FLOOD-HAZARD STUDY--100-YEAR FLOOD STAGE
FOR LUCERNE LAKE
SAN BERNARDINO COUNTY, CALIFORNIA

U.S. GEOLOGICAL SURVEY
Open-File Report 77-597

Prepared in cooperation with the San Bernardino County Flood Control District
FLOOD-HAZARD STUDY--100-YEAR FLOOD STAGE
FOR LUCERNE LAKE
SAN BERNARDINO COUNTY, CALIFORNIA
By Mark W. Busby

Open-File Report 77-597

Prepared in cooperation with the
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Menlo Park, California
July 1977
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CONVERSION FACTORS

For readers who prefer metric units rather than English units, the conversion factors for the terms used in this report are listed below:

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<th>Multiply English unit</th>
<th>By</th>
<th>To obtain metric unit</th>
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DESCRIPTION OF AREA

The objective of this study was to develop an elevation-frequency curve for Lucerne Lake.

DESCRIPTION OF AREA

Lucerne Lake is in Lucerne Valley in the high-desert part of southwestern San Bernardino County, about 20 mi east of Victorville, 26 mi south of Barstow, and 32 mi north of San Bernardino. The lake occupies the lowest part of a closed desert basin that is about 20 mi wide and 23 mi long with a drainage area of about 335 mi². The lakebed is at an elevation of 2,848 ft above sea level with mountains rising to an elevation of 3,900 ft to the east, 5,000 ft to the north, 5,200 ft to the west, and 8,200 ft to the south.

The mountains to the north, east, and west of Lucerne Valley are barren, rugged, and isolated, typical of the deserts of southern California. They are composed mostly of schist and gneiss. Quartzite, quartz monzonite, granodiorite, limestone, and sandstone are also found in the bedrock complex. The higher mountains to the south are the San Bernardino Mountains and are mainly pine covered at the higher elevations and brush and shrub covered at the lower elevations. They are also composed mostly of schist and gneiss, with granitic intrusions and some quartzite, sandstone, and conglomerate. Extensive limestone quarries are operated in the southeast edge of the basin. Figures 2, 3, and 4 show some of the mountains around Lucerne Valley.

Runoff mainly originates in the mountains surrounding the valley, but little generally reaches the playa. All streams in the valley are ephemeral. Most of the channels in the northern part of the basin have well-defined courses only in the mountains; the channels become braided and ill defined and usually disappear within a few miles after leaving the mountains. A multiplicity of parallel channels cross the steeper alluvial slopes below the San Bernardino Mountains, but these too disappear after they leave the steeper slopes. Figure 5 shows some of these features.

Mean annual precipitation on the study area ranges from about 4 in on the valley floor to about 25 in on the San Bernardino Mountains. Data gathered by the California Division of Forestry at its fire station in Lucerne Valley show that the mean annual precipitation for the 22-year period through 1972 was 4.07 in. The mean annual temperature for 24 years of record was 60.7°F, and the mean monthly temperature ranged from 43°F in December to 82°F in July.
METHOD OF ANALYSIS

Because of the similarity to the hydrologic problems involved in the Apple Valley study (Busby, 1975), a similar synthetic-hydrologic analysis approach is required in this study.

Adequate regional relations for basin characteristics have not been developed at this time for the desert regions. Other methods such as the rational method or the runoff-curve-number method require coefficients that have not been developed for Lucerne Valley. Channel geometry has been used successfully by others as shown in the Apple Valley study, and the equations were available for this method for the desert areas. Thus, channel-geometry techniques were selected to determine the peak discharges using a simple loss coefficient to route the flows to the playa. Other methods of channel routing and channel losses were investigated for this study, including the
FIGURE 3.—Mountains along the east boundary of Lucerne Valley. A part of the valley is in the right background.

method described by Durbin and Hardt (1974) for the Mojave River, but none of those methods proved to be practical for use at this stage of development of arid-lands hydrologic techniques. The method of Durbin and Hardt (1974) was used, however, as an approximate method to help substantiate the final results. For a detailed discussion of the channel-geometry method used, reference should be made to the Apple Valley report (Busby, 1975). Figure 6 shows typical channel features measured for this study.

Equations relating the width and mean depth of the active channel were developed by the author for the 5-, 10-, 25-, 50-, and 100-year peak discharges for the deserts of southern California. Table 1 presents the equations used to define the flood-frequency relation for each site for this report.
TABLE 1. Channel geometry flood-frequency equations

Equations are of the general form $Q_{RI} = K\dot{W}^{b}H^{d}$

where $Q_{RI}$ = discharge for the given recurrence interval, cubic feet per second
$\dot{W}$ = channel-geometry width, feet
$D$ = channel-geometry depth, feet

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FIGURE 5.—Aerial view of parallel channels crossing the steeper slopes below the San Bernardino Mountains (flow direction is from left to right).

Using the method described in the Apple Valley report (Busby, 1975), channel dimensions were measured at 59 sites in Lucerne Valley. Drainage area-discharge relations developed from channel-geometry data for sites nearby (fig. 7) were used to estimate the discharge at 12 additional sites where channel geometry could not be measured. Figure 8 shows the location of these 71 sites. Table 2 lists the channel dimensions as measured in the field and the computed discharges for these data.
FIGURE 6.--Channel features, site 102, Lucerne Valley.

Obviously, in order to compute the total volume discharged into the playa it is necessary to convert the peak discharges to volumes. This could be done either before or after the routing. Because the relation between peak and volume is nonlinear, it was decided to convert to volumes before routing. From the Apple Valley report (Busby, 1975) the relation between peak discharge and flood volume for the deserts of California was:

\[ V = 0.034 F^{1.15} \]  

where \( V \) is the flood volume, in acre-feet, and \( F \) is the peak discharge, in cubic feet per second (Fig. 9). This equation was used to compute the flood volumes for routing into Lucerne Lake.

The conversion from peaks to volumes before routing also reduces the problem of timing of the flood peaks from the various areas. Obviously, flood volumes can be added to give a total volume regardless of timing of these volumes, whereas peaks must occur simultaneously in order to be added.
FIGURE 7.--Relation of discharge to drainage area for Lucerne Valley.
FIGURE 8.—Location of data sites.
<table>
<thead>
<tr>
<th>Site</th>
<th>Width (feet)</th>
<th>Depth (feet)</th>
<th>Active channel dimension</th>
<th>Computed peak discharge (cubic feet per second)</th>
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FIGURE 9.--Flood peak versus flood volume for desert basins in California.

One of the basic assumptions in this study is that the flow would increase downstream to the limit of contributing area (see fig. 8) and then would decrease further downstream. An exponential die-away equation can be used to describe discharges downstream from the point at which the channel begins to lose flow.
The equation used for computing the discharge at the downstream end of a losing reach was:

\[ Q_d = Q_u \times e^{-\delta D} \]  

(2)

where \( Q_d \) and \( Q_u \) are the downstream and upstream volumes, in acre-feet, \( \delta \) is an empirical coefficient, and \( D \) is the distance the flows are to be routed, in miles. This equation is a simplistic approximation of the flow process. The coefficient \( \delta \) can vary the rate of loss within a reach and can allow for an increase or decrease in discharge.

Using upstream-downstream pairs of volumes computed from Lucerne Valley data, the equation for the coefficient was computed using the Rosenbrock optimization scheme (Rosenbrock, 1960) in a computer program developed by D. R. Dawdy (written commun., 1972). The developed equation was:

\[ \delta = 0.08 + 0.008 D \]  

(3)

where \( D \) is the distance from the downstream limit of contributing flow as outlined in figure 9 to the upstream end of the routing reach. \( D \) is defined as negative if the routing is upstream of the limit and positive if downstream. This equation was chosen because it was the simplest relation between \( \delta \) and \( D \) that would meet the requirements. A more complex relation involving more variables was not felt justified.

Runoff from the northern part of the valley is usually caused by summer thunderstorms, whereas runoff from the southern part is usually from winter frontal storms. Therefore, probably not all the contributing areas would cause flooding at the same time. The basin was divided into a north part and a south part as shown in figure 8; the areas common to both parts could be affected by either summer thunderstorms or winter frontal storms.

Flow volumes were computed for each part separately, with the larger volume of the two parts being used for further computations. This assumption recognizes flow from only one part or the other, which is probably not adequate. In order to reflect the minor flows probable from the part not used in the computations, 10 percent of the smaller volume was added to the larger volume to give a final total volume of flow into the playa.

Using channel-geometry methods, 5-, 10-, 25-, 50-, and 100-year peak-discharge estimates were available for all areas that drain into Lucerne Lake.

The entire flow network from the various discharge points into the playa from each of the two parts was schematically represented, and the discharges were routed down to the playa using equations 1, 2, and 3.
Ten percent of the volume from the smaller part was added to the discharge of the other part to obtain the total volume into the playa for each of the five recurrence intervals. Supplemental data at the end of the report show the flow networks used in the routing of the floods to the playa.

RESULTS

Table 3 presents the flood-volume frequency for Lucerne Lake. This represents flow from the north part of the basin, the larger of the two discharges, plus 10 percent of the flow from the south part. The flood-volume frequency of Table 3, together with the area-capacity curves of Figure 10, were used to develop the elevation-frequency curve of Figure 11. The 100-year flood stage for Lucerne Lake was determined to be at elevation 2,849.3 ft with a corresponding surface area of 5,730 acres. Table 3 also has a summary of the elevation frequency developed for this study.

<table>
<thead>
<tr>
<th>Recurrence Interval (years)</th>
<th>Flood Volume (acre-feet)</th>
<th>Elevation (feet above mean sea level)</th>
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As with any analytical technique, the possibility exists of the answer being in error. The magnitude of this error is not directly measurable from a method as involved as the one used in this study. The easiest way to approach the errors would be to discuss each phase of analysis separately. The first step was to compute the peak discharges from the channel dimensions. The standard error of estimate from the channel-geometry equations was 0.78 log units. The next step was to convert to volumes. The graphical standard error of estimate for this was 0.33 log units. The last step is to route the volume to the playa. No error estimators are available for this step, but a sensitivity analysis of the routing equations indicates an error of 0.36 log units to be reasonable. These three values were combined using the square root of the sum of the squares, or 0.9 log units. This would be the standard error of estimate for any one discharge routed to the playa. In determining the final volume in the playa, a number of
discharges were routed, allowing some compensation of positive and negative errors. The individual errors should thus be adjusted for the number of routings. For the north part there are about 15 separate channels into the playa, so the value was adjusted for 15 routings by dividing the total error by the square root of 15. This gave a final error estimator for the volume of 0.2 log units, or about 50 percent. This translates to a stage error of about 0.75 ft. Thus the true 100-year flood stage should probably be within the range of 2,848.5 ft to 2,850.0 ft.
An examination of photographs taken in the summer of 1969 shows a distinct textural and vegetal change at about the 2,850-ft contour, giving a general confirmation of the probable high water in the past. Figures 12 and 13 show this change.

Possible future channel-improvement work would alter the 100-year flood stage. Channelization would allow the water to reach the playa faster with an appropriate decrease in channel losses and a consequent increase in the 100-year flood stage.

The results presented in table 3 and figure 11 are considered to be the best available at the time of preparation of this report. The results of this study should not be extrapolated to other desert basins.
A mathematical model, described by Durbin and Hardt (1974), that simulates the advance of discharge down an initially dry river channel was also used to simulate inflow to Lucerne Lake. This model represents an attempt to simulate the physical conditions in a channel by a mathematical model that is based on the physical laws governing open-channel hydraulics and flow through porous media.

This model was originally calibrated for the Mojave River, a much larger stream than any in Lucerne Valley, so that a new calibration would be needed for Lucerne Valley. Because of the lack of real data, however, the calibration was only partially successful, and firm values for the model parameters could not be determined.
FIGURE 13.—Vertical aerial view of vegetal change at about the 2,850-foot elevation shown in figure 12.

Several sets of parameters were estimated, based partially on the Lucerne Valley calibrations, partially on the Mojave River calibrations, partially on data gathered by Smith (1972a, b), and partially on knowledge of the model, in order to determine a set of approximate results. Table 4 presents the model parameters used for the Lucerne Valley trials.

Using these parameters, the computed discharges into the playa (table 5) ranged from 4,100 to 4,800 acre-ft for the southern part and from 5,600 to 6,200 acre-ft for the northern part. Again using the 10-percent addition for minor flow from the other part, the model results indicate a 100-year flood volume into the playa of 6,000 to 6,700 acre-ft. These values, while smaller, are very close to those presented herein and show, by an independent technique, that the results as shown in table 3 are reasonable.
DISCUSSION

TABLE 4.--Model parameters used for Lucerne Valley

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<td>.00012</td>
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1See Durbin and Hardt (1974) for a description of the parameters.

TABLE 5.--Computed discharges into Lucerne Valley

[acre-feet]

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DISCUSSION

The Apple Valley report (Busby, 1975) discussed the assumptions and difficulties with the synthetic-hydrologic techniques used in that study. Many of the difficulties also are present in this study.

Most of the differences between that study and this one are attempts to improve the techniques and resolve some of the difficulties. For instance, the splitting of the basin into a northern part and a southern part is a partial answer to the summer-winter storm problem.
This study has shown that more research is needed to answer the many problems involving flow onto desert playas.

As with the Apple Valley study, the techniques used in the determination of the 100-year flood stage are far from the final solution, but they are judged to provide reasonable answers.

REFERENCES


## 100-Year Flood Stage, Lucerne Lake, San Bernardino Co., Calif.

### Supplemental Data for Routing to Playa

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<tr>
<th>Upstream point&lt;sup&gt;1&lt;/sup&gt;</th>
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<th>Routing distance&lt;sup&gt;2&lt;/sup&gt; (miles)</th>
<th>100-year discharge at upstream end&lt;sup&gt;2&lt;/sup&gt; (Q) (cubic feet per second)</th>
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### SUPPLEMENTAL DATA FOR ROUTING TO PLAYA--Continued

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#### Whole basin contributing--Continued

#### Northern part contributing

|      |       |                               |                                     |                                           |
|------|------|--------------------------------|-----------------------------------------------------------------------------|
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| 10   | -    | .8                             | 5,970                            | 1.0                                      |
| 11   | 2,10 | .3                             | -                                 | 2.3                                      |
| 12   | -    | .3                             | 1,150                            | 1.2                                      |
| 13   | 11,12 | .25                           | -                                 | 2.6                                      |
| 14   | -    | .5                             | 1,000                            | .5                                       |
| 15   | 13,14 | 1.0                            | -                                 | 2.85                                     |
| 16   | -    | .8                             | 2,740                            | .4                                       |
| 19   | -    | .8                             | 1,300                            | .3                                       |
| 21   | 15,18,19 | .55                          | -                                 | 2.35                                     |
| 22   | -    | .5                             | 760                               | .8                                       |
| 23   | 21,22 | 1.8                            | -                                 | 2.7                                      |
| 34   | -    | .5                             | 2,380                            | .7                                       |
| 35   | -    | .15                            | 5,560                            | .8                                       |
| 36   | 34,38 | .2                             | -                                 | .95                                      |
| 37   | -    | .45                            | 1,430                            | .9                                       |
| 39   | 23,36,37 | .65                          | -                                 | 4.5                                      |
| 52   | -    | .8                             | 1,430                            | .9                                       |
| 55   | 39,52 | .45                            | -                                 | 5.15                                     |
| 54   | -    | .75                            | 760                               | .75                                      |

See footnotes at end of table.
### SUPPLEMENTAL DATA FOR ROUTING TO PLAYA—Continued

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<td>3,170</td>
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<td>-</td>
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<td>102,103,104</td>
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</tr>
</tbody>
</table>

\(^1\)Upstream point is the upstream end of routing reach, routed as defined in point routed from. Numbers refer to points used in computation (fig. 8 ).

\(^2\)Discharge is from data on channel geometry or drainage area relation.