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Meteorological Analysis for the Las Vegas, Nevada, Flood of 3 July 1975

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ABSTRACT

Meteorological data are analyzed to determine the location and intensity of the rainstorms that led to flash flooding in the Las Vegas Valley and resulted in approximately $4.5 million in damages on 3 July 1975. The effective precipitation contributing to the flood was found to cover an area of 550 km². Within this area two centers of heavy rainfall were found, one situated approximately 14 km southwest of the central business district and the other about 13 km north-northwest. Maximum rainfall amounts are estimated to be of the order of 3.0 inch. A maximum rainfall rate of 1.0 inch per hour was detected in a weighing-bucket raingage. Hail and surface wind gusts of about 50 kt were observed in the northwestern portion of the city. Furthermore, the area of heavy rainfall is shown to have developed over the Las Vegas Valley and not over the surrounding mountains. Integration of an isohyetal analysis shows that, at least, 2.3×10^7 m³ (1.9×10^4 acre ft) of water was available before infiltration. This amount of detail in the documentation of southwestern desert rainstorms is rarely available.

1. Introduction

On 3 July 1975, between approximately 1100 and 1500 LST, heavy rainshower activity occurred over the extreme western and northern portions of the Las Vegas Valley. As a result, extensive flooding occurred in Las Vegas and in North Las Vegas, Nev., between 1500 and 1900 LST. In North Las Vegas, two men were swept away and drowned in a flash flood. In the Las Vegas Valley, an estimated $4.5 million in damage resulted from the flooding. Approximately 300 automobiles were lost in flash floods and considerable damage occurred to streets, homes, and private businesses (Fig. 1). In mid-July 1975, the federal government declared Las Vegas a disaster loan area.

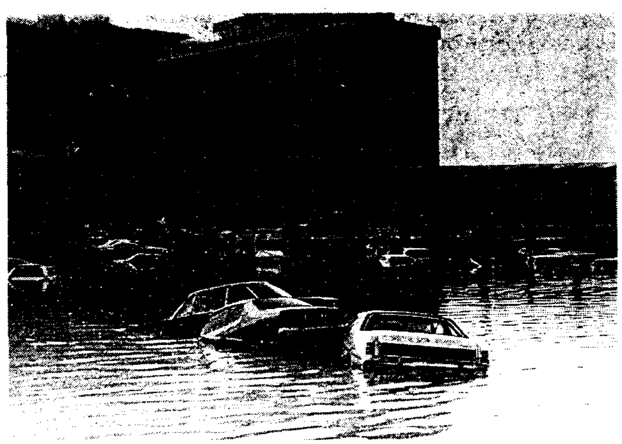

FIG. 1. Front entrance to Caesars Palace Hotel, 3 July 1975. Courtesy of the Las Vegas *Review Journal*. Photograph by Gary Thompson.

2. Historical perspective

Flash floods associated with summertime thunderstorms have occurred in Las Vegas in the past. To get a proper perspective of the magnitude of the flooding of 3 July 1975, it is instructive to review past incidents. A tabulation of some warm season (June through September) storms in Las Vegas is given in Table 1. Data contained in Table 1 are from climatological records and from local newspaper accounts of the various events. Reported precipitation amounts occurring between 1949 and 1975 are for McCarran International Airport located approximately 10 km south of Casino Center in downtown Las Vegas. Prior to 1948,

TABLE 1. Historical tabulation of some warm season storm damage in the Las Vegas valley.

Date	Event	Estimated damage dollars	Estimated metropolitan population
23 July 1923	1.98 inch rain, hail, flooding	20 000	5000
10 July 1932	flooding	1000's	9000
9 Aug 1942	1.58 inch rain, hail, flooding	1000's	10 000
13 June 1955	hail, flooding	2 million	50 000
24 July 1955	strong winds, flooding	200 000	50 000
21 Aug. 1957	2.57 inch rain, flooding	500 000	70 000
16 Sept. 1961	hail, wind est. 80–90 mph	1–2 million	125 000
4 Sept. 1963	1.07 inch rain, flooding	1 million	150 000
19 June 1967	flooding	light	225 000
12 Sept. 1969	flooding	250 000	250 000
14 July 1971	75 mph winds	minor	275 000
3 July 1975	flooding	4.5 million	350 000

rainfall amounts were taken by cooperative observers in the downtown area and also at a site that is now Nellis Air Force Base (Fig. 8). The normal annual precipitation for Las Vegas (1941–1970) is 3.76 inches. The normal precipitation for July is 0.44 inch.

3. Macroscale flow

The pre-flood, large-scale flow regime for 0400 LST (1200 GMT) 3 July 1975 is portrayed by the 500 mb chart in Fig. 2. Significant features include a large anticyclonic circulation cell centered over Nebraska with a cutoff cyclonic circulation off the California coast. The cyclone developed southerly flow aloft over Nevada. Analysis of the dew point depressions revealed moisture-laden air over western Arizona. Location of this moist tongue was aided by clouds visible in SMS-1 satellite imagery for 0330 LST (1130 GMT) and 0530 LST (1330 GMT). This band of moist air extended from extreme northwestern Mexico, northward into southern Canada.

In Fig. 2, the gradient in the depression isopleths helps to illustrate the marked contrast between the dry air over western Nevada and the nearly saturated air along the Utah-Nevada border and over northwestern Arizona. The dry air appears to be associated with the cyclonic flow regime while the moist air is flowing around the western extremities of the anticyclonic center.

The 0400 LST (1200 GMT) 700 mb chart shown in Fig. 3 describes the flow regime at a lower level—the flow pattern being quite similar to that at 500 mb. Of particular interest is the dew point depression analysis. Without supplemental information, the dew point depressions at Tuscon and Winslow, Ariz., indicated that moist air was confined to eastern Arizona. However, SMS-1 satellite imagery and surface observations showed an extensive layer of middle-layer cloudiness in central and western Arizona. With the aid of these data the depression isopleths were analyzed as in Fig. 3, portraying an elongated band of moist air extending from extreme northern Mexico through western Arizona

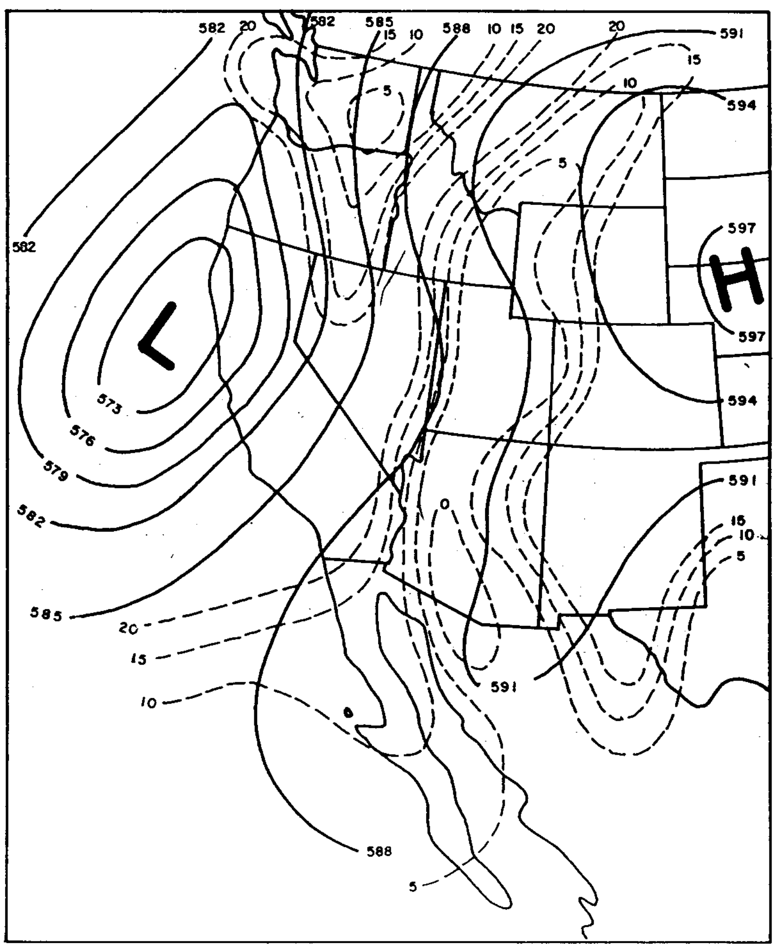

FIG. 2. Height contours (solid lines) and dew point depression contours (dashed lines, °C) for the 500 mb level, 0400 LST (1200 GMT) 3 July 1975. Upper air data not plotted to simplify the diagram.

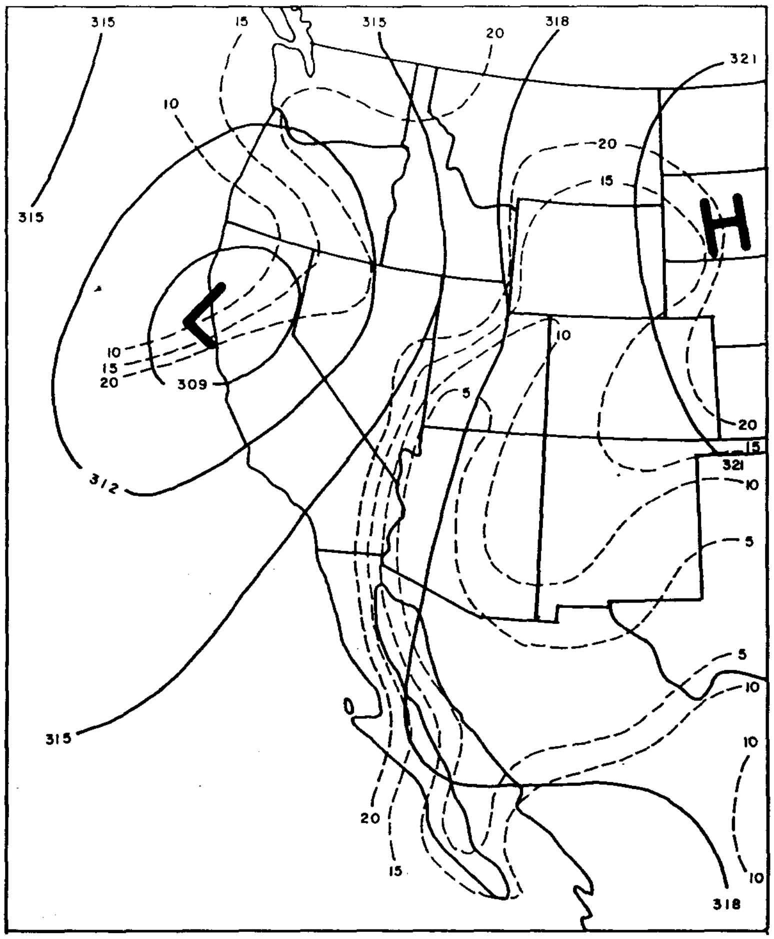

FIG. 3. As in Fig. 2 except for 700 mb.

into Utah and Wyoming. That portion of the moisture band in Arizona exhibited a westward component of motion during the day, and moved into southern and eastern Nevada by late morning.

Figs. 2 and 3 provide information on the moisture content of the mid-tropospheric region, but knowledge of surface level moisture is required to complete the picture of the moisture content of the atmosphere over southern Nevada. Analyses of the surface dew point temperature field for 0400, 1000, and 1300 LST are displayed in Figs. 4, 5, and 6, respectively. At 0400 LST, Fig. 4 shows that dew points of the order of 50° to 60°F covered most of Arizona while very dry air dominated the weather regime over Nevada. However, by 1000 LST (Fig. 5), the dew point at Las Vegas had risen by 31°F to 52°F. A 12°F rise in dew point was observed and reported by the National Weather Service (NWS) station at McCarran International Airport between 0900 and 1000 LST. This upward surge in the local atmospheric moisture content was accompanied by an increase in the surface wind speed from the southeast. By 1300 LST (Fig. 6), the atmospheric moisture content had increased over nearly all of extreme eastern Nevada and a thunderstorm was in progress at Las Vegas. In Fig. 6, notice the difference in dew points in central Nevada and those to the east; a 30–40°F gradient existed over distances of the order of 200 km.

From the analysis of upper air and surface charts it appears that the moisture available for the development of thunderstorms over Las Vegas had at least two sources. The upper-level source, identified on the 500 mb charts, was associated with a westward moving trough that carried moisture with it from the Gulf of Mexico to over central Mexico. On 2 July this moisture-laden air flowed north-northwestward into a region of strong confluence over extreme western Arizona and southwestern Utah. By 1600 LST 2 July, the axis of confluence at the 500 mb level appears to have separated very dry air, flowing toward the north-northeast over California and Nevada, from moist tropical air flowing north-northwestward through Arizona. Figs. 2 and 3 confirm that this type flow regime continued on 3 July.

In the surface layer, some of the moisture appears to have originated over the tropical southeastern Pacific Ocean and moved northward over the Gulf of California into Arizona (as proposed by Hales, 1972, 1974). Some

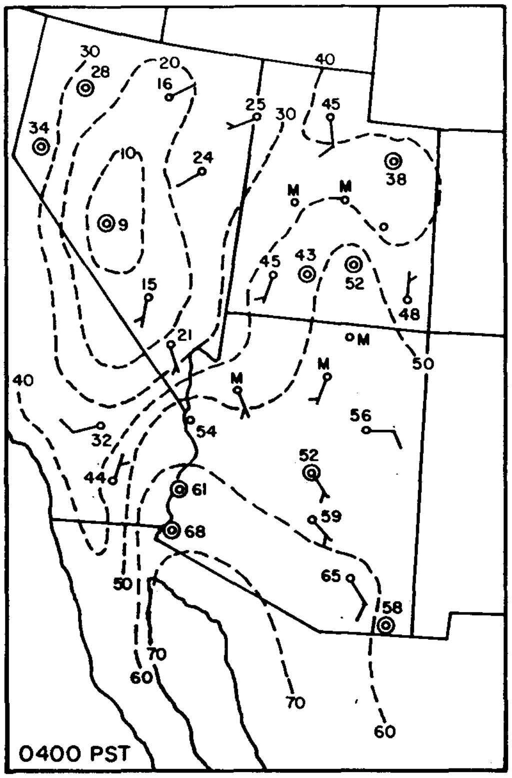

FIG. 4. Surface isodrosotherm analysis for 0400 LST 3 July 1975.

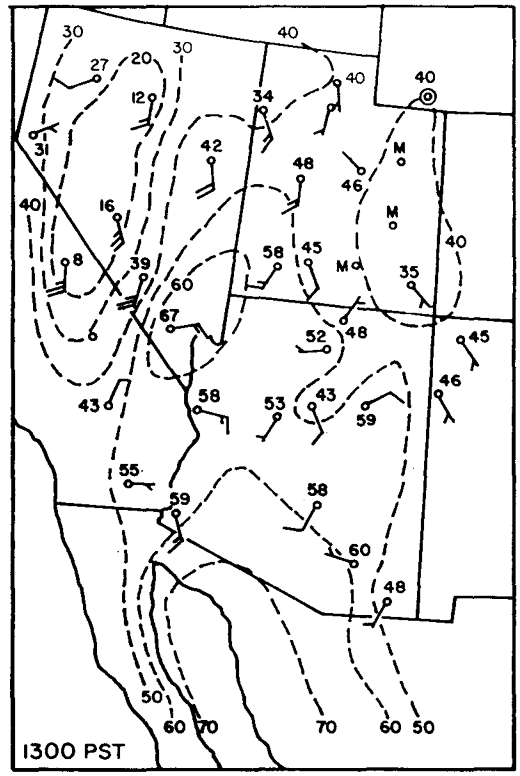

FIG. 6. As in Fig. 4 except for 1300 LST 3 July 1975.

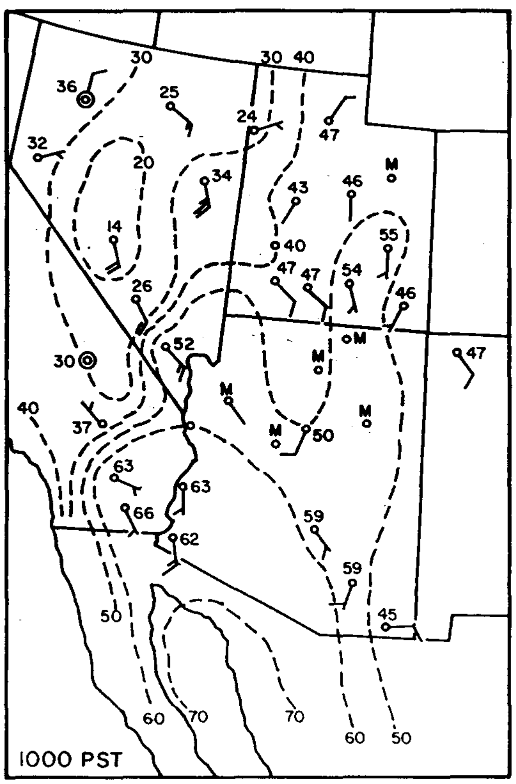

FIG. 5. As in Fig. 4 except for 1000 LST 3 July 1975.

additional surface moisture could have resulted from the modification of surface-layer air, over eastern Arizona, by precipitation accompanying the upper-level moisture influx. Evidence for this type modification was obtained from the western region, hourly, composite radar charts, from surface observations, and from satellite imagery. Both sources of surface moisture appear to have consolidated over Arizona and moved north-northwestward into Utah and extreme eastern and southern Nevada. For some other extreme rainfalls in the southwestern United States, Hansen (1975) has provided some evidence of the potential enhancement of moisture from the tropical Pacific Ocean (primary source) by mid-tropospheric moisture from the Gulf of Mexico.

4. Local surface observations

The boundary between the moist and dry air masses was quite distinct and could be seen as a rapid increase in cloudiness. For example, the NWS station at McCarran airport reported that cloud conditions changed from 140 SCT at 1000 LST to E90BKN 250BKN at 1150 LST with TRW− and RW+ southwest and northwest through north by 1300 LST. A similar increase in cloudiness was reported by the weather observers at Nellis Air Force Base. Heavy rainshowers were reported in the west quadrant from

McCarran airport in the hourly airways sequences for 1300, 1400 and 1500 LST.

In the Las Vegas Valley there were surface observations of hail, heavy rain, and surface wind gusts of 35 to 50 kt. About 5 km northwest of the North Las Vegas airport, very strong surface winds and blowing dust were reported at about 1215 LST, just prior to the beginning of heavy rain. Heavy rain with some hail began to fall between 1230 and 1300 LST, the heavy rain lasting until 1630 LST. A report of ½ inch hail was obtained at a site approximately 5 km west of downtown Las Vegas.

5. Radar analysis

Radar echoes from moist convection are available on an hourly basis from the Western Region RAFAX network. These radar echoes are traced from the various Air Route Traffic Control Center (ARTCC) radar scopes, a composite is made for the western United States and transmitted on the facsimile line. It is important to emphasize that ARTCC radars were designed and sited to provide the best possible detection of aircraft. Furthermore, these radars are equipped with special circuitry, such as moving-target indicator and circumpolarization, to specifically remove most weather related targets. Such design qualities do not provide for optimum detection of precipitation. Despite these limitations, Benner (1965) demonstrated that the ARTCC radars are capable of providing much useful weather data while Ronne (1971) concluded that ARTCC radars probably display only moderate or greater precipitation intensities. Moreover, in summertime, the probability of radar detection of surface precipitation in the Las Vegas Valley is approximately 90%, according to NWS Western Regional Technical Attachment No. 74-10 (9 April 1974).

To facilitate analysis of the echo pattern in southern Nevada, a 10 min by 10 min latitude-longitude grid was constructed and centered at 36°N, 115°W, near Las Vegas. This grid was laid over each hourly ARTCC weather-echo radar chart. If a radar echo was present in any portion of a grid square, 1 h of echo activity was assigned to that square. A summary of the number of hours of echo activity was developed for the seven radar charts from 1045 LST (just before initial activity through 1645 LST (the time of local flooding). Results of this summary, displayed in Fig. 7, can be used as a guide for locating the regions of maximum and minimum thunderstorm activity. Fig. 7 clearly shows an axis of minimum duration of echo activity extending from the south of Las Vegas to the center of the city. Extensive echo activity occurred to the southwest of the city with a secondary maximum to the east. Perhaps the most useful information provided by Fig. 7 is the portrayal of the sharp demarcation between the areas of no echo activity (to the south) and the very active region to west and southwest of the city. In addition, the figure shows that the region of maximum echo duration was not over the Spring Mountains, located to the west of Las Vegas, but over the rather flat terrain (see Fig. 8) just west of the city.

Information plotted on the 1245 LST ARTCC weather radar facsimile chart indicated TRW− with isolated TRW+ in the Las Vegas area. Visible cloud tops, as reported by aircraft, ranged from 37 000 ft to 41 000 ft above mean sea level (MSL). By 1345 LST the echoes were classified as scattered TRW+ and at 1445 as TRW− with scattered TRW+. By 1545 LST the activity was upgraded to TRW, TRW+ and that classification remained in the Las Vegas area until midnight. The echoes were apparently moving northward at about 15 kt, normal to the natural drainage channels (Fig. 8). Glancy and Harmsen (1975) documented a heavy thunderstorm and flash flood that moved down a small canyon, thereby compounding runoff rates. Nine people were drowned in this flash flood that occurred roughly 70 km southeast of Las Vegas.

An FPS/77 (5.4 cm) weather radar at Nellis AFB detected strong echoes around Las Vegas between 1120 LST and 1430 LST with isolated echo tops ranging

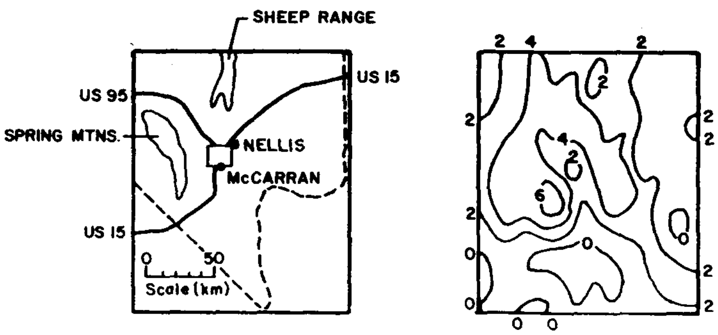

FIG. 7. Major terrain features and weather stations in the vicinity of Las Vegas, Nev. (left-hand chart) and total number of hours of echo activity (right-hand chart) occurring between 1045 LST and 1645 LST 3 July 1975. The echo activity chart can be overlaid on the other chart.

between 33 000 and 41 000 ft MSL. Based on the calibration of this radar, rainfall rates ranged from 0.5 to 1.0 inches h^{-1} from the strongest echoes. The echoes developed to the west of Las Vegas, moved northward, and then seemed to remain in an area just north of the city, but south of the Sheep Range (Fig. 7).

6. Precipitation analysis

During June 1974, a raingage network was established in the Las Vegas Valley to help document the spatial variability of rainfall from summertime thunderstorms. The network shown in Fig. 8 consists of 14 raingages including six weighing gages with recorders (W), four standard 8 inch, stick type raingages (S), two homemade gages sited at the residences of two ARL meteorologists (H), one plastic raingage (P), and one tipping bucket gage located at the NWS station at McCarran International Airport. Fig. 8 also describes the locations of the channels of the dry washes, the local topography, referenced airports, and the major highway accesses to Las Vegas.

Terrain surrounding the city is rather flat, except to the west and north where the Spring Mountains and Sheep Range (Fig. 7) rise above the valley to nearly 12 000 ft and 10 000 ft MSL, respectively. A series of dry washes originate in the surrounding mountains and flow through and around the cities of Las Vegas and North Las Vegas, terminating in the Las Vegas Wash located east of Las Vegas. Las Vegas Wash drains into Lake Mead. Some of the wash channels are shallow and poorly defined as they cross the desert in the western part of the valley. Therefore, during periods of high runoff, some of the flows intermingle and approach the metropolitan area in the form of sheet flow rather than in well-defined channels.

Fig. 8 shows that the raingage network is confined to the Las Vegas area. Beyond the gage network, supplemental data on rainfall amounts were obtained from a bucket survey made by me on the morning of 4 July and by Partick Glancy, a hydrologist with the U. S. Department of the Interior, on 5–9 July. In addition, vacationing meteorologists and meteorological technicians from ARL noted soil wetness, erosion, and silt and rock deposits on local roads over the July 4th holiday weekend. These observations are plotted in Fig. 9. All these data were used to help isolate the region of heavy precipitation and flooding.

In a bucket survey made southwest of Las Vegas on the morning of 4 July, a maximum of 3 inches of storm

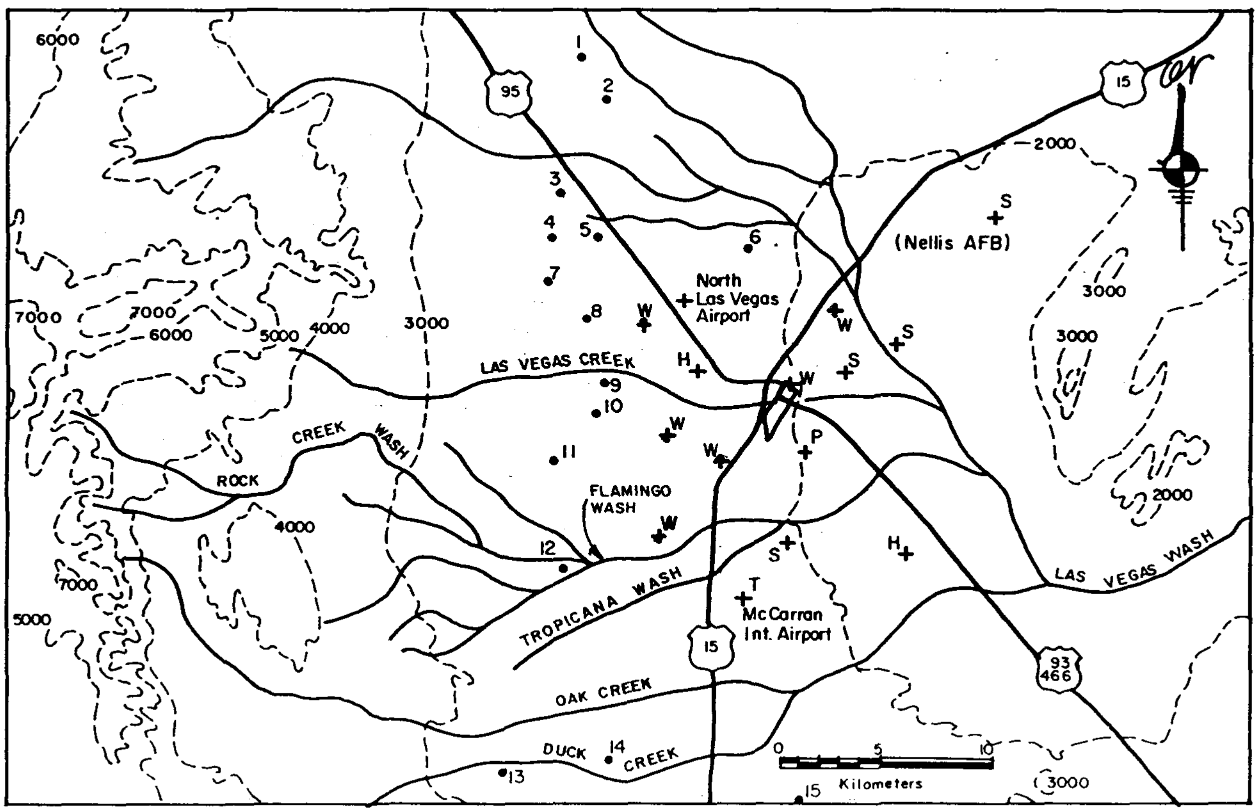

FIG. 8. Locations of the various raingages in the Las Vegas raingage network (letters) and sites of bucket survey estimates (numbers). Topography (dashed lines, ft), dry washes, and major highways in the Las Vegas Valley are also shown. W = weighing gage with recorder, S = standard 8 inch stick gage, P = 6 inch plastic gage, T = tipping-bucket gage, and H = homemade gage.

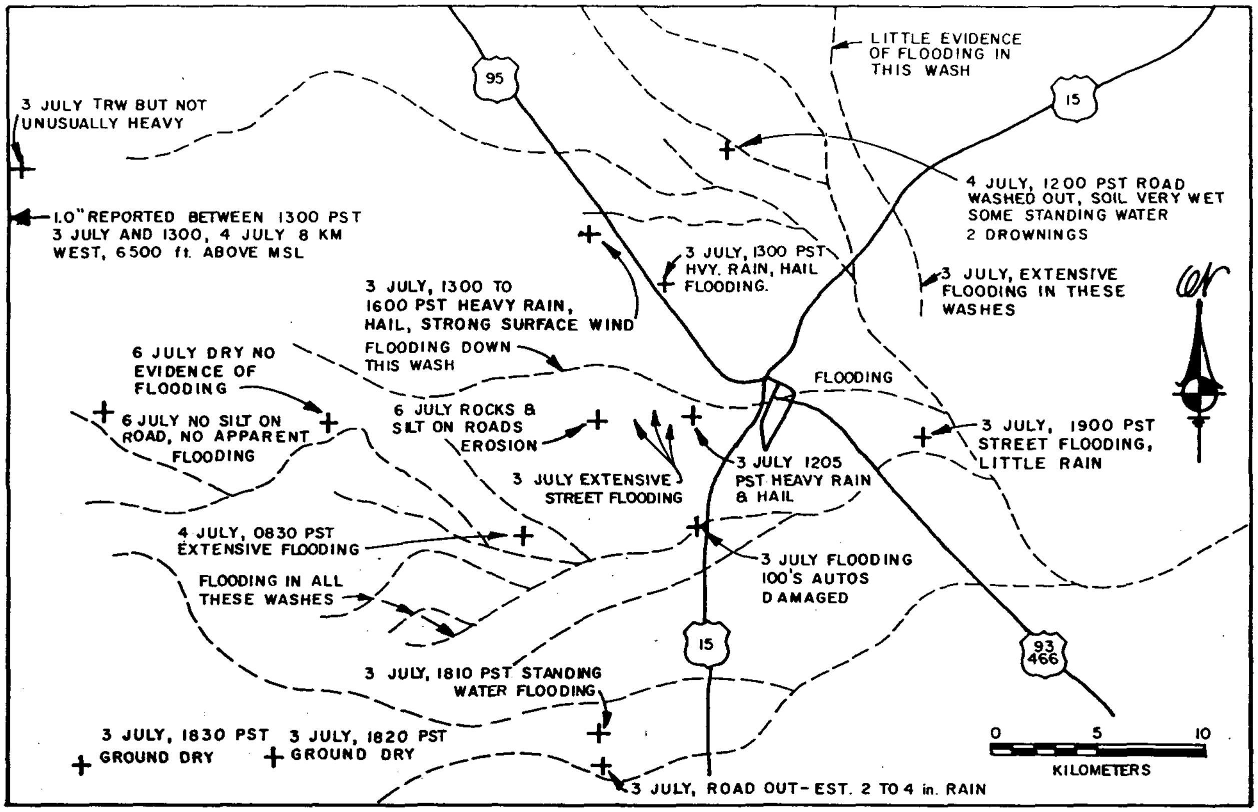

FIG. 9. Information and observations pertaining to the Las Vegas, Nev., flood of 3 July 1975.

rainfall was obtained. This measurement was made 14 km southwest of the central business district.[1]

At position #10 in Fig. 8, 2.5 inches of water was measured in a styrofoam container. At position #5 a water depth of 3.13 inch was measured in a 3 lb coffee can. This amount was rounded to 3.0 inch and plotted on Fig. 10.

Data from the raingage network, from the bucket surveys, and from the supplemental observations were all integrated to provide the information required to reconstruct the rainfall distribution pattern displayed in Fig. 10. Data plotted in this figure represent estimates from the bucket surveys and amounts measured by the raingages. Values from the bucket surveys are plotted to the nearest half inch (except at two sites) and they are followed by either an E or +. The E denotes estimated values and the + indicates that the estimate is likely to be larger due to evaporative loss. Rainfall amounts collected by raingages are plotted to the nearest 0.01 inch. Implicit in this analysis is the assumption that the *0.5 inch isohyet encloses the area of effective precipitation contributing to the flood.*

Fig. 10 shows two distinct centers of maximum rainfall, one to the west of Interstate 15, the other to the north-northwest of the city. For analysis purposes, these two centers were divided in two by a line labeled "separator" in Fig. 10. The only logic used in defining the separator was to partition the drainage region to the north from that to the south of the line, thereby subjectively separating the flood zone to the north from the one to the south of the city.

Based on the available rainfall data and on supplemental information, the area of heavy rainfall analyzed to the west of Interstate 15 is believed to be a good representation of the actual distribution of rain; however, the isohyetal field to the north of Las Vegas is considered only a fair representation because of the lack of information to the north and east of the estimated area of maximum rainfall. Nevertheless, Pat Glancy did report that in this sparse data area a dry wash (Fig. 9, northeasternmost wash) draining southward from the mountains, showed little evidence of flooding so that he was led to believe the area of heaviest rainfall was to the west of this wash. Consequently, north of the city, the general location of the center of maximum precipitation is considered to be a good estimate, but the shape of the isohyetal field is believed to be only a fair estimate of the actual pattern.

In the data-dense area west of Interstate 15 but east of the axis of maximum precipitation, gradients of the order of 0.3 inch km^{-1} (0.5 inch mi^{-1}) are apparent.

[1] Central business district defined as the center of the square formed by the street intersections in the right-center portion of Figs. 8, 9, and 10.

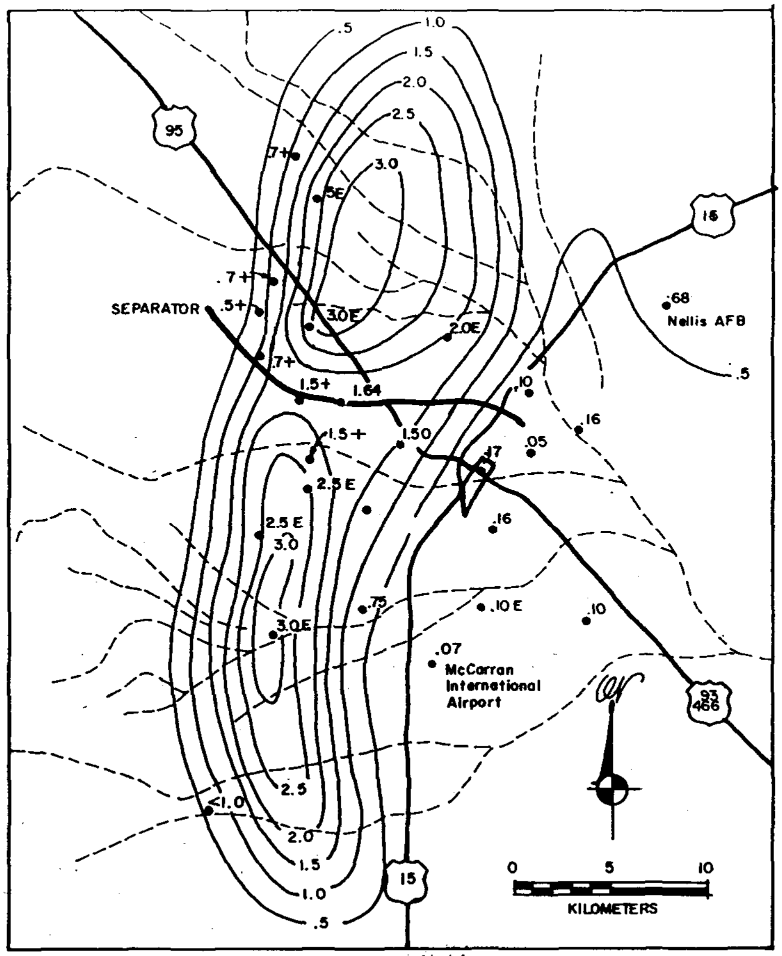

FIG. 10. Isohyetal analysis for Las Vegas, Nev., 3 July 1975.

This gradient seems large, especially when compared with the extreme rainfall gradients estimated by Huff (1967) in an analysis of 186 warm season storms that occurred over a dense raingage network in central Illinois. Huff defined extreme rainfall gradients as those that would not be exceeded more than 5% of the time. For a maximum gage measurement of 3.0 inch, Huff's regression equations yield an extreme gradient of the order of 0.2 inch km^{-1} for the Illinois storms. Rainfall gradients of this magnitude help emphasize that use of the official rainfall amount (0.07 inch, up to 1600 LST), as measured at the NWS station at McCarran airport, would be totally unrepresentative of the magnitude and intensity of this storm.

The isohyetal field in Fig. 10 was planimetered to obtain an estimate of the effective volume of water deposited on the ground and available for flooding before infiltration. In the northeastern quadrant, the area enclosed between the 1.0 and 0.5 inch isohyet was assumed to be concentric with the 1.0 inch isohyet and to have a gradient equivalent to that between the 1.0 and 2.0 inch isohyets. Approximately 1.2×10^7 m^3 (1.0×10^4 acre ft) of water fell on the ground in the isohyetal area north of the separator (Fig. 10) and about 1.1×10^7 m^3 (9.1×10^3 acre ft) fell to the south for a total volume of 2.3×10^7 m^3 (1.9×10^4 acre ft). The spatial coverage of the area of effective precipitation was 553 km^2. If a 0.25 inch isohyet is considered as the lower limit to the effective precipitation contributing to the flooding, the above volumes should be increased by 7% and the enclosed area by approximately 25%.

Some rainfall rates were available from the three westernmost weighing gages (Fig. 8). The gage near Flamingo Wash detected a rainfall rate of 0.3 inch h^{-1} while the gage located 3.5 km east of Site # 10 measured 0.5 inch h^{-1}. The maximum rainfall rate detected by a weighing gage was collected by the gage situated 2 km southwest of the North Las Vegas airport (Fig. 8). This gage detected a rainfall rate of 1.0 inch h^{-1} between 1100 and 1200 LST. A copy of the chart from this gage is displayed in Fig. 11 which shows that the most intense rainfall at this site occurred between 1100 and 1300 LST. Furthermore, reference to Section 5 shows rainfall rates of 0.5 to 1.0 inch h^{-1} were determined

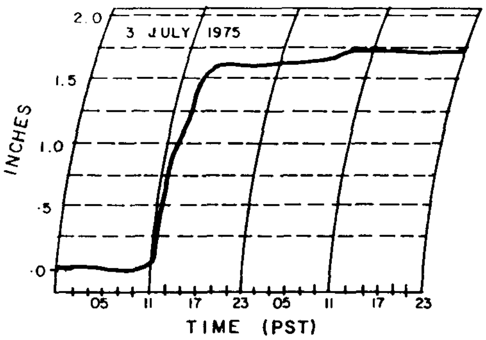

FIG. 11. Rainfall record from the weighing raingage located 2 km southwest of the North Las Vegas airport (Fig. 8).

from the intensity of the strongest echoes detected by the Nellis AFB weather radar. Consequently, with maximum rainfall rates of 1.0 inch h^{-1} being measured physically and detected electronically, and with some reports of heavy rainfall for two or more hours, rainfall amounts of 2–3 inches do seem likely in some areas of the valley. This conclusion provides evidence for supporting the large rainfall amounts detected in the bucket survey.

7. Conclusions

Locally heavy rainfall that developed the flash floods in the Las Vegas Valley on 3 July 1975 fell into a 550 km^2 area covering the western and northern extremities of the valley. The heaviest rainfall, of approximately 3 inches, was concentrated in two separate areas, one to the north and the other to the southwest of the central business district. Rainfall intensities of the order of 1 inch h^{-1} were detected and rainfall gradients of the order of 0.3 inch km^{-1} were measured. Furthermore, surface observations show that severe thunderstorm activity occurred and was accompanied by $\frac{1}{2}$ inch hail, heavy rain, and surface wind gusts of approximately 50 kt. In addition, the thunderstorms producing the heavy rain did not form over mountainous terrain and move into the valley; instead, the storms formed over the valley. Calculations show that before infiltration, rainfall produced 2.3×10^7 m^3 (1.9×10^4 acre ft) of water available to the natural drainage channels in a period of 2–4 h.

Why these thunderstorms formed where they did is difficult to explain because the scale of the activity was much smaller than the scale of the meaningful meteorological data. However, it is clear that the activity did form near the leading edge of a strong moisture gradient, in a region of large-scale convergence, and over terrain that had been heated sufficiently to release convection in an unstable air mass.

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