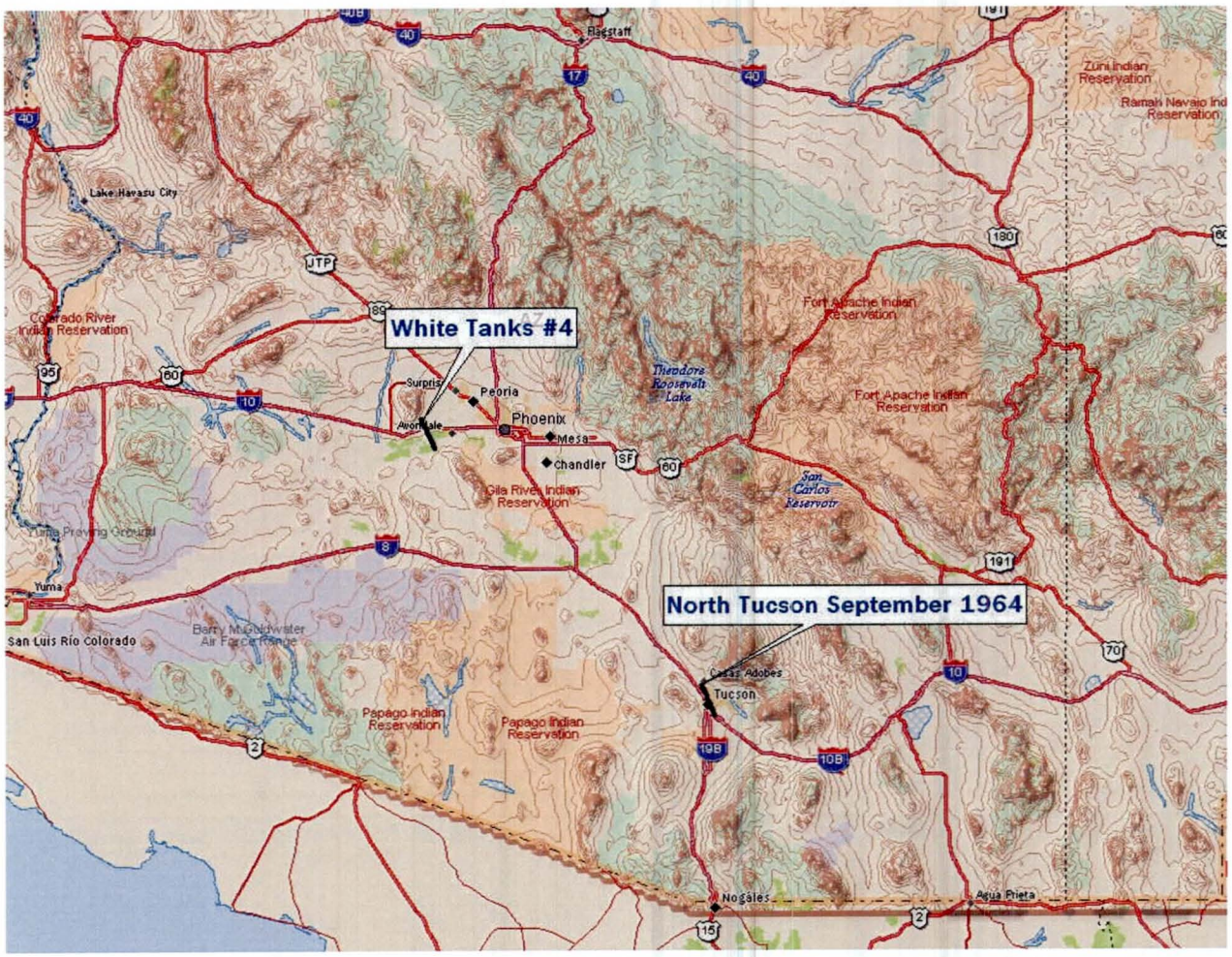
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **3.3** | **4.9** | **5.0** | **5.0** | **5.0** | **5.1** | **5.1** | **5.1** | | |
| 10 sq miles | **2.7** | **3.9** | **4.2** | **4.2** | **4.2** | **4.2** | **4.3** | **4.3** | | |
| 50 sq miles | **1.9** | **2.7** | **2.9** | **3.0** | **3.0** | **3.0** | **3.1** | **3.1** | | |
| 100 sq miles | **1.5** | **2.2** | **2.4** | **2.5** | **2.5** | **2.5** | **2.5** | **2.6** | | |
| 200 sq miles | **1.3** | **1.8** | **2.0** | **2.0** | **2.0** | **2.0** | **2.1** | **2.1** | | |
| 500 sq miles | **1.0** | **1.4** | **1.5** | **1.5** | **1.6** | **1.6** | **1.6** | **1.7** | | |
| 1000 sq miles | **0.8** | **1.1** | **1.2** | **1.2** | **1.2** | **1.3** | **1.4** | **1.4** | | |
| 2000 sq miles | **0.5** | **0.8** | **0.9** | **0.9** | **0.9** | **0.9** | **1.1** | **1.1** | | |
| 5000 sq miles | | | | | | | | | | |

**Adjusted Storm Depth-Area-Duration**

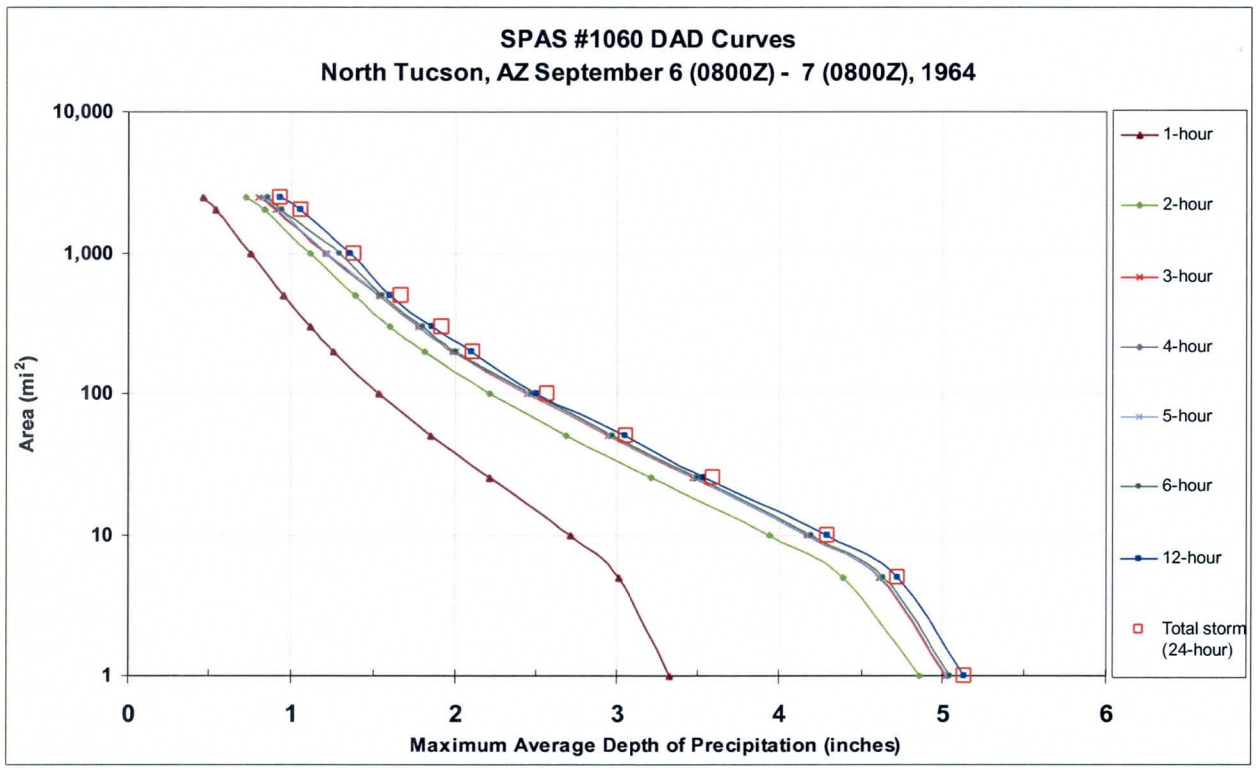
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **5.0** | **7.3** | **7.5** | **7.5** | **7.5** | **7.6** | **7.7** | **7.7** | | |
| 10 sq miles | **4.1** | **5.9** | **6.3** | **6.3** | **6.3** | **6.3** | **6.4** | **6.4** | | |
| 50 sq miles | **2.8** | **4.0** | **4.4** | **4.4** | **4.4** | **4.5** | **4.6** | **4.6** | | |
| 100 sq miles | **2.3** | **3.3** | **3.7** | **3.7** | **3.7** | **3.7** | **3.8** | **3.9** | | |
| 200 sq miles | **1.9** | **2.7** | **3.0** | **3.0** | **3.0** | **3.0** | **3.2** | **3.2** | | |
| 500 sq miles | **1.4** | **2.1** | **2.3** | **2.3** | **2.3** | **2.3** | **2.4** | **2.5** | | |
| 1000 sq miles | **1.1** | **1.7** | **1.8** | **1.8** | **1.8** | **1.9** | **2.0** | **2.1** | | |
| 2000 sq miles | **0.8** | **1.2** | **1.4** | **1.4** | **1.4** | **1.4** | **1.6** | **1.6** | | |
| 5000 sq miles | | | | | | | | | | |

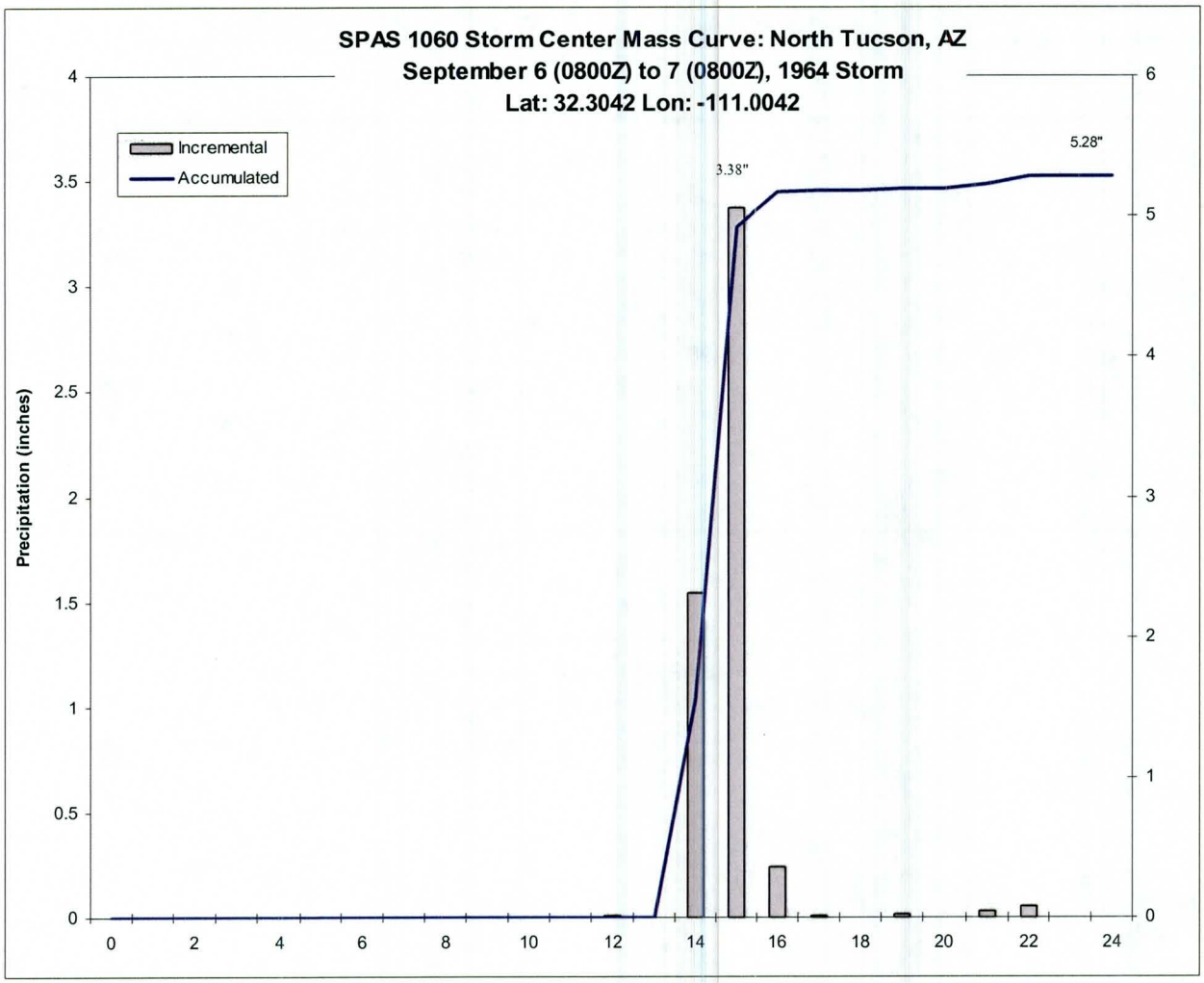
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1060-North Tucson** | |
| Storm Date(s) | 9/6-7/1964 | |
| Storm Type | Local Storm | |
| Storm Location | 32.30 N | 111.00 W |
| Storm Center Elevation | 2250 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 5.19 inches 6 hours 3.38" in 1hr and 4.92" in 2hrs (SPAS 1060 DAD) | |
| | | |
| Storm Representative Dewpoint | 71.5 F | 3hr ave KTUS, KDMA |
| Storm Representative Dewpoint Location | 32.17 N | 110.93 W |
| In-place Maximum Dewpoint | 80.5 F | |
| Moisture Inflow Vector | SSE @ 10 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 20-Aug | |
| Transposition Dewpoint Location | 33.37 N | 112.45 W |
| Transposition Maximum Dewpoint | 80.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.50 | |

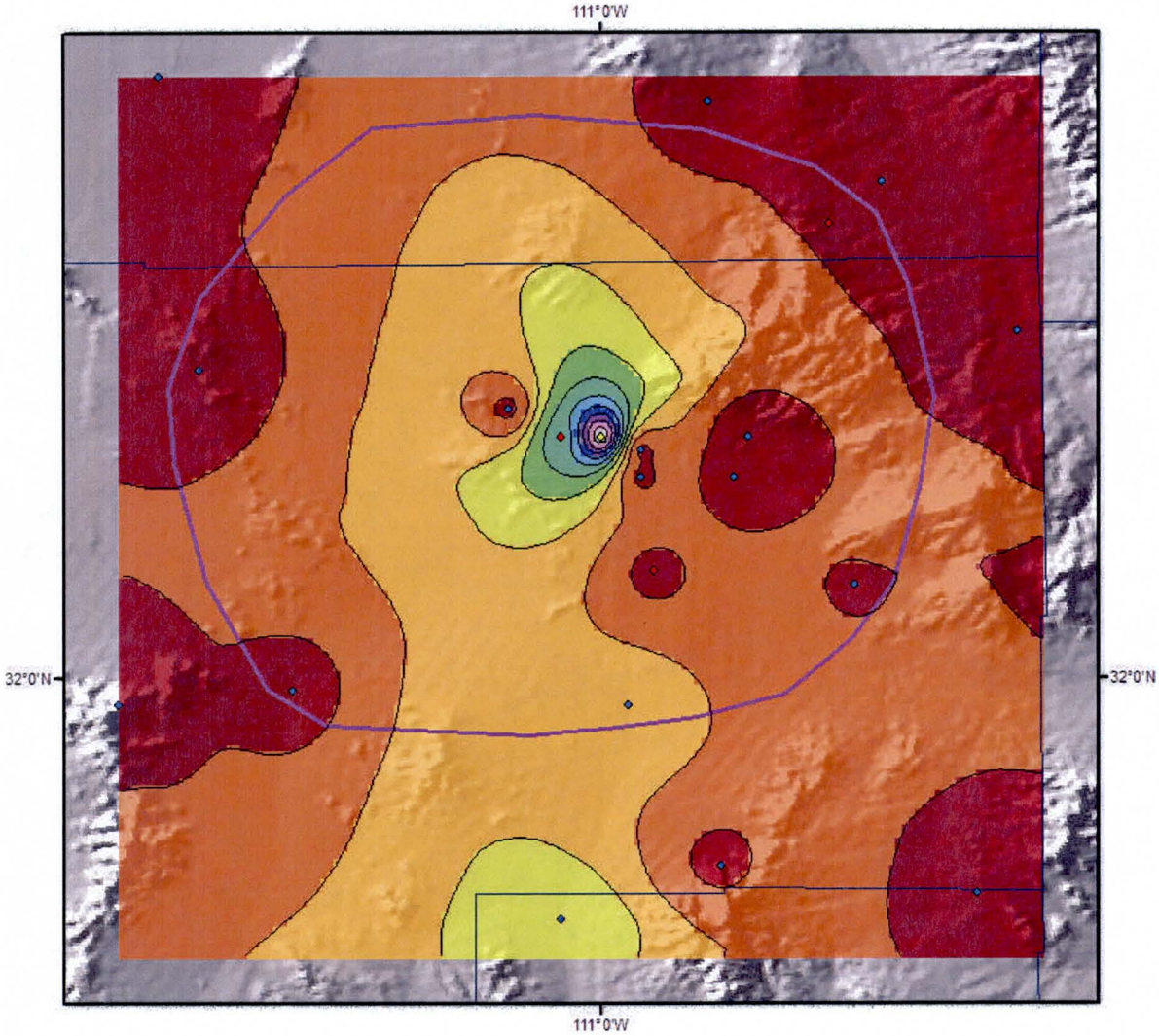

White Tanks #4
North Tucson September 1964
Flagstaff
Zuni Indian Reservation
Ramah Navajo Ind Reservation
Lake Havasu City
Colorado River Indian Reservation
Fort Apache Indian Reservation
Theodore Roosevelt Lake
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Gila River Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Casas Adobes
Tucson
Papago Indian Reservation
Nogales
Agua Prieta

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) 1 | 2 | 3 | 4 | 5 | 6 | 12 | total |
|---|---|---|---|---|---|---|---|---|
| **0.28** | 3.38 | 4.92 | 5.16 | 5.17 | 5.17 | 5.19 | 5.28 | 5.28 |
| **1** | 3.33 | 4.86 | 5.02 | 5.03 | 5.03 | 5.05 | 5.14 | 5.14 |
| **5** | 3.01 | 4.39 | 4.61 | 4.62 | 4.62 | 4.64 | 4.73 | 4.73 |
| **10** | 2.71 | 3.94 | 4.17 | 4.17 | 4.18 | 4.20 | 4.29 | 4.29 |
| **25** | 2.21 | 3.21 | 3.47 | 3.48 | 3.48 | 3.50 | 3.54 | 3.59 |
| **50** | 1.85 | 2.68 | 2.94 | 2.95 | 2.95 | 2.97 | 3.05 | 3.06 |
| **100** | 1.53 | 2.21 | 2.44 | 2.45 | 2.45 | 2.47 | 2.50 | 2.57 |
| **200** | 1.26 | 1.81 | 1.98 | 1.98 | 2.00 | 2.00 | 2.10 | 2.11 |
| **300** | 1.11 | 1.60 | 1.77 | 1.77 | 1.78 | 1.80 | 1.86 | 1.92 |
| **500** | 0.95 | 1.39 | 1.53 | 1.53 | 1.55 | 1.55 | 1.60 | 1.67 |
| **1,000** | 0.75 | 1.11 | 1.21 | 1.21 | 1.22 | 1.29 | 1.36 | 1.38 |
| **2,000** | 0.54 | 0.83 | 0.90 | 0.91 | 0.93 | 0.94 | 1.05 | 1.05 |
| **2,443** | 0.46 | 0.72 | 0.80 | 0.81 | 0.83 | 0.85 | 0.93 | 0.93 |




SPAS 1060 Storm Center Mass Curve: North Tucson, AZ
September 6 (0800Z) to 7 (0800Z), 1964 Storm
Lat: 32.3042 Lon: -111.0042
Incremental
Accumulated
3.38"
5.28"
Precipitation (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
18
20
22
24




**Total Rainfall (24-hours)**
**North Tuscon, AZ 1964 Storm**
**Storm #1060 September 6 (0800 Z) to 7 (0800 Z), 1964**

Miles
0 3.75 7.5 15
Kilometers
0 5 10 20 30

**Gauging Station**

- Hourly
- Daily
- Hourly Pseudo
- Supplemental

N

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.01 - 0.50 | 1.51 - 2.00 | 3.01 - 3.50 | 4.51 - 5.00 |
| 0.51 - 1.00 | 2.01 - 2.50 | 3.51 - 4.00 | 5.01 - 5.50 |
| 1.01 - 1.50 | 2.51 - 3.00 | 4.01 - 4.50 | |

*Coordinate system: GCS North American 1983*
*Scale: 1:781,680*

Metstat/AWA March 30, 2000

# Sahuarita, AZ

**September 9-11, 1964**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| **Storm Name:** | **SPAS-1059-Sahuarita** |
| **Storm Date:** | **9/9-11/1964** |
| **AWA Analysis Date:** | **10/15/2009** |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** **25-Aug**

| | Lat | Long |
|---|---|---|
| **Storm center location** | **32.01 N** | **110.90 W** |
| **Storm Rep dew point location** | **32.50 N** | **114.00 W** |
| **Transposition dewpoint location** | **33.99 N** | **115.68 W** |
| **Basin location** | **33.55 N** | **112.55 W** |

| | | |
|---|---|---|
| **Moisture Inflow Direction:** | **WSW @ 18!** | miles |
| **Basin Elevation** | **3,650** | feet |
| **Storm Elevation** | **2,750** | feet |
| **Effective Barrier Height** | **3,650** | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | **75.0 F** | with total precipitable water above sea level of | | | **2.85** | inches. |
| The in-place maximum dew point is | **78.5 F** | with total precipitable water above sea level of | | | **3.37** | inches. |
| The transpositioned maximum dew point is | **78.0 F** | with total precipitable water above sea level of | | | **3.37** | inches. |
| The in-place storm elevation is | **2,750** | which subtracts | **0.65** | inches of precipitable water at | **75.0 F** | |
| The in-place storm elevation is | **2,750** | which subtracts | **0.73** | inches of precipitable water at | **78.5 F** | |
| Basin elevation at | **3,650** | which subtracts | **0.93** | inches of precipitable water at | **78.0 F** | |
| The inflow barrier height/basin elevation is | **3,650** | which subtracts | **0.93** | inches of precipitable water at | **78.0 F** | |

| | |
|---|---|
| The in-place maximization factor is | **1.20** |
| The transposition/elevation factor is | **0.93** |
| The elevation/barrier adjustment factor is | **1.00** |
| The total adjustment factor is | **1.11** |

Notes: KYUM 12hr ave on the 9th used.

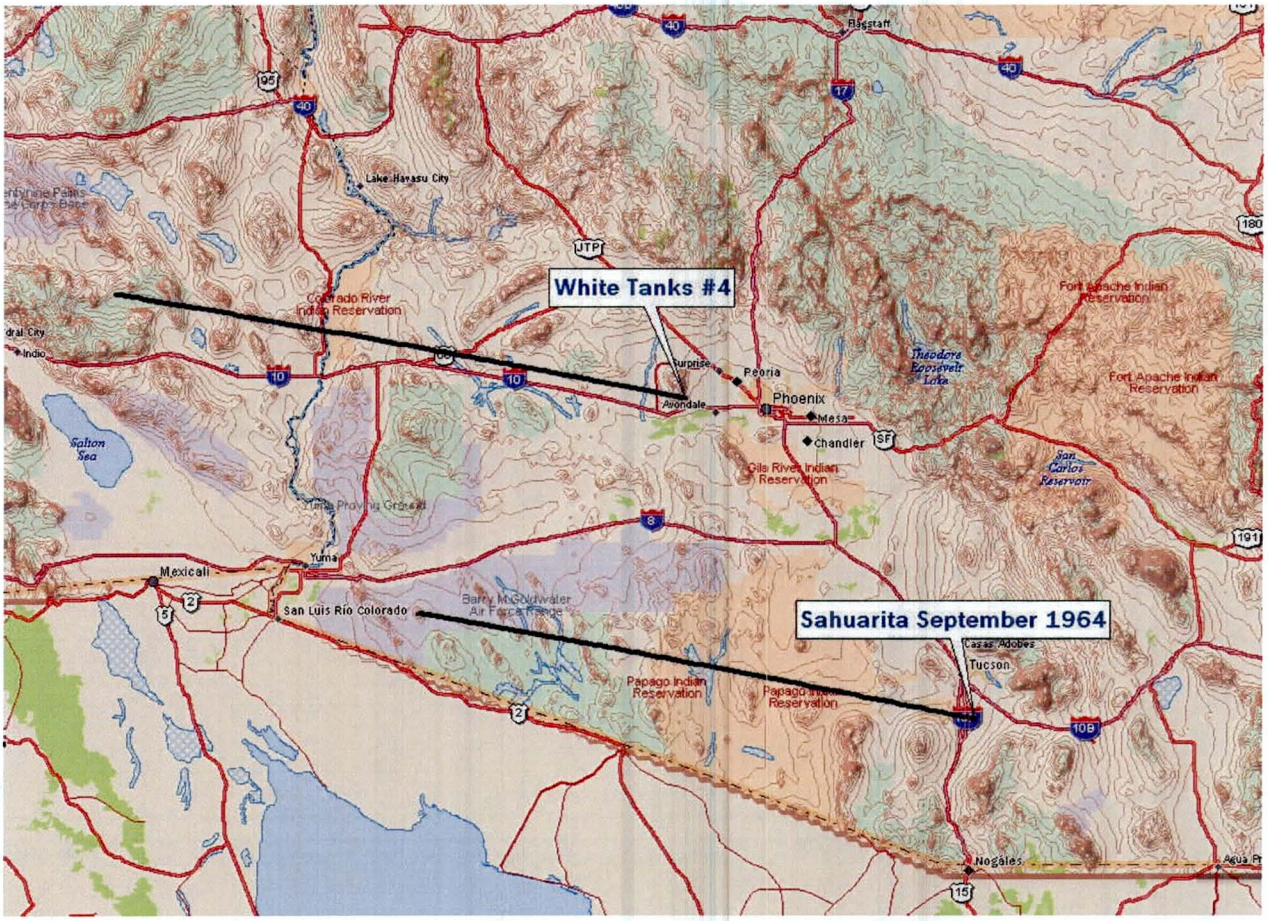
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **1.6** | **2.1** | **2.3** | **2.6** | **2.9** | **3.2** | **5.8** | **6.2** | **6.5** | **6.6** |
| 10 sq miles | **1.6** | **2.1** | **2.3** | **2.6** | **2.8** | **3.0** | **5.8** | **6.2** | **6.4** | **6.6** |
| 50 sq miles | **1.5** | **1.8** | **2.1** | **2.5** | **2.7** | **3.0** | **5.4** | **5.8** | **6.1** | **6.2** |
| 100 sq miles | **1.3** | **1.7** | **1.9** | **2.5** | **2.6** | **2.9** | **5.2** | **5.7** | **6.0** | **6.2** |
| 200 sq miles | **1.2** | **1.6** | **1.8** | **2.3** | **2.4** | **2.9** | **5.0** | **5.4** | **5.7** | **5.9** |
| 500 sq miles | **1.0** | **1.3** | **1.6** | **2.1** | **2.3** | **2.7** | **4.4** | **4.8** | **5.2** | **5.4** |
| 1000 sq miles | **0.8** | **1.3** | **1.4** | **1.9** | **2.1** | **2.5** | **4.0** | **4.5** | **5.0** | **5.1** |
| 2000 sq miles | **0.7** | **1.0** | **1.2** | **1.6** | **1.8** | **2.1** | **3.4** | **4.0** | **4.5** | **4.6** |
| 5000 sq miles | **0.4** | **0.5** | **0.7** | **1.1** | **1.2** | **1.4** | **2.3** | **2.9** | **3.2** | **3.3** |

**Adjusted Storm Depth-Area-Duration**

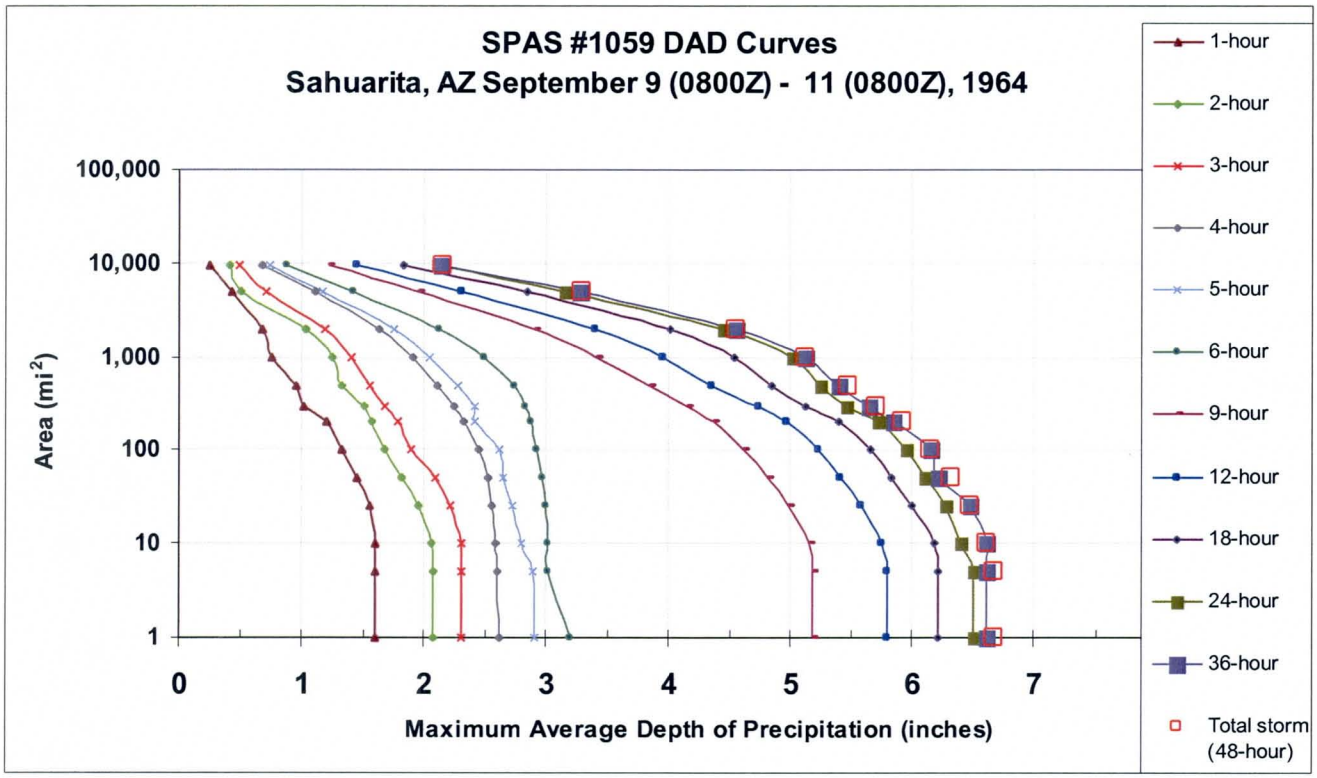
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **1.8** | **2.3** | **2.6** | **2.9** | **3.2** | **3.6** | **6.4** | **6.9** | **7.2** | **7.3** |
| 10 sq miles | **1.8** | **2.3** | **2.6** | **2.9** | **3.1** | **3.3** | **6.4** | **6.9** | **7.1** | **7.3** |
| 50 sq miles | **1.6** | **2.0** | **2.3** | **2.8** | **2.9** | **3.3** | **6.0** | **6.5** | **6.8** | **6.9** |
| 100 sq miles | **1.5** | **1.9** | **2.1** | **2.7** | **2.9** | **3.3** | **5.8** | **6.3** | **6.6** | **6.8** |
| 200 sq miles | **1.3** | **1.7** | **2.0** | **2.6** | **2.7** | **3.2** | **5.5** | **6.0** | **6.4** | **6.5** |
| 500 sq miles | **1.1** | **1.5** | **1.7** | **2.3** | **2.5** | **3.0** | **4.8** | **5.4** | **5.8** | **6.0** |
| 1000 sq miles | **0.8** | **1.4** | **1.6** | **2.1** | **2.3** | **2.8** | **4.4** | **5.0** | **5.6** | **5.7** |
| 2000 sq miles | **0.7** | **1.1** | **1.3** | **1.8** | **2.0** | **2.4** | **3.8** | **4.5** | **4.9** | **5.1** |
| 5000 sq miles | **0.5** | **0.6** | **0.8** | **1.2** | **1.3** | **1.6** | **2.6** | **3.2** | **3.5** | **3.6** |

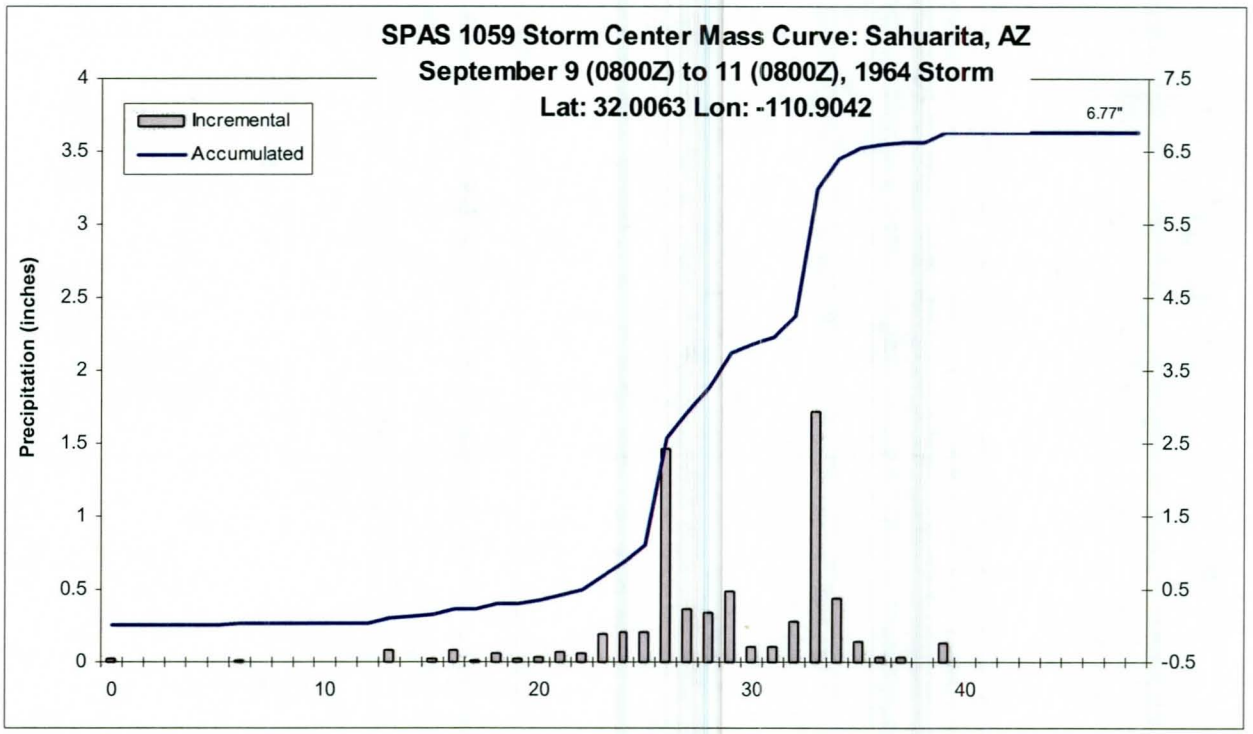
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1059-Sahuarita** | |
| Storm Date(s) | 9/9-11/1964 | |
| Storm Type | Local-Tropcial | |
| Storm Location | 32.01 N | 110.90 W |
| Storm Center Elevation | 2750 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 5.92 inches 12 hours 6.74" in 36hrs (SPAS 1059 DAD) | |
| | | |
| Storm Representative Dewpoint | 75.0 F | 12hr ave at KYUM |
| Storm Representative Dewpoint Location | 32.50 N | 114.00 W |
| In-place Maximum Dewpoint | 78.5 F | |
| Moisture Inflow Vector | WSW @ 185 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 25-Aug | |
| Transposition Dewpoint Location | 33.99 N | 115.68 W |
| Transposition Maximum Dewpoint | 78.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.11 | |

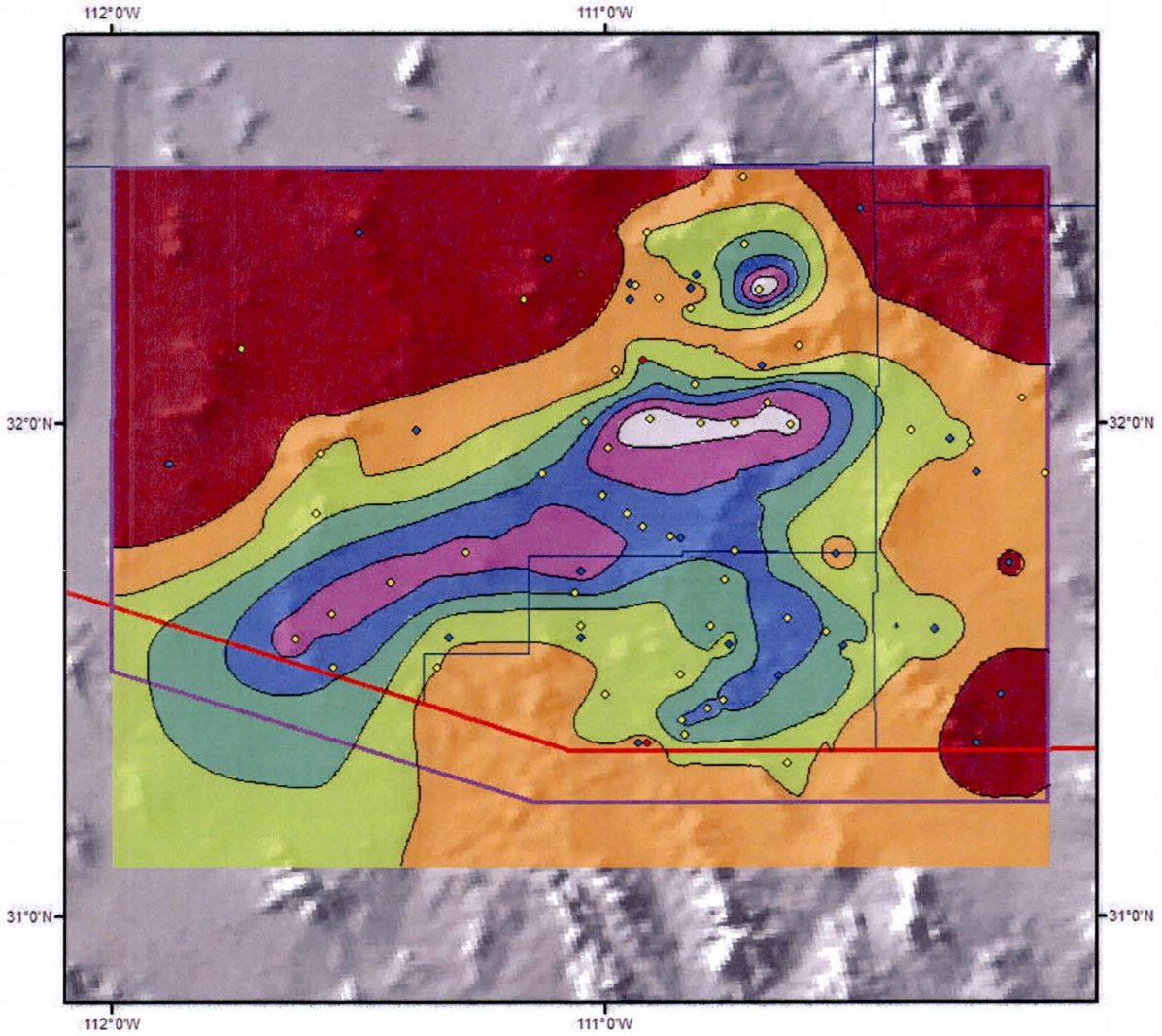

White Tanks #4
Sahuarita September 1964
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Indio
Salton Sea
Yuma Proving Ground
Yuma
Mexicali
San Luis Rio Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Surprise
Peoria
Avondale
Phoenix
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt Lake
Fort Apache Indian Reservation
Fort Apache Indian Reservation
San Carlos Reservoir

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 9 | 12 | 18 | 24 | 36 | total |
| **0.28** | 1.73 | 2.16 | 2.44 | 2.74 | 3.03 | 3.26 | 5.31 | 5.92 | 6.34 | 6.62 | 6.74 | 6.77 |
| **1** | 1.60 | 2.07 | 2.31 | 2.61 | 2.90 | 3.20 | 5.19 | 5.80 | 6.22 | 6.50 | 6.61 | 6.67 |
| **5** | 1.60 | 2.07 | 2.31 | 2.60 | 2.89 | 3.01 | 5.19 | 5.80 | 6.22 | 6.50 | 6.61 | 6.67 |
| **10** | 1.60 | 2.06 | 2.31 | 2.59 | 2.80 | 3.01 | 5.16 | 5.76 | 6.18 | 6.40 | 6.61 | 6.62 |
| **25** | 1.56 | 1.95 | 2.22 | 2.56 | 2.73 | 3.00 | 4.99 | 5.59 | 6.00 | 6.27 | 6.47 | 6.48 |
| **50** | 1.45 | 1.82 | 2.09 | 2.52 | 2.65 | 2.97 | 4.82 | 5.42 | 5.83 | 6.11 | 6.22 | 6.32 |
| **100** | 1.33 | 1.67 | 1.89 | 2.45 | 2.61 | 2.93 | 4.62 | 5.23 | 5.66 | 5.95 | 6.15 | 6.16 |
| **200** | 1.20 | 1.57 | 1.79 | 2.33 | 2.42 | 2.88 | 4.37 | 4.97 | 5.40 | 5.73 | 5.85 | 5.92 |
| **300** | 1.02 | 1.51 | 1.67 | 2.25 | 2.41 | 2.83 | 4.16 | 4.74 | 5.13 | 5.46 | 5.65 | 5.70 |
| **500** | 0.96 | 1.33 | 1.55 | 2.11 | 2.28 | 2.74 | 3.84 | 4.36 | 4.84 | 5.24 | 5.40 | 5.47 |
| **1,000** | 0.75 | 1.25 | 1.40 | 1.91 | 2.05 | 2.49 | 3.41 | 3.96 | 4.54 | 5.01 | 5.12 | 5.13 |
| **2,000** | 0.67 | 1.03 | 1.18 | 1.63 | 1.76 | 2.12 | 2.91 | 3.40 | 4.01 | 4.45 | 4.55 | 4.56 |
| **5,000** | 0.43 | 0.51 | 0.70 | 1.10 | 1.17 | 1.41 | 1.96 | 2.30 | 2.85 | 3.15 | 3.27 | 3.29 |
| **9,403** | 0.25 | 0.41 | 0.49 | 0.68 | 0.74 | 0.87 | 1.22 | 1.44 | 1.83 | 2.10 | 2.14 | 2.15 |




SPAS 1059 Storm Center Mass Curve: Sahuarita, AZ
September 9 (0800Z) to 11 (0800Z), 1964 Storm
Lat: 32.0063 Lon: -110.9042
Incremental
Accumulated
6.77"
Precipitation (inches)
4
3.5
3
2.5
2
1.5
1
0.5
0
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
0
10
20
30
40




**Total Rainfall (48-hours)**
**Sahuarita, AZ 1964 Storm**
**Storm #1059 September 9 (0800 Z) to 11 (0800 Z), 1964**

**Gauging Stations**

- Daily
- Hourly
- Hourly Pseudo
- Supplemental

Miles: 0 4.5 9 18
Kilometers: 0 10 20 40 60

N

**Precipitation (inches)**

- 0.24 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00
- 6.01 - 7.00

*Coordinate system: GCS North American 1983*
*Scale:* 1:1,271,778

*NetstatAWA March 25, 2009*

# Norma, AZ

**September 4-7, 1970**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| Storm Name: | SPAS-1075-Norma Zone 1 |
| Storm Date: | 9/4-6/1970 |
| AWA Analysis Date: | 10/16/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 18-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 31.96 N | 111.63 W |
| Storm Rep dew point location | 32.79 N | 113.13 W |
| Transposition dewpoint location | 34.78 N | 114.08 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | NW @ 105 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 4,950 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 75.0 F | with total precipitable water above sea level of | | | 2.85 | inches. |
| The in-place maximum dew point is | 77.5 F | with total precipitable water above sea level of | | | 3.21 | inches. |
| The transpositioned maximum dew point is | 77.5 F | with total precipitable water above sea level of | | | 3.21 | inches. |
| The in-place storm elevation is | 4,950 | which subtracts | 1.08 | inches of precipitable water at | 75.0 F | |
| The in-place storm elevation is | 4,950 | which subtracts | 1.18 | inches of precipitable water at | 77.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.91 | inches of precipitable water at | 77.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.91 | inches of precipitable water at | 77.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.15 |
| The transposition factor is | 1.13 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.30 |

Notes: Storm rep Td taken from KGBN, KYUM 24hr ave

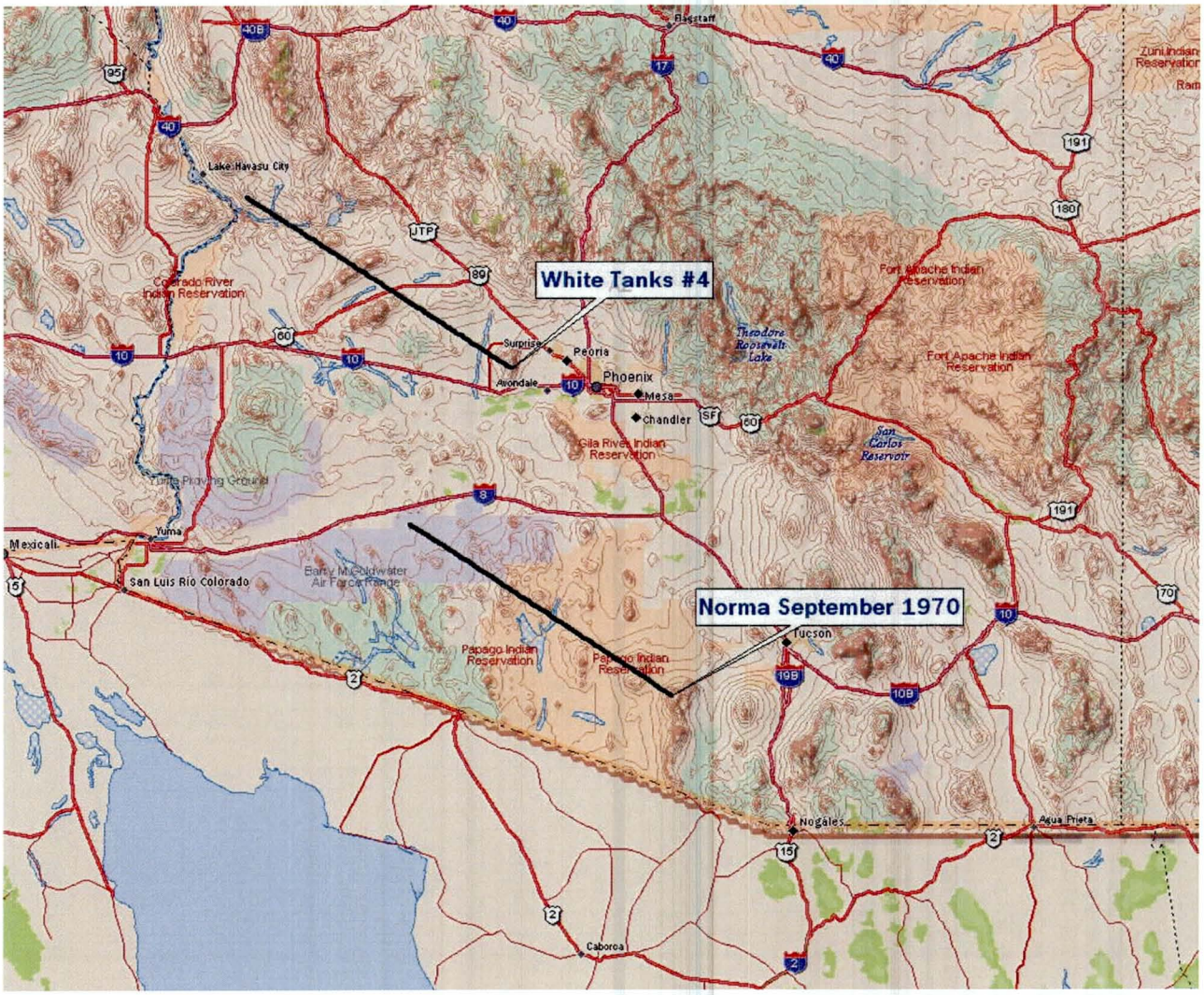
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.1 | - | - | - | - | 2.8 | 4.7 | 6.1 | - | 6.3 | 7.6 |
| 10 sq miles | 1.1 | - | - | - | - | 2.8 | 4.6 | 5.8 | - | 6.2 | 7.3 |
| 100 sq miles | 1.0 | - | - | - | - | 2.8 | 3.5 | 4.8 | - | 5.4 | 6.7 |
| 200 sq miles | 0.8 | - | - | - | - | 2.8 | 3.3 | 4.7 | - | 5.2 | 6.5 |
| 500 sq miles | 0.7 | - | - | - | - | 2.5 | 3.1 | 4.4 | - | 4.9 | 6.1 |
| 1000 sq miles | 0.6 | - | - | - | - | 2.3 | 2.9 | 4.1 | - | 4.5 | 5.8 |
| 2000 sq miles | 0.5 | - | - | - | - | 1.8 | 2.6 | 3.8 | - | 4.2 | 5.4 |
| 5000 sq miles | 0.4 | - | - | - | - | 1.4 | 1.9 | 3.1 | - | 3.7 | 4.7 |
| 10000 sq miles | 0.4 | - | - | - | - | 1.0 | 1.4 | 2.5 | - | 3.4 | 4.0 |
| 20000 sq miles | 0.2 | - | - | - | - | 0.7 | 1.0 | 1.8 | - | 2.6 | 3.2 |

**Adjusteded Storm Depth-Area-Duration**

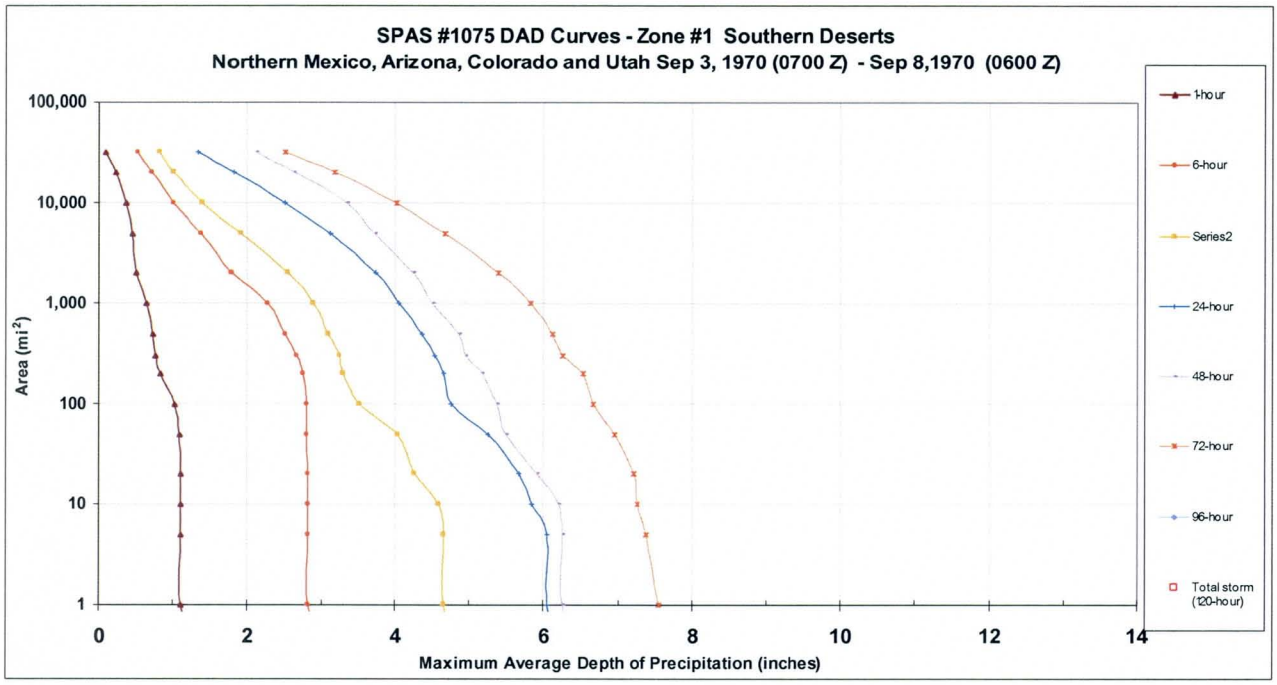
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.4 | - | - | - | - | 3.7 | 6.0 | 7.9 | - | 8.1 | 9.8 |
| 10 sq miles | 1.4 | - | - | - | - | 3.7 | 6.0 | 7.6 | - | 8.1 | 9.4 |
| 100 sq miles | 1.3 | - | - | - | - | 3.6 | 4.6 | 6.2 | - | 7.0 | 8.7 |
| 200 sq miles | 1.1 | - | - | - | - | 3.6 | 4.3 | 6.0 | - | 6.7 | 8.5 |
| 500 sq miles | 0.9 | - | - | - | - | 3.2 | 4.0 | 5.7 | - | 6.3 | 8.0 |
| 1000 sq miles | 0.8 | - | - | - | - | 2.9 | 3.7 | 5.3 | - | 5.8 | 7.6 |
| 2000 sq miles | 0.6 | - | - | - | - | 2.3 | 3.3 | 4.9 | - | 5.5 | 7.0 |
| 5000 sq miles | 0.6 | - | - | - | - | 1.8 | 2.5 | 4.1 | - | 4.8 | 6.1 |
| 10000 sq miles | 0.5 | - | - | - | - | 1.3 | 1.8 | 3.3 | - | 4.4 | 5.2 |
| 20000 sq miles | 0.3 | - | - | - | - | 0.9 | 1.3 | 2.4 | - | 3.4 | 4.1 |

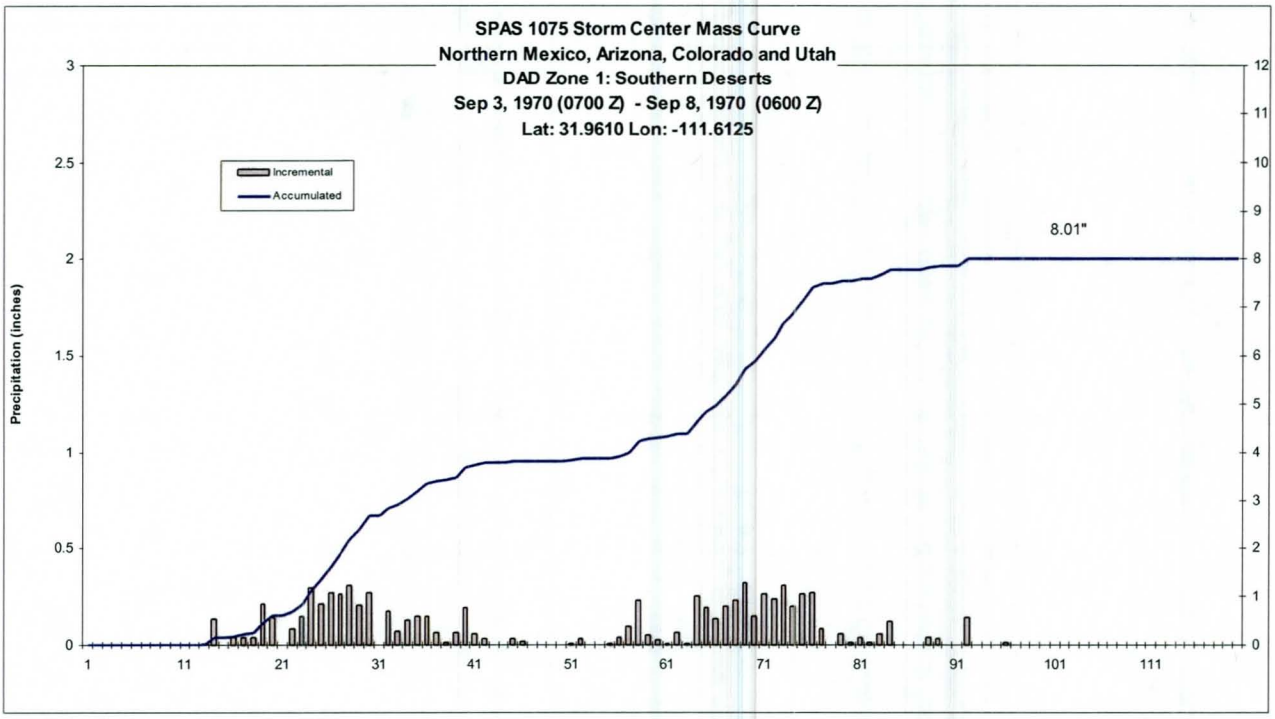
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1075-Norma Zone 1 | |
| Storm Date(s) | 9/4-6/1970 | |
| Storm Type | Tropical | |
| Storm Location | 31.96 N | 111.63 W |
| Storm Center Elevation | 4950 | orographic Isolated mtn SW of Tucson |
| Precipitation Total & Duration (10 sq mi) | 8.01 inches 72 hours (SPAS 1075 DAD) | |
| | | |
| Storm Representative Dewpoint | 75.0 F | 24hr ave KGBN, KYUM |
| Storm Representative Dewpoint Location | 32.79 N | 113.13 W |
| In-place Maximum Dewpoint | 77.5 F | |
| Moisture Inflow Vector | NW @ 105 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 18-Aug | |
| Transposition Dewpoint Location | 34.78 N | 114.08 W |
| Transposition Maximum Dewpoint | 77.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

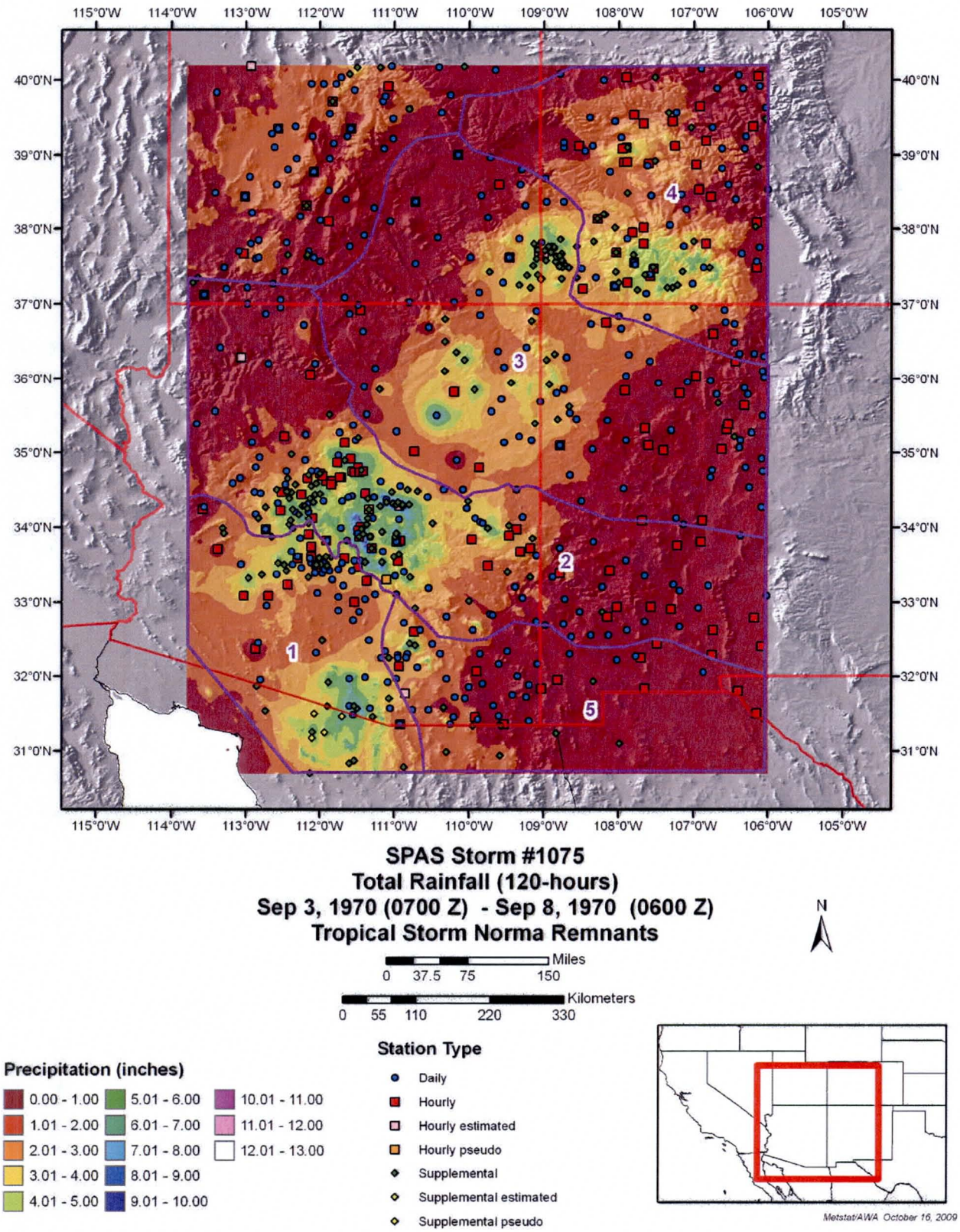

White Tanks #4
Norma September 1970
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Avondale
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
Fort Apache Indian Reservation
Gila River Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
Mexicali
San Luis Rio Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Pascua Indian Reservation
Tucson
Nogales
Agua Prieta
Caborca

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area (mi²) | Duration (hours) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | Total |
| 0.27 | 1.36 | | | | | 3.07 | 4.86 | | 6.26 | | 6.47 | 7.79 | | |
| 1 | 1.10 | | | | | 2.81 | 4.65 | | 6.05 | | 6.25 | 7.56 | | |
| 5 | 1.10 | | | | | 2.81 | 4.65 | | 6.05 | | 6.25 | 7.39 | | |
| 10 | 1.10 | | | | | 2.81 | 4.58 | | 5.84 | | 6.20 | 7.27 | | |
| 20 | 1.10 | | | | | 2.81 | 4.26 | | 5.67 | | 5.91 | 7.21 | | |
| 50 | 1.08 | | | | | 2.80 | 4.03 | | 5.26 | | 5.49 | 6.95 | | |
| 100 | 1.01 | | | | | 2.80 | 3.52 | | 4.75 | | 5.37 | 6.66 | | |
| 200 | 0.83 | | | | | 2.75 | 3.30 | | 4.65 | | 5.17 | 6.53 | | |
| 300 | 0.75 | | | | | 2.67 | 3.24 | | 4.54 | | 4.95 | 6.26 | | |
| 500 | 0.73 | | | | | 2.50 | 3.10 | | 4.36 | | 4.86 | 6.12 | | |
| 1,000 | 0.63 | | | | | 2.27 | 2.88 | | 4.06 | | 4.50 | 5.82 | | |
| 2,000 | 0.49 | | | | | 1.78 | 2.55 | | 3.75 | | 4.24 | 5.40 | | |
| 5,000 | 0.44 | | | | | 1.37 | 1.91 | | 3.12 | | 3.72 | 4.68 | | |
| 10,000 | 0.36 | | | | | 1.00 | 1.39 | | 2.51 | | 3.35 | 4.02 | | |
| 20,000 | 0.23 | | | | | 0.70 | 0.99 | | 1.82 | | 2.62 | 3.17 | | |
| 31,725 | 0.09 | | | | | 0.52 | 0.81 | | 1.34 | | 2.11 | 2.50 | | |




SPAS 1075 Storm Center Mass Curve
Northern Mexico, Arizona, Colorado and Utah
DAD Zone 1: Southern Deserts
Sep 3, 1970 (0700 Z) - Sep 8, 1970 (0600 Z)
Lat: 31.9610 Lon: -111.6125
Incremental
Accumulated
8.01"
Precipitation (inches)
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
9
10
11
12
1
11
21
31
41
51
61
71
81
91
101
111




**SPAS Storm #1075**
**Total Rainfall (120-hours)**
**Sep 3, 1970 (0700 Z) - Sep 8, 1970 (0600 Z)**
**Tropical Storm Norma Remnants**

# Phoenix, AZ

**June 22, 1972**

**Storm Type: Local Convective**

| | |
|---|---|
| **Storm Name:** | **SPAS-1062-Phoenix** |
| **Storm Date:** | **June 22, 1972** |
| **AWA Analysis Date:** | **10/15/2009** |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** **5-Jul**

| | Lat | Long |
|---|---|---|
| **Storm center location** | **33.52 N** | **112.02 W** |
| **Storm Rep dew point location** | **33.52 N** | **112.02 W** |
| **Transposition dewpoint location** | **33.41 N** | **112.52 W** |
| **Basin location** | **33.55 N** | **112.55 W** |

| | | |
|---|---|---|
| **Moisture Inflow Direction:** | **S @ 10** | miles |
| **Basin Elevation** | **3,650** | feet |
| **Storm Elevation** | **1,200** | feet |
| **Effective Barrier Height** | **3,650** | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | **70.0 F** | with total precipitable water above sea level of | | | **2.25** | inches. |
| The in-place maximum dew point is | **78.5 F** | with total precipitable water above sea level of | | | **3.37** | inches. |
| The transpositioned maximum dew point is | **78.5 F** | with total precipitable water above sea level of | | | **3.37** | inches. |
| The in-place storm elevation is | **0** | which subtracts | **0.00** | inches of precipitable water at | **70.0 F** | |
| The in-place storm elevation is | **0** | which subtracts | **0.000** | inches of precipitable water at | **78.5 F** | |
| Basin elevation at | **0** | which subtracts | **0.000** | inches of precipitable water at | **78.5 F** | |
| The inflow barrier height/basin elevation is | **0** | which subtracts | **0.000** | inches of precipitable water at | **78.5 F** | |

| | |
|---|---|
| The in-place maximization factor is | **1.50** |
| The transposition factor is | **1.00** |
| The elevation/barrier adjustment factor is | **1.00** |
| The total adjustment factor is | **1.50** |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. Used 3hr average from KPHX, KLUF.

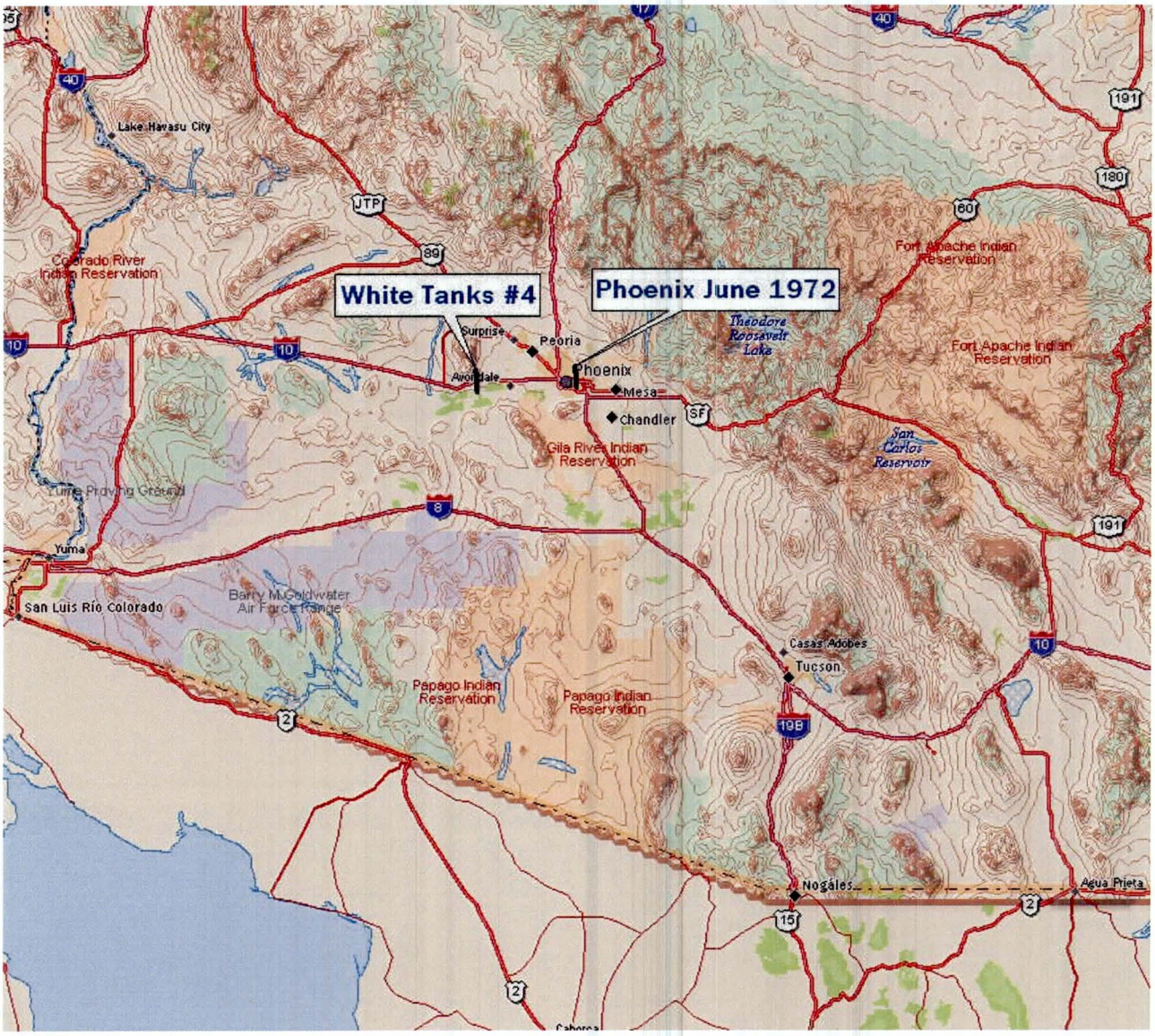
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **3.6** | **4.7** | **4.7** | **5.1** | **5.1** | **5.1** | **5.1** | **5.4** | **5.4** | |
| 10 sq miles | **3.2** | **4.2** | **4.2** | **4.5** | **4.5** | **4.5** | **4.5** | **4.9** | **5.0** | |
| 50 sq miles | **2.6** | **3.4** | **3.4** | **3.6** | **3.6** | **3.6** | **3.6** | **4.0** | **4.1** | |
| 100 sq miles | **2.1** | **2.7** | **2.7** | **3.0** | **3.0** | **3.0** | **3.0** | **3.3** | **3.4** | |
| 200 sq miles | **1.6** | **2.1** | **2.1** | **2.3** | **2.3** | **2.3** | **2.3** | **2.5** | **2.6** | |
| 500 sq miles | **1.0** | **1.3** | **1.3** | **1.3** | **1.3** | **1.3** | **1.3** | **1.6** | **1.6** | |
| 1000 sq miles | **0.7** | **0.7** | **0.8** | **0.8** | **0.9** | **0.9** | **0.9** | **1.0** | **1.0** | |
| 2000 sq miles | **0.5** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **0.7** | **0.8** | |
| 5000 sq miles | | | | | | | | | | |

**Adjusted Storm Depth-Area-Duration**

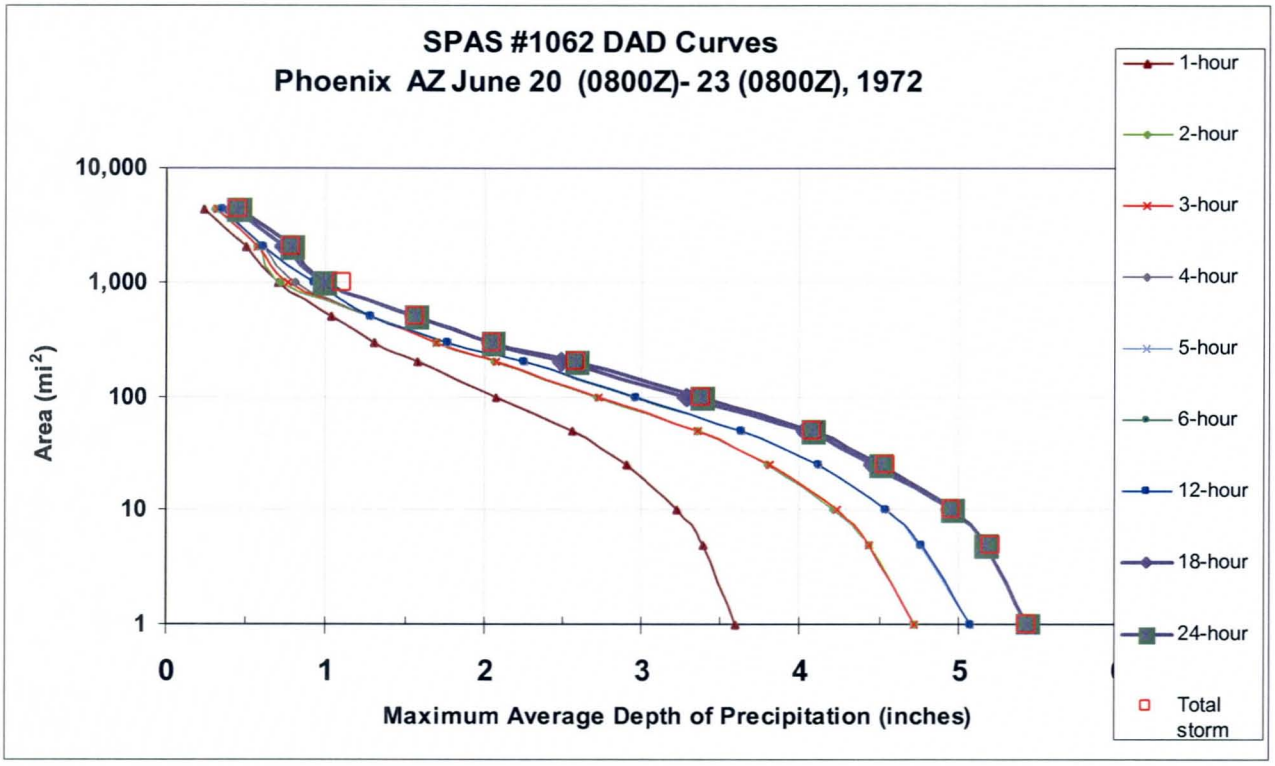
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | **5.4** | **7.1** | **7.1** | **7.6** | **7.6** | **7.6** | **7.6** | **8.1** | **8.1** | |
| 10 sq miles | **4.8** | **6.3** | **6.3** | **6.8** | **6.8** | **6.8** | **6.8** | **7.4** | **7.4** | |
| 50 sq miles | **3.8** | **5.0** | **5.0** | **5.4** | **5.4** | **5.4** | **5.4** | **6.0** | **6.1** | |
| 100 sq miles | **3.1** | **4.1** | **4.1** | **4.4** | **4.4** | **4.4** | **4.4** | **4.9** | **5.1** | |
| 200 sq miles | **2.4** | **3.1** | **3.1** | **3.4** | **3.4** | **3.4** | **3.4** | **3.7** | **3.9** | |
| 500 sq miles | **1.5** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **2.3** | **2.3** | |
| 1000 sq miles | **1.0** | **1.1** | **1.1** | **1.2** | **1.4** | **1.4** | **1.4** | **1.5** | **1.5** | |
| 2000 sq miles | **0.7** | **0.9** | **0.9** | **0.9** | **0.9** | **0.9** | **0.9** | **1.1** | **1.2** | |
| 5000 sq miles | | | | | | | | | | |

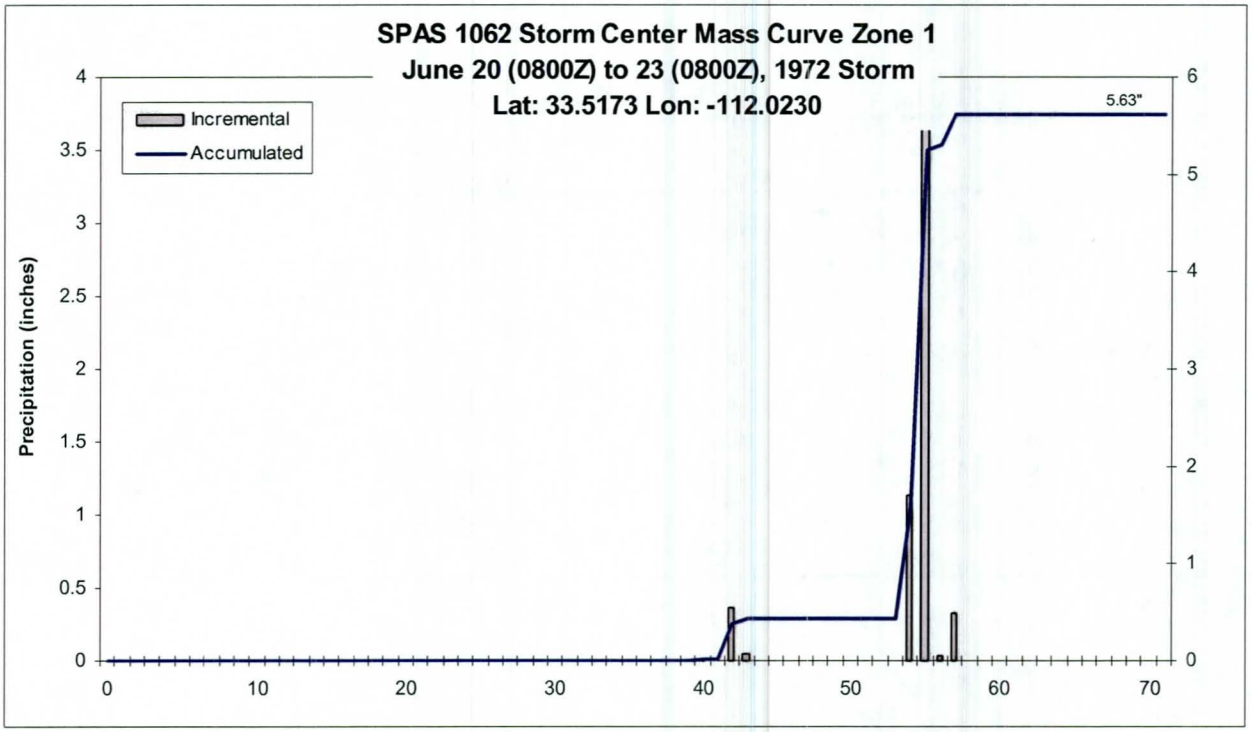
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1062-Phoenix** | |
| Storm Date(s) | 6/22/72 | |
| Storm Type | Local Storm | |
| Storm Location | 33.52 N | 112.02 W |
| Storm Center Elevation | 1200 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 5.19 inches 4 hours 3.69" in 1hr and 4.82" in 2hrs (SPAS 1062 DAD) | |
| | | |
| Storm Representative Dewpoint | 70.0 F | 3hr ave KPHX |
| Storm Representative Dewpoint Location | 33.52 N | 112.02 W |
| In-place Maximum Dewpoint | 78.5 F | |
| Moisture Inflow Vector | S @ 10 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 5-Jul | |
| Transposition Dewpoint Location | 33.41 N | 112.52 W |
| Transposition Maximum Dewpoint | 78.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.50 | |

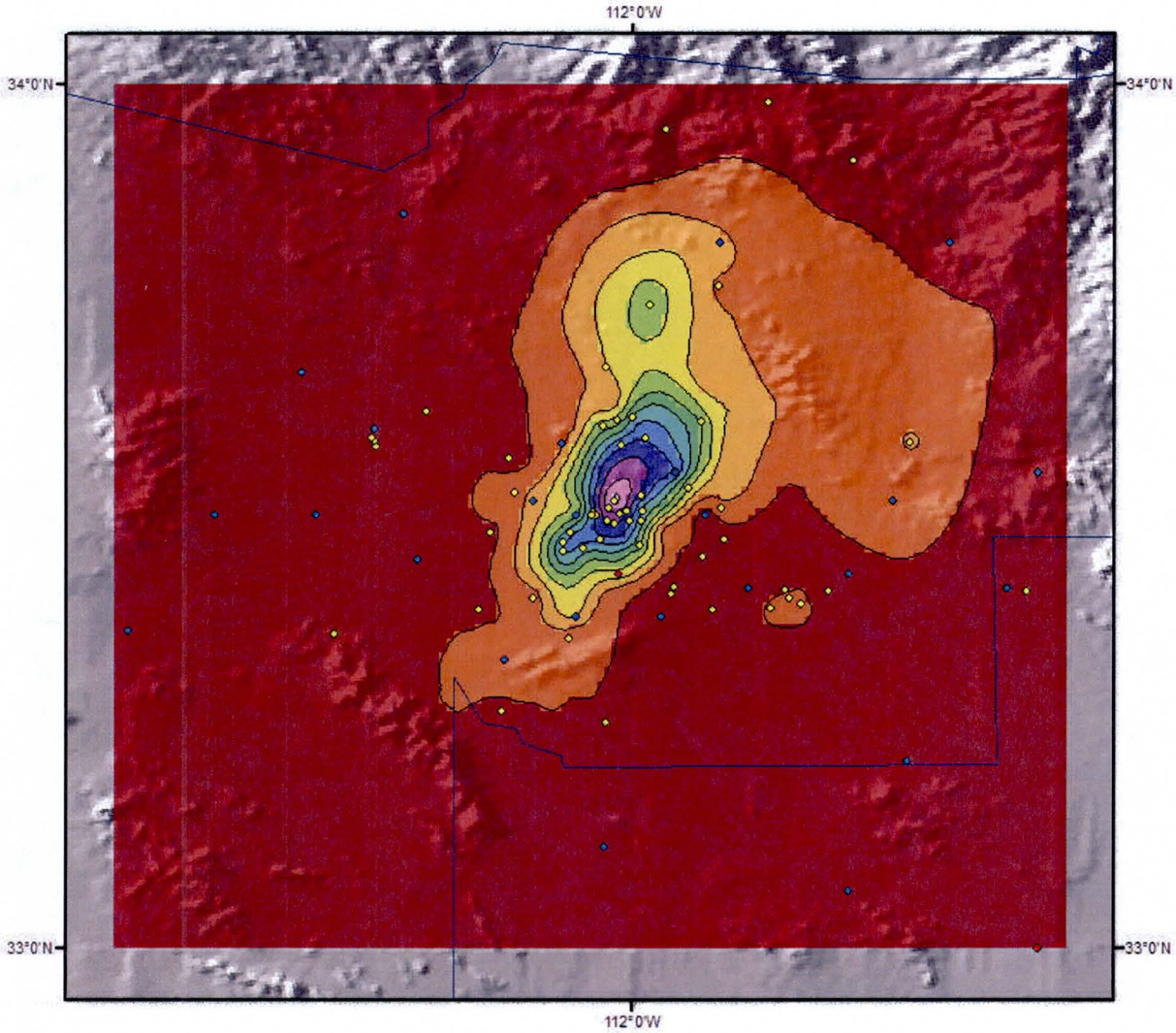

White Tanks #4
Phoenix June 1972
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Avondale
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
Fort Apache Indian Reservation
Fort Apache Indian Reservation
Gila River Indian Reservation
San Carlos Reservoir
Yuma
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Casas Adobes
Tucson
Papago Indian Reservation
Papago Indian Reservation
Nogales
Agua Prieta

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | total |
| **0.28** | 3.69 | 4.82 | 4.86 | 5.19 | 5.19 | 5.19 | 5.19 | 5.62 | 5.62 | 5.62 |
| **1** | 3.59 | 4.72 | 4.72 | 5.07 | 5.07 | 5.08 | 5.08 | 5.43 | 5.43 | 5.43 |
| **5** | 3.39 | 4.43 | 4.44 | 4.76 | 4.76 | 4.77 | 4.77 | 5.17 | 5.17 | 5.20 |
| **10** | 3.23 | 4.21 | 4.23 | 4.54 | 4.54 | 4.54 | 4.54 | 4.94 | 4.96 | 4.96 |
| **25** | 2.91 | 3.80 | 3.81 | 4.11 | 4.11 | 4.11 | 4.12 | 4.46 | 4.50 | 4.54 |
| **50** | 2.56 | 3.35 | 3.35 | 3.63 | 3.63 | 3.63 | 3.63 | 4.03 | 4.08 | 4.08 |
| **100** | 2.07 | 2.72 | 2.73 | 2.95 | 2.95 | 2.95 | 2.96 | 3.29 | 3.38 | 3.38 |
| **200** | 1.58 | 2.06 | 2.07 | 2.25 | 2.25 | 2.25 | 2.25 | 2.49 | 2.59 | 2.59 |
| **300** | 1.31 | 1.70 | 1.70 | 1.77 | 1.77 | 1.77 | 1.77 | 2.04 | 2.05 | 2.05 |
| **500** | 1.03 | 1.28 | 1.28 | 1.28 | 1.28 | 1.28 | 1.28 | 1.55 | 1.56 | 1.57 |
| **1,000** | 0.70 | 0.71 | 0.76 | 0.81 | 0.92 | 0.93 | 0.93 | 0.99 | 0.99 | 1.10 |
| **2,000** | 0.50 | 0.57 | 0.57 | 0.60 | 0.61 | 0.61 | 0.61 | 0.74 | 0.78 | 0.78 |
| **4,377** | 0.24 | 0.31 | 0.32 | 0.34 | 0.34 | 0.35 | 0.36 | 0.43 | 0.45 | 0.45 |




SPAS 1062 Storm Center Mass Curve Zone 1
June 20 (0800Z) to 23 (0800Z), 1972 Storm
Lat: 33.5173 Lon: -112.0230
Incremental
Accumulated
5.63"
Precipitation (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70




**Total Rainfall (72-hours)**
**Phoenix, AZ 1972 Storm**
**Storm #1062 June 20 (0800Z) to 23 (0800 Z), 1972**

Miles: 0 4.5 9 18
Kilometers: 0 5 10 20 30 40

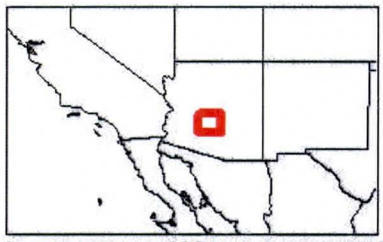
**Gauging Stations**

- Daily
- Hourly
- Hourly Psuedo
- Supplemental

N

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.00 - 0.50 | 1.51 - 2.00 | 3.01 - 3.50 | 4.51 - 5.00 |
| 0.51 - 1.00 | 2.01 - 2.50 | 3.51 - 4.00 | 5.01 - 5.50 |
| 1.01 - 1.50 | 2.51 - 3.00 | 4.01 - 4.50 | 5.51 - 6.00 |



*Coordinate system: GCS North American 1983*
*Scale:* 1:723,188

*MetstatAWA April 28, 2009*

# Joanne, AZ

**October 3-7, 1972**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| Storm Name: | SPAS-1102-Joanne-Zone 1 |
| Storm Date: | 10/3-7/1972 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 20-Sep

| | Lat | Long |
|---|---|---|
| Storm center location | 31.78 N | 113.50 W |
| Storm Rep dew point location | 32.77 N | 111.49 W |
| Transposition dewpoint location | 34.48 N | 110.47 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SW @ 80 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 800 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 73.0 F | with total precipitable water above sea level of | | | 2.60 | inches. |
| The in-place maximum dew point is | 75.5 F | with total precipitable water above sea level of | | | 2.92 | inches. |
| The transpositioned maximum dew point is | 74.0 F | with total precipitable water above sea level of | | | 2.92 | inches. |
| The in-place storm elevation is | 800 | which subtracts | 0.19 | inches of precipitable water at | 73.0 F | |
| The in-place storm elevation is | 800 | which subtracts | 0.205 | inches of precipitable water at | 75.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.78 | inches of precipitable water at | 74.0 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.78 | inches of precipitable water at | 74.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.13 |
| The transposition/elevation factor is | 0.79 |
| The barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 0.89 |

Notes: 24hr ave from KTUS and KPHX

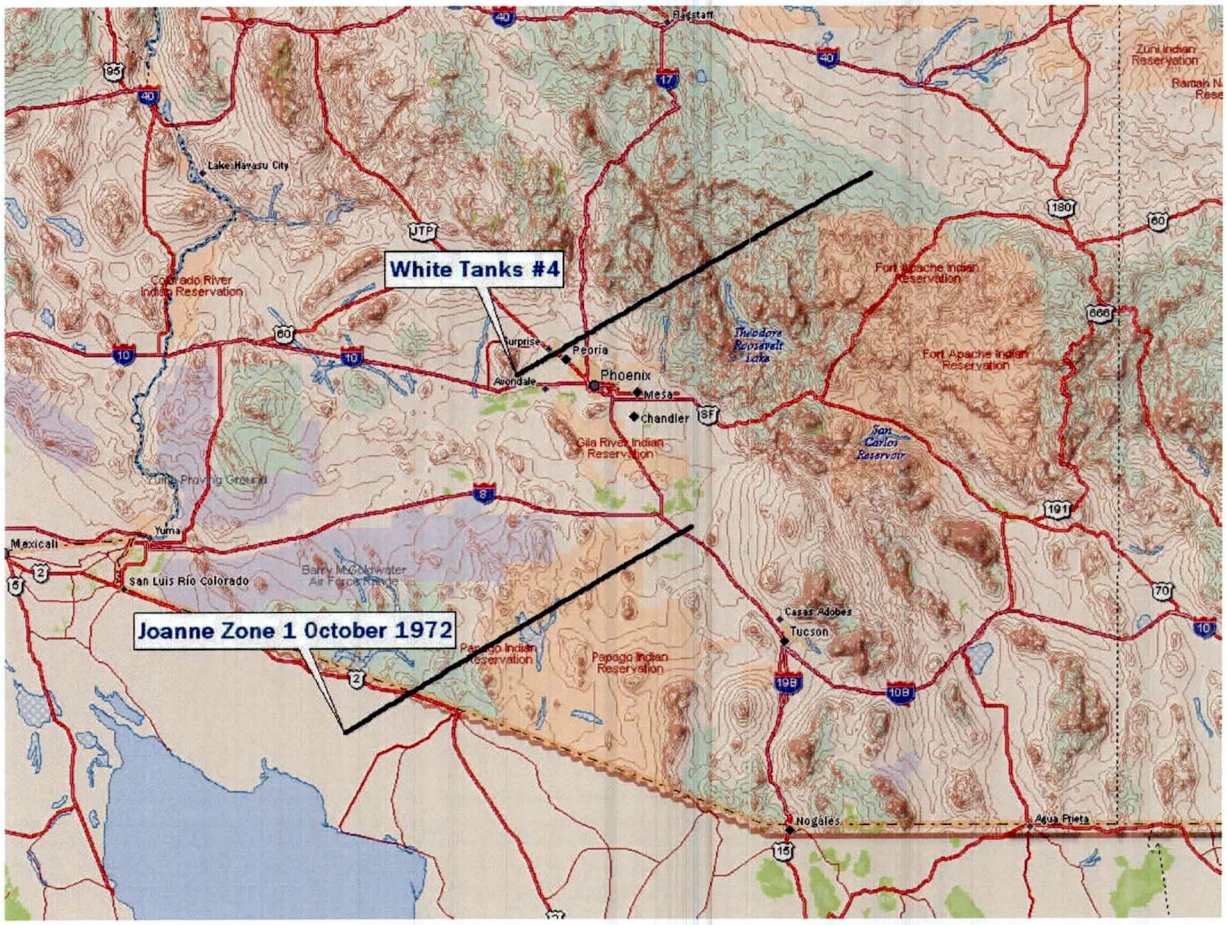
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.0 | - | 1.8 | - | - | 3.0 | 4.2 | 5.9 | 6.6 | 7.0 | 7.2 |
| 10 sq miles | 1.0 | - | 1.8 | - | - | 3.0 | 3.7 | 5.2 | 5.5 | 6.0 | 6.4 |
| 50 sq miles | 1.0 | - | 1.8 | - | - | 2.6 | 3.3 | 4.5 | 5.1 | 5.5 | 5.6 |
| 100 sq miles | 1.0 | - | 1.7 | - | - | 2.4 | 3.2 | 4.4 | 4.9 | 5.3 | 5.4 |
| 200 sq miles | 1.0 | - | 1.7 | - | - | 2.1 | 3.0 | 4.1 | 4.5 | 5.0 | 5.0 |
| 500 sq miles | 0.9 | - | 1.4 | - | - | 2.1 | 2.6 | 3.4 | 4.1 | 4.5 | 4.6 |
| 1000 sq miles | 0.7 | - | 1.1 | - | - | 1.8 | 2.2 | 3.3 | 3.7 | 4.0 | 4.2 |
| 2000 sq miles | 0.6 | - | 0.9 | - | - | 1.6 | 2.1 | 2.8 | 3.3 | 3.6 | 3.7 |
| 5000 sq miles | 0.3 | - | 0.8 | - | - | 1.2 | 2.0 | 2.6 | 2.9 | 3.1 | 3.2 |
| 10000 sq miles | 0.2 | - | 0.6 | - | - | 1.2 | 1.8 | 2.3 | 2.5 | 2.8 | 2.9 |

**Adjusteded Storm Depth-Area-Duration**

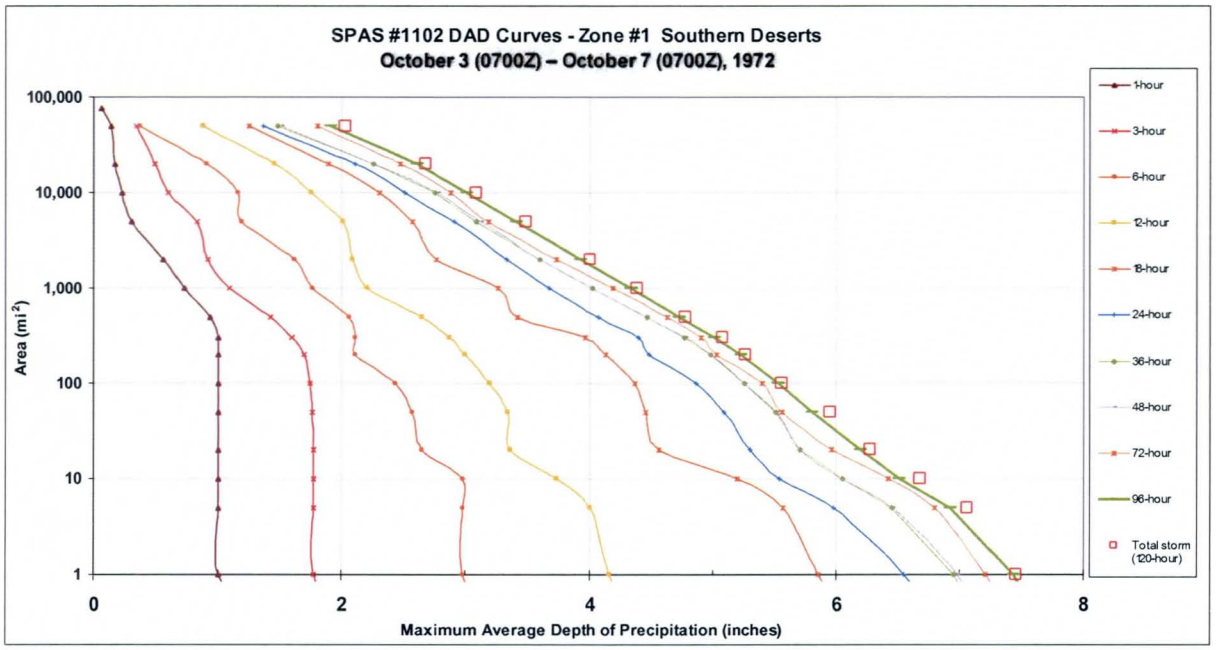
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.9 | - | 1.6 | - | - | 2.6 | 3.7 | 5.2 | 5.8 | 6.2 | 6.4 |
| 10 sq miles | 0.9 | - | 1.6 | - | - | 2.6 | 3.3 | 4.6 | 4.9 | 5.4 | 5.7 |
| 50 sq miles | 0.9 | - | 1.6 | - | - | 2.3 | 3.0 | 4.0 | 4.5 | 4.9 | 4.9 |
| 100 sq miles | 0.9 | - | 1.5 | - | - | 2.2 | 2.8 | 3.9 | 4.3 | 4.7 | 4.8 |
| 200 sq miles | 0.9 | - | 1.5 | - | - | 1.9 | 2.7 | 3.7 | 4.0 | 4.4 | 4.5 |
| 500 sq miles | 0.8 | - | 1.3 | - | - | 1.8 | 2.3 | 3.0 | 3.6 | 4.0 | 4.1 |
| 1000 sq miles | 0.6 | - | 1.0 | - | - | 1.6 | 2.0 | 2.9 | 3.3 | 3.6 | 3.7 |
| 2000 sq miles | 0.5 | - | 0.8 | - | - | 1.4 | 1.9 | 2.5 | 3.0 | 3.2 | 3.3 |
| 5000 sq miles | 0.3 | - | 0.7 | - | - | 1.0 | 1.8 | 2.3 | 2.6 | 2.8 | 2.8 |
| 10000 sq miles | 0.2 | - | 0.5 | - | - | 1.0 | 1.6 | 2.0 | 2.2 | 2.5 | 2.6 |

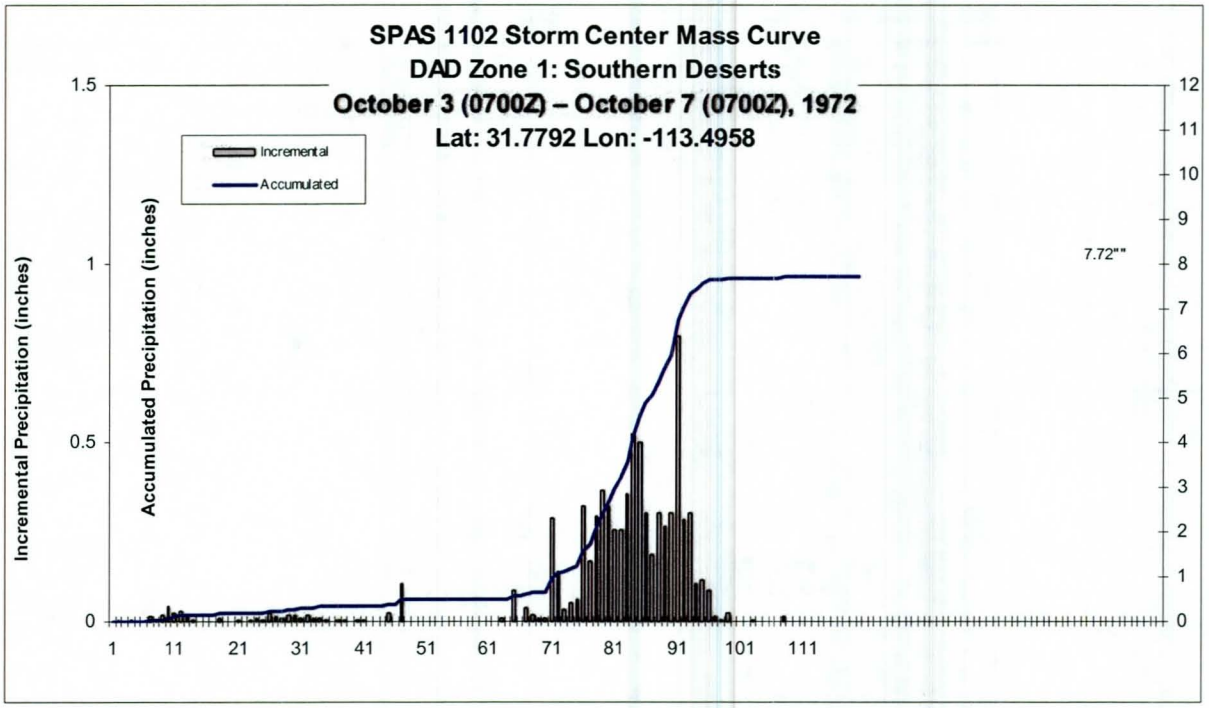
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1102-Joanne-Zone 1** | |
| Storm Date(s) | 10/3-7/1972 | |
| Storm Type | Tropical | |
| Storm Location | 31.78 N | 113.50 W |
| Storm Center Elevation | 800 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 7.27 inches 72 hours 3.27" in 6hrs and 6.79" in 24hrs (SPAS 1102 DAD) | |
| | | |
| Storm Representative Dewpoint | 73.0 F | 24hr ave KTUS, KPHX |
| Storm Representative Dewpoint Location | 32.77 N | 111.49 W |
| In-place Maximum Dewpoint | 75.5 F | |
| Moisture Inflow Vector | SW @ 80 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 20-Sep | |
| Transposition Dewpoint Location | 34.48 N | 110.47 W |
| Transposition Maximum Dewpoint | 74.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

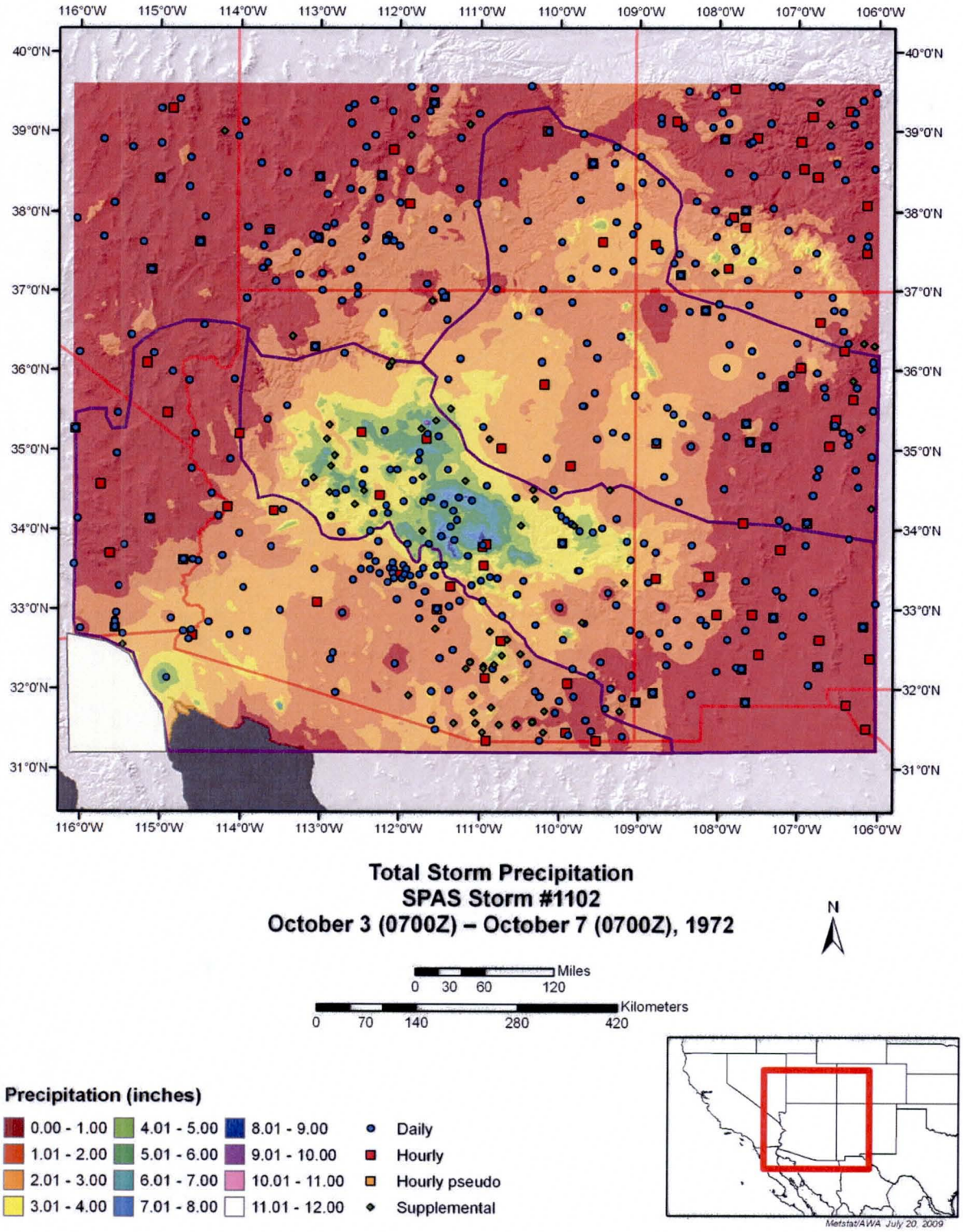

White Tanks #4
Joanne Zone 1 October 1972
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Avondale
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
Fort Apache Indian Reservation
Gila River Indian Reservation
San Carlos Reservoir
Zuni Indian Reservation
Yuma Proving Ground
Yuma
Mexicali
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| | Duration (hours) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($mi^2$) | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | Total |
| 0.27 | 1.32 | | 2.08 | | | 3.27 | 4.38 | 6.10 | 6.79 | 7.20 | 7.23 | 7.47 | 7.69 | 7.71 |
| 1 | 1.00 | | 1.77 | | | 2.98 | 4.16 | 5.86 | 6.55 | 6.95 | 6.98 | 7.21 | 7.43 | 7.45 |
| 5 | 1.00 | | 1.77 | | | 2.98 | 4.00 | 5.57 | 5.98 | 6.45 | 6.46 | 6.80 | 6.92 | 7.06 |
| 10 | 1.00 | | 1.77 | | | 2.98 | 3.73 | 5.20 | 5.54 | 6.05 | 6.04 | 6.42 | 6.51 | 6.68 |
| 20 | 1.00 | | 1.77 | | | 2.64 | 3.36 | 4.56 | 5.31 | 5.71 | 5.71 | 5.96 | 6.20 | 6.28 |
| 50 | 1.00 | | 1.76 | | | 2.57 | 3.34 | 4.46 | 5.09 | 5.51 | 5.52 | 5.56 | 5.81 | 5.95 |
| 100 | 1.00 | | 1.74 | | | 2.43 | 3.19 | 4.37 | 4.87 | 5.26 | 5.26 | 5.41 | 5.53 | 5.56 |
| 200 | 1.00 | | 1.69 | | | 2.11 | 3.00 | 4.13 | 4.48 | 4.98 | 4.98 | 5.03 | 5.23 | 5.27 |
| 300 | 1.00 | | 1.60 | | | 2.11 | 2.87 | 3.97 | 4.40 | 4.77 | 4.78 | 4.91 | 5.01 | 5.08 |
| 500 | 0.93 | | 1.42 | | | 2.06 | 2.64 | 3.42 | 4.07 | 4.47 | 4.47 | 4.63 | 4.73 | 4.78 |
| 1000 | 0.72 | | 1.09 | | | 1.76 | 2.20 | 3.26 | 3.67 | 4.02 | 4.02 | 4.19 | 4.34 | 4.39 |
| 2000 | 0.56 | | 0.91 | | | 1.62 | 2.09 | 2.76 | 3.33 | 3.59 | 3.59 | 3.73 | 3.93 | 4.00 |
| 5000 | 0.30 | | 0.82 | | | 1.18 | 2.01 | 2.57 | 2.91 | 3.08 | 3.12 | 3.18 | 3.41 | 3.49 |
| 10000 | 0.23 | | 0.60 | | | 1.16 | 1.75 | 2.30 | 2.51 | 2.75 | 2.77 | 2.88 | 3.01 | 3.08 |
| 20000 | 0.17 | | 0.49 | | | 0.90 | 1.45 | 1.89 | 2.11 | 2.25 | 2.25 | 2.47 | 2.60 | 2.67 |
| 50000 | 0.14 | | 0.34 | | | 0.37 | 0.87 | 1.24 | 1.36 | 1.48 | 1.51 | 1.80 | 1.91 | 2.03 |
| 77692 | 0.06 | | | | | | | | | | | | | |




SPAS 1102 Storm Center Mass Curve
DAD Zone 1: Southern Deserts
October 3 (0700Z) – October 7 (0700Z), 1972
Lat: 31.7792 Lon: -113.4958
Incremental
Accumulated
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
7.72""
1.5
1
0.5
0
12
11
10
9
8
7
6
5
4
3
2
1
0
1
11
21
31
41
51
61
71
81
91
101
111


116°0'W
115°0'W
114°0'W
113°0'W
112°0'W
111°0'W
110°0'W
109°0'W
108°0'W
107°0'W
106°0'W
40°0'N
39°0'N
38°0'N
37°0'N
36°0'N
35°0'N
34°0'N
33°0'N
32°0'N
31°0'N
Total Storm Precipitation
SPAS Storm #1102
October 3 (0700Z) – October 7 (0700Z), 1972
N
Miles
0 30 60 120
Kilometers
0 70 140 280 420
Precipitation (inches)
0.00 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
Daily
Hourly
Hourly pseudo
Supplemental
Metstat/AWA July 20, 2009

# Yuma Valley, AZ

**August 15, 1977**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1042-Yuma Valley |
| Storm Date: | August 15, 1977 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 15-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 32.61 N | 114.63 W |
| Storm Rep dew point location | 32.65 N | 114.60 W |
| Transposition dewpoint location | 33.44 N | 112.52 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 5 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 192 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The storm representative dew point is | 77.0 F | with total precipitable water above sea level of | | | | 3.14 | inches. |
| The in-place maximum dew point is | 82.0 F | with total precipitable water above sea level of | | | | 3.92 | inches. |
| The transpositioned maximum dew point is | 82.0 F | with total precipitable water above sea level of | | | | 3.92 | inches. |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 77.0 F | |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 82.0 F | |
| Basin elevation at | 0 | which subtracts | 0.00 | inches of precipitable water at | | 82.0 F | |
| The inflow barrier height/basin elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 82.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.25 |
| The transposition factor is | 1.00 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.25 |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms.

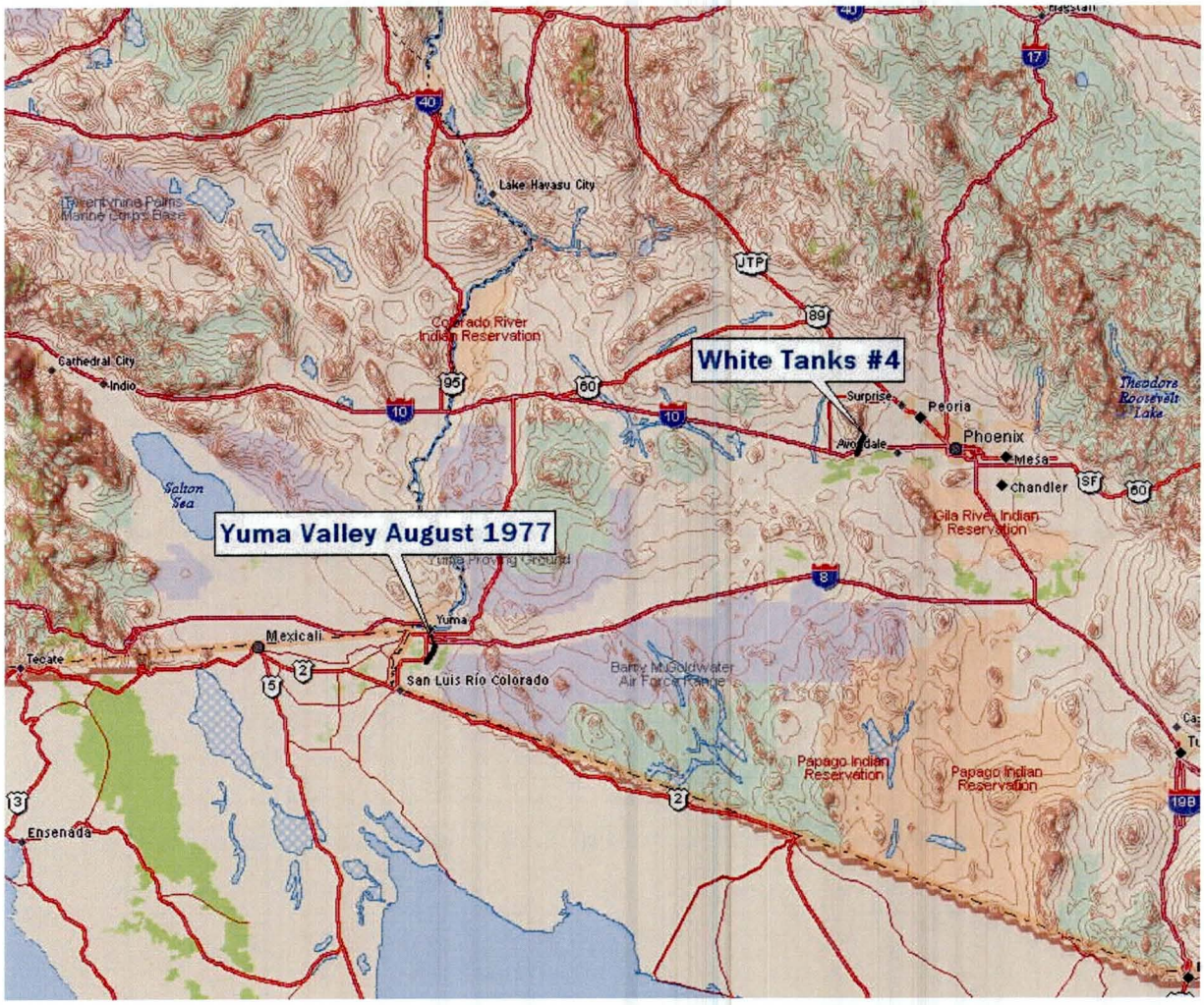
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours |
|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 2.2 | 3.7 | 5.1 | 5.1 | 5.1 | 5.1 | 5.9 | 6.0 | 6.0 |
| 10 sq miles | 2.0 | 3.3 | 4.5 | 4.6 | 4.6 | 4.6 | 5.2 | 5.3 | 5.3 |
| 50 sq miles | 1.7 | 2.9 | 4.0 | 4.0 | 4.0 | 4.0 | 4.6 | 4.7 | 4.7 |
| 100 sq miles | 1.6 | 2.7 | 3.7 | 3.7 | 3.7 | 3.7 | 4.3 | 4.4 | 4.4 |
| 200 sq miles | 1.5 | 2.5 | 3.3 | 3.4 | 3.4 | 3.4 | 3.9 | 4.0 | 4.0 |
| 500 sq miles | 1.2 | 2.0 | 2.7 | 2.8 | 2.8 | 2.8 | 3.2 | 3.3 | 3.3 |
| 1000 sq miles | 1.1 | 1.7 | 2.4 | 2.4 | 2.4 | 2.4 | 2.7 | 2.8 | 2.8 |
| 2000 sq miles | 0.9 | 1.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.3 | 2.4 | 2.5 |
| 5000 sq miles | 0.6 | 1.0 | 1.4 | 1.4 | 1.4 | 1.5 | 1.7 | 1.7 | 1.9 |

**Adjusted Storm Depth-Area-Duration**

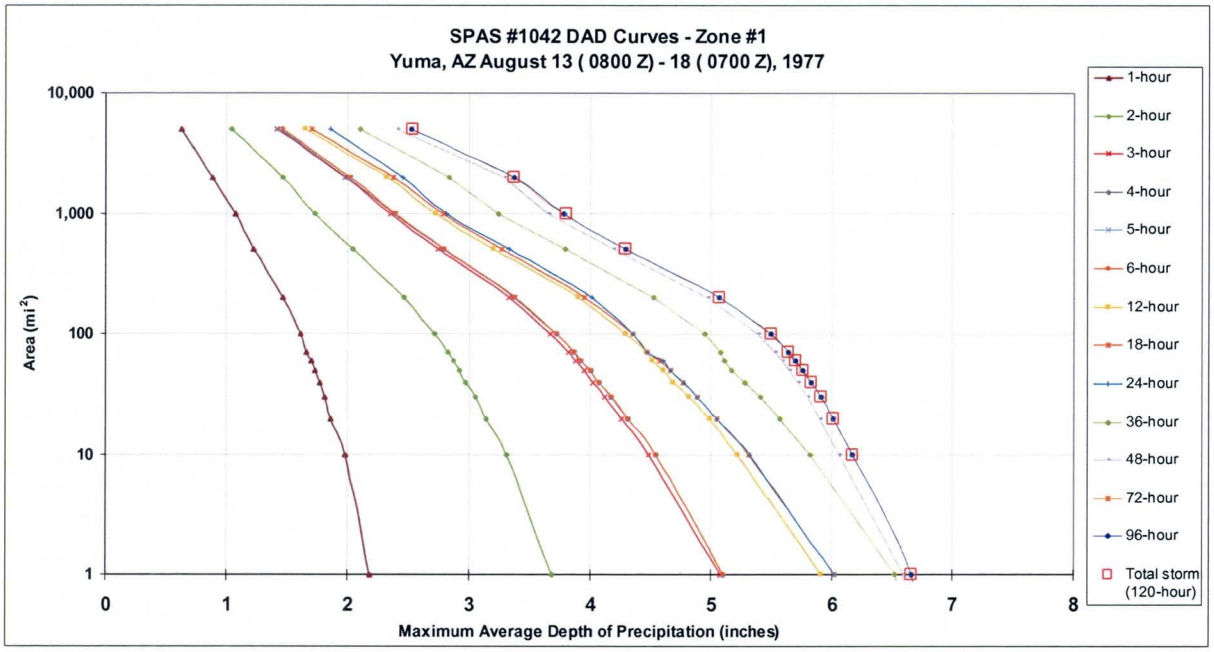
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours |
|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 2.7 | 4.6 | 6.3 | 6.4 | 6.4 | 6.4 | 7.4 | 7.5 | 7.5 |
| 10 sq miles | 2.5 | 4.1 | 5.6 | 5.7 | 5.7 | 5.7 | 6.5 | 6.6 | 6.6 |
| 50 sq miles | 2.2 | 3.6 | 4.9 | 5.0 | 5.0 | 5.0 | 5.8 | 5.8 | 5.8 |
| 100 sq miles | 2.0 | 3.4 | 4.6 | 4.6 | 4.6 | 4.6 | 5.4 | 5.4 | 5.4 |
| 200 sq miles | 1.8 | 3.1 | 4.2 | 4.2 | 4.2 | 4.2 | 4.9 | 4.9 | 5.0 |
| 500 sq miles | 1.5 | 2.5 | 3.4 | 3.5 | 3.5 | 3.5 | 4.0 | 4.1 | 4.2 |
| 1000 sq miles | 1.3 | 2.2 | 2.9 | 3.0 | 3.0 | 3.0 | 3.4 | 3.5 | 3.5 |
| 2000 sq miles | 1.1 | 1.8 | 2.5 | 2.5 | 2.5 | 2.5 | 2.9 | 3.0 | 3.1 |
| 5000 sq miles | 0.8 | 1.3 | 1.8 | 1.8 | 1.8 | 1.8 | 2.1 | 2.1 | 2.3 |

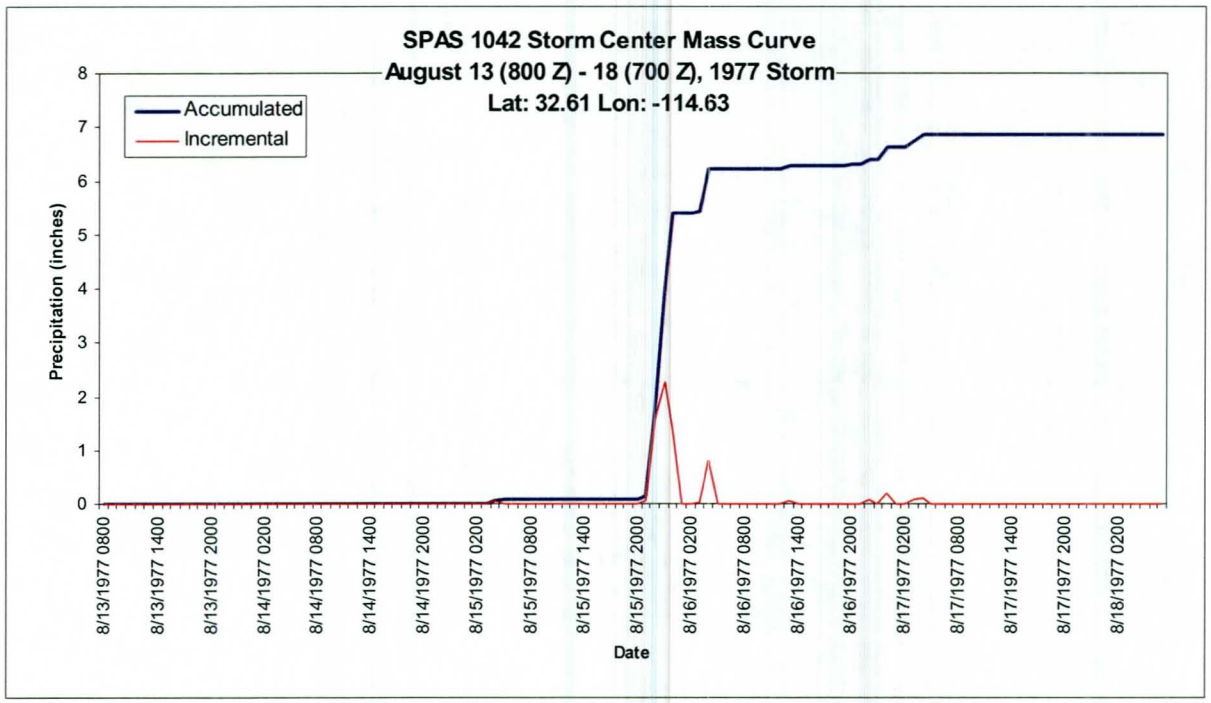
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1042-Yuma Valley** | |
| Storm Date(s) | August 15, 1977 | |
| Storm Type | Local Storm | |
| Storm Location | 32.61 N | 114.63 W |
| Storm Center Elevation | 192 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 5.33 inches 4 hours 6.85" in 72hrs (SPAS 1042DAD) | |
| | | |
| Storm Representative Dewpoint | 77.0 F | 3hr ave 13Z-15Z on the 15th at KYUM |
| Storm Representative Dewpoint Location | 32.65 N | 114.60 W |
| In-place Maximum Dewpoint | 82.0 F | Using KYUM location |
| Moisture Inflow Vector | S @ 5 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 33.44 N | 112.52 W |
| Transposition Maximum Dewpoint | 82.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.25 | |

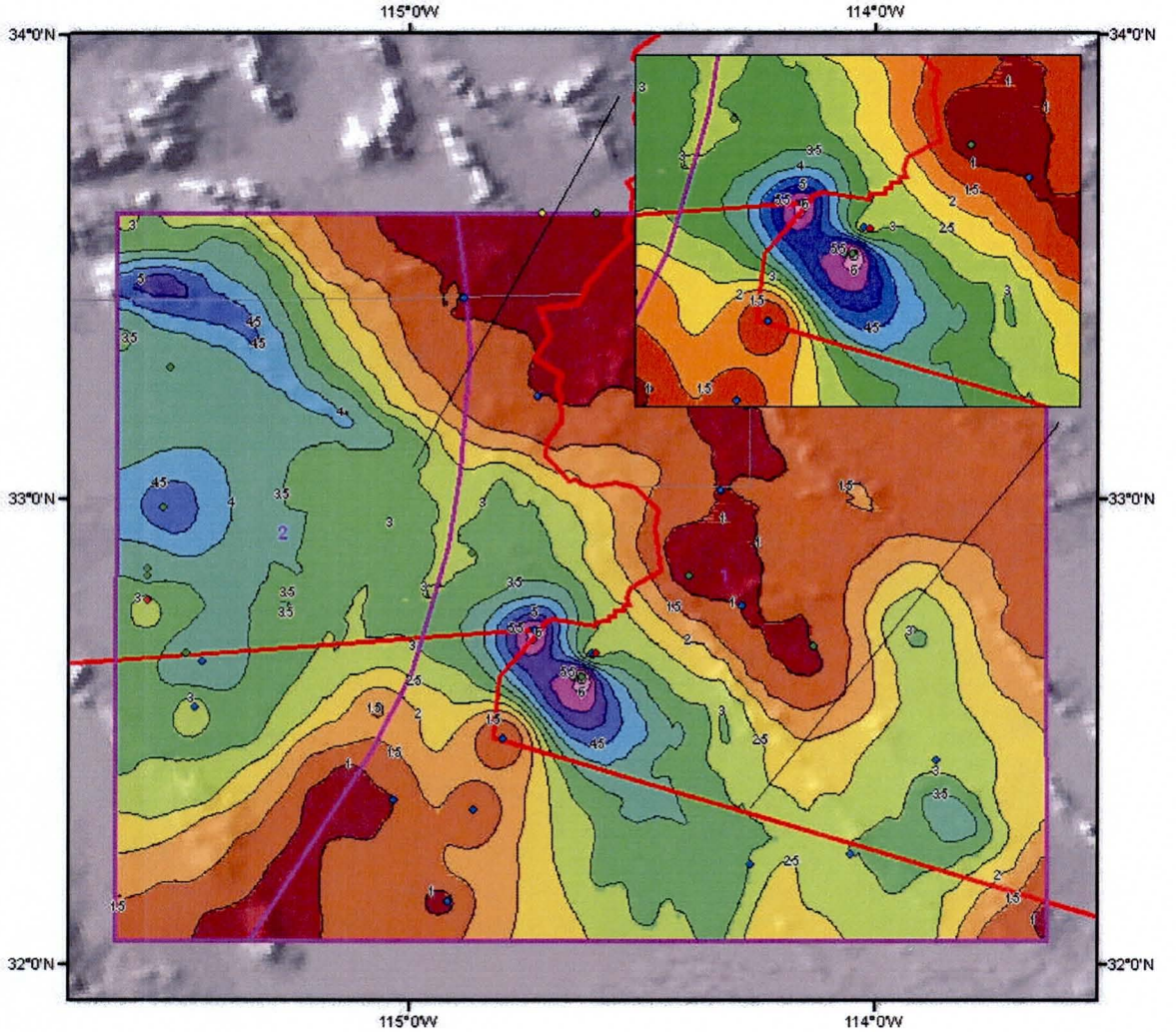

White Tanks #4
Yuma Valley August 1977
Lake Havasu City
Twentynine Palms Marine Corps Base
Colorado River Indian Reservation
Cathedral City
Indio
Salton Sea
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Theodore Roosevelt Lake
Gila River Indian Reservation
Yuma Proving Ground
Yuma
Mexicali
Tecate
San Luis Río Colorado
Barry M Goldwater Air Force Range
Papago Indian Reservation
Papago Indian Reservation
Ensenada

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | Total |
| **0.07** | 2.29 | 3.88 | 5.26 | 5.33 | 5.33 | 5.33 | 6.17 | 6.17 | 6.18 | 6.78 | 6.79 | 6.85 | 6.85 | 6.85 |
| **1** | 2.18 | 3.68 | 5.08 | 5.10 | 5.10 | 5.10 | 5.91 | 6.02 | 6.02 | 6.52 | 6.59 | 6.66 | 6.66 | 6.66 |
| **10** | 1.98 | 3.31 | 4.49 | 4.55 | 4.55 | 4.55 | 5.22 | 5.31 | 5.32 | 5.82 | 6.06 | 6.17 | 6.17 | 6.17 |
| **20** | 1.86 | 3.14 | 4.27 | 4.32 | 4.32 | 4.32 | 4.99 | 5.05 | 5.05 | 5.57 | 5.90 | 6.01 | 6.01 | 6.01 |
| **30** | 1.81 | 3.05 | 4.13 | 4.18 | 4.18 | 4.19 | 4.82 | 4.89 | 4.89 | 5.41 | 5.80 | 5.91 | 5.91 | 5.91 |
| **40** | 1.77 | 2.97 | 4.03 | 4.08 | 4.08 | 4.08 | 4.69 | 4.77 | 4.78 | 5.28 | 5.72 | 5.83 | 5.83 | 5.83 |
| **50** | 1.73 | 2.92 | 3.95 | 4.00 | 4.00 | 4.00 | 4.61 | 4.67 | 4.67 | 5.17 | 5.65 | 5.75 | 5.76 | 5.76 |
| **60** | 1.70 | 2.87 | 3.88 | 3.92 | 3.92 | 3.92 | 4.52 | 4.58 | 4.61 | 5.11 | 5.59 | 5.69 | 5.70 | 5.70 |
| **70** | 1.66 | 2.82 | 3.82 | 3.86 | 3.87 | 3.87 | 4.47 | 4.48 | 4.48 | 5.08 | 5.53 | 5.64 | 5.64 | 5.64 |
| **100** | 1.61 | 2.71 | 3.67 | 3.72 | 3.72 | 3.72 | 4.30 | 4.36 | 4.36 | 4.95 | 5.39 | 5.49 | 5.50 | 5.50 |
| **200** | 1.46 | 2.46 | 3.33 | 3.37 | 3.38 | 3.38 | 3.90 | 3.95 | 4.02 | 4.53 | 4.97 | 5.07 | 5.07 | 5.07 |
| **500** | 1.22 | 2.04 | 2.74 | 2.78 | 2.78 | 2.79 | 3.20 | 3.27 | 3.33 | 3.79 | 4.20 | 4.30 | 4.30 | 4.30 |
| **1,000** | 1.07 | 1.73 | 2.35 | 2.38 | 2.39 | 2.39 | 2.72 | 2.78 | 2.81 | 3.24 | 3.65 | 3.77 | 3.78 | 3.80 |
| **2,000** | 0.88 | 1.46 | 1.98 | 1.99 | 2.02 | 2.02 | 2.32 | 2.37 | 2.45 | 2.83 | 3.29 | 3.36 | 3.37 | 3.37 |
| **5,000** | 0.63 | 1.04 | 1.41 | 1.43 | 1.44 | 1.46 | 1.65 | 1.70 | 1.86 | 2.10 | 2.40 | 2.52 | 2.52 | 2.53 |




SPAS 1042 Storm Center Mass Curve
August 13 (800 Z) - 18 (700 Z), 1977 Storm
Lat: 32.61 Lon: -114.63
Accumulated
Incremental
Precipitation (inches)
0
1
2
3
4
5
6
7
8
8/13/1977 0800
8/13/1977 1400
8/13/1977 2000
8/14/1977 0200
8/14/1977 0800
8/14/1977 1400
8/14/1977 2000
8/15/1977 0200
8/15/1977 0800
8/15/1977 1400
8/15/1977 2000
8/16/1977 0200
8/16/1977 0800
8/16/1977 1400
8/16/1977 2000
8/17/1977 0200
8/17/1977 0800
8/17/1977 1400
8/17/1977 2000
8/18/1977 0200
Date




**Total Rainfall (120-hours)**
**Yuma, AZ 1977 Storm**
**SPAS Storm #1042- August 13 (800 Z) to 18 (700 Z), 1977**

Miles: 0 5 10 20 30
Kilometers: 0 12.5 25 50 75

**Gauging Stations**

- Hourly
- Daily
- Hourly Pseudo
- Supplemental

N

**Precipitation (inches)**

| | | | | |
|---|---|---|---|---|
| 0.54 - 1.00 | 2.01 - 2.50 | 3.51 - 4.00 | 5.01 - 5.50 | 6.51 - 7.00 |
| 1.01 - 1.50 | 2.51 - 3.00 | 4.01 - 4.50 | 5.51 - 6.00 | |
| 1.51 - 2.00 | 3.01 - 3.50 | 4.51 - 5.00 | 6.01 - 6.50 | |

*Coordinate system: GCS North American 1983*
*Scale:* 1:1,345,743

# Bear Spring, AZ

**February 27 – March 3, 1978**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1150-Bear Spring-Zone 1 |
| Storm Date: | 2/27-3-3/1978 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 15-Feb

| | Lat | Long |
|---|---|---|
| Storm center location | 33.70 N | 111.60 W |
| Storm Rep dew point location | 32.60 N | 111.83 W |
| Transposition dewpoint location | 32.40 N | 112.80 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SSW @ 100 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,300 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 58.5 F | with total precipitable water above sea level of | | | 1.28 | inches. |
| The in-place maximum dew point is | 61.0 F | with total precipitable water above sea level of | | | 1.45 | inches. |
| The transpositioned maximum dew point is | 61.0 F | with total precipitable water above sea level of | | | 1.45 | inches. |
| The in-place storm elevation is | 2,300 | which subtracts | 0.315 | inches of precipitable water at | 58.5 F | |
| The in-place storm elevation is | 2,300 | which subtracts | 0.34 | inches of precipitable water at | 61.0 F | |
| Basin elevation at | 3,650 | which subtracts | 0.52 | inches of precipitable water at | 61.0 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.52 | inches of precipitable water at | 61.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.15 |
| The transposition factor is | 0.84 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 0.97 |

Notes: 24hr ave KGBN, KDMA, KTUS, KFHU

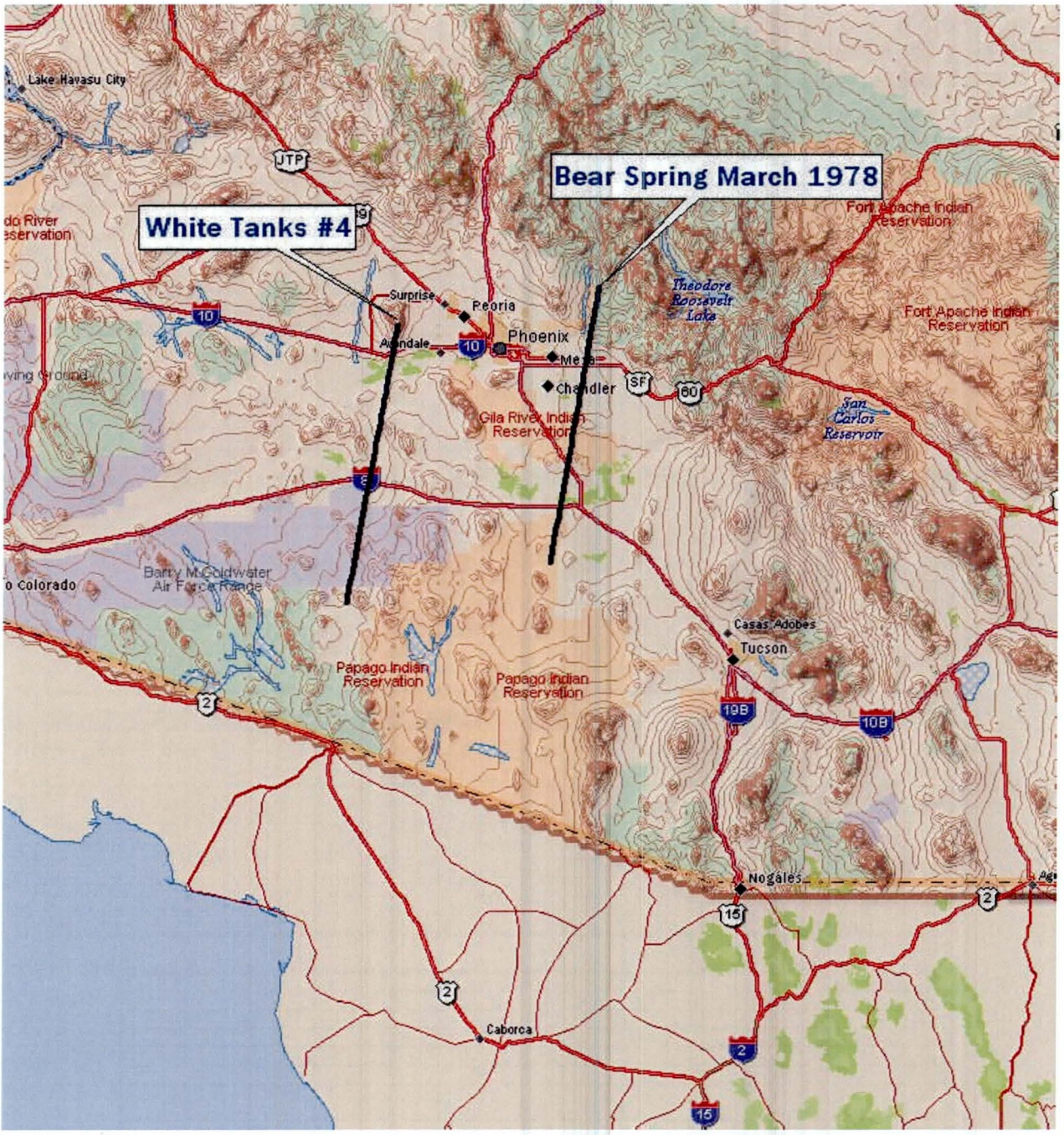
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.0 | 3.6 | 4.6 | 5.2 | 5.9 | - | - | 9.3 | - | 11.7 |
| 10 sq miles | 1.0 | 3.6 | 4.6 | 5.2 | 5.9 | - | - | 9.3 | - | 11.6 |
| 100 sq miles | 0.8 | 2.5 | 3.3 | 4.0 | 4.9 | - | - | 6.9 | - | 9.0 |
| 200 sq miles | 0.8 | 2.1 | 2.8 | 3.4 | 4.3 | - | - | 6.5 | - | 8.3 |
| 500 sq miles | 0.7 | 1.8 | 2.2 | 2.7 | 3.4 | - | - | 5.1 | - | 6.8 |
| 1000 sq miles | 0.4 | 1.4 | 1.9 | 2.1 | 2.8 | - | - | 4.4 | - | 5.9 |
| 2000 sq miles | 0.2 | 1.1 | 1.5 | 1.9 | 2.3 | - | - | 3.7 | - | 4.9 |
| 5000 sq miles | 0.2 | 0.7 | 1.1 | 1.3 | 1.6 | - | - | 2.8 | - | 3.8 |
| 10000 sq miles | 0.2 | 0.6 | 0.9 | 1.0 | 1.3 | - | - | 2.1 | - | 2.9 |
| 20000 sq miles | 0.1 | 0.5 | 0.6 | 0.9 | 1.0 | - | - | 1.7 | - | 2.2 |

**Adjusteded Storm Depth-Area-Duration**

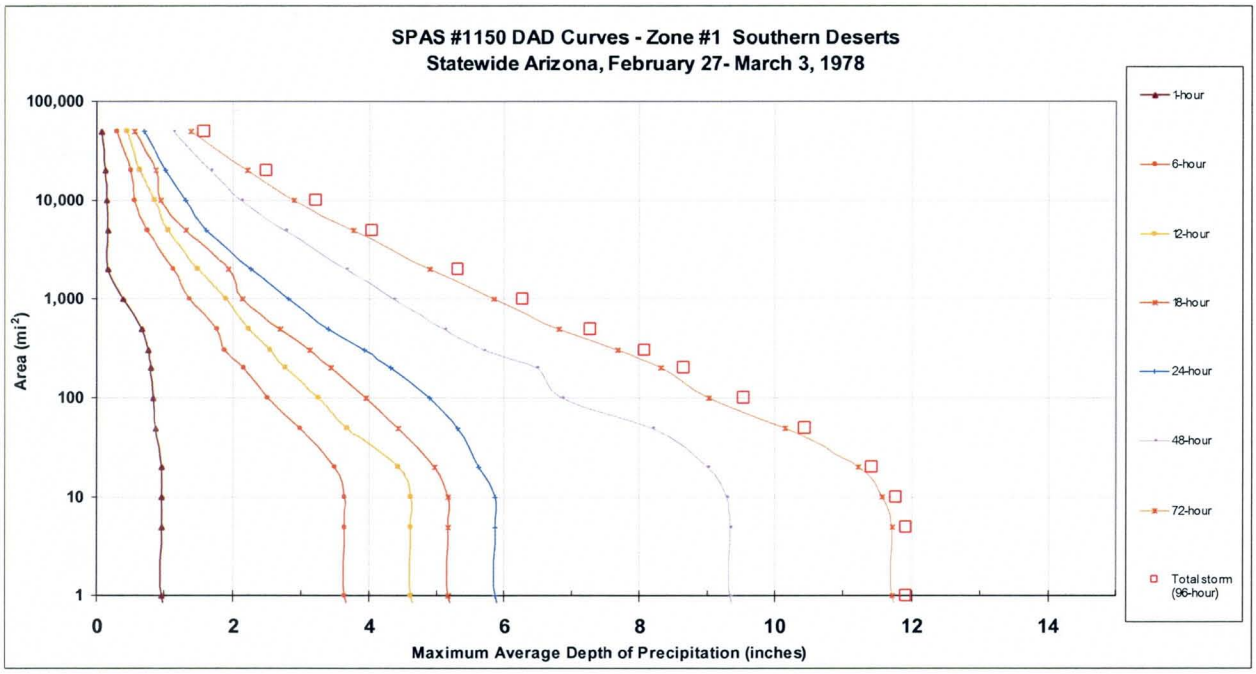
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.9 | 3.5 | 4.5 | 5.0 | 5.7 | - | - | 9.0 | - | 11.3 |
| 10 sq miles | 0.9 | 3.5 | 4.5 | 5.0 | 5.7 | - | - | 9.0 | - | 11.2 |
| 100 sq miles | 0.8 | 2.4 | 3.1 | 3.8 | 4.7 | - | - | 6.6 | - | 8.7 |
| 200 sq miles | 0.8 | 2.1 | 2.7 | 3.3 | 4.2 | - | - | 6.3 | - | 8.1 |
| 500 sq miles | 0.6 | 1.7 | 2.2 | 2.6 | 3.3 | - | - | 5.0 | - | 6.6 |
| 1000 sq miles | 0.4 | 1.3 | 1.8 | 2.1 | 2.7 | - | - | 4.2 | - | 5.7 |
| 2000 sq miles | 0.2 | 1.1 | 1.4 | 1.9 | 2.2 | - | - | 3.5 | - | 4.7 |
| 5000 sq miles | 0.2 | 0.7 | 1.0 | 1.3 | 1.6 | - | - | 2.7 | - | 3.7 |
| 10000 sq miles | 0.1 | 0.5 | 0.8 | 0.9 | 1.3 | - | - | 2.0 | - | 2.8 |
| 20000 sq miles | 0.1 | 0.5 | 0.6 | 0.8 | 1.0 | - | - | 1.6 | - | 2.1 |

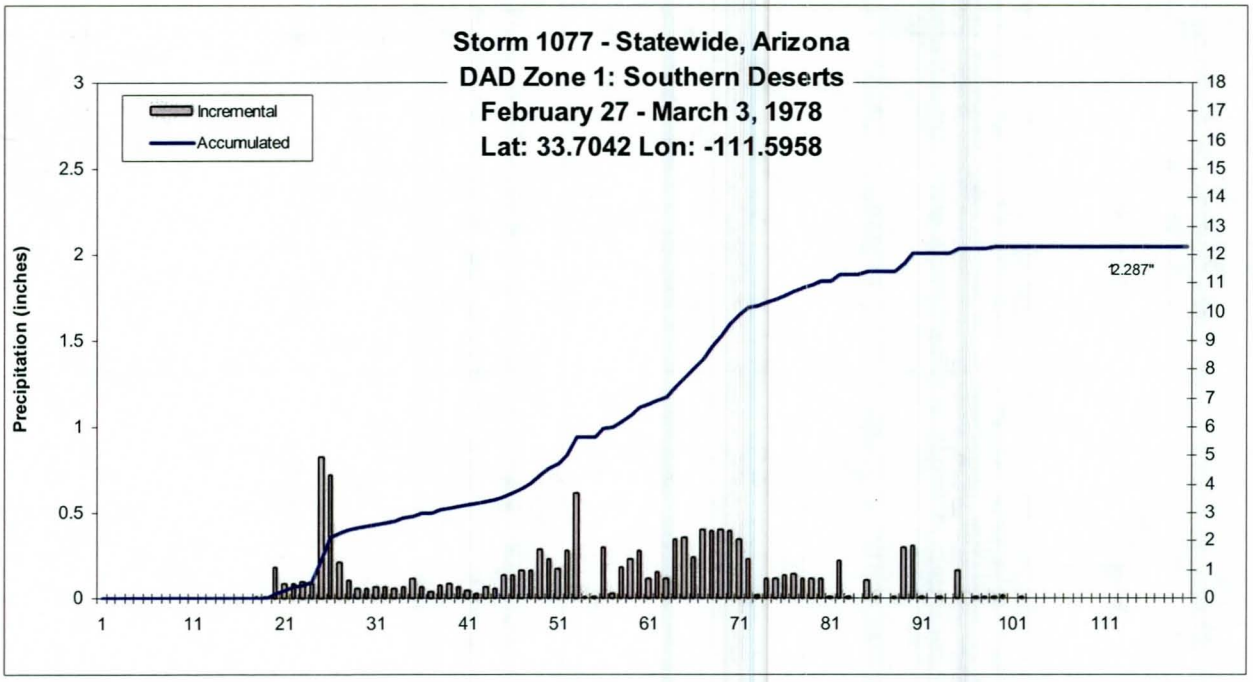
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1150-Bear Spring-Zone 1 | |
| Storm Date(s) | 2/27-3-3/1978 | |
| Storm Type | General | |
| Storm Location | 33.70 N | 111.60 W |
| Storm Center Elevation | 2300 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 12.04 inches 72 hours | |
| | | |
| Storm Representative Dewpoint | 58.5 F | 24hr ave KGBN, KDMA, KTUS, KFHU |
| Storm Representative Dewpoint Location | 32.60 N | 111.83 W |
| In-place Maximum Dewpoint | 61.0 F | |
| Moisture Inflow Vector | SSW @ 100 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Feb | verify |
| Transposition Dewpoint Location | 32.40 N | 112.80 W |
| Transposition Maximum Dewpoint | 61.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

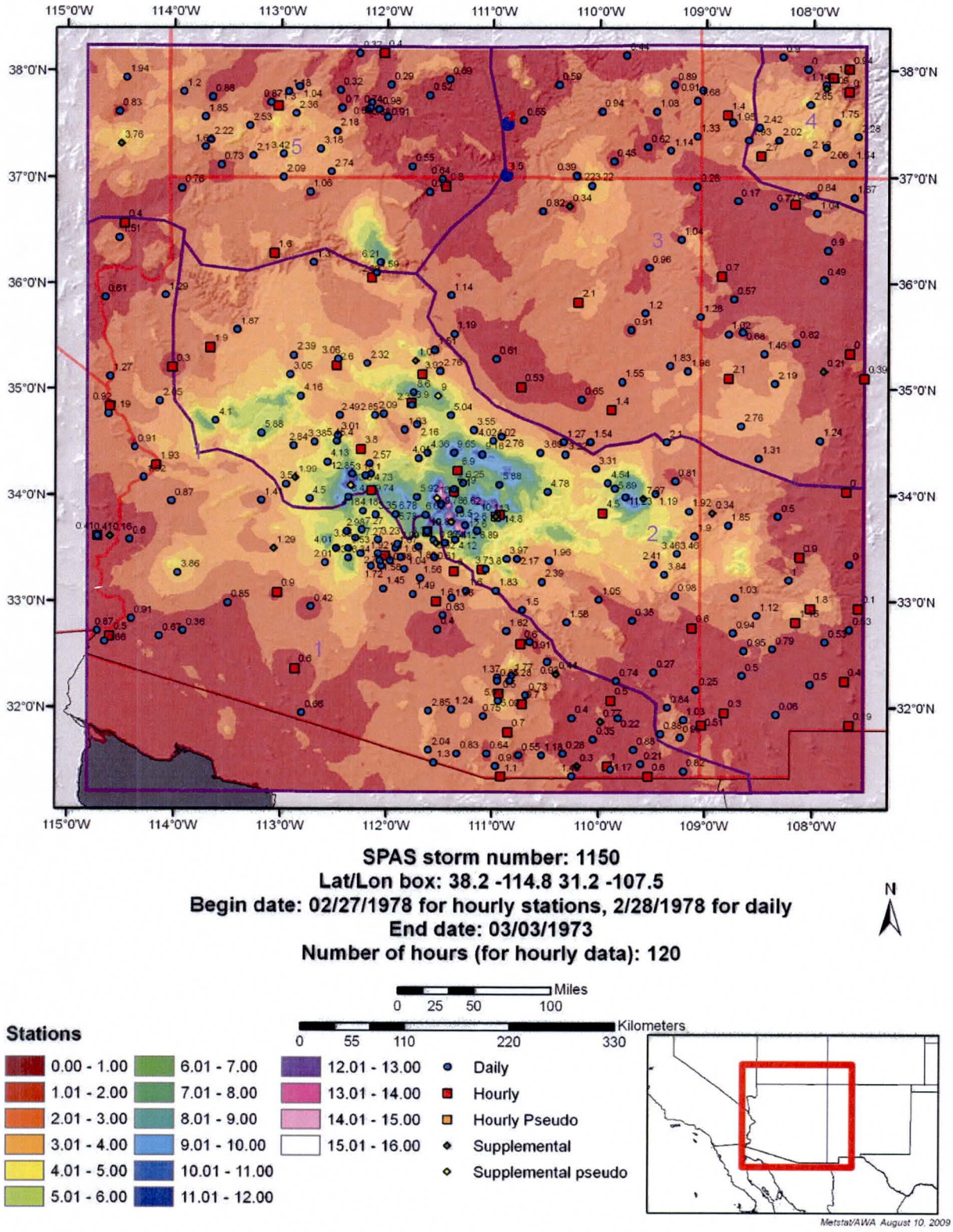

Bear Spring March 1978
White Tanks #4
Lake Havasu City
JTP
Fort Apache Indian Reservation
Theodore Roosevelt Lake
Surprise
Peoria
Phoenix
Mesa
Chandler
Gila River Indian Reservation
San Carlos Reservoir
Barry M. Goldwater Air Force Range
Casas Adobes
Tucson
Papago Indian Reservation
Nogales
Caborca

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| Area (mi²) | Duration (hours) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | Total |
| 0.27 | 1.2 | | | | | 3.89 | 4.89 | 5.46 | 6.13 | | 9.61 | 12.04 | 12.23 |
| 1 | 0.96 | | | | | 3.64 | 4.61 | 5.18 | 5.87 | | 9.33 | 11.71 | 11.92 |
| 5 | 0.96 | | | | | 3.64 | 4.61 | 5.18 | 5.87 | | 9.33 | 11.71 | 11.92 |
| 10 | 0.96 | | | | | 3.64 | 4.61 | 5.18 | 5.87 | | 9.28 | 11.57 | 11.77 |
| 20 | 0.96 | | | | | 3.5 | 4.44 | 4.96 | 5.63 | | 8.99 | 11.21 | 11.41 |
| 50 | 0.86 | | | | | 2.97 | 3.68 | 4.43 | 5.32 | | 8.18 | 10.15 | 10.44 |
| 100 | 0.84 | | | | | 2.49 | 3.25 | 3.95 | 4.9 | | 6.85 | 9.02 | 9.54 |
| 200 | 0.79 | | | | | 2.14 | 2.75 | 3.43 | 4.33 | | 6.48 | 8.31 | 8.64 |
| 300 | 0.75 | | | | | 1.86 | 2.53 | 3.13 | 3.93 | | 5.7 | 7.68 | 8.07 |
| 500 | 0.67 | | | | | 1.75 | 2.22 | 2.68 | 3.4 | | 5.11 | 6.81 | 7.28 |
| 1000 | 0.39 | | | | | 1.36 | 1.89 | 2.12 | 2.8 | | 4.36 | 5.86 | 6.28 |
| 2000 | 0.16 | | | | | 1.12 | 1.47 | 1.92 | 2.26 | | 3.65 | 4.9 | 5.32 |
| 5000 | 0.16 | | | | | 0.74 | 1.06 | 1.32 | 1.6 | | 2.76 | 3.77 | 4.05 |
| 10000 | 0.15 | | | | | 0.56 | 0.85 | 0.95 | 1.31 | | 2.11 | 2.89 | 3.22 |
| 20000 | 0.13 | | | | | 0.5 | 0.62 | 0.86 | 1.02 | | 1.66 | 2.2 | 2.48 |
| 50000 | 0.08 | | | | | 0.3 | 0.45 | 0.55 | 0.7 | | 1.13 | 1.38 | 1.57 |
| 51059 | | | | | | | | | | | | | |




Storm 1077 - Statewide, Arizona
DAD Zone 1: Southern Deserts
February 27 - March 3, 1978
Lat: 33.7042 Lon: -111.5958
Incremental
Accumulated
Precipitation (inches)
12.287"
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
11
21
31
41
51
61
71
81
91
101
111




**SPAS storm number: 1150**
**Lat/Lon box: 38.2 -114.8 31.2 -107.5**
**Begin date: 02/27/1978 for hourly stations, 2/28/1978 for daily**
**End date: 03/03/1973**
**Number of hours (for hourly data): 120**

# Browns Peak, AZ

**December 17-19, 1978**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1134-Browns Peak Zone 1 |
| Storm Date: | 12/17-19/1978 |
| AWA Analysis Date: | 10/16/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 1-Dec

| | Lat | Long |
|---|---|---|
| Storm center location | 33.43 N | 111.45 W |
| Storm Rep dew point location | 25.00 N | 118.00 W |
| Transposition dewpoint location | 25.09 N | 119.08 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SW @ 720 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 3,400 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The storm representative dew point is | 69.5 F | with total precipitable water above sea level of | | | | 2.20 | inches. |
| The in-place maximum dew point is | 72.0 F | with total precipitable water above sea level of | | | | 2.47 | inches. |
| The transpositioned maximum dew point is | 70.5 F | with total precipitable water above sea level of | | | | 2.32 | inches. |
| The in-place storm elevation is | 3,400 | which subtracts | 0.65 | inches of precipitable water at | | 69.5 F | |
| The in-place storm elevation is | 3,400 | which subtracts | 0.71 | inches of precipitable water at | | 72.0 F | |
| Basin elevation at | 3,650 | which subtracts | 0.72 | inches of precipitable water at | | 70.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.72 | inches of precipitable water at | | 70.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.14 |
| The transposition factor is | 0.91 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.03 |

Notes: Daily SST used since moisture source on land not found because of rain contamination and unrepresentative values. In-place maximization factor of 1.83 calculated, but held to 1.50.

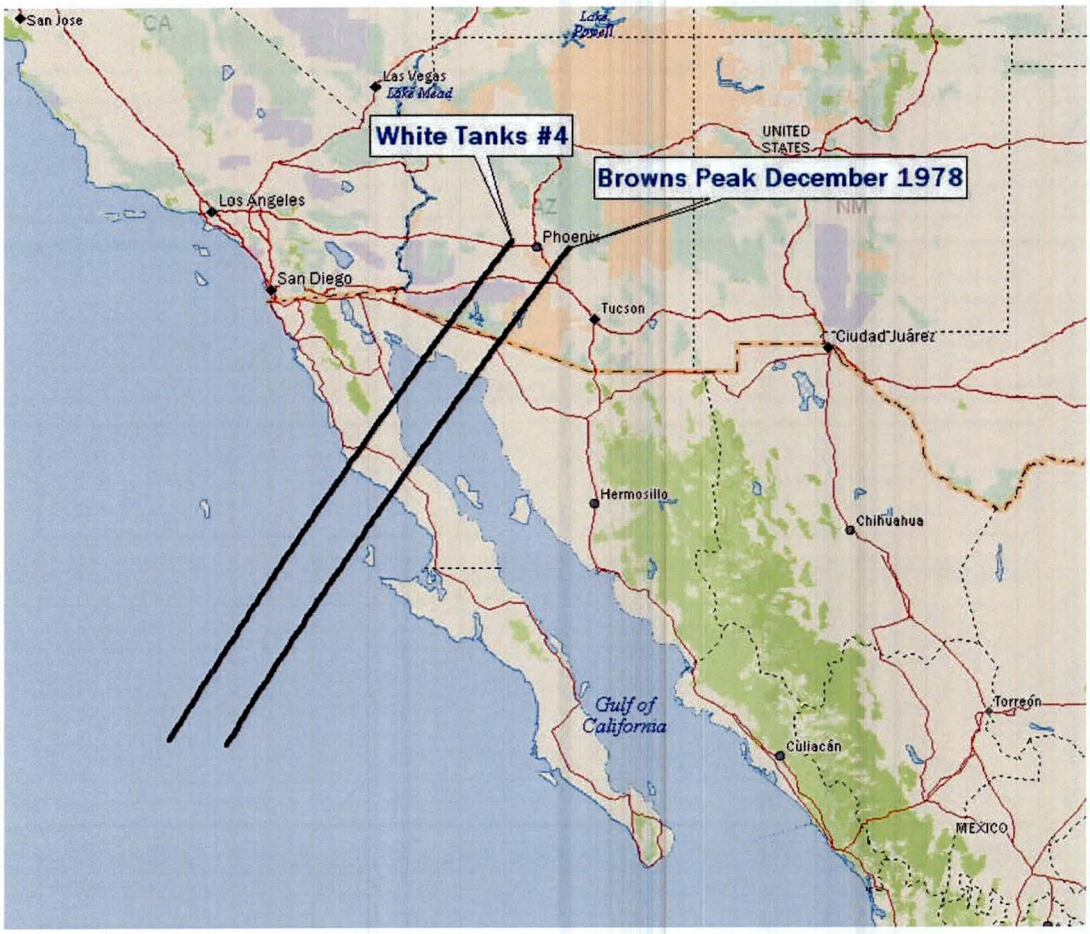
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.7 | 2.1 | 2.2 | - | 3.2 | - | - | 5.0 | - | 5.3 |
| 10 sq miles | 0.7 | 2.1 | 2.2 | - | 3.2 | - | - | 5.0 | - | 5.3 |
| 100 sq miles | 0.7 | 1.8 | 1.8 | - | 2.8 | - | - | 4.2 | - | 4.6 |
| 200 sq miles | 0.7 | 1.4 | 1.7 | - | 2.7 | - | - | 4.2 | - | 4.5 |
| 500 sq miles | 0.7 | 1.1 | 1.6 | - | 2.5 | - | - | 3.8 | - | 4.1 |
| 1000 sq miles | 0.7 | 1.0 | 1.4 | - | 2.2 | - | - | 3.5 | - | 3.8 |
| 2000 sq miles | 0.6 | 0.9 | 1.4 | - | 2.0 | - | - | 3.2 | - | 3.3 |
| 5000 sq miles | 0.5 | 0.7 | 1.1 | - | 1.7 | - | - | 2.7 | - | 2.7 |
| 10000 sq miles | 0.3 | 0.5 | 0.9 | - | 1.5 | - | - | 2.3 | - | 2.4 |
| 20000 sq miles | 0.2 | 0.5 | 0.7 | - | 1.2 | - | - | 2.0 | - | 2.0 |

**Adjusteded Storm Depth-Area-Duration**

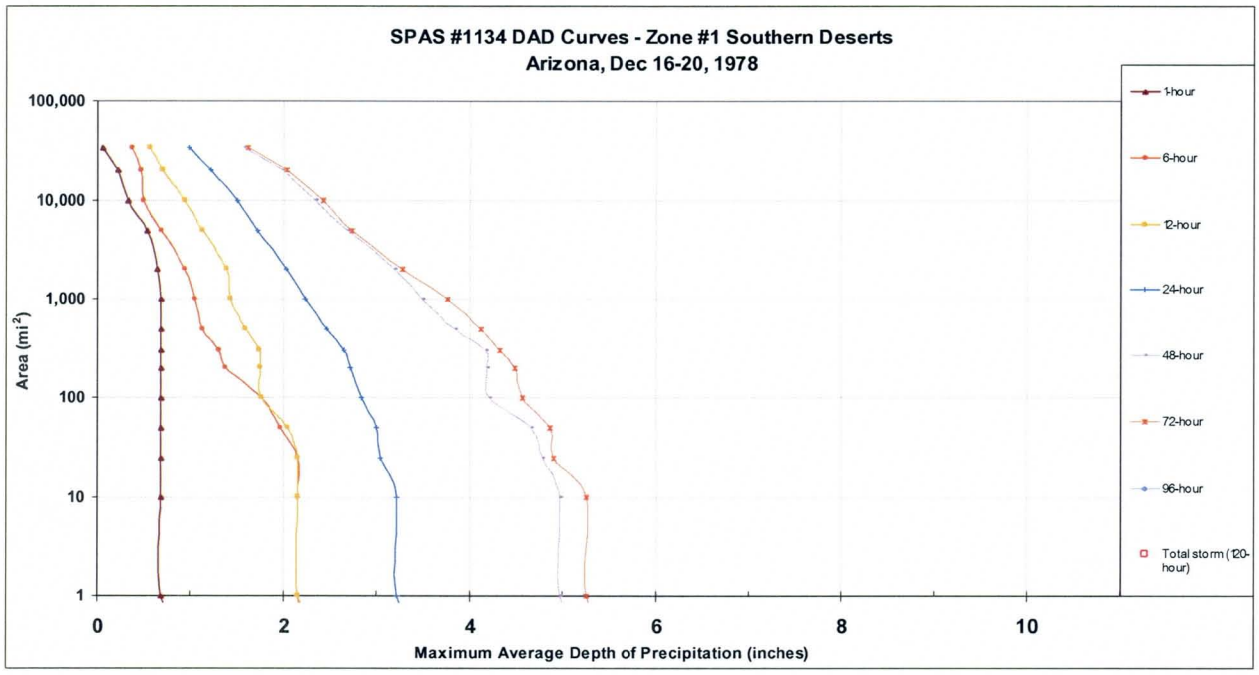
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.7 | 2.2 | 2.2 | - | 3.3 | - | - | 5.1 | - | 5.4 |
| 10 sq miles | 0.7 | 2.2 | 2.2 | - | 3.3 | - | - | 5.1 | - | 5.4 |
| 100 sq miles | 0.7 | 1.8 | 1.8 | - | 2.9 | - | - | 4.3 | - | 4.7 |
| 200 sq miles | 0.7 | 1.4 | 1.8 | - | 2.8 | - | - | 4.3 | - | 4.6 |
| 500 sq miles | 0.7 | 1.2 | 1.6 | - | 2.5 | - | - | 4.0 | - | 4.2 |
| 1000 sq miles | 0.7 | 1.1 | 1.5 | - | 2.3 | - | - | 3.6 | - | 3.9 |
| 2000 sq miles | 0.7 | 1.0 | 1.4 | - | 2.1 | - | - | 3.3 | - | 3.4 |
| 5000 sq miles | 0.5 | 0.7 | 1.2 | - | 1.8 | - | - | 2.8 | - | 2.8 |
| 10000 sq miles | 0.3 | 0.5 | 1.0 | - | 1.5 | - | - | 2.4 | - | 2.5 |
| 20000 sq miles | 0.2 | 0.5 | 0.7 | - | 1.3 | - | - | 2.1 | - | 2.1 |

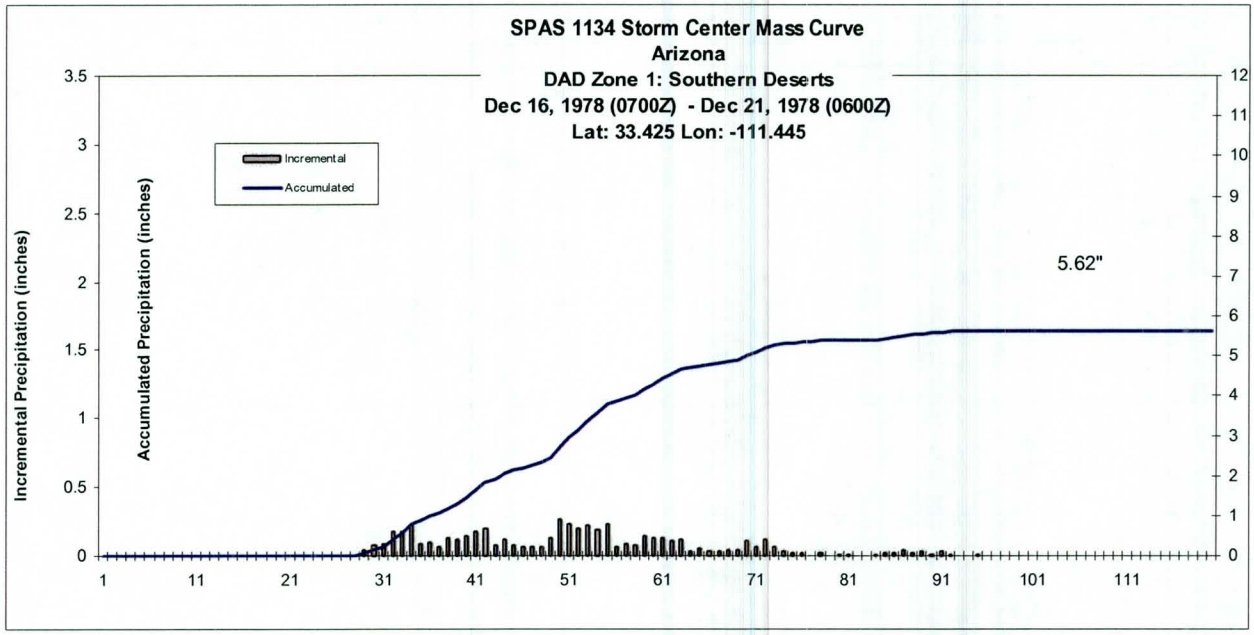
| | | | | |
|---|---|---|---|---|
| Storm or Storm Center Name | SPAS-1134-Browns Peak Zone 1 | | | |
| Storm Date(s) | 12/17-19/1978 | | | |
| Storm Type | General | | | |
| Storm Location | 33.43 N | 111.45 W | | |
| Storm Center Elevation | 3400 | orographic first upslope outside of Phoenix | | |
| Precipitation Total & Duration (10 sq mi) | 5.61 inches 72 hours (SPAS 1134 DAD) | | | |
| | | | | |
| Storm Representative Dewpoint | 69.5 F | SST | 24hr ave KTUS, KDMA 53 | |
| Storm Representative Dewpoint Location | 25.00 N | 118.00 W | 32.18 N | 110.85 W |
| In-place Maximum Dewpoint | 72.0 F | | 72 | |
| Moisture Inflow Vector | SW @ 720 | | SSE @ 115 | |
| In-place Maximization Factor | | | | |
| | | | | |
| Temporal Transposition (Date) | 1-Dec | | | |
| Transposition Dewpoint Location | 25.09 N | 119.08 W | | |
| Transposition Maximum Dewpoint | 70.5 F | | | |
| Transposition Adjustment Factor | | | | |
| Average Basin Elevation | 3,650 | | | |
| Highest Elevation in Basin | 3,655 | | | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | | | |
| Elevation Adjustment Factor | | | | |

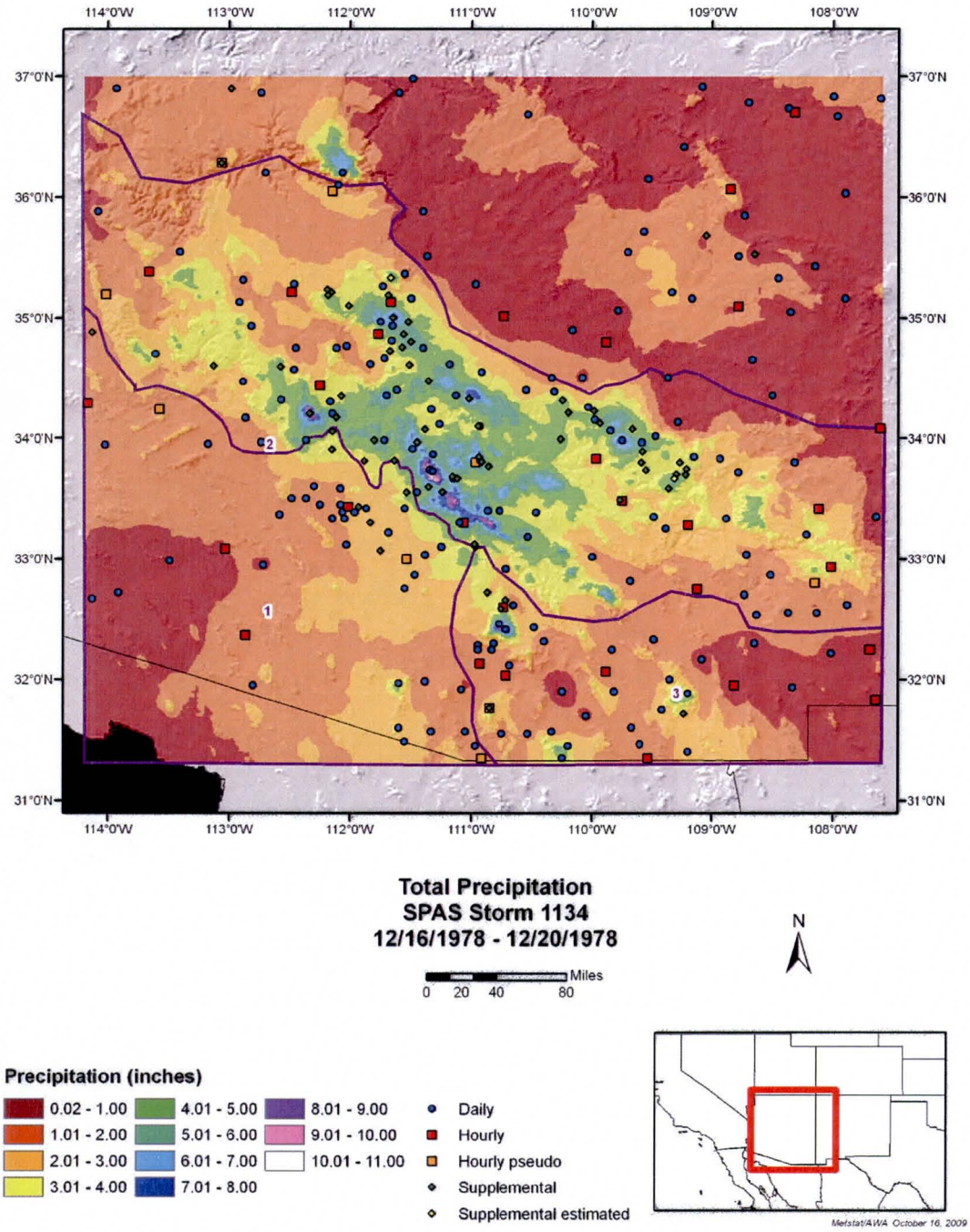

San Jose
CA
Lake Powell
Las Vegas
Lake Mead
White Tanks #4
UNITED STATES
Browns Peak December 1978
Los Angeles
AZ
NM
Phoenix
San Diego
Tucson
Ciudad Juárez
Hermosillo
Chihuahua
Gulf of California
Torreón
Culiacán
MEXICO

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area (mi²) | Duration (hours) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | Total (120-hr |
| 0.39 | 1.05 | | | | | 2.38 | 2.41 | | 3.56 | | 5.34 | 5.61 | | |
| 1 | 0.68 | | | | | 2.14 | 2.15 | | 3.21 | | 4.97 | 5.25 | | |
| 10 | 0.68 | | | | | 2.14 | 2.15 | | 3.21 | | 4.97 | 5.25 | | |
| 25 | 0.68 | | | | | 2.14 | 2.15 | | 3.04 | | 4.78 | 4.9 | | |
| 50 | 0.68 | | | | | 1.96 | 2.04 | | 2.99 | | 4.65 | 4.86 | | |
| 100 | 0.68 | | | | | 1.76 | 1.75 | | 2.84 | | 4.21 | 4.56 | | |
| 200 | 0.68 | | | | | 1.36 | 1.74 | | 2.71 | | 4.19 | 4.48 | | |
| 300 | 0.68 | | | | | 1.30 | 1.73 | | 2.64 | | 4.17 | 4.32 | | |
| 500 | 0.68 | | | | | 1.12 | 1.58 | | 2.45 | | 3.83 | 4.11 | | |
| 1000 | 0.67 | | | | | 1.04 | 1.42 | | 2.23 | | 3.48 | 3.75 | | |
| 2000 | 0.63 | | | | | 0.93 | 1.37 | | 2.02 | | 3.18 | 3.26 | | |
| 5000 | 0.52 | | | | | 0.67 | 1.12 | | 1.71 | | 2.69 | 2.73 | | |
| 10000 | 0.33 | | | | | 0.48 | 0.93 | | 1.50 | | 2.34 | 2.41 | | |
| 20000 | 0.22 | | | | | 0.46 | 0.69 | | 1.22 | | 1.99 | 2.03 | | |
| 33934 | 0.05 | | | | | 0.37 | 0.56 | | 0.99 | | 1.57 | 1.61 | | |




SPAS 1134 Storm Center Mass Curve
Arizona
DAD Zone 1: Southern Deserts
Dec 16, 1978 (0700Z) - Dec 21, 1978 (0600Z)
Lat: 33.425 Lon: -111.445
Incremental
Accumulated
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
5.62"
3.5
3
2.5
2
1.5
1
0.5
0
12
11
10
9
8
7
6
5
4
3
2
1
0
1
11
21
31
41
51
61
71
81
91
101
111


114°0'W
113°0'W
112°0'W
111°0'W
110°0'W
109°0'W
108°0'W
37°0'N
36°0'N
35°0'N
34°0'N
33°0'N
32°0'N
31°0'N
1
2
3
Total Precipitation
SPAS Storm 1134
12/16/1978 - 12/20/1978
Miles
0 20 40 80
N
Precipitation (inches)
0.02 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
Daily
Hourly
Hourly pseudo
Supplemental
Supplemental estimated
Mefstat/AWA October 16, 2009

# Crown King, AZ

**February 13-22, 1980**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1138-Crown King Zone 1 |
| Storm Date: | 2/13-22/1980 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 15-Feb

| | Lat | Long |
|---|---|---|
| Storm center location | 34.01 N | 112.26 W |
| Storm Rep dew point location | 32.48 N | 112.35 W |
| Transposition dewpoint location | 31.98 N | 112.61 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 120 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,900 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The storm representative dew point is | 60.0 F | with total precipitable water above sea level of | | | | 1.38 | inches. |
| The in-place maximum dew point is | 61.0 F | with total precipitable water above sea level of | | | | 1.45 | inches. |
| The transpositioned maximum dew point is | 61.0 F | with total precipitable water above sea level of | | | | 1.45 | inches. |
| The in-place storm elevation is | 2,900 | which subtracts | 0.410 | inches of precipitable water at | | 60.0 F | |
| The in-place storm elevation is | 2,900 | which subtracts | 0.42 | inches of precipitable water at | | 61.0 F | |
| Basin elevation at | 3,650 | which subtracts | 0.52 | inches of precipitable water at | | 61.0 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.52 | inches of precipitable water at | | 61.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.06 |
| The transposition factor is | 0.91 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 0.96 |

Notes: 24hr ave KP65, KTUS, KLUF

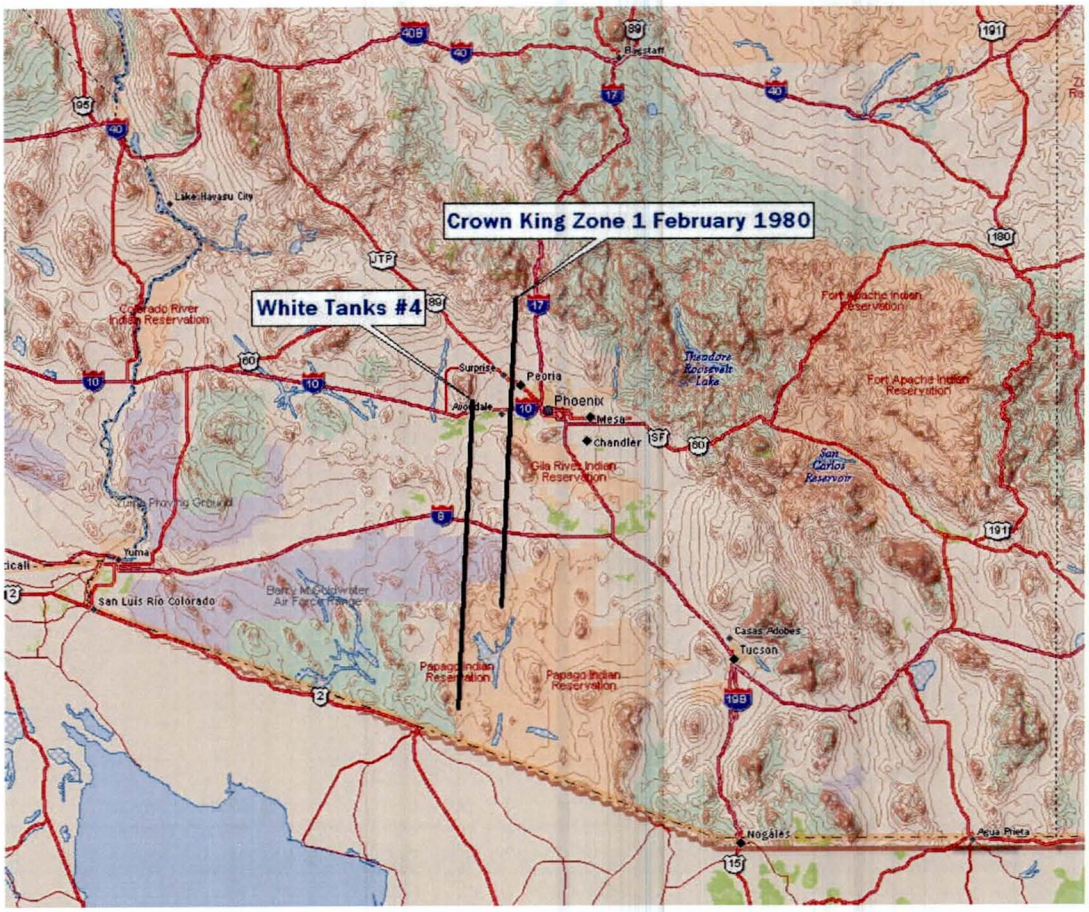
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.8 | 2.3 | 2.8 | 4.3 | 5.7 | - | 6.2 | 6.9 | - | 7.8 |
| 10 sq miles | 0.8 | 2.3 | 2.8 | 4.2 | 5.5 | - | 6.0 | 6.7 | - | 7.5 |
| 100 sq miles | 0.8 | 1.8 | 2.1 | 3.1 | 4.2 | - | 4.6 | 5.0 | - | 5.8 |
| 200 sq miles | 0.4 | 1.6 | 1.7 | 2.6 | 3.6 | - | 3.8 | 4.2 | - | 4.9 |
| 500 sq miles | 0.3 | 1.0 | 1.5 | 2.2 | 2.5 | - | 3.1 | 3.5 | - | 4.0 |
| 1000 sq miles | 0.3 | 1.0 | 1.3 | 1.8 | 2.4 | - | 2.6 | 3.1 | - | 3.5 |
| 2000 sq miles | 0.3 | 0.8 | 1.1 | 1.4 | 2.1 | - | 2.4 | 2.7 | - | 3.2 |
| 5000 sq miles | 0.3 | 0.7 | 0.9 | 1.3 | 1.7 | - | 2.0 | 2.3 | - | 2.7 |
| 10000 sq miles | 0.2 | 0.5 | 0.8 | 1.0 | 1.5 | - | 1.6 | 2.0 | - | 2.3 |
| 20000 sq miles | 0.2 | 0.4 | 0.6 | 0.8 | 1.2 | - | 1.3 | 1.6 | - | 1.8 |

**Adjusteded Storm Depth-Area-Duration**

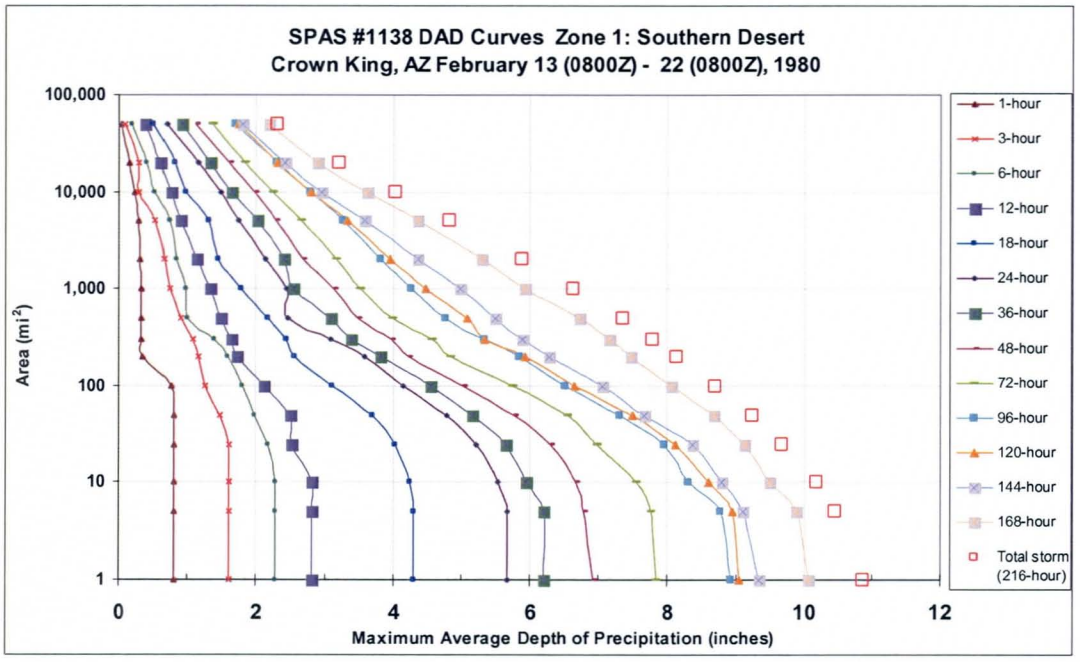
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.8 | 2.2 | 2.7 | - | 5.5 | - | 6.0 | 6.7 | - | 7.6 |
| 10 sq miles | 0.8 | 2.2 | 2.7 | - | 5.3 | - | 5.7 | 6.4 | - | 7.3 |
| 100 sq miles | 0.7 | 1.7 | 2.0 | - | 4.0 | - | 4.4 | 4.8 | - | 5.5 |
| 200 sq miles | 0.3 | 1.5 | 1.7 | - | 3.4 | - | 3.7 | 4.1 | - | 4.7 |
| 500 sq miles | 0.3 | 1.0 | 1.4 | - | 2.4 | - | 3.0 | 3.4 | - | 3.8 |
| 1000 sq miles | 0.3 | 0.9 | 1.3 | - | 2.4 | - | 2.5 | 3.0 | - | 3.4 |
| 2000 sq miles | 0.3 | 0.8 | 1.1 | - | 2.1 | - | 2.3 | 2.6 | - | 3.0 |
| 5000 sq miles | 0.3 | 0.7 | 0.9 | - | 1.7 | - | 1.9 | 2.2 | - | 2.6 |
| 10000 sq miles | 0.2 | 0.5 | 0.7 | - | 1.4 | - | 1.6 | 1.9 | - | 2.2 |
| 20000 sq miles | 0.2 | 0.4 | 0.6 | - | 1.1 | - | 1.3 | 1.5 | - | 1.8 |

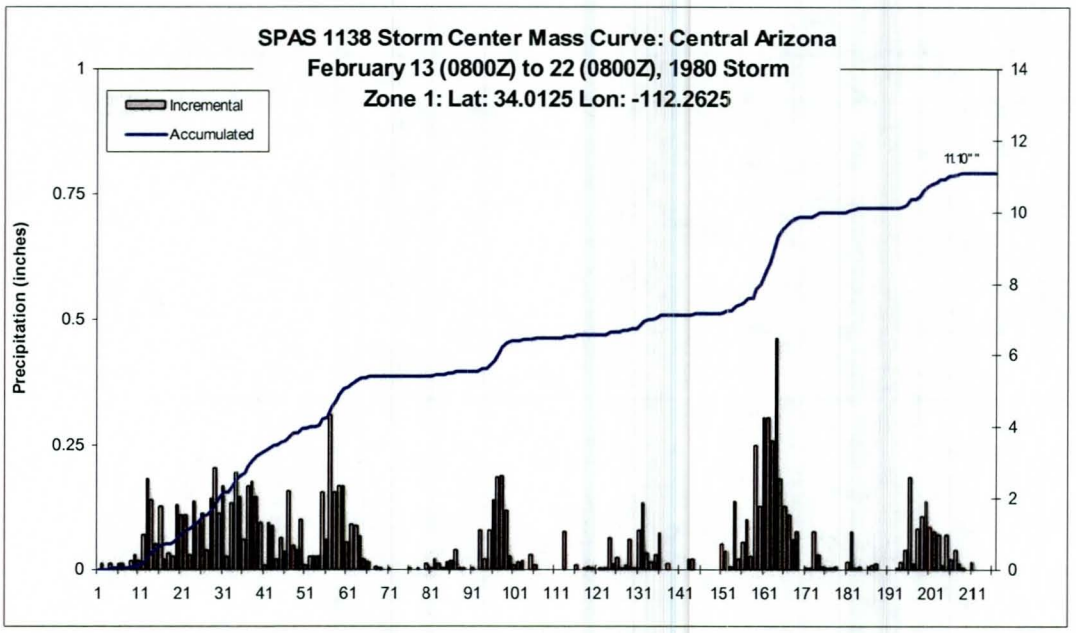
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1138-Crown King Zone 1 | |
| Storm Date(s) | 2/13-22/1980 | |
| Storm Type | General | |
| Storm Location | 34.01 N | 112.26 W |
| Storm Center Elevation | 2900 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 8.09 inches 72 hours 11.10" 216 hrs (SPAS 1138 DAD) | |
| | | |
| Storm Representative Dewpoint | 60.0 F | 24hr ave P65, KTUS, KLUF |
| Storm Representative Dewpoint Location | 32.48 N | 112.35 W |
| In-place Maximum Dewpoint | 61.0 F | |
| Moisture Inflow Vector | S @ 120 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Feb | |
| Transposition Dewpoint Location | 31.98 N | 112.61 W |
| Transposition Maximum Dewpoint | 61.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

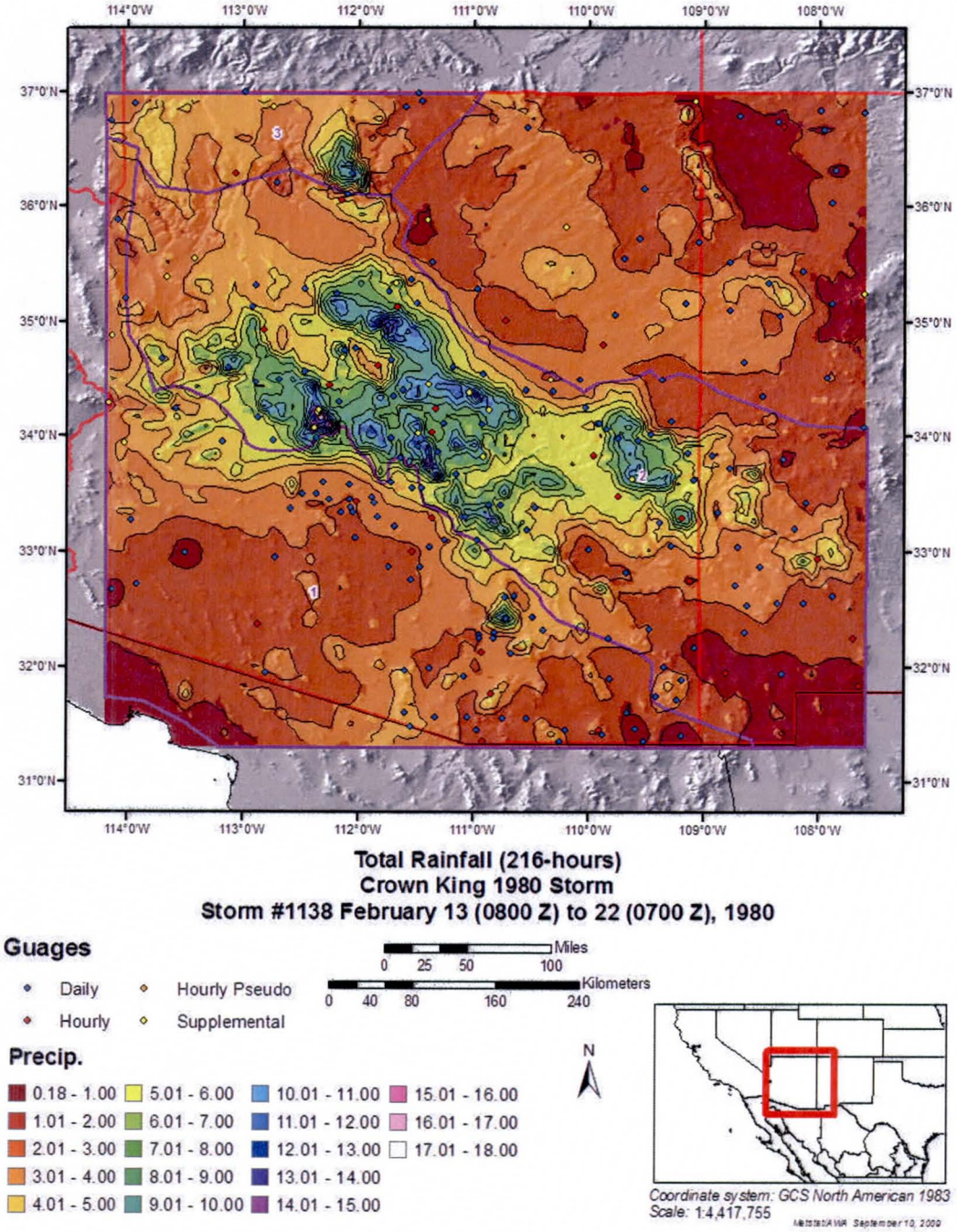

Crown King Zone 1 February 1980
White Tanks #4
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt Lake
Fort Apache Indian Reservation
San Carlos Reservoir
Yuma
San Luis Rio Colorado
Casas Adobes
Tucson
Papago Indian Reservation
Nogales
Agua Prieta

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| | Duration (hours) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area (mi²) | 1 | 3 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | 120 | 144 | 168 | total |
| 0.27 | 1.12 | 1.90 | 2.55 | 3.14 | 4.61 | 5.98 | 6.50 | 7.16 | 8.09 | 9.18 | 9.33 | 9.60 | 10.33 | 11.10 |
| 1 | 0.80 | 1.60 | 2.28 | 2.82 | 4.29 | 5.67 | 6.19 | 6.92 | 7.84 | 8.94 | 9.05 | 9.34 | 10.06 | 10.87 |
| 5 | 0.80 | 1.60 | 2.28 | 2.82 | 4.29 | 5.67 | 6.19 | 6.79 | 7.76 | 8.78 | 8.95 | 9.10 | 9.88 | 10.46 |
| 10 | 0.80 | 1.60 | 2.28 | 2.82 | 4.24 | 5.53 | 5.95 | 6.66 | 7.54 | 8.31 | 8.59 | 8.80 | 9.50 | 10.18 |
| 25 | 0.80 | 1.60 | 2.17 | 2.52 | 4.02 | 5.21 | 5.64 | 6.29 | 6.97 | 7.96 | 8.12 | 8.36 | 9.12 | 9.68 |
| 50 | 0.80 | 1.46 | 1.98 | 2.51 | 3.70 | 4.79 | 5.16 | 5.77 | 6.54 | 7.30 | 7.48 | 7.67 | 8.67 | 9.24 |
| 100 | 0.77 | 1.25 | 1.80 | 2.11 | 3.11 | 4.15 | 4.55 | 5.03 | 5.75 | 6.50 | 6.64 | 7.05 | 8.05 | 8.70 |
| 200 | 0.35 | 1.16 | 1.59 | 1.72 | 2.57 | 3.57 | 3.81 | 4.23 | 4.85 | 5.85 | 5.93 | 6.28 | 7.47 | 8.14 |
| 300 | 0.34 | 1.07 | 1.39 | 1.64 | 2.44 | 3.08 | 3.39 | 3.96 | 4.58 | 5.34 | 5.34 | 5.88 | 7.16 | 7.78 |
| 500 | 0.33 | 0.89 | 0.99 | 1.49 | 2.17 | 2.46 | 3.09 | 3.48 | 3.99 | 4.77 | 5.08 | 5.50 | 6.73 | 7.34 |
| 1,000 | 0.33 | 0.75 | 0.97 | 1.32 | 1.77 | 2.44 | 2.55 | 3.12 | 3.52 | 4.26 | 4.48 | 4.98 | 5.93 | 6.62 |
| 2,000 | 0.32 | 0.67 | 0.84 | 1.13 | 1.44 | 2.13 | 2.41 | 2.68 | 3.16 | 3.82 | 3.95 | 4.36 | 5.30 | 5.88 |
| 5,000 | 0.29 | 0.52 | 0.74 | 0.90 | 1.31 | 1.73 | 2.02 | 2.28 | 2.66 | 3.27 | 3.33 | 3.58 | 4.35 | 4.82 |
| 10,000 | 0.23 | 0.30 | 0.53 | 0.77 | 0.98 | 1.49 | 1.64 | 1.97 | 2.25 | 2.80 | 2.80 | 2.96 | 3.61 | 4.02 |
| 20,000 | 0.16 | 0.29 | 0.42 | 0.60 | 0.83 | 1.16 | 1.33 | 1.60 | 1.83 | 2.30 | 2.30 | 2.43 | 2.89 | 3.20 |
| 50,000 | 0.03 | 0.09 | 0.20 | 0.39 | 0.50 | 0.71 | 0.92 | 1.12 | 1.37 | 1.71 | 1.74 | 1.80 | 2.18 | 2.30 |




SPAS 1138 Storm Center Mass Curve: Central Arizona
February 13 (0800Z) to 22 (0800Z), 1980 Storm
Zone 1: Lat: 34.0125 Lon: -112.2625
Incremental
Accumulated
Precipitation (inches)
1
0.75
0.5
0.25
0
14
12
10
8
6
4
2
0
1 11 21 31 41 51 61 71 81 91 101 111 121 131 141 151 161 171 181 191 201 211


114°0'W
113°0'W
112°0'W
111°0'W
110°0'W
109°0'W
108°0'W
37°0'N
36°0'N
35°0'N
34°0'N
33°0'N
32°0'N
31°0'N
Total Rainfall (216-hours)
Crown King 1980 Storm
Storm #1138 February 13 (0800 Z) to 22 (0700 Z), 1980
Guages
Daily
Hourly
Hourly Pseudo
Supplemental
Miles
0 25 50 100
Kilometers
0 40 80 160 240
N
Precip.
0.18 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00
13.01 - 14.00
14.01 - 15.00
15.01 - 16.00
16.01 - 17.00
17.01 - 18.00
Coordinate system: GCS North American 1983
Scale: 1:4,417,755

# Harquahala Valley, AZ

**September 1, 1984**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1122-Harquahala Valley |
| Storm Date: | September 1, 1984 |
| AWA Analysis Date: | 11/17/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 15-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 33.49 N | 113.25 W |
| Storm Rep dew point location | 33.17N | 114.72 W |
| Transposition dewpoint location | 33.18 N | 113.94 W |
| Basin location | 33.50 N | 112.52 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | WSW @ 85 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 1,200 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The storm representative dew point is | 77.0 F | with total precipitable water above sea level of | | | | 3.14 | inches. |
| The in-place maximum dew point is | 82.0 F | with total precipitable water above sea level of | | | | 3.92 | inches. |
| The transpositioned maximum dew point is | 82.0 F | with total precipitable water above sea level of | | | | 3.92 | inches. |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 77.0 F | |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 82.0 F | |
| Basin elevation at | 0 | which subtracts | 0.00 | inches of precipitable water at | | 82.0 F | |
| The inflow barrier height/basin elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 82.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.25 |
| The transposition factor is | 1.00 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.25 |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. Ratios for 1 to 10, 50, 100, 200, and 500 sqmi taken from SPAS 1086 storm analysis because of lack of data on storm. 24hr values use 6hr ratios. 11" total storm valuye invalidated based on further analysuis.

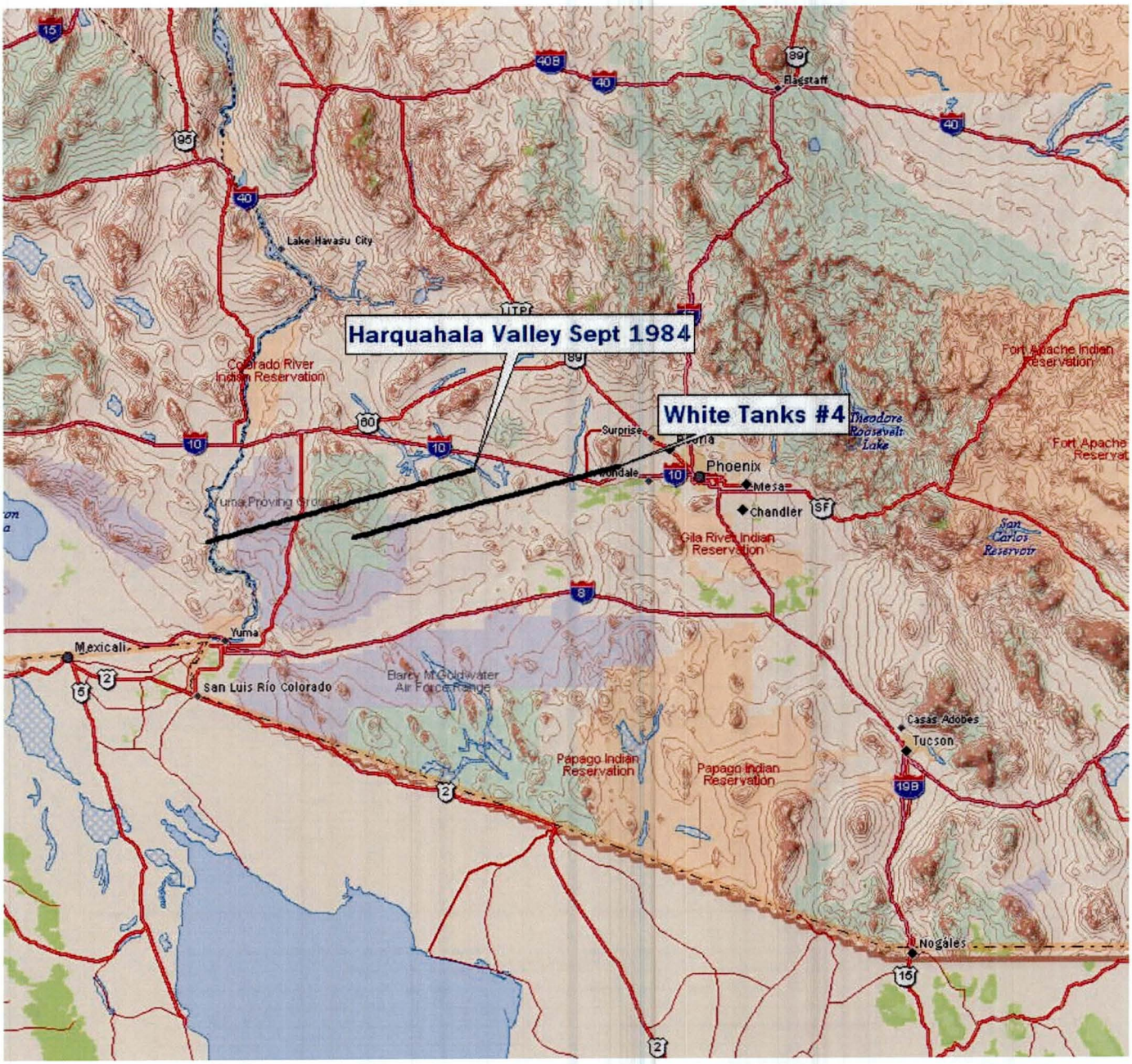
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 3.1 | 5.2 | 7.4 | 7.7 | 7.7 | 7.7 | - | - | 7.7 | - |
| 10 sq miles | 2.6 | 4.7 | 6.5 | 6.5 | 6.5 | 6.5 | - | - | 6.5 | - |
| 50 sq miles | 1.8 | 3.5 | 4.9 | 4.9 | 4.9 | 4.9 | - | - | 4.9 | - |
| 100 sq miles | 1.4 | 2.8 | 4.0 | 4.1 | 4.1 | 4.1 | - | - | 4.1 | - |
| 200 sq miles | 1.0 | 2.2 | 3.1 | 3.1 | 3.2 | 3.2 | - | - | 3.3 | - |
| 500 sq miles | 0.6 | 1.4 | 2.0 | 2.1 | 2.1 | 2.2 | - | - | 2.2 | - |
| 1000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

**Adjusted Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 3.8 | 6.5 | 9.2 | 9.6 | 9.6 | 9.6 | - | - | 9.6 | - |
| 10 sq miles | 3.2 | 5.8 | 8.2 | 8.2 | 8.2 | 8.2 | - | - | 8.2 | - |
| 50 sq miles | 2.2 | 4.4 | 6.2 | 6.2 | 6.2 | 6.2 | - | - | 6.2 | - |
| 100 sq miles | 1.7 | 3.5 | 4.9 | 5.1 | 5.1 | 5.1 | - | - | 5.1 | - |
| 200 sq miles | 1.3 | 2.7 | 3.8 | 3.8 | 4.0 | 4.0 | - | - | 4.1 | - |
| 500 sq miles | 0.7 | 1.7 | 2.5 | 2.6 | 2.7 | 2.8 | - | - | 2.8 | - |
| 1000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

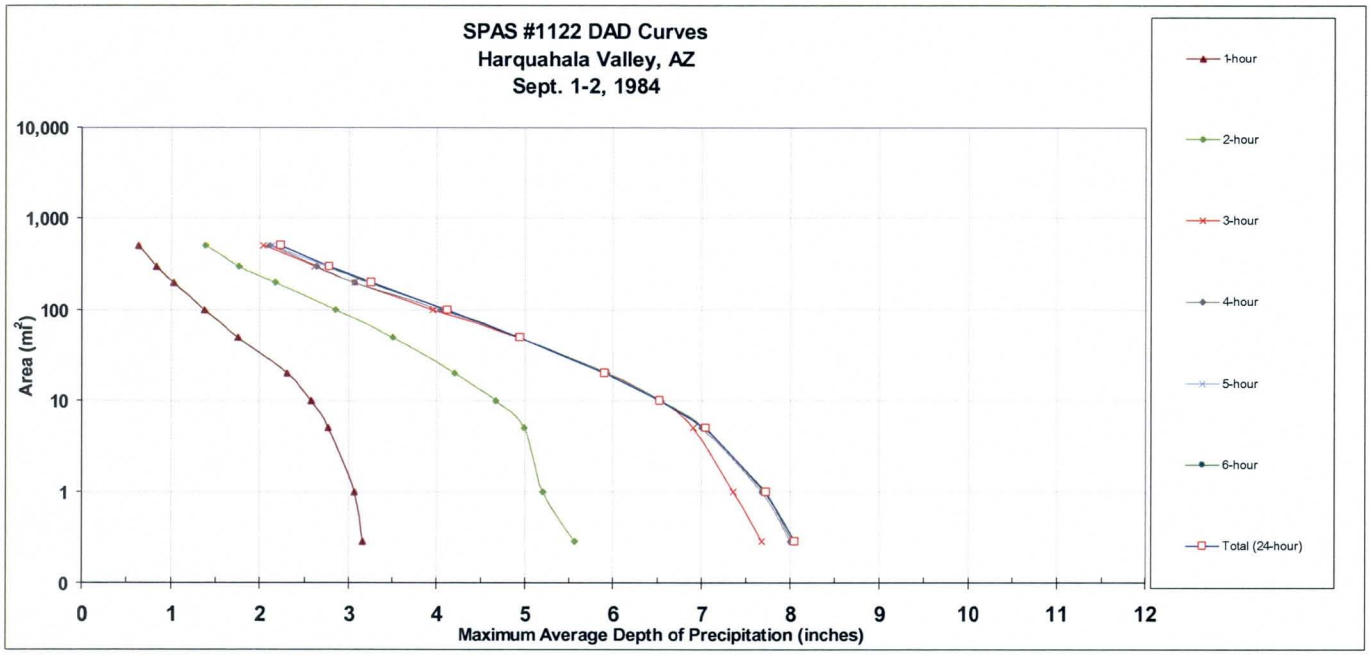
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1122-Harquahala Valley | |
| Storm Date(s) | 9/1/84 | |
| Storm Type | Local Storm | |
| Storm Location | 33.49 N | 113.25 W |
| Storm Center Elevation | 1200 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 4.34 inches 1 hour 8.98" in 6hrs (SPAS 1094 DAD) | |
| | | |
| Storm Representative Dewpoint | 77.0 F | 3hr ave KYUM, KBLH |
| Storm Representative Dewpoint Location | 33.17N | 114.72 W |
| In-place Maximum Dewpoint | 82.0 F | |
| Moisture Inflow Vector | WSW @ 85 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 33.18 N | 113.94 W |
| Transposition Maximum Dewpoint | 82.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.25 | |

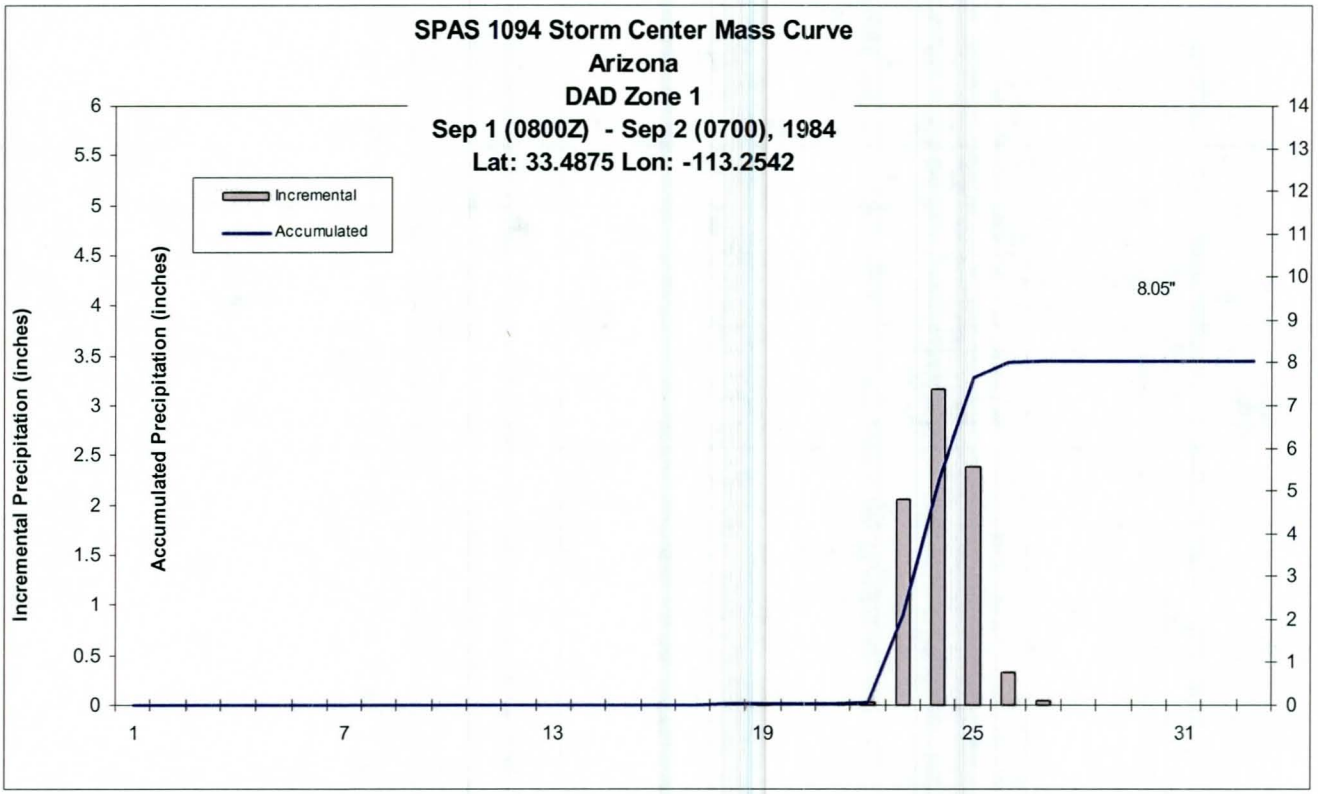

Harquahala Valley Sept 1984
White Tanks #4
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Fort Apache Indian Reservation
Theodore Roosevelt Lake
Surprise
Peoria
Phoenix
Mesa
Chandler
Gila River Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
Mexicali
San Luis Río Colorado
Barry M Goldwater Air Force Range
Casas Adobes
Tucson
Papago Indian Reservation
Papago Indian Reservation
Nogales

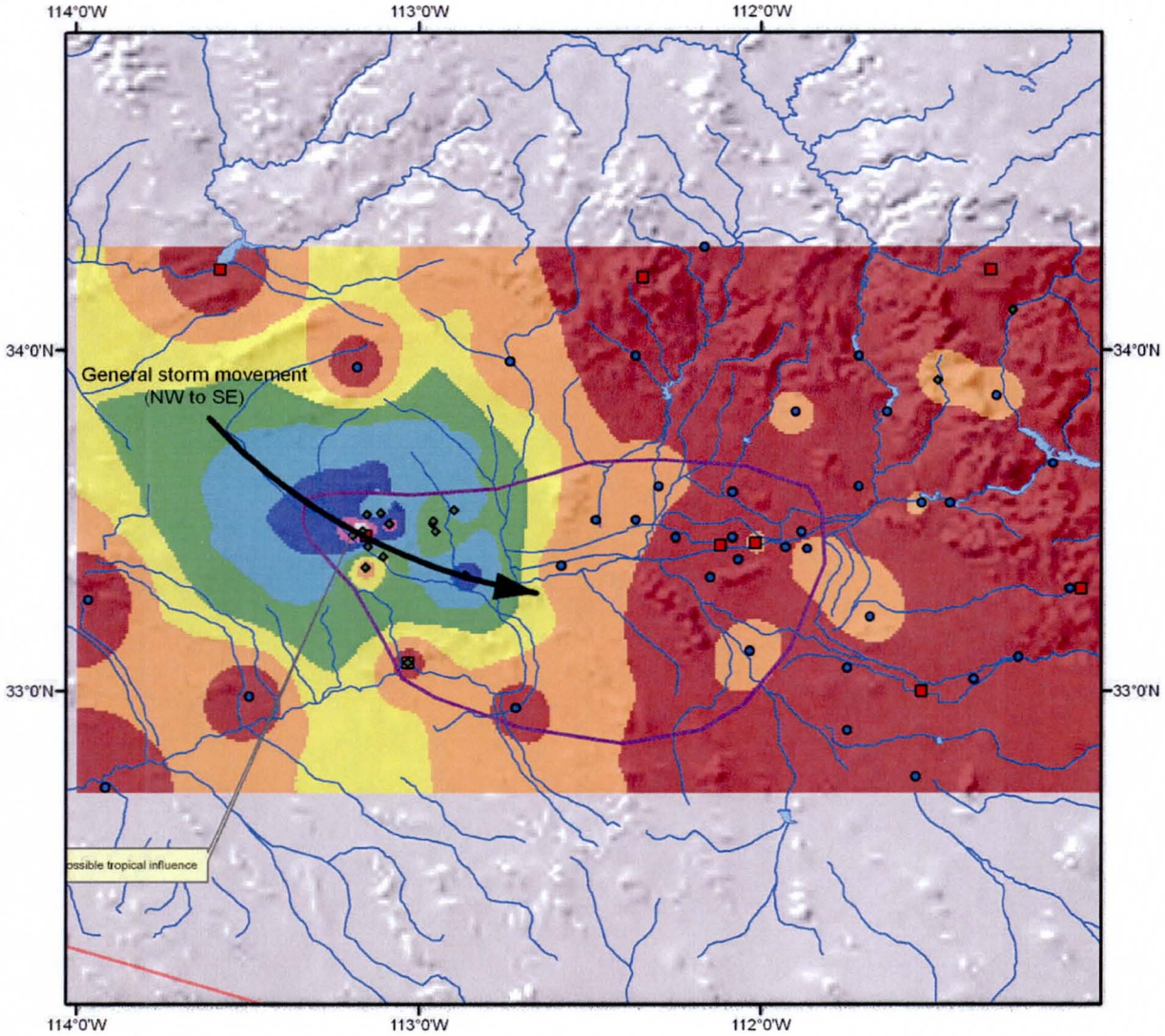
## SPAS Storm 1122 - Harquahala Valley, AZ Sept. 1-2, 1984

### MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| | Duration (hours) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($mi^2$) | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | total (24hr) |
| **0.28** | 3.16 | 5.57 | 7.68 | 8.00 | 8.02 | 8.02 | | | | | | | 8.05 |
| **1** | 3.07 | 5.21 | 7.35 | 7.67 | 7.70 | 7.70 | | | | | | | 7.72 |
| **5** | 2.76 | 4.99 | 6.91 | 7.00 | 7.02 | 7.02 | | | | | | | 7.05 |
| **10** | 2.58 | 4.67 | 6.53 | 6.53 | 6.53 | 6.53 | | | | | | | 6.52 |
| **20** | 2.30 | 4.21 | 5.92 | 5.93 | 5.93 | 5.93 | | | | | | | 5.90 |
| **50** | 1.75 | 3.51 | 4.93 | 4.93 | 4.93 | 4.93 | | | | | | | 4.94 |
| **100** | 1.37 | 2.84 | 3.96 | 4.05 | 4.09 | 4.11 | | | | | | | 4.12 |
| **200** | 1.02 | 2.17 | 3.06 | 3.06 | 3.22 | 3.24 | | | | | | | 3.25 |
| **300** | 0.83 | 1.76 | 2.61 | 2.64 | 2.74 | 2.77 | | | | | | | 2.78 |
| **500** | 0.63 | 1.38 | 2.04 | 2.10 | 2.14 | 2.22 | | | | | | | 2.23 |




SPAS 1094 Storm Center Mass Curve
Arizona
DAD Zone 1
Sep 1 (0800Z) - Sep 2 (0700), 1984
Lat: 33.4875 Lon: -113.2542
Incremental
Accumulated
8.05"
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1
7
13
19
25
31




**SPAS Storm #1122**
**HARQUAHALA VALLEY, AZ**
**9/1-3/1984**

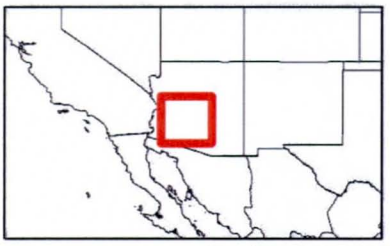
Miles: 0 12.5 25 50
Kilometers: 0 12.5 25 50 75

N

**Precipitation (inches)**

- 0.01 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00
- 6.01 - 7.00
- 7.01 - 8.00

- Daily
- Hourly
- Hourly pseudo
- Supplemental



Metstat/AWA November 18, 2009

# Knoles Hole Spring, AZ

**January 5-10, 1993**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1139-Knoles Hole Spring-Zo |
| Storm Date: | 1/5-10/1993 |
| AWA Analysis Date: | 10/16/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 20-Dec

| | Lat | Long |
|---|---|---|
| Storm center location | 33.04 N | 111.00 W |
| Storm Rep dew point location | 31.95 N | 110.91 W |
| Transposition dewpoint location | 32.46 N | 112.45 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 75 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,900 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 60.0 F | with total precipitable water above sea level of | | | 1.38 | inches. |
| The in-place maximum dew point is | 62.5 F | with total precipitable water above sea level of | | | 1.60 | inches. |
| The transpositioned maximum dew point is | 62.5 F | with total precipitable water above sea level of | | | 1.49 | inches. |
| The in-place storm elevation is | 2,900 | which subtracts | 0.41 | inches of precipitable water at | 60.0 F | |
| The in-place storm elevation is | 2,900 | which subtracts | 0.45 | inches of precipitable water at | 62.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.55 | inches of precipitable water at | 62.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.55 | inches of precipitable water at | 62.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.19 |
| The transposition factor is | 0.81 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 0.97 |

Notes: 24hr ave from KTUS, KDMA, KDUG

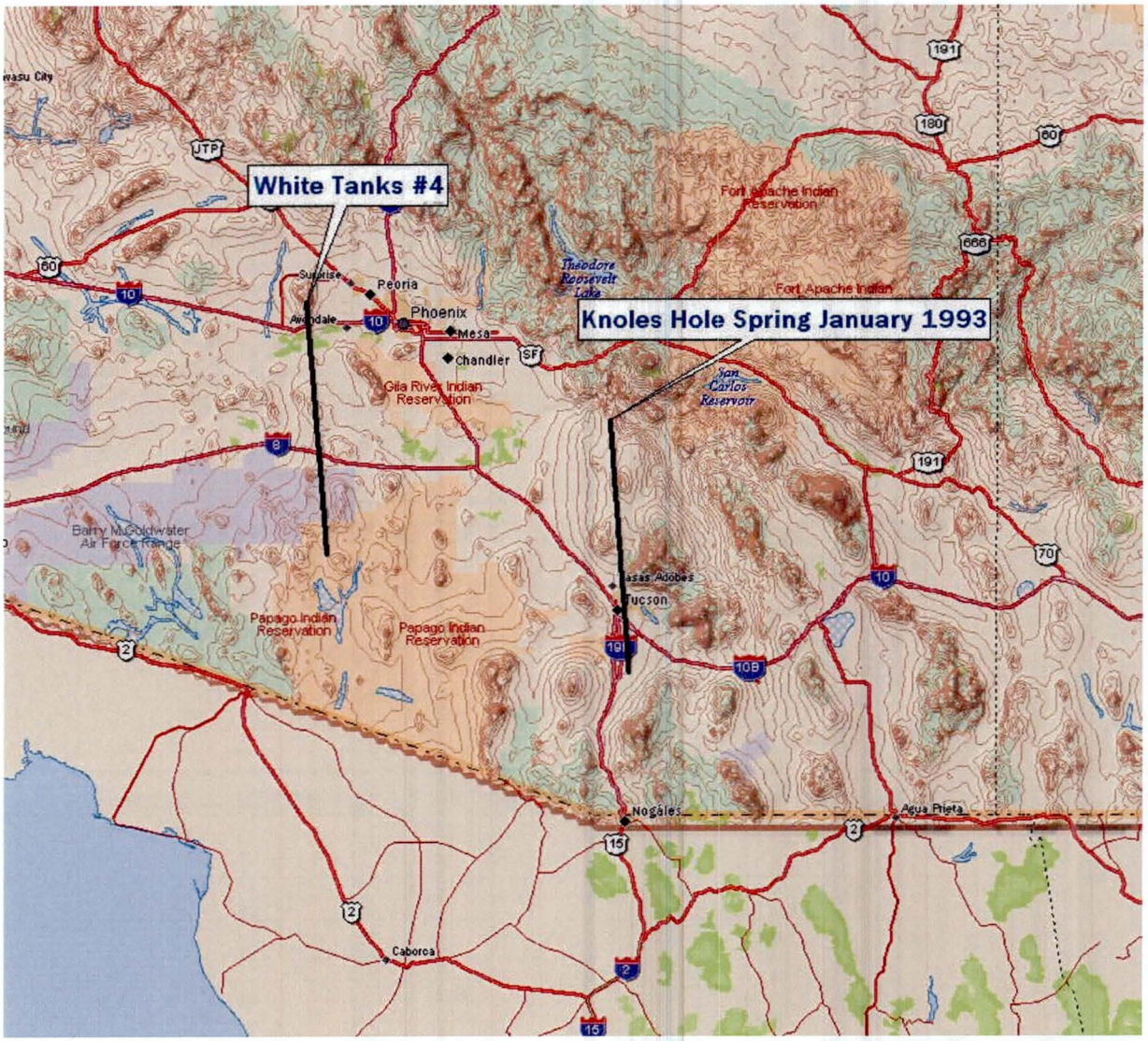
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.4 | 2.0 | 3.3 | 5.7 | 5.4 | - | 7.8 | 6.3 | - | 6.7 |
| 10 sq miles | 0.4 | 1.8 | 3.2 | 5.6 | 5.3 | - | 7.5 | 6.1 | - | 6.4 |
| 100 sq miles | 0.4 | 1.5 | 2.1 | 4.0 | 4.0 | - | 5.7 | 4.5 | - | 4.9 |
| 200 sq miles | 0.4 | 1.3 | 1.6 | 3.5 | 3.3 | - | 4.7 | 3.9 | - | 4.3 |
| 500 sq miles | 0.4 | 1.1 | 1.3 | 2.7 | 2.7 | - | 3.9 | 3.3 | - | 3.5 |
| 1000 sq miles | 0.3 | 0.9 | 1.1 | 2.4 | 2.4 | - | 3.4 | 2.9 | - | 3.0 |
| 2000 sq miles | 0.2 | 0.8 | 1.0 | 2.1 | 2.0 | - | 2.9 | 2.4 | - | 2.6 |
| 5000 sq miles | 0.2 | 0.6 | 0.7 | 1.6 | 1.6 | - | 2.3 | 2.0 | - | 2.1 |
| 10000 sq miles | 0.2 | 0.5 | 0.7 | 1.3 | 1.3 | - | 1.9 | 1.6 | - | 1.8 |
| 20000 sq miles | 0.2 | 0.4 | 0.5 | 1.0 | 1.1 | - | 1.5 | 1.3 | - | 1.4 |

**Adjusteded Storm Depth-Area-Duration**

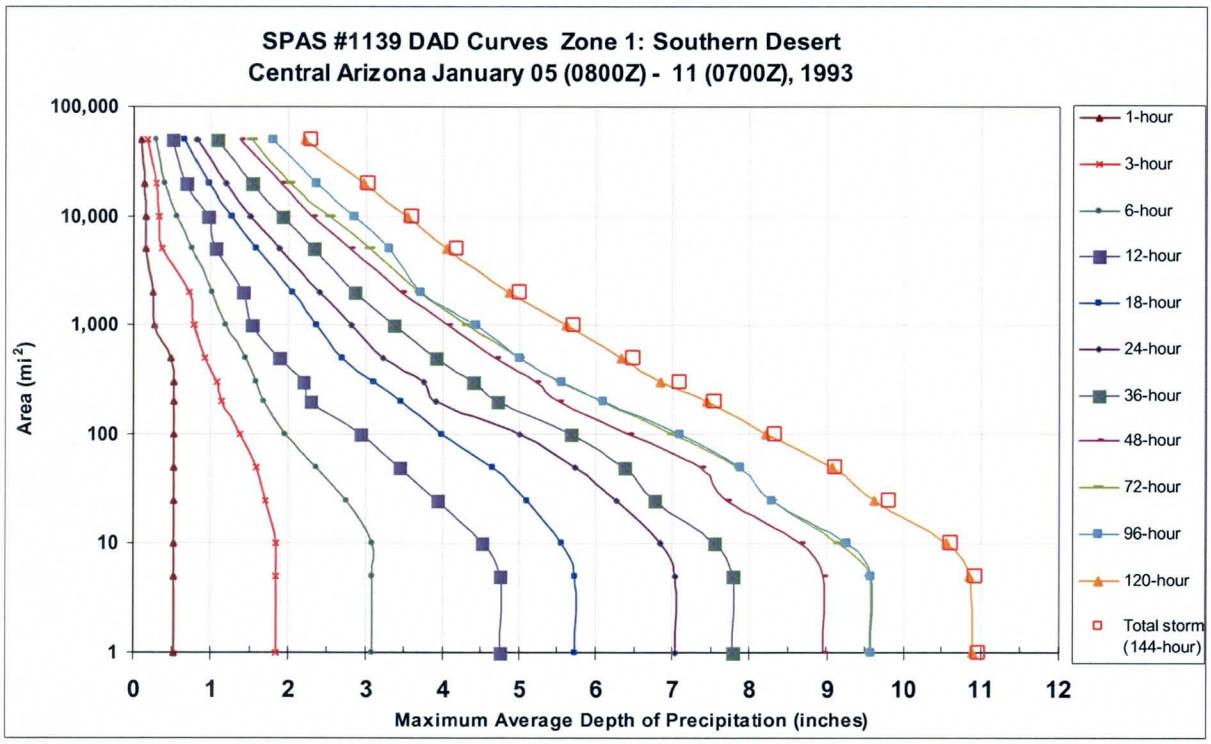
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.4 | 1.9 | 3.2 | - | 5.2 | - | 7.5 | 6.1 | - | 6.5 |
| 10 sq miles | 0.4 | 1.8 | 3.1 | - | 5.1 | - | 7.3 | 5.9 | - | 6.2 |
| 100 sq miles | 0.4 | 1.4 | 2.0 | - | 3.9 | - | 5.5 | 4.4 | - | 4.7 |
| 200 sq miles | 0.4 | 1.3 | 1.6 | - | 3.2 | - | 4.6 | 3.8 | - | 4.2 |
| 500 sq miles | 0.4 | 1.0 | 1.3 | - | 2.6 | - | 3.8 | 3.2 | - | 3.4 |
| 1000 sq miles | 0.3 | 0.9 | 1.1 | - | 2.3 | - | 3.3 | 2.8 | - | 2.9 |
| 2000 sq miles | 0.2 | 0.8 | 1.0 | - | 1.9 | - | 2.8 | 2.3 | - | 2.5 |
| 5000 sq miles | 0.2 | 0.6 | 0.7 | - | 1.6 | - | 2.2 | 1.9 | - | 2.0 |
| 10000 sq miles | 0.2 | 0.5 | 0.6 | - | 1.3 | - | 1.9 | 1.6 | - | 1.7 |
| 20000 sq miles | 0.2 | 0.4 | 0.5 | - | 1.1 | - | 1.5 | 1.3 | - | 1.4 |

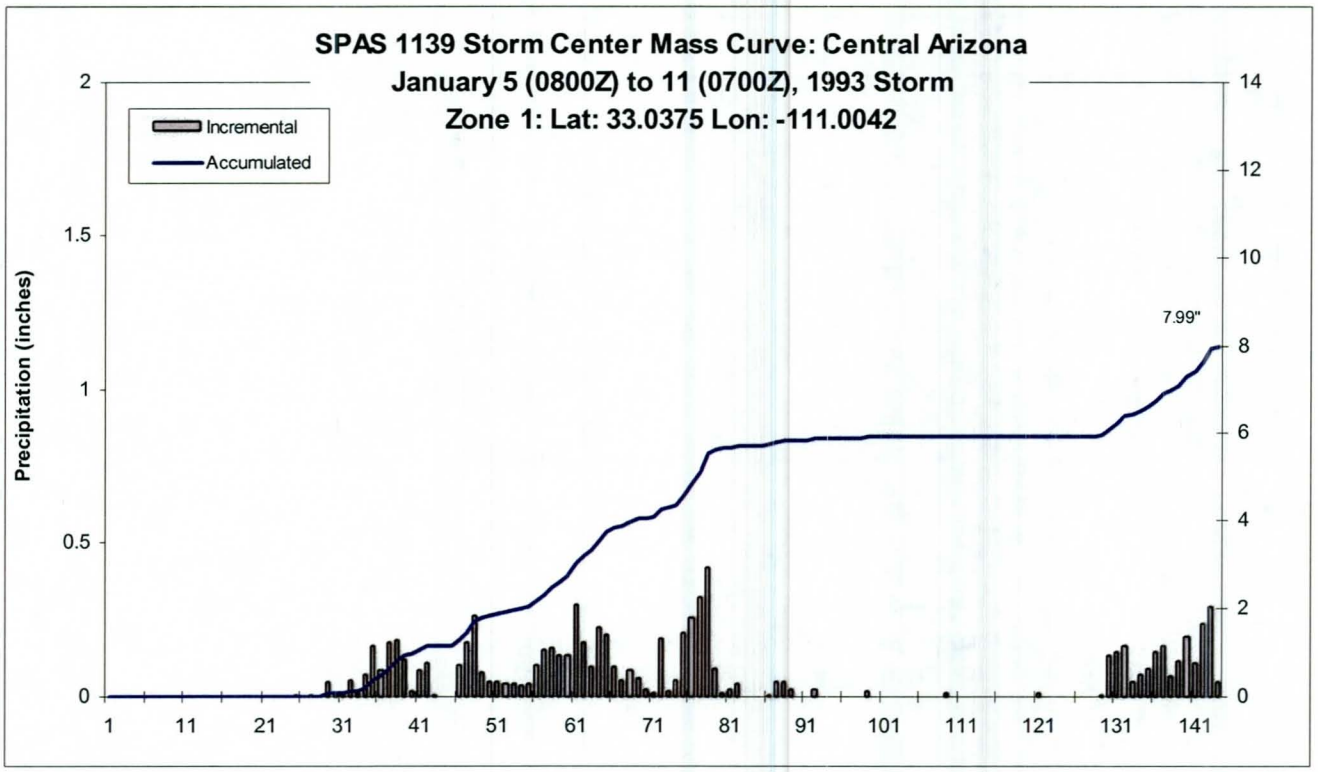
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1139-Knoles Hole Spring-Zone 1 | |
| Storm Date(s) | 1/5-10/1993 | |
| Storm Type | General | |
| Storm Location | 33.04 N | 111.00 W |
| Storm Center Elevation | 2900 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 7.99 inches 72 hours (SPAS 1139 DAD) | |
| | | |
| Storm Representative Dewpoint | 60.0 F | 24hr ave KTUS, KDMA, KDUG |
| Storm Representative Dewpoint Location | 31.95 N | 110.91 W |
| In-place Maximum Dewpoint | 62.5 F | |
| Moisture Inflow Vector | S @ 75 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 20-Dec | |
| Transposition Dewpoint Location | 32.46 N | 112.45 W |
| Transposition Maximum Dewpoint | 62.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

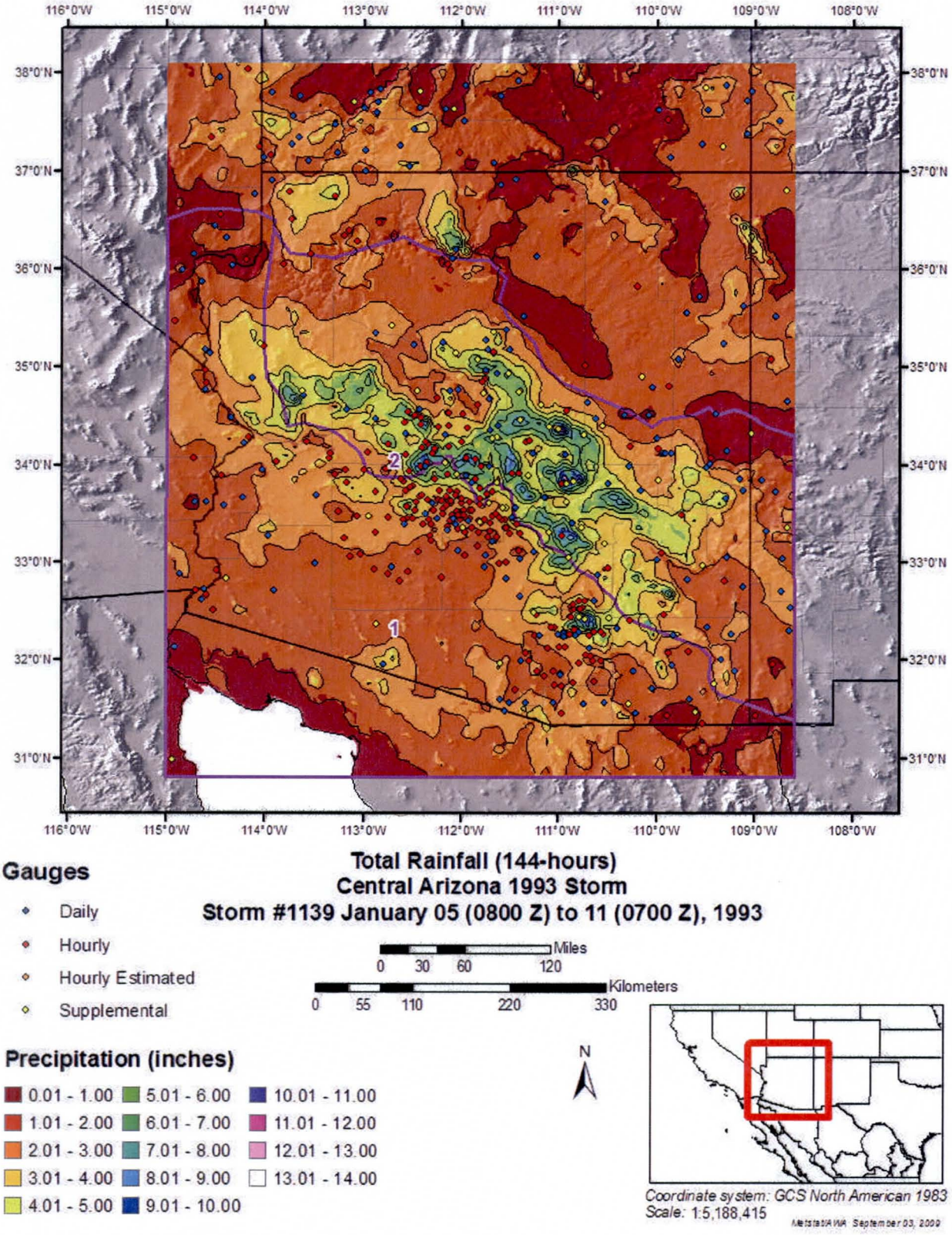

White Tanks #4
Knoles Hole Spring January 1993
Peoria
Phoenix
Mesa
Chandler
Tucson
Nogales
Agua Prieta
Caborca
Gila River Indian Reservation
Papago Indian Reservation
Papago Indian Reservation
Fort Apache Indian Reservation
Fort Apache Indian
Theodore Roosevelt Lake
San Carlos Reservoir
Barry M. Goldwater Air Force Range

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 6 | 12 | 18 | 24 | 36 | 48 | 72 | 96 | 120 | total |
| **0.27** | 0.92 | 2.07 | 3.35 | 4.98 | 5.96 | 7.25 | 7.99 | 9.17 | 9.76 | 9.81 | 11.08 | 11.15 |
| **1** | 0.52 | 1.84 | 3.08 | 4.74 | 5.73 | 7.03 | 7.77 | 8.96 | 9.55 | 9.57 | 10.88 | 10.97 |
| **5** | 0.52 | 1.84 | 3.08 | 4.74 | 5.73 | 7.03 | 7.77 | 8.96 | 9.55 | 9.57 | 10.85 | 10.92 |
| **10** | 0.52 | 1.84 | 3.08 | 4.51 | 5.55 | 6.85 | 7.54 | 8.66 | 9.15 | 9.27 | 10.56 | 10.62 |
| **25** | 0.52 | 1.70 | 2.75 | 3.93 | 5.11 | 6.27 | 6.77 | 7.71 | 8.28 | 8.28 | 9.62 | 9.81 |
| **50** | 0.52 | 1.58 | 2.37 | 3.43 | 4.66 | 5.72 | 6.38 | 7.36 | 7.86 | 7.87 | 9.06 | 9.11 |
| **100** | 0.52 | 1.36 | 1.96 | 2.94 | 3.98 | 5.00 | 5.67 | 6.43 | 7.00 | 7.09 | 8.21 | 8.33 |
| **200** | 0.52 | 1.14 | 1.68 | 2.29 | 3.46 | 3.90 | 4.71 | 5.51 | 6.08 | 6.09 | 7.44 | 7.55 |
| **300** | 0.52 | 1.08 | 1.59 | 2.19 | 3.11 | 3.76 | 4.40 | 5.21 | 5.53 | 5.55 | 6.85 | 7.09 |
| **500** | 0.48 | 0.92 | 1.45 | 1.87 | 2.70 | 3.23 | 3.91 | 4.70 | 5.00 | 5.01 | 6.34 | 6.48 |
| **1,000** | 0.27 | 0.79 | 1.20 | 1.53 | 2.37 | 2.81 | 3.37 | 4.07 | 4.32 | 4.43 | 5.61 | 5.71 |
| **2,000** | 0.25 | 0.73 | 1.02 | 1.41 | 2.05 | 2.40 | 2.85 | 3.46 | 3.69 | 3.72 | 4.86 | 5.01 |
| **5,000** | 0.16 | 0.37 | 0.76 | 1.05 | 1.59 | 1.88 | 2.32 | 2.79 | 3.04 | 3.30 | 4.05 | 4.18 |
| **10,000** | 0.15 | 0.33 | 0.57 | 0.96 | 1.28 | 1.50 | 1.91 | 2.30 | 2.54 | 2.85 | 3.53 | 3.60 |
| **20,000** | 0.14 | 0.29 | 0.42 | 0.69 | 0.98 | 1.20 | 1.52 | 1.89 | 2.02 | 2.37 | 2.98 | 3.03 |
| **50,000** | 0.09 | 0.18 | 0.30 | 0.50 | 0.66 | 0.83 | 1.07 | 1.37 | 1.52 | 1.79 | 2.20 | 2.29 |




SPAS 1139 Storm Center Mass Curve: Central Arizona
January 5 (0800Z) to 11 (0700Z), 1993 Storm
Zone 1: Lat: 33.0375 Lon: -111.0042
Incremental
Accumulated
Precipitation (inches)
7.99"
0
0.5
1
1.5
2
0
2
4
6
8
10
12
14
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141


116°0'W
115°0'W
114°0'W
113°0'W
112°0'W
111°0'W
110°0'W
109°0'W
108°0'W
38°0'N
37°0'N
36°0'N
35°0'N
34°0'N
33°0'N
32°0'N
31°0'N
2
1
Gauges
Daily
Hourly
Hourly Estimated
Supplemental
Total Rainfall (144-hours)
Central Arizona 1993 Storm
Storm #1139 January 05 (0800 Z) to 11 (0700 Z), 1993
Miles
0 30 60 120
Kilometers
0 55 110 220 330
N
Precipitation (inches)
0.01 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00
13.01 - 14.00
Coordinate system: GCS North American 1983
Scale: 1:5,188,415
MetstatAWA September 03, 2009

# Tucson, AZ

**September 3, 1996**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1086-Tucson |
| Storm Date: | September 3, 1996 |
| AWA Analysis Date: | 11/2/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 18-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 32.39 N | 110.80 W |
| Storm Rep dew point location | 32.65N | 114.60 W |
| Transposition dewpoint location | 33.75 N | 116.36 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | W @ 220 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 5,750 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 77.5 F | with total precipitable water above sea level of | | | 3.21 | inches. |
| The in-place maximum dew point is | 82.0 F | with total precipitable water above sea level of | | | 3.92 | inches. |
| The transpositioned maximum dew point is | 81.0 F | with total precipitable water above sea level of | | | 3.76 | inches. |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 77.5 F | |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 82.0 F | |
| Basin elevation at | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.0 F | |
| The inflow barrier height/basin elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.22 |
| The transposition factor is | 0.96 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.17 |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. KYUM 3hr ave on the 2nd from 9-12Z

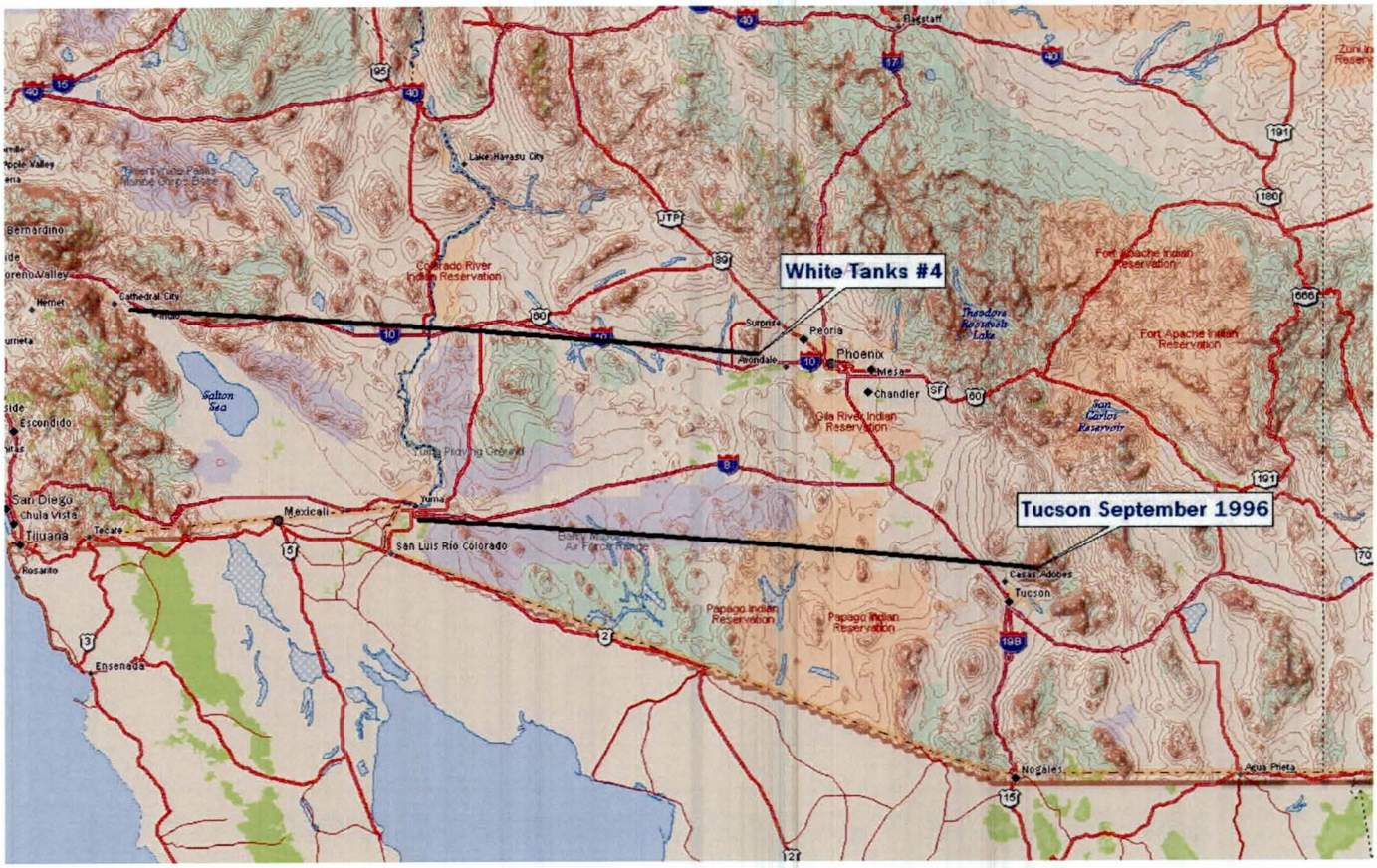
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 3.2 | 4.8 | 5.2 | 5.5 | 5.5 | 5.5 | 6.9 | - | - | - |
| 10 sq miles | 2.7 | 4.3 | 4.7 | 4.6 | 4.6 | 4.6 | 5.9 | - | - | - |
| 50 sq miles | 1.8 | 3.2 | 3.5 | 3.5 | 3.5 | 3.5 | 4.1 | - | - | - |
| 100 sq miles | 1.4 | 2.6 | 2.8 | 2.9 | 2.9 | 2.9 | 3.2 | - | - | - |
| 200 sq miles | 1.1 | 2.0 | 2.2 | 2.1 | 2.3 | 2.3 | 2.6 | - | - | - |
| 500 sq miles | 0.7 | 1.3 | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | - | - | - |
| 1000 sq miles | 0.4 | 0.8 | 0.9 | 1.0 | 1.0 | 1.1 | 1.2 | - | - | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

**Adjusted Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 3.8 | 5.6 | 6.1 | 6.4 | 6.4 | 6.4 | 8.1 | - | - | - |
| 10 sq miles | 3.2 | 5.0 | 5.4 | 5.4 | 5.4 | 5.4 | 6.9 | - | - | - |
| 50 sq miles | 2.1 | 3.8 | 4.1 | 4.1 | 4.1 | 4.1 | 4.8 | - | - | - |
| 100 sq miles | 1.7 | 3.1 | 3.3 | 3.4 | 3.4 | 3.4 | 3.8 | - | ` | - |
| 200 sq miles | 1.3 | 2.3 | 2.6 | 2.5 | 2.7 | 2.7 | 3.0 | - | - | - |
| 500 sq miles | 0.8 | 1.5 | 1.7 | 1.8 | 1.8 | 1.9 | 1.9 | - | - | - |
| 1000 sq miles | 0.5 | 1.0 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | - | - | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

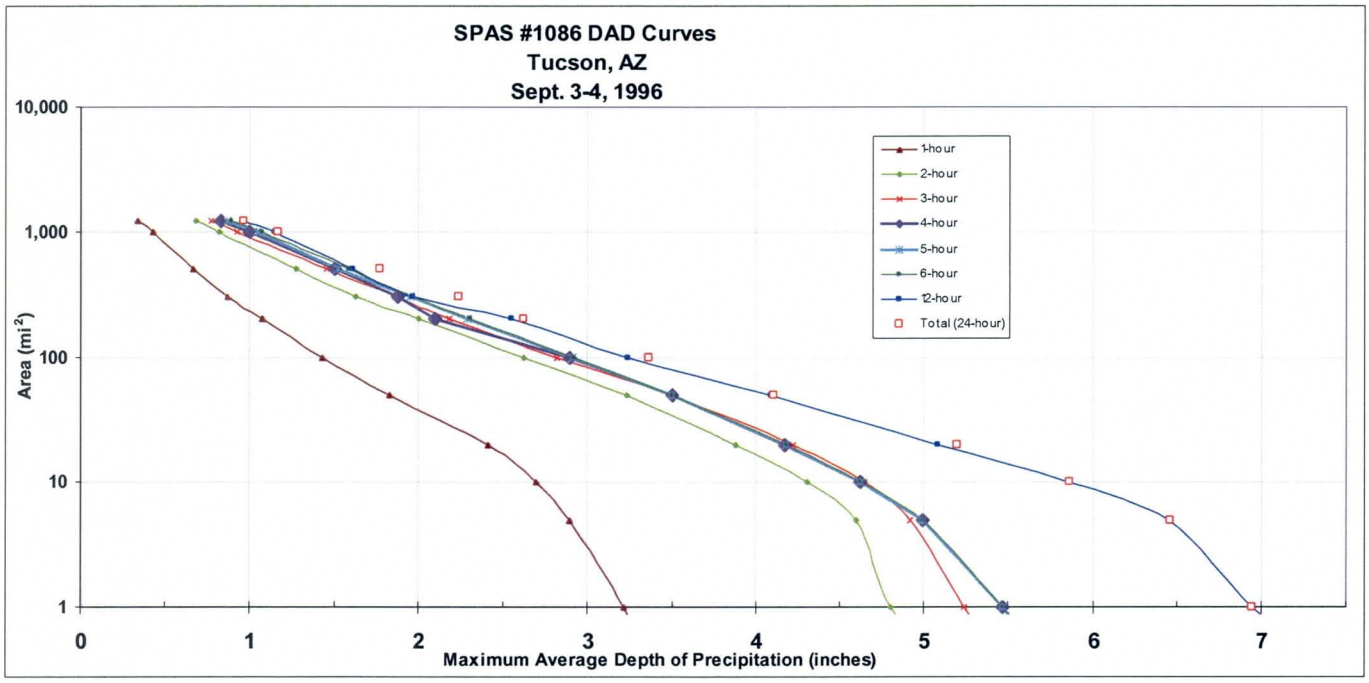
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1086-Tucson | |
| Storm Date(s) | 9/3/96 | |
| Storm Type | Local Storm | |
| Storm Location | 32.39 N | 110.80 W |
| Storm Center Elevation | 5750 | orographic |
| Precipitation Total & Duration (10 sq mi) | 3.31 inches 1 hour 5.47" in 3hrs (SPAS 1086 DAD) | |
| | | |
| Storm Representative Dewpoint | 77.5 F | 3hr ave KYUM |
| Storm Representative Dewpoint Location | 32.65N | 114.60 W |
| In-place Maximum Dewpoint | 82.0 F | |
| Moisture Inflow Vector | W @ 220 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 18-Aug | |
| Transposition Dewpoint Location | 33.75 N | 116.36 W |
| Transposition Maximum Dewpoint | 81.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.17 | |

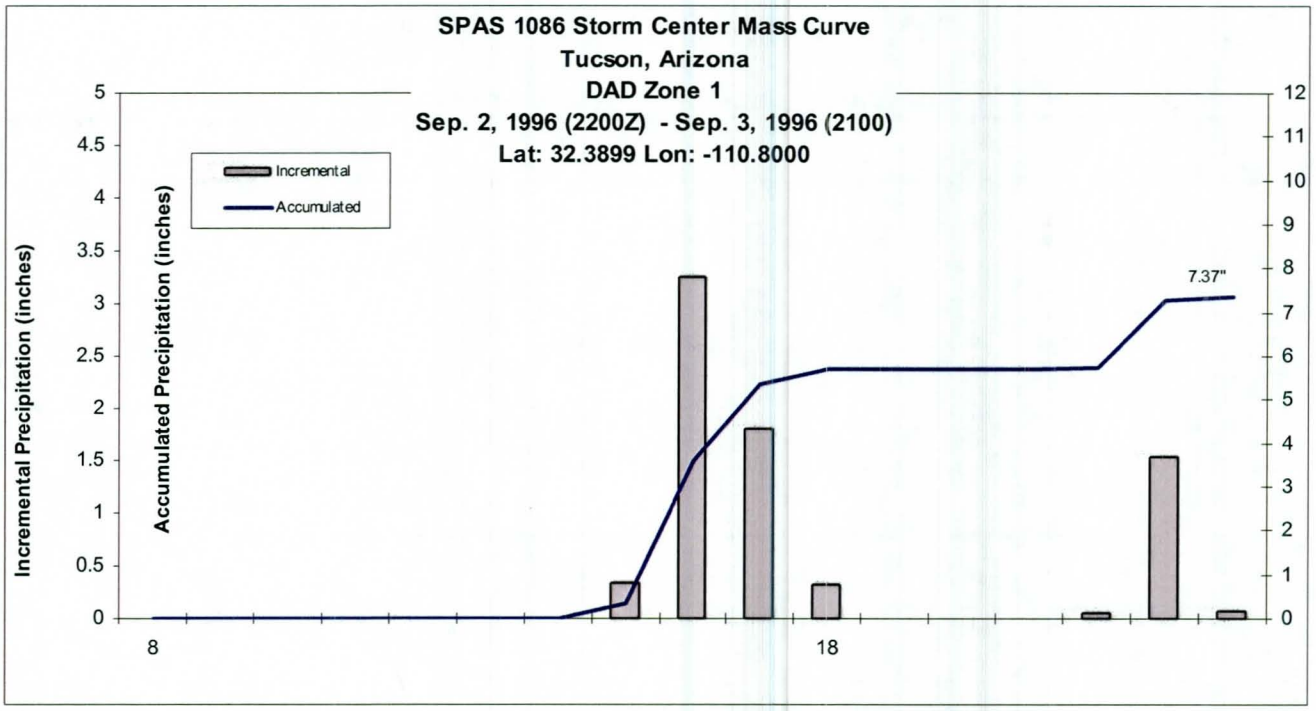

White Tanks #4
Tucson September 1996
Flagstaff
Lake Havasu City
Cathedral City
Hemet
Bernardino
Moreno Valley
Escondido
San Diego
Chula Vista
Tijuana
Tecate
Rosarito
Ensenada
Mexicali
Yuma
San Luis Rio Colorado
Salton Sea
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt Lake
San Carlos Reservoir
Fort Apache Indian Reservation
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta

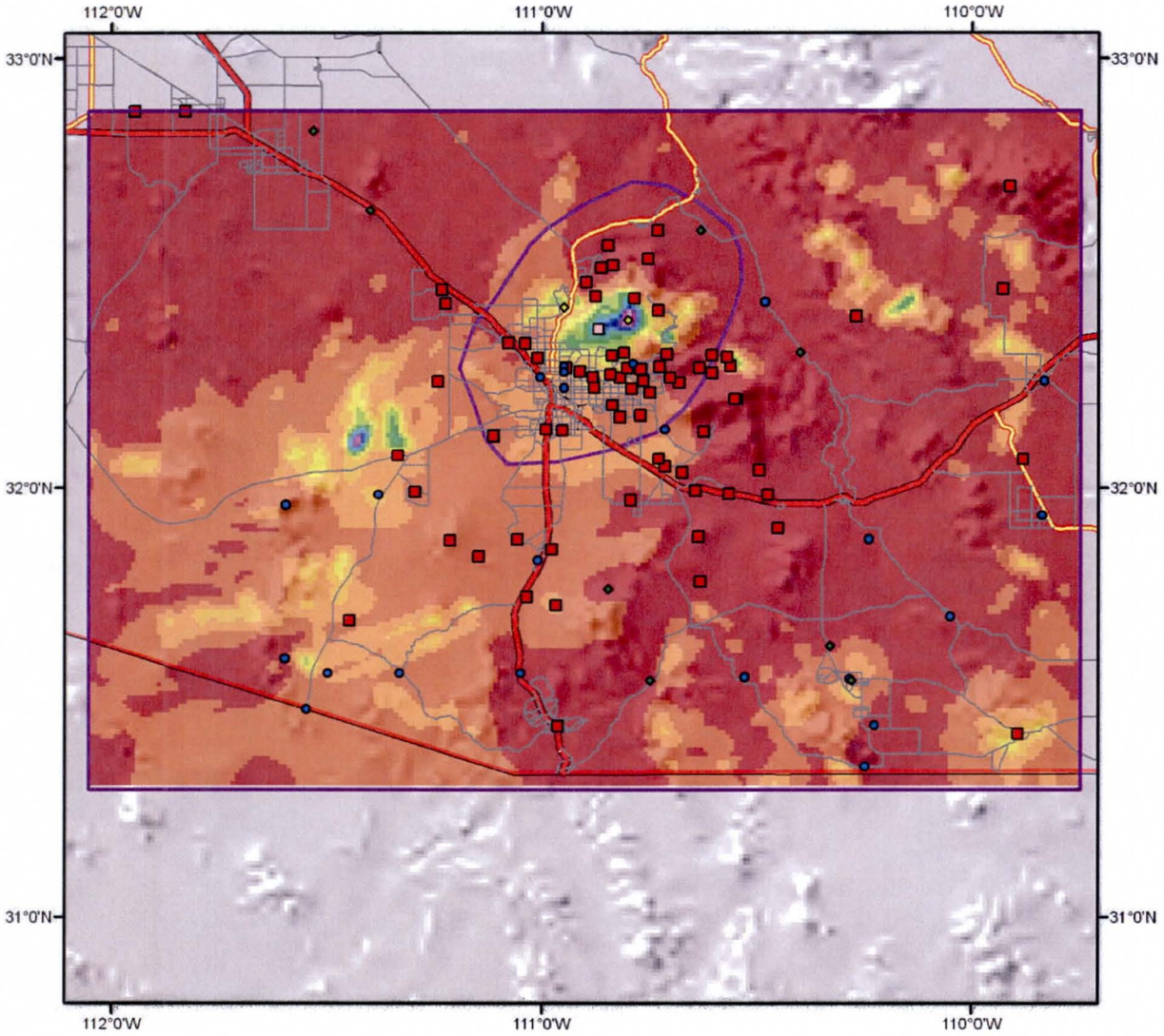
## SPAS Storm 1086 - Tucson, AZ Sept. 3-4, 1996

### MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| | Duration (hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Area ($mi^2$) | 1 | 2 | 3 | 4 | 5 | 6 | 12 | total (24-hr) |
| **0.4** | 3.31 | 5.13 | 5.47 | 5.70 | 5.70 | 5.70 | 7.37 | 7.37 |
| **1** | 3.21 | 4.80 | 5.24 | 5.47 | 5.47 | 5.47 | 6.94 | 6.94 |
| **5** | 2.89 | 4.60 | 4.92 | 4.99 | 4.99 | 4.99 | 6.45 | 6.46 |
| **10** | 2.70 | 4.30 | 4.65 | 4.62 | 4.62 | 4.62 | 5.85 | 5.86 |
| **20** | 2.41 | 3.88 | 4.22 | 4.17 | 4.18 | 4.18 | 5.08 | 5.20 |
| **50** | 1.83 | 3.23 | 3.51 | 3.50 | 3.50 | 3.50 | 4.09 | 4.11 |
| **100** | 1.43 | 2.62 | 2.82 | 2.89 | 2.91 | 2.92 | 3.24 | 3.36 |
| **200** | 1.07 | 2.00 | 2.18 | 2.10 | 2.29 | 2.30 | 2.55 | 2.62 |
| **300** | 0.87 | 1.62 | 1.86 | 1.88 | 1.95 | 1.97 | 1.97 | 2.24 |
| **500** | 0.66 | 1.27 | 1.45 | 1.50 | 1.52 | 1.58 | 1.61 | 1.77 |
| **1,000** | 0.43 | 0.82 | 0.93 | 1.00 | 1.04 | 1.07 | 1.15 | 1.16 |
| **1,213** | 0.34 | 0.68 | 0.77 | 0.83 | 0.87 | 0.89 | 0.97 | 0.97 |




SPAS 1086 Storm Center Mass Curve
Tucson, Arizona
DAD Zone 1
Sep. 2, 1996 (2200Z) - Sep. 3, 1996 (2100)
Lat: 32.3899 Lon: -110.8000
Incremental
Accumulated
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
7.37"
8
18




**Total Precipitation**
**SPAS Storm #1086**
**Sep. 2, 1996 (2200Z) - Sep. 3, 1996 (2100)**

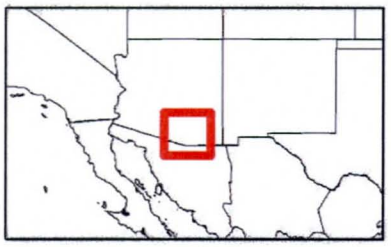
N

Miles
0 5 10 20

Kilometers
0 10 20 40 60

**Stations**

| | | | |
|---|---|---|---|
| 0.00 - 0.50 | 2.51 - 3.00 | 5.01 - 5.50 | Daily |
| 0.51 - 1.00 | 3.01 - 3.50 | 5.51 - 6.00 | Hourly |
| 1.01 - 1.50 | 3.51 - 4.00 | 6.01 - 6.50 | Hourly estimated |
| 1.51 - 2.00 | 4.01 - 4.50 | 6.51 - 7.00 | Supplemental |
| 2.01 - 2.50 | 4.51 - 5.00 | 7.01 - 7.50 | Supplemental estimated |



*Metstat/AWA August 24, 2009*

# Harquahala Mountain-Nora, AZ

**September 25-27, 1997**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| Storm Name: | SPAS-1084-Harquahala Mtn-Nora |
| Storm Date: | 9/25-27/1997 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 10-Sep

| | Lat | Long |
|---|---|---|
| Storm center location | 33.82 N | 113.34 W |
| Storm Rep dew point location | 33.00 N | 113.00 W |
| Transposition dewpoint location | 32.69 N | 112.18 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SSE @ 60 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 4,900 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 73.5 F | with total precipitable water above sea level of | | | 2.67 | inches. |
| The in-place maximum dew point is | 76.5 F | with total precipitable water above sea level of | | | 3.07 | inches. |
| The transpositioned maximum dew point is | 76.5 F | with total precipitable water above sea level of | | | 3.07 | inches. |
| The in-place storm elevation is | 4,900 | which subtracts | 1.02 | inches of precipitable water at | 73.5 F | |
| The in-place storm elevation is | 4,900 | which subtracts | 1.13 | inches of precipitable water at | 76.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.88 | inches of precipitable water at | 76.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.88 | inches of precipitable water at | 76.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.18 |
| The transposition/elevation factor is | 1.13 |
| The barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.33 |

Notes: Storm rep taken from 24hr ave KYUM, KBLH, KSDL.

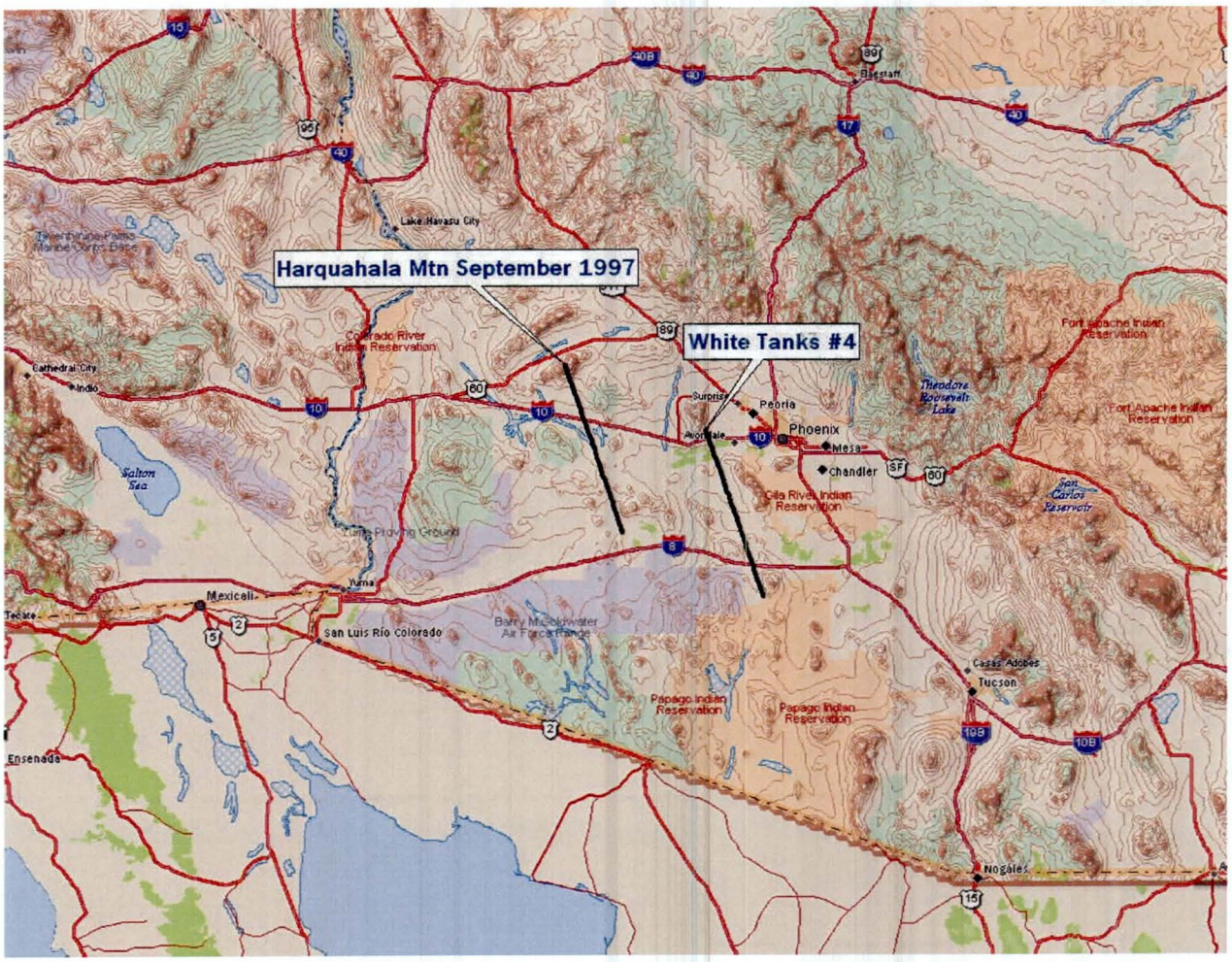
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours | 48 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 3.4 | 4.1 | 4.7 | 5.1 | 5.8 | 6.4 | 9.9 | 12.0 | 12.1 | 12.1 | 12.1 |
| 10 sq miles | 2.7 | 3.4 | 4.1 | 4.8 | 5.4 | 5.9 | 9.0 | 10.9 | 10.9 | 10.9 | 10.9 |
| 100 sq miles | 1.6 | 2.3 | 2.6 | 3.3 | 3.8 | 4.1 | 5.8 | 7.2 | 7.3 | 7.4 | 7.5 |
| 200 sq miles | 1.5 | 2.1 | 2.4 | 2.8 | 3.2 | 3.5 | 4.9 | 6.1 | 6.1 | 6.3 | 6.3 |
| 500 sq miles | 1.3 | 1.9 | 2.2 | 2.4 | 2.7 | 3.0 | 4.0 | 5.0 | 5.0 | 5.1 | 5.2 |
| 1000 sq miles | 1.1 | 1.7 | 1.9 | 2.1 | 2.4 | 2.6 | 3.5 | 4.2 | 4.2 | 4.4 | 4.4 |
| 2000 sq miles | 0.8 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 | 3.0 | 3.5 | 3.6 | 3.7 | 3.8 |
| 5000 sq miles | 0.5 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.3 | 2.7 | 2.8 | 3.1 | 3.1 |
| 10000 sq miles | 0.4 | 0.7 | 0.9 | 1.1 | 1.3 | 1.4 | 2.0 | 2.2 | 2.3 | 2.6 | 2.6 |
| 20000 sq miles | 0.3 | 0.5 | 0.7 | 0.9 | 1.0 | 1.2 | 1.6 | 1.7 | 1.9 | 2.1 | 2.1 |

**Adjusteded Storm Depth-Area-Duration**

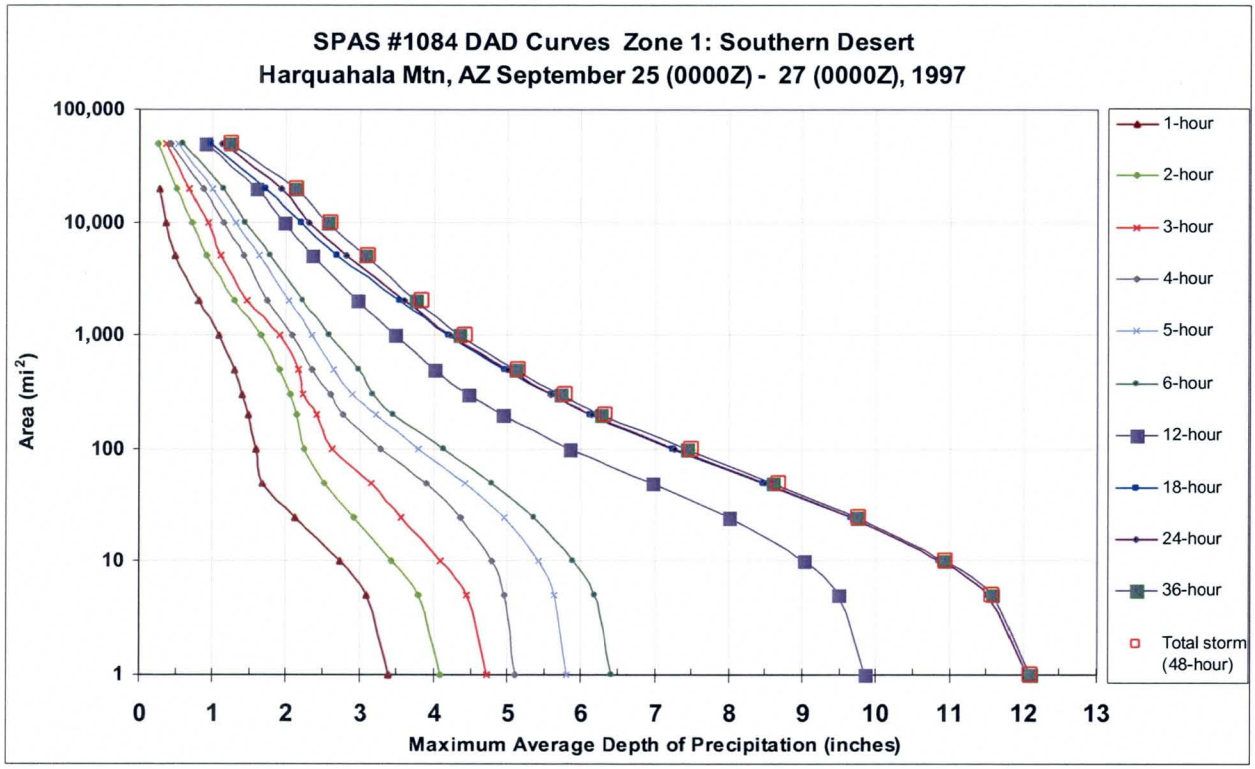
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours | 48 Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 4.5 | 5.4 | 6.3 | 6.8 | 7.7 | 8.5 | 13.1 | 16.0 | 16.0 | 16.0 | 16.0 |
| 10 sq miles | 3.6 | 4.6 | 5.4 | 6.3 | 7.2 | 7.8 | 12.0 | 14.4 | 14.4 | 14.5 | 14.5 |
| 100 sq miles | 2.1 | 3.0 | 3.5 | 4.4 | 5.0 | 5.5 | 7.8 | 9.6 | 9.6 | 9.9 | 9.9 |
| 200 sq miles | 2.0 | 2.8 | 3.2 | 3.7 | 4.3 | 4.6 | 6.5 | 8.1 | 8.1 | 8.3 | 8.4 |
| 500 sq miles | 1.7 | 2.5 | 2.9 | 3.1 | 3.5 | 4.0 | 5.3 | 6.6 | 6.6 | 6.8 | 6.8 |
| 1000 sq miles | 1.4 | 2.2 | 2.5 | 2.8 | 3.1 | 3.4 | 4.6 | 5.6 | 5.6 | 5.8 | 5.9 |
| 2000 sq miles | 1.1 | 1.7 | 1.9 | 2.3 | 2.7 | 2.9 | 3.9 | 4.7 | 4.8 | 5.0 | 5.1 |
| 5000 sq miles | 0.7 | 1.2 | 1.5 | 1.9 | 2.2 | 2.3 | 3.1 | 3.6 | 3.7 | 4.1 | 4.1 |
| 10000 sq miles | 0.5 | 0.9 | 1.2 | 1.5 | 1.8 | 1.9 | 2.6 | 2.9 | 3.1 | 3.4 | 3.5 |
| 20000 sq miles | 0.4 | 0.7 | 0.9 | 1.1 | 1.3 | 1.5 | 2.1 | 2.3 | 2.5 | 2.8 | 2.8 |

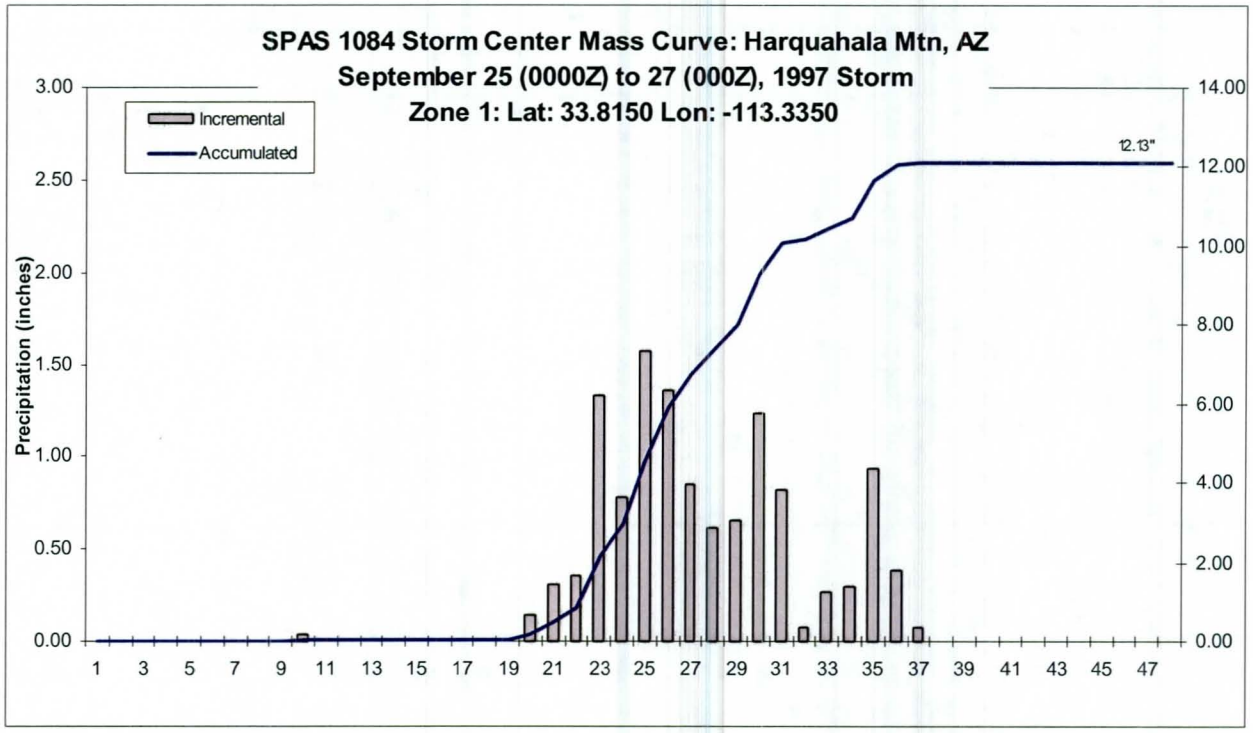
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1084-Harquahala Mtn-Nora | |
| Storm Date(s) | 9/25-27/1997 | |
| Storm Type | Tropical | |
| Storm Location | 33.82 N | 113.34 W |
| Storm Center Elevation | 4900 | orographic isolated ridge-same as White Tanks |
| Precipitation Total & Duration (10 sq mi) | 12.09 inches 24 hours (SPAS 1084 DAD) | |
| | | |
| Storm Representative Dewpoint | 73.5 F | 24hr ave KYUM, KBLH, KSDL |
| Storm Representative Dewpoint Location | 33.00 N | 113.00 W |
| In-place Maximum Dewpoint | 76.5 F | |
| Moisture Inflow Vector | SSE @ 60 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 10-Sep | |
| Transposition Dewpoint Location | 32.69 N | 112.18 W |
| Transposition Maximum Dewpoint | 76.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

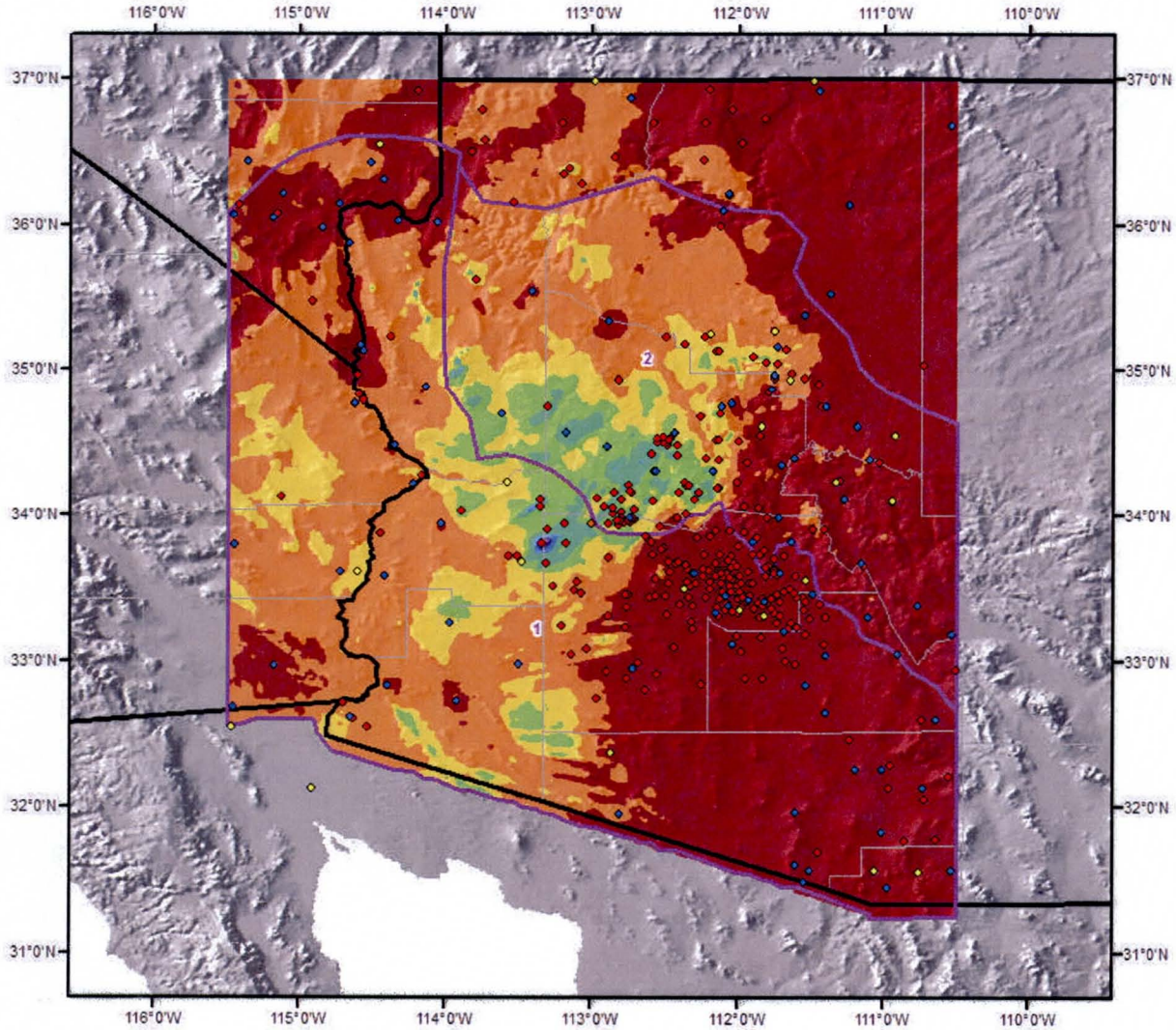

Harquahala Mtn September 1997
White Tanks #4
Lake Havasu City
Colorado River Indian Reservation
Cathedral City
Indio
Salton Sea
Yuma Proving Ground
Yuma
Mexicali
Tecate
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Ensenada
Surprise
Peoria
Phoenix
Glendale
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt Lake
Fort Apache Indian Reservation
San Carlos Reservoir
Casas Adobes
Tucson
Papago Indian Reservation
Nogales
Flagstaff

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.4** | 3.46 | 4.16 | 4.80 | 5.23 | 5.89 | 6.51 | 10.03 | 12.08 | 12.09 | 12.13 | 12.13 |
| **1** | 3.38 | 4.08 | 4.73 | 5.11 | 5.81 | 6.42 | 9.85 | 12.04 | 12.05 | 12.09 | 12.09 |
| **5** | 3.09 | 3.79 | 4.45 | 4.96 | 5.64 | 6.18 | 9.48 | 11.52 | 11.53 | 11.57 | 11.58 |
| **10** | 2.73 | 3.43 | 4.09 | 4.78 | 5.42 | 5.88 | 9.01 | 10.86 | 10.87 | 10.93 | 10.94 |
| **25** | 2.11 | 2.92 | 3.56 | 4.37 | 4.96 | 5.36 | 8.00 | 9.66 | 9.65 | 9.73 | 9.76 |
| **50** | 1.68 | 2.53 | 3.15 | 3.89 | 4.43 | 4.79 | 6.96 | 8.47 | 8.49 | 8.59 | 8.69 |
| **100** | 1.59 | 2.25 | 2.62 | 3.29 | 3.80 | 4.12 | 5.84 | 7.24 | 7.26 | 7.43 | 7.49 |
| **200** | 1.49 | 2.13 | 2.41 | 2.77 | 3.22 | 3.46 | 4.93 | 6.12 | 6.13 | 6.27 | 6.34 |
| **300** | 1.40 | 2.05 | 2.23 | 2.61 | 2.90 | 3.18 | 4.47 | 5.58 | 5.59 | 5.71 | 5.77 |
| **500** | 1.30 | 1.91 | 2.16 | 2.35 | 2.65 | 2.98 | 4.00 | 4.95 | 5.00 | 5.11 | 5.15 |
| **1,000** | 1.09 | 1.66 | 1.91 | 2.08 | 2.35 | 2.59 | 3.48 | 4.20 | 4.22 | 4.35 | 4.43 |
| **2,000** | 0.80 | 1.30 | 1.46 | 1.74 | 2.03 | 2.22 | 2.96 | 3.53 | 3.60 | 3.74 | 3.84 |
| **5,000** | 0.49 | 0.92 | 1.11 | 1.41 | 1.63 | 1.77 | 2.34 | 2.69 | 2.82 | 3.06 | 3.11 |
| **10,000** | 0.36 | 0.71 | 0.93 | 1.14 | 1.32 | 1.43 | 1.96 | 2.20 | 2.30 | 2.56 | 2.60 |
| **20,000** | 0.27 | 0.50 | 0.68 | 0.86 | 1.00 | 1.15 | 1.59 | 1.72 | 1.92 | 2.12 | 2.14 |
| **50,000** | - | 0.25 | 0.35 | 0.43 | 0.52 | 0.60 | 0.89 | 0.98 | 1.13 | 1.23 | 1.25 |




SPAS 1084 Storm Center Mass Curve: Harquahala Mtn, AZ
September 25 (0000Z) to 27 (000Z), 1997 Storm
Zone 1: Lat: 33.8150 Lon: -113.3350
Incremental
Accumulated
12.13"
Precipitation (inches)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47




**Total Rainfall (48-hours)**
**Harquahala Mtn, AZ 1997 Storm**
**Storm #1084 September 25 (0000 Z) to 27 (0000 Z), 1997**

Miles: 0 30 60 120
Kilometers: 0 45 90 180 270

**Gauging Stations**

- Daily
- Hourly
- Hourly Estimated
- Hourly Pseudo
- Supplemental

N

**Precipitation (inches)**

- 0.00 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 - 11.00
- 11.01 - 13.00

*Coordinate system: GCS North American 1983*
*Scale: 1:4,274,365*
*MetstatAWA August 24, 2009*

# Sols Wash, AZ

**August 29, 2000**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1043-Sols Wash |
| Storm Date: | August 29, 2000 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 15-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 34.13 N | 113.08 W |
| Storm Rep dew point location | 33.00 N | 113.00 W |
| Transposition dewpoint location | 32.34 N | 112.45 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 80 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,650 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 71.5 F | with total precipitable water above sea level of | | | 2.42 | inches. |
| The in-place maximum dew point is | 79.0 F | with total precipitable water above sea level of | | | 3.44 | inches. |
| The transpositioned maximum dew point is | 79.0 F | with total precipitable water above sea level of | | | 3.44 | inches. |
| The in-place storm elevation is | 2,650 | which subtracts | 0.56 | inches of precipitable water at | 71.5 F | |
| The in-place storm elevation is | 2,650 | which subtracts | 0.715 | inches of precipitable water at | 79.0 F | |
| Basin elevation at | 3,650 | which subtracts | 0.96 | inches of precipitable water at | 79.0 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.96 | inches of precipitable water at | 79.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.47 |
| The transposition/elevation factor is | 0.91 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.34 |

Notes: Storm rep determined from combination of KGBN and KLUF using 12hr average. Because this was a 12-hr event, used the normal procedure for elevation adjustments.

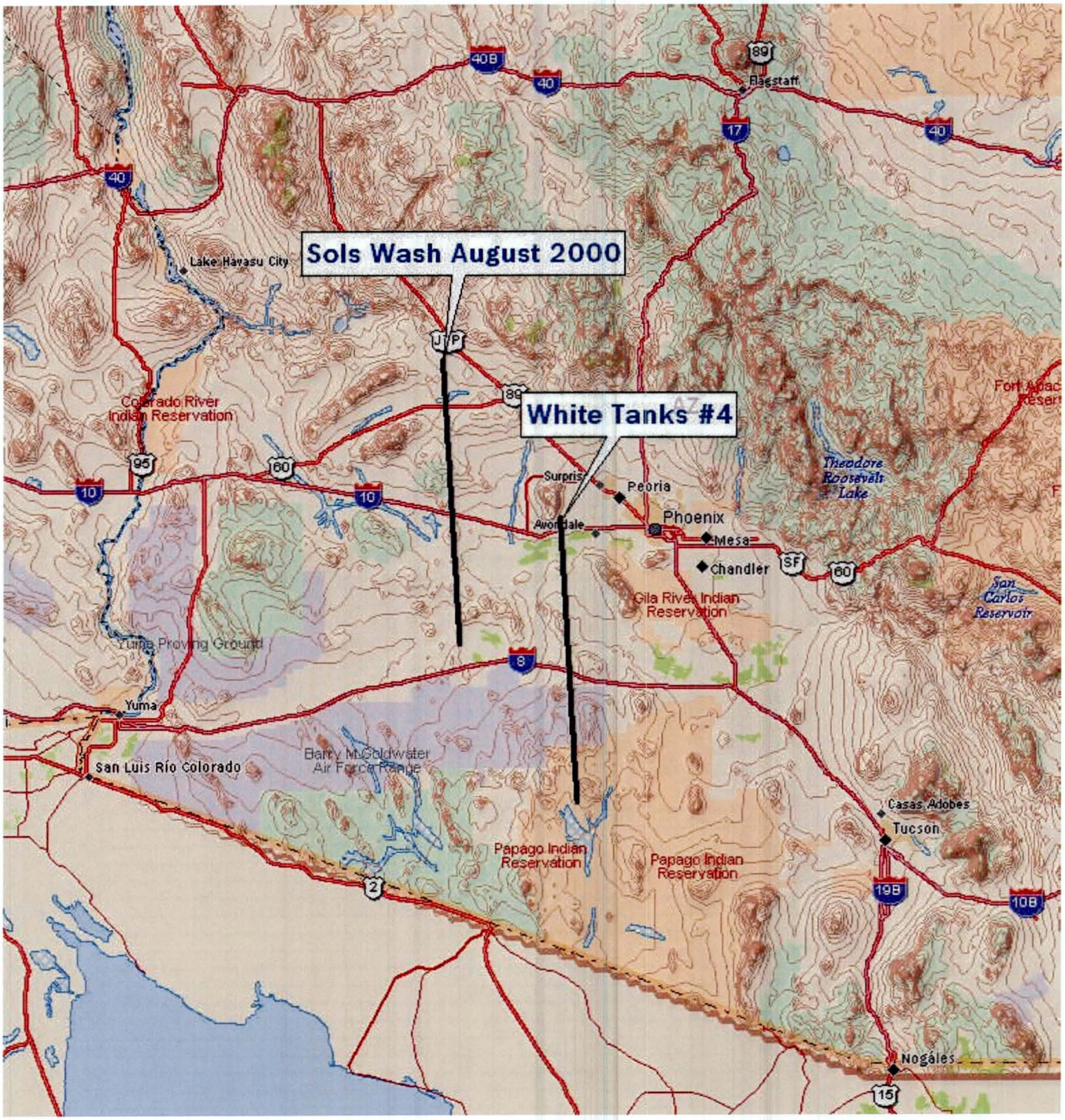
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours |
|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.4 | 2.5 | 2.9 | 3.5 | 4.1 | 4.6 | 5.4 | 5.4 | 5.4 |
| 10 sq miles | 1.4 | 2.4 | 2.9 | 3.5 | 4.0 | 4.5 | 5.3 | 5.4 | 5.4 |
| 50 sq miles | 1.3 | 2.2 | 2.8 | 3.4 | 3.8 | 4.1 | 4.8 | 4.8 | 4.9 |
| 100 sq miles | 1.1 | 2.0 | 2.7 | 3.2 | 3.7 | 3.9 | 4.5 | 4.6 | 4.6 |
| 200 sq miles | 1.0 | 1.8 | 2.4 | 3.0 | 3.4 | 3.6 | 4.2 | 4.2 | 4.2 |
| 500 sq miles | 0.8 | 1.4 | 1.9 | 2.5 | 3.0 | 3.2 | 3.7 | 3.7 | 3.7 |
| 1000 sq miles | 0.7 | 1.1 | 1.6 | 2.1 | 2.5 | 2.8 | 3.3 | 3.3 | 3.3 |
| 2000 sq miles | 0.5 | 0.9 | 1.3 | 1.6 | 1.9 | 2.1 | 2.6 | 2.7 | 2.7 |
| 5000 sq miles | 0.4 | 0.7 | 1.0 | 1.2 | 1.3 | 1.4 | 1.8 | 1.8 | 1.8 |

**Adjusted Storm Depth-Area-Duration**

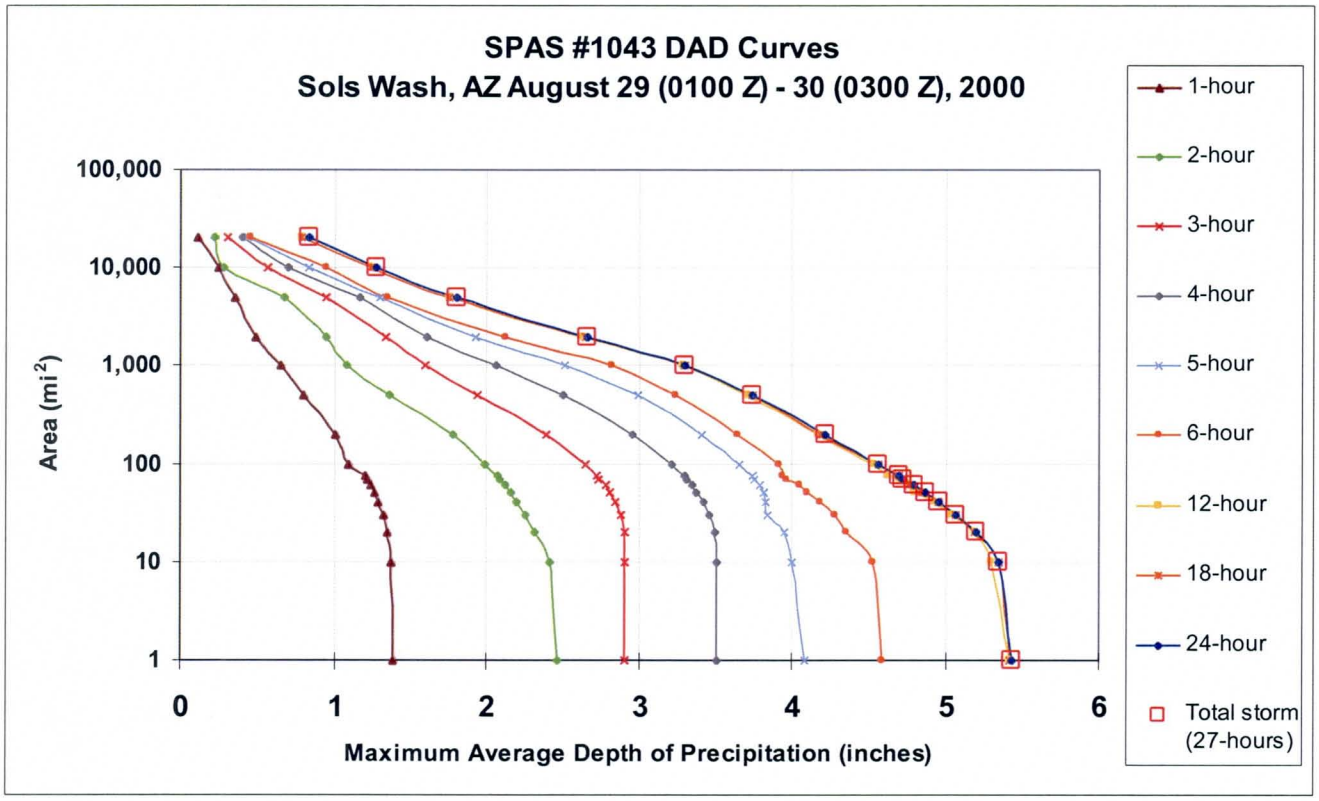
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours |
|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.9 | 3.3 | 3.9 | 4.7 | 5.5 | 6.1 | 7.2 | 7.2 | 7.3 |
| 10 sq miles | 1.8 | 3.2 | 3.9 | 4.7 | 5.3 | 6.1 | 7.1 | 7.1 | 7.1 |
| 50 sq miles | 1.7 | 2.9 | 3.8 | 4.5 | 5.1 | 5.5 | 6.4 | 6.5 | 6.5 |
| 100 sq miles | 1.5 | 2.7 | 3.5 | 4.3 | 4.9 | 5.2 | 6.1 | 6.1 | 6.1 |
| 200 sq miles | 1.3 | 2.4 | 3.2 | 4.0 | 4.6 | 4.9 | 5.6 | 5.6 | 5.6 |
| 500 sq miles | 1.1 | 1.8 | 2.6 | 3.3 | 4.0 | 4.3 | 5.0 | 5.0 | 5.0 |
| 1000 sq miles | 0.9 | 1.4 | 2.1 | 2.8 | 3.4 | 3.8 | 4.4 | 4.4 | 4.4 |
| 2000 sq miles | 0.7 | 1.3 | 1.8 | 2.2 | 2.6 | 2.8 | 3.5 | 3.5 | 3.6 |
| 5000 sq miles | 0.5 | 0.9 | 1.3 | 1.5 | 1.7 | 1.8 | 2.4 | 2.4 | 2.4 |

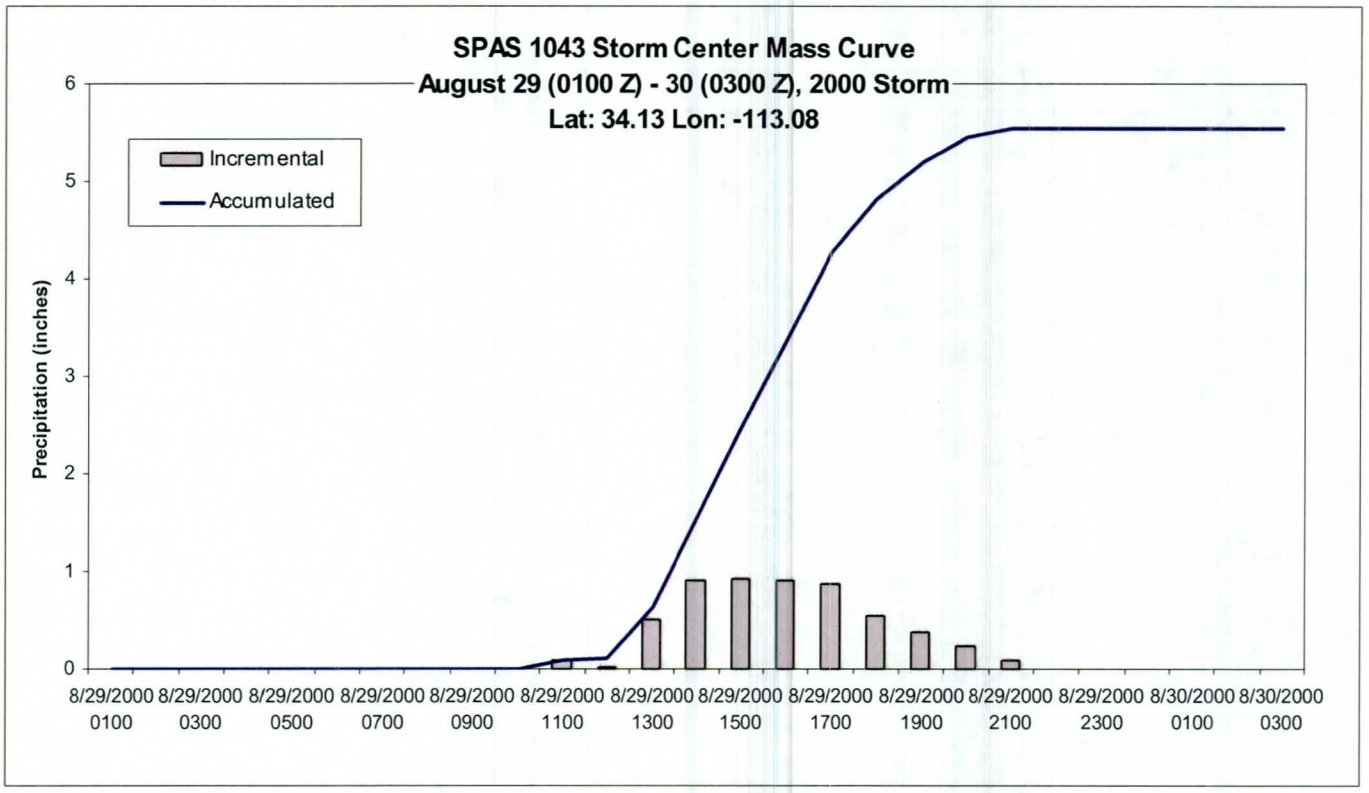
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1043-Sols Wash** | |
| Storm Date(s) | August 29, 2000 | |
| Storm Type | Local Storm | |
| Storm Location | 34.13 N | 113.08 W |
| Storm Center Elevation | 2650 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 4.70 inches 6 hours 5.54" in 24hrs (SPAS 1043 DAD) | |
| | | |
| Storm Representative Dewpoint | 71.5 F | 12hr ave KGBN, KLUF |
| Storm Representative Dewpoint Location | 33.00 N | 113.00 W |
| In-place Maximum Dewpoint | 79.0 F | |
| Moisture Inflow Vector | S @ 80 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 32.34 N | 112.45 W |
| Transposition Maximum Dewpoint | 79.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.34 | |

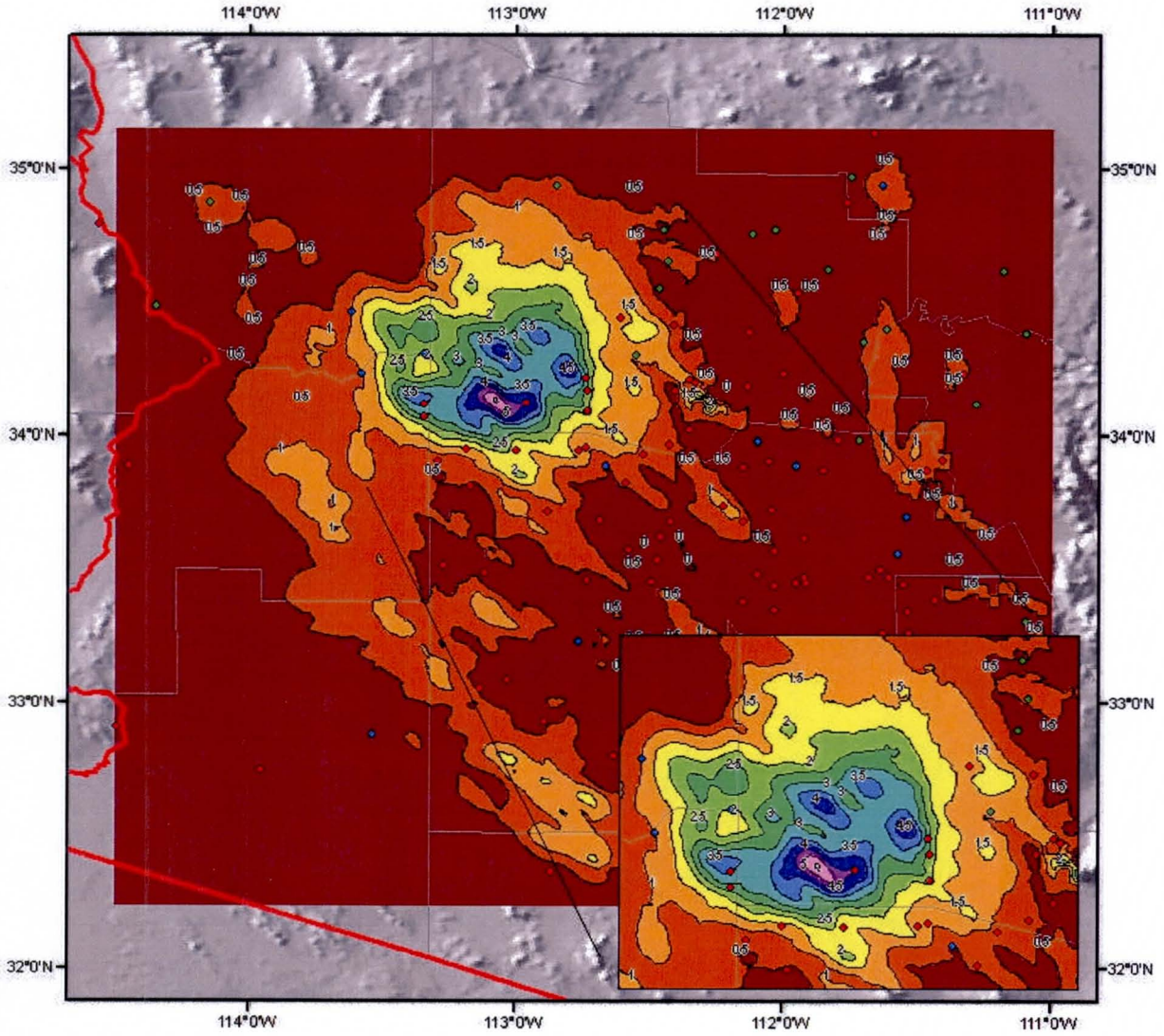

Sols Wash August 2000
White Tanks #4
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Theodore Roosevelt Lake
Gila River Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Papago Indian Reservation
Casas Adobes
Tucson
Nogales

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | Total |
| **0.28** | 1.48 | 2.58 | 3.03 | 3.63 | 4.18 | 4.70 | 5.53 | 5.54 | 5.54 | 5.54 |
| **1** | 1.39 | 2.47 | 2.91 | 3.51 | 4.09 | 4.59 | 5.42 | 5.42 | 5.43 | 5.43 |
| **10** | 1.38 | 2.42 | 2.91 | 3.51 | 4.00 | 4.53 | 5.30 | 5.35 | 5.35 | 5.35 |
| **20** | 1.35 | 2.32 | 2.91 | 3.50 | 3.95 | 4.36 | 5.19 | 5.19 | 5.20 | 5.20 |
| **30** | 1.32 | 2.26 | 2.88 | 3.46 | 3.84 | 4.28 | 5.04 | 5.07 | 5.07 | 5.07 |
| **40** | 1.29 | 2.20 | 2.85 | 3.42 | 3.83 | 4.18 | 4.92 | 4.96 | 4.96 | 4.96 |
| **50** | 1.26 | 2.16 | 2.81 | 3.38 | 3.82 | 4.10 | 4.80 | 4.83 | 4.87 | 4.87 |
| **60** | 1.24 | 2.12 | 2.78 | 3.35 | 3.79 | 4.05 | 4.76 | 4.76 | 4.80 | 4.80 |
| **70** | 1.21 | 2.08 | 2.74 | 3.31 | 3.75 | 3.96 | 4.71 | 4.72 | 4.72 | 4.72 |
| **75** | 1.20 | 2.07 | 2.73 | 3.30 | 3.74 | 3.94 | 4.62 | 4.70 | 4.70 | 4.70 |
| **100** | 1.09 | 1.99 | 2.65 | 3.21 | 3.66 | 3.91 | 4.53 | 4.56 | 4.57 | 4.57 |
| **200** | 1.00 | 1.78 | 2.39 | 2.96 | 3.41 | 3.64 | 4.17 | 4.19 | 4.22 | 4.22 |
| **500** | 0.80 | 1.36 | 1.94 | 2.50 | 2.99 | 3.24 | 3.71 | 3.74 | 3.74 | 3.74 |
| **1,000** | 0.65 | 1.08 | 1.59 | 2.06 | 2.51 | 2.82 | 3.29 | 3.30 | 3.30 | 3.30 |
| **2,000** | 0.49 | 0.94 | 1.34 | 1.61 | 1.93 | 2.12 | 2.64 | 2.65 | 2.66 | 2.66 |
| **5,000** | 0.36 | 0.67 | 0.95 | 1.16 | 1.30 | 1.35 | 1.76 | 1.76 | 1.80 | 1.80 |
| **10,000** | 0.25 | 0.28 | 0.56 | 0.70 | 0.83 | 0.94 | 1.24 | 1.24 | 1.27 | 1.27 |
| **20,000** | 0.11 | 0.22 | 0.31 | 0.41 | 0.44 | 0.46 | 0.79 | 0.79 | 0.84 | 0.84 |




SPAS 1043 Storm Center Mass Curve
August 29 (0100 Z) - 30 (0300 Z), 2000 Storm
Lat: 34.13 Lon: -113.08
Incremental
Accumulated
Precipitation (inches)
0
1
2
3
4
5
6
8/29/2000 0100
8/29/2000 0300
8/29/2000 0500
8/29/2000 0700
8/29/2000 0900
8/29/2000 1100
8/29/2000 1300
8/29/2000 1500
8/29/2000 1700
8/29/2000 1900
8/29/2000 2100
8/29/2000 2300
8/30/2000 0100
8/30/2000 0300




**Total Rainfall (27-hours)**
**Sols Wash, AZ 2000 Storm**
**Storm #1043 August 29 (0100 Z) to 30 (0300 Z), 2000**

Miles
0 12.5 25 50
Kilometers
0 20 40 80 120

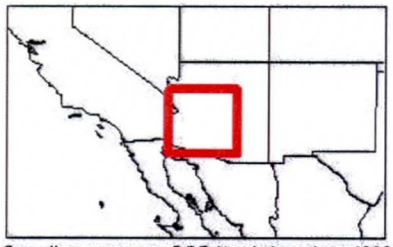
**Gauging Stations**

Hourly Daily Supplemental

N

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.00 - 0.50 | 1.51 - 2.00 | 3.01 - 3.50 | 4.51 - 5.00 |
| 0.51 - 1.00 | 2.01 - 2.50 | 3.51 - 4.00 | 5.01 - 5.50 |
| 1.01 - 1.50 | 2.51 - 3.00 | 4.01 - 4.50 | 5.51 - 6.00 |



*Coordinate system: GCS North American 1983*
*Scale: 1:2,342,749*

NEXRAD October 18, 2007

# Castle Hot Springs, AZ

**August 27, 2003**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1094-Castle Hot Springs |
| Storm Date: | August 27, 2003 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 15-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 33.95 N | 112.34 W |
| Storm Rep dew point location | 33.50N | 113.00 W |
| Transposition dewpoint location | 33.05 N | 113.18 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SW @ 50 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 1,850 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 74.0 F | with total precipitable water above sea level of | | | 2.73 | inches. |
| The in-place maximum dew point is | 79.0 F | with total precipitable water above sea level of | | | 3.44 | inches. |
| The transpositioned maximum dew point is | 79.0 F | with total precipitable water above sea level of | | | 3.44 | inches. |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 74.0 F | |
| The in-place storm elevation is | 0 | which subtracts | 0.000 | inches of precipitable water at | 79.0 F | |
| Basin elevation at | 0 | which subtracts | 0.000 | inches of precipitable water at | 79.0 F | |
| The inflow barrier height/basin elevation is | 0 | which subtracts | 0.000 | inches of precipitable water at | 79.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.26 |
| The transposition factor is | 1.00 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.26 |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. 12 hour average used from KGYR and KCGZ.

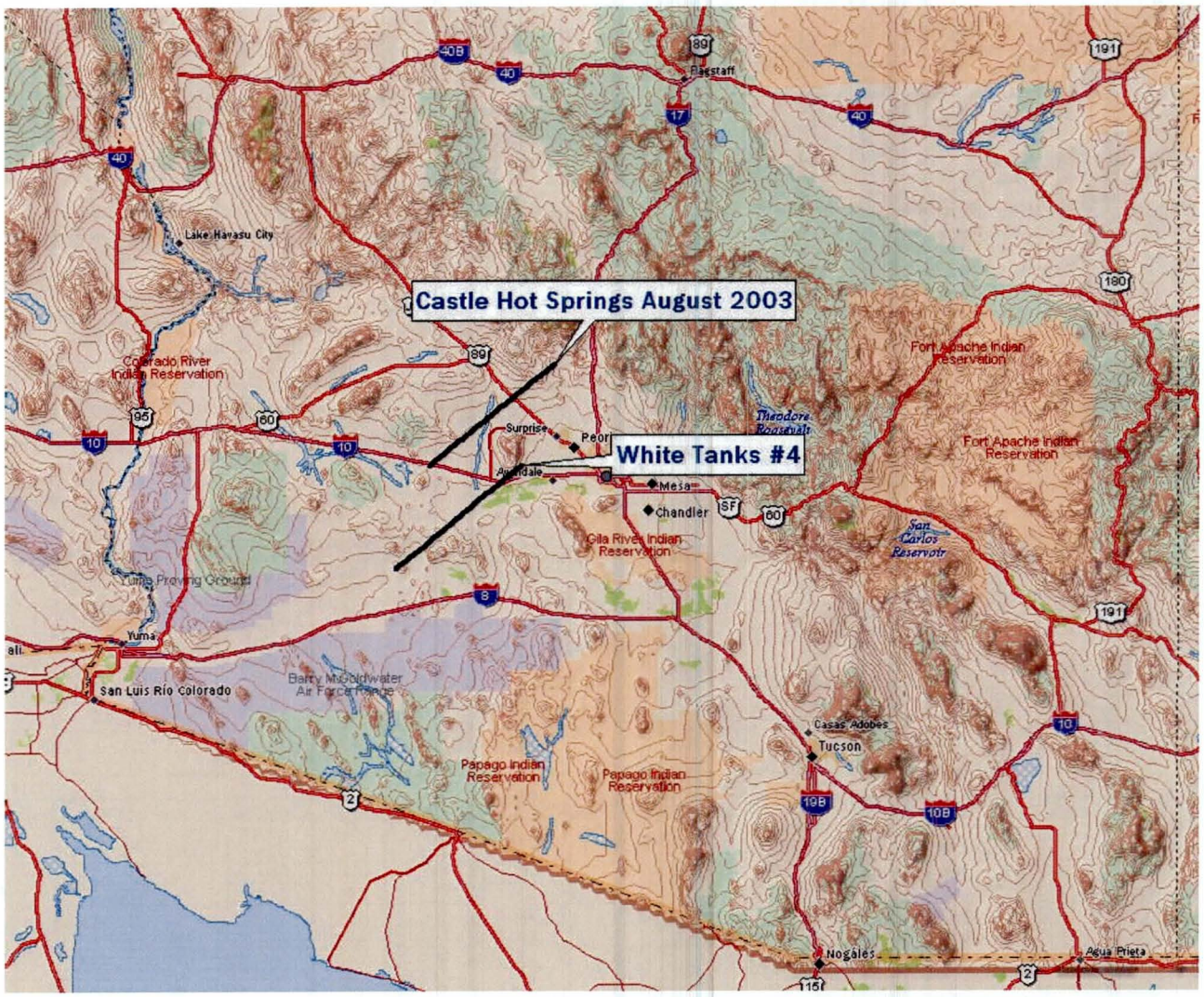
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 4.1 | 4.9 | 5.0 | 5.0 | 5.7 | 8.8 | 9.8 | 10.0 | 10.1 | - |
| 10 sq miles | 3.5 | 4.2 | 4.3 | 4.3 | 4.8 | 7.3 | 8.0 | 8.2 | 8.3 | - |
| 50 sq miles | 2.1 | 2.9 | 3.1 | 3.2 | 3.2 | 3.6 | 4.5 | 4.8 | 5.1 | - |
| 100 sq miles | 1.7 | 2.5 | 2.7 | 2.8 | 2.8 | 2.8 | 3.5 | 4.0 | 4.2 | - |
| 200 sq miles | 1.0 | 1.8 | 2.0 | 2.0 | 2.0 | 2.1 | 2.5 | 3.0 | 3.1 | - |
| 500 sq miles | 0.8 | 1.2 | 1.4 | 1.5 | 1.5 | 1.5 | 1.7 | 2.0 | 2.3 | - |
| 1000 sq miles | 0.3 | 0.6 | 0.8 | 0.9 | 0.9 | 0.9 | 1.1 | 1.4 | 1.6 | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

**Adjusted Storm Depth-Area-Duration**

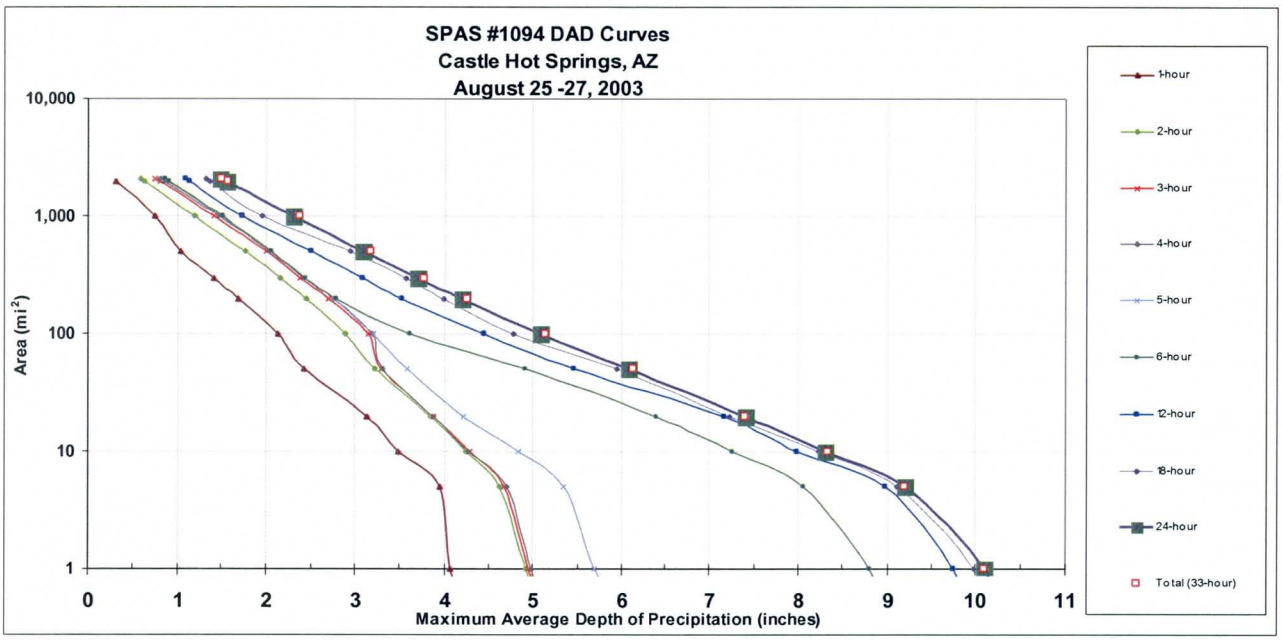
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 5.1 | 6.2 | 6.2 | 6.3 | 7.2 | 11.1 | 12.3 | 12.6 | 12.7 | - |
| 10 sq miles | 4.4 | 5.3 | 5.4 | 5.4 | 6.1 | 9.1 | 10.1 | 10.4 | 10.5 | - |
| 50 sq miles | 2.7 | 3.6 | 4.0 | 4.0 | 4.0 | 4.5 | 5.6 | 6.0 | 6.4 | - |
| 100 sq miles | 2.1 | 3.1 | 3.4 | 3.5 | 3.5 | 3.5 | 4.4 | 5.0 | 5.3 | - |
| 200 sq miles | 1.3 | 2.2 | 2.5 | 2.6 | 2.6 | 2.6 | 3.2 | 3.7 | 3.9 | - |
| 500 sq miles | 0.9 | 1.5 | 1.8 | 1.9 | 1.9 | 1.9 | 2.2 | 2.5 | 2.9 | - |
| 1000 sq miles | 0.4 | 0.8 | 1.0 | 1.1 | 1.1 | 1.1 | 1.4 | 1.7 | 2.0 | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

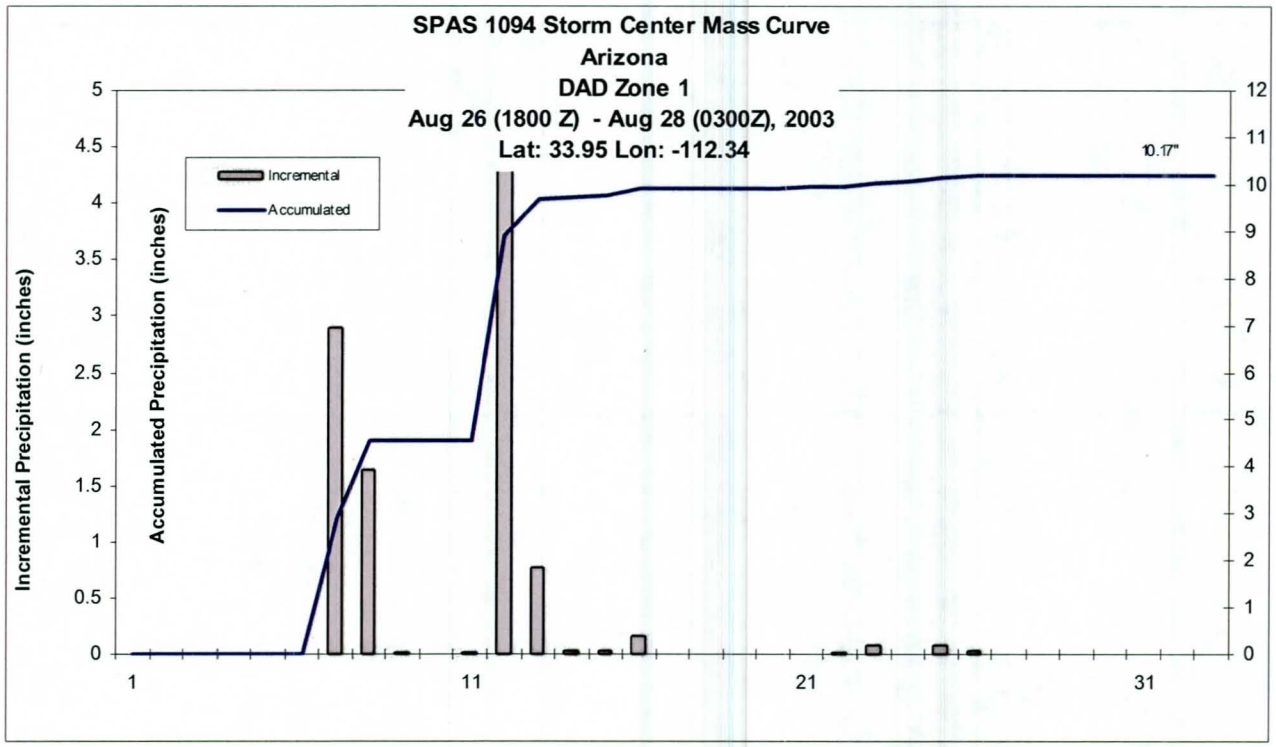
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1094-Castle Hot Springs | |
| Storm Date(s) | 8/27/03 | |
| Storm Type | Local Storm | |
| Storm Location | 33.95 N | 112.34 W |
| Storm Center Elevation | 1850 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 4.34 inches 1 hour 8.98" in 6hrs (SPAS 1094 DAD) | |
| | | |
| Storm Representative Dewpoint | 74.0 F | 12hr ave KGYR, KCGZ |
| Storm Representative Dewpoint Location | 33.50N | 113.00 W |
| In-place Maximum Dewpoint | 79.0 F | |
| Moisture Inflow Vector | SW @ 50 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 33.05 N | 113.18 W |
| Transposition Maximum Dewpoint | 79.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.26 | |

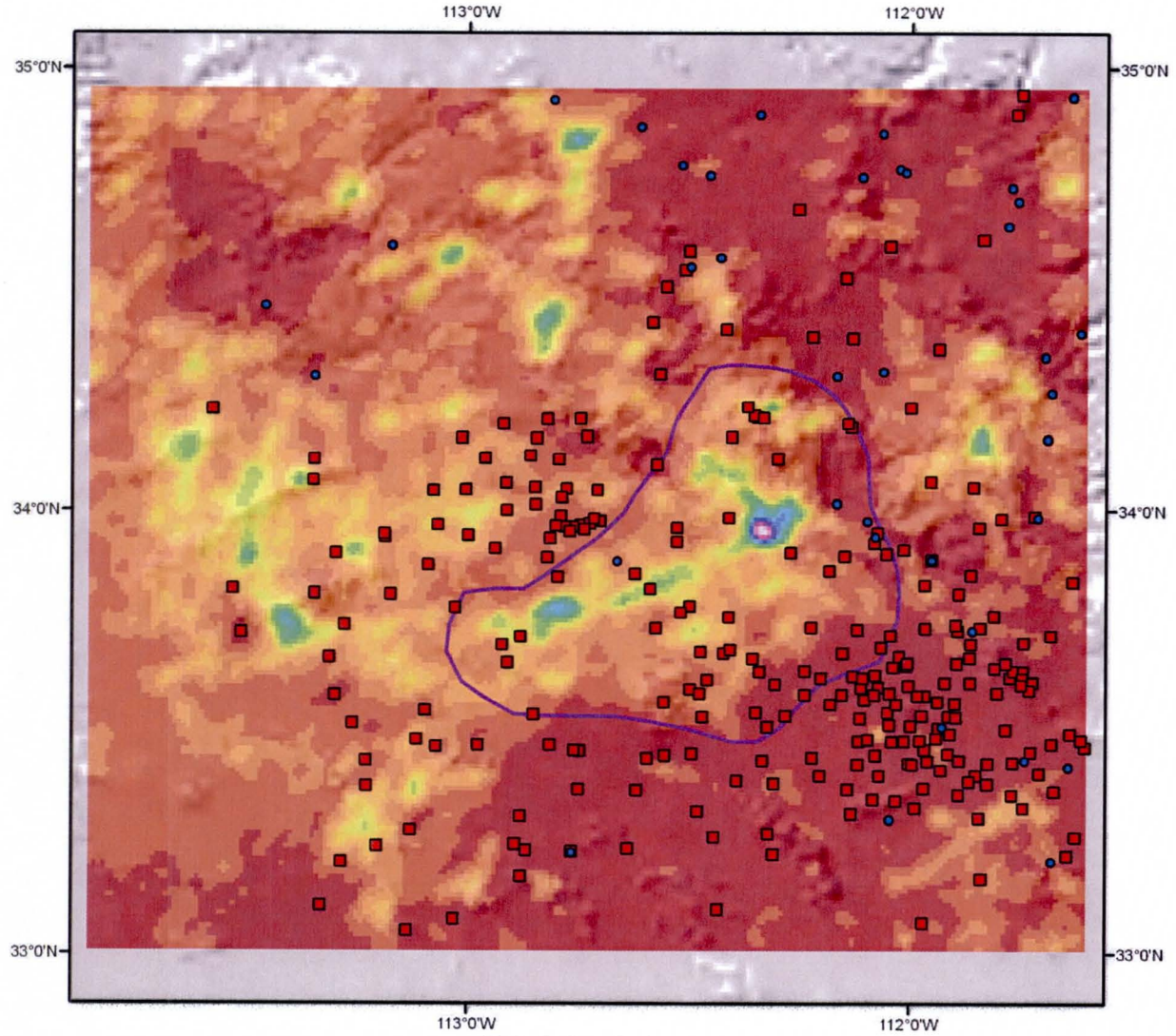

Castle Hot Springs August 2003
White Tanks #4
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peor
Avondale
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt
Fort Apache Indian Reservation
Fort Apache Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Casas Adobes
Tucson
Papago Indian Reservation
Papago Indian Reservation
Nogales
Agua Prieta

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | total (33-hr) |
|---|---|---|---|---|---|---|---|---|---|---|
| **0.4** | 4.34 | 5.12 | 5.16 | 5.18 | 6.02 | 8.98 | 9.93 | 10.05 | 10.17 | 10.17 |
| **1** | 4.07 | 4.92 | 4.96 | 4.98 | 5.69 | 8.80 | 9.75 | 9.98 | 10.09 | 10.09 |
| **5** | 3.95 | 4.62 | 4.67 | 4.70 | 5.35 | 8.06 | 8.98 | 9.10 | 9.19 | 9.20 |
| **10** | 3.48 | 4.24 | 4.28 | 4.27 | 4.83 | 7.25 | 7.98 | 8.23 | 8.31 | 8.33 |
| **20** | 3.13 | 3.85 | 3.87 | 3.88 | 4.21 | 6.39 | 7.17 | 7.23 | 7.4 | 7.40 |
| **50** | 2.42 | 3.22 | 3.29 | 3.30 | 3.59 | 4.91 | 5.47 | 5.95 | 6.07 | 6.13 |
| **100** | 2.13 | 2.88 | 3.14 | 3.19 | 3.20 | 3.61 | 4.45 | 4.78 | 5.09 | 5.14 |
| **200** | 1.69 | 2.45 | 2.69 | 2.75 | 2.75 | 2.78 | 3.52 | 3.99 | 4.19 | 4.26 |
| **300** | 1.41 | 2.15 | 2.38 | 2.42 | 2.43 | 2.43 | 3.09 | 3.57 | 3.7 | 3.77 |
| **500** | 1.03 | 1.77 | 1.99 | 2.04 | 2.04 | 2.06 | 2.51 | 2.95 | 3.09 | 3.17 |
| **1,000** | 0.75 | 1.2 | 1.42 | 1.47 | 1.50 | 1.51 | 1.73 | 1.95 | 2.3 | 2.37 |
| **2,000** | 0.31 | 0.63 | 0.80 | 0.85 | 0.89 | 0.91 | 1.14 | 1.37 | 1.56 | 1.57 |
| **2,105** | | 0.58 | 0.75 | 0.80 | 0.84 | 0.86 | 1.09 | 1.32 | 1.49 | 1.50 |




SPAS 1094 Storm Center Mass Curve
Arizona
DAD Zone 1
Aug 26 (1800 Z) - Aug 28 (0300Z), 2003
Lat: 33.95 Lon: -112.34
Incremental
Accumulated
10.17"
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
1
2
3
4
5
6
7
8
9
10
11
12
1
11
21
31




**Total Precipitation**
**SPAS Storm #1094**
**8/25-27/2003**

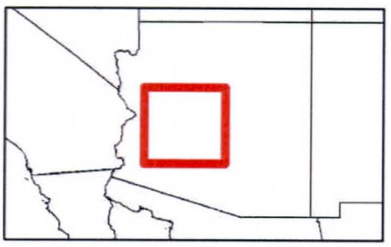
Miles
0 4 8 16

Kilometers
0 4 8 16 24

N

**Precipitation (inches)**

| | | | | |
|---|---|---|---|---|
| 0.00 - 0.50 | 3.01 - 3.50 | 6.01 - 6.50 | 9.01 - 9.50 | Daily |
| 0.51 - 1.00 | 3.51 - 4.00 | 6.51 - 7.00 | 9.51 - 10.00 | Hourly |
| 1.01 - 1.50 | 4.01 - 4.50 | 7.01 - 7.50 | 10.01 - 10.50 | |
| 1.51 - 2.00 | 4.51 - 5.00 | 7.51 - 8.00 | | |
| 2.01 - 2.50 | 5.01 - 5.50 | 8.01 - 8.50 | | |
| 2.51 - 3.00 | 5.51 - 6.00 | 8.51 - 9.00 | | |



*Metstat/AWA August 19, 2009*

# Cypress Mountain, AZ

**September 18-20, 2004**

**Storm Type: Remnant Tropical**

| | |
|---|---|
| Storm Name: | SPAS-1088-Cypress Mountain-Zor |
| Storm Date: | 9/18-20/2004 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White tanks #4

**Temporal Transposition Date** 5-Sep

| | Lat | Long |
|---|---|---|
| Storm center location | 34.52 N | 113.86 W |
| Storm Rep dew point location | 32.98 N | 115.10 W |
| Transposition dewpoint location | 31.97 N | 113.76 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SW @ 170 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,400 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 73.5 F | with total precipitable water above sea level of | | | 2.67 | inches. |
| The in-place maximum dew point is | 78.5 F | with total precipitable water above sea level of | | | 3.37 | inches. |
| The transpositioned maximum dew point is | 78.5 F | with total precipitable water above sea level of | | | 3.37 | inches. |
| The in-place storm elevation is | 2,400 | which subtracts | 0.55 | inches of precipitable water at | 73.5 F | |
| The in-place storm elevation is | 2,400 | which subtracts | 0.64 | inches of precipitable water at | 78.5 F | |
| Basin elevation at | 3,650 | which subtracts | 0.94 | inches of precipitable water at | 78.5 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.94 | inches of precipitable water at | 78.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.29 |
| The transposition/elevation factor is | 0.89 |
| The barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.15 |

Notes: 12hr ave KYUM, KNYL, KIPL

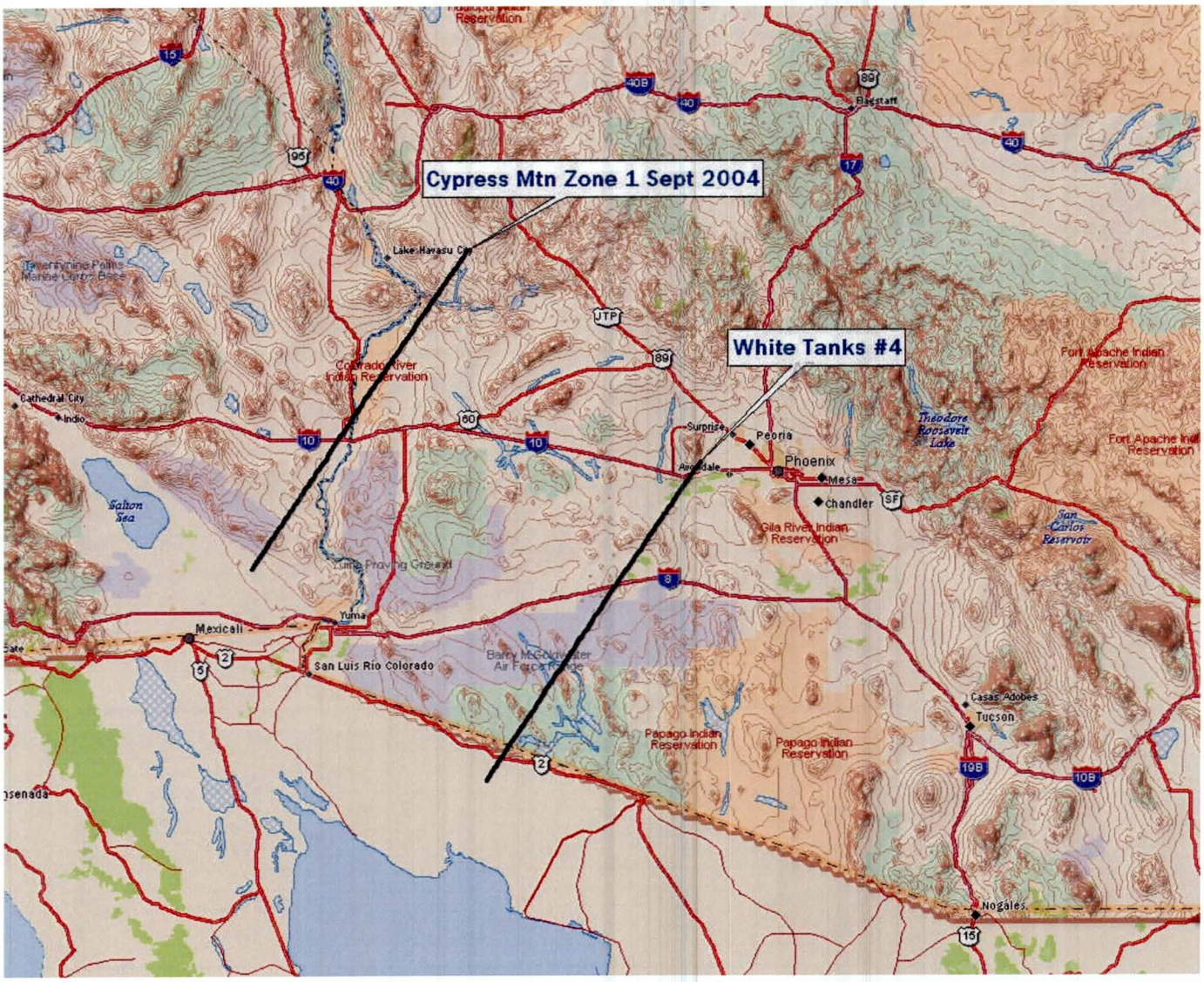
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 48 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 4.5 | - | 4.8 | - | - | 5.3 | 6.6 | - | 6.8 | 6.8 |
| 10 sq miles | 4.3 | - | 4.6 | - | - | 4.8 | 6.0 | - | 6.2 | 6.2 |
| 50 sq miles | 3.4 | - | 3.5 | - | - | 3.8 | 4.8 | - | 5.1 | 5.1 |
| 100 sq miles | 2.8 | - | 3.0 | - | - | 3.3 | 4.3 | - | 4.5 | 4.6 |
| 200 sq miles | 2.1 | - | 2.4 | - | - | 2.7 | 3.4 | - | 3.9 | 4.1 |
| 500 sq miles | 1.4 | - | 1.8 | - | - | 2.1 | 2.7 | - | 3.1 | 3.4 |
| 1000 sq miles | 0.8 | - | 1.3 | - | - | 1.9 | 2.1 | - | 2.6 | 3.0 |
| 2000 sq miles | 0.3 | - | 1.2 | - | - | 1.4 | 1.7 | - | 2.2 | 2.6 |
| 5000 sq miles | 0.3 | - | 0.8 | - | - | 1.2 | 1.2 | - | 1.7 | 2.1 |
| 10000 sq miles | 0.3 | - | 0.6 | - | - | 0.8 | 0.9 | - | 1.3 | 1.7 |

**Adjusteded Storm Depth-Area-Duration**

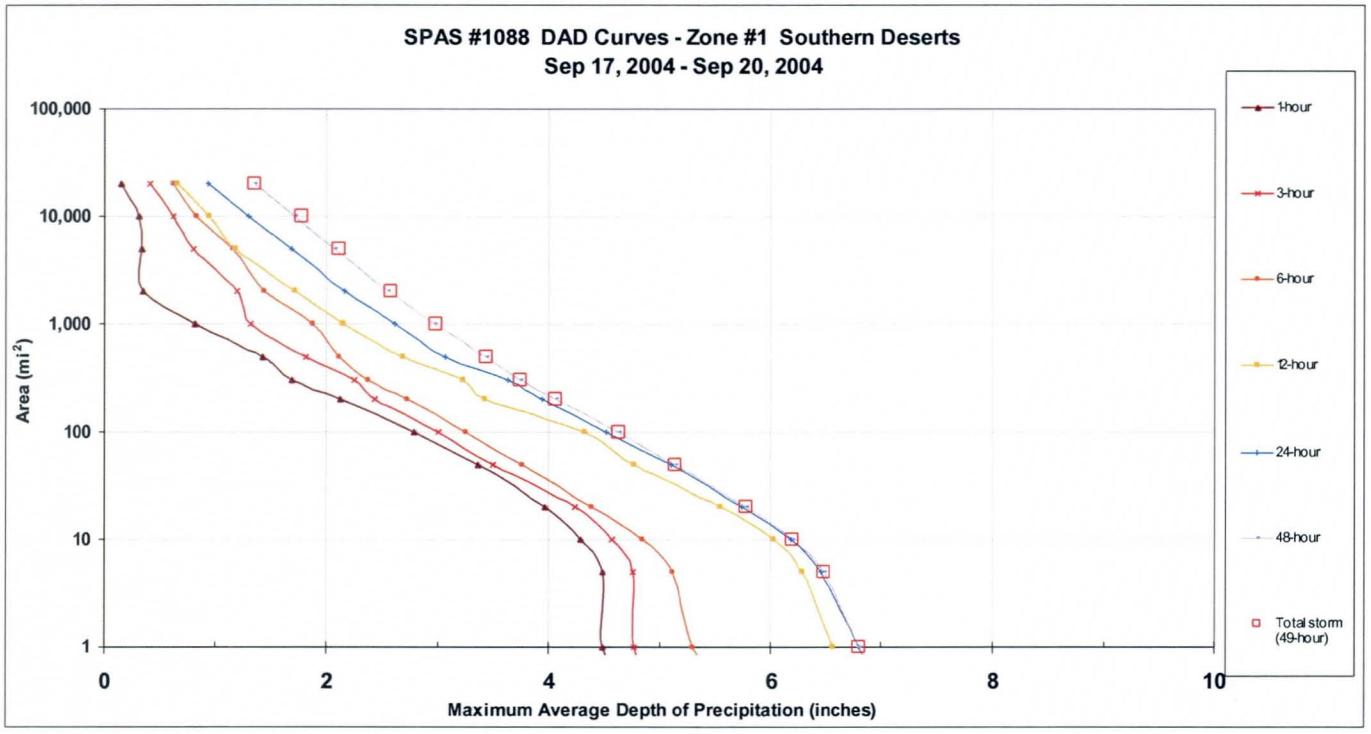
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 24 Hours | 36 Hours | 48 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 5.1 | - | 5.5 | - | - | 6.1 | 7.5 | - | 7.8 | 7.8 |
| 10 sq miles | 4.9 | - | 5.2 | - | - | 5.5 | 6.9 | - | 7.1 | 7.1 |
| 50 sq miles | 3.9 | - | 4.0 | - | - | 4.3 | 5.5 | - | 5.8 | 5.9 |
| 100 sq miles | 3.2 | - | 3.4 | - | - | 3.7 | 5.0 | - | 5.2 | 5.3 |
| 200 sq miles | 2.4 | - | 2.8 | - | - | 3.1 | 3.9 | - | 4.5 | 4.7 |
| 500 sq miles | 1.6 | - | 2.1 | - | - | 2.4 | 3.1 | - | 3.5 | 3.9 |
| 1000 sq miles | 0.9 | - | 1.5 | - | - | 2.1 | 2.5 | - | 3.0 | 3.4 |
| 2000 sq miles | 0.4 | - | 1.4 | - | - | 1.7 | 2.0 | - | 2.5 | 2.9 |
| 5000 sq miles | 0.4 | - | 0.9 | - | - | 1.3 | 1.4 | - | 1.9 | 2.4 |
| 10000 sq miles | 0.4 | - | 0.7 | - | - | 1.0 | 1.1 | - | 1.5 | 2.0 |

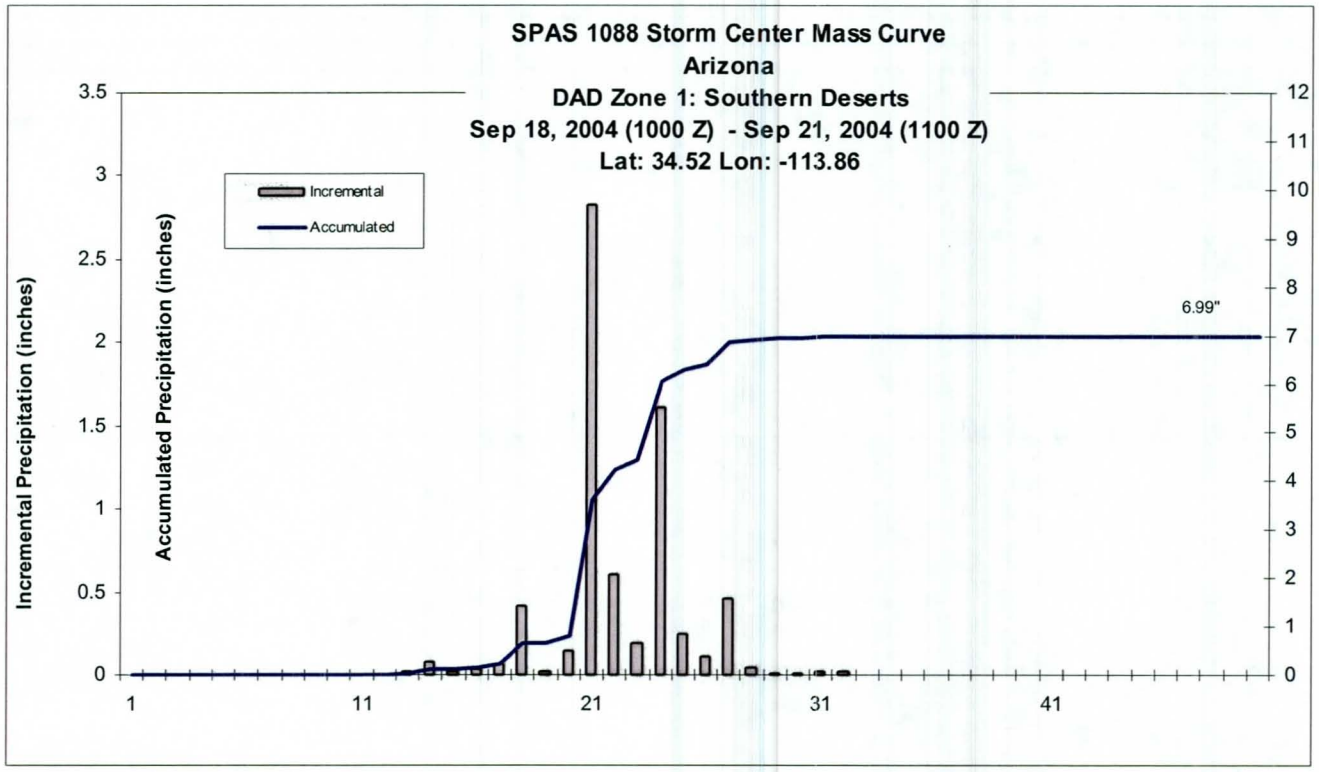
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1088-Cypress Mountain-Zone I | |
| Storm Date(s) | 9/18-20/2004 | |
| Storm Type | Local-Tropical | |
| Storm Location | 34.52 N | 113.86 W |
| Storm Center Elevation | 2400 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 6.99 inches 48 hours 3.35" in 1hr and 5.88" in 3hrs (SPAS 1088 DAD) | |
| | | |
| Storm Representative Dewpoint | 73.5 F | 12hr ave KYUM, KNYL, KIPL |
| Storm Representative Dewpoint Location | 32.98 N | 115.10 W |
| In-place Maximum Dewpoint | 78.5 F | |
| Moisture Inflow Vector | SW @ 170 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 5-Sep | |
| Transposition Dewpoint Location | 31.97 N | 113.76 W |
| Transposition Maximum Dewpoint | 78.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

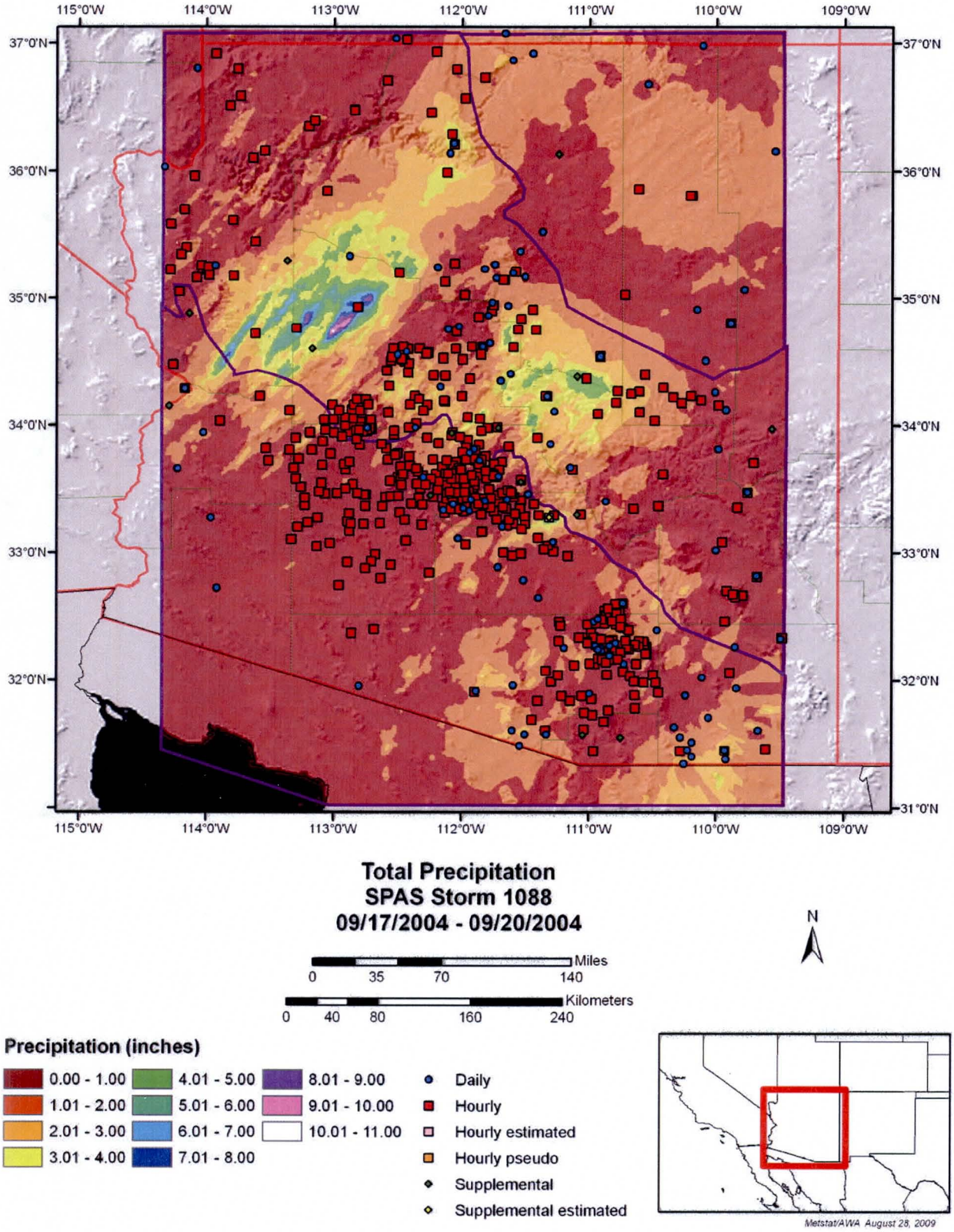

Cypress Mtn Zone 1 Sept 2004
White Tanks #4
Lake Havasu City
Colorado River Indian Reservation
Cathedral City
Indio
Salton Sea
Yuma Proving Ground
Yuma
Mexicali
San Luis Rio Colorado
Barry M Goldwater Air Force Range
Papago Indian Reservation
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Flagstaff
Surprise
Peoria
Phoenix
Mesa
Chandler
Avondale
Gila River Indian Reservation
Theodore Roosevelt Lake
Fort Apache Indian Reservation
Fort Apache Indian Reservation
San Carlos Reservoir

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area (mi²) | Duration (hours) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | Total (49-hr) |
| **0.39** | 4.74 | | 4.98 | | | 5.63 | 6.76 | | 6.99 | | 6.99 | 6.99 |
| **1** | 4.48 | | 4.76 | | | 5.30 | 6.56 | | 6.80 | | 6.80 | 6.80 |
| **5** | 4.48 | | 4.75 | | | 5.11 | 6.28 | | 6.45 | | 6.48 | 6.48 |
| **10** | 4.29 | | 4.57 | | | 4.84 | 6.02 | | 6.18 | | 6.20 | 6.20 |
| **20** | 3.96 | | 4.24 | | | 4.38 | 5.54 | | 5.74 | | 5.77 | 5.77 |
| **50** | 3.36 | | 3.50 | | | 3.75 | 4.77 | | 5.10 | | 5.14 | 5.14 |
| **100** | 2.78 | | 3.00 | | | 3.25 | 4.32 | | 4.52 | | 4.63 | 4.63 |
| **200** | 2.12 | | 2.43 | | | 2.72 | 3.42 | | 3.94 | | 4.06 | 4.06 |
| **300** | 1.69 | | 2.24 | | | 2.37 | 3.23 | | 3.63 | | 3.74 | 3.74 |
| **500** | 1.43 | | 1.81 | | | 2.11 | 2.69 | | 3.07 | | 3.43 | 3.44 |
| **1,000** | 0.81 | | 1.32 | | | 1.87 | 2.14 | | 2.61 | | 2.97 | 2.98 |
| **2,000** | 0.34 | | 1.19 | | | 1.44 | 1.71 | | 2.16 | | 2.55 | 2.58 |
| **5,000** | 0.33 | | 0.80 | | | 1.16 | 1.18 | | 1.69 | | 2.07 | 2.11 |
| **10,000** | 0.31 | | 0.61 | | | 0.83 | 0.94 | | 1.30 | | 1.71 | 1.77 |
| **20,000** | 0.15 | | 0.41 | | | 0.61 | 0.65 | | 0.94 | | 1.36 | 1.36 |




SPAS 1088 Storm Center Mass Curve
Arizona
DAD Zone 1: Southern Deserts
Sep 18, 2004 (1000 Z) - Sep 21, 2004 (1100 Z)
Lat: 34.52 Lon: -113.86
Incremental
Accumulated
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
6.99"
3.5
3
2.5
2
1.5
1
0.5
0
12
11
10
9
8
7
6
5
4
3
2
1
0
1
11
21
31
41


115°0'W
114°0'W
113°0'W
112°0'W
111°0'W
110°0'W
109°0'W
37°0'N
36°0'N
35°0'N
34°0'N
33°0'N
32°0'N
31°0'N
Total Precipitation
SPAS Storm 1088
09/17/2004 - 09/20/2004
N
Miles
0 35 70 140
Kilometers
0 40 80 160 240
Precipitation (inches)
0.00 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
Daily
Hourly
Hourly estimated
Hourly pseudo
Supplemental
Supplemental estimated
Metstat/AWA August 28, 2009

# Big Pine Flat, AZ

**February 10-13, 2005**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1147-Big Pine Flat-Zone 1 |
| Storm Date: | 2/10-13/2005 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for the White Tanks #4

**Temporal Transposition Date** 15-Feb

| | Lat | Long |
|---|---|---|
| Storm center location | 33.36 N | 111.33 W |
| Storm Rep dew point location | 32.25 N | 110.93 W |
| Transposition dewpoint location | 32.40 N | 112.12 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SSE @ 100 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,450 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 58.5 F | with total precipitable water above sea level of | | | 1.28 | inches. |
| The in-place maximum dew point is | 60.0 F | with total precipitable water above sea level of | | | 1.38 | inches. |
| The transpositioned maximum dew point is | 61.0 F | with total precipitable water above sea level of | | | 1.38 | inches. |
| The in-place storm elevation is | 2,450 | which subtracts | 0.330 | inches of precipitable water at | 58.5 F | |
| The in-place storm elevation is | 2,450 | which subtracts | 0.35 | inches of precipitable water at | 60.0 F | |
| Basin elevation at | 3,650 | which subtracts | 0.52 | inches of precipitable water at | 61.0 F | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.52 | inches of precipitable water at | 61.0 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.08 |
| The transposition factor is | 0.84 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 0.91 |

Notes: 24 hour average taken from KPHX, KIWA, KDMA, and KTUS

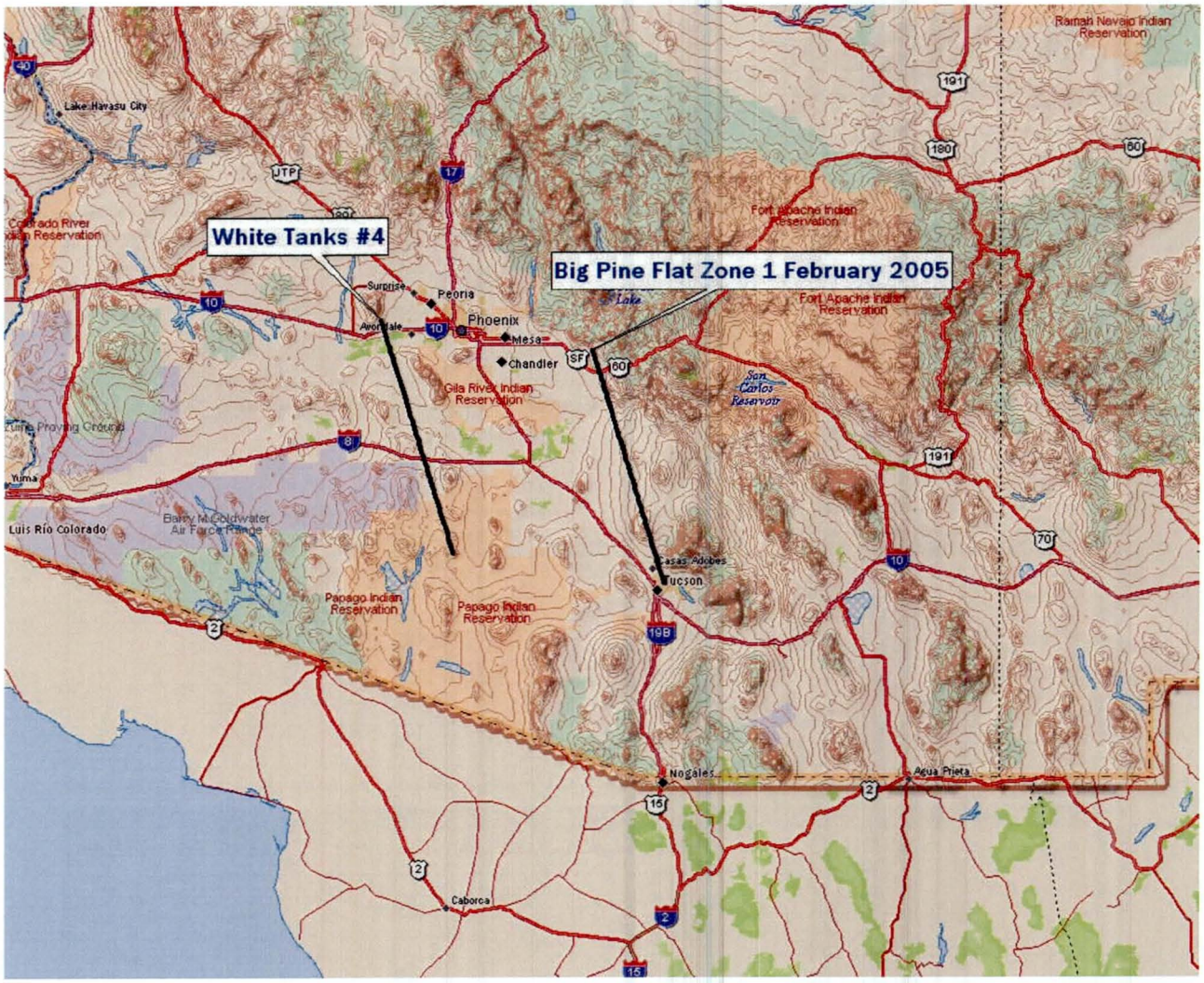
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.0 | 2.5 | 3.7 | 4.7 | 5.2 | - | 5.5 | 5.6 | - | 5.8 |
| 10 sq miles | 1.0 | 2.5 | 3.4 | 4.2 | 4.7 | - | 5.2 | 5.4 | - | 5.6 |
| 100 sq miles | 0.7 | 1.7 | 2.7 | 3.2 | 3.7 | - | 4.3 | 4.5 | - | 4.7 |
| 200 sq miles | 0.6 | 1.6 | 2.4 | 2.9 | 3.4 | - | 3.9 | 4.2 | - | 4.4 |
| 500 sq miles | 0.4 | 1.4 | 2.1 | 2.4 | 2.9 | - | 3.4 | 3.7 | - | 3.9 |
| 1000 sq miles | 0.3 | 1.1 | 2.0 | 2.3 | 2.8 | - | 3.2 | 3.4 | - | 3.5 |
| 2000 sq miles | 0.3 | 1.0 | 1.8 | 2.1 | 2.4 | - | 2.8 | 3.1 | - | 3.2 |
| 5000 sq miles | 0.2 | 0.6 | 1.4 | 1.8 | 2.0 | - | 2.3 | 2.4 | - | 2.8 |
| 10000 sq miles | 0.2 | 0.6 | 1.0 | 1.4 | 1.8 | - | 2.1 | 2.3 | - | 2.4 |
| 20000 sq miles | 0.1 | 0.5 | 0.9 | 1.2 | 1.5 | - | 1.8 | 1.9 | - | 2.0 |

**Adjusteded Storm Depth-Area-Duration**

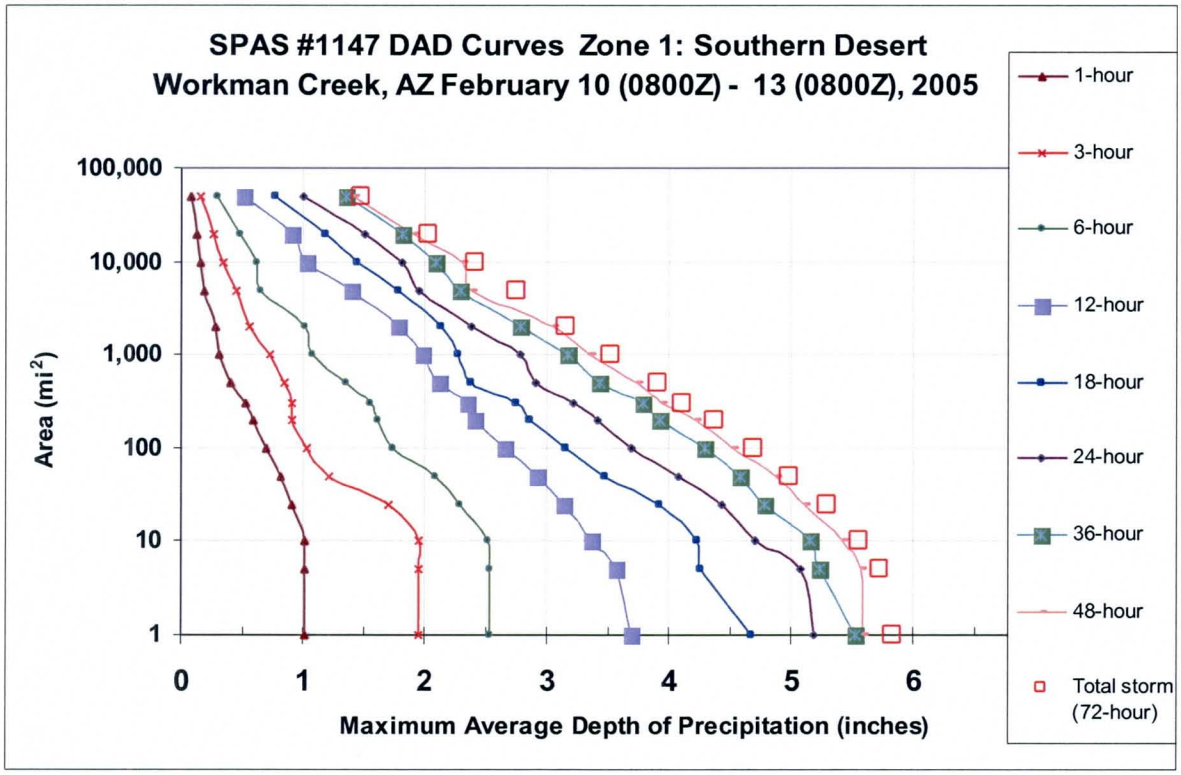
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.9 | 2.3 | 3.4 | 4.3 | 4.7 | - | 5.0 | 5.1 | - | 5.3 |
| 10 sq miles | 0.9 | 2.3 | 3.1 | 3.9 | 4.3 | - | 4.7 | 4.9 | - | 5.1 |
| 100 sq miles | 0.6 | 1.6 | 2.4 | 2.9 | 3.4 | - | 3.9 | 4.1 | - | 4.3 |
| 200 sq miles | 0.5 | 1.5 | 2.2 | 2.6 | 3.1 | - | 3.6 | 3.8 | - | 4.0 |
| 500 sq miles | 0.4 | 1.2 | 1.9 | 2.2 | 2.6 | - | 3.1 | 3.4 | - | 3.6 |
| 1000 sq miles | 0.3 | 1.0 | 1.8 | 2.1 | 2.5 | - | 2.9 | 3.1 | - | 3.2 |
| 2000 sq miles | 0.3 | 0.9 | 1.6 | 1.9 | 2.2 | - | 2.5 | 2.8 | - | 2.9 |
| 5000 sq miles | 0.2 | 0.6 | 1.3 | 1.6 | 1.8 | - | 2.1 | 2.2 | - | 2.5 |
| 10000 sq miles | 0.1 | 0.6 | 0.9 | 1.3 | 1.7 | - | 1.9 | 2.1 | - | 2.2 |
| 20000 sq miles | 0.1 | 0.4 | 0.8 | 1.1 | 1.4 | - | 1.7 | 1.7 | - | 1.8 |

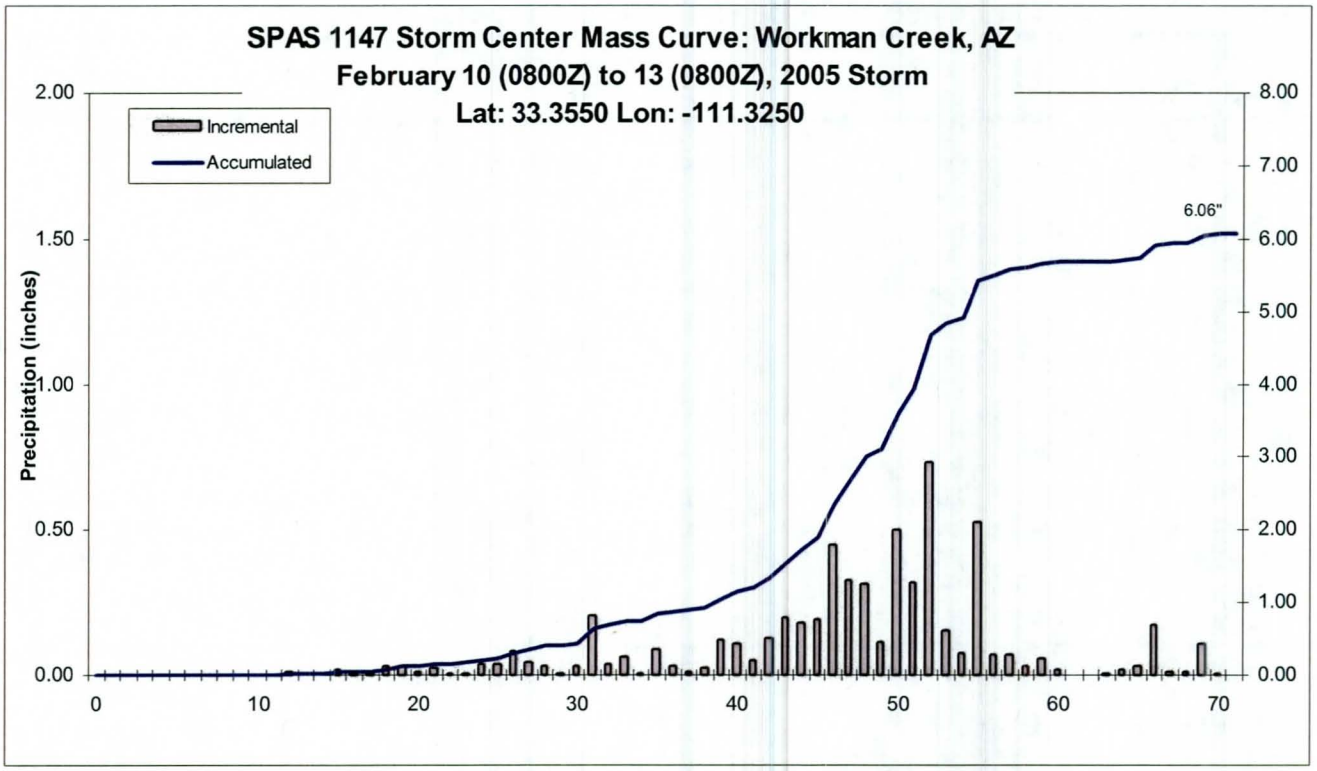
| | | | |
|---|---|---|---|
| Storm or Storm Center Name | SPAS-1147-Big Pine Flat-Zone 1 | | |
| Storm Date(s) | 2/10-13/2005 | | |
| Storm Type | General | | |
| Storm Location | 33.36 N | 111.33 W | |
| Storm Center Elevation | 2450 | non-orographic | |
| Precipitation Total & Duration (10 sq mi) | 6.06 inches 72 hours (SPAS 1147 DAD) | | |
| | | | |
| Storm Representative Dewpoint | 58.5 F | 24hr ave | KPHX, KIWA, KIWA, KDMA, KTUS |
| Storm Representative Dewpoint Location | 32.25 N | 110.93 W | |
| In-place Maximum Dewpoint | 60.0 F | | |
| Moisture Inflow Vector | SSE @ 100 | | |
| In-place Maximization Factor | | | |
| | | | |
| Temporal Transposition (Date) | 15-Feb | | |
| Transposition Dewpoint Location | 32.40 N | 112.12 W | |
| Transposition Maximum Dewpoint | 61.0 F | | |
| Transposition Adjustment Factor | | | |
| Average Basin Elevation | 3,650 | | |
| Highest Elevation in Basin | 3,655 | | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | | |
| Elevation Adjustment Factor | | | |

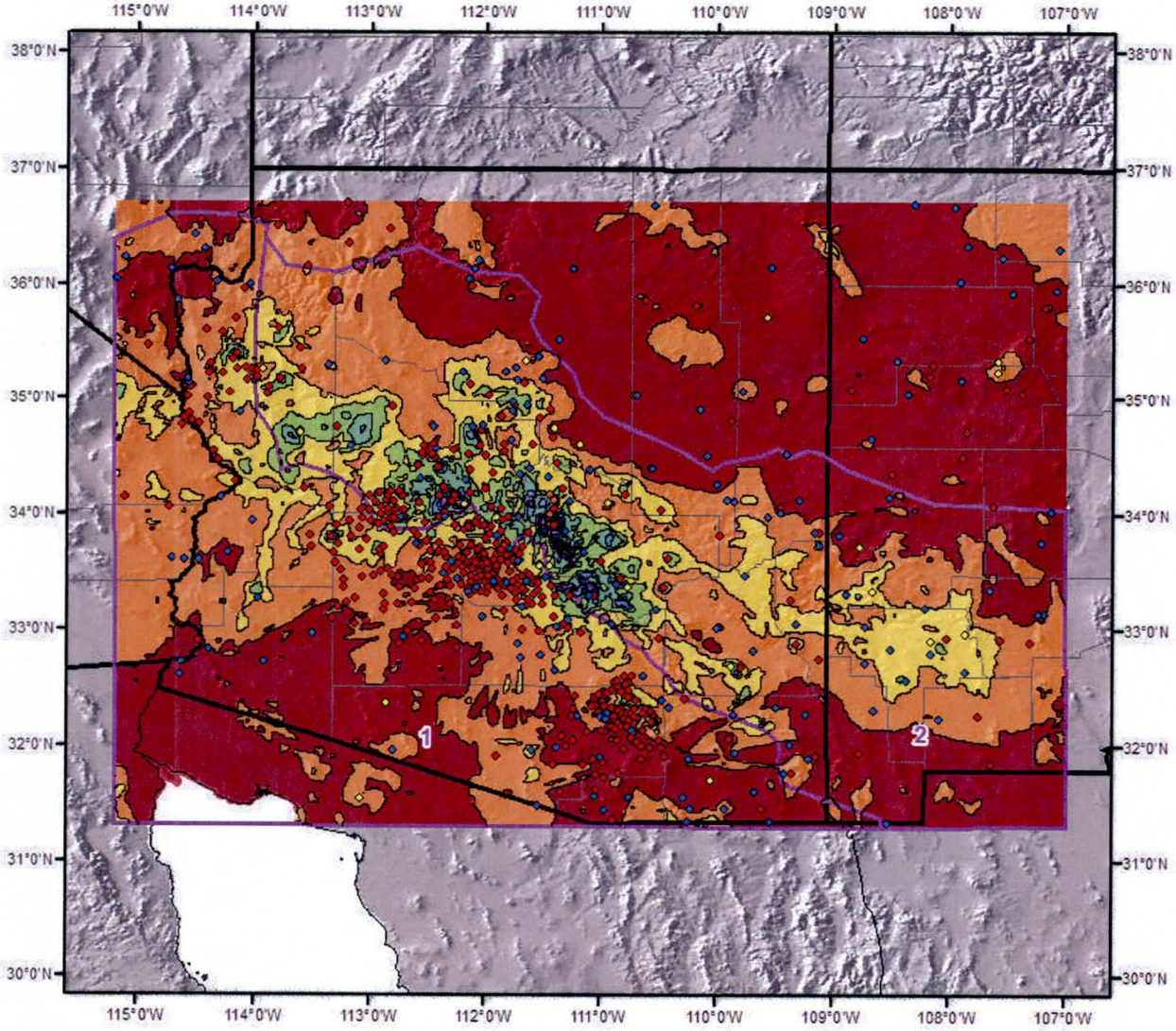

White Tanks #4
Big Pine Flat Zone 1 February 2005
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Gila River Indian Reservation
Fort Apache Indian Reservation
San Carlos Reservoir
Ramah Navajo Indian Reservation
Yuma
Luis Río Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta
Caborca

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) 1 | 3 | 6 | 12 | 18 | 24 | 36 | 48 | total |
|---|---|---|---|---|---|---|---|---|---|
| **0.4** | 1.27 | 2.22 | 2.77 | 3.96 | 4.93 | 5.48 | 5.84 | 5.90 | 6.06 |
| **1** | 1.01 | 1.95 | 2.54 | 3.69 | 4.67 | 5.18 | 5.52 | 5.59 | 5.83 |
| **5** | 1.01 | 1.95 | 2.54 | 3.57 | 4.26 | 5.07 | 5.23 | 5.57 | 5.73 |
| **10** | 1.01 | 1.95 | 2.52 | 3.37 | 4.23 | 4.71 | 5.16 | 5.41 | 5.55 |
| **25** | 0.91 | 1.70 | 2.29 | 3.14 | 3.93 | 4.43 | 4.79 | 5.11 | 5.29 |
| **50** | 0.81 | 1.22 | 2.09 | 2.93 | 3.48 | 4.08 | 4.58 | 4.87 | 4.99 |
| **100** | 0.69 | 1.03 | 1.74 | 2.66 | 3.15 | 3.69 | 4.29 | 4.53 | 4.69 |
| **200** | 0.58 | 0.91 | 1.61 | 2.41 | 2.86 | 3.41 | 3.92 | 4.21 | 4.37 |
| **300** | 0.52 | 0.91 | 1.55 | 2.35 | 2.76 | 3.21 | 3.78 | 3.94 | 4.10 |
| **500** | 0.40 | 0.84 | 1.36 | 2.13 | 2.38 | 2.90 | 3.43 | 3.74 | 3.90 |
| **1,000** | 0.30 | 0.72 | 1.07 | 1.99 | 2.28 | 2.78 | 3.17 | 3.35 | 3.52 |
| **2,000** | 0.28 | 0.56 | 1.02 | 1.78 | 2.14 | 2.39 | 2.78 | 3.05 | 3.16 |
| **5,000** | 0.19 | 0.44 | 0.64 | 1.40 | 1.79 | 1.96 | 2.29 | 2.39 | 2.75 |
| **10,000** | 0.16 | 0.34 | 0.61 | 1.03 | 1.44 | 1.82 | 2.09 | 2.30 | 2.41 |
| **20,000** | 0.13 | 0.26 | 0.47 | 0.90 | 1.19 | 1.51 | 1.82 | 1.90 | 2.03 |
| **50,000** | 0.07 | 0.16 | 0.29 | 0.50 | 0.77 | 1.00 | 1.36 | 1.41 | 1.47 |




SPAS 1147 Storm Center Mass Curve: Workman Creek, AZ
February 10 (0800Z) to 13 (0800Z), 2005 Storm
Lat: 33.3550 Lon: -111.3250
Incremental
Accumulated
6.06"
Precipitation (inches)
2.00
1.50
1.00
0.50
0.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70




**Legend**

- Daily
- Hourly
- Hourly Estimated
- Hourly Pseudo
- Supplemental

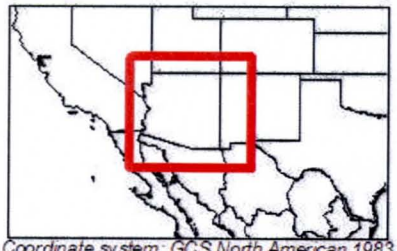
**Total Rainfall (72-hours)**
**SPAS Storm #1147**
**Feb 10, 2005 (0800Z) - Feb 13, 2005 (0800Z)**

Miles: 0 30 60 120
Kilometers: 0 30 60 120 180 240

**Precipitation (inches)**

| | | |
|---|---|---|
| 0.11 - 1.00 | 3.01 - 4.00 | 6.01 - 7.00 |
| 1.01 - 2.00 | 4.01 - 5.00 | 7.01 - 8.00 |
| 2.01 - 3.00 | 5.01 - 6.00 | 8.01 - 9.00 |

N



*Coordinate system: GCS North American 1983*
*Scale: 1:5,391,256*

MetstatAWA August 28, 2009

# Camp Creek, AZ

**September 3, 2005**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1091-Camp Creek-Zone 1 |
| Storm Date: | September 3, 2005 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 18-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 34.04 N | 111.81 W |
| Storm Rep dew point location | 33.18 N | 111.81 W |
| Transposition dewpoint location | 32.63 N | 112.52 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 60 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 2,750 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 68.0 F | with total precipitable water above sea level of | | | 2.05 | inches. |
| The in-place maximum dew point is | 81.0 F | with total precipitable water above sea level of | | | 3.76 | inches. |
| The transpositioned maximum dew point is | 81.5 F | with total precipitable water above sea level of | | | 3.84 | inches. |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 68.0 F | |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.0 F | |
| Basin elevation at | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.5 F | |
| The inflow barrier height/basin elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.50 |
| The transposition factor is | 1.02 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.53 |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. In-Place max factor 1.83 calculated, held to 1.50

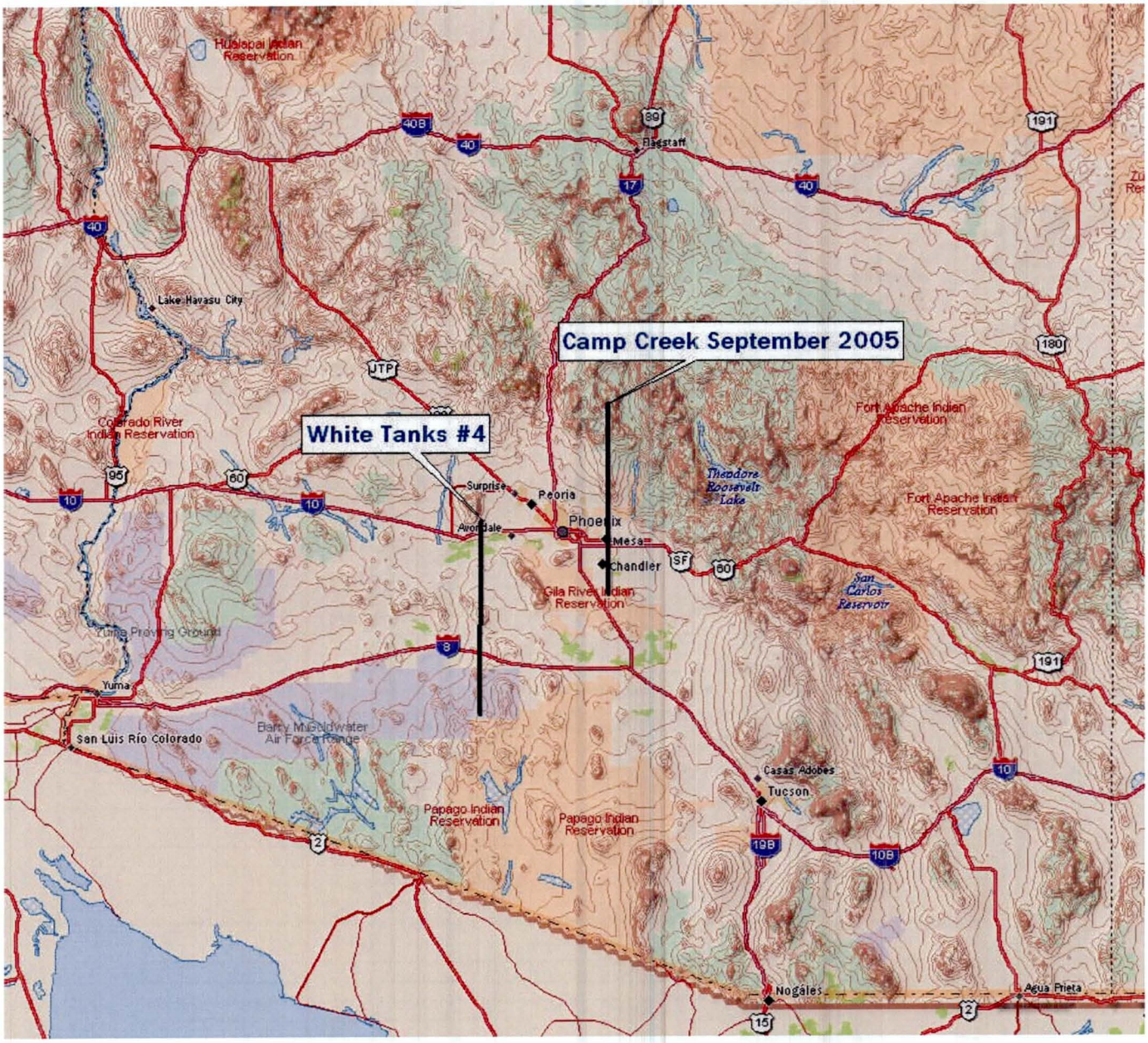
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 3.0 | 4.2 | 4.4 | 4.4 | 4.4 | 4.4 | 4.5 | - | - | - |
| 10 sq miles | 2.5 | 3.5 | 3.6 | 3.8 | 3.8 | 3.8 | 3.8 | - | - | - |
| 50 sq miles | 1.7 | 2.6 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | - | - | - |
| 100 sq miles | 1.3 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | - | - | - |
| 200 sq miles | 0.9 | 1.6 | 1.7 | 1.7 | 1.7 | 1.9 | 1.9 | - | - | - |
| 500 sq miles | 0.5 | 1.0 | 1.1 | 1.1 | 1.1 | 1.3 | 1.3 | - | - | - |
| 1000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

**Adjusted Storm Depth-Area-Duration**

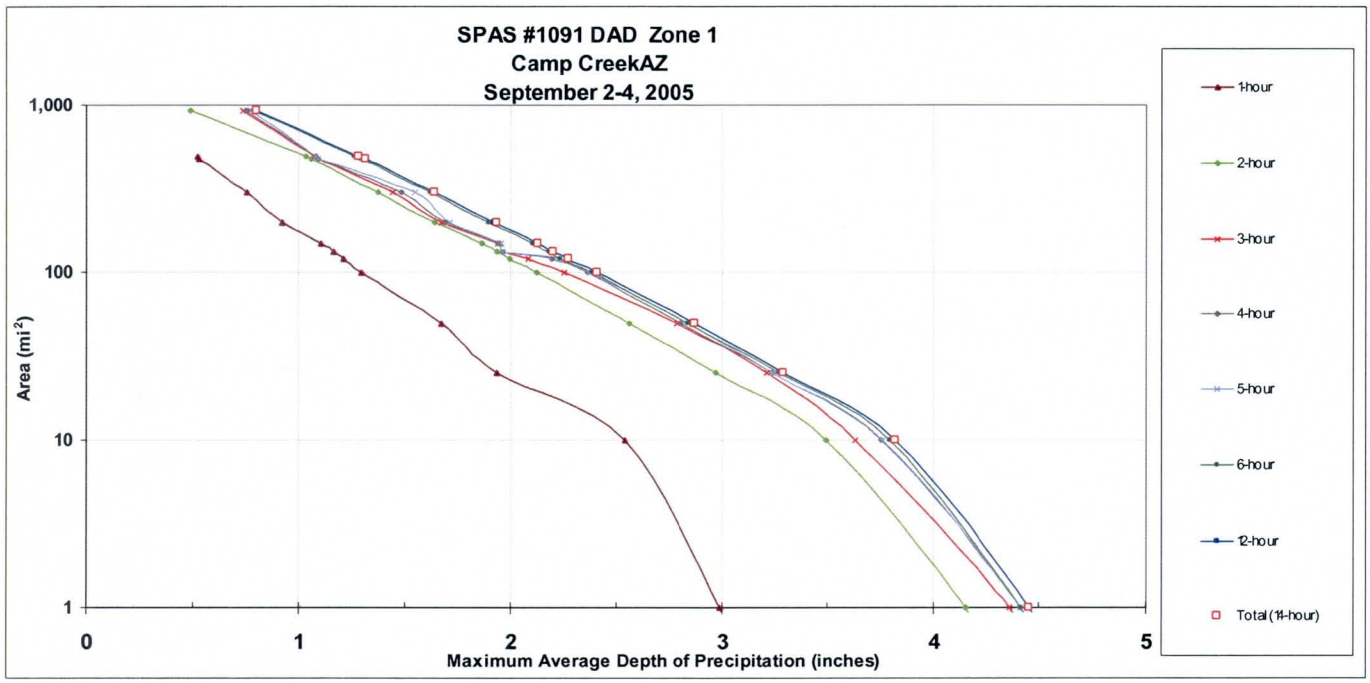
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 4.6 | 6.4 | 6.7 | 6.8 | 6.8 | 6.8 | 6.8 | - | - | - |
| 10 sq miles | 3.9 | 5.3 | 5.6 | 5.7 | 5.8 | 5.8 | 5.9 | - | - | - |
| 50 sq miles | 2.6 | 3.9 | 4.3 | 4.3 | 4.4 | 4.4 | 4.4 | - | - | - |
| 100 sq miles | 2.0 | 3.2 | 3.4 | 3.6 | 3.6 | 3.6 | 3.7 | - | - | - |
| 200 sq miles | 1.4 | 2.5 | 2.6 | 2.6 | 2.6 | 2.9 | 2.9 | - | - | - |
| 500 sq miles | 0.8 | 1.6 | 1.6 | 1.7 | 1.7 | 1.9 | 1.9 | - | - | - |
| 1000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 2000 sq miles | - | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - | - |

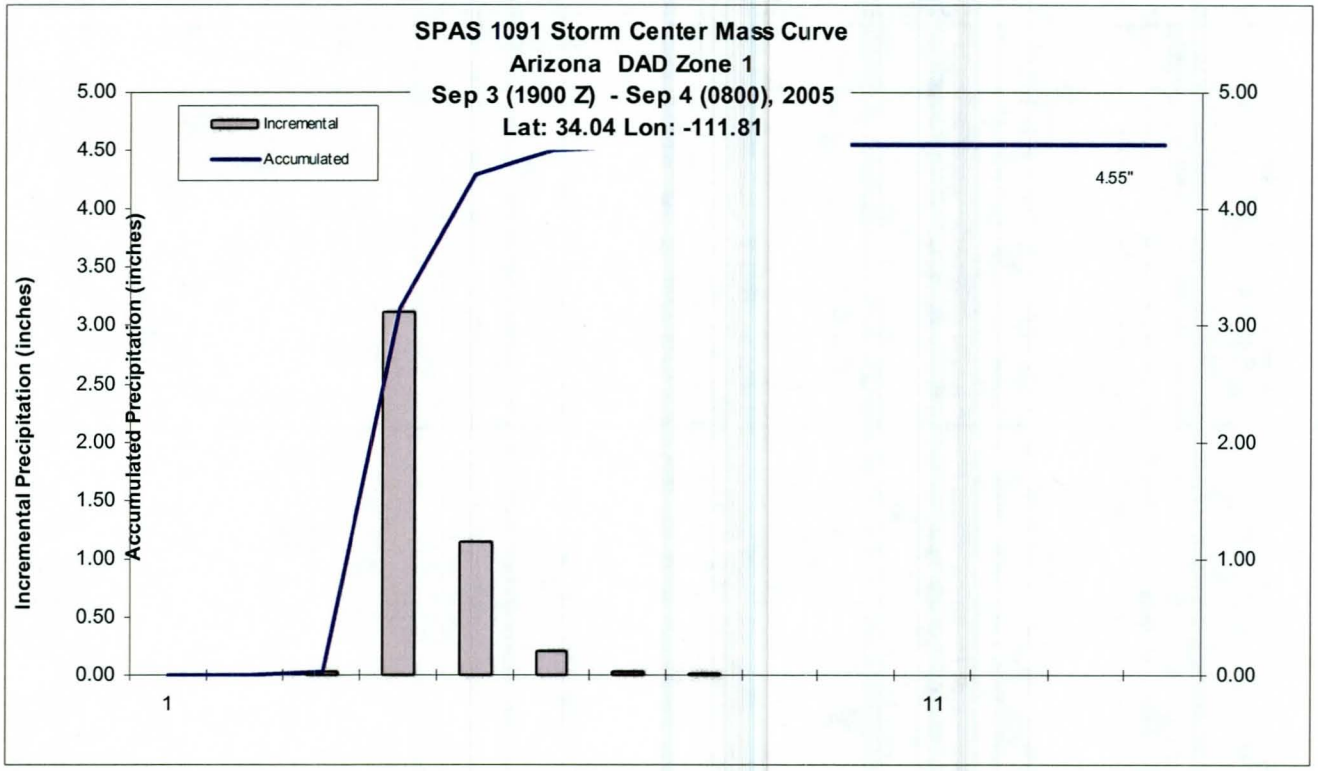
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1091-Camp Creek-Zone 1 | |
| Storm Date(s) | 9/3/05 | |
| Storm Type | Local Storm | |
| Storm Location | 34.04 N | 111.81 W |
| Storm Center Elevation | 2750 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 3.34 inches 1 hour 4.82" in 2hrs (SPAS 1091 DAD) | |
| | | |
| Storm Representative Dewpoint | 68.0 F | 3hr ave KIWA, KCHD, KCGZ |
| Storm Representative Dewpoint Location | 33.18 N | 111.81 W |
| In-place Maximum Dewpoint | 81.0 F | |
| Moisture Inflow Vector | S @ 60 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 18-Aug | |
| Transposition Dewpoint Location | 32.63 N | 112.52 W |
| Transposition Maximum Dewpoint | 81.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.53 | |

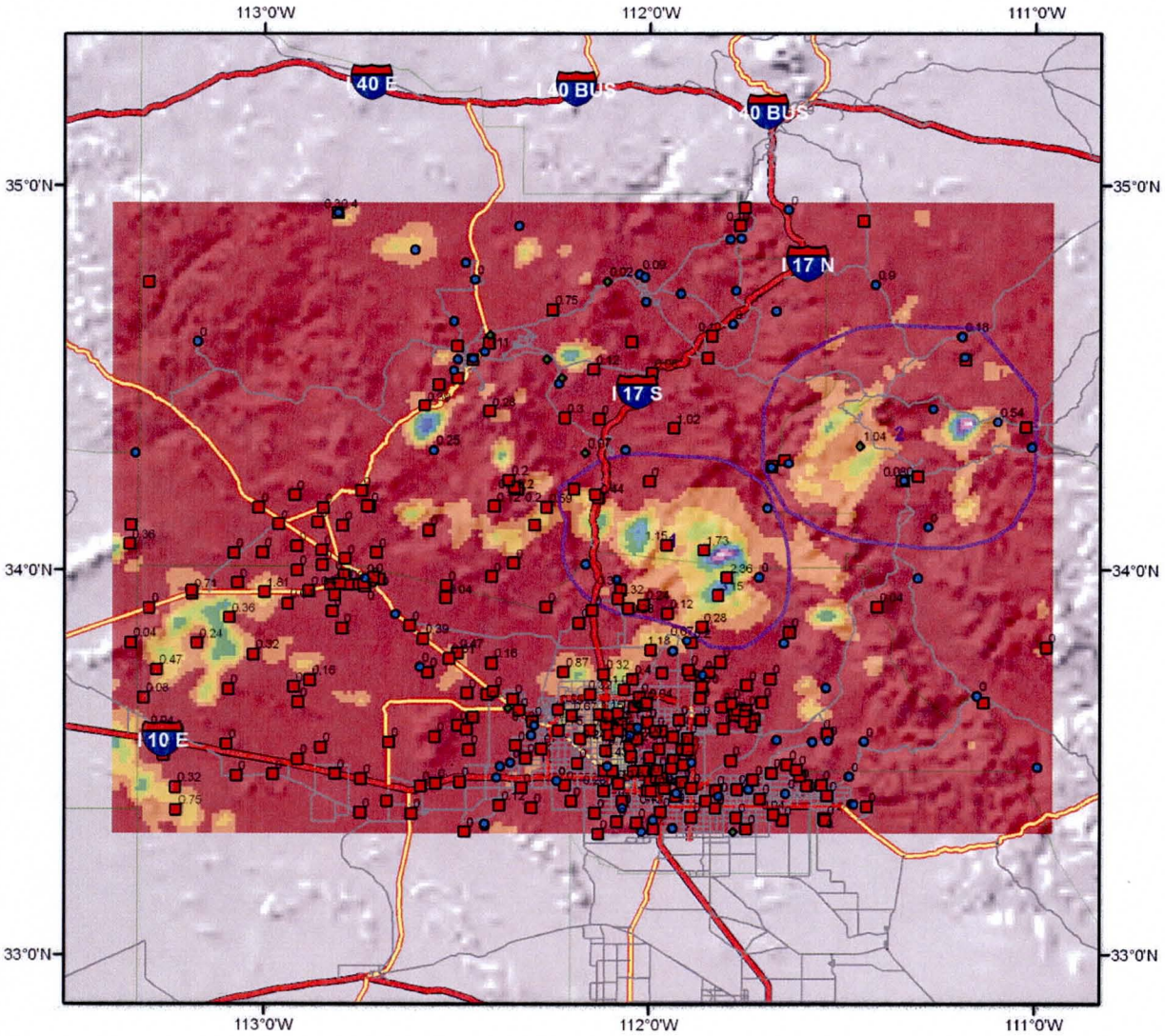

Camp Creek September 2005
White Tanks #4
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Mesa
Chandler
Gila River Indian Reservation
Theodore Roosevelt Lake
Fort Apache Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta
Flagstaff

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) 1 | 2 | 3 | 4 | 5 | 6 | 12 | total (14-hr) |
|---|---|---|---|---|---|---|---|---|
| **0.39** | 3.13 | 4.26 | 4.47 | 4.51 | 4.53 | 4.55 | 4.55 | 4.55 |
| **1** | 2.99 | 4.15 | 4.36 | 4.41 | 4.41 | 4.41 | 4.45 | 4.45 |
| **10** | 2.54 | 3.49 | 3.63 | 3.75 | 3.76 | 3.79 | 3.82 | 3.82 |
| **25** | 1.93 | 2.97 | 3.21 | 3.24 | 3.24 | 3.27 | 3.29 | 3.29 |
| **50** | 1.67 | 2.56 | 2.79 | 2.81 | 2.84 | 2.84 | 2.87 | 2.87 |
| **100** | 1.29 | 2.12 | 2.25 | 2.36 | 2.37 | 2.38 | 2.41 | 2.41 |
| **121** | 1.21 | 1.99 | 2.08 | 2.19 | 2.23 | 2.23 | 2.27 | 2.27 |
| **135** | 1.16 | 1.93 | 1.96 | 1.96 | 1.96 | 2.18 | 2.20 | 2.20 |
| **150** | 1.10 | 1.86 | 1.94 | 1.94 | 1.95 | 2.10 | 2.13 | 2.13 |
| **200** | 0.92 | 1.64 | 1.67 | 1.69 | 1.71 | 1.89 | 1.92 | 1.93 |
| **300** | 0.76 | 1.37 | 1.44 | 1.48 | 1.55 | 1.62 | 1.64 | 1.64 |
| **475** | 0.53 | 1.06 | 1.09 | 1.09 | 1.09 | 1.29 | 1.31 | 1.31 |
| **500** | 0.52 | 1.03 | 1.07 | 1.08 | 1.08 | 1.26 | 1.27 | 1.28 |
| **933** | | 0.49 | 0.74 | 0.76 | 0.78 | 0.79 | 0.80 | 0.80 |




SPAS 1091 Storm Center Mass Curve
Arizona DAD Zone 1
Sep 3 (1900 Z) - Sep 4 (0800), 2005
Lat: 34.04 Lon: -111.81
Incremental
Accumulated
4.55"
Incremental Precipitation (inches)
Accumulated Precipitation (inches)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1
11




**Total Precipitation**
**SPAS Storm #1091**
**09/2/2005 - 9/4/2005**

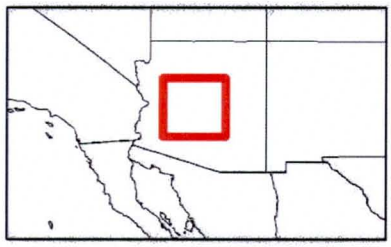
N

Miles
0 5 10 20

Kilometers
0 12.5 25 50 75

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.00 - 0.50 | 2.01 - 2.50 | 4.01 - 4.50 | Daily |
| 0.51 - 1.00 | 2.51 - 3.00 | 4.51 - 5.00 | Hourly |
| 1.01 - 1.50 | 3.01 - 3.50 | | Hourly pseudo |
| 1.51 - 2.00 | 3.51 - 4.00 | | Supplemental |



Metstat/AWA ugust 14, 2009

# Cooks Mesa, AZ

**November 30 – December 2, 2007**

**Storm Type: General Frontal**

| | |
|---|---|
| Storm Name: | SPAS-1149-Cooks Mesa Zone 1 |
| Storm Date: | 11/30-12-2/2007 |
| AWA Analysis Date: | 10/16/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 15-Nov

| | Lat | Long |
|---|---|---|
| Storm center location | 35.41 N | 114.16 W |
| Storm Rep dew point location | 31.70 N | 111.11 W |
| Transposition dewpoint location | 29.85 N | 109.54 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SSE @ 310 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 4,900 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The storm representative dew point is | 63.5 F | with total precipitable water above sea level of | | | | 1.68 | inches. |
| The in-place maximum dew point is | 65.0 F | with total precipitable water above sea level of | | | | 1.77 | inches. |
| The transpositioned maximum dew point is | 65.0 F | with total precipitable water above sea level of | | | | 1.77 | inches. |
| The in-place storm elevation is | 4,900 | which subtracts | 0.72 | inches of precipitable water at | 63.5 F | | |
| The in-place storm elevation is | 4,900 | which subtracts | 0.76 | inches of precipitable water at | 65.0 F | | |
| Basin elevation at | 3,650 | which subtracts | 0.60 | inches of precipitable water at | 65.0 F | | |
| The inflow barrier height/basin elevation is | 3,650 | which subtracts | 0.60 | inches of precipitable water at | 65.0 F | | |

| | |
|---|---|
| The in-place maximization factor is | 1.05 |
| The transposition factor is | 1.16 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.22 |

Notes: 24hr ave KCGZ, KOLS, KFHU, KPHX, KTUS

**Observed Storm Depth-Area-Duration**

| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.6 | 2.6 | 3.1 | - | 5.1 | - | - | 5.3 | - | - |
| 10 sq miles | 0.6 | 2.6 | 3.1 | - | 4.6 | - | - | 5.0 | - | - |
| 100 sq miles | 0.6 | 2.6 | 3.1 | - | 3.7 | - | - | 4.3 | - | - |
| 200 sq miles | 0.6 | 2.3 | 3.0 | - | 3.6 | - | - | 3.9 | - | - |
| 500 sq miles | 0.6 | 2.2 | 2.7 | - | 3.5 | - | - | 3.7 | - | - |
| 1000 sq miles | 0.6 | 1.9 | 2.6 | - | 3.2 | - | - | 3.4 | - | - |
| 2000 sq miles | 0.6 | 1.8 | 2.4 | - | 2.9 | - | - | 3.2 | - | - |
| 5000 sq miles | 0.5 | 1.4 | 1.9 | - | 2.5 | - | - | 2.7 | - | - |
| 10000 sq miles | 0.3 | 1.3 | 1.8 | - | 2.2 | - | - | 2.4 | - | - |
| 20000 sq miles | 0.3 | 1.1 | 1.4 | - | 1.9 | - | - | 2.0 | - | - |

**Adjusteded Storm Depth-Area-Duration**

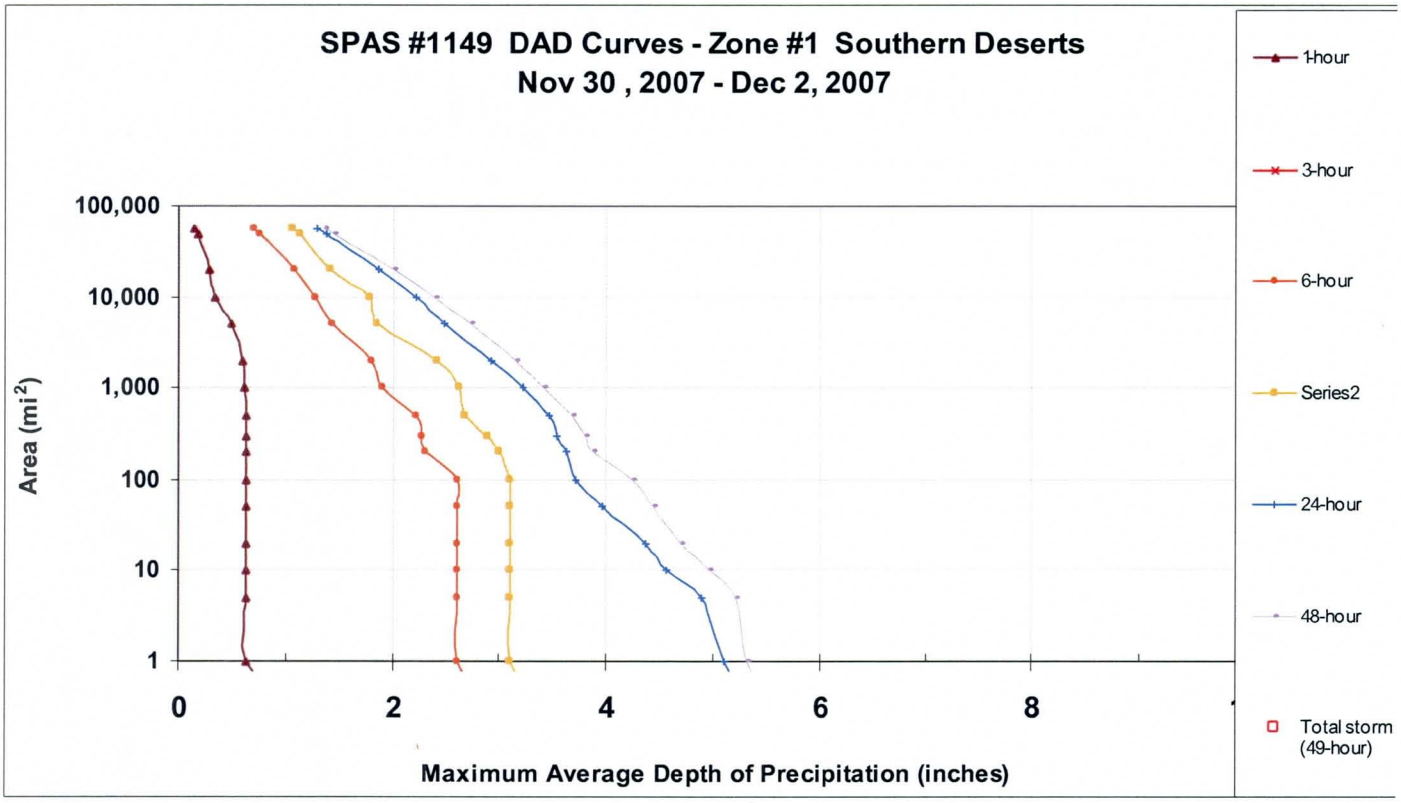
| | 1 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 30 Hours | 36 Hours | 48 Hours | 60 Hours | 72 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 0.8 | 3.2 | 3.8 | - | 6.2 | - | - | 6.5 | - | - |
| 10 sq miles | 0.8 | 3.2 | 3.8 | - | 5.6 | - | - | 6.0 | - | - |
| 100 sq miles | 0.8 | 3.2 | 3.8 | - | 4.5 | - | - | 5.2 | - | - |
| 200 sq miles | 0.8 | 2.8 | 3.6 | - | 4.4 | - | - | 4.7 | - | - |
| 500 sq miles | 0.8 | 2.7 | 3.3 | - | 4.2 | - | - | 4.5 | - | - |
| 1000 sq miles | 0.8 | 2.3 | 3.2 | - | 3.9 | - | - | 4.2 | - | - |
| 2000 sq miles | 0.7 | 2.2 | 2.9 | - | 3.6 | - | - | 3.8 | - | - |
| 5000 sq miles | 0.6 | 1.7 | 2.3 | - | 3.0 | - | - | 3.3 | - | - |
| 10000 sq miles | 0.4 | 1.5 | 2.2 | - | 2.7 | - | - | 2.9 | - | - |
| 20000 sq miles | 0.3 | 1.3 | 1.7 | - | 2.3 | - | - | 2.4 | - | - |

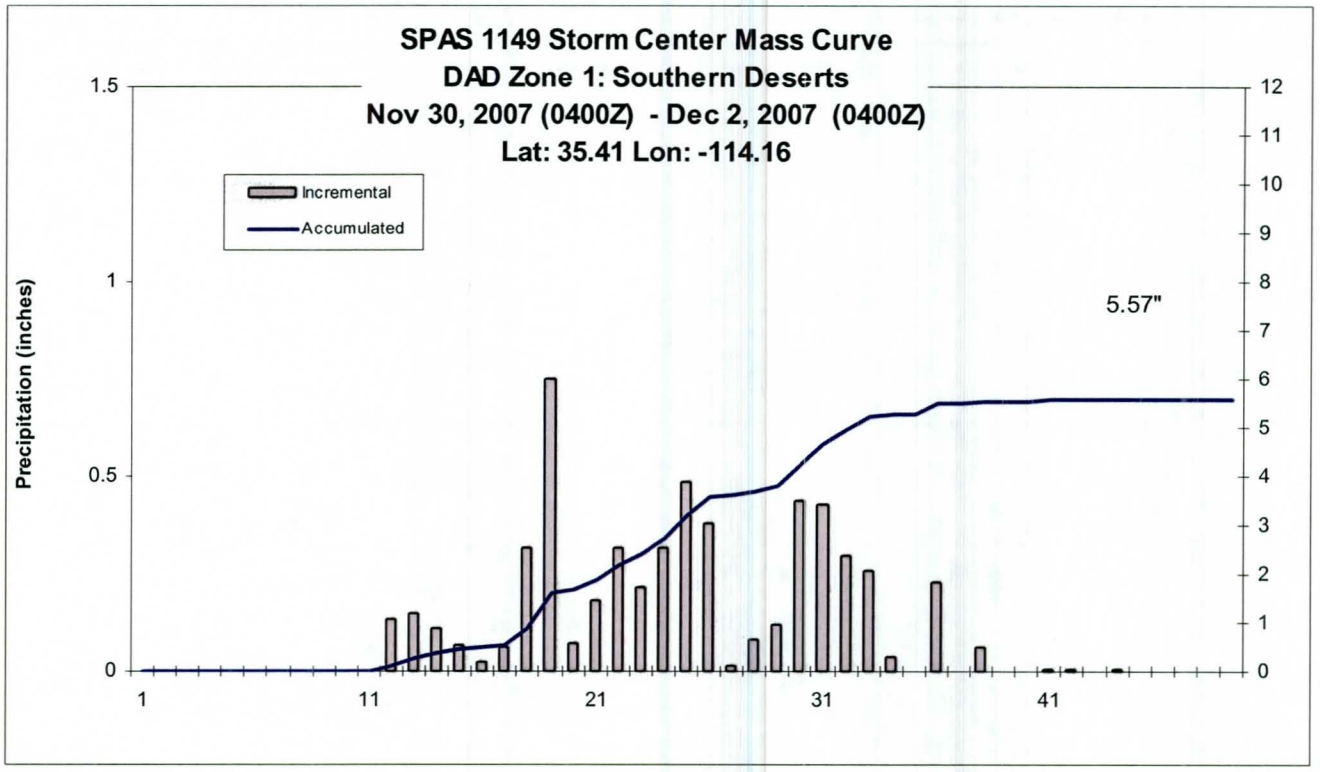
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1149-Cooks Mesa Zone 1 | |
| Storm Date(s) | 11/30-12-2/2007 | |
| Storm Type | General | |
| Storm Location | 35.41 N | 114.16 W |
| Storm Center Elevation | 4900 | orographic Mt Lemmon |
| Precipitation Total & Duration (10 sq mi) | 6.54 inches 49 hours (SPAS 1147 DAD) | |
| | | |
| Storm Representative Dewpoint | 63.5 F | 24hr ave KCGZ, KOLS, KFHU, KPHX, KTUS |
| Storm Representative Dewpoint Location | 31.70 N | 111.11 W |
| In-place Maximum Dewpoint | 65.0 F | |
| Moisture Inflow Vector | SSE @ 310 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Nov | |
| Transposition Dewpoint Location | 29.85 N | 109.54 W |
| Transposition Maximum Dewpoint | 65.0 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |

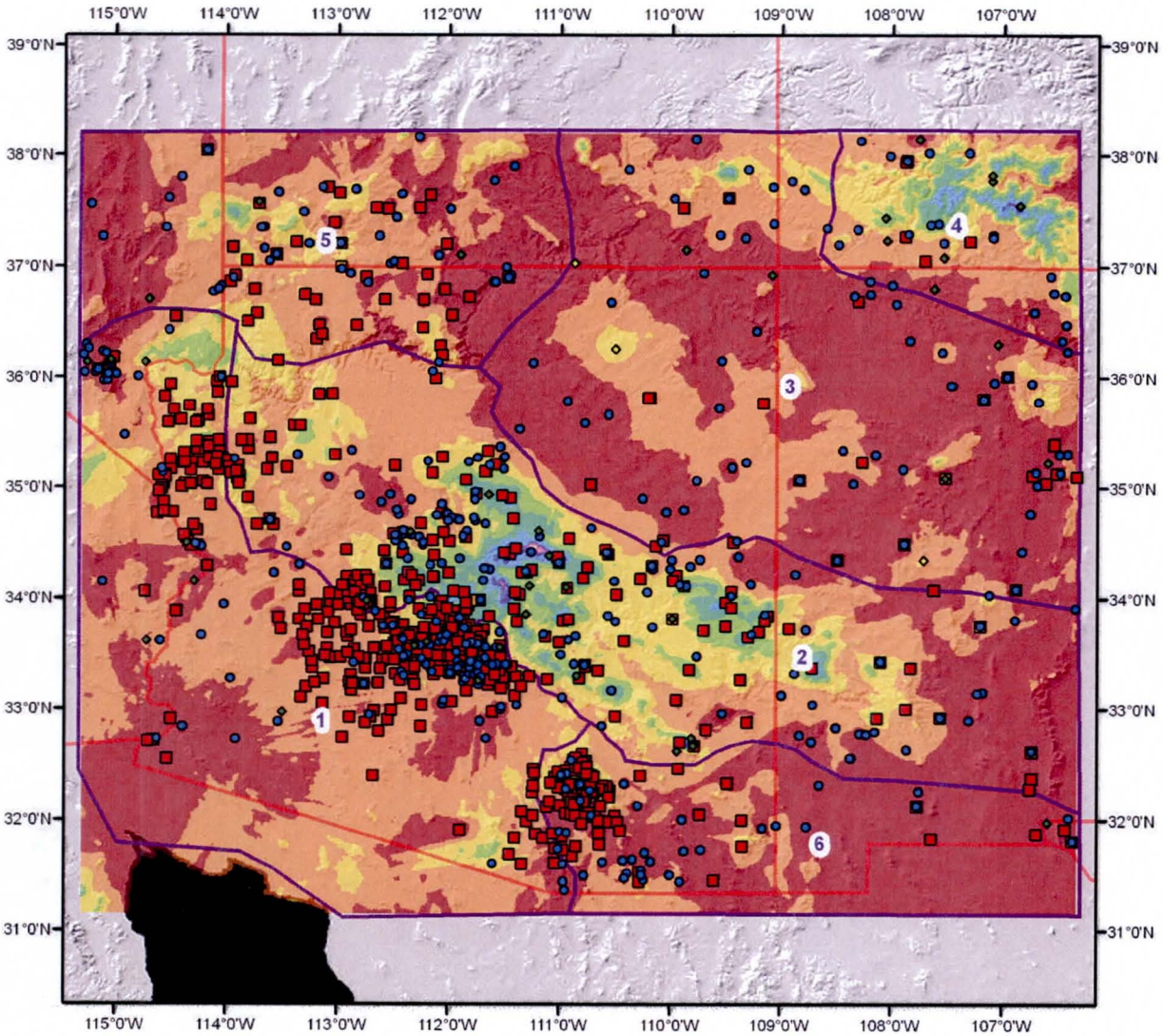
Cooks Mesa November 2007
White Tanks #4
Las Vegas
Lake Mead
Flagstaff
Albuque
Riverside
Oceanside
Escondido
San Diego
Tijuana
Salton Sea
Mexicali
San Luis Río Colorado
Ensenada
Phoenix
Gilbert
Tucson
Nogáles
Hermosillo
Plutarco Elías Calles
Guaymas
Ciudad Obregón
AZ

**MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)**

| | Duration (hours) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($mi^2$) | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | 36 | 48 | Total (49-hr) |
| 0.39 | 1.02 | | | | | 2.92 | 3.44 | | 5.36 | | 5.57 | |
| 1 | 0.64 | | | | | 2.60 | 3.09 | | 5.11 | | 5.31 | |
| 5 | 0.64 | | | | | 2.60 | 3.09 | | 4.90 | | 5.21 | |
| 10 | 0.64 | | | | | 2.60 | 3.09 | | 4.56 | | 4.96 | |
| 20 | 0.64 | | | | | 2.60 | 3.09 | | 4.36 | | 4.70 | |
| 50 | 0.64 | | | | | 2.60 | 3.09 | | 3.96 | | 4.44 | |
| 100 | 0.64 | | | | | 2.60 | 3.09 | | 3.71 | | 4.25 | |
| 200 | 0.64 | | | | | 2.30 | 2.99 | | 3.62 | | 3.87 | |
| 300 | 0.64 | | | | | 2.27 | 2.88 | | 3.53 | | 3.80 | |
| 500 | 0.64 | | | | | 2.22 | 2.67 | | 3.46 | | 3.68 | |
| 1,000 | 0.62 | | | | | 1.90 | 2.63 | | 3.23 | | 3.41 | |
| 2,000 | 0.59 | | | | | 1.80 | 2.42 | | 2.93 | | 3.15 | |
| 5,000 | 0.49 | | | | | 1.43 | 1.85 | | 2.49 | | 2.73 | |
| 10,000 | 0.33 | | | | | 1.26 | 1.78 | | 2.22 | | 2.40 | |
| 20,000 | 0.28 | | | | | 1.08 | 1.41 | | 1.86 | | 2.01 | |
| 50,000 | 0.17 | | | | | 0.76 | 1.12 | | 1.38 | | 1.45 | |
| 56,916 | 0.14 | | | | | 0.71 | 1.05 | | 1.28 | | 1.35 | |




SPAS 1149 Storm Center Mass Curve
DAD Zone 1: Southern Deserts
Nov 30, 2007 (0400Z) - Dec 2, 2007 (0400Z)
Lat: 35.41 Lon: -114.16
Incremental
Accumulated
5.57"
Precipitation (inches)
1.5
1
0.5
0
12
11
10
9
8
7
6
5
4
3
2
1
0
1
11
21
31
41




**Total Storm Precipitation**
**SPAS Storm #1149**
**Nov. 30, 2007 - Dec. 2, 2007**

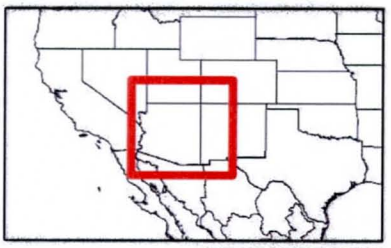
Miles: 0 35 70 140
Kilometers: 0 35 70 140 210

N

**Precipitation (inches)**

| | | |
|---|---|---|
| 0.00 - 1.00 | 3.01 - 4.00 | 6.01 - 7.00 |
| 1.01 - 2.00 | 4.01 - 5.00 | 7.01 - 8.00 |
| 2.01 - 3.00 | 5.01 - 6.00 | 8.01 - 9.00 |

- Daily
- Hourly
- Hourly psuedo
- Supplemental
- Supplemental estimated



Metstat/AWA October 16, 2009

# Magma, AZ

**July 10, 2008**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1051-Magma |
| Storm Date: | July 10, 2008 |
| AWA Analysis Date: | 10/15/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 25-Jul

| | Lat | Long |
|---|---|---|
| Storm center location | 33.20 N | 111.35 W |
| Storm Rep dew point location | 32.20 N | 110.93 W |
| Transposition dewpoint location | 32.50 N | 112.10 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | SSE @ 75 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 1,800 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| The storm representative dew point is | 73.5 F | with total precipitable water above sea level of | | | | 2.67 | inches. |
| The in-place maximum dew point is | 80.5 F | with total precipitable water above sea level of | | | | 3.68 | inches. |
| The transpositioned maximum dew point is | 80.5 F | with total precipitable water above sea level of | | | | 3.68 | inches. |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 73.5 F | |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 80.5 F | |
| Basin elevation at | 0 | which subtracts | 0.00 | inches of precipitable water at | | 80.5 F | |
| The inflow barrier height/basin elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | | 80.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.38 |
| The transposition factor is | 1.00 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.38 |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms.

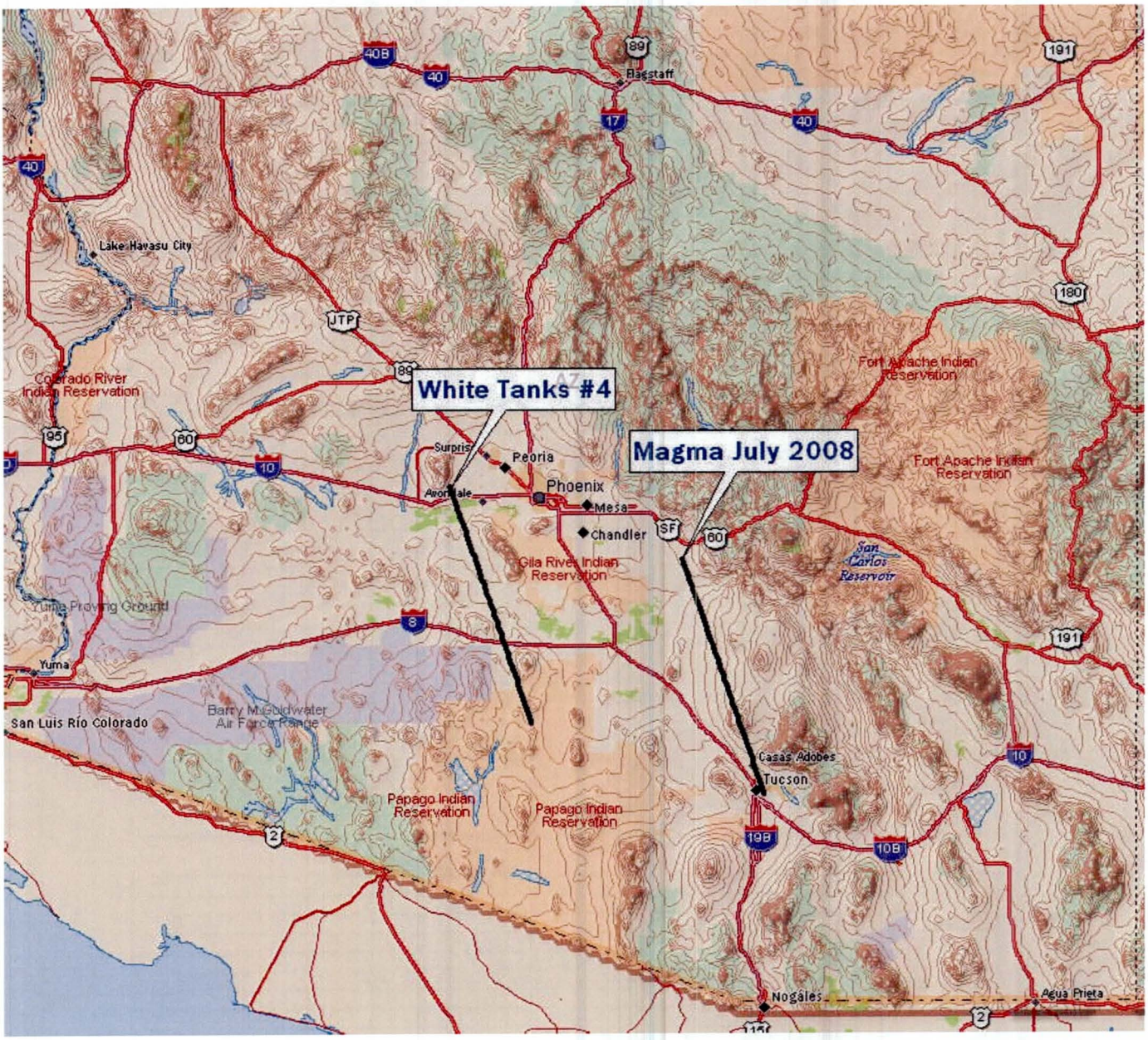
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours |
|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 1.6 | 2.6 | 3.8 | 4.0 | 4.2 | 4.3 | 4.4 | 4.8 | 4.8 |
| 10 sq miles | 1.6 | 2.6 | 3.6 | 4.0 | 4.1 | 4.2 | 4.3 | 4.7 | 4.7 |
| 50 sq miles | 1.4 | 2.1 | 2.9 | 3.5 | 3.8 | 3.9 | 4.0 | 4.2 | 4.2 |
| 100 sq miles | 1.3 | 2.1 | 2.7 | 3.2 | 3.5 | 3.7 | 3.7 | 3.9 | 4.0 |
| 200 sq miles | 1.2 | 1.9 | 2.5 | 3.0 | 3.2 | 3.4 | 3.5 | 3.6 | 3.7 |
| 500 sq miles | 0.9 | 1.5 | 2.1 | 2.5 | 2.7 | 2.8 | 3.0 | 3.1 | 3.1 |
| 1000 sq miles | 0.6 | 1.0 | 1.4 | 1.7 | 1.9 | 2.0 | 2.2 | 2.4 | 2.4 |
| 2000 sq miles | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - |

**Adjusted Storm Depth-Area-Duration**

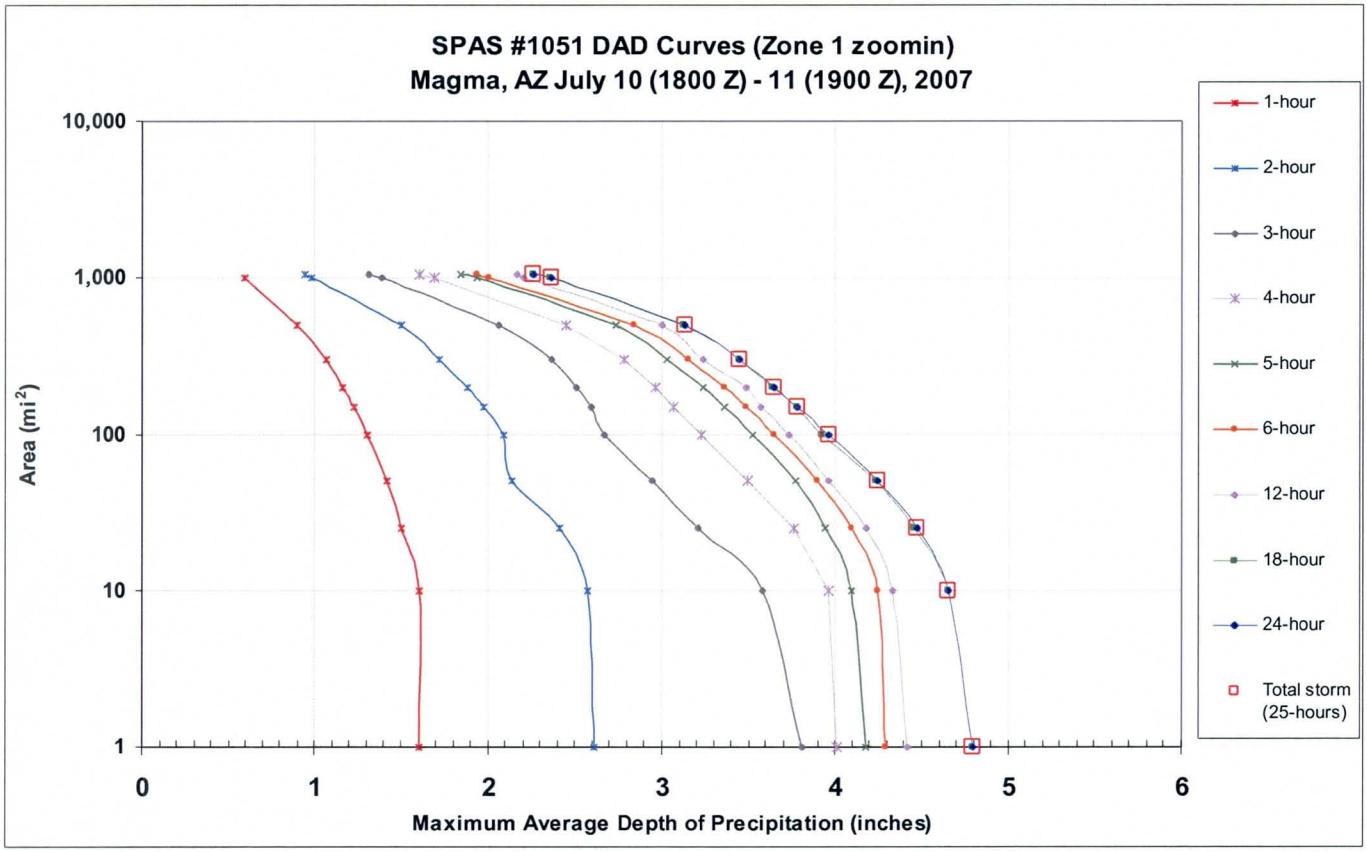
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours |
|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 2.2 | 3.6 | 5.3 | 5.5 | 5.8 | 5.9 | 6.1 | 6.6 | 6.6 |
| 10 sq miles | 2.2 | 3.5 | 4.9 | 5.5 | 5.6 | 5.8 | 6.0 | 6.4 | 6.4 |
| 50 sq miles | 1.9 | 2.9 | 4.1 | 4.8 | 5.2 | 5.4 | 5.5 | 5.8 | 5.8 |
| 100 sq miles | 1.8 | 2.9 | 3.7 | 4.5 | 4.9 | 5.0 | 5.1 | 5.4 | 5.5 |
| 200 sq miles | 1.6 | 2.6 | 3.5 | 4.1 | 4.5 | 4.6 | 4.8 | 5.0 | 5.0 |
| 500 sq miles | 1.2 | 2.1 | 2.8 | 3.4 | 3.8 | 3.9 | 4.1 | 4.3 | 4.3 |
| 1000 sq miles | 0.8 | 1.4 | 1.9 | 2.3 | 2.7 | 2.8 | 3.0 | 3.2 | 3.3 |
| 2000 sq miles | - | - | - | - | - | - | - | - | - |
| 5000 sq miles | - | - | - | - | - | - | - | - | - |

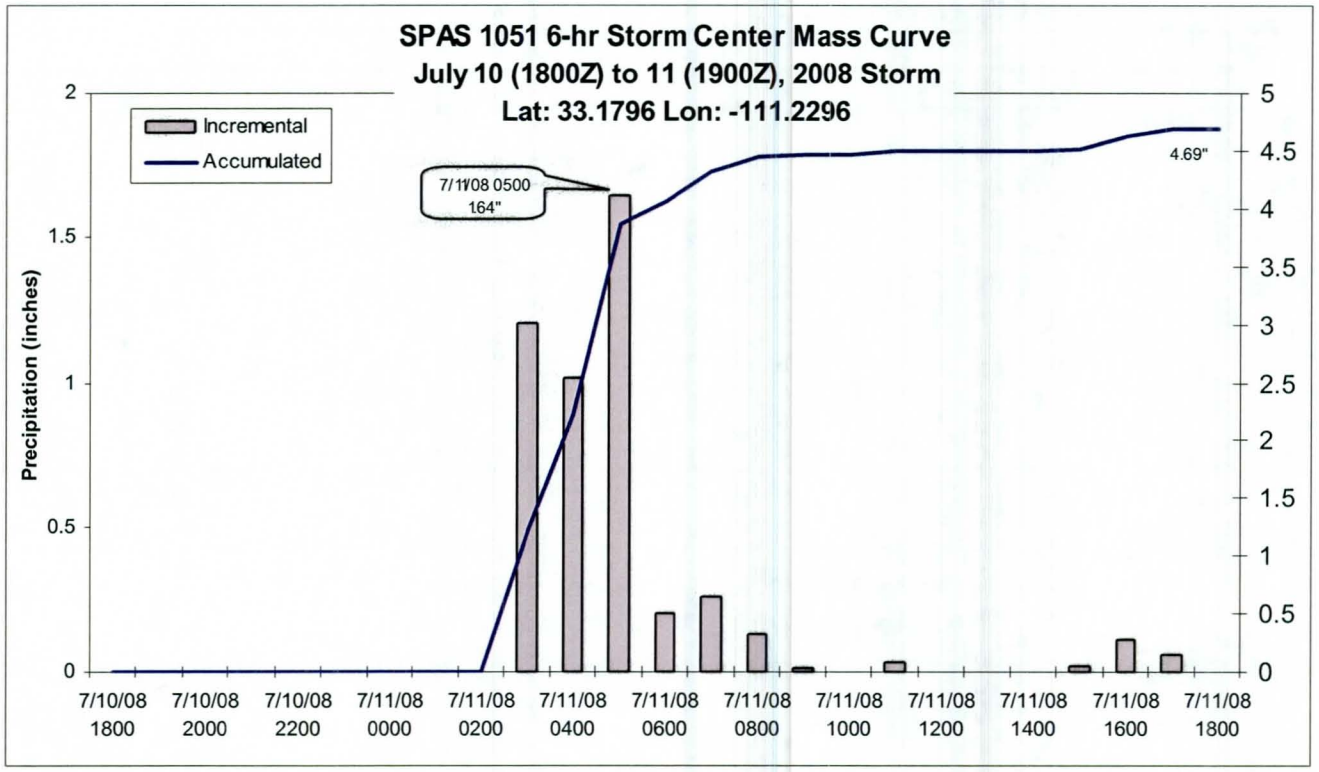
| | | |
|---|---|---|
| Storm or Storm Center Name | SPAS-1051-Magma | |
| Storm Date(s) | July 10, 2008 | |
| Storm Type | Local Storm | |
| Storm Location | 33.20 N | 111.35 W |
| Storm Center Elevation | 1800 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 4.89 inches 18 hours 3.89" in 3hrs (SPAS 1051DAD) | |
| | | |
| Storm Representative Dewpoint | 73.5 F | 3hr ave |
| Storm Representative Dewpoint Location | 32.20 N | 110.93 W |
| In-place Maximum Dewpoint | 80.5 F | |
| Moisture Inflow Vector | SSE @ 75 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 25-Jul | |
| Transposition Dewpoint Location | 32.50 N | 112.10 W |
| Transposition Maximum Dewpoint | 80.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.38 | |

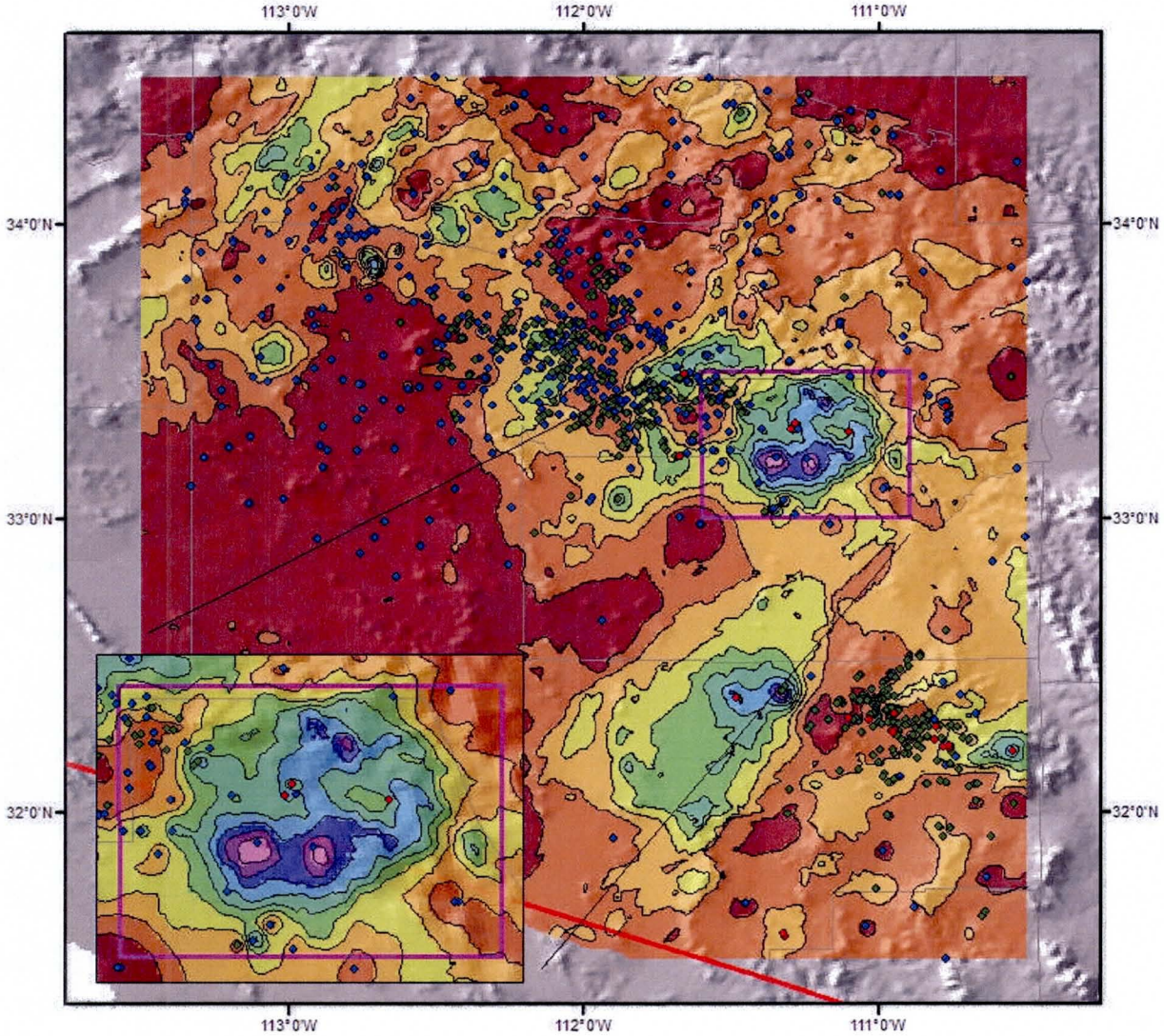

White Tanks #4
Magma July 2008
Flagstaff
Lake Havasu City
Colorado River Indian Reservation
Surprise
Peoria
Phoenix
Avondale
Mesa
Chandler
Gila River Indian Reservation
Fort Apache Indian Reservation
San Carlos Reservoir
Yuma Proving Ground
Yuma
San Luis Río Colorado
Barry M. Goldwater Air Force Range
Papago Indian Reservation
Casas Adobes
Tucson
Nogales
Agua Prieta

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 12 | 18 | 24 | Total |
| **0.28** | 1.72 | 2.72 | 3.89 | 4.12 | 4.32 | 4.45 | 4.55 | 4.87 | 4.87 | 4.87 |
| **1** | 1.60 | 2.61 | 3.81 | 4.01 | 4.18 | 4.29 | 4.41 | 4.79 | 4.79 | 4.79 |
| **10** | 1.60 | 2.57 | 3.58 | 3.96 | 4.09 | 4.24 | 4.33 | 4.65 | 4.65 | 4.65 |
| **25** | 1.50 | 2.41 | 3.21 | 3.76 | 3.94 | 4.09 | 4.18 | 4.45 | 4.47 | 4.47 |
| **50** | 1.41 | 2.14 | 2.94 | 3.49 | 3.77 | 3.89 | 3.96 | 4.23 | 4.24 | 4.24 |
| **100** | 1.30 | 2.09 | 2.67 | 3.23 | 3.52 | 3.65 | 3.73 | 3.92 | 3.96 | 3.96 |
| **150** | 1.22 | 1.97 | 2.59 | 3.07 | 3.36 | 3.48 | 3.57 | 3.78 | 3.78 | 3.78 |
| **200** | 1.16 | 1.88 | 2.51 | 2.96 | 3.24 | 3.36 | 3.48 | 3.64 | 3.65 | 3.65 |
| **300** | 1.06 | 1.72 | 2.36 | 2.78 | 3.03 | 3.15 | 3.24 | 3.45 | 3.45 | 3.45 |
| **500** | 0.89 | 1.50 | 2.06 | 2.45 | 2.73 | 2.84 | 3.00 | 3.12 | 3.13 | 3.13 |
| **1,000** | 0.59 | 0.98 | 1.39 | 1.69 | 1.94 | 2.00 | 2.20 | 2.35 | 2.36 | 2.36 |
| **1,064** | - | 0.94 | 1.31 | 1.60 | 1.84 | 1.94 | 2.16 | 2.26 | 2.26 | 2.26 |




SPAS 1051 6-hr Storm Center Mass Curve
July 10 (1800Z) to 11 (1900Z), 2008 Storm
Lat: 33.1796 Lon: -111.2296
Incremental
Accumulated
7/11/08 0500
1.64"
4.69"
Precipitation (inches)
2
1.5
1
0.5
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
7/10/08 1800
7/10/08 2000
7/10/08 2200
7/11/08 0000
7/11/08 0200
7/11/08 0400
7/11/08 0600
7/11/08 0800
7/11/08 1000
7/11/08 1200
7/11/08 1400
7/11/08 1600
7/11/08 1800




**Total Rainfall (25-hours)**
**Magma, AZ 2008 Storm**
**Storm #1051 July 10 (1800 Z) to 11 (1900 Z), 2008**

Miles: 0 10 20 40
Kilometers: 0 15 30 60 90
N

**Gauging Stations**

- Daily
- Hourly Pseudo
- Hourly
- Supplemental

**Precipitation (inches)**

| | | | |
|---|---|---|---|
| 0.00 - 0.50 | 1.51 - 2.00 | 3.01 - 3.50 | 4.51 - 5.00 |
| 0.51 - 1.00 | 2.01 - 2.50 | 3.51 - 4.00 | 5.01 - 5.50 |
| 1.01 - 1.50 | 2.51 - 3.00 | 4.01 - 4.50 | |

*Coordinate system: GCS North American 1983*
*Scale: 1:2,133,219*

Metstat/AWA September 11, 2008

# Wenden Bouse, AZ

**August 26, 2008**

**Storm Type: Local Convective**

| | |
|---|---|
| Storm Name: | SPAS-1085-Wenden Bouse |
| Storm Date: | August 26, 2008 |
| AWA Analysis Date: | 12/4/2009 |

# Storm Adjustment for White Tanks #4

**Temporal Transposition Date** 15-Aug

| | Lat | Long |
|---|---|---|
| Storm center location | 33.92 N | 113.91 W |
| Storm Rep dew point location | 33.20N | 114.00 W |
| Transposition dewpoint location | 32.78 N | 112.61 W |
| Basin location | 33.55 N | 112.55 W |

| | | |
|---|---|---|
| Moisture Inflow Direction: | S @ 50 | miles |
| Basin Elevation | 3,650 | feet |
| Storm Elevation | 1,200 | feet |
| Effective Barrier Height | 3,650 | feet |

| | | | | | | |
|---|---|---|---|---|---|---|
| The storm representative dew point is | 73.0 F | with total precipitable water above sea level of | | | 2.60 | inches. |
| The in-place maximum dew point is | 81.5 F | with total precipitable water above sea level of | | | 3.84 | inches. |
| The transpositioned maximum dew point is | 81.5 F | with total precipitable water above sea level of | | | 3.84 | inches. |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 73.0 F | |
| The in-place storm elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.5 F | |
| Basin elevation at | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.5 F | |
| The inflow barrier height/basin elevation is | 0 | which subtracts | 0.00 | inches of precipitable water at | 81.5 F | |

| | |
|---|---|
| The in-place maximization factor is | 1.48 |
| The transposition factor is | 1.00 |
| The elevation/barrier adjustment factor is | 1.00 |
| The total adjustment factor is | 1.48 |

Notes: No adjustment made for elevations below 6000 feet following HMR guidance for local storms. 3hr ave KNYL, KBLH, KGBN

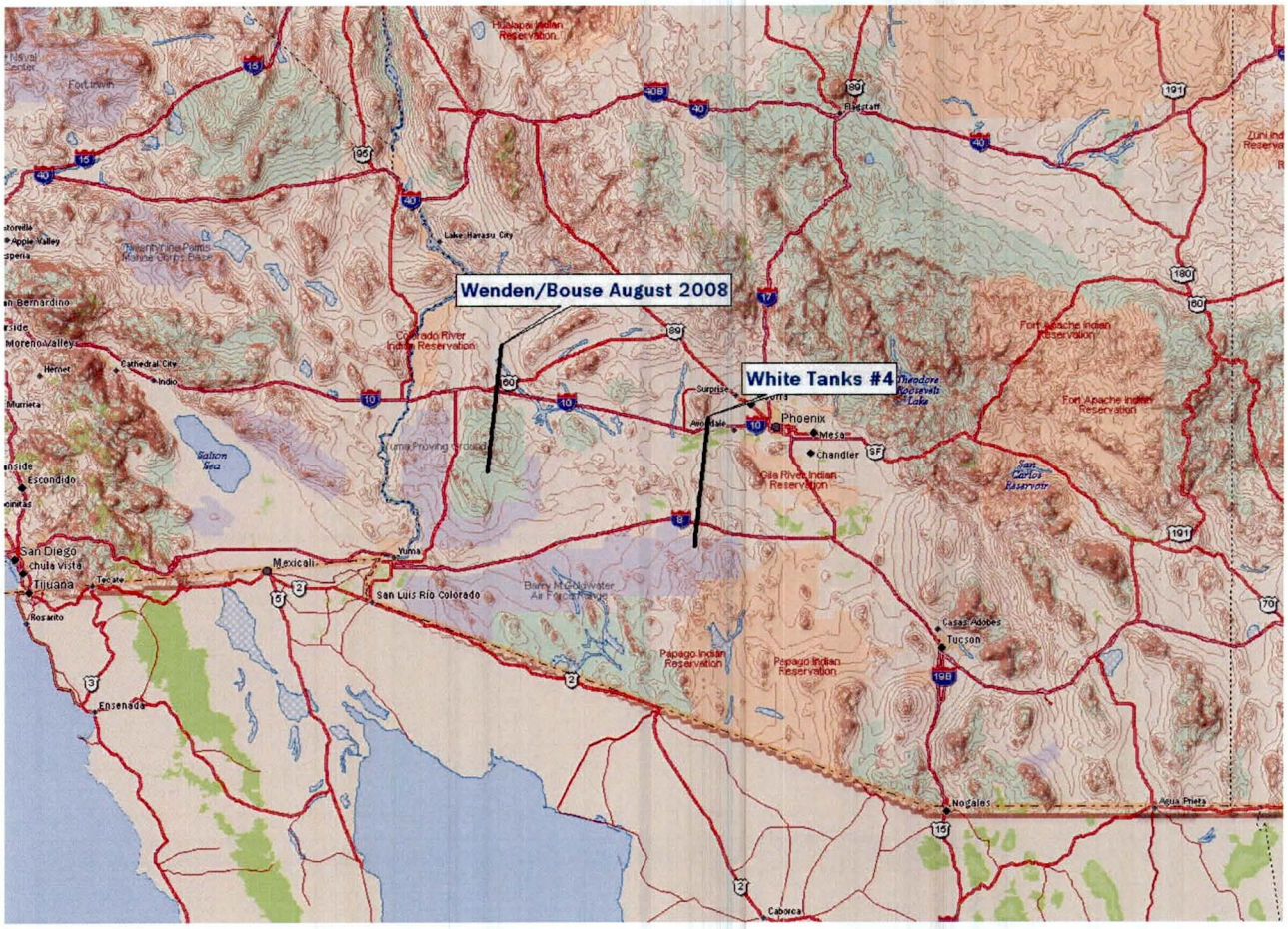
**Observed Storm Depth-Area-Duration**

| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 3.7 | 3.8 | 3.9 | 4.1 | 4.1 | 4.3 | 4.7 | - | | |
| 10 sq miles | 3.2 | 3.5 | 3.7 | 3.8 | 3.9 | 4.3 | 4.6 | - | | |
| 50 sq miles | 2.6 | 3.1 | 3.2 | 3.5 | 3.7 | 3.9 | 4.3 | - | | |
| 100 sq miles | 2.3 | 2.8 | 3.0 | 3.3 | 3.4 | 3.7 | 4.0 | - | | |
| 200 sq miles | 2.1 | 2.5 | 2.8 | 3.1 | 3.1 | 3.4 | 3.8 | - | | |
| 500 sq miles | 1.6 | 2.1 | 2.4 | 2.7 | 2.8 | 3.1 | 3.4 | - | | |
| 1000 sq miles | 1.3 | 1.8 | 2.1 | 2.3 | 2.5 | 2.7 | 3.0 | - | | |
| 2000 sq miles | 1.0 | 1.4 | 1.7 | 2.0 | 2.1 | 2.3 | 2.6 | - | | |
| 5000 sq miles | 0.6 | 1.0 | 1.1 | 1.4 | 1.6 | 1.8 | 2.0 | - | | |

**Adjusted Storm Depth-Area-Duration**

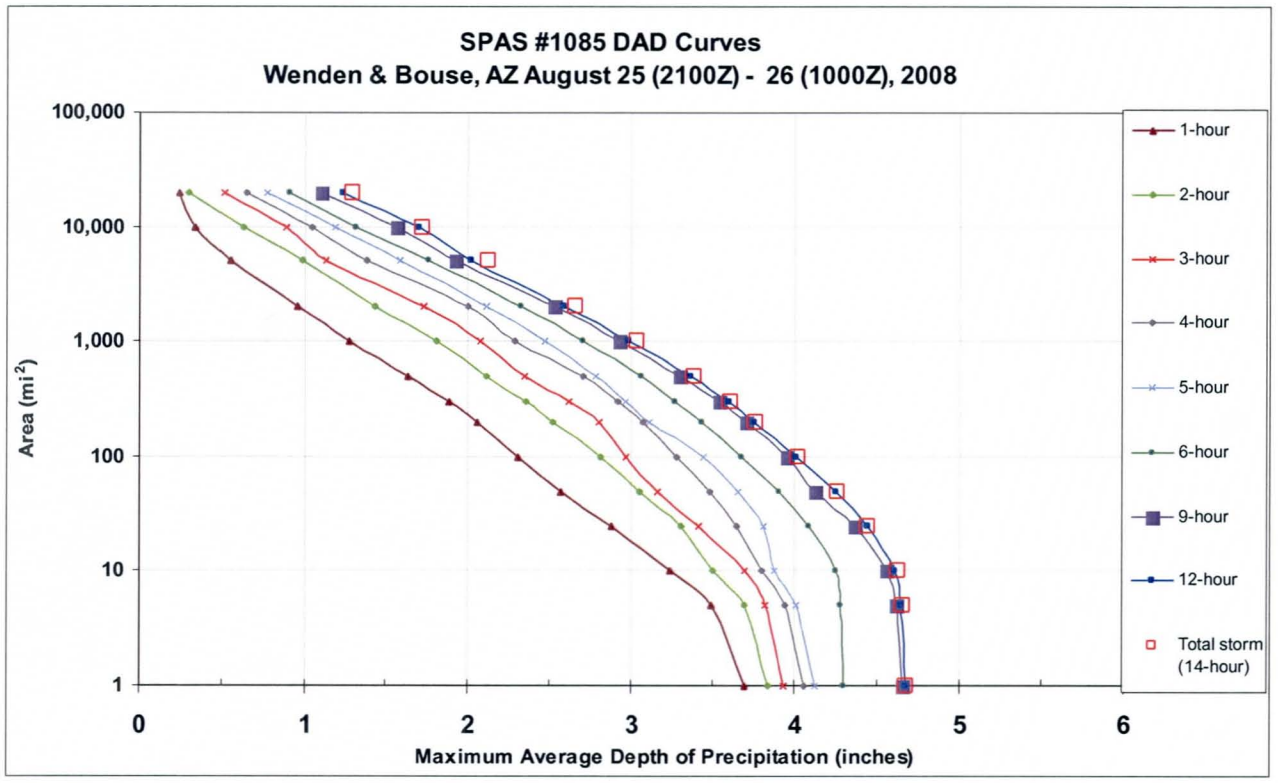
| | 1 Hours | 2 Hours | 3 Hours | 4 Hours | 5 Hours | 6 Hours | 12 Hours | 18 Hours | 24 Hours | 36 Hours |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 sq miles | 5.4 | 5.7 | 5.8 | 6.0 | 6.1 | 6.4 | 6.9 | - | | |
| 10 sq miles | 4.8 | 5.2 | 5.4 | 5.6 | 5.7 | 6.3 | 6.8 | - | | |
| 50 sq miles | 3.8 | 4.5 | 4.7 | 5.1 | 5.4 | 5.8 | 6.3 | - | | |
| 100 sq miles | 3.4 | 4.2 | 4.4 | 4.8 | 5.1 | 5.4 | 5.9 | - | | |
| 200 sq miles | 3.0 | 3.7 | 4.1 | 4.5 | 4.6 | 5.1 | 5.5 | - | | |
| 500 sq miles | 2.4 | 3.1 | 3.5 | 4.0 | 4.1 | 4.5 | 5.0 | - | | |
| 1000 sq miles | 1.9 | 2.7 | 3.1 | 3.4 | 3.6 | 4.0 | 4.4 | - | | |
| 2000 sq miles | 1.4 | 2.1 | 2.6 | 3.0 | 3.1 | 3.4 | 3.8 | - | | |
| 5000 sq miles | 0.8 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 | 3.0 | - | | |

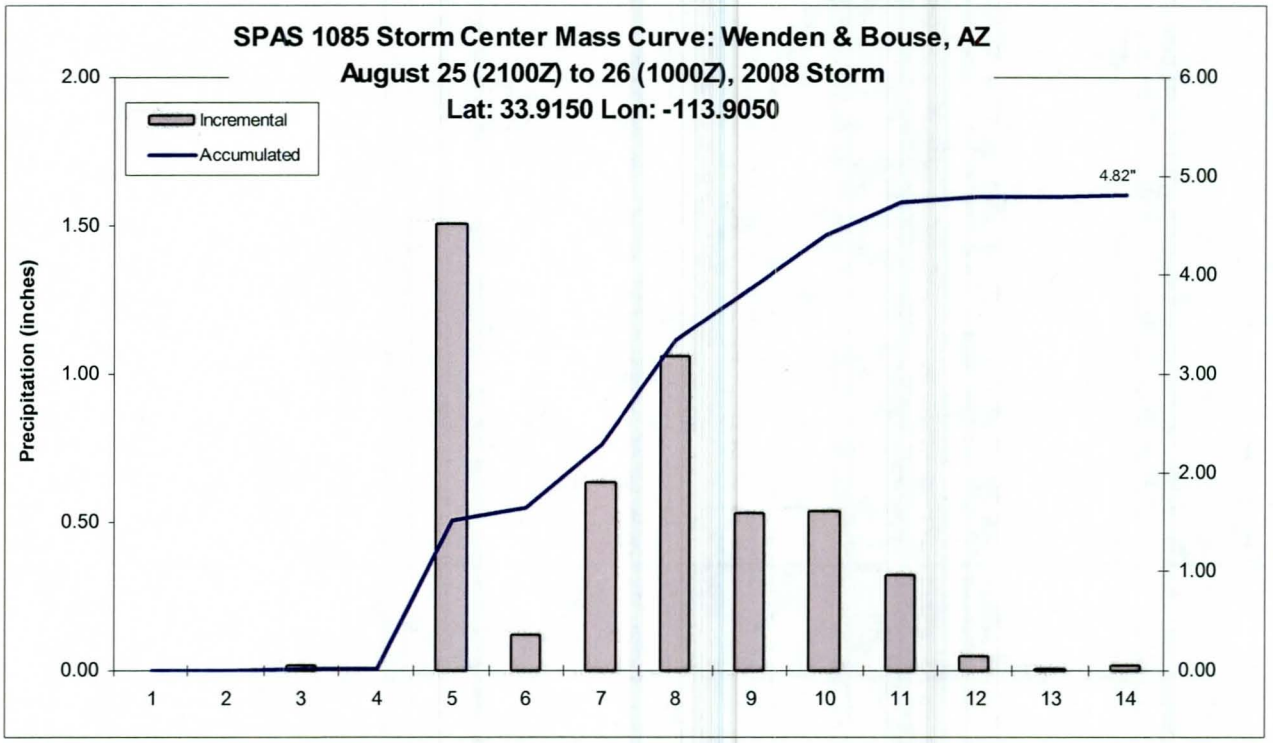
| | | |
|---|---|---|
| Storm or Storm Center Name | **SPAS-1085-Wenden Bouse** | |
| Storm Date(s) | 8/26/08 | |
| Storm Type | Local Storm | |
| Storm Location | 33.92 N | 113.91 W |
| Storm Center Elevation | 1200 | non-orographic |
| Precipitation Total & Duration (10 sq mi) | 3.78 inches 1 hour 4.01" in 3hrs (SPAS 1085 DAD) | |
| | | |
| Storm Representative Dewpoint | 73.0 F | 3hr ave KNYL, KBLH, KGBN |
| Storm Representative Dewpoint Location | 33.20N | 114.00 W |
| In-place Maximum Dewpoint | 81.5 F | |
| Moisture Inflow Vector | S @ 50 | |
| In-place Maximization Factor | | |
| | | |
| Temporal Transposition (Date) | 15-Aug | |
| Transposition Dewpoint Location | 32.78 N | 112.61 W |
| Transposition Maximum Dewpoint | 81.5 F | |
| Transposition Adjustment Factor | | |
| Average Basin Elevation | 3,650 | |
| Highest Elevation in Basin | 3,655 | |
| Higher of Basin Elevation/Inflow Barrier Height | 3,650 | |
| Elevation Adjustment Factor | | |
| Total Adjustment Factor | 1.48 | |

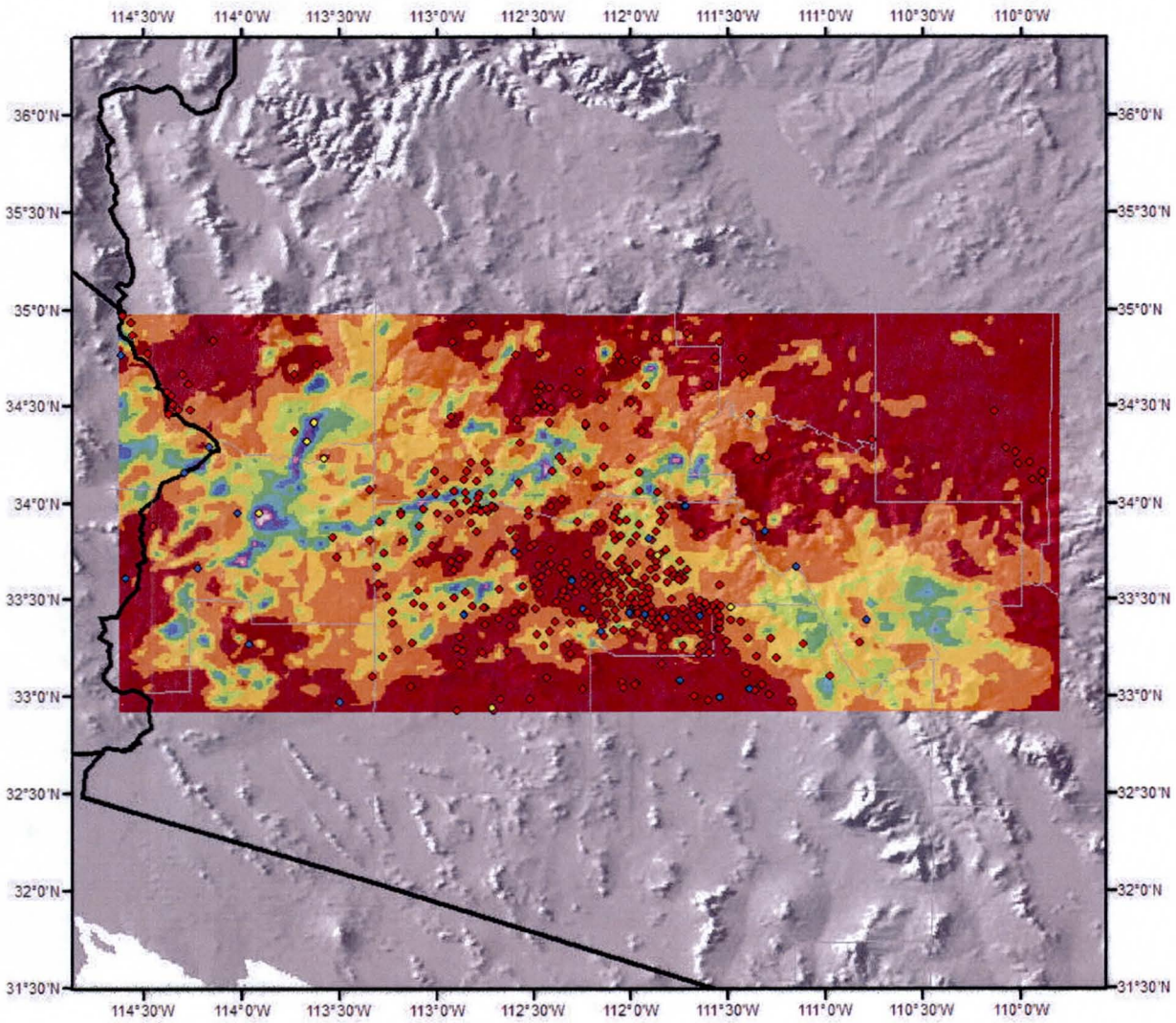

Wenden/Bouse August 2008
White Tanks #4
Phoenix
Mesa
Chandler
Tucson
Yuma
Mexicali
San Diego
Tijuana
Ensenada
Nogales
Lake Havasu City
Flagstaff
Fort Irwin
Salton Sea
Colorado River Indian Reservation
Gila River Indian Reservation
Papago Indian Reservation
Fort Apache Indian Reservation
San Carlos Reservoir
Theodore Roosevelt Lake
Yuma Proving Ground
San Luis Rio Colorado
Casas Adobes
Cananea
Agua Prieta

## MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

| Area ($mi^2$) | Duration (hours) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 9 | 12 | total |
| **0.28** | 3.78 | 3.92 | 4.01 | 4.15 | 4.17 | 4.42 | 4.78 | 4.81 | 4.82 |
| **1** | 3.69 | 3.84 | 3.93 | 4.06 | 4.13 | 4.30 | 4.66 | 4.68 | 4.68 |
| **5** | 3.49 | 3.69 | 3.82 | 3.94 | 4.01 | 4.28 | 4.62 | 4.65 | 4.66 |
| **10** | 3.24 | 3.50 | 3.69 | 3.80 | 3.87 | 4.25 | 4.56 | 4.61 | 4.63 |
| **25** | 2.88 | 3.30 | 3.41 | 3.64 | 3.81 | 4.09 | 4.37 | 4.44 | 4.44 |
| **50** | 2.57 | 3.05 | 3.16 | 3.48 | 3.65 | 3.90 | 4.13 | 4.25 | 4.26 |
| **100** | 2.31 | 2.81 | 2.97 | 3.28 | 3.44 | 3.67 | 3.95 | 4.01 | 4.02 |
| **200** | 2.06 | 2.52 | 2.80 | 3.07 | 3.11 | 3.43 | 3.70 | 3.75 | 3.76 |
| **300** | 1.88 | 2.36 | 2.62 | 2.92 | 2.97 | 3.27 | 3.54 | 3.59 | 3.60 |
| **500** | 1.63 | 2.12 | 2.35 | 2.71 | 2.78 | 3.06 | 3.29 | 3.36 | 3.38 |
| **1,000** | 1.28 | 1.81 | 2.08 | 2.29 | 2.47 | 2.71 | 2.93 | 2.99 | 3.03 |
| **2,000** | 0.96 | 1.43 | 1.73 | 2.00 | 2.12 | 2.33 | 2.53 | 2.59 | 2.66 |
| **5,000** | 0.55 | 0.99 | 1.13 | 1.38 | 1.58 | 1.76 | 1.92 | 2.02 | 2.13 |
| **10,000** | 0.34 | 0.63 | 0.89 | 1.04 | 1.19 | 1.31 | 1.57 | 1.70 | 1.72 |
| **20,000** | 0.24 | 0.30 | 0.51 | 0.65 | 0.77 | 0.91 | 1.10 | 1.24 | 1.29 |




SPAS 1085 Storm Center Mass Curve: Wenden & Bouse, AZ
August 25 (2100Z) to 26 (1000Z), 2008 Storm
Lat: 33.9150 Lon: -113.9050
Incremental
Accumulated
4.82"
Precipitation (inches)
2.00
1.50
1.00
0.50
0.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14




**Total Rainfall (14-hours)**
**Wenden & Bouse, AZ 2008 Storm**
**Storm #1085 August 25 (2100 Z) to 26 (1000 Z), 2008**

**Gauging Stations**

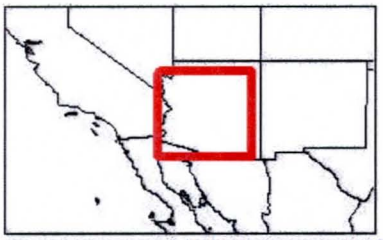
- Daily
- Supplemental
- Hourly

Miles: 0 20 40 80
Kilometers: 0 30 60 120 180

N

**Precipitation (inches)**

- 0.00 - 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- 3.01 - 3.50
- 3.51 - 4.00
- 4.01 - 4.50
- 4.51 - 5.00



*Coordinate system: GCS North American 1983*
*Scale:* 1:3,175,582

Metstat/AWA August 03, 2009