DRAFT (01/17/06)

DRAINAGE STUDY
FOR
BAILEY CANYON BASIN

LOCATED IN
WASHOE COUNTY AND STORY COUNTY, NEVADA

PREPARED FOR:
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JANUARY 17, 2006
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25TH ANNIVERSARY
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INTRODUCTION

This report presents the result of our drainage study for the Bailey Canyon Basin located in Washoe County and Story County, Nevada. The primary purpose of this study is to perform a detailed hydrologic study to estimate the basin discharge for 100yr/24hr storm event. The study also includes a hydraulic analysis of Bailey Creek adjacent to State Route 341 (Geiger Grade).

SITE DESCRIPTION

Bailey Canyon is a headwater basin which is approximately 15.18 sq.miles in size and lies between latitude 39°18' and 39°24' and longitude 119°39' and 119°44'. The basin is located south of Geiger Grade and northwest of Virginia City (Refer to Figures 1 & 2). The basin vegetation consists of pinyon, juniper and pine trees over a ground cover of litter, grass, and brush. Bailey Canyon Creek is an ephemeral stream that generally consists of cobbles and boulders with vertical drops and meanders.

HYDROLOGIC METHODS

The basin was modeled using the Corps of Engineers HEC-HMS computer program with two separate methods for comparison: the SCS Curve Number Method and the Green & Ampt Loss Method. For both methods, the USBR lag equation was used. The rainfall depths and storm distribution was obtained/developed from the NOAA Atlas 14. For evaluation of the models, a USGS regression equation (NFF) and the USGS Frequency Analysis program (PEAKFQ) were used. To ascertain model prediction uncertainty, a Monte Carlo analysis was performed. Hydraulic Calculations for Bailey Creek were performed with the Corps of Engineers HEC-2 program.

PREVIOUS STUDIES

1. The Flood Insurance Study for Washoe County by FEMA (FEMA, 1990) estimated a 100yr / 24hr peak flow at the mouth of Bailey Canyon Creek as 1,120 cfs using a regional regression analysis.

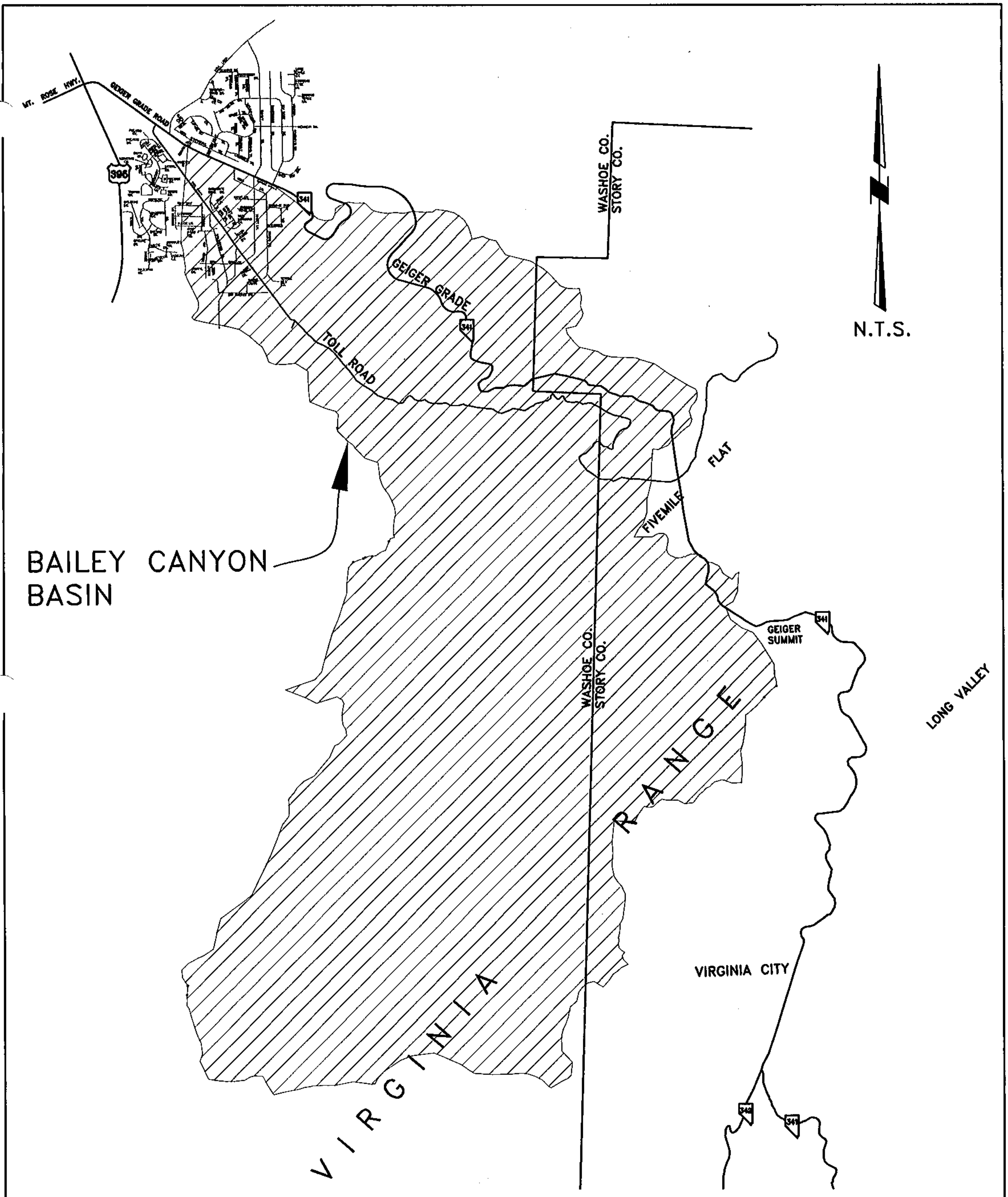

FIGURE # 1

VICINITY MAP

BAILEY CANYON

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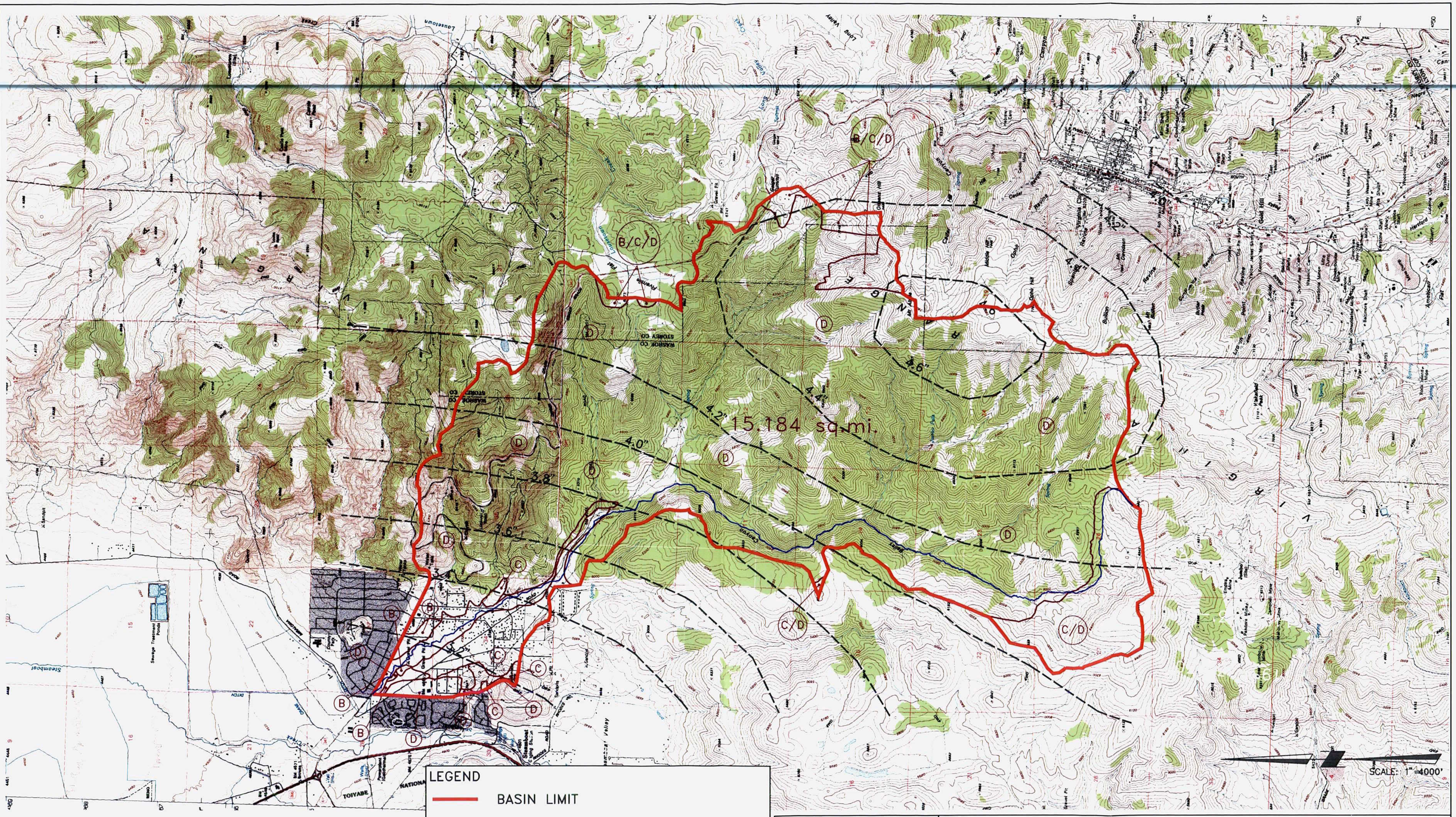

cfa

FIGURE # 2
BAILEY CANYON
HYDROLOGICAL MAP

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2. Nimbus Engineers performed hydrology study for Cottonwood Creek Estates in February 1995 (Nimbus, 1995a). This study utilized the SCS method and USBR lag equation to obtain a 100yr peak flow of 3673 cfs (Appendix G).
3. The Southeast Truckee Meadows Flood Control Master Plan by Nimbus Engineers in September 1995 (Nimbus, 1995b) calculated the 100yr peak flow as 2158 cfs. This model used the SCS Upland method for time of concentration / lag time determination.
4. In August 1999, Stantec Consulting prepared a Master Drainage Report for Geiger Grade / Toll Road Improvements. Using a 100yr discharge value of 3673 cfs (Nimbus, 1995a) they estimated that approximately 540 cfs would overtop Geiger Grade to the south. This was assuming the Geiger Grade improvements in the interim condition, which is more or less the pre-developed condition.

FIELD RECONNAISSANCE AND CONDITION SURVEY

A detail basin condition survey along the major watercourse and upper elevations was conducted over three days to verify channel roughness and vegetative cover. The vegetation in the basin typically consists of pinyon, juniper and pine trees over a ground cover of litter, grass, and brush (Figure 3, Refer Appendix A for additional photos). Besides a relatively small amount of development in the lower elevations, the basin is undeveloped and for the most part appears to be in good condition. The primary channels generally consist of cobbles and boulders with drops and meanders (Figure 4). Extensive future development of this basin seems to be doubtful due to its steep slopes.


Figure 3. Typical Ground Cover


Figure 4. Typical Bailey Canyon Creek Channel

MODEL INPUT AND PARAMETERS

Basin Mapping. As shown in Figure 2, a 1:24,000 scale USGS quad was utilized for the delineation of the watershed. From this mapping, we obtained a basin area of 15.18 sq. mi. and a longest watercourse length of 9.03 miles. The basin slopes range from 3% at the lower elevations to 60% at higher elevations.

Precipitation Depths and Distribution. Point values of the 100-year/24-hour precipitation depths from the NOAA 14 Atlas were plotted over the basin. Isohyetal contours were then interpreted from the point values on the basin map (Figure 2). This resulted in an average precipitation depth for the basin of 4.10 inches for the 100-year/24-hour event.

A site-specific storm distribution for Bailey Canyon was developed based on the NOAA Atlas 14 precipitation frequency estimates (Table B.1 and Figure B.1, Appendix B). For comparison, the NOAA 14 design storm is plotted with the SCS Type IA and II synthetic curves in Figure 5. As shown, the design storm lies between the two SCS curves, which appear to be reasonable since the site is near the geographical boundary between the Type IA and II zones.

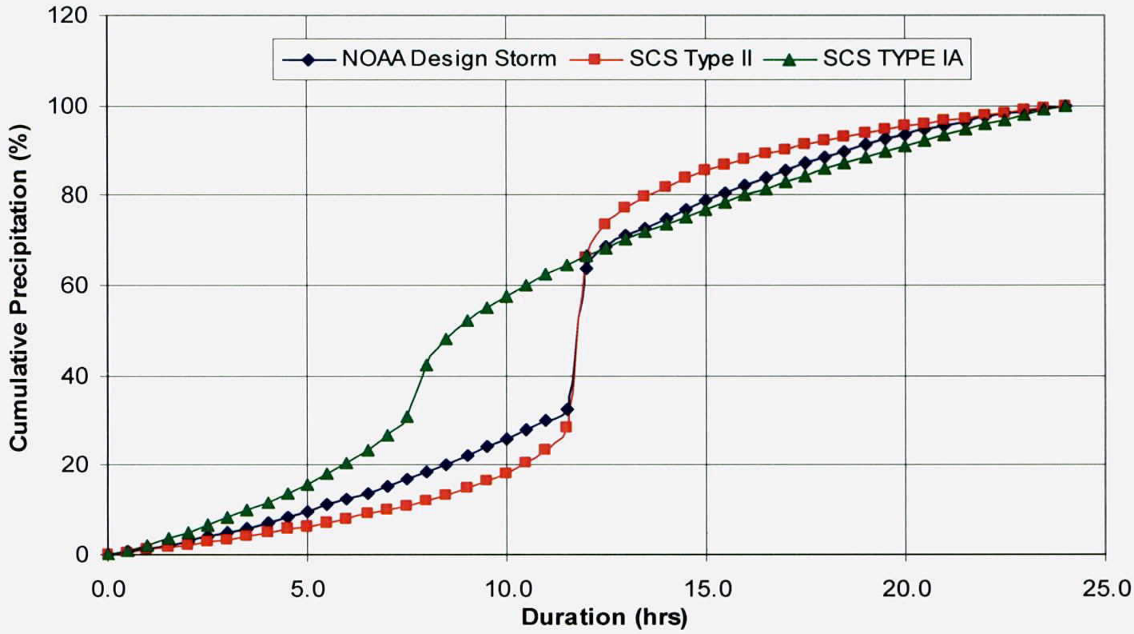

Figure 5. Hyetograph Comparison (24 hours)

Lag Time. For lag time, the USBR lag time equation was used. WRC (Washoe County Drainage Design Manual) adjusted the USBR lag equation for the Washoe County area (Appendix B). Based on a channel roughness coefficient of 0.06, the lag time was calculated as 1.88 hours.

SCS Curve Number. The most sensitive parameter in the SCS methodology is the Curve Number (CN), which is a parameter based on soil permeability and vegetative cover (Refer sensitivity analysis on page 6). Soil types were plotted in the basin, with most of the soil falling into the D category (Figure 2 and Table B.2, Appendix B). Utilizing a cover condition type between fair and good, a CN of 74.7 was estimated.

Green & Ampt Loss Parameters. As suggested by the US Army Corps of Engineers HEC-HMS Technical Reference Manual (March 2000), initial loss was estimated as 0.68 inches using SCS initial abstraction (Appendix C). The soil parameters for each soil type were obtained from the Maricopa County, Arizona Drainage Design Manual. The weighted averages of hydraulic conductivity, wetting front suction, and average volumetric soil moisture deficit were estimated as 0.35 in/hr, 4.88 inches, and 0.23 respectively (Refer Table C.1, Appendix C).

HYDROLOGIC MODEL RESULTS

SCS Model. A HEC-HMS model with SCS method was configured with the parameters identified above, which resulted in a 100-year/ 24-hour peak discharge of 2824 cfs (Figure 6).

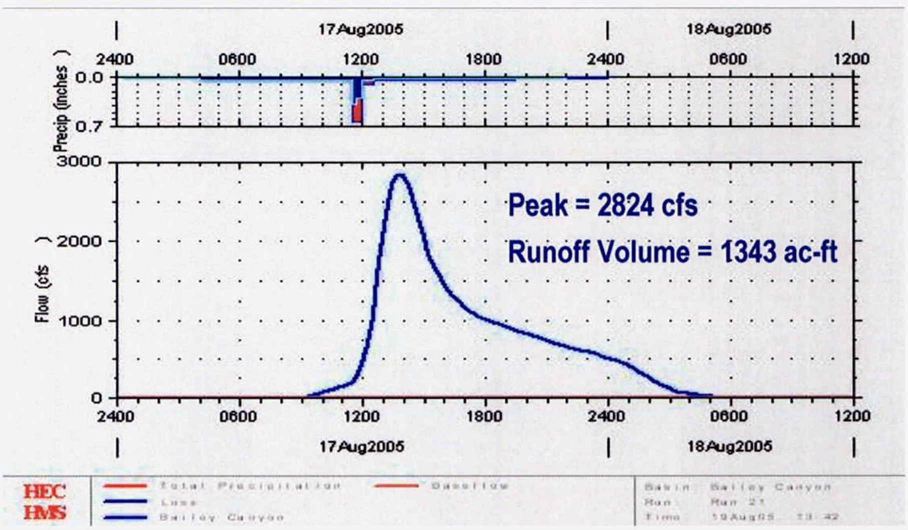

Figure 6. Hydrograph for 100 Yr/24 hr Storm Event using the SCS Method

Green & Ampt Model. For the Green and Ampt Loss method, the 100-year/24-hour peak discharge was estimated as 2890 cfs (Figure 7).

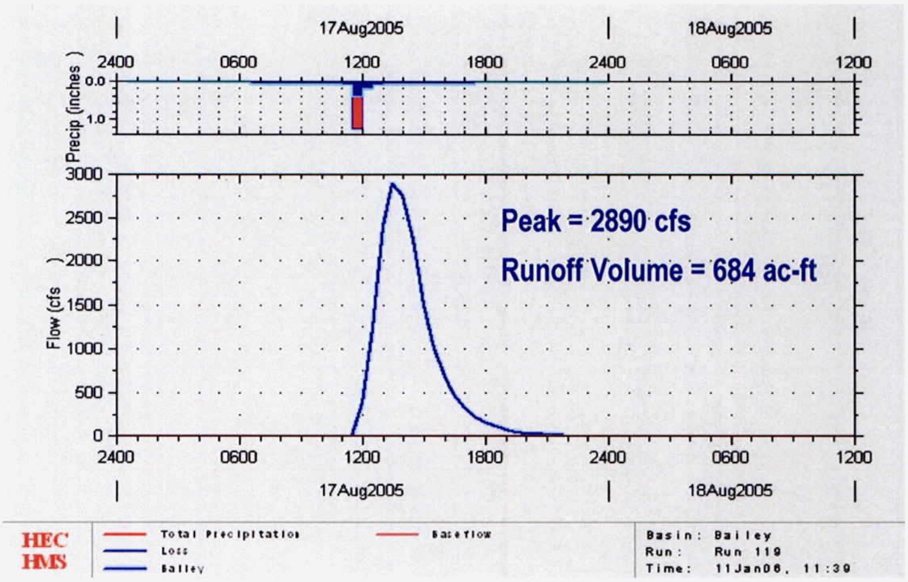

Figure 7. Hydrograph for 100 Yr- 24 hr Storm Event using Green & Ampt Loss Method

HYDROLOGIC MODEL EVALUATION

SCS Method and Green & Ampt Loss Method Comparison. There was good agreement in the peaks between the SCS and Green & Ampt methodologies (Figure 8). The Green & Ampt method peak of 2890 cfs is only 2% greater than the SCS peak of 2824 cfs. However, the hydrographs differ significantly in shape and volume. The SCS volume is almost two times the Green & Ampt volume.

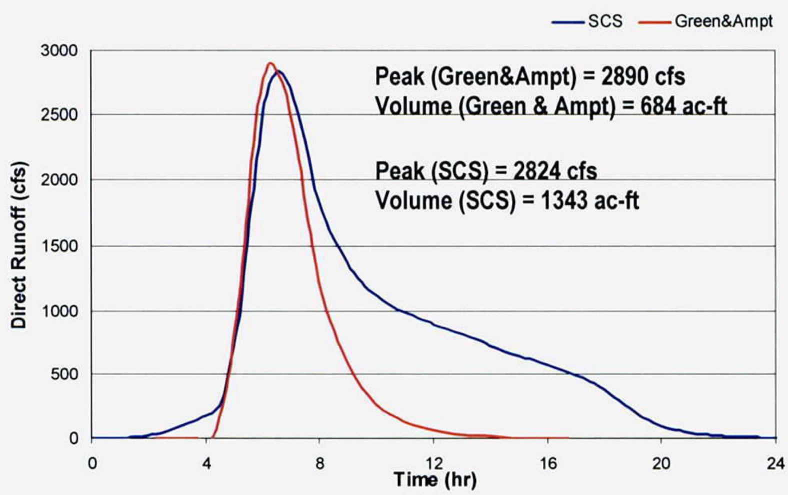

Figure 8. Comparison of Hydrographs for SCS Method and Green & Ampt Loss Method

Sensitivity Analysis. A sensitivity analysis was performed with the CN and lag time parameters in order to identify the parameters the model is most sensitive to. While holding one parameter constant at the estimated value, the other parameter was varied plus and minus 5%. As shown in the figure 9 and 10, the model is much more sensitive to curve number, where a 5% change in the curve number yields a flow change of 18%.

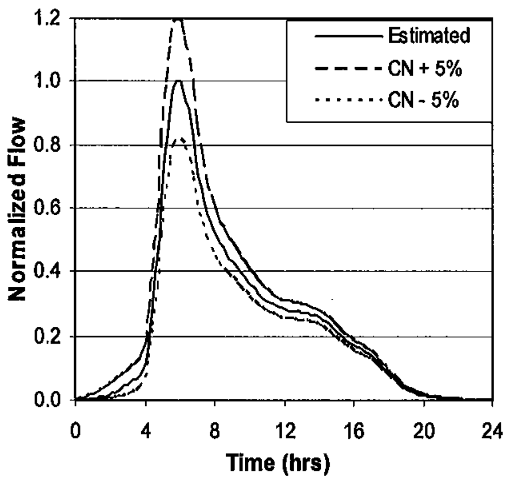

Figure 9. Sensitivity to CN. Plot indicates a 5% a increase in CN yields 19% increase in peak and a 5% decrease in CN yields 18% decrease in peak flow.

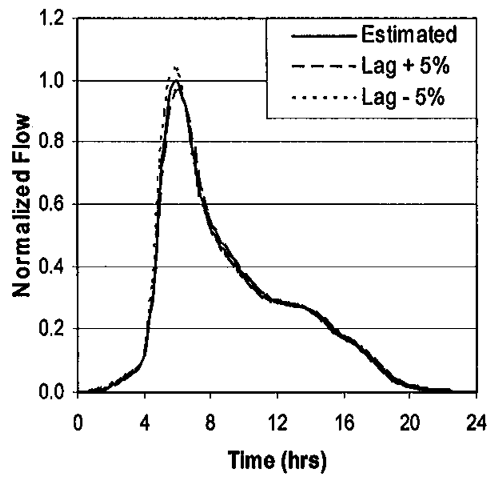

Figure 10. Sensitivity to Lag Time. Plot indicates that a 5 % increase in lag time yields 4% increase in flow and a 5 %decrease in lag time yields 3% decrease in peak flow.

Uncertainty Analysis. Physically based conceptual models such as SCS and Green & Ampt depend on parameters such as the curve number and lag time. If the model is sensitive to an uncertain parameter, then model prediction uncertainty will exist. As shown previously, the SCS model is very sensitive to the curve number. Selection of the curve number is based on soil types which have been surveyed (SCS, 1981 & 1983), and by estimating the condition of the vegetative ground cover in the field (Table B.3, Appendix B). Of these two characteristics, there is much more variability in selecting the condition of the cover type. There is a wide range of curve numbers for a given cover type and field surveys are subjective. However, one can narrow the bounds and perform a statistical analysis to estimate confidence intervals to quantify the model prediction uncertainty (i.e., Monte Carlo analysis).

For curve number, the basin cover type is predominately pinyon-juniper in fair to good condition. The mean value was estimated as 74.7, with lower (good) and upper (fair) bounds set at 69.7 and 80.7, respectively. For the lag time, which is much more deterministic, the mean was estimated as 1.88 hrs, with bounds of 1.74 hrs and 2.04 hrs.

A Monte Carlo analysis was performed by randomly selecting the parameters from a normal distribution within the bounds and running the model 10,000 times. The flows were calculated at each time step for the mean and the lower and upper bounds of the 90% confidence interval. As shown in the Figure 11, the peak flow varies between 2404 cfs and 3276 cfs. Since there is a 90% probability that the flow is between the bounds, there is a 5% chance that it is above or below based on parameter uncertainty.

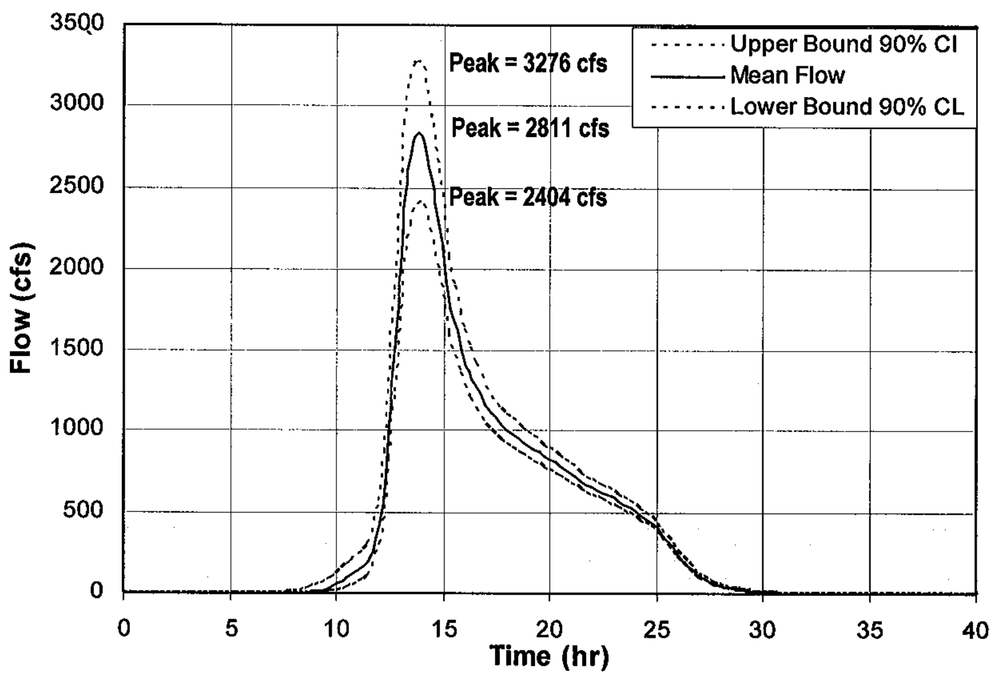

Figure 11. Monte Carlo Analysis – Mean and 90% Confidence Intervals

Frequency analysis. Using the USGS peak flow data for Bailey Canyon, a frequency analysis were performed and resulted in flow of 2152 cfs (Appendix D). However, since there was only 4 years of recorded peak data, these results are not very reliable.

USGS Regression Equation (NFF Program). The USGS regression analysis was performed for Bailey Canyon resulting in a 100-year peak discharge of 2040 cfs (Appendix E). The regression equations in the NFF program were developed based on regional watershed and climatic characteristics.

Bryant Creek Comparison. Bryant Creek basin, a gaged basin, which has similar soils type, ground cover and basin orientation was used to evaluate the reasonableness of the Bailey Canyon model. Since the basin is gaged with several years of peak flow data, a frequency analysis can be performed with improved reliability. Bryant Creek basin is approximately 31.5 sq.miles in size and lies south of Gardnerville, NV. The 100-year peak flow for Bryant Creek using the USGS frequency analysis program, PEAKFQ, was estimated as 4146 cfs (Appendix F). An SCS model was then calibrated by varying the curve number until the peak flow of 4146 cfs was obtained. The resultant calibrated curve number of 61.6 is much less than the estimated value on Bailey Canyon (74.7).

December 2005 Storm Observations. On December 30 and 31, 2005, the Reno and Carson City areas experienced a significant storm/runoff event. Flooding was observed in many locations including the South Reno area. Bailey Canyon Creek was observed flooding over Toll Road and areas downstream (Reference photos Appendix G).

While the flows were contained within the banks upstream of Toll Road, the flooding appeared to be caused by inadequate culvert capacity under Toll Road. Downstream of Toll Road, the stormwaters sheetflooded the properties south of Geiger Grade.

A portion of the flow reached the roadside ditch along the south side of Geiger Grade, where it caused shallow flooding of the south lane of Geiger Grade. Two locations of flooding onto Geiger Grade were observed which appeared to be due to insufficient capacity of driveway culverts. Flooding over Geiger Grade was not observed, however, the Chandler and Crane ditch culvert crossings were running full.

There are three rainfall gages in the Reno area: Reno-Tahoe Airport, South Reno at Wolf Run Golf Course, and Carson City. Unofficial data was obtained from NOAA and Western Regional Climatic Center for the primary storm over a 28-hour period (Figure G.1, G.3, and G.5, Appendix G). 24-hour cumulative amounts were estimated for the Reno Airport, South Reno, and Carson gages as 2.32", 3.86", and 5.40", respectively (Figure G.2, G.4, and G.6, Appendix G).

A simple comparison to NOAA 14 frequency analysis indicates that the storm exceeded the 200-year storm at the South Reno Gage (TableG.2, Appendix G). However, the exceedence at Reno Airport and Carson City were 50 year and 1000 year, respectively.

A review of radar images from NOAA NEXRAD during the storm period was conducted. The composite reflectivity, which indicates storm intensity, showed that the storm intensity over Bailey Canyon was equal to or greater than the intensity at the South Reno gage (Figure G.7 to G.12, Appendix G). This would suggest that the cumulative rainfall in Bailey Canyon may have been around 4 inches. This depth is close to the NOAA 14 Atlas 100year/24hour rainfall amount (4.1").

Evaluation Summary. Table 1 is a summary of 100 year peak flows estimated previously and per this study using different models and methodology. As shown, the values range from 1,120 cfs to 3673 cfs.

Table 1: Summary of 100 Year Peak Flow Values

	Studies	Peak Flow (cfs)
1	Flood Insurance Study (FIS) for Washoe County (FEMA, 1990)	1,120
2	Cottonwood Creek Estates Study (Nimbus, 1995a)	3,673
3	Southeast Truckee Meadows Flood Control Master Plan (Nimbus, 1995b)	2,158
4	SCS Method (CFA, 2006)	2,824
5	Green and Ampt Loss Method (CFA, 2006)	2,890
6	Monte Carlo Uncertainty Analysis – Lower and Upper 90% confidence Interval (CFA, 2006)	2,404 – 3,276
7	Frequency Analysis (CFA, 2006)	2,152
8	USGS Regression Equation (CFA, 2006)	2,040

HYDRAULIC ANALYSIS

TBD

DISCUSSION AND RECOMMONDATIONS

Hydrology Discussion. This study has shown that peak flow prediction may vary significantly depending on the methodology and model parameters.

In February of 1995, the Cottonwood Creek Estates Study (Nimbus, 1995a) established the currently recognized flow of 3673 cfs. This study, using the SCS methodology, utilized lower resolution topography which resulted in a larger basin delineation and shorter watercourse length. For the lag time, the USBR equation adjusted for Las Vegas was used. Since then, a more appropriate equation has been developed for Washoe County (Washoe County, 1996). Rainfall was based on an SCS Type II storm and the older NOAA atlas 2.

The Southeast Truckee Meadows Flood Control Master Plan (Nimbus 1995b) estimated a peak flow of 2158 cfs in September of 1995. The Master Plan used the SCS upland method for lag time, which may not be appropriate for the size of the basin. The rainfall was also based on an SCS Type II storm and the NOAA Atlas 2.

The FIS study (FEMA, 1990) and USGS regression equations (CFA, 2006) are regional in scale and do not take into account a particular basins characteristics. As such, they should only be used as a ballpark estimate. They do, however, support a reduction in the current recognized flow of 3673 cfs.

The frequency analysis of Bailey Canyon gage date (CFA, 2006) is based on only 4 peak flows and is not a reliable estimate of the 100 year flow. However, the flow of 2152 cfs does not indicate that the flow should be set higher than modeled flows.

The SCS method (CFA, 2006) and the Green & Ampt (CFA, 2006) method are in agreement within the magnitude of error inherent in conceptual models. The SCS flow of 2824 cfs is just 2% less than the Green & Ampt flow of 2890 cfs. These models were based on the best information available including a NOAA Atlas 14 storm distribution, topography, USBR Lag equation adjusted for the region, and a thorough field survey.

To judge the reasonableness of the curve number selected for Bailey Canyon, a similar gaged watershed (Bryant Creek) was modeled. Compared to a Bryant Creek calibrated curve number of

61.6, the Bailey Canyon curve number of 74.7 appears to be very reasonable.

The Monte Carlo statistical analysis showed that the uncertainty in parameter estimation could vary the peak flow values from 2404 cfs to 3276 cfs. The upper 90% bound of 3276 cfs would offer a greater degree of confidence in peak flow estimates.

The December 30 and 31 precipitation records indicate that a storm in the magnitude of 200 years occurred in South Reno. While there is no precipitation gage in Bailey Canyon, it is reasonable to assume that Bailey Canyon could have received a rainfall event greater than the 100-year event. The NEXRAD radar images in Appendix G indicate that the storm was at least as intense over Bailey Canyon as it was at the South Reno gage. If that was the case, there is evidence that overtopping of Geiger Grade will not occur in a 100-year storm event.

Hydrology Recommendations. The initial model results for the SCS and Green & Ampt Models provided good flow estimates for the basin. However, there is some uncertainty due to parameter variability (e.g. curve number). If the flow is underestimated due to this uncertainty, there is a potential for the construction of inadequate flood control structures and subsequent damage downstream. In light of these considerations, a peak flow of 3276 (upper 90% confidence interval) is recommended.

REFERENCES

Army Corps of Engineers (2000), "HEC-HMS Technical Reference Manual".

FEMA (1990), "Flood Insurance Study for Washoe County Nevada Unincorporated Areas".

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Washoe County (1996), "Hydrologic Criteria and Drainage Design Manual".

APPENDIX A
FIELD RECONNAISSANCE AND CONDITION SURVEY FOR BAILEY CANYON

PHOTOGRAPHS OF BAILEY CANYON FIELD CONDITION SURVEY, 2005

Figure A.1. Terrain at upper elevations of Bailey

Figure A.2. Terrain at upper elevations of Bailey

Figure A.3. Terrain at upper elevations of Bailey

Figure A.4. Terrain at upper elevations of Bailey

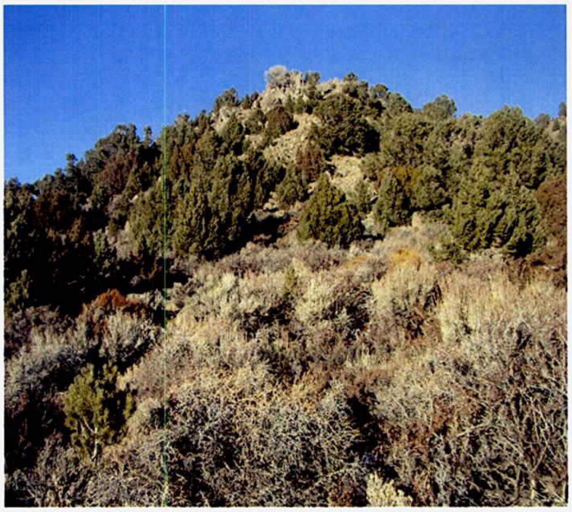


Figure A.5. Terrain at upper elevations of Bailey

Figure A.6. Terrain at lower elevation slopes

Figure A.7. Tributary to main channel

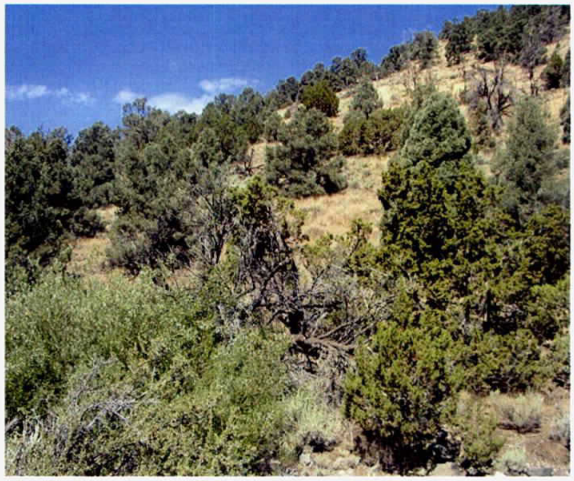


Figure A.8. Typical ground cover along main channel

Figure A.9. Main channel upper elevation vertical drop

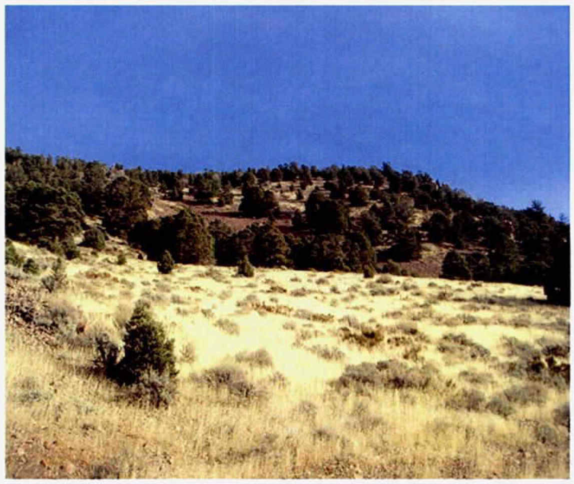


Figure A.10. Terrain off of Toll Road

Figure A.11. Terrain at upper elevation of Toll Road

Figure A.12. Terrain at upper elevation of Toll Road

APPENDIX B
SCS METHOD ANALYSIS FOR BAILEY CANYON

Table B.1. Cumulative Precipitation for 100 yr – 24 hr Storm Event

Design Storm Hyetograph Calculation

Duration min	Duration (hr)	Precip * (inches)	Inc. Depth (inches)	Rank	Re-Ordered (inches)	Cumulative (inches)	Cumulative %	Cumul. w/ P= 4.1	Cumul*.98 DAR
0	0.0	0.00			0.00	0	0	0.000	0.000
30	0.5	0.95	0.95	1.00	0.02	0.02	0.66	0.027	0.027
60	1.0	1.10	0.15	2.00	0.02	0.04	1.32	0.054	0.053
90	1.5	1.17	0.07	3.00	0.02	0.06	1.98	0.081	0.080
120	2.0	1.23	0.07	4.00	0.03	0.09	2.97	0.122	0.119
150	2.5	1.30	0.06	5.00	0.03	0.12	3.96	0.162	0.159
180	3.0	1.36	0.06	6.00	0.03	0.15	4.95	0.203	0.199
210	3.5	1.42	0.06	7.00	0.03	0.18	5.94	0.244	0.239
240	4.0	1.48	0.06	8.00	0.03	0.21	6.93	0.284	0.278
270	4.5	1.54	0.06	9.00	0.04	0.25	8.25	0.338	0.332
300	5.0	1.60	0.06	10.00	0.04	0.29	9.57	0.392	0.385
330	5.5	1.66	0.06	11.00	0.04	0.33	10.89	0.447	0.438
360	6.0	1.71	0.06	12.00	0.04	0.37	12.21	0.501	0.491
390	6.5	1.77	0.06	13.00	0.04	0.41	13.53	0.555	0.544
420	7.0	1.82	0.05	14.00	0.05	0.46	15.18	0.622	0.610
450	7.5	1.88	0.05	15.00	0.05	0.51	16.83	0.690	0.676
480	8.0	1.93	0.05	16.00	0.05	0.56	18.48	0.758	0.743
510	8.5	1.98	0.05	17.00	0.05	0.61	20.13	0.825	0.809
540	9.0	2.03	0.05	18.00	0.06	0.67	22.11	0.907	0.888
570	9.5	2.08	0.05	19.00	0.06	0.73	24.09	0.988	0.968
600	10.0	2.13	0.05	20.00	0.06	0.79	26.07	1.069	1.048
630	10.5	2.18	0.05	21.00	0.06	0.85	28.05	1.150	1.127
660	11.0	2.22	0.05	22.00	0.06	0.91	30.03	1.231	1.207
690	11.5	2.27	0.04	23.00	0.07	0.98	32.34	1.326	1.300
720	12.0	2.31	0.04	24.00	0.95	1.93	63.70	2.612	2.559
750	12.5	2.35	0.04	25.00	0.15	2.08	68.65	2.815	2.758
780	13.0	2.39	0.04	26.00	0.07	2.15	70.96	2.909	2.851
810	13.5	2.43	0.04	27.00	0.06	2.21	72.94	2.990	2.931
840	14.0	2.47	0.04	28.00	0.06	2.27	74.92	3.072	3.010
870	14.5	2.51	0.04	29.00	0.06	2.33	76.90	3.153	3.090
900	15.0	2.55	0.04	30.00	0.06	2.39	78.88	3.234	3.169
930	15.5	2.58	0.04	31.00	0.05	2.44	80.53	3.302	3.236
960	16.0	2.62	0.03	32.00	0.05	2.49	82.18	3.369	3.302
990	16.5	2.65	0.03	33.00	0.05	2.54	83.83	3.437	3.368
1020	17.0	2.69	0.03	34.00	0.05	2.59	85.48	3.505	3.435
1050	17.5	2.72	0.03	35.00	0.05	2.64	87.13	3.572	3.501
1080	18.0	2.75	0.03	36.00	0.04	2.68	88.45	3.626	3.554
1110	18.5	2.78	0.03	37.00	0.04	2.72	89.77	3.681	3.607
1140	19.0	2.81	0.03	38.00	0.04	2.76	91.09	3.735	3.660
1170	19.5	2.83	0.03	39.00	0.04	2.80	92.41	3.789	3.713
1200	20.0	2.86	0.03	40.00	0.03	2.83	93.40	3.829	3.753
1230	20.5	2.89	0.03	41.00	0.03	2.86	94.39	3.870	3.793
1260	21.0	2.91	0.02	42.00	0.03	2.89	95.38	3.911	3.832
1290	21.5	2.93	0.02	43.00	0.03	2.92	96.37	3.951	3.872
1320	22.0	2.95	0.02	44.00	0.03	2.95	97.36	3.992	3.912
1350	22.5	2.98	0.02	45.00	0.02	2.97	98.02	4.019	3.938
1380	23.0	3.00	0.02	46.00	0.02	2.99	98.68	4.046	3.965
1410	23.5	3.01	0.02	47.00	0.02	3.01	99.34	4.073	3.991
1440	24.0	3.03	0.02	48.00	0.02	3.03	100.00	4.100	4.018

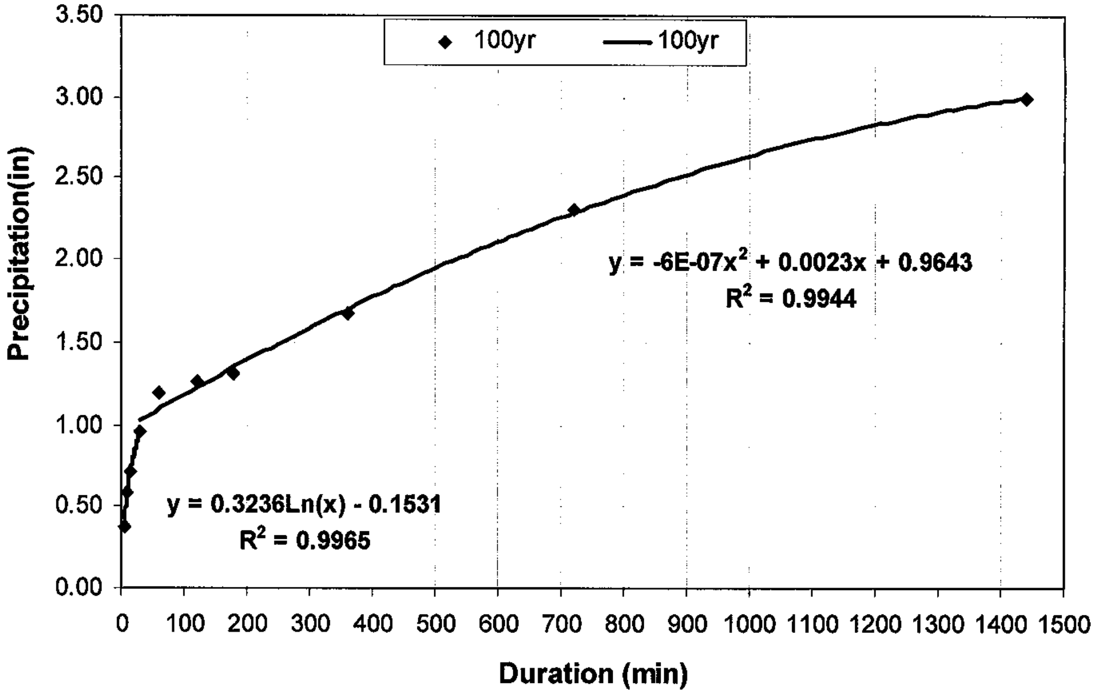


Figure B.1 Bailey Canyon Precipitation / Frequency Curve

Lag Time (TLAG) Calculation

$$TLAG = 22.1\ K_n\ (LLc/S^{0.5})^{0.33}$$

Where K_n = Roughness factor for the basin channels
L = Length of longest watercourse (miles)
L_c = Length of longest watercourse measured upstream to a point opposite the centroid of the basin (miles)
S = Representative (average) slope of the longest watercourse (ft/mile)

This equation is based on the United States Bureau of Reclamation's (USBR's) analysis of the above parameters for several drainage basins in the Southwest desert, Great basin, and Colorado Plateau are (U.S. Department of Interior, 1989). Since the Soil Conversion Services (SCS) and the USBR define lag differently, this equation was developed by modifying the USBR's S-graph lag equation to correspond to the SCS's definition of the dimensionless unit hydrograph lag equation.

For the Bailey Canyon Basin,
K_n = 0.06
L = 9.034 miles
L_c = 4.553 miles
S = 203.38 ft/mile

$$TLAG = 22.1 * 0.06 * (9.034*4.553/203.38^{0.5})^{0.33}$$
$$= 1.881 \text{ hours}$$

Average Slope (S) Calculation

$$S = (L/l)^2 \text{ ft/ft}$$

Where L = Length of longest watercourse (ft)

$l = \Sigma\ (L_i^3/H_i)^{0.5}$ (ft), i = 1, 2, 3, ...
L_i = incremental change in length along the longest watercourse in feet
H_i = incremental change in height along the longest watercourse in feet

$$l = (15624^3/400)^{0.5} + (26659^3/1120)^{0.5} + (2778^3/320)^{0.5} + (2640^3/360)^{0.5}$$
$$= 243045 \text{ ft}$$

$$S = (9.034*5280/243045)^2$$
$$= 0.0385 \text{ ft/ft}$$

S = 203.38 ft/mile

on the storm excess precipitation applied to the unit hydrograph whose parameters are determined by TLAG. TLAG is defined and discussed in Section 705.3.

705.2 ASSUMPTIONS

The basic assumptions made when applying the SCS Unit Hydrograph method (and all other unit hydrograph methods) are as follows:

1. The effects of all physical characteristics of a given drainage basin are reflected in the shape of the storm runoff hydrograph for that basin.

2. At a given point on a stream, discharge ordinates of different unit graphs of the same unit time of rainfall excess are mutually proportional to respective volumes.

3. A hydrograph of storm discharge that would result from a series of bursts of excess rain or from continuous excess rain of variable intensity may be constructed from a series of overlapping unitgraphs each resulting from a single increment of excess rain of unit duration.

705.3 LAG TIME

Input data for the Soil Conservation Service dimensionless unit hydrograph method (SCS, 1985) consists of a single parameter, TLAG, which is equal to the lag (in hours) between the center of mass of rainfall excess and the peak of the unit hydrograph. For small drainage basins (less than one square mile) and basin slopes less than ten percent the lag time may be related to the time of concentration, t_c, by the following empirical relationship:

$$TLAG = 0.6\, t_c \qquad (709)$$

The t_c is computed as presented in Section 702.

For larger drainage basins (greater than one square mile)and basins with a basin slope equal to or greater than ten percent, the lag time (and t_c) is generally governed mostly by the concentrated flow travel time, not the initial overland flow time. In addition, as the basin gets increasingly larger, the average flow velocity (and associated travel time) becomes more difficult to estimate. Therefore, for these basins, the following lag equation is recommended for use in computing TLAG:

$$TLAG = 22.1\, K_n\, (L\, L_c/S^{0.5})^{0.33} \qquad (710)$$

where K_n = Roughness factor for the basin channels
L = Length of longest watercourse (miles)
L_c = Length along longest watercourse measured upstream to a point opposite the centroid of the basin (miles)
S = Representative (average) slope of the longest watercourse (feet per mile)

This lag equation is based on the United States Bureau of Reclamation's analysis of the above parameters for several drainage basins in the Southwest desert, Great Basin, and Colorado Plateau area (U.S. Department of Interior, 1989). Since the SCS and the USBR define lag differently, this equation was developed by modifying the USBR's S-graph lag equation to correspond to the SCS's definition of the dimensionless unit hydrograph lag equation.

Table B.2. Curve No. Calculation for the Bailey Canyon Basin

Soil Name	Area (SF)	Hydrological Soil Group	Area (acre)	Curve No. (C_n)	C_n x Area (acre)
110	77493.9	D	1.78	76	135.21
171	2394673.2	D	54.97	76	4178.03
251	12816566.6	C	294.23	67	19713.27
350	345126.5	D	7.92	76	602.15
360	160511.1	B	3.68	50	184.24
482	6347759.6	B	145.72	50	7286.23
730	100127	D	2.30	76	174.69
880	1449019.1	C	33.26	67	2228.75
893	24439714	C / D	561.06	72	40396.22
930	849372.1	D	19.50	76	1481.92
971	1943674.5	B	44.62	50	2231.03
1194	92078.1	C	2.11	67	141.63
1410	8311926.4	B / C / D	190.82	64	12212.20
1520	363983529.1	D	8355.91	76	635049.32
		Sum:	**9717.90**	**Sum:**	**726014.87**
		Ave. C_n =	**74.71**		

Table B.3. Curve No. for Arid and Semiarid Rangelands (SCS, TR-55)

Table 2-2d.—Runoff curve numbers for arid and semiarid rangelands[1]

Cover type	Hydrologic condition[2]	A[3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	→ 50	67	76
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[1]Average runoff condition, and $I_a = 0.2S$. For range in humid regions, use table 2-2c.

[2]*Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.

[3]Curve numbers for group A have been developed only for desert shrub.

C & D = 72

B, C & D = 64

Project :	Bailey Canyon	Run Name :	Run 131	Subbasin :	Bailey

Start of Run :	17Aug05 0000	Basin Model :	Bailey
End of Run :	18Aug05 1200	Met. Model :	NOAA 30
Execution Time :	11Jan06 1433	Control Specs :	Control-15 Min

Volume Units : ( ) Inches (•) Acre-Feet

Computed Results

Peak Discharge :	2824.0	(cfs)	Date/Time of Peak Discharge :	17 Aug 05 1345	
Total Precipitation :	4.02	(in)	Total Direct Runoff :	1343	(ac-ft)
Total Loss :	2.36	(in)	Total Baseflow :	0.0	(ac-ft)
Total Excess :	1.66	(in)	Total Discharge :	1343.3	(ac-ft)

Figure B.2. HEC-HMS Results using SCS Method

APPENDIX C
GREEN & AMPT LOSS METHOD ANALYSIS FOR BAILEY CANYON

Initial Loss Calculation used for Green & Ampt Loss Model:

According to the Hydrologic Modeling System HEC-HMS Technical Reference Manual (US Army Corps of Engineers, March 2000), initial loss (or initial abstraction) for the Green & Ampt Loss Model may be estimated using similar methods as other loss models. Therefore, the initial abstraction concept derived from the Soil Conservation Service (SCS) Curve Number Loss Model, which is based on antecedent moisture and soil cover characteristics, can be used to estimate the initial loss for the Green and Ampt model.

SCS Curve Number uses the following equation to estimate the initial loss, $\mathbf{I_a}$, which was developed from an empirical relationship shared with the potential maximum retention, **S**, derived from analysis of many small watersheds:

$$\mathbf{I_a = 0.2*S}$$

Also, the potential maximum retention, **S**, and watershed characteristics are related through the curve number, **CN**, with the following equation:

$$\mathbf{S = [1000-(10*CN)] / CN} \qquad \text{(US system)}$$

Therefore, the initial loss equation can be summarized as:

$$\mathbf{I_a = 0.2*([1000-(10*CN)] / CN)}$$

For the Bailey Canyon Basin, the weighted average CN number was calculated as 74.71 (refer to Table 3, Appendix A). Therefore:

$$I_a = 0.2*([1000-(10*74.71)] / 74.71)$$

$$= \underline{\mathbf{0.68\ inches}}$$

Sources:

- *US Army Corps of Engineers, March 2000, Hydrologic Modeling System HEC-HMS Technical Reference Manual, pp 40-42.*

may not be correct. Incorrect results could cause serious consequences for flood control planning and design. Therefore, it is recommended that, for watersheds consisting of relatively small subareas of sand, the Green and Ampt parameter values for loamy sand be used for the sand portion of the watershed. If the area contains a large portion of sand, then either the Green and Ampt method should be used with the parameter values for loamy sand or the IL+ULR method should be used with the appropriately determined values for the parameters.

Table 4.1
GREEN AND AMPT LOSS RATE PARAMETER VALUES FOR BARE GROUND

Soil Texture Classification (1)	XKSAT inches/hour (2)	PSIF inches (3)	DTHETA[1] Dry (4)	DTHETA[1] Normal (5)	DTHETA[1] Saturated (6)
loamy sand & sand	1.20	2.4	0.35	0.30	0
sandy loam	0.40	4.3	0.35	0.25	0
loam	0.25	3.5	0.35	0.25	0
silty loam	0.15	6.6	0.40	0.25	0
silt	0.10	7.5	0.35	0.15	0
sandy clay loam	0.06	8.6	0.25	0.15	0
clay loam	0.04	8.2	0.25	0.15	0
silty clay loam	0.04	10.8	0.30	0.15	0
sandy clay	0.02	9.4	0.20	0.10	0
silty clay	0.02	11.5	0.20	0.10	0
clay	0.01	12.4	0.15	0.05	0

Notes:

1. Selection of DTHETA

Dry	=	Nonirrigated lands, such as desert and rangeland;
Normal	=	Irrigated lawn, turf, and permanent pasture;
Saturated	=	Irrigated agricultural land.

Project :	Bailey-Green-Ampt	Run Name :	Run 119	Subbasin :	Bailey
	Start of Run :	17Aug05 0000	Basin Model :	Bailey	
	End of Run :	18Aug05 1200	Met. Model :	NOAA 30	
	Execution Time :	11Jan06 1137	Control Specs :	Control-30 Min	

Volume Units : Inches • Acre-Feet

Computed Results

Peak Discharge :	2890.0	(cfs)	Date/Time of Peak Discharge :	17 Aug 05 1330	
Total Precipitation :	4.02	(in)	Total Direct Runoff :	683.8	(ac-ft)
Total Loss :	3.17	(in)	Total Baseflow :	0.0	(ac-ft)
Total Excess :	0.84	(in)	Total Discharge :	683.84	(ac-ft)

Figure C.1. HEC-HMS Results using Green & Ampt Loss Method

APPENDIX D
FREQUENCY ANALYSIS FOR BAILEY CANYON BASIN

Water Resources

Data Category: Surface Water | Geographic Area: United States | go

Peak Streamflow for the Nation

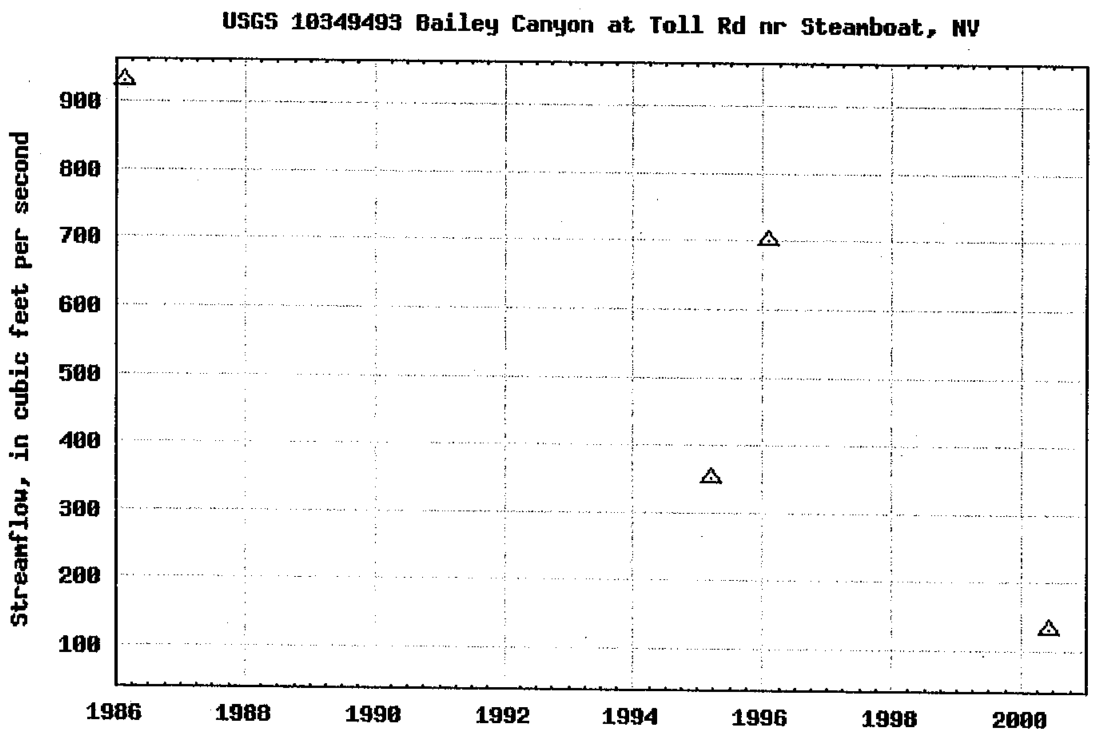
USGS 10349493 Bailey Canyon at Toll Rd nr Steamboat, NV

Available data for this site Site home page GO

Washoe County, Nevada
Hydrologic Unit Code 16050102
Latitude 39°22'31", Longitude 119°42'51" NAD27
Drainage area 12.7 square miles
Gage datum 4,830. feet above sea level NGVD29

Output formats

- Table
- Graph
- Tab-separated file
- WATSTORE formatted file
- Reselect output format



Download a presentation-quality graph

STATISTICS AND FREQUENCY CURVE COORDINATES
Bailey Canyon (Gage) Basin, Nevada

Year	Annual Max Peak Flow (cfs) X	Sorted Year	Sorted Peak Flow (cfs) X	Y=logX	Y^2	Y^3	Rank m	Weibull Plot *f* P=m/n+1 x100	Annual Max Peak Flow (cfs) X
1986	930	1986	930	2.96848	8.81189	26.15795	1	100.0	930
1995	350	1996	700	2.84510	8.09458	23.02988	2	200.0	700
1996	700	1995	350	2.54407	6.47228	16.46593	3	300.0	350
2000	130	2000	130	2.11394	4.46876	9.44670	4	400.0	130
			SUM =	**10.4716**	**27.8475**	**75.1005**			

MEAN: Y_m= sumY/n = 2.6179

STD. DEVIATION: $S = ((sumY^2-(sumY)^2/n)/(n-1))^{0.5}$ = 0.3803

SKEW COEFF: $G = ((n^2*sumY^3)-(3*n*sumY*sumY^2)+2*(sumY)^3)/(n*(n-1)*(n-2)*S^3)$ = -0.8916

FREQUENCY CURVE COORDINATES: LOG-PEARSON TYPE III **WITH G =** -0.8916 (unweighted)

log X = Ym + KS

Return Period (Tr)	Exceedance Probability (%)	Devate K (Table)	log X	Pk. Flow X (cfs)
100.0	1.000	1.6760	3.2553	1800

AREA ADJUSTMENT:

Peak flow for Bailey Canyon = (1800/12.7)*15.18 =2152 cfs

INPUT SKEW AND PROBABILITY TO FIND LP3 DEVIATE, K

Note: It appears that this is a close estimate to the table (see table comparison)

$$K = \frac{2}{G}\left\{\left[\left(Z_{1-P} - \frac{G}{6}\right)\frac{G}{6} + 1\right]^3 - 1\right\}$$

where:

$P \leq 0.5$

$$Z_{1-p} = t - \frac{C_0 + C_1 t + C_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}$$

$$t = \left[-2\ln(P)\right]^{\frac{1}{2}}$$

$P > 0.5$

$$Z_{1-p} = -\left(t - \frac{C_0 + C_1 t + C_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right)$$

$$t = \left[-2\ln(1-P)\right]^{\frac{1}{2}}$$

Enter G (Use 0.000001 for 0)

Skew, G = -0.891600

C_0 = 2.515517 d_1 = 1.432788

C_1 = 0.802853 d_2 = 0.189269

C_2 = 0.010328 d_3 = 0.001308

Probability, P	**Z_{1-P}**	**t less**	**t greater**	**Deviate, K**	
0.0100	2.3268	3.0349	0.14178	1.676	**Result**
Enter P					

APPENDIX E
USGS REGRESSION ANALYSIS FOR BAILEY CANYON

National Flood Frequency Program
Version 3.0
Based on Water-Resources Investigations Report 02-4168
Equations from database C:\Program Files\NFF\NFF files\NFFv3.2_2004-12-14.mdb
Updated by kries 9/22/2004 at 4:03:24 PM fixed decimal place in constant
Equations for Nevada developed using English units

Site: Bailey Canyon, Nevada
User: Mathy
Date: Friday, January 13, 2006 11:33 AM

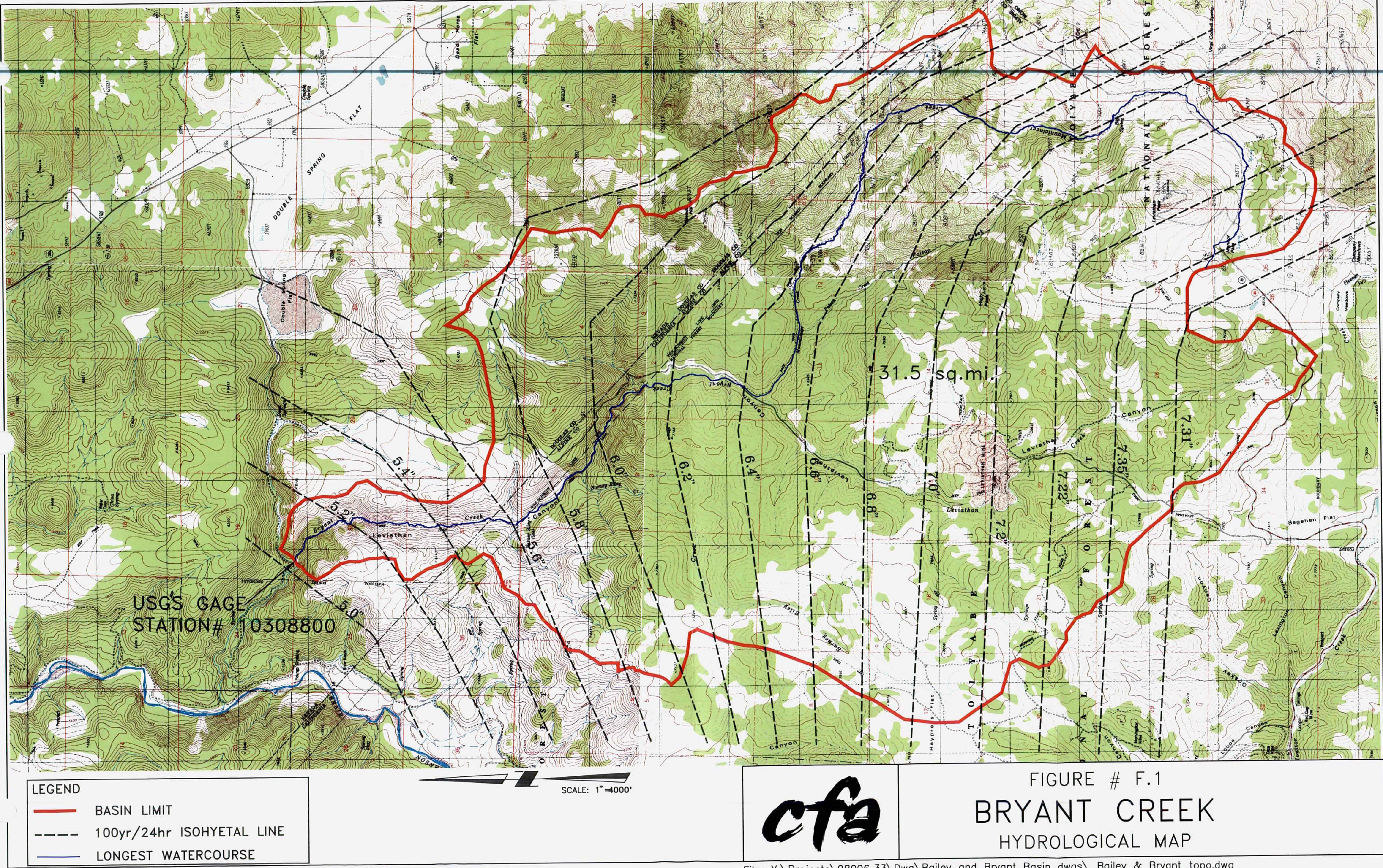
Rural Estimate: Bailey-Gage
Basin Drainage Area: 15.2 mi2
1 Region
Region: Eastern_Sierras_Region_5
Drainage_Area = 15.2 mi2
Mean_Basin_Elevation = 6160 ft
Latitude_of_Site = 39.4 decimal degrees
Crippen & Bue Region 16

Flood Peak Discharges, in cubic feet per second

Estimate	Recurrence Interval, yrs	Peak, cfs	Standard Error, %	Equivalent Years
Bailey-Gage	2	75.8	140	0.2
	5	244	100	0.7
	10	466	84	1.7
	25	923	87	2.6
	50	1420	91	3.3
	100	**2040**	95	3.8
	500	4590		

Maximum: 86700 (for C&B region 16)

APPENDIX F
SCS METHOD ANALYSIS FOR BRYANT CREEK



cfa

FIGURE # F.1

BRYANT CREEK

HYDROLOGICAL MAP

File: X:\Projects\98006.33\Dwg\Bailey and Bryant Basin dwgs\ Bailey & Bryant_topo.dwg
<Mathy> Tue, 17 Jan 2006 - 2:48pm

Water Resources

Data Category: Surface Water | Geographic Area: United States | go

?eak Streamflow for the Nation

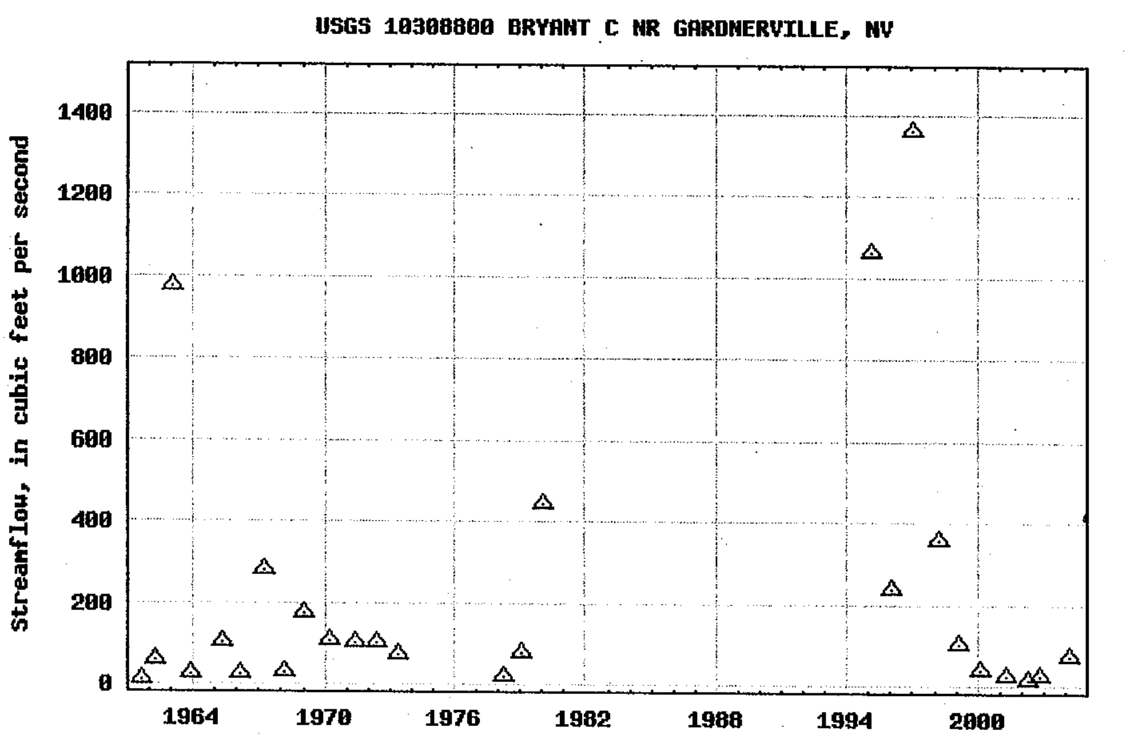
USGS 10308800 BRYANT C NR GARDNERVILLE, NV

Available data for this site Site home page | GO

Douglas County, Nevada
Hydrologic Unit Code 16050201
Latitude 38°47'38", Longitude 119°40'18" NAD27
Drainage area 31.5 square miles
Gage datum 5,449.70 feet above sea level NGVD29

Output formats

- Table
- Graph
- Tab-separated file
- WATSTORE formatted file
- Reselect output format



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U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 4.1, February, 2002)

--- PROCESSING DATE/TIME ---

2005 DEC 21 09:52:32

--- PROCESSING OPTIONS ---

```
Plot option           = None
Basin char output     = None
Print option          = Yes
Debug print           = No
Input peaks listing   = Long
Input peaks format    = WATSTORE peak file
```

U. S. GEOLOGICAL SURVEY
ANNUAL PEAK FLOW FREQUENCY ANALYSIS
Following Bulletin 17-B Guidelines
Program peakfq
(Version 4.1, February, 2002)

Station - 10308800 BRYANT C NR GARDNERVILLE, NV
2005 DEC 21 09:52:32

I N P U T   D A T A   S U M M A R Y

```
Number of peaks in record               =       26
Peaks not used in analysis              =        0
Systematic peaks in analysis            =       26
Historic peaks in analysis              =        0
Years of historic record                =        0
Generalized skew                        =    0.153
Standard error of generalized skew      =    0.550
Skew option                             =   WEIGHTED
Gage base discharge                     =      0.0
User supplied high outlier threshold    =    --
User supplied low outlier criterion     =    --
Plotting position parameter             =     0.00
```

```
*********  NOTICE  --  Preliminary machine computations.          *********
*********  User responsible for assessment and interpretation.    *********

WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                   0.0
WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.              2.9
WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.      2765.5
```

Station - 10308800 BRYANT C NR GARDNERVILLE, NV
2005 DEC 21 09:52:32

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

```
            FLOOD BASE                  LOGARITHMIC
      ---------------------  ------------------------------
```

	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	1.9517	0.5955	0.399
BULL.17B ESTIMATE	0.0	1.0000	1.9517	0.5955	0.293

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	3.8	4.4	2.9	1.3	7.8
0.9900	5.0	5.5	4.0	1.8	9.8
0.9500	10.6	11.1	9.5	4.7	18.8
0.9000	16.2	16.5	15.1	7.9	27.3
0.8000	27.8	27.7	26.8	15.2	44.5
0.5000	83.7	81.7	83.7	52.9	131.4
0.2000	277.1	274.2	290.2	173.4	503.8
0.1000	538.5	544.3	591.9	316.6	1125.0
0.0400	1127.0	1179.0	1347.0	602.3	2818.0
0.0200	1847.0	1986.0	2392.0	917.6	5255.0
0.0100	2911.0	3226.0	4146.0	1347.0	9373.0
0.0050	4458.0	5095.0	7092.0	1925.0	16150.0
0.0020	7563.0	9017.0	14260.0	2988.0	31810.0
0.6667	47.1	(1.50-year flood)			
0.4292	106.5	(2.33-year flood)			

Station - 10308800 BRYANT C NR GARDNERVILLE, NV
2005 DEC 21 09:52:32

I N P U T   D A T A   L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1961	8.0		1978	19.9	
1962	58.0		1979	78.0	
1963	975.0		1980	442.0	
1964	24.0		1995	1060.0	
1965	99.0		1996	236.0	
1966	25.0		1997	1360.0	
1967	278.0		1998	356.0	
1968	28.0		1999	103.0	
1969	176.0		2000	40.0	
1970	106.0		2001	22.0	
1971	103.0		2002	15.0	
1972	100.0		2003	25.0	
1973	70.0		2004	70.0	

Explanation of peak discharge qualification codes

PEAKFQ CODE	WATSTORE CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

Station - 10308800 BRYANT C NR GARDNERVILLE, NV
2005 DEC 21 09:52:32

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1997	1360.0	0.0370	0.0370
1995	1060.0	0.0741	0.0741
1963	975.0	0.1111	0.1111
1980	442.0	0.1481	0.1481
1998	356.0	0.1852	0.1852
1967	278.0	0.2222	0.2222
1996	236.0	0.2593	0.2593
1969	176.0	0.2963	0.2963
1970	106.0	0.3333	0.3333
1971	103.0	0.3704	0.3704
1999	103.0	0.4074	0.4074
1972	100.0	0.4444	0.4444
1965	99.0	0.4815	0.4815
1979	78.0	0.5185	0.5185
1973	70.0	0.5556	0.5556
2004	70.0	0.5926	0.5926
1962	58.0	0.6296	0.6296
2000	40.0	0.6667	0.6667
1968	28.0	0.7037	0.7037
1966	25.0	0.7407	0.7407

Project :	Bailey Canyon	Run Name :	Run 134	Subbasin :	Bryant(6.6" Rain)
Start of Run :	17Aug05 0000	Basin Model :	Bryant(6.6" Rain)		
End of Run :	18Aug05 1200	Met. Model :	NOAA-30 Bryant-6.6"		
Execution Time :	11Jan06 1446	Control Specs :	Control-30 Min		

Volume Units : ◯ Inches ◉ Acre-Feet

Computed Results

Peak Discharge :	4142.7	(cfs)	Date/Time of Peak Discharge :	17 Aug 05 1530	
Total Precipitation :	6.49	(in)	Total Direct Runoff :	4021	(ac-ft)
Total Loss :	4.09	(in)	Total Baseflow :	0.0	(ac-ft)
Total Excess :	2.39	(in)	Total Discharge :	4020.7	(ac-ft)

Figure F.2. Bryant Creek Results with mean rainfall (6.62") (CN = 61.6, Lag = 1.916 hrs)

APPENDIX G
DECEMBER 2005 STORM OBSERVATIONS

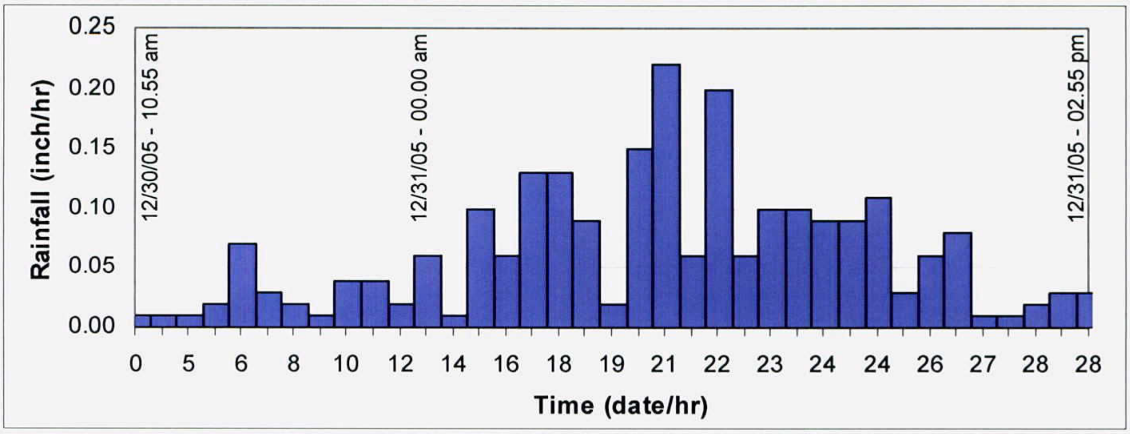

Figure G.1. Incremental Rainfall Data for Gage at Reno-Tahoe Airport (12/30/05-12/31/05).

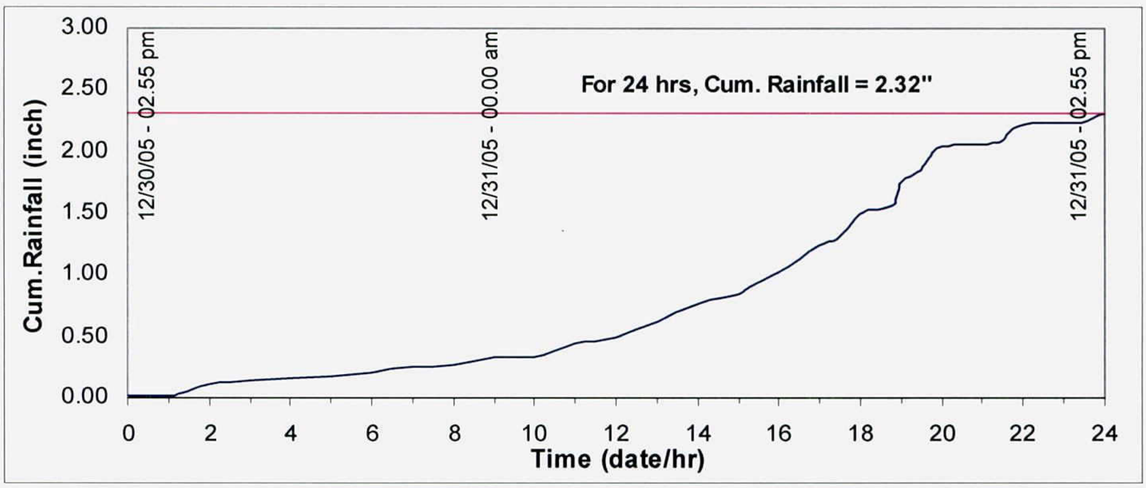

Figure G.2. Cumulative Rainfall Data for Gage at Reno-Tahoe Airport (12/30/05-12/31/05).

Table G.1. NOAA Atlas 14 Precipitation Frequency Estimates for Gage at Reno-Tahoe Airport.

Precipitation Frequency Estimates (inches)																	
ARI* (years)	**5 min**	**10 min**	**15 min**	**30 min**	**60 min**	**120 min**	**3 hr**	**6 hr**	**12 hr**	**24 hr**	**48 hr**	**4 day**	**7 day**	**10 day**	**20 day**	**30 day**	**45 day**	**60 day**
2	0.11	0.16	0.20	0.27	0.33	0.45	0.53	0.73	0.92	1.11	1.33	1.56	1.81	2.02	2.39	2.69	3.20	3.71
5	0.14	0.22	0.27	0.36	0.45	0.58	0.67	0.90	1.16	1.43	1.72	2.02	2.35	2.62	3.09	3.45	4.11	4.75
10	0.17	0.26	0.33	0.44	0.55	0.68	0.76	1.02	1.34	1.68	2.02	2.40	2.79	3.09	3.62	4.04	4.80	5.50
25	0.23	0.34	0.43	0.57	0.71	0.83	0.90	1.18	1.57	2.03	2.46	2.93	3.40	3.74	4.33	4.83	5.71	6.46
50	0.27	0.41	0.51	0.69	0.85	0.95	1.00	1.30	1.75	2.31	2.82	3.35	3.89	4.26	4.87	5.43	6.40	7.16
100	0.33	0.50	0.61	0.83	1.02	1.09	1.14	1.41	1.93	[illegible]60	3.18	3.80	4.42	4.81	5.44	6.05	7.09	7.83
200	0.39	0.59	0.73	0.99	1.22	1.24	1.29	1.52	2.10	2.92	3.57	4.27	4.96	5.37	5.99	6.67	7.78	8.47
500	0.49	0.75	0.93	1.25	1.55	1.56	1.61	1.65	2[illegible]	3.34	4.11	4.93	5.74	6.14	6.76	7.50	8.70	9.31
1000	0.58	0.89	1.10	1.49	1.84	1.86	1.90	1.91	[illegible].49	3.67	4.55	5.47	6.37	6.75	7.33	8.13	9.39	9.89

100 yr/24 hr Rainfall = 2.32", Approximately a 50 year storm event

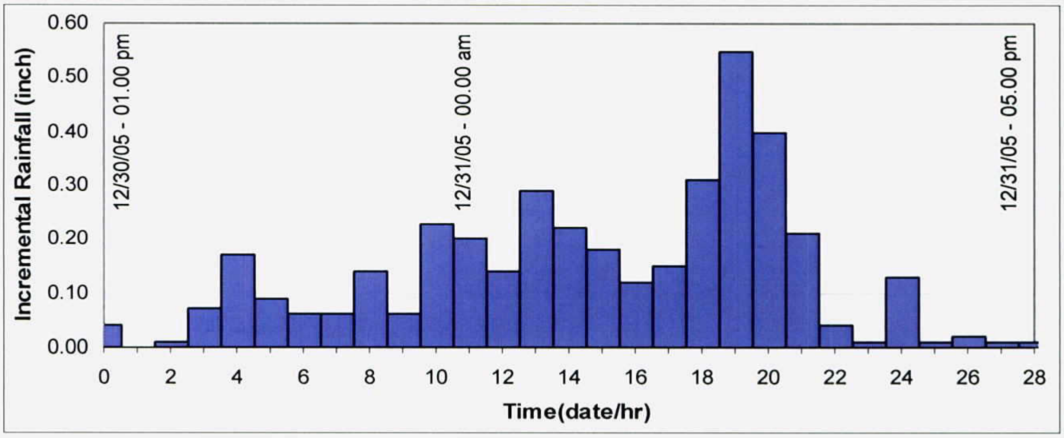

Figure G.3. Incremental Rainfall Data for Gage at South Reno (Wolf Run Golf Course) (12/30/05-12/31/05).

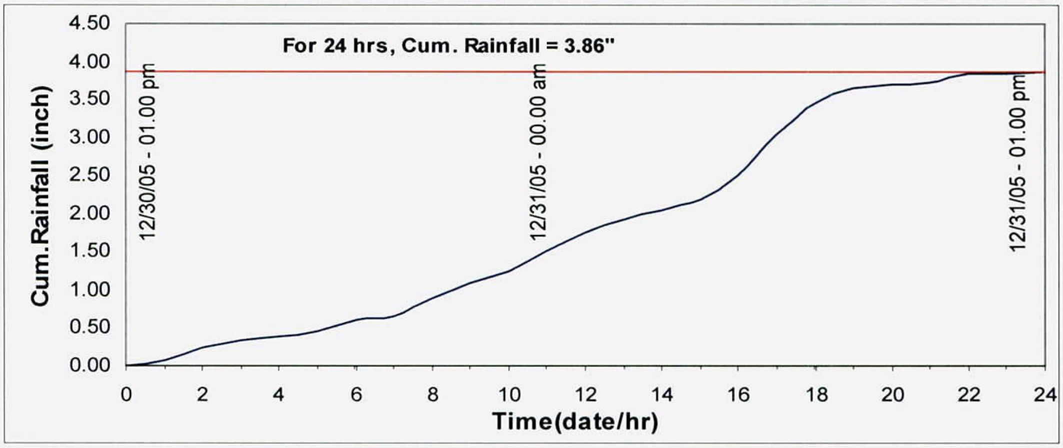

Figure G.4. Cumulative Rainfall Data for Gage at South Reno (Wolf Run Golf Course) (12/30/05-12/31/05).

Table G.2. NOAA Atlas 14 Precipitation Frequency Estimates for Gage at South Reno (Wolf Run Golf Course).

Precipitation Frequency Estimates (inches)																	
ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.12	0.18	0.22	0.30	0.37	0.49	0.59	0.84	1.10	1.42	1.72	2.10	2.46	2.77	3.47	4.08	4.91	5.64
5	0.16	0.24	0.30	0.41	0.51	0.64	0.75	1.05	1.40	1.82	2.22	2.73	3.23	3.65	4.55	5.35	6.42	7.36
10	0.20	0.30	0.38	0.51	0.62	0.76	0.87	1.21	1.64	2.15	2.62	3.25	3.87	4.35	5.39	6.32	7.55	8.60
25	0.26	0.40	0.49	0.66	0.82	0.95	1.04	1.41	1.94	2.61	3.21	4.00	4.75	5.33	6.53	7.65	9.07	10.19
50	0.32	0.48	0.60	0.81	1.00	1.10	1.17	1.56	2.18	2.98	3.68	4.62	5.48	6.10	7.41	8.68	10.22	11.37
100	0.39	0.59	0.73	0.98	1.22	1.28	1.33	1.72	2.42	3.37	4.17	5.27	6.25	6.92	8.33	9.74	11.39	12.51
200	0.47	0.71	0.88	1.19	1.47	1.49	1.55	1.87	2.66	3.78	4.70	5.97	7.06	7.78	9.26	10.82	12.55	13.61
500	0.60	0.91	1.13	1.52	1.88	1.91	1.96	2.08	2.9[illegible]	4.35	5.45	6.98	8.22	8.96	10.55	12.30	14.11	15.04
1000	0.72	1.10	1.36	1.83	2.27	2.29	2.33	2.35	[illegible].23	4.81	6.05	7.80	9.17	9.91	11.55	13.45	15.29	16.06

Cumulative 100 yr/24 hr Rainfall = 3.86”, Approximately a 200 year storm event

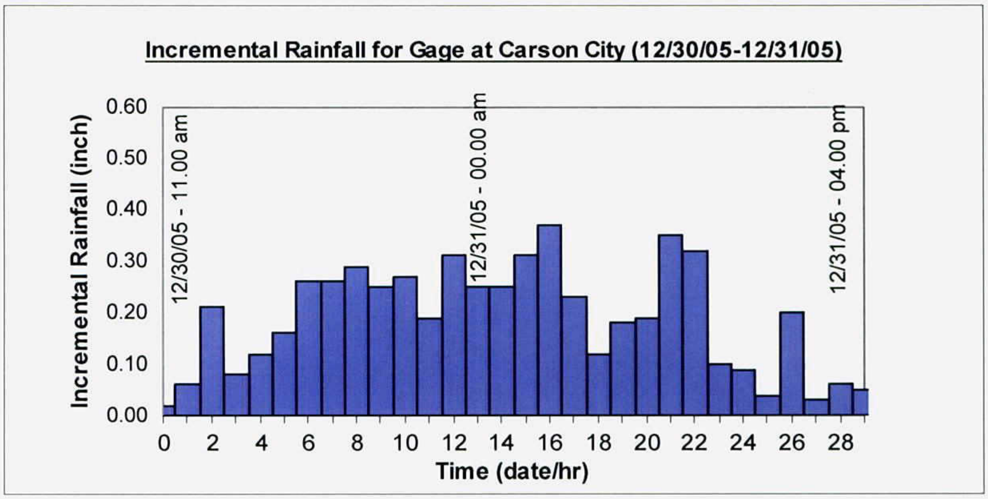

Figure G.5. Incremental Rainfall Data for Gage at Carson City (12/30/05-12/31/05).

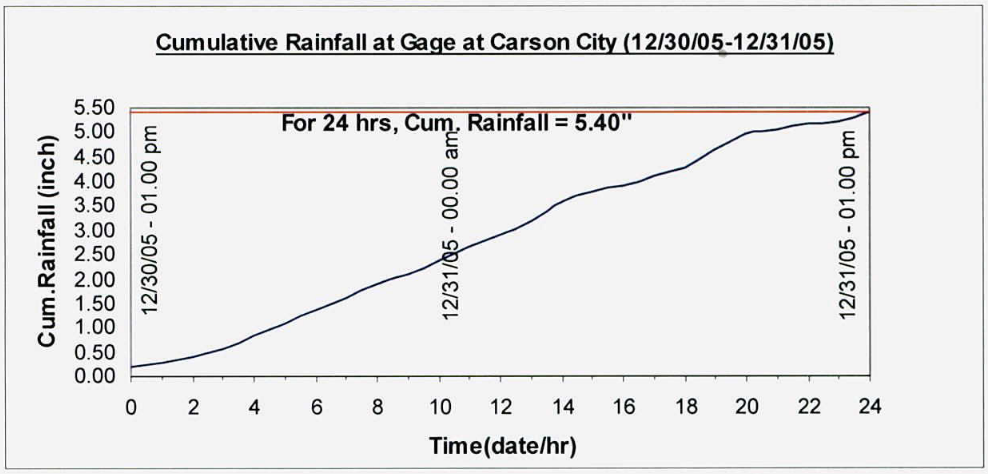

Figure G.6. Cumulative Rainfall Data for Gage at Carson City (12/30/05-12/31/05).

Table G.3. NOAA Atlas 14 Precipitation Frequency Estimates for Gage at Carson City.

Precipitation Frequency Estimates (inches)																	
ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.12	0.19	0.23	0.32	0.39	0.53	0.64	0.91	1.22	1.67	2.07	2.53	2.97	3.36	4.26	4.99	6.00	7.02
5	0.17	0.25	0.32	0.42	0.53	0.68	0.81	1.14	1.56	2.13	2.67	3.29	3.89	4.40	5.55	6.49	7.80	9.11
10	0.21	0.32	0.39	0.53	0.66	0.81	0.94	1.31	1.82	2.50	3.15	3.92	4.63	5.23	6.53	7.64	9.15	10.61
25	0.28	0.42	0.52	0.70	0.86	1.01	1.13	1.55	2.17	3.01	3.84	4.80	5.68	6.37	7.87	9.19	10.94	12.53
50	0.34	0.51	0.63	0.85	1.06	1.18	1.28	1.73	2.44	3.43	4.39	5.52	6.53	7.28	8.89	10.38	12.29	13.93
100	0.41	0.62	0.77	1.04	1.29	1.38	1.45	1.91	2.72	3.86	4.98	6.29	7.43	8.23	9.96	11.61	13.66	15.31
200	0.50	0.76	0.94	1.26	1.57	1.63	1.70	2.11	3.00	4.31	5.60	7.12	8.39	9.22	11.03	12.85	15.03	16.65
500	0.64	0.97	1.21	1.62	2.01	2.05	2.10	2.39	3.38	4.93	6.47	8.28	9.73	10.59	12.49	14.53	16.84	18.35
1000	0.77	1.17	1.45	1.96	2.42	2.46	2.50	2.63	3.6[illegible]	5.43	7.18	9.23	10.83	11.68	13.62	15.83	18.23	19.60

100 yr/24 hr Rainfall = 5.40", Approximately a 1000 year storm event

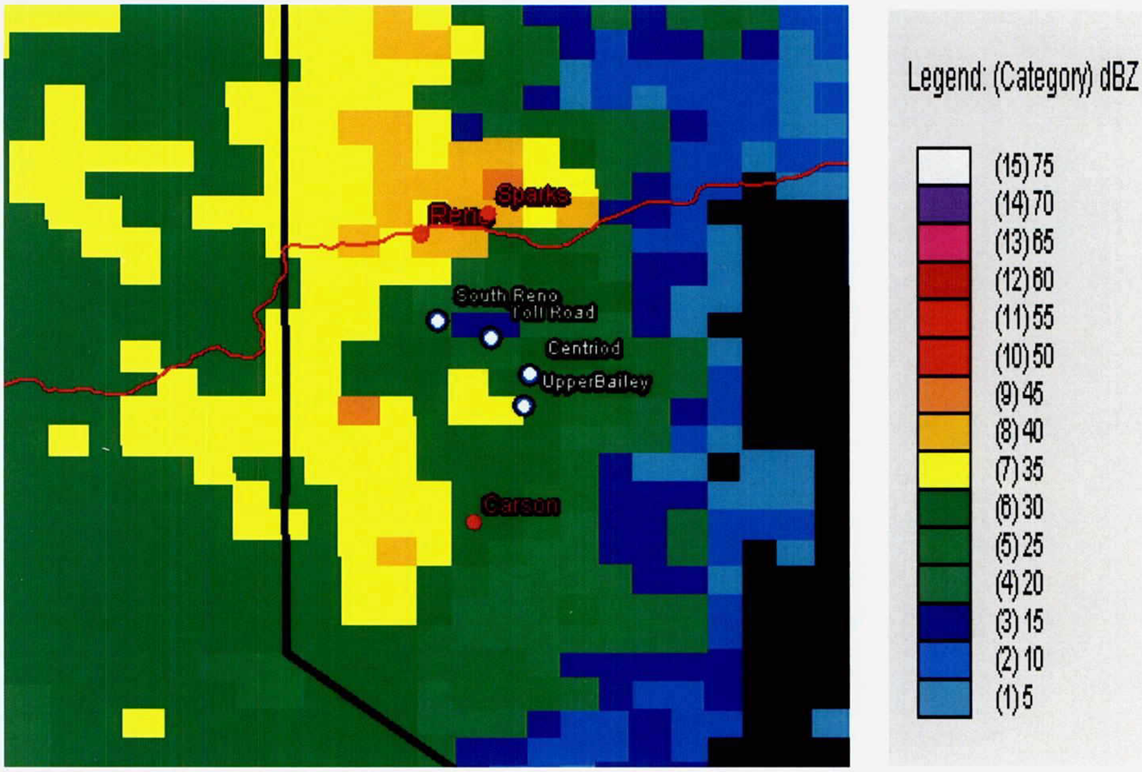

Figure G.7. NEXRAD Composite Reflectivity on 12/30/05 at 4.00 pm

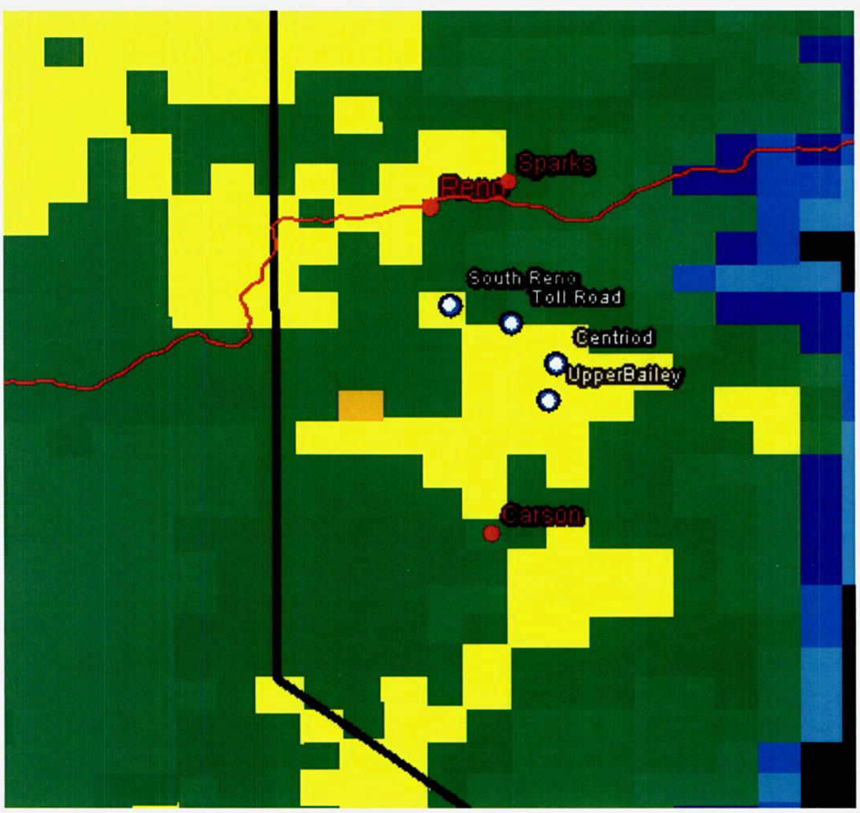

Figure G.8. NEXRAD Composite Reflectivity on 12/30/05 at 8.00 pm

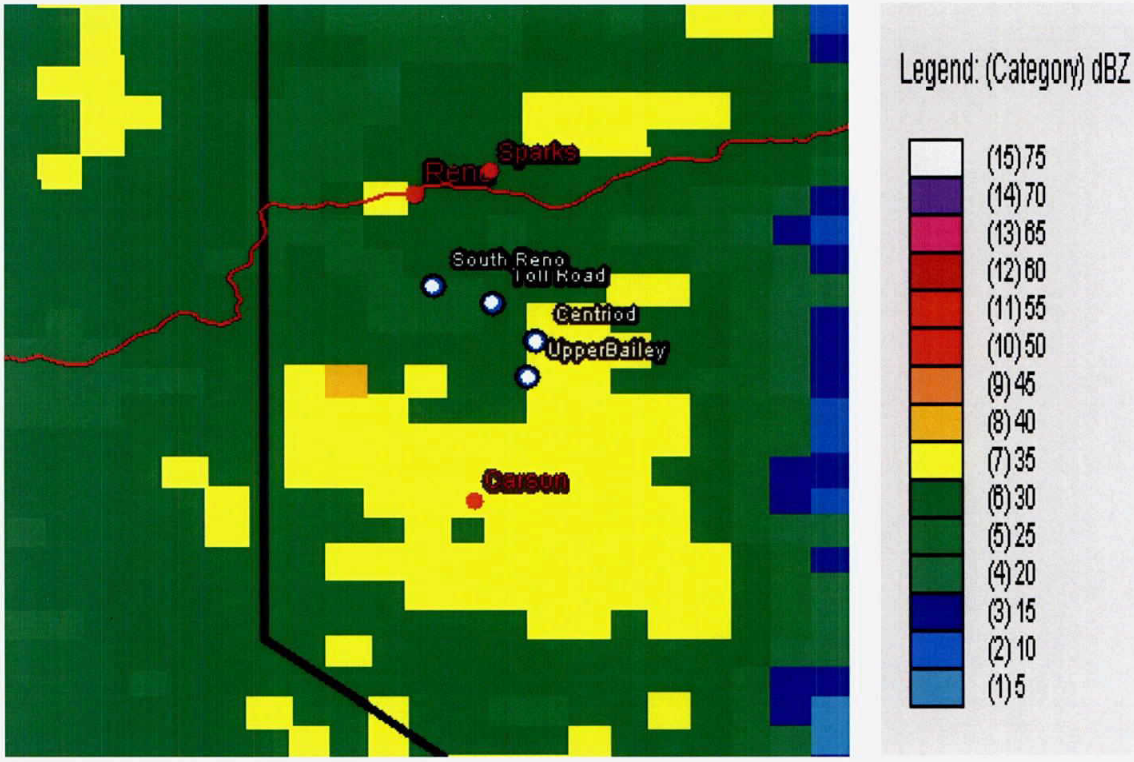

Figure G.9. NEXRAD Composite Reflectivity on 12/31/05 at 0.00 am

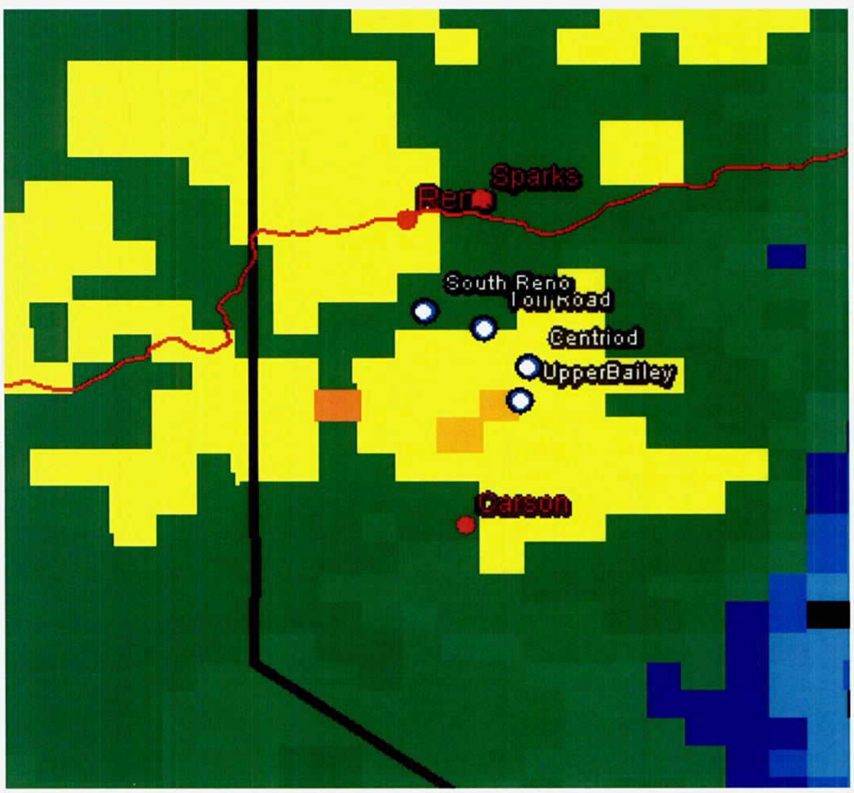

Figure G.10. NEXTRAD Composite Reflectivity on 12/31/05 at 4.00 am

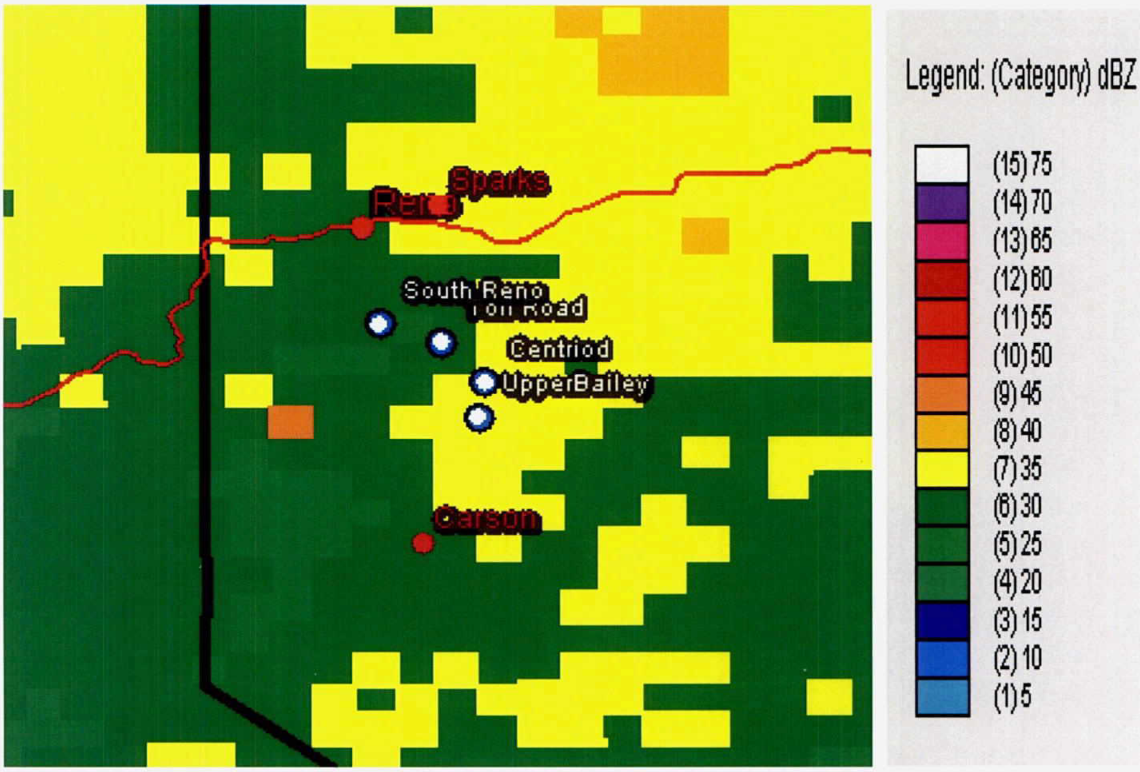

Figure G.11. NEXTRAD Composite Reflectivity on 12/31/05 at 8.00 am

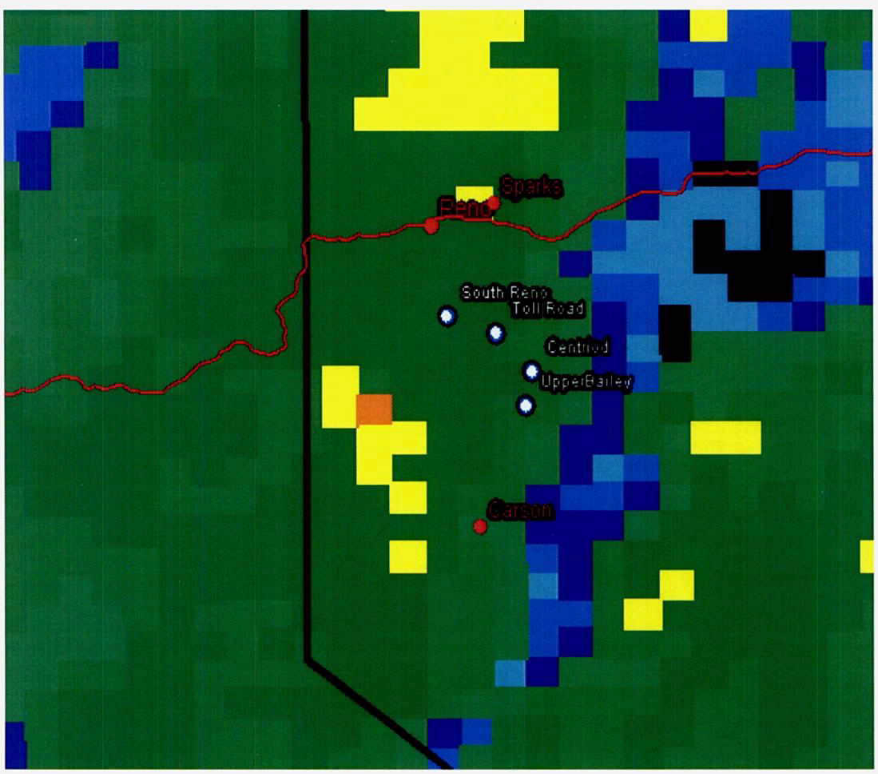

Figure G.12. NEXTRAD Composite Reflectivity on 12/31/05 at 12.00 pm

PHOTOGRAPHS OF BAILEY CANYON FLOODING, DEC. 31, 2005


Figure G.13. Bailey Canyon Creek looking downstream towards Toll Road


Figure G.14. Bailey Canyon Creek looking upstream of Toll Road


Figure G.15. Bailey Canyon Creek overtopping Toll Road (looking south)


Figure G.16. Bailey Canyon Creek sheetflow against Bus Barn

Figure G.17. Bailey Canyon Creek looking west along Geiger Grade

Figure G18. Bailey Canyon Creek looking west along Geiger Grade

Figure G.19. Geiger Channel & Chandler overflowing (north side of Geiger)

Figure G.20. Geiger Channel & Chandler overflowing (north side of Geiger)

APPENDIX H
NIMBUS ENGINEERS' COTTONWOOD CREEK ESTATES STUDY

Nimbus Engineers
3710 Grant Dr., Suite D • Reno, NV 89509
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630 • Fax (702) 689-8614

February 13, 1995

RECEIVED
FEB 13 1995
OFFICE OF
WASHOE COUNTY ENGINEER

Ms. Kris Klein
Engineering Department
Washoe County Public Works
1001 E. 9th Street
Reno, Nv 89520

RE: Cottonwood Creek Estates Hydrology

Dear Ms. Klein:

At your request, Nimbus Engineers has reevaluated the hydrology for the upper Bailey Canyon Creek watershed. The total 24-hour rainfall depth was revised and an areal reduction factor was used in accordance with the NOAA. The basin slope was recalculated using the mean slope method (Hydrology Manual for Engineering Design and Floodplain Management, Pima County Flood Control District, 1979). The lag time was computed using the lag equation developed by converting the U.S. Bureau of Reclamation's S-graph lag equation to a dimensionless unit hydrograph lag equation (Hydrologic Criteria and Drainage Design Manual, Clark County Regional Flood Control District, 1990). These changes generated a new 100-year peak flow of 3673 cfs.

Nimbus feels this revised model adequately reflects the Bailey Canyon Creek watershed. We have enclosed the revised HEC-1 model and supporting documentation for your review.

Sincerely,
Nimbus Engineers

Ann C Pagni

Ann C. Pagni, E.I.T.

RETURN TO WASHOE COUNTY ENGINEERING

Attached HEC-1 Calcs & peak flow OK per Leonard Crowe. 2/14/95
Called Ann Pagni 2/14/95 & told her the attached HEC-1 run & flows are acceptable [illegible]

Per Ann, the attached calcs will be included

```
****************************************                     ****************************************
*                                      *                     *                                      *
*  FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                     *   U.S. ARMY CORPS OF ENGINEERS       *
*             MAY   1991               *                     *   HYDROLOGIC ENGINEERING CENTER      *
*         VERSION 4.0.1E               *                     *          609 SECOND STREET           *
*                                      *                     *       DAVIS, CALIFORNIA 95616        *
* RUN DATE  02/10/95  TIME  11:47:16   *                     *           (916) 551-1748             *
*                                      *                     *                                      *
****************************************                     ****************************************
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X       X  XXXXXXX   XXXXX           X
X       X  X        X     X         XX
X       X  X        X                X
XXXXXXX  XXXX       X         XXXXX  X
X       X  X        X                X
X       X  X        X     X          X
X       X  XXXXXXX   XXXXX          XXX
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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


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LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1         ID  ************************************************************************
  2         ID  *                                                                      *
  3         ID  *             HYDROLOGIC STUDY PERFORMED FOR COTTONWOOD ESTATES        *
  4         ID  *                                                                      *
  5         ID  *                                                                      *
  6         ID  * NIMBUS JOB #:        9411                                            *
  7         ID  *                                                                      *
  8         ID  * FILENAME:            STEIN.DAT                                       *
  9         ID  * VERSION:             FINAL                                           *
 10         ID  * DATE:                FEBRUARY 10, 1995                               *
 11         ID  * ORIGINAL FILE:       COMSTOCK.DAT (JANUARY 1994)                     *
 12         ID  *                                                                      *
 13         ID  * NOTES/COMMENTS:      1. TOTAL 24-HOUR RAINFALL DEPTH ON PB RECORD -  *
 14         ID  *                         AREAL REDUCTION .98 FROM NOAA                *
 15         ID  *                      2. SCS TYPE II RAINFALL DISTRIBUTION.           *
 16         ID  *                      3. BUREAU OF RECLAMATION METHOD USED FOR LAG TIME *
 17         ID  *                      4. KO AND KF RECORDS ADDED TO PLOT HYDROGRAPH IN *
 18         ID  *                         EXCEL FORMAT.                                *
 19         ID  *                      5. IT.04 SET TO 450 TO COMPUTE ENTIRE HYDROGRAPH. *
 20         ID  *                      6. SCS CURVE NUMBER LOSS MODEL.                 *
 21         ID  *                                                                      *
 22         ID  ************************************************************************
```

```
23      IT      5                     450
24      IO      5       0
25      IN     15
26      JR    PREC    .98

27      KK     B35BAILEY CANYON
28      BA    15.3
29      PB    2.95
30      PC    .000   .002   .005   .008   .011   .014   .017   .020   .023   .026
31      PC    .029   .032   .035   .038   .041   .044   .048   .052   .056   .060
32      PC    .064   .068   .072   .076   .080   .085   .090   .095   .100   .105
33      PC    .110   .115   .120   .126   .133   .140   .147   .155   .163   .172
34      PC    .181   .191   .203   .218   .236   .257   .283   .387   .663   .707
35      PC    .735   .758   .776   .791   .804   .815   .825   .834   .842   .849
36      PC    .856   .863   .869   .875   .881   .887   .893   .898   .903   .908
37      PC    .913   .918   .922   .926   .930   .934   .938   .942   .946   .950
38      PC    .953   .956   .959   .962   .965   .968   .971   .974   .977   .980
39      PC    .983   .986   .989   .992   .995   .998  1.000
40      LS             80
41      UD     1.2
42      KF         (F12.2)
43      KO                            1
44      ZZ
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****************************************                   ****************************************
*                                      *                   *                                      *
*  FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                   *     U.S. ARMY CORPS OF ENGINEERS     *
*             MAY   1991               *                   *     HYDROLOGIC ENGINEERING CENTER    *
*          VERSION 4.0.1E              *                   *           609 SECOND STREET          *
*                                      *                   *       DAVIS, CALIFORNIA 95616        *
*  DATE  02/10/95  TIME  11:47:16      *                   *           (916) 551-1748             *
*                                      *                   *                                      *
****************************************                   ****************************************
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**********************************************************************
*                                                                    *
*          HYDROLOGIC STUDY PERFORMED FOR COTTONWOOD ESTATES         *
*                                                                    *
*                                                                    *
* NIMBUS JOB #:      9411                                            *
*                                                                    *
* FILENAME:          STEIN.DAT                                       *
* VERSION:           FINAL                                           *
* DATE:              FEBRUARY 10, 1995                               *
* ORIGINAL FILE:     COMSTOCK.DAT (JANUARY 1994)                     *
*                                                                    *
* NOTES/COMMENTS:    1. TOTAL 24-HOUR RAINFALL DEPTH ON PB RECORD -  *
*                       AREAL REDUCTION .98 FROM NOAA                *
*                    2. SCS TYPE II RAINFALL DISTRIBUTION.           *
*                    3. BUREAU OF RECLAMATION METHOD USED FOR LAG TIME *
*                    4. KO AND KF RECORDS ADDED TO PLOT HYDROGRAPH IN *
*                       EXCEL FORMAT.                                *
*                    5. IT.04 SET TO 450 TO COMPUTE ENTIRE HYDROGRAPH. *
*                    6. SCS CURVE NUMBER LOSS MODEL.                 *
*                                                                    *
**********************************************************************
```
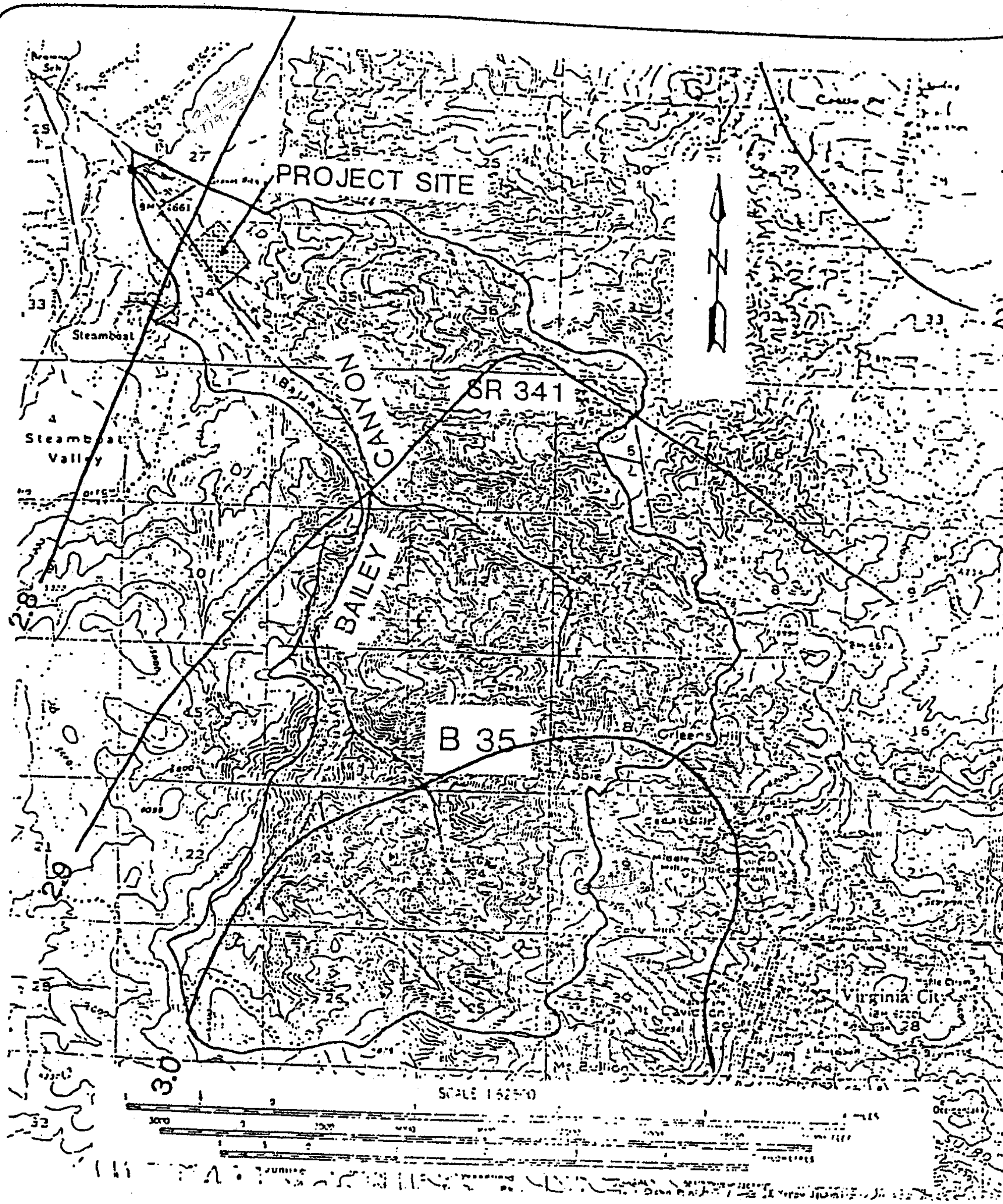

```
10          OUTPUT CONTROL VARIABLES
                 IPRNT           5  PRINT CONTROL
                 IPLOT           0  PLOT CONTROL
                 QSCAL          0.  HYDROGRAPH PLOT SCALE

            HYDROGRAPH TIME DATA
                  NMIN           5  MINUTES IN COMPUTATION INTERVAL
                 IDATE      1    0  STARTING DATE
                 ITIME        0000  STARTING TIME
                    NQ         450  NUMBER OF HYDROGRAPH ORDINATES
                NDDATE      2    0  ENDING DATE
                NDTIME        1325  ENDING TIME
                 ICENT          19  CENTURY MARK

              COMPUTATION INTERVAL    0.08 HOURS
                   TOTAL TIME BASE   37.42 HOURS

        ENGLISH UNITS
            DRAINAGE AREA          SQUARE MILES
            PRECIPITATION DEPTH    INCHES
            LENGTH, ELEVATION      FEET
            FLOW                   CUBIC FEET PER SECOND
            STORAGE VOLUME         ACRE-FEET
            SURFACE AREA           ACRES
            TEMPERATURE            DEGREES FAHRENHEIT

   JP        MULTI-PLAN OPTION
                 NPLAN           1  NUMBER OF PLANS

   JR        MULTI-RATIO OPTION
                RATIOS OF PRECIPITATION
               0.98


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *


          **************
          *            *
  27 KK   *      B35   *     BAILEY CANYON
          *            *
          **************

  43 KO        OUTPUT CONTROL VARIABLES
                   IPRNT           5  PRINT CONTROL
                   IPLOT           0  PLOT CONTROL
                   QSCAL          0.  HYDROGRAPH PLOT SCALE
                   IPNCH           1  PUNCH COMPUTED HYDROGRAPH
                    IOUT           0  SAVE HYDROGRAPH ON THIS UNIT
                   ISAV1           1  FIRST ORDINATE PUNCHED OR SAVED
                   ISAV2         450  LAST ORDINATE PUNCHED OR SAVED
                  TIMINT       0.083  TIME INTERVAL IN HOURS


            PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                            FLOWS IN CUBIC FEET PER SECOND,  AREA IN SQUARE MILES
                                        TIME TO PEAK IN HOURS
```

RATIOS APPLIED TO PRECIPITATION

OPERATION	STATION	AREA	PLAN		RATIO 1
					0.98
HYDROGRAPH AT					
	B35	15.30	1	FLOW	3673.
				TIME	13.17

*** NORMAL END OF HEC-1 ***



Nimbus Engineers
3710 Grant Dr., Suite D, Reno, NV 89509
Mail : P.O. Box 10220, Reno, NV 89510
(702) 689-8630

LOCATION/WATERSHED MAP
FIGURE 1

Nimbus Engineers
3710 Grant Dr., Suite A • Reno, NV 89509
Mail: P.O. Box 10220 • Reno, NV 89510
(702) 689-8630 FAX (702) 689-8614

JOB ______

SHEET NO. ______ OF ______

CALCULATED BY ACP DATE 2/6/95

CHECKED BY ______ DATE ______

SCALE ______

REVISED LAG TIME CALCULATION

$$T_{LAG} = 20\ K_n \left(\frac{L L_c}{S^{.5}} \right)^{.33}$$

$K_n = .050$

$L = 7.51$ MI

$L_c = 3.7$ MI

$$S = \frac{.0484\ \text{FT}}{\text{FT}} \left(\frac{5280\ \text{FT}}{\text{MI}} \right) = 255.55\ \text{FT/MI}$$

$$T_{LAG} = 20\ (.050) \left[\frac{(7.51)(3.7)}{(255.55)^{.5}} \right]^{.33}$$

$T_{LAG} = 1.20$ HRS

determined for the SCS Unit Hydrograph method based on the storm excess precipitation applied to the unit hydrograph whose parameters are determined by TLAG. TLAG is defined and discussed in Section 606.3.

606.2 ASSUMPTIONS

The basic assumptions make when applying the SCS Unit Hydrograph method (and all other unit hydrograph methods) are as follows:

1. The effects of all physical characteristics of a given drainage basin are reflected in the shape of the storm runoff hydrograph for that basin.

2. At a given point on a stream, discharge ordinates of different unitgraphs of the same unit time of rainfall excess are mutually proportional to respective volumes.

3. A hydrograph of storm discharge that would result from a series of bursts of excess rain or from continuous excess rain of variable intensity may be constructed from a series of overlapping unitgraphs each resulting from a single increment of excess rain of unit duration.

606.3 LAG TIME

Input data for the Soil Conservation Service, SCS dimensionless unit hydrograph method (SCS, 1985) consists of a single parameter, TLAG, which is equal to the lag (in hours) between the center of mass of rainfall excess and the peak of the unit hydrograph. For small drainage basins (less than one square mile) in the Clark County area, the lag time may be related to the time of concentration, t_c, by the following empirical relationship:

$$TLAG = 0.6\, t_c \qquad (612)$$

The t_c is computed as presented in Section 602.

For larger drainage basins (greater than one square mile), the lag time (and t_c) is generally governed mostly by the concentrated flow travel time, not the initial overland flow time. In addition, as the basin gets increasingly larger, the average flow velocity (and associated travel time) becomes more difficult to estimate. Therefore, for these basins, the following lag equation is recommended for use in computing TLAG:

$$TLAG = 20\, K_n\, (L\, L_c / S^{0.5})^{0.33} \qquad (613)$$

where K_n = Manning's roughness factor for the basin channels

L = Length of longest watercourse (miles)

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

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

This lag equation is based on the United States Bureau of Reclamations analysis of the above parameters for several drainage basins in the Southwest desert, Great Basin, and Colorado Plateau area (USBR, 1989). This equation was developed by converting the USBR's S-graph lag equation to a dimensionless unit hydrograph lag equation.

In order to obtain comparable results between the t_c calculation and the TLAG calculation, it is recommended that either method be used as a check of the other method for drainage areas around one square mile in size.

606.3.1 ROUGHNESS FACTOR

The selection of a proper roughness factor for use in the lag time calculation is highly subjective. Therefore, in order to obtain more consistent lag time and runoff analysis results, the roughness factor, K_n, shall be determined using the factors presented in Table 604. These factors are based on roughness factor analysis by the USACE (1982) and USBR (1989) as compared to the typical watershed channels found in the Clark County area. The reader is referred to these documents for further discussion on selection of a proper roughness factor.

For partially developed basins, the roughness factor should be interpolated in relationship to the percent of each land use in the basin.

606.4 UNIT STORM DURATION

The minimum unit duration, Δt, is dependent on the time of concentration of a given basin. If the basin is large (i.e. > one square mile), a larger unit duration may be used. If the basin is small (i.e. < one square mile) a smaller unit duration should be used. The unit duration, Δt, should be $\leq .25\ T_p$, where T_p is the time-to-peak of the unit hydrograph. For the CCRFCD area the maximum unit storm duration should be 5 minutes unless conditions warrant otherwise.

606.5 SUB-BASIN SIZING

The determination of the peak rate of runoff at a given design point is affected by the discretization of sub-basins in the subject basin. Typically, the more discrete the analysis of a given basin (more

LAG EQUATION ROUGHNESS FACTORS

WATERSHED CHARACTERISTICS	ROUGHNESS FACTOR, K_n
Urbanized Areas: Water courses in the drainage area consist of street, storm sewer, and improved channels.	.015
Natural Areas: Water courses in the drainage area are well defined, unimproved channels or washes. Watershed has minimal vegetation.	.030
Natural Areas: Water courses in the drainage area are not well defined, and consist of many small rills and braided wash areas. Runoff from area combines slowly into channels. Includes mountainous channels with large boulders and flow restrictions.	.050

Revision	Date

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JOB 321
SHEET NO. ______ OF ______
CALCULATED BY ACP DATE 2/6/19
CHECKED BY ______ DATE ______
SCALE ______

MEAN SLOPE

$$S = \left(\frac{L}{I}\right)^2 \qquad I = \left(\frac{L_1^3}{H_1}\right)^{1/2} + \left(\frac{L_2^3}{H_2}\right)^{1/2} + \left(\frac{L_3^3}{H_3}\right)^{1/2} + \ldots$$

$L_1 = 300$, $H_1 = 20$ — $I = 1162$

$L_2 = 3400$, $H_2 = 360$ — $I = 10449$

$L_3 = 1800$, $H_3 = 120$ — $I = 6971$

$L_4 = 11200$, $H_4 = 480$ — $I = 54101$

$L_5 = 2000$, $H_5 = 120$ — $I = 8165$

$L_6 = 8200$, $H_6 = 360$ — $I = 39135$

$L_7 = 3400$, $H_7 = 120$ — $I = 18098$

$L_8 = 4000$, $H_8 = 240$ — $I = 16330$

$L_9 = 1800$, $H_9 = 80$ — $I = 8538$

$L_{10} = 600$, $H_{10} = 40$ — $I = 2323$

$L_{11} = 3000$, $H_{11} = 120$ — $I = 15000$

TOTAL I = 180,272 FT

TOTAL L = 39,700 FT

$$S = \left(\frac{39{,}700}{180{,}272}\right)^2 = .0484 \text{ FT/FT}$$

DETERMINATION OF MEAN SLOPE (S_c)

To determine the mean slope (S_c) of the longest watercourse within a watershed, the following equation should be used:

$$S_c = \left[\frac{L_c}{I}\right]^2 \qquad \text{(ft./ft.)}.$$

Where

L_c = the length of the longest watercourse within the watershed, in feet.

$$I = \left[\frac{L_1{}^3}{H_1}\right]^{\frac{1}{2}} + \left[\frac{L_2{}^3}{H_2}\right]^{\frac{1}{2}} + \left[\frac{L_3{}^3}{H_3}\right]^{\frac{1}{2}} + \ldots\text{(feet)}.$$

And

L_1, L_2, L_3, etc. = incremental changes in length (L_i) along longest watercourse, in feet.

H_1, H_2, H_3, etc. = incremental changes in height (H_i) along longest watercourse, in feet.

This equation is defined as a hypothetical uniform slope for the longest watercourse within a watershed which would give the same travel time through the watershed as reach by reach calculation. (An assumption is made in the derivation of the equation that the roughness coefficient and hydraulic radius of the watercourse are the same for all reaches of the watershed; that is, the watershed is homogeneous).

EXAMPLE:

The longest watercourse within a watershed has a length of 15,000 feet, and the following profile:

Incremental Change in Length (L_i)	Incremental Change in Height (H_i)
3,000 feet	300 feet
8,000 feet	200 feet
4,000 feet	40 feet

Determine the mean slope (S_c).

First, "I" is computed:

$$I = \left[\frac{(3000)^3}{300}\right]^{\frac{1}{2}} + \left[\frac{(8000)^3}{200}\right]^{\frac{1}{2}} + \left[\frac{(4000)^3}{40}\right]^{\frac{1}{2}} \text{ feet}.$$

$$I = 100{,}083 \text{ feet.}$$

Then

$$S_c = \left[\frac{15,000}{100,083}\right]^2 = \underline{\underline{.0225 \text{ ft./ft.}}}$$

Note that if the slope for the watershed had been calculated in the conventional manner, dividing the total length by the total change in height, a value of .036 ft./ft. would have resulted, leading to a shorter time of concentration and consequently higher peak rate of discharge than might actually occur.

The number of "slope breaks", or incremental segments of channel length, to be utilized in calculating the mean slope (S_c) depends to a great extent upon the profile along the main channel length (L_c). However, the maximum number of segments generally need not exceed four (4) unless the watershed under investigation is unusually complex and contains numerous topographic variations. Typically, new incremental segments should be initiated whenever a significant change in the slope of the main channel length profile becomes apparent. This can usually best be estimated with the use of U.S.G.S. quad sheets and/or topographic maps.

APPENDIX I
HYDRAULIC ANALYSIS