HYDROLOGIC ANALYSIS OF SILVER LAKE AND LEMMON VALLEY PLAYAS

12/5/88

See p. 6 for support of storage idea.

See p. 15 - question accuracy of study with 5' contour map.

p. 20 why this scenario

See appendix B Dept of Commerce letter re storage

p. 14 - calibration appears

LOCATED IN CITY OF RENO, NEVADA AND WASHOE COUNTY, NEVADA

FOR:

FEDERAL EMERGENCY MANAGEMENT AGENCY

(CONTRACT #EMW-86-C-2239)

JULY 1987

REVISED DECEMBER 1987

NIMBUS JOB #8601

12/5/88

Nimbus Engineers

240 Linden St., Suite B • Reno, NV 89502

Mail: P.O. Box 10220 • Reno, NV 89510

(702) 689-8630

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

1.0 - INTRODUCTION AND PURPOSE

This report is prepared in conjunction with a current Federal Emergency Management Agency (FEMA) flood insurance re-study for the Reno/Sparks Area. The re-study includes a hydrologic and hydraulic analysis for the Silver Lake and Lemmon Valley watersheds in order to determine 100 year water surface elevations for the major playas within these areas. The previous flood insurance study mapped these playas using approximate methods. Due to the increase in development immediately adjacent to these lakes, it has become necessary to determine regulatory flood elevations for the lake areas.

A brief version of this report that addressed the calibration procedure used in this study was sent to the U.S. Geological Survey, National Weather Service Forecast Office in Reno, the Corps of Engineers, The Soil Conservation Service, the Federal Emergency Management Agency, and local agencies for review. Comments were received from each of these agencies. This report was revised to address each of the comments received and include the analysis of the 100 year runoff volumes. The letters that were received in response to the original report are contained in Appendix A with a section that specifically addresses each comment.

During February 1986, a significant precipitation event occurred which allowed the collection of valuable data for evaluating the hydrologic characteristics of these watersheds. This report presents the results of Nimbus Engineers calibration of the HEC-1 hydrologic models using the available data from the February 1986 event. This calibration was used to determine reasonable initial and constant loss rates to be used in the hydrologic models that will determine the runoff volumes from a 100 year, 10 day event.

Both the Lemmon Valley and Silver Lake Playas are terminal lakes within closed basins. Closed basin lakes present a unique and difficult regulatory problem for western flood plain managers. The only outflow from most of these lakes is evaporation, as is the case with the playas evaluated in this study. When flooding occurs from lake level fluctuations, the period of inundation can be weeks or months. This results in substantially higher damages to structures and roadways than shorter duration riverine flooding. Because of this fact, considerable care must be taken in determining an accurate level for the desired recurrence interval to be used for management purposes.

Due to insufficient historical lake level data for the playas evaluated in this study, the level for a 100 year recurrence interval must be established with a hydrologic model and tested with a variety of potential types and patterns of storms. This report presents the method used to calibrate the hydrologic model used and the rainfall patterns and distributions that were used to determine the potential lake level.

2.0 - PHYSICAL DESCRIPTION OF STUDY AREA

The two watersheds evaluated in this report are shown on Figure 1. These basins are located in southern Washoe County just north of the Reno area. Most of the area is within unincorporated Washoe County, Nevada with some portions incorporated into the City of Reno. Elevations within the watershed range from a maximum of 8266 feet to a minimum of 4906. Vegetation types in the watershed vary from sparse Pinon in the upper elevations to sage/grass in the majority of the watershed. Large portions of these watersheds consist of gently sloping alluvial material with a poorly defined drainage pattern. Most of the runoff within the watershed occurs as shallow sheet flow and braided flow. The primary drainages are so poorly defined that many of the major drainages are not readily discernable from the ground. Aerial photos provide a better reference for identification of the drainage patterns than field inspection. Both watersheds in the study area are closed basins draining to playas. The only losses from these playas are evaporation and infiltration.

The Silver Lake watershed is 53.8 square miles in size. The watershed is long and narrow with the playa located in the southern extreme of the watershed. The Lemmon Valley watershed is 43.02 square miles in size with the playa being centrally located within the basin.

3.0 - HISTORICAL DATA

Peak lake levels in the playas have not been recorded in the past since the lakes did not threaten any structures until recent encroachments have resulted in damage to structures. The only information on lake levels prior to 1983 only exists in a few photos with uncertain dates and indistinguishable shorelines.

In 1982 the Desert Research Institute (DRI) installed a staff gauge in Silver Lake to monitor lake level fluctuations. The purpose of their study was to determine the surface and groundwater contributions to the lake throughout the year for water supply studies. The staff gauge was destroyed by vandals soon after it was installed and has not been re-established.

Beginning in 1985, Pyramid Engineers and Land Surveyors began monitoring the lake level of Silver Lake and the two adjacent playas to the northeast, with periodic surveys of the water surface elevations.

During the flooding of February 1986, the Washoe County Utility Department began monitoring the water surface elevations of Lemmon Valley playa. The lake had risen to the point that it was inundating the sewage treatment plant at the southeast corner of the playa. The flooding of the playa resulted in closure of the plant and temporary discharge of raw sewage into the playa.

3.1 - 4 DAY STORM OF DECEMBER 1955

The 1955 storm was used by the Corps of Engineers in their analysis of the Truckee River Basin (Ref 25). The Corps developed an isohyetal map of the December 21-25, 1955 event for the Truckee River Basin. This map suggests that the precipitation totals within the study area was 1.2 to 1.4 times greater than the totals at Reno-Cannon International Airport. This event consisted of a 4-5 day rainfall on an existing snowpack that caused significant runoff on many of the major watercourses such as the Truckee River.

3.2 - 3 DAY STORM OF FEBRUARY 1963

The Corps of Engineers also prepared a isohyetal map of the January 30 to February 1, 1963 event, for their use in the Truckee River analysis (Ref 25). This event produced one of the highest recorded discharges on the Truckee River. The storm was a 3 day rainfall event. The Corps considered the snowpack to be light enough to be considered insignificant to the peak runoff response in the Truckee River.

Precipitation totals in the study area during the 1963 event appear to have been 1.6 to 2.3 times greater than the totals at the Reno airport gauge.

3.3 - WINTER OF 1982 - 1983

Unusually wet conditions existed before and during the winter of 1982 and 1983. Many of the terminal lakes and sinks in Nevada experienced higher than average runoff volumes and lake levels. The peak elevation of Silver Lake during 1983 was estimated by the Desert Research Institute as 4962.5.

3.4 - 9 DAY STORM OF FEBRUARY 1986

A significant amount of flooding occurred in the Reno/Sparks area during February 1986. The flooding was caused by a large warm Pacific storm that began February 12th and extended through February 20th. Daily precipitation totals for the storm were collected at 14 sites in and around the Reno area. Three of these gauges are located within the study area; two in the southern portion of the Silver Lake watershed and one in the northern portion of the Lemmon Valley watershed. The only recording rain gauge in the area was the National Weather Service gauge at the Reno-Cannon International Airport. Hourly totals of the rainfall which occurred at Cannon International Airport are graphed and shown in Figure 2.

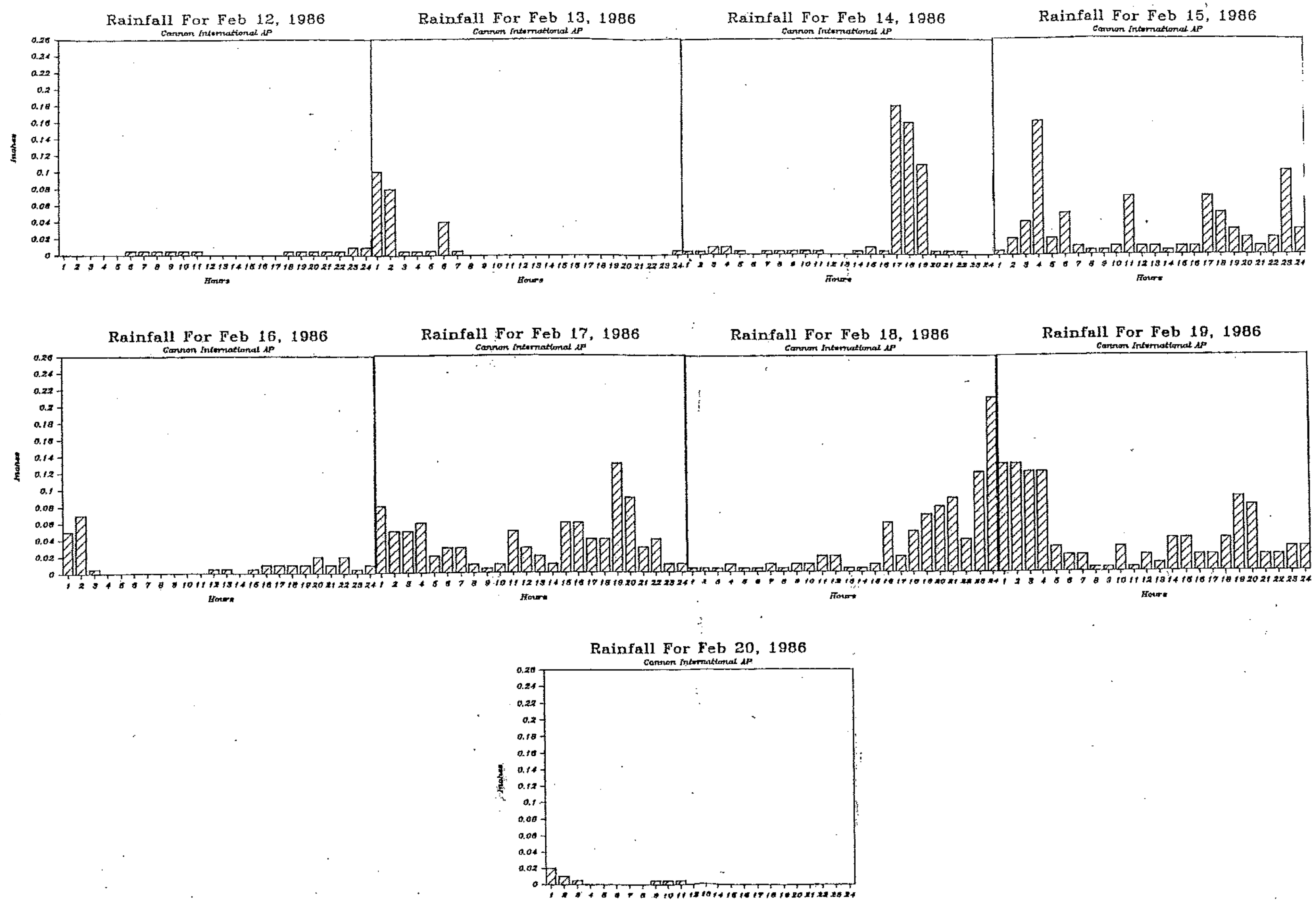


FIGURE 2

Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

Analysis of the rainfall data collected during that event was done by Washoe County Department of Comprehensive Planning (Ref. 4). Their analysis indicates that the rainfall totals vary consistently with elevation. This would suggest that the storm was large enough to have a relatively consistent spatial and temporal distribution over the area of interest. Rainfall totals at specific sites appeared to be dependant upon orographic effects. The National Weather Service Forecast Office at Reno, prepared a report on the February 1986 event which included a map of the 10 day precipitation totals for the Truckee River Basin (Ref. 28). Using the rainfall information from the 15 rain gauges, the NWS report, and the analysis by Washoe County, a reasonable Isohyetal Map was constructed for the area of interest. This map is included as Figure 3, as it was revised by NWS staff.

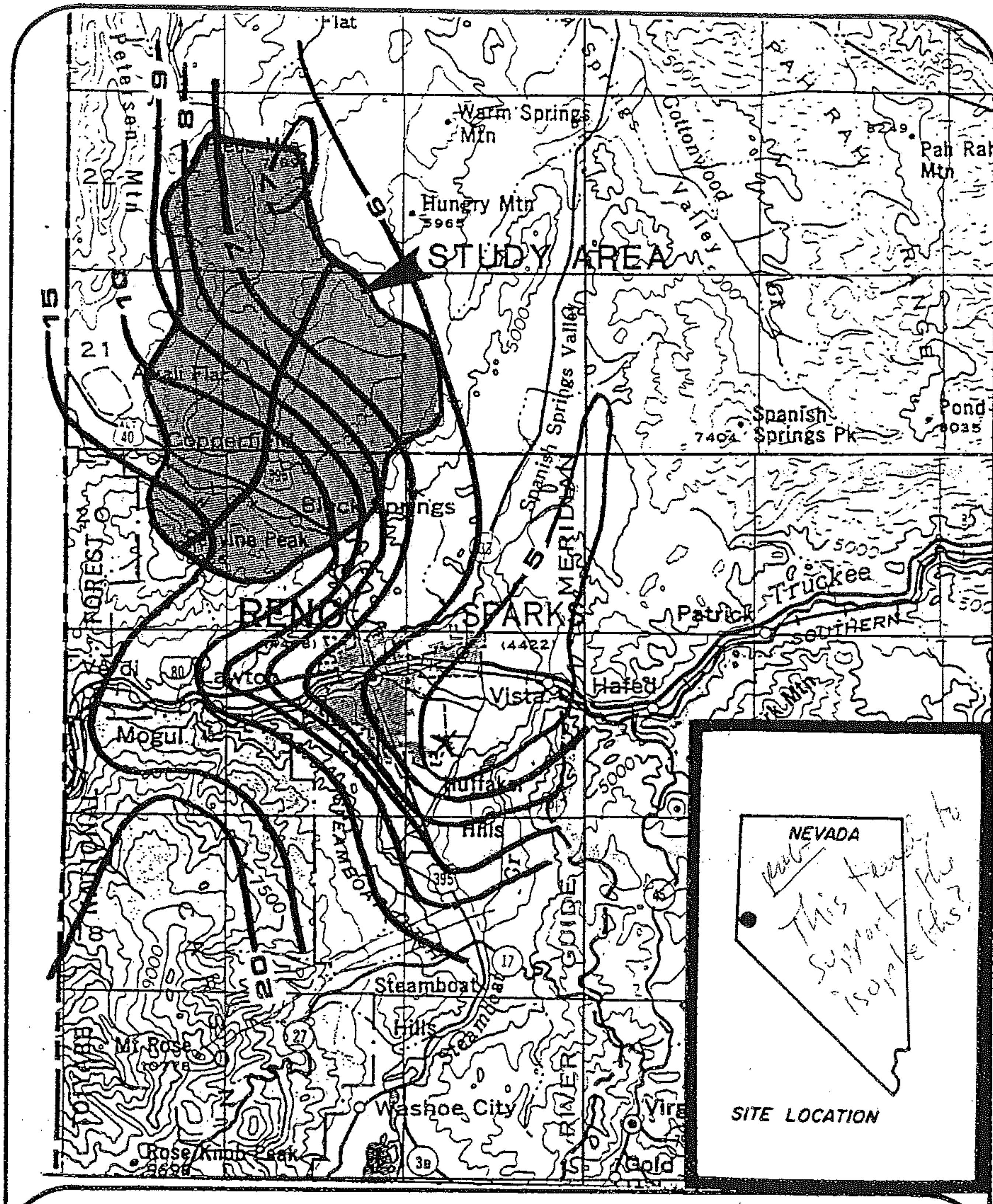
Figure 4 is a rainfall mass curve from the event using the hourly totals from the National Weather Service gauge at the airport. This mass curve indicates that the highest intensity rainfall occurred between 2300 hours on February 18 and 400 hours on February 19th. Figure 5 shows the short duration precipitation that indicates that the intensities during the storm were low. The storm was a long duration and low intensity event that only produced high peak flows in the larger watercourses. Since the most significant portion of the total rainfall occurred at the end of the nine day period, the soils within the watershed were saturated during the key period.

Nimbus Engineers performed field inspections of the study area before, during, and after the February event. The Washoe County Utility Department took frequent water level measurements of the Lemmon Valley playa which recorded the lake's response to the runoff from the watershed. The graph prepared by Washoe County is included as Figure 6. Frequent lake level measurements that recorded Silver Lake's response to the event were also recorded by Pyramid Engineers. Their data has been plotted in the same format as the Lemmon Valley playa and is included as Figure 7. Both playas had minimal or no initial volume at the beginning of the event.

The precipitation data and lake levels are the only hard data collected. Watercourses were also inspected by Nimbus staff during and after the event to determine which areas of the watersheds contributed significantly to the watershed discharges.

4.0 - OTHER STUDIES

The original flood insurance study for Washoe County developed flood limits for these playas using approximate methods. Therefore this study does not provide useful information for this study.



Nimbus Engineers

240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

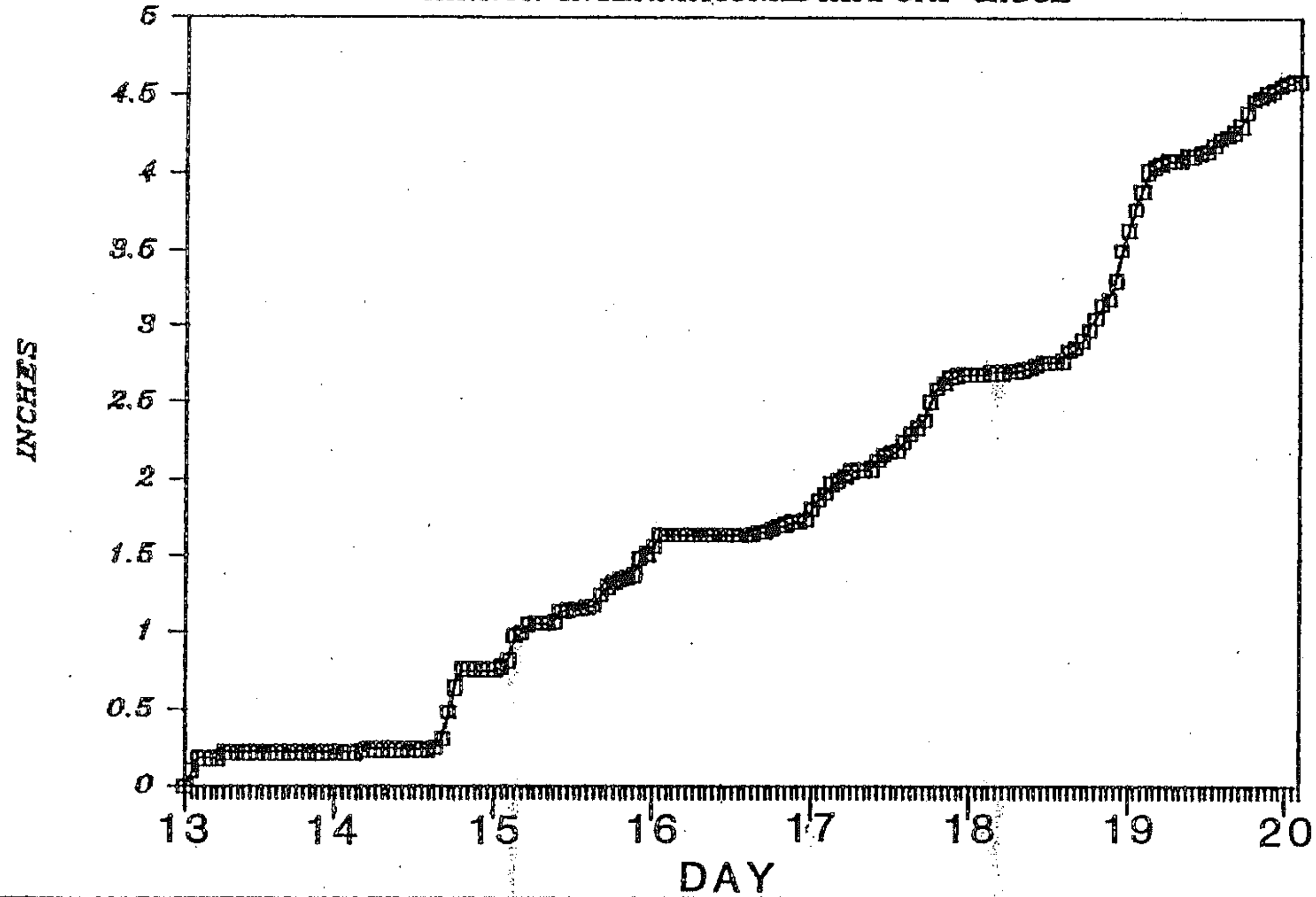
FIGURE 3

ISOHYETAL MAP

FEBRUARY 12-20, 1986

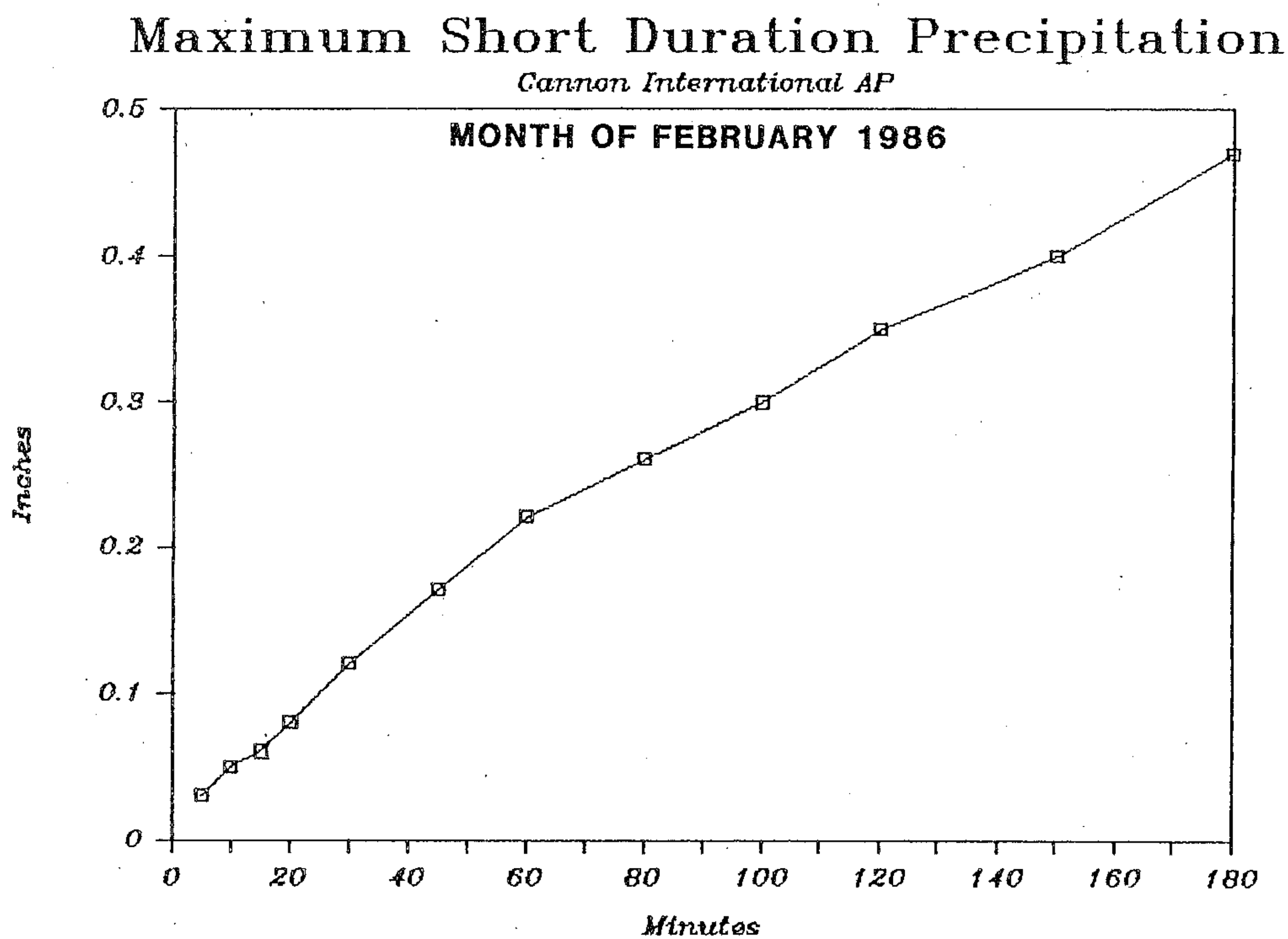
RAINFALL MASS CURVE FOR FEB 13–19, 1986

CANNON INTERNATIONAL AIRPORT GAUGE



Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 4



Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 5

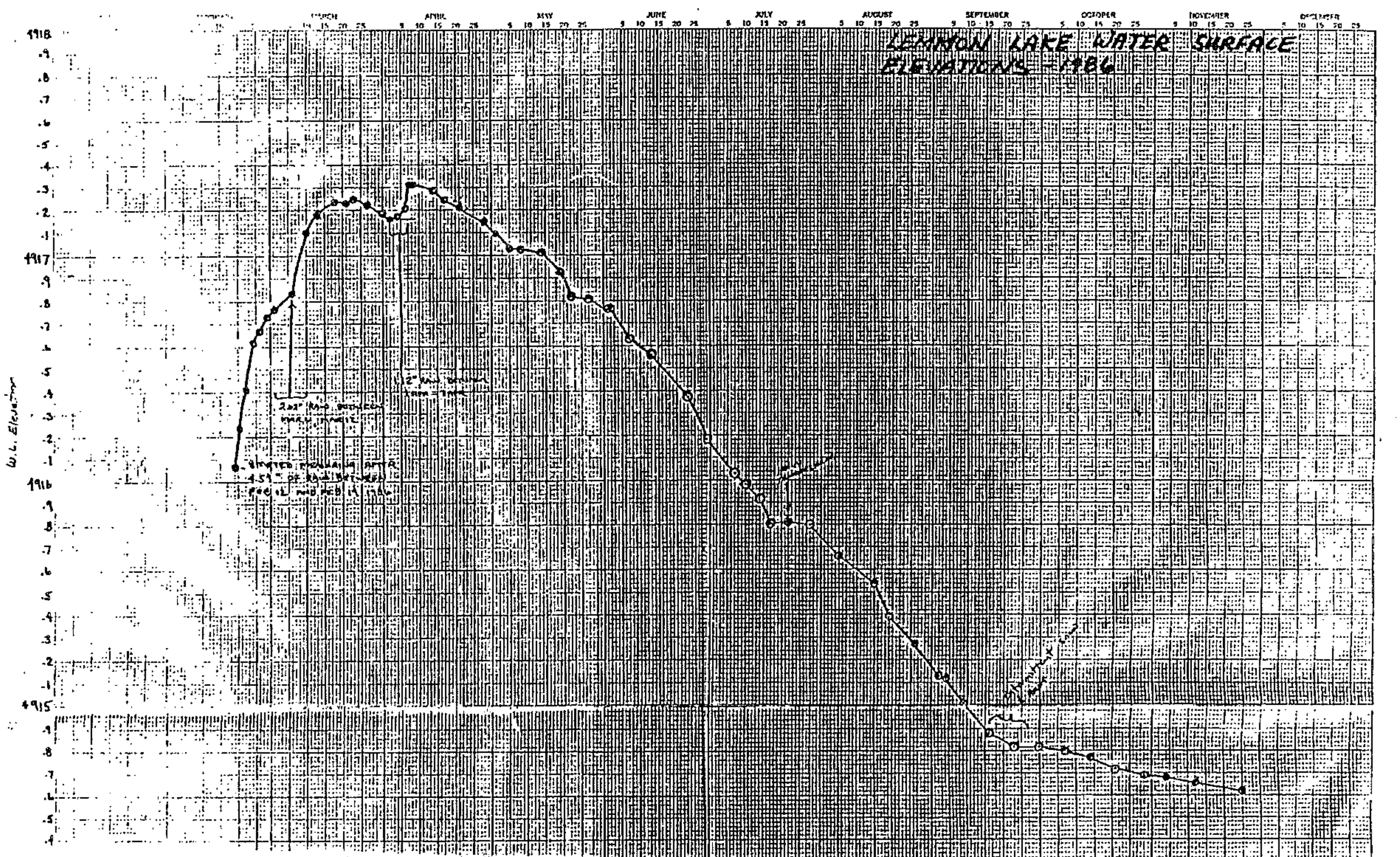
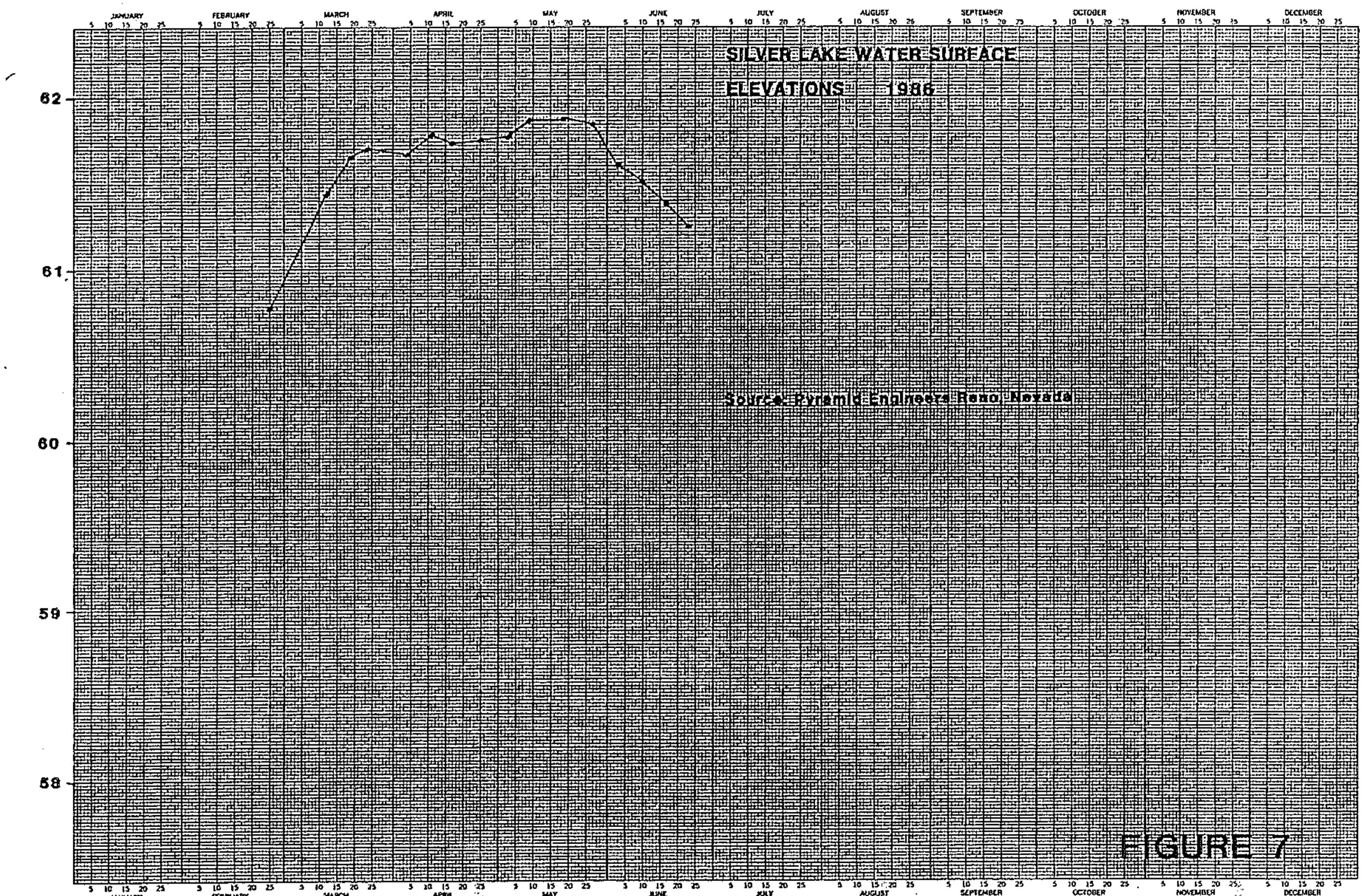

LEMMON LAKE WATER SURFACE ELEVATIONS - 1986
W.L. Elevation
4918
4917
4916
4915
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

FIGURE 6



SILVER LAKE WATER SURFACE
ELEVATIONS 1986
Source: Pyramid Engineers Reno, Nevada
62
61
60
59
58
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

FIGURE 7

Reimer and Associates of Burlingame, California and Schaff & Wheeler Consulting Civil Engineers of San Jose, California submitted a request for Letter of Map Revision (LOMR) to the FEMA (Ref. 12 & 14) in 1985. This LOMR request included a hydrologic analysis of Silver Lake for the purpose of establishing a 100 year lake level. This level was needed for the design of a project that is proposed for a site at the northeast side of Silver Lake. The study used the curve number method of computing runoff volumes from the watershed. The rainfall used in the computations was derived from NOAA Atlas (Ref. 26) with a rainfall pattern distributed according to the pattern observed during the December 1955 to January 1956 event. The resulting water surface elevation from this analysis of Silver Lake was 4965.0.

Desert Research Institute has been performing studies of the Silver Lake Watershed for water harvesting studies. These studies, were performed to develop information on recharge and yield from smaller events and to determine information for average annual conditions. The studies were also isolated to small watersheds on Peavine Mountain. The information developed by DRI does not address extreme events.

5.0 - ALTERNATIVES FOR HYDROLOGIC ANALYSIS

Due to insufficient historical lake level data to perform a statistical analysis of lake level recurrence intervals, these levels must be estimated with hydrologic analysis. This study does not include calculation of water surface profiles, therefore peak discharge is not important to the study. Runoff volumes from the watershed for a given storm pattern or series of storm patterns is the desired result. The total runoff volume for the storm(s) deemed to be a reasonable estimate of a 100 year condition would then be translated into a lake level based on the calculated stage - discharge relationship for the lake of concern.

5.1 - SINGLE EVENT MODELS

5.1.1 - Curve Number Procedure

The most common method of calculating runoff volumes from a watershed is the SCS curve number method. This can be done using 24 hour daily rainfall information with 24 hour curve numbers and then summing the volumes for each day of the storm of interest. The curve number method can also be applied to a 10 day storm by reducing the 24 hour curve number to a 10 day curve number using the procedure described in the SCS Technical Release No. 60 (TR-60).

5.1.1 - SCS Computer Program TR-20

The SCS computer program TR-20 develops a hydrograph for a watershed using the equations developed for the curve number procedure. The results using TR-20 should be very similar to the hand calculation method of the curve number procedure, in terms of runoff volume.

5.1.2 - Corps of Engineers Computer Program HEC-1

The Corps of Engineers Hydrologic Engineering Center developed a single event flood hydrograph package called HEC-1. HEC-1 is commonly used by engineers for developing hydrographs to be used in flood studies. HEC-1 allows the use of many methods of computing rainfall distributions, infiltration losses, routing methods, and hydrograph generation. One of the options includes the curve number method that is very similar to TR-20.

5.2 - CONTINUOUS EVENT MODELS

There are several continuous event models that will model long term runoff, and soil moisture accounting for a watershed. One example of this type of model is the Stanford Watershed Model. A continuous event model would likely produce the most accurate information for use in this type of study, but the data required to perform a continuous event simulation is extensive and is not available for the study area.

6.0 - MODEL CALIBRATION

The February 1986 event was very significant because it produced severe flooding in many parts of California and Nevada. During and after this event rainfall and lake level data was collected. There is sufficient information from this event to reasonably model the runoff response from the watershed as a single event simulation. Using this information, several of the methods described in Section 5 were tested for their ability to reproduce the results that were observed.

Since the purpose of this study is to determine the runoff volume to the playa areas, peak flows were not considered as being important in the selection of model parameters. For this reason, the two areas were lumped into two separate large watersheds and *basin wide averages were used in selecting the parameters for the model. The isohyetal map included as Figure 3 was used to determine basin average precipitation for each watershed. Lag times were estimated using both the curve number and Upland methods and average values were selected. Impervious cover was estimated including the lake surfaces, roads and residential/commercial areas.*

Observations made during and after the storm indicated that the upper elevations within the watersheds received a considerable amount of their precipitation as snowfall. Since snowfall would not contribute to the initial runoff response from the watershed, a certain amount of the watershed was excluded from the model. Based on the information presented in the NWS report and observations made in the field, the area above 5600 feet was selected as the area that received the bulk of it's precipitation as snowfall. This is probably a conservatively low level. If a higher level was selected, there would be a greater area of contributing watershed and the precipitation losses per unit area would need to be greater. The 5600 level is considered to be an appropriate and conservative estimate. This modification decreased the effective watershed area for Silver Lake from 53.8 square miles to 37 square miles, and for the Lemmon Valley playa from 43.02 square miles to 36 square miles.

The period of rainfall modeled was from 1100 hours on February 14 to the end of the storm. The modeling period does not include the first portion of the storm in order to concentrate the computational period to the end of the storm. This assumes that the rainfall that occurred prior to the 1100 hours on the 14th was lost as initial abstraction. Since the precipitation that occurred prior to this period was minimal, this assumption is not considered to be significant. Including this rainfall into the model would increase the runoff volume predicted and thus cause the predicted losses to be higher. Therefore, this is a conservative assumption.

6.1 - SCS CURVE NUMBER METHOD

Schaff and Wheeler estimated the 24 hour curve number for the Silver Lake watershed to be 82 (for AMC II). Based on the soil survey, vegetation types and the curve numbers presented in TR-55 for sage-grass conditions, this estimate appears to be reasonable. Based on Table 2-3 in TR-60, the corresponding 10 day curve number would be 68.

Imputing this 10 day curve number into the HEC-1 model for Silver Lake using the February 1986 storm data, yields a runoff volume of 9300 acre feet.

The curve number for Lemmon Valley playa was estimated to be 86 which translates into a 10 day curve number of 74. The runoff volume and corresponding lake level for Lemmon Valley playa is 10,200 acre feet and 4919.6 respectively.

As compared to the observed runoff volume, the SCS curve number method significantly over-predicted the runoff volumes for the watershed. For the Silver Lake watershed, the resulting volume predicted by the model with the reduced watershed area was over 2.6 times greater than the observed runoff volume of approximately 3600 acre-feet. In order to duplicate the observed runoff volume for this watershed, the curve number had to be adjusted to approximately 41.

Use of the 10 day curve number for Lemmon Lake watershed produced a runoff volume of 10,200 acre feet as compared to the observed runoff volume of 7100 acre-feet. In order to duplicate the observed runoff volume for this watershed, the curve number was adjusted to approximately 58.

TABLE 1

COMPARISON OF OBSERVED VOLUMES WITH RESULTS FROM CURVE NUMBER METHOD

BASIN	OBSERVED VOLUME (AC-FT)	OBSERVED ELEVATION	* MODELED VOLUME (AC-FT)	MODELED ELEVATION
SILVER LAKE	3600	4961.7	9300	4967.9
LEMMON VALLEY	7100	4917.3	10,200	4919.6

** Using CNs of 68 and 74 for Silver Lake and Lemmon Valley respectively.*

Because of the results of this analysis, the curve number method was determined to be inappropriate for this task. The curve number method appears to give reasonable results in terms of peak discharge values, but over-predicts the total volume under the hydrograph.

6.2 - INITIAL AND CONSTANT LOSS RATES

The Sacramento District of the Corps of Engineers prepared a hydrology report for the Truckee River basin in 1980 (Ref. 25). This report presents the results of their calibration of the initial and constant loss rates within that watershed during the 1955 and 1963 events. The results of their analysis indicated that an initial loss rate of 0.30 and constant loss rates of between 0.05 and 0.23 resulted in reasonable duplications of observed hydrographs for those events. They adopted a constant loss rate of 0.10 for general rain, probable maximum and standard project events.

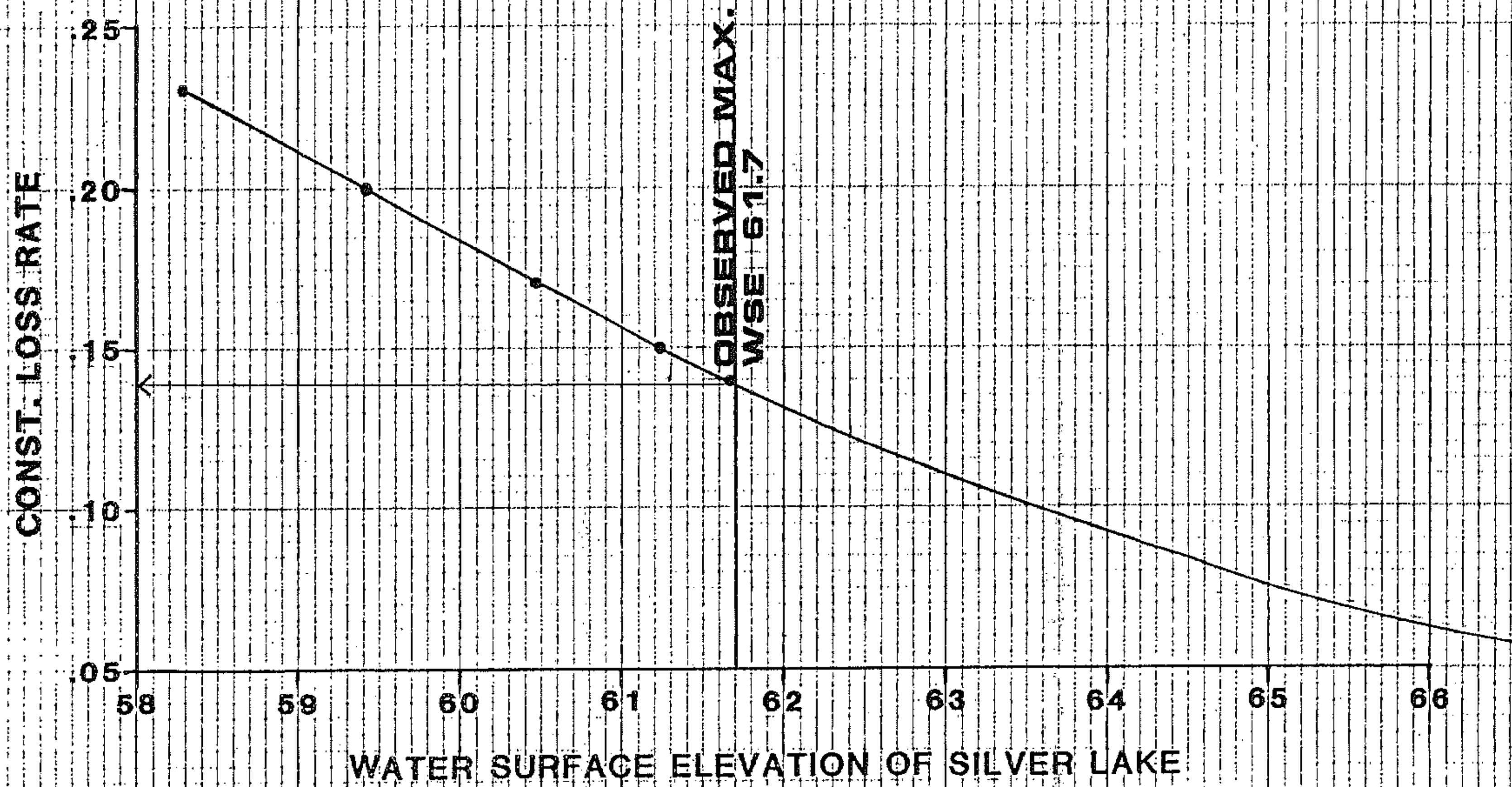
Since our calibration model for this eight day event was not very sensitive to the initial loss rate, the value of 0.30 was chosen as a reasonable value. Each watershed model was then tested using varying constant loss rates to determine which constant loss rate would produce the observed runoff volume. The results of this analysis is presented in graphical form on Figures 8 and 10. Figures 9 and 11 are the stage-storage curves for these two major playas. The results indicate that the appropriate constant loss rates for the Silver Lake and Lemmon Valley watersheds are 0.14 and 0.072 respectively. These values are within the range of values observed by the Corps of Engineers for the adjacent watershed areas. These values are also very similar to the infiltration rates reported for the soils in the watersheds (Ref 21).

The stage-storage curves presented as Figures 9 and 11 were derived using References 5 and 7. Reference 7 is a topographic map of the Silver Lake area at a contour interval of 5 feet with frequent spot elevations. One foot contours were estimated and compared to the bathometric survey map in Reference 2. The areas under each contour were measured and compared to the information on the 7.5 min USGS quad. Once the stage area information was obtained, this information was input into the HEC-1 model and HEC-1 calculated the storage volumes at each stage using the conic method.

1979 aerial photos of the Lemmon Valley playa were used to obtain spot elevations on a 100 foot grid of the playa area. This digital information was analyzed to obtain a stage-area relationship for the playa area. This information combined with the USGS quad, were utilized to obtain the final stage-area information that was input into the HEC-1 model.

Runoff volumes for Lemmon Valley playa are higher per unit area than for Silver Lake. As a result of the higher observed volumes, there is a lower calibrated loss rate for Lemmon Valley playa. The higher runoff potential for this basin is also observed in the greater percentage of soils in hydrologic soil groups C and D. This also results in a higher estimated curve number based on the soil survey and observed vegetation types and densities. Another factor that influences the runoff volumes is

Silver Lake Playa
Results of Calibration Modeling Using February 1986 Data

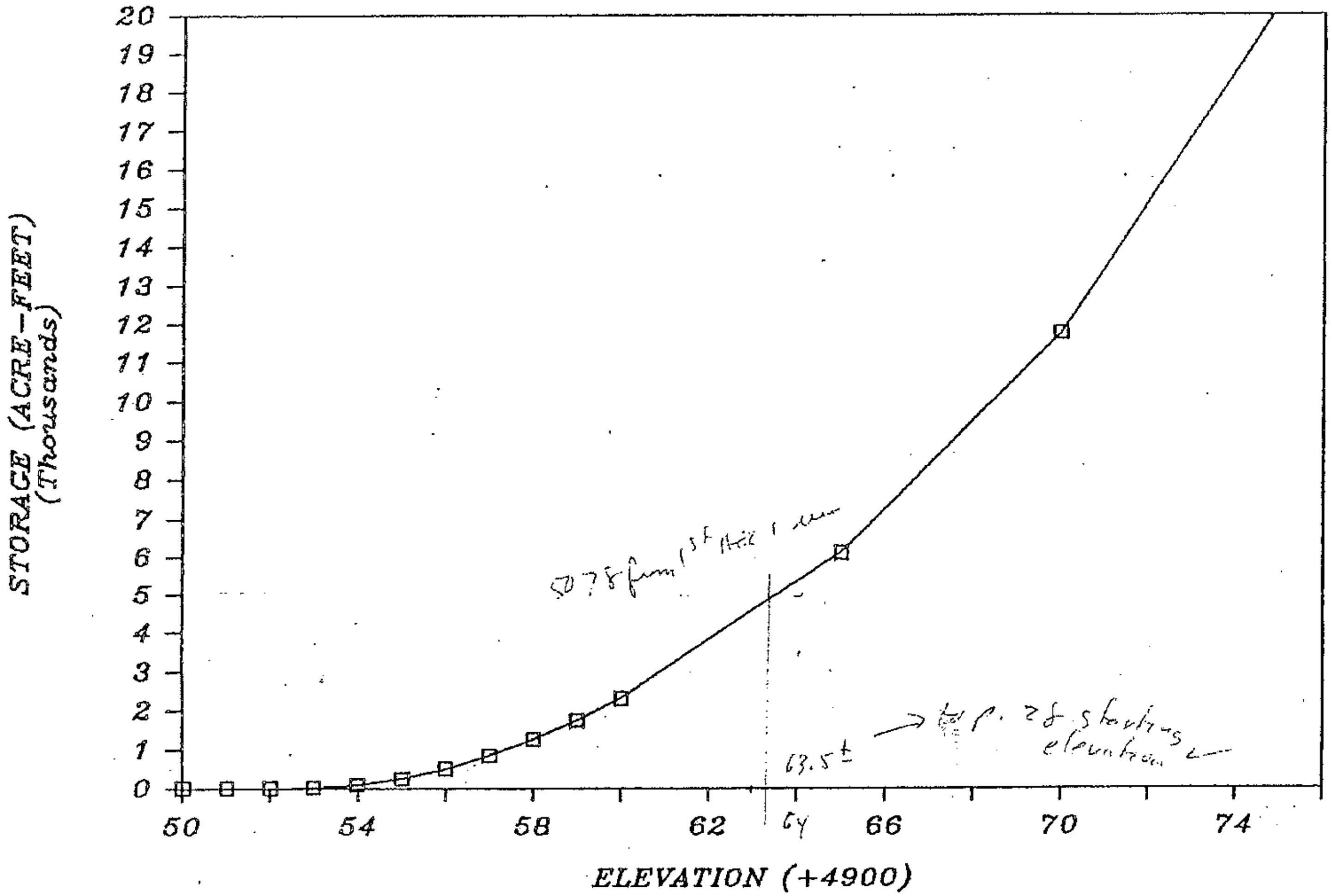


Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 8

SILVER LAKE PLAYA

STAGE–STORAGE RELATIONSHIP

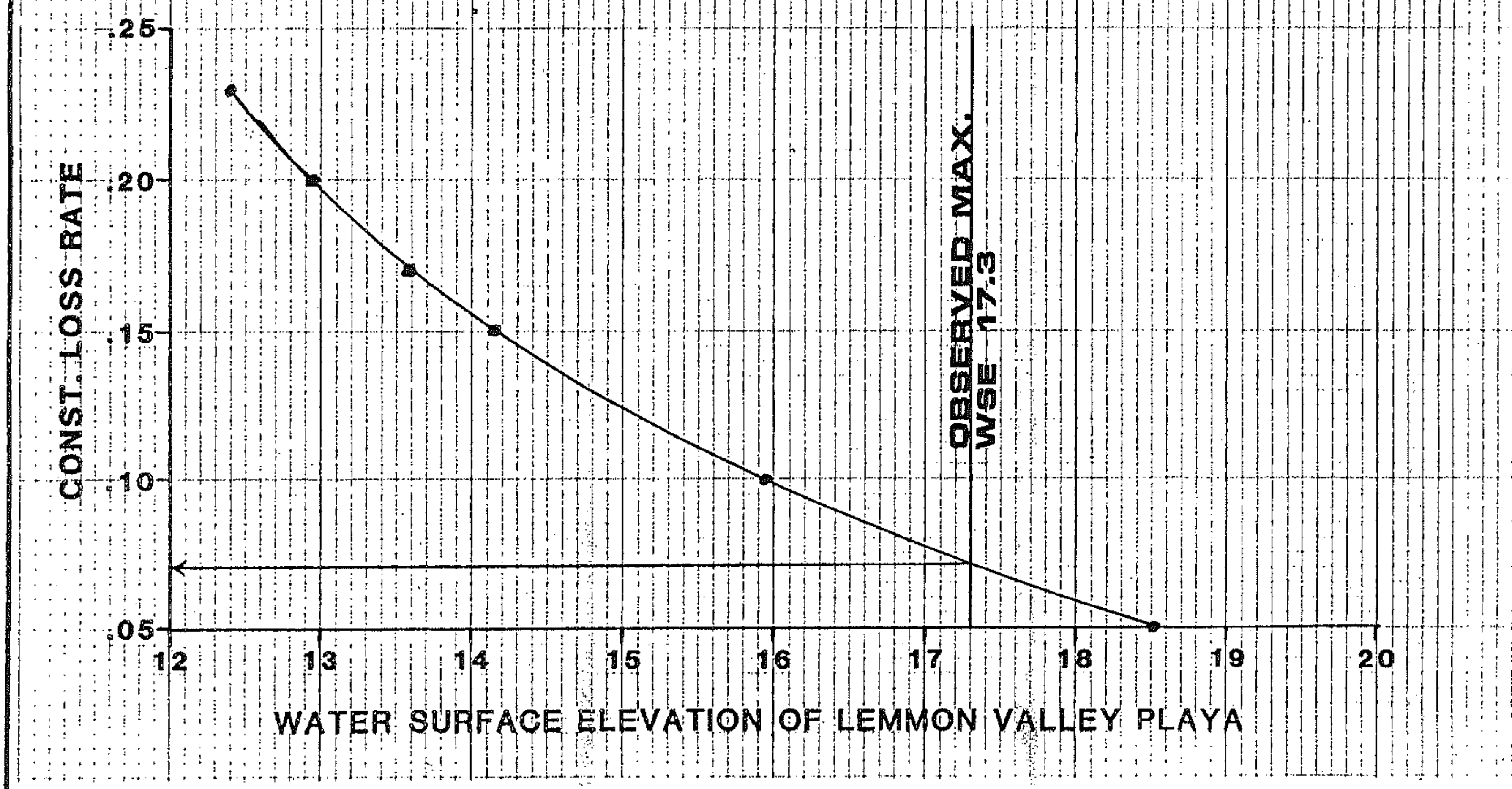


Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 9

Lemmon Valley Playa

Results of Calibration Modeling Using February 1986 Data

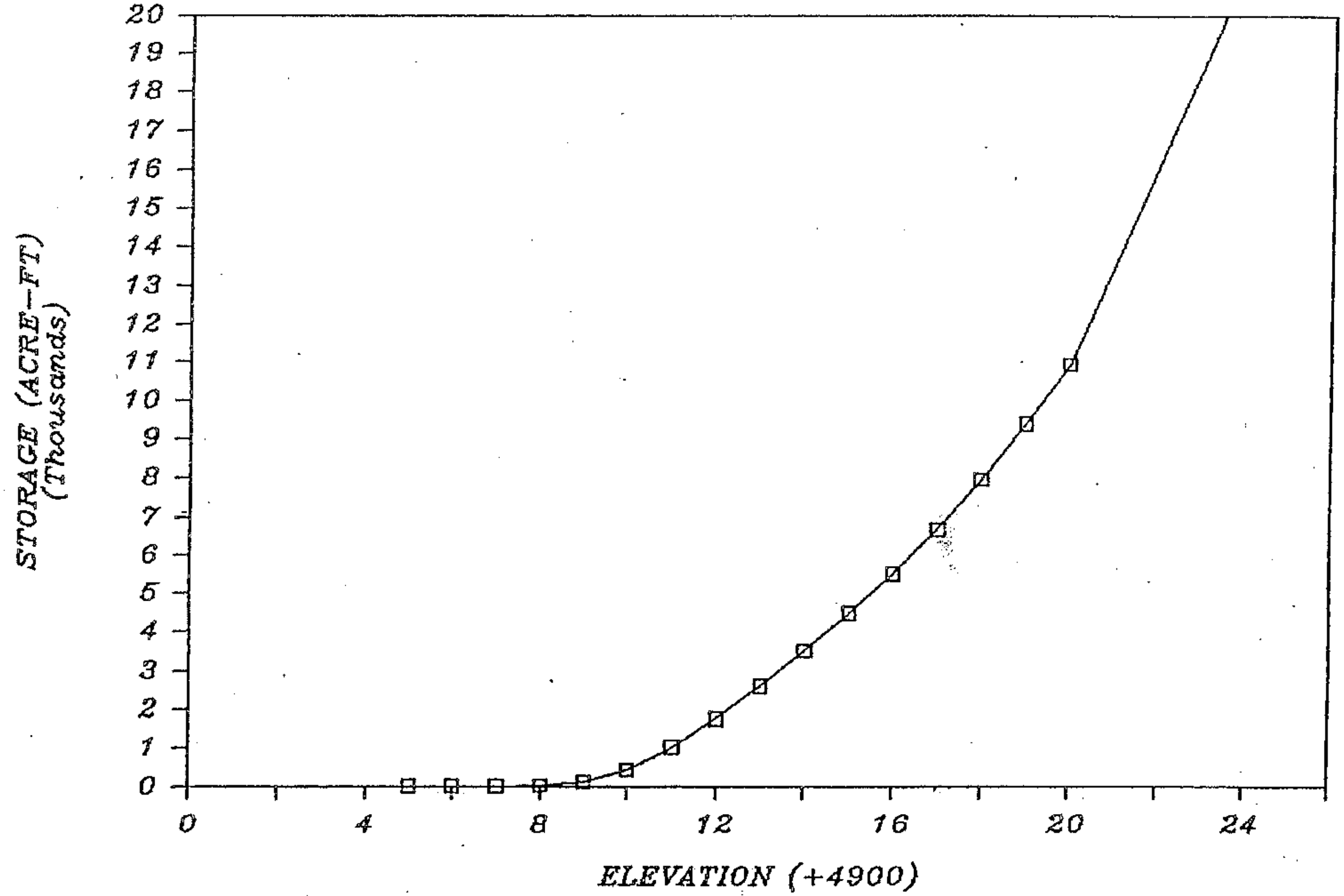


Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 10

LEMMON VALLEY PLAYA

STAGE–STORAGE RELATIONSHIP



Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 11

channel infiltration losses. The Silver Lake watershed has longer channel reaches than Lemmon Valley because of the differences in watershed shape and location of the playa within the watershed. This higher potential for channel infiltration losses in the Silver Lake watershed results in higher constant loss rates than Lemmon Valley. These two factors provide a reasonable explanation for the differences noted between the constant loss rates obtained in the calibration analysis.

6.3 - RESULTS OF CALIBRATION MODELING

The SCS curve number method was deemed to be inappropriate for this analysis because of the excessive volumes of runoff predicted. The use of initial and constant loss rates were determined to be the most accurate means of duplicating the watershed characteristics observed during the February 1986 event, with the limited data available. The constant loss rate values determined by this analysis, are the result of a one event calibration attempt with limited data. Since the purpose of the calibration is to determine the loss rates to use in a 10 day, 100 year event, which is similar to the type of event experienced, the results are considered to be appropriate for use in the final analysis.

In order to get a final 100 year lake level for each of the playa areas, the model will need to incorporate an estimate of initial storage and possibly a smaller event that follows the 100 year event within the same year.

7.0 - STATISTICAL RAINFALL INFORMATION

Once the basic models were developed for the study area the next problem was identification of appropriate statistical rainfall information, storm pattern(s) and storm duration to be used for the study area. In the comments received from Washoe County Department of Comprehensive Planning, Leonard Crowe objected to the use of NOAA Atlas 2 for this study. In previous studies done by the Planning Department (Ref. 4), NOAA Atlas was found to under predict rainfall amounts near the eastern slopes of the Sierras.

During the course of this study several references were reviewed and data was compiled for gauges in the surrounding areas. The following sections provide a brief description of each reference and the method utilized in this study.

7.1 - NOAA ATLAS 2 AND TECHNICAL PAPER NO. 49

Prior to 1972, the NWS publications that provided statistical rainfall information for the entire United States was NWS Technical Paper No. 40. and 49. Technical Paper 40 provides information for durations of 5 minutes to 24 hours and Technical Paper 49 provides information for durations of 2 to 10 days. In the early 1970's, Technical Paper 40 was replaced with NOAA Atlas 2 for the western states. Technical Paper 40 is still used in the eastern states. Technical Paper 49 has not been replaced by the National Weather Service.

Each isopluvial line that passes through the study area in each of these references, also passes through Reno at the location of the Reno Airport. Therefore, each of these references suggests that the study area (at an average elevation of over 5000 feet) has similar rainfall statistics as the Reno Airport, which is at an elevation of 4411 feet. Past storms such as the 1955, 1963 and 1986 events suggest that this assumption is not correct (see sections 3.1 to 3.4). Appendix A contains two letters from Leonard Crowe that provide some additional storm by storm comparisons between the Reno Airport gauge and the Stead Gauge located in the study area. This analysis also suggests that the study area can receive up to twice the rainfall amount experienced in the Truckee Meadows from the same storm.

Since the use of accurate rainfall information is critical to this study, additional analysis was warranted. Table 2 identifies the rainfall values that would be obtained using NOAA Atlas 2.

TABLE 2
100 YEAR
PRECIPITATION DEPTH-DURATION INFORMATION
USING NOAA ATLAS 2

DURATION	DEPTH
5 MIN	0.35
1 HR	1.19
6 HR	1.70
12 HR	1.90
24 HR	2.62

7.2 - SCS TECHNICAL NOTE PO-6

Since the National Weather Service did not update Technical Paper 49 after NOAA Atlas was released, the SCS developed an alternative to Paper 49 with a short release known as Technical Note PO-6 - Hydrology. This reference describes a procedure for determining the 2 and 100 year, 10 day precipitation amounts from NOAA Atlas. Since this reference is based on NOAA Atlas 2, it also suggests that the study area and Reno Airport have similar statistics. The 100 year, 10 day total derived using this reference is 5.6 inches.

7.3 - NATIONAL WEATHER SERVICE FORECAST OFFICE IN RENO

On August 12, 1987, a letter was sent to the NWS office in Reno requesting their input on the problem of accurate information for the study area. The request letter and the response from Ron Olson are contained in Appendix B. This response contains several items of particular interest:

A. *Ron Olson was in agreement with Leonard Crowe, that NOAA Atlas does not accurately represent the orographic and elevation differences that would be experienced in the study area.*

B. *Short duration totals do not tend to increase with elevation as much as the long duration precipitation values.*

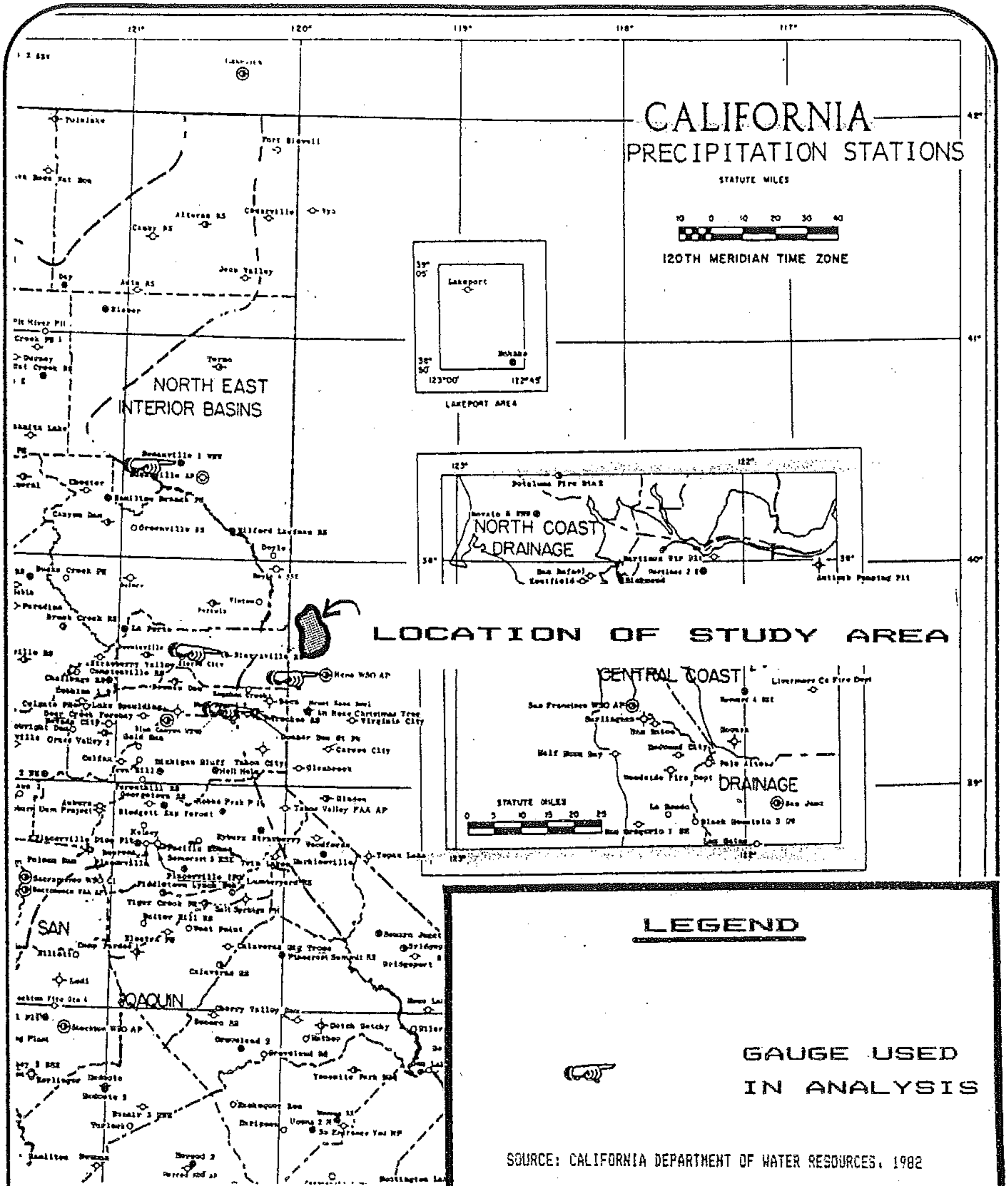
C. *The February 1986 areal distribution pattern is reasonably representative of long duration, winter type of extreme events.*

D. *There is a very good possibility of having more than one sizable precipitation event within the watershed during the same season.*

7.4 - CALIFORNIA DEPARTMENT OF WATER RESOURCES

The California Department of Water Resources published a report that contained a Log Pearson Type III analysis of each gauge in California and extreme eastern Nevada. There were not any gauges in the study area prior to 1981, but there are several gauges in the surrounding areas that provide very useful information.

The closest gauges that had analysis for both short and long duration events were selected for comparison purposes. Figure 12 is a map identifying the four sites selected. Figure 13 is a plot of the 100 year depth-duration information for four nearby



Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 12

LOCATION OF GAUGES USED IN COMPARISON OF RAINFALL STATISTICS

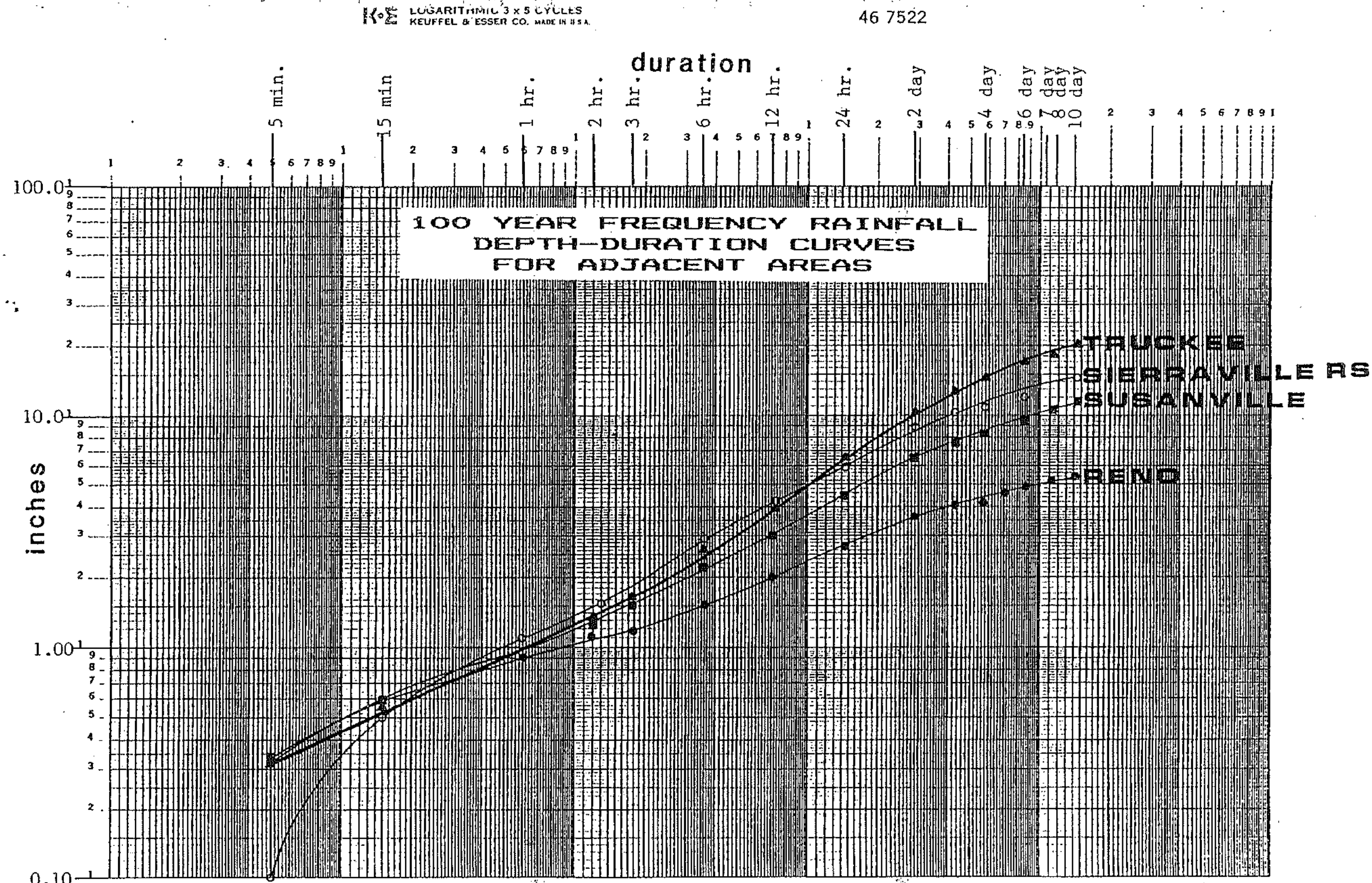
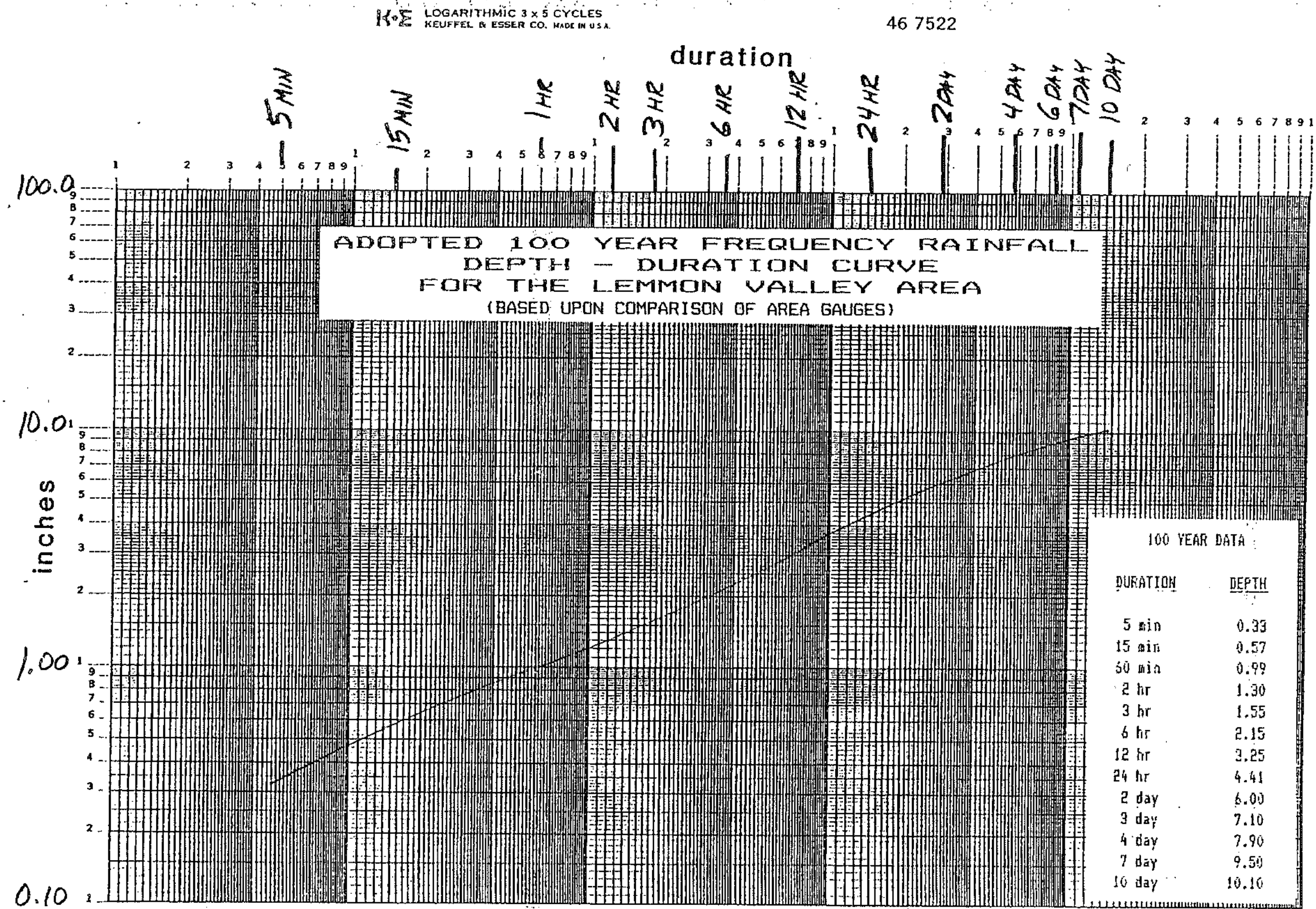


FIGURE 13

Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 889-8630

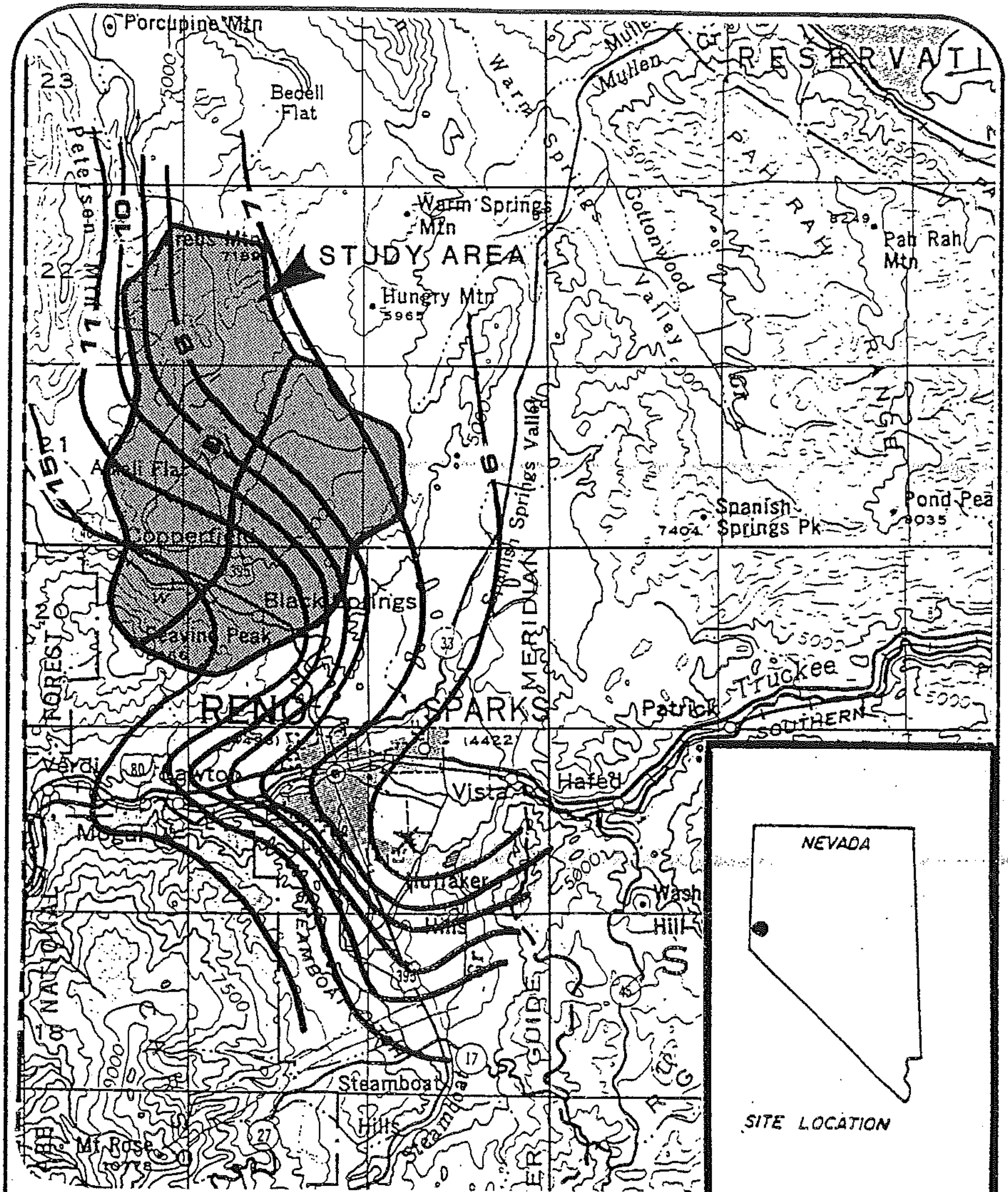


100 YEAR DATA

DURATION	DEPTH
5 min	0.33
15 min	0.57
60 min	0.99
2 hr	1.30
3 hr	1.55
6 hr	2.15
12 hr	3.25
24 hr	4.41
2 day	6.00
3 day	7.10
4 day	7.90
7 day	9.50
10 day	10.10

Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 14



Nimbus Engineers

240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 15

100 YEAR, 10 DAY ISOPLETH MAP

BASED UPON FEBRUARY 1986
STORM PATTERN

gauges. This graph clearly confirms the comments by Ron Olson summarized in item B of section 7.3. The shorter duration totals do not increase with elevation. Only the long duration totals are increasing with higher elevations.

7.5 - SELECTION OF 100 YEAR, 10 DAY VALUES

Leonard Crowe suggested that a ratio of the February 1986 event totals be applied to the 10 day value for the Reno gauge to obtain a value for the study area. This approach was also discussed with Ron Olson at the NWS who agreed that in absence of more definitive data this approach would provide a more reasonable estimate than the other sources.

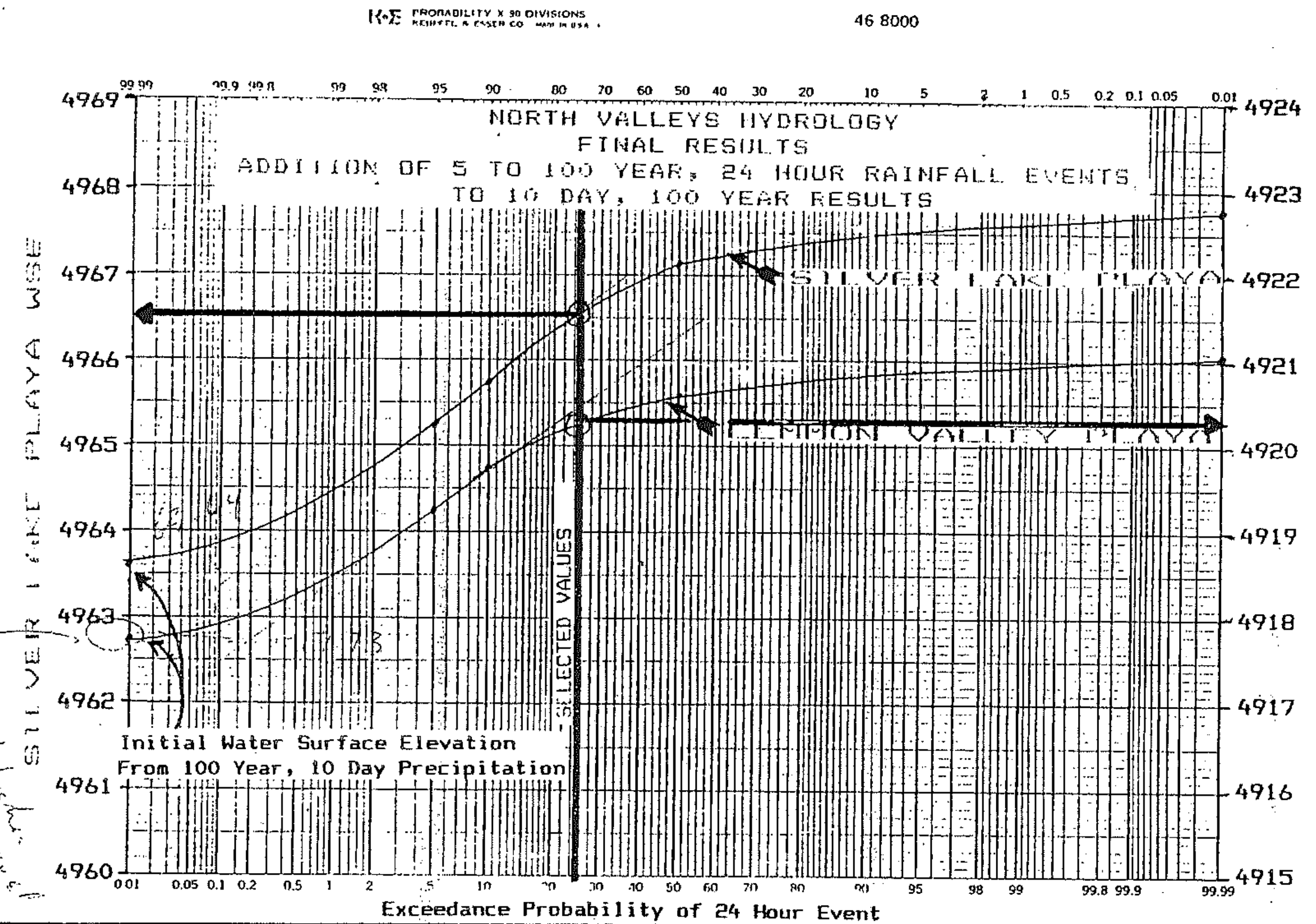
Based on a comparison of the similarities and differences of the four sites identified on Figures 12 and 13 and the precipitation pattern and ratios from the February 1986 event, a depth-duration curve was adopted for the study area and is included as Figure 14. Figure 15 is the adopted 100 year, 10 day isopleth map.

8.0 - 100 YEAR LAKE LEVEL ANALYSIS

A HEC-1 model was developed using the initial and constant loss rates that were determined from the calibration model and a hypothetical storm based on the values obtained from Figure 14. The final rainfall total input into the model is a basin wide average based on the aerial distribution from Figure 15. The results of this model should be a reasonable estimate of runoff volumes that would result from a 100 year, 10 day hypothetical storm.

This runoff volume alone would not be representative of a 100 year lake level since there could be some initial storage and the possibility of multiple events in the same season, as was indicated in the comments from the NWS summarized in section 7.3 D. Each of the lakes was tested by incorporating initial storage in each lake that is representative of the volumes produced from 5 to 50 year, 24 hour events. Figure 16 is a graph of the results of this analysis. The HEC-1 model that produced the data for Figure 16 is contained in Appendix C.

The point on the curve that was considered a reasonable estimate of a 100 year lake level based on past events (see Appendix A) is identified on the graph by the heavy line. The resulting water surface elevations for Silver Lake and Lemmon Valley playa are 4966.5 and 4920.3 respectively.



Nimbus Engineers
240 Linden St., Suite B • Reno, NV 89502
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630

FIGURE 16

8.1 - OTHER METHODS

Use of the SCS curve number method in this analysis results in a 100 year, 10 day volume and elevations of 17,551 acre feet and 4975.17 for Silver Lake and 16,226 acre feet and 4922.05 for Lemmon Lake. Adding an additional 25 year, 24 hour runoff volume results in elevations of 4977.60 and 4923.60 for Silver Lake and Lemmon Valley respectively. A water surface of 4977.60 in Silver Lake would result in over topping of the topographic divide between the two watersheds. These results are considered to be very unreasonable.

Rainfall on an existing snowpack could also be considered in determination of these lake levels. This possiblity was not evaluated in this analysis since there is a relatively small percentage of the total watershed areas above 7000 feet where a persistant snowpack is likely to exist. A large storm on a very heavy snowpack that extends down into the lowerer elevations is considered to be an event with a greater than one percent chance of occurrence.

9.0 - REFERENCES

1. California, State of, Department of Water Resources, Division of Planning, Rainfall Depth-Duration-Frequency for California, Revised November 1982.

2. Chow, Ven Te, Handbook of Applied Hydrology, McGraw Hill, Inc. 1964.

3. Cochran, G.F., J. M. Barry, M.W. Dale, P.R. Sones, Water Harvest From Peavine Mountain With Artificial Recharge in Golden Valley, Nevada: Hydrologic Feasibility and Effects, Desert Research Institute Publication #41103, October 1986.

4. Crowe, Leonard E., Jr., Storm Amounts Recorded During the February 1986 Flooding, Washoe County Department of Comprehensive Planning, Memo dated April 3, 1986.

5. Federal Emergency Management Agency, Flood Insurance Study, Washoe County, Nevada, Unincorporated Areas, February 1984.

6. Harrill, James R., Evaluation of the Water Resources of Lemmon Valley, Washoe County, Nevada, with Emphasis on Effects of Groundwater Development to 1971, US Geological Survey and the State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources, Bulletin No. 42, 1973.

7. Great Basin Aerial Survey, Spot Elevation Map of Lemmon Valley Playa, Scale: 1"=400', June 1987.

8. Linsley/Kohler/Paulhus, Hydrology for Engineers, McGraw Hill, Inc. 1982.

9. Millard Spink Assoc. Inc., Lear Reno, Reno/Stead Development Company, Topographic Base Maps, Scale: 1"=100', Undated.

10. Pyramid Engineers and Land Surveyors, North Reno Business Center, Moya Boulevard Improvements, "As Built" plans dated February 1987.

11. City of Reno, Department of Public Works, Engineering Division, Public Works Design Manual, July 1, 1985.

12. Reimer and Associates, Request for a Letter of Map Revision For North Reno Business Park, Reno, Nevada, July 1985.

13. SEA Engineers/Planners, Flow Profile Investigations on the North Truckee Drain East Prater Way to Interstate 80 Sparks, Nevada, July 13, 1981.

14. Schaaf and Wheeler, Consulting Civil Engineers, Hydrology Report for Silver Lake in Reno, Nevada, March 1985.

15. The Spink Corporation, Lear Reno, Reno/Stead Development Company, Topographic Base Maps, Date unknown, From photos dated Aug. 1968.

16. Tipton and Kalmback, Inc., Consulting Engineers, Denver Colorado, Rainfall-Runoff Modeling,(Short Course), February 1985.

17. U. S. Department of Agriculture, Soil Conservation Service, SCS National Engineering Handbook, Section 4, Hydrology, August 1972.

18. U. S. Department of Agriculture, Soil Conservation Service, TSC Technical Note - Hydrology - PO-6 (Rev. 2), Use of National Weather Service Revised Precipitation-Frequency Maps and Estimation of 10-Day Precipitation Values, October 1975.

19. U. S. Department of Agriculture, Soil Conservation Service, Engineering Division, Earth Dams and Reservoirs, Technical Release No. 60, Revised October 1985.

20. U. S. Department of Agriculture, Soil Conservation Service, Engineering Division, Urban Hydrology for Small Watersheds, Technical Release 55, June 1986.

21. U. S. Department of Agriculture, Soil Conservation Service, Soil Survey of Washoe County, Nevada, South Part, August 1983.

22. U. S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center, Computer Program 723-X6-L2010, HEC-1, Flood Hydrograph Package, January 1985.

23. U. S. Department of the Army, Corps of Engineers, Engineering and Design, Flood Hydrograph Analysis and Computations EM-1110-2-1405, August 31, 1959.

24. U. S. Department of the Army, Corps of Engineers, Engineering and Design, Routing of Floods Through River Channels EM-1110-2-1408, March 1, 1960.

25. U. S. Department of the Army, Corps of Engineers, Sacramento District, Truckee River, California and Nevada, Hydrology, February 1980.

26. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, NOAA Atlas 2, Precipitation - Frequency Atlas of the Western United States, Volume VII - Nevada, 1973.

27. U. S. Department of Commerce, National Weather Service, Two to Ten-Day Precipitation for Return Periods of 2 to 100 years in the Contiguous United States, Technical Paper No. 49, 1964.

28. U. S. Department of Commerce, National Weather Service Forecast Office, Reno, Nevada Report on the February 1986 Flood in Western Nevada, March 1986.

29. University of California, Davis, University Extension, Flood Plain Hydrology Using HEC-1 on the IBM PC (Short Course), April 1986.

30. Winzler and Kelly Consulting Engineers, Reno Drainage Study, Preliminary Report: Analysis of Drainage Deficiency Areas Within the City Limits, December 1984.