NDOT Research Report

Report No. 674-19-803

Modernize Hydrologic Prediction Processes by Creating Custom Statewide SSURGO Green and Ampt Parameter Database

Task 5: Hydrologic Model Testing

December 2020

Nevada Department of Transportation
1263 South Stewart Street
Carson City, NV 89712

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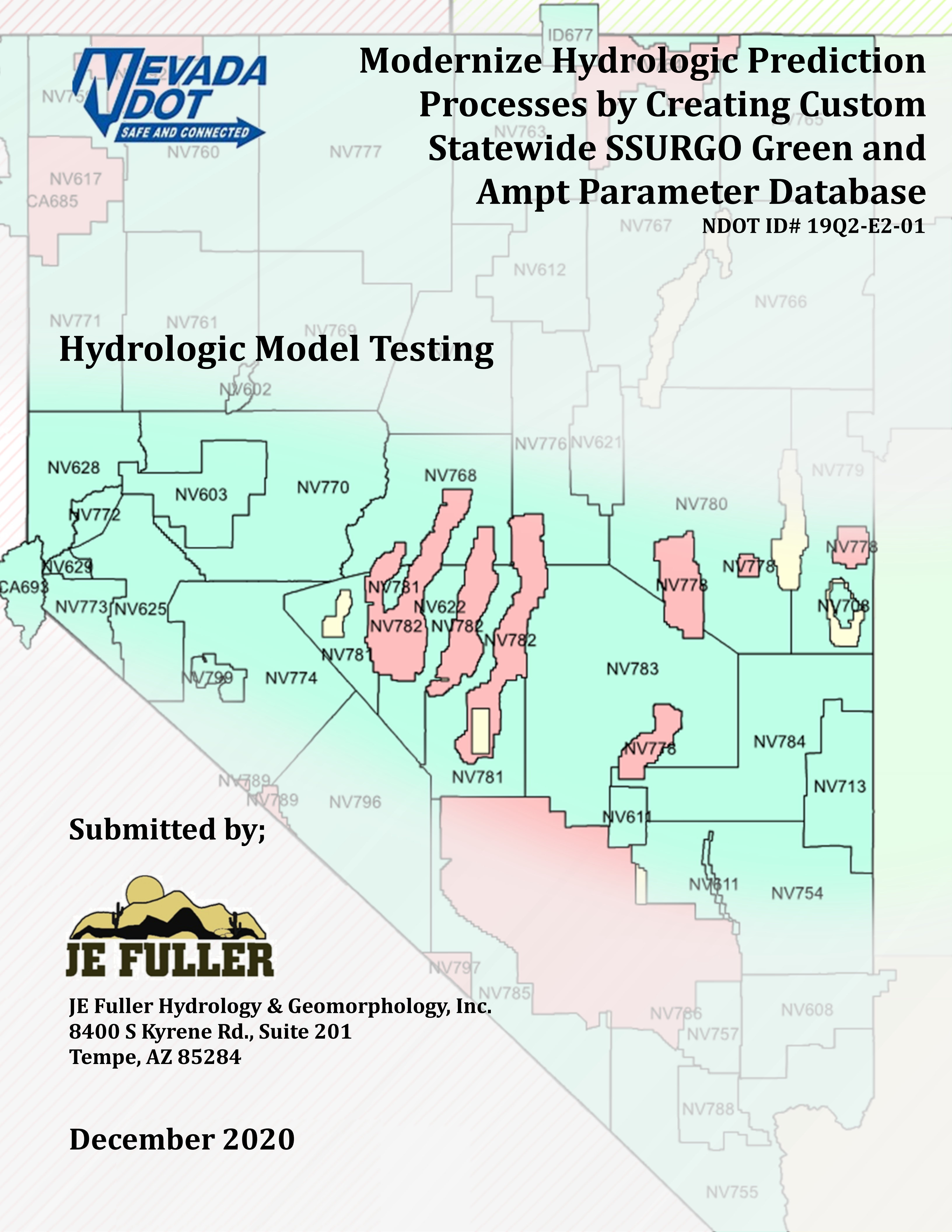

Modernize Hydrologic Prediction Processes by Creating Custom Statewide SSURGO Green and Ampt Parameter Database

NDOT ID# 19Q2-E2-01

Hydrologic Model Testing

Submitted by;

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December 2020

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1. Introduction

This document is intended to function as an example of the use of soils data and methods required to implement the Green and Ampt methodology within the state of Nevada. An example hydrologic watershed model was supplied by Nevada Department of Transportation (NDOT). The hydrologic model used the Natural Resources Conservation Service (NRCS) curve number methodology for estimation of rainfall losses and utilized the United States Army Corps of Engineers (USACE) HEC-1 computer program to conduct the assessment.

For the purposes of this assessment, the original HEC-1 model was migrated to the USACE Hydrologic Modeling System (HEC-HMS) (v4.6) software platform using the HEC-1 input text contained in the technical documentation for the original hydrologic study (Kimley Horn and Associates, Inc., 2011). Simple basin area averages were used to incorporate land use and percent effective imperviousness adjustments to Green and Ampt soils parameters. All results contained in this document are based upon HEC-HMS analysis to eliminate any potential influence due to different hydrologic calculation platforms.

2. Original Hydrologic Study

The reference Bailey Canyon Hydrologic Study was completed for the Washoe County Regional Transit Commission (RTC) in 2011. The project location and vicinity are shown in **Figure 1**. The hydrologic analysis consisted of a HEC-1 model with 11 subbasins, 6 routing reaches, 1 flow diversion, and 9 concentration points (Junctions). Rainfall losses were originally calculated using the NRCS curve number methodology and utilized soil, vegetation, and land use data. Flows were developed using the unit-hydrograph methodology. The precipitation depth was specified using NOAA Atlas 14 data with a fixed areal reduction of 0.98 of the point rainfall applied to all subbasins. The precipitation hyetograph was specified in the HEC-1 model using a JR record for a balanced storm distribution. Limited GIS data was available from the original hydrologic study documentation provided.

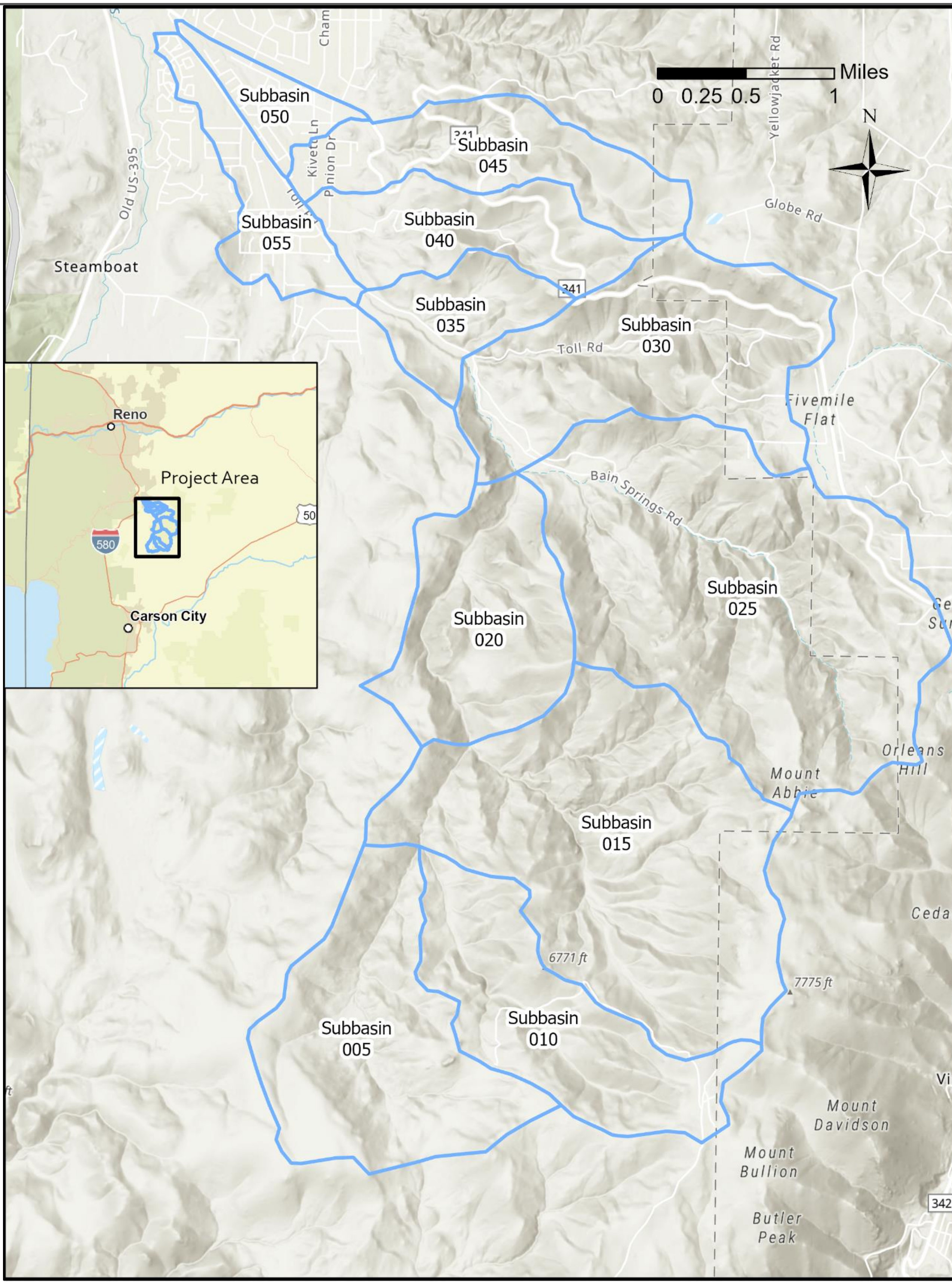

Figure 1 Project Location and Vicinity

Transfer of the original HEC-1 attributes to HEC-HMS was generally accomplished by direct transfer of attributes. The point rainfall reduction was accomplished by multiplying the NOAA Atlas 14 point precipitation values by 0.98 and entering those values into HMS for the precipitation data.

The original GIS data was not available for the study; subbasin boundaries were digitized from exhibits within the original hydrologic study. Parameters for other elements, included routing reaches, were taken directly from the HEC-1 input text which is included in **Appendix A**.

3. Green and Ampt Parameter Calculation

Calculation of Green and Ampt parameters was accomplished using NDOT Geographic Information System (GIS) data derived from NRCS soils surveys. The project watersheds fall within survey areas Nevada (NV) 628 and NV772 and data was calculated for the most restrictive layer within the top three inches of the soil column.

Calculation of detailed parameters for each of the soil column depths follows an identical process with only the input soils dataset differing. Polygons of the subbasins were intersected with NDOT soils data to determine Green and Ampt parameter regions within each subbasin. For subbasins with multiple soil map units present, XKSAT, PSIF, saturated content (Sat), and Initial Content (Wpoint/FCapac) values were averaged based upon their relative coverage (%) in each of the subbasins. Mathematically, XKSAT and PSIF were calculated based upon a logarithmic area weighted average of the soil map units while the other components are calculated via simple area weighted averaging.

Within Green and Ampt methodology, the “Percent Impervious Area” attribute is calculated through a composite of soils (natural) imperviousness and land use imperviousness. Land use attribution from the original hydrologic study was used to determine the land use composition within each subbasin. Land use codes were then cross referenced with **Table 1** to determine the approximate percent impervious area for each area and then combined using area weighted averaging of the land use in each subbasin.

Table 1 Assigned Land Use with Initial Moisture and % Impervious Assumptions

Land Use Code	Land Use Name	Initial Moisture Condition	Land use Imperviousness [% 0-100]
OS	Open Space	dry	0
GR	General Rural	dry	12
LDS	Low Density Suburban	dry	14
MDS	Medium Density Suburban	normal	22
MDR	Medium Density Rural	normal	6
PR	Parks and Recreation	dry	0
PSP	Public and Semi-Public Facilities	dry	0
GC	General Commercial	dry	85
HDS	High Density Suburban	normal	54

Once values for percent impervious area were determined based upon both soil and land use attributes, the two values are then added together for use within HEC-HMS; values for soil and land use based imperviousness are shown in **Table 2**.

Table 2 Subbasin Effective Imperviousness			
Subbasin	**Weighted Soils (Natural) Imperviousness [% 0-100]**	**Weighted Land Use Imperviousness [% 0-100]**	**[1]Weighted Effective Imperviousness [% 0-100]**
005	0	0.00	0.00
010	0	0.00	0.00
015	0	0.00	0.00
020	0	0.02	0.02
025	0	1.39	1.39
030	0	4.31	4.31
035	0	6.01	6.01
040	0	12.11	12.11
045	0	10.66	10.66
050	0	22.10	22.10
055	3	19.73	22.73

Note 1: Weighted Effective Imperviousness is the sum of Weighted Soils (Natural) Imperviousness and Weighted Land use Imperviousness for each subbasin.

Initial soil moisture content within each subbasin is assigned based upon the soil parameters present and land use. For agricultural land uses, saturated initial conditions are assumed. For irrigated landscapes such as lawns, a normal condition saturation content, specified as the soil field capacity is assumed, and for natural or non-irrigated landscapes, a dry condition, as represented by the wilting point, is utilized. Average initial soil moisture values for use within HEC-HMS were calculated based upon the percent of each watershed represented by each moisture condition (saturated, irrigated, or dry) and are calculated via simple area weighted average based upon the soil and land use composite data from the original hydrologic study. Land use initial moisture assumptions and average initial content for each subbasin are shown in **Table 3**.

Table 3 Average Initial Content Adjusted for Land Use					
Subbasin	**% Normal Saturation"**	**% Dry Saturation"**	**Field Capacity**	**Wilting Point**	**Initial Content**
005	0.0	100.0	0.237	0.121	0.121
010	0.0	100.0	0.231	0.114	0.114
015	0.0	100.0	0.232	0.115	0.115
020	0.0	100.0	0.231	0.114	0.114
025	0.0	100.0	0.235	0.117	0.117
030	0.0	100.0	0.235	0.116	0.116
035	3.6	96.4	0.225	0.112	0.116
040	17.5	82.5	0.226	0.112	0.132
045	14.6	85.4	0.227	0.113	0.130
050	69.2	30.8	0.153	0.075	0.129
055	71.8	28.2	0.197	0.105	0.171

Green and Ampt parameters adjusted for land use initial content and percent imperviousness are summarized (for the top 3” soil horizon dataset) in **Table 4**.

Results for the Green and Ampt infiltration method are presented in **Section 5** of this document.

Table 4 Green and Ampt Soil Parameter Summary for Top 3 inches

Subbasin	Initial Content WPOINT or FCAPAC [IN]	Saturation SAT [IN]	Suction PSIF [IN]	Conductivity XKSAT [IN/HR]	Effective Imperviousness [% 0-100]
005	0.121	0.434	7.628	0.2516	0.00
010	0.114	0.438	7.022	0.2763	0.00
015	0.115	0.437	7.172	0.2717	0.00
020	0.114	0.437	7.107	0.276	0.02
025	0.117	0.437	7.644	0.2578	1.39
030	0.116	0.437	7.622	0.2625	4.31
035	0.116	0.437	5.599	0.2942	6.01
040	0.132	0.437	5.315	0.2941	12.11
045	0.130	0.437	5.833	0.2875	10.66
050	0.129	0.426	0.842	0.7199	22.10
055	0.171	0.429	2.963	0.3703	22.73

4. USGS Regression Hydrology

The United State Geological Survey (USGS) has developed a series of regression equations for the state of Nevada to assist in calculating peak discharges for rural watersheds (United States Geological Survey, 1999). Within Nevada, the USGS has identified six hydrologic regions, five of which are defined by spatial extents and the sixth, defined as Region 1, which is defined by an elevation/latitude curve. All subbasins for the project area are located in spatial Region 5 and are located below the threshold for inclusion in Region 1.

Within Region 5, peak discharge estimates are calculated based upon three input variables – subbasin drainage area, mean basin elevation, and site latitude. For the project subbasins, mean basin elevation was determined by geographically intersecting subbasin boundaries with USGS 3dep digital elevation model (DEM) data to determine the average basin elevation. Site latitude was sampled at the subbasin centroids. Based upon the published range of explanatory variables in USGS Fact Sheet 13-98, the project subbasins are below the range of values used in developing the equations for drainage area and, for subbasins 025, 035, 040, 045, 050, and 055, mean basin elevation; however there is no explicit indication that the equations are ill-suited for use on watersheds like those considered in this document and the results appear to be reasonable. Calculation results are shown in **Table 5**.

Table 5 USGS Regression Inputs and Results

Basin Name/ID	Assigned Geographic Region	Recommended Region	Area	ELEV	LAT	Peak Flow 100-year
			(sq. mi.)	ft, NAVD88	deg	(cfs)
005	5	5	1.67	6237.04	39.31399	341.5
010	5	5	1.31	6594.07	39.31616	250.1
015	5	5	3.00	6530.34	39.32954	491.2
020	5	5	1.19	6308.57	39.34852	258.3
025	5	5	3.38	5675.18	39.35073	737.9
030	5	5	1.74	5810.45	39.37014	420.8
035	5	5	0.52	5140.70	39.37367	213.0
040	5	5	0.82	5371.91	39.38046	278.2
045	5	5	0.94	5514.25	39.38629	293.1
050	5	5	0.29	4665.88	39.39113	168.0
055	5	5	0.54	4730.49	39.38337	265.9

5. Results Comparison

Individual HEC-HMS models were developed for each of the below cases

1. Curve Numbers (original hydrologic study)
2. Green and Ampt (Top 3” Horizons)

Additionally, subbasin-level hydrologic parameters were calculated based upon USGS regional regression equations. USGS regression-based data was not routed within HMS as regression methods are intended for a reasonableness comparison of the infiltration methods. Results for the 4 hydrologic methods are shown in **Table 6**. These results indicate that use of the top 6” Horizons data with the Green and Ampt methodology results in conditions which are universally more conservative than for the top 3” horizons usage. Additionally, results for the top 3” horizons with Green and Ampt infiltration result in discharges that are generally greater than the applied curve number hydrology, but of the same magnitude.

Table 6 HMS-Results Comparison

HEC-HMS ID	100-year Peak Flows					
	Baseline (Curve Number)		G&A (Top 3" Horizons)		USGS Regression	
	Value (cfs)	% Baseline	Value (cfs)	% Baseline	Value (cfs)	% Baseline
CP010	630	100.0%	694	110.1%	-	-
CP015	1,181	100.0%	1,471	124.6%	-	-
CP025	1,896	100.0%	2,506	132.2%	-	-
CP030	2,221	100.0%	2,881	129.8%	-	-
CP035	2,274	100.0%	2,913	128.1%	-	-
CP040	2,042	100.0%	2,448	119.9%	-	-
CP045	2,178	100.0%	2,557	117.4%	-	-
CP050	2,201	100.0%	2,567	116.6%	-	-

Table 6 HMS-Results Comparison

HEC-HMS ID	100-year Peak Flows					
	Baseline (Curve Number)		G&A (Top 3" Horizons)		USGS Regression	
	Value (cfs)	% Baseline	Value (cfs)	% Baseline	Value (cfs)	% Baseline
CP055	373	100.0%	568	152.1%	-	-
CP055B	2,574	100.0%	3,132	121.7%	-	-
D040	1,944	100.0%	2,375	122.2%	-	-
D055	332	100.0%	538	162.0%	-	-
R015	630	100.0%	694	110.2%	-	-
R025	1,180	100.0%	1,469	124.6%	-	-
R030	1,897	100.0%	2,504	132.0%	-	-
R035	2,221	100.0%	2,880	129.7%	-	-
R040	1,943	100.0%	2,374	122.2%	-	-
R045	2,042	100.0%	2,451	120.0%	-	-
R050	2,179	100.0%	2,557	117.3%	-	-
005	433	100.0%	389	89.8%	341.5	78.9%
010	198	100.0%	305	154.6%	250.1	126.6%
015	580	100.0%	816	140.6%	491.2	84.7%
020	222	100.0%	309	139.1%	258.3	116.1%
025	511	100.0%	754	147.6%	737.9	144.5%
030	511	100.0%	589	115.2%	420.8	82.3%
035	284	100.0%	297	104.4%	213	75.0%
040	401	100.0%	414	103.2%	278.2	69.4%
045	404	100.0%	399	98.7%	293.1	72.5%
050	159	100.0%	182	114.9%	168	106.0%
055	243	100.0%	343	141.2%	265.9	109.6%

Table 6 shows a comparison of discharges for the curve number and top 3” horizons approaches with USGS regression estimates as the comparative baseline. While flows are generally comparable between the USGS regression and Green and Ampt values, Subbasin 015 exhibits the highest relative discharge difference at 55.9% greater than the USGS regression estimate for the same watershed. The infiltration parameters for Subbasin 015 due not indicate any substantial difference in Green and Ampt attributes that would explain the larger value; however, Subbasin 015 possesses the lowest discharge per unit area of any of the USGS regression results, as shown in **Table 7** and **Figure 2**.

Table 7 USGS Baseline Comparison

HEC-HMS ID	100-year Peak Flows					
	USGS Regression (Baseline)		Curve Number		G&A (Top 3" Horizon)	
	Value (cfs)	% Baseline	Value (cfs)	% Baseline	Value (cfs)	% Baseline
005	341.5	100.0%	433	126.7%	389	113.8%
010	250.1	100.0%	198	79.0%	305	122.1%
015	491.2	100.0%	580	118.1%	816	166.1%
020	258.3	100.0%	222	86.1%	309	119.8%
025	737.9	100.0%	511	69.2%	754	102.2%
030	420.8	100.0%	511	121.5%	589	140.0%
035	213	100.0%	284	133.3%	297	139.2%
040	278.2	100.0%	401	144.0%	414	148.6%
045	293.1	100.0%	404	137.9%	399	136.0%
050	168	100.0%	159	94.3%	182	108.4%
055	265.9	100.0%	243	91.2%	343	128.8%

Based upon these unit discharge values, the unit discharge for Subbasin 015 is within a normal range for the Green and Ampt calculations and the relative increase over the USGS regression discharge is due in part to the low USGS regression unit discharge for that subbasin.

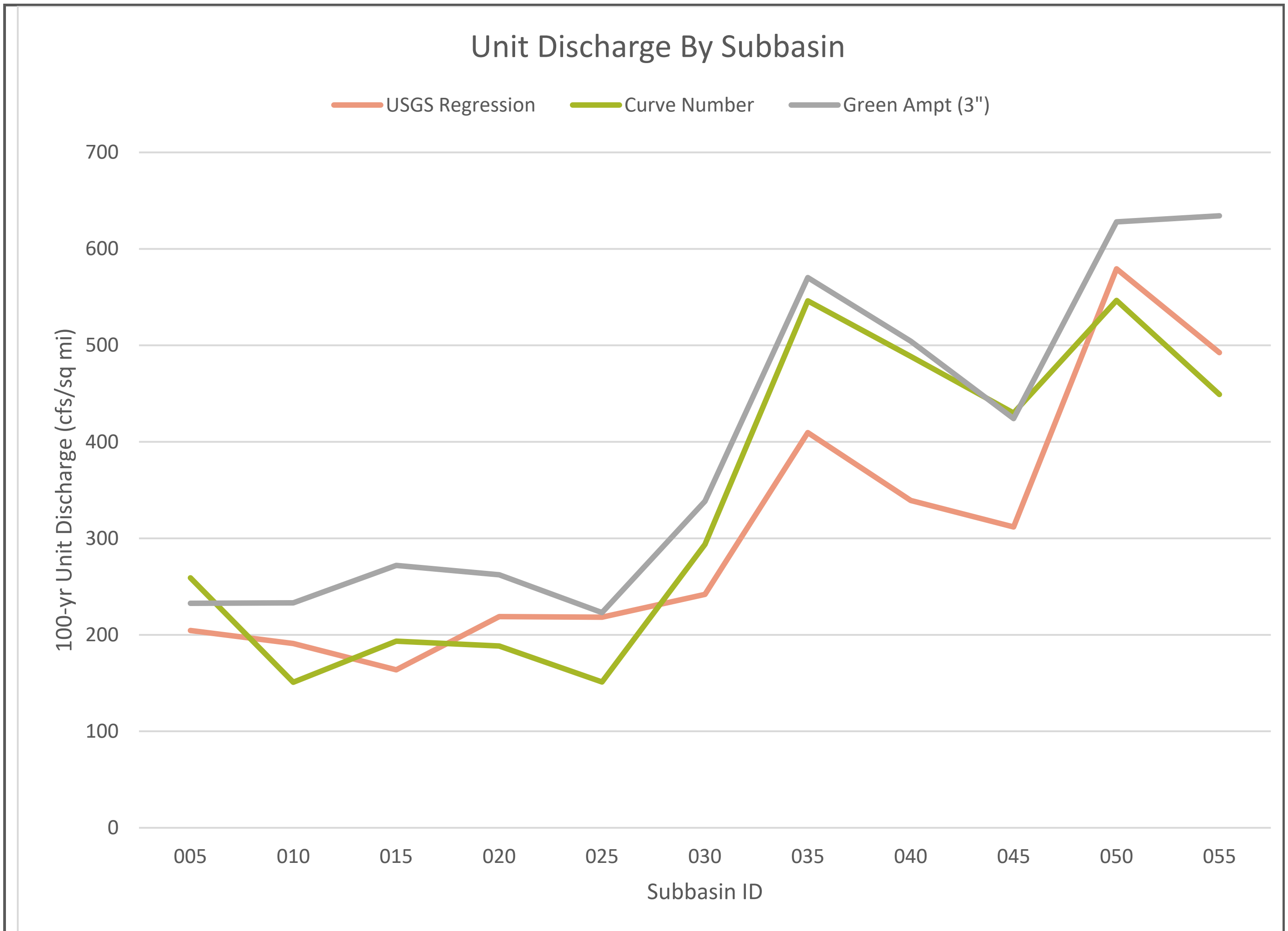

Figure 2 Unit Discharge vs Subbasin

Figure 3 illustrates the unit discharge relationships versus drainage area for all of the subbasins within the project area; USGS is generally exhibits the lowest unit discharge of the three methods evaluated.

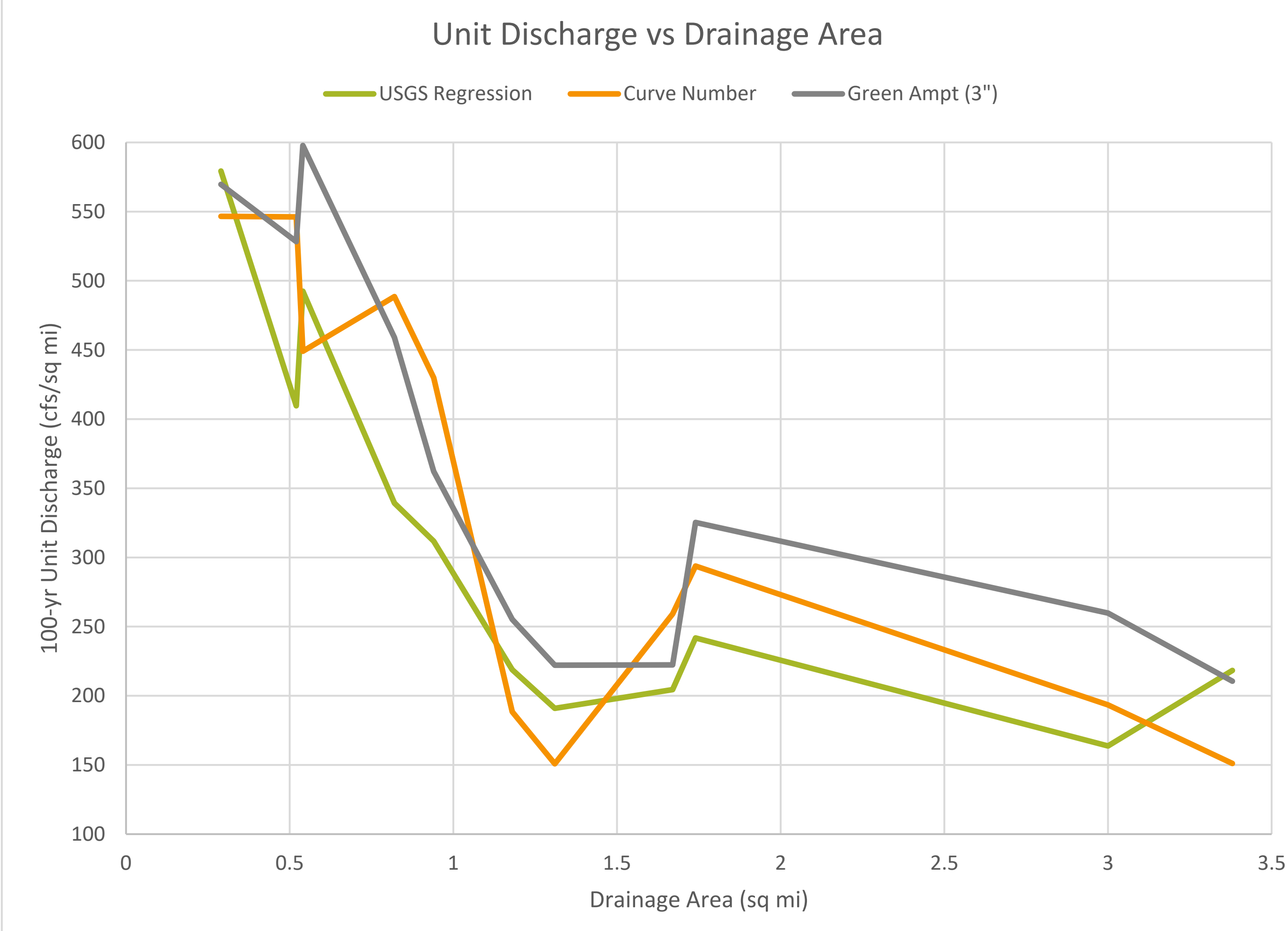

Figure 3 Unit Discharge vs Drainage Area

Also, of note is that the original curve number analysis did not separately include subbasin imperviousness, which HEC-HMS supports for curve number infiltration, although land use was utilized in determination of the curve numbers. Imperviousness values shown in **Table 1** correlate well to high unit discharges shown in **Table 8** for the Green and Ampt methodology.

An additional difference between the original curve number methodology and the applied Green and Ampt methodology is the inclusion of a vegetation cover adjustment. Curve number methodology allows for adjustment of the applied curve number based upon both the “type” and “quality” of vegetation present. While some agencies incorporate a vegetative cover adjustment with Green and Ampt infiltration (Flood Control District of Maricopa County, 2018), which would act to decrease runoff, no vegetative cover adjustment has been incorporated in this analysis.

Table 8 100-year Discharges Per Unit Area

HEC-HMS ID	Subbasin Area (sq mi)	100-yr Unit Discharges (cfs/sq mi)		
		USGS Regression (Baseline)	Curve Number	G&A (Top 3" Horizons)
005	1.67	204	259	233
010	1.31	191	151	233
015	3	164	193	272
020	1.18	219	188	262
025	3.38	218	151	223
030	1.74	242	294	339
035	0.52	410	546	570
040	0.82	339	489	504
045	0.94	312	430	424
050	0.29	579	547	628
055	0.54	492	449	634

6. Additional Considerations

Attempts have been made in this document to provide an “apples to apples” comparison of Green and Ampt methodology with NRCS Curve Number methodology. However, there are additional considerations for a detailed synthetic hydrologic analysis that should be noted.

As discussed previously, vegetative cover effects are embedded within the curve number analysis but are not considered in the included Green and Ampt analyses. Beyond vegetative cover, no consideration has been included in either Green and Ampt or Curve Number analyses to account for initial abstraction in the form of surface storage loss. Surface storage loss is typically implemented within HEC-HMS using the “Surface” component of a subbasin object and allows an initial and maximum surface storage depth to be included in the analysis. Additional information and guidance regarding “surface storage” and selection of appropriate initial abstraction values may be found in the ADOT Hydrology Manual (Arizona Department of Transportation, 2014).

7. References

Arizona Department of Transportation, 2014, Highway Drainage Design Manual Hydrology, prepared by JE Fuller Hydrology and Geomorphology, Inc.

Flood Control District of Maricopa County, 2018, Drainage Design Manual for Maricopa County, Hydrology.

Kimley Horn and Associates, Inc., 2011. Geiger Grade Road Realignment Project. Washoe County Regional Transportation Commission.

Mohave County Flood Control District, May 2018. Drainage Design Manual for Mohave County, 3rd Edition.

United States Geological Survey, 1999. The National Flood-Frequency Program -- Methods for Estimating Flood Magnitude and Frequency in Rural Areas in Nevada. US Department of the Interior, US Geological Survey.

Appendix A. Baseline Study Documentation

FINAL TECHNICAL MEMORANDUM

GEIGER GRADE ROAD REALIGNMENT PROJECT

TO: JULIE MASTERPOOL, RTC
JEFF LERUD, NDOT | JOSELIO RAMIREZ, NDOT
KIMBLE CORBRIDGE, WASHOE COUNTY | WALT WEST, WASHOE COUNTY
JOE COUDRIET, CITY OF RENO | BILL GALL, CITY OF RENO

FROM: LAURIE MARIN, KHA | RANDY CARROLL, KHA | TONY DOUCETTE, KHA

DATE: NOVEMBER 29, 2011

RE: **BAILEY CANYON CREEK HYDROLOGIC ANALYSIS**

INTRODUCTION:

The Regional Transportation Commission of Washoe County contracted with Kimley-Horn and Associates, Inc. to provide engineering services for the design of the Geiger Grade Realignment Project. Geiger Grade Road is located in Washoe County, Nevada, near the southern limits of the City of Reno. Also known as State Route 341, Geiger Grade Road connects State Route 430 (US 395) and Virginia City. Location and Vicinity Maps are provided in **Figure 1** and **Figure 2**. The Geiger Grade Realignment Project includes the final design and preparation of construction documents for the realignment of Geiger Grade Road in a westerly direction at its intersection with Toll Road/Equestrian Road to a new intersection with State Route 430 (US 395). The realignment will include a new bridge structure across Steamboat Creek, a roundabout at the intersection of the realigned Geiger Grade Road and State Route 430 (US 395), and modification of the signalized intersection of Geiger Grade Road with Toll Road and Equestrian Road to a two-lane roundabout. Improvements to the intersection of Geiger Grade Road with Toll Road/Equestrian Road include rainfall runoff conveyance facilities to accommodate Bailey Canyon Creek through the project, upstream of its confluence with Steamboat Creek.

PURPOSE:

The purpose of this technical memorandum is to document the methodology and results for the hydrologic analysis of Bailey Canyon Creek as part of the Geiger Grade Road Realignment Project. This technical memorandum will provide the hydrologic basis for the flow rate to be used for the design of rainfall runoff conveyance structures at the two proposed crossings of Geiger Grade Road over Bailey Canyon Creek near the Geiger Grade Road and Toll Road intersection.

BACKGROUND:

Bailey Canyon Creek is a tributary to Steamboat Creek with a contributing watershed of approximately 15 square miles. The watershed begins in the Virginia Range east of the Steamboat Valley and joins Steamboat Creek south of the existing intersection of Geiger Grade Road (SR 341), Mt. Rose Highway (SR 431) and Virginia Street (US 395/SR 430). Steamboat Creek joins the Truckee River at a confluence east of Reno and Sparks, Nevada.

The existing Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Bailey Canyon Creek is dated 2009 and provides a 100-year effective flow rate of 1,120 cubic feet per second (cfs). Several hydrologic investigations have been completed for Bailey Canyon Creek over the past 15 years. The studies report 100-year flow rates for Bailey Canyon Creek ranging between 2,000 and 3,700 cfs. Previous hydrology models used various methodologies and assumptions. Given the wide range of flow rates and varying development assumptions, Washoe County and City of Reno recommended that Kimley-Horn conduct an independent hydrologic analysis based on existing conditions and current Washoe County methodology. The outcome of the hydrologic model will be a design flow rate for the two proposed crossings of Bailey Canyon Creek.

HYDROLOGIC PARAMETER DEVELOPMENT:

The procedures and methodology discussed in this technical memorandum primarily reference the *Truckee Meadows Regional Drainage Manual (TMRDM)*, dated April 30, 2009.

FIELD INVESTIGATIONS:

Kimley-Horn conducted a field investigation of the Bailey Canyon Creek Watershed on September 12-13, 2011. The purpose of the field investigation was to observe existing soil conditions, vegetation, land use, and creek roughness in the upper, undeveloped watershed. Observations were used to determine runoff parameters for contributing subbasins and routing reaches of Bailey Canyon Creek. Additionally, Kimley-Horn staff followed Bailey Canyon Creek through the developed portion of the downstream watershed and observed and measured existing drainage features and flow-split locations to aid in subbasin delineations. Photographs of selected locations are provided in Attachment 1.

DRAINAGE AREAS:

The Bailey Canyon Creek watershed was delineated using the "USA Topographic Maps" online GIS server available from ArcGIS at http://goto.arcgisonline.com/maps/USA_Topo_Maps and available 2-ft topographic contour data from Washoe County. The "USA Topographic Maps" server consists of land cover imagery and detailed topographic maps for the United States. The map includes seamless, scanned images of United States Geological Survey (USGS) paper topographic maps at 1:100,000 and 1:24,000 scales. The Bailey Canyon Creek watershed is contained within the following 7.5 minute USGS Quadrangle Sheets:

- Steamboat, NV (dated 1994)
- Virginia City, NV (dated 1994)

Supplemental 2-ft contour data from Washoe County was provided for the following sections (with dates in parenthesis):

- Township 17 North, Range 20 East Section 3 (2007)
- Township 18 North, Range 20 East Sections 27 (2006), 28, 33, and 34 (2007)

Subbasin boundaries, flowpaths and routing reaches are provided in Figure 3. A summary of the contributing subbasin areas is provided in Table 1.

Table 1. Subbasin Drainage Areas

Subbasin	Subbasin Area [mi^2]
005	1.67
010	1.31
015	3.00
020	1.18
025	3.38
030	1.74
035	0.52
040	0.82
045	0.94
050	0.29
055	0.54
Total	15.39

PRECIPITATION:

National Oceanic and Atmospheric Administration Atlas 14 (NOAA Atlas 14) point precipitation frequency estimates for the centroid of the Bailey Canyon Creek watershed are provided in Attachment 2. The tabular report provides estimates with 90% confidence intervals for durations ranging from 5-minutes to 60-days across recurrence intervals from 1-year to 1,000 years. This technical memorandum evaluates the 100-year, 24-hour storm event.

UNIT HYDROGRAPH:

The Soil Conservation Service (SCS) Unit Hydrograph method was used for Bailey Canyon Creek. The SCS Unit Hydrograph methodology is dimensionless and computes rainfall excess hydrographs for a unit amount of rainfall applied uniformly over a subbasin for a unit duration. The rainfall excess hydrographs are transformed to a subbasin hydrograph by superimposing the excess hydrographs lagged by the unit duration. The shape of the SCS Unit Hydrograph is curvilinear and based on the time-to-peak (T_p) and the point of inflection of the falling leg of the unit hydrograph.

Input data for the SCS Unit Hydrograph consists of the single parameter TLAG, defined as the lag time in hours between the center of mass of rainfall excess and the peak of the unit hydrograph. Calculation of TLAG depends on the size of the drainage basin. For small drainage basins with a contributing area of less than one square mile, and basin slopes less than ten percent, the lag time is controlled by initial overland flow time and related to the time of concentration (t_c). For drainage basins greater than one square mile and with basin slopes equal to or greater than ten percent, the lag time and time of concentration is generally governed by the concentrated flow travel time rather than initial overland flow time. The lag time for larger, steeper basins can be computed as follows:

$$TLAG = 22.1 K_n \left(\frac{L L_c}{S^{0.5}} \right)^{0.33}$$

Where K_n = Roughness factor for the basin channels (from Table 703 of the City of Sparks HCDDM)
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)

The representative slope of the longest watercourse was computed by the Mean Basin Slope (S) methodology from the City of Tucson *Standards Manual for Drainage Design and Floodplain Management* as follows:

$$S = \left(\frac{L_c}{G}\right)^2$$

Where S = mean basin slope (feet per foot)
L_c = Length of hydraulically longest watercourse (ft)

$$G = \left(\frac{\Delta L_1^3}{\Delta H_1}\right)^{1/2} + \left(\frac{\Delta L_2^3}{\Delta H_2}\right)^{1/2} + \left(\frac{\Delta L_3^3}{\Delta H_3}\right)^{1/2} + \left(\frac{\Delta L_4^3}{\Delta H_4}\right)^{1/2}$$

ΔL = Change in length factor (ft)
ΔH = Change in elevation factor (ft)

The City of Tucson mean basin slope methodology is appropriate for mountainous watersheds because of the varying slopes within the watershed (steep and mountainous in the upper portions compared to the flatter valleys) and has been previously approved for hydrology studies in Nevada.

TLAG calculations for Bailey Canyon Creek are provided in Attachment 3, and a summary of the TLAG results is provided in Table 2.

Table 2. TLAG Summary Table

Subbasin	K_n [---]	L [mi]	L_c [mi]	S [ft/mi]	TLAG [hrs]
005	0.12	2.64	1.22	329	1.50
010	0.12	2.78	1.42	617	1.45
015	0.12	2.64	0.98	693	1.24
020	0.12	2.36	0.89	360	1.28
025	0.12	2.99	1.66	615	1.56
030	0.10	2.29	1.03	603	1.02
035	0.08	1.41	0.50	395	0.59
040	0.07	2.36	1.09	620	0.73
045	0.07	2.71	1.44	510	0.87
050	0.05	1.25	0.74	81	0.52
055	0.05	1.89	1.02	133	0.61

RAINFALL LOSSES:

Rainfall losses were computed using the SCS Curve Number methodology. The curve number methodology relates soil cover, land use, vegetation and antecedent moisture conditions to a runoff curve number used to quantify excess runoff in response to precipitation.

Determinations of the hydrologic soil group and land use parameters for curve number calculations are discussed in the "Soils" and "Land Use" sections of this technical memorandum, and the antecedent moisture condition for the Washoe County area is AMC-II. With these parameters, curve numbers were assigned to the Bailey Canyon Creek subbasin areas from Table 702 of the *TMRDM*. Because of the large subbasin sizes, multiple hydrologic soil groups, land uses and vegetative cover conditions occur in some basins. As a result, a composite curve number was computed for each subbasin that provides an area weighted average. Composite curve number calculations are provided in Attachment 4, and a summary is provided in Table 3.

Table 3. Composite Curve Number Summary Table

Subbasin	Composite CN
005	80
010	69
015	71
020	71
025	70
030	76
035	81
040	82
045	82
050	79
055	77

SOILS:

The SCS (now the Natural Resources Conservation Service, or NRCS) established a soil classification system for soil survey maps across the United States that provides the hydrologic soil groups (A, B, C or D). The soil survey areas used for Bailey Canyon Creek include:

- NV 628 for Washoe County, Nevada, South Part, dated 11/2/2009
- NV 772 for Storey County Area, Nevada, dated 11/9/2009

A map of the soil groups within the Bailey Canyon Creek watershed is provided in Figure 4, and a summary table of soil group areas by subbasins is provided in Attachment 5.

LAND USE:

Washoe County provided land use shape files for the *South Valleys Area Plan* (September, 2010) and *Southeast Truckee Meadows Area Plan* (July, 2011) components of the Washoe County Master Plan. Land use data is typically based on zoning, general planning information and existing topography. Areas within the Bailey Canyon Creek watershed that did not have a land use assigned from the Master Plan were designated as open space and verified with recent aerial mapping. A land use map is provided in Figure 5, and a summary of land use codes and reference maps are provided in Attachment 6.

CHANNEL ROUTING:

The Muskingum-Cunge routing methodology was used to route subbasin hydrographs. The channel routing technique accounts for hydrograph diffusion based on the physical channel properties and the inflowing hydrograph. Muskingum-Cunge can be used for channels with standard prismatic shapes or with irregular cross sections. Data inputs consist of a representative channel cross section, routing reach length, Manning's roughness coefficients, and channel bed slope. Routing reaches are illustrated in Figure 3, and input parameters are provided in Attachment 7 and summarized in Table 4.

Table 4. Muskingum-Cunge Routing Input Data Summary Table

Routing Reach	Length [ft]	Upstream Elevation [ft]	Downstream Elevation [ft]	Slope [ft/ft]	Manning's n	Bottom Width [ft]	Side Slopes [XX:1]
R015	3,529	5720	5560	0.045	0.073	100	2
R025	9,817	5560	5120	0.045	0.078	50	2
R030	4,069	5120	4960	0.039	0.100	25	3
R035	3,714	4960	4834	0.034	0.108	70	4
R040	3,539	4834	4730	0.029	0.073	30	50
R045	1,734	4730	4690	0.023	0.086	30	50
R050	5,748	4690	4588	0.018	0.053	20	2
R055	9,490	4834	4588	0.026	0.045	8	10

FLOW SPLITS:

Bailey Canyon Creek Crosses Toll Road southwest of the intersection of Toll Road with Ravazza Road in two 8-ft by 5-ft concrete box culverts. During high flow events when flow depths exceed the existing roadway elevation, flow is divided at this crossing. A portion of the runoff crosses under Toll Road in the box culverts, and the remainder overtops the road. The majority of the flow that overtops the road continues in Bailey Canyon Creek, however, some does split from the channel and flow down Toll Road. The capacity of the box culverts was evaluated using the Federal Highway Administration (FHWA) HY-8 version 7.2 culvert modeling software and used to create a rating curve for the crossing. Supporting documentation for the flow split is provided in Attachment 8.

A second flow split location was evaluated at Geiger Grade Road between Western Skies Drive and High Chaparral Way where Bailey Canyon Creek flows adjacent to Geiger Grade Road. Normal depth analysis shows that a breakout does not occur unless the flow rate exceeds 3,288 cfs. The 100-year, 24-hour runoff calculated in that area is 2,179 cfs. Supporting Flowmaster cross sections and input data are included in Attachment 8.

HYDROLOGIC MODEL:

The United States Army Corps of Engineers (USACE) Hydrologic Engineering Center HEC-1 Flood Hydrograph Package was used to calculate runoff for the Bailey Canyon Creek Watershed using the parameters discussed in this technical memorandum. HEC-1 output results are included in Attachment 9.

RESULTS:

Bailey Canyon Creek crosses the proposed Geiger Grade Road Realignment in two locations: first under the Toll Road approach south of the proposed roundabout, and again under Geiger Grade Road west of the proposed roundabout. The two crossings are illustrated in Attachment 10. Due to the flow split upstream where Bailey Canyon Creek crosses Toll Road near the intersection of Toll Road and Ravazza road, the design flow rates for each crossing are different. The first crossing under Toll Road includes flow that continued in Bailey Canyon Creek from the flow split and is represented in the hydrologic model by CP050. The second crossing under Geiger Grade Road includes both the flow from Bailey Canyon Creek, and the flow that splits to Toll Road and continues along Toll Road to the intersection. The second crossing is represented in the hydrologic model by CP055. The split flow routed along Toll Road (represented by R055) flows along the road and in the ditches on both sides of the road. Since the ditch on the east side of Toll Road crosses under the first crossing, approximately half of the split flow routed along Toll Road is added to the first crossing. A summary of the design flow rates is provided in Table 5.

Table 5. Design Flow Rates Summary Table

HEC-1 ID	Crossing 1 Under Toll Road	Crossing 2 Under Geiger Grade Road
CP050	2,179	-
1/2 of R055	161	-
CP055	-	2,541
Design Flow Rate	2,340	2,541

REFERENCES:

1. ArcGIS Online servers. http://goto.arcgisonline.com/maps/USA_Topo_Maps. 2011.
2. City of Sparks. "Hydrologic Criteria and Drainage Design Manual". June 30, 1998.
3. City of Tucson. "Standards Manual for Drainage Design and Floodplain Management". July, 1998.
4. United States Army Corps of Engineers Hydrologic Engineering Center. "HEC-1 Flood Hydrograph Package User's Manual". June, 1998.
5. Washoe County Department of Community Development. "South Valleys Area Plan" September, 2010.
6. Washoe County Department of Community Development. "Southeast Truckee Meadows Area Plan". July, 2011
7. Washoe County Department of Community Development. "Washoe County Master Plan – Land use and Transportation Element". September, 2010.
8. Washoe County Department of Public Works. "Truckee Meadows Regional Drainage Manual". April 30, 2009.

FIGURES:

1. Location Map
2. Vicinity Map
3. Hydrology Map
4. Soils Map
5. Land Use Map

ATTACHMENTS:

1. Field Photographs
2. NOAA Atlas 14 Rainfall
3. TLAG Calculations
4. Composite Curve Number Calculations
5. Soil Parameters
6. Land Use Parameters
7. Muskingum-Cunge Channel Routing
8. Flow Split Calculations
9. HEC-1 Model Output
10. Geiger Grade Road Realignment Exhibit

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1. Location Map
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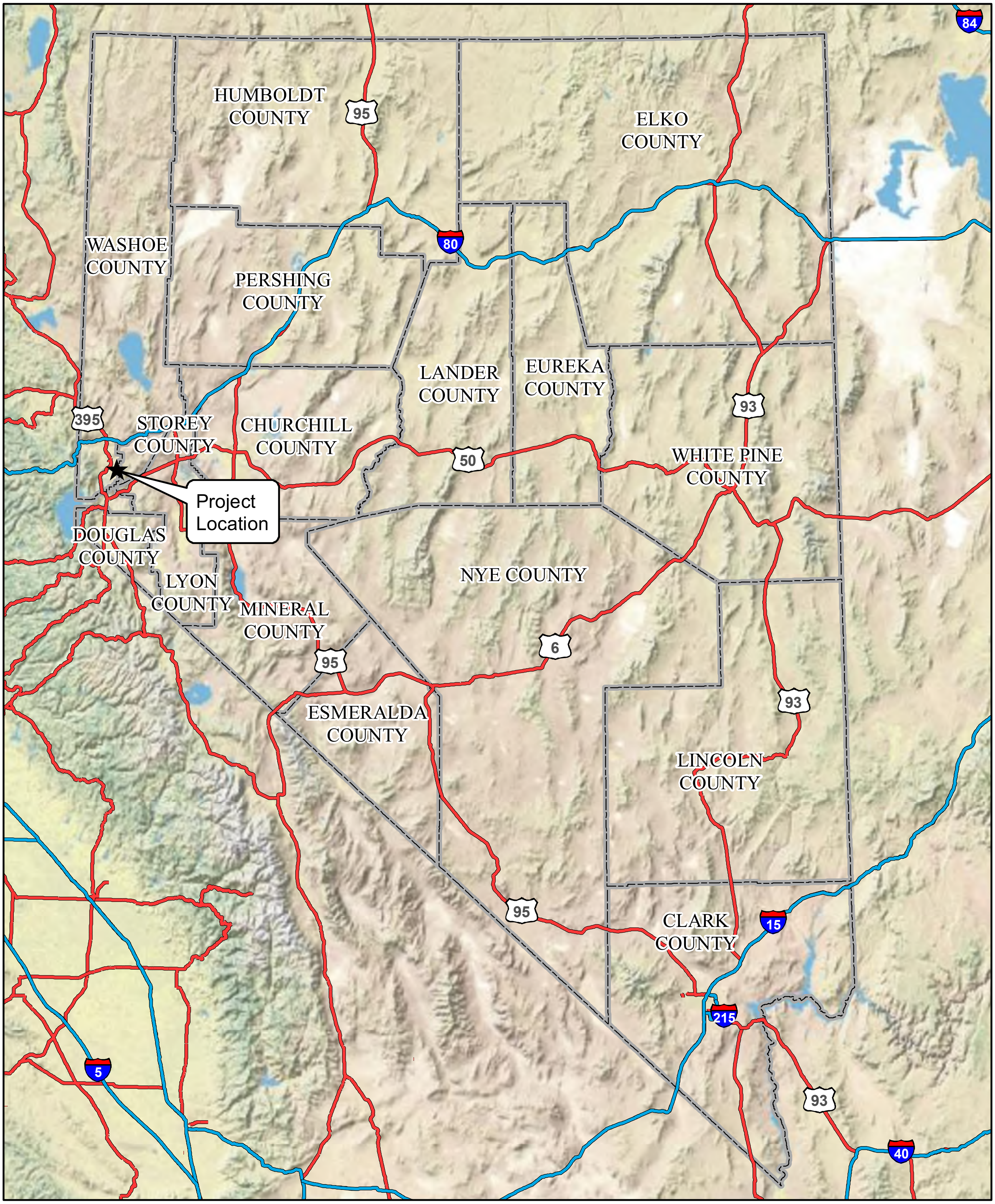
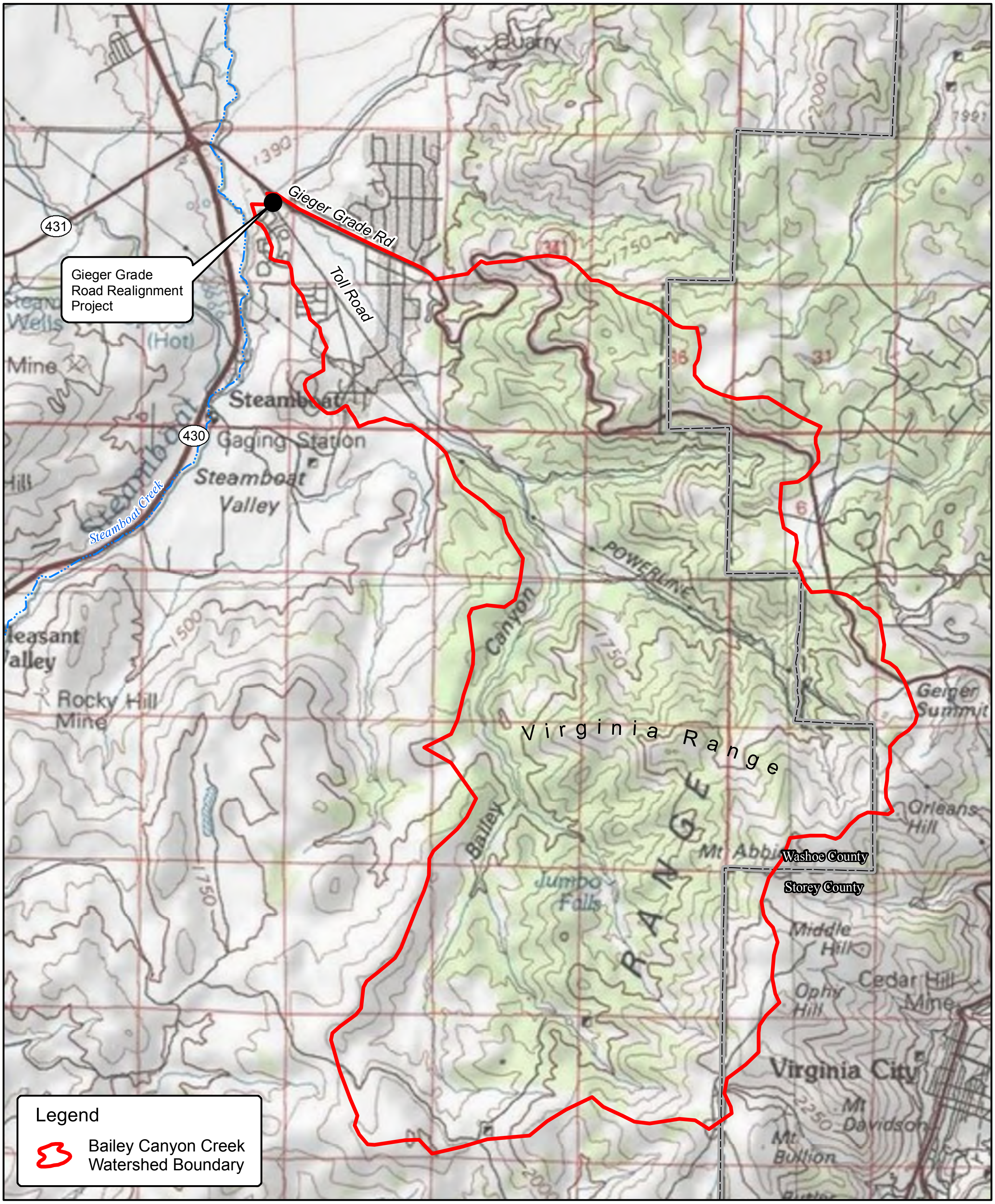


Kimley-Horn and Associates, Inc.

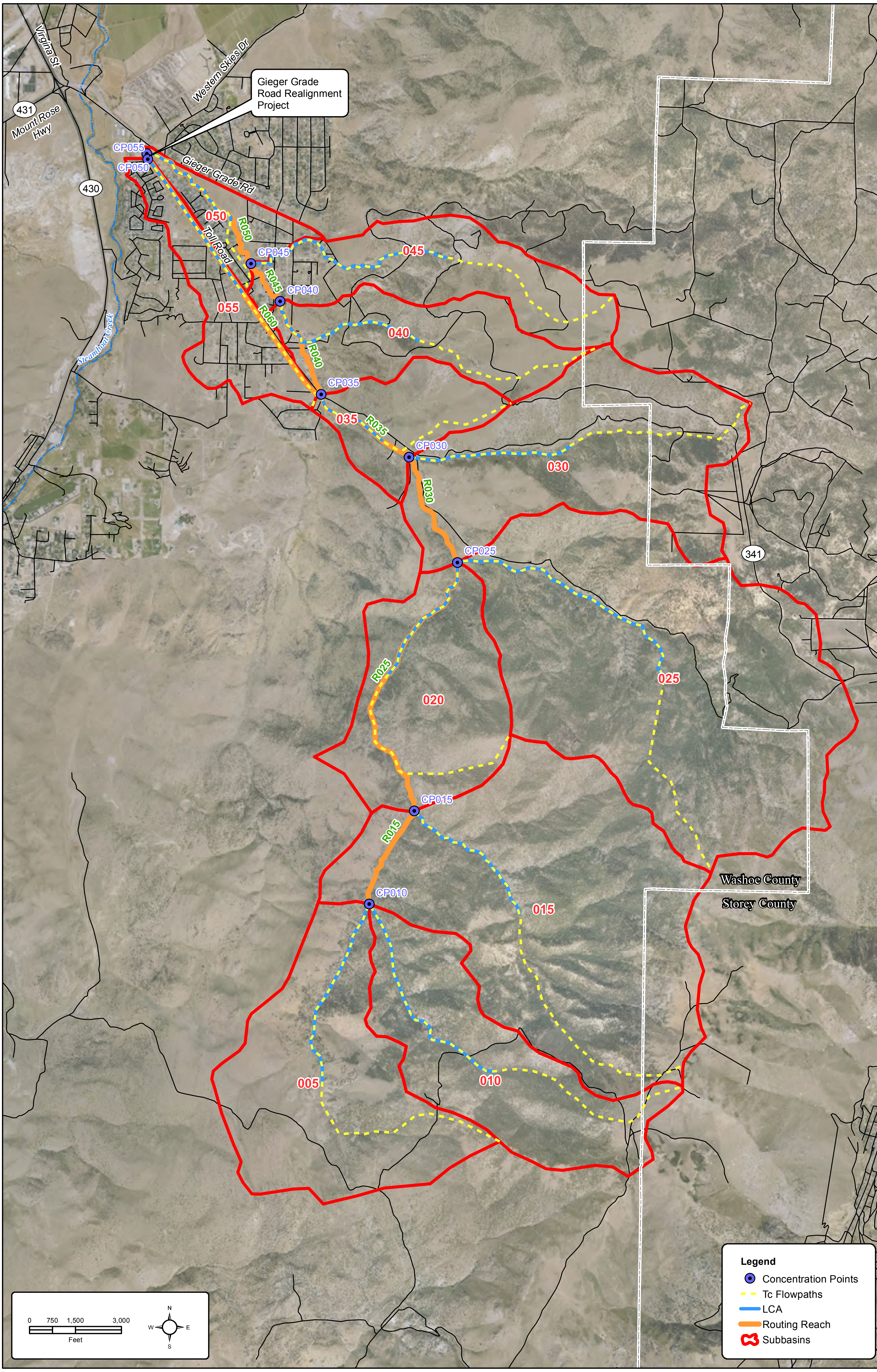
Gieger Grade Road Realignment
Bailey Canyon Creek Hydrologic Analysis

Washoe, County

Figure 1. Location Map

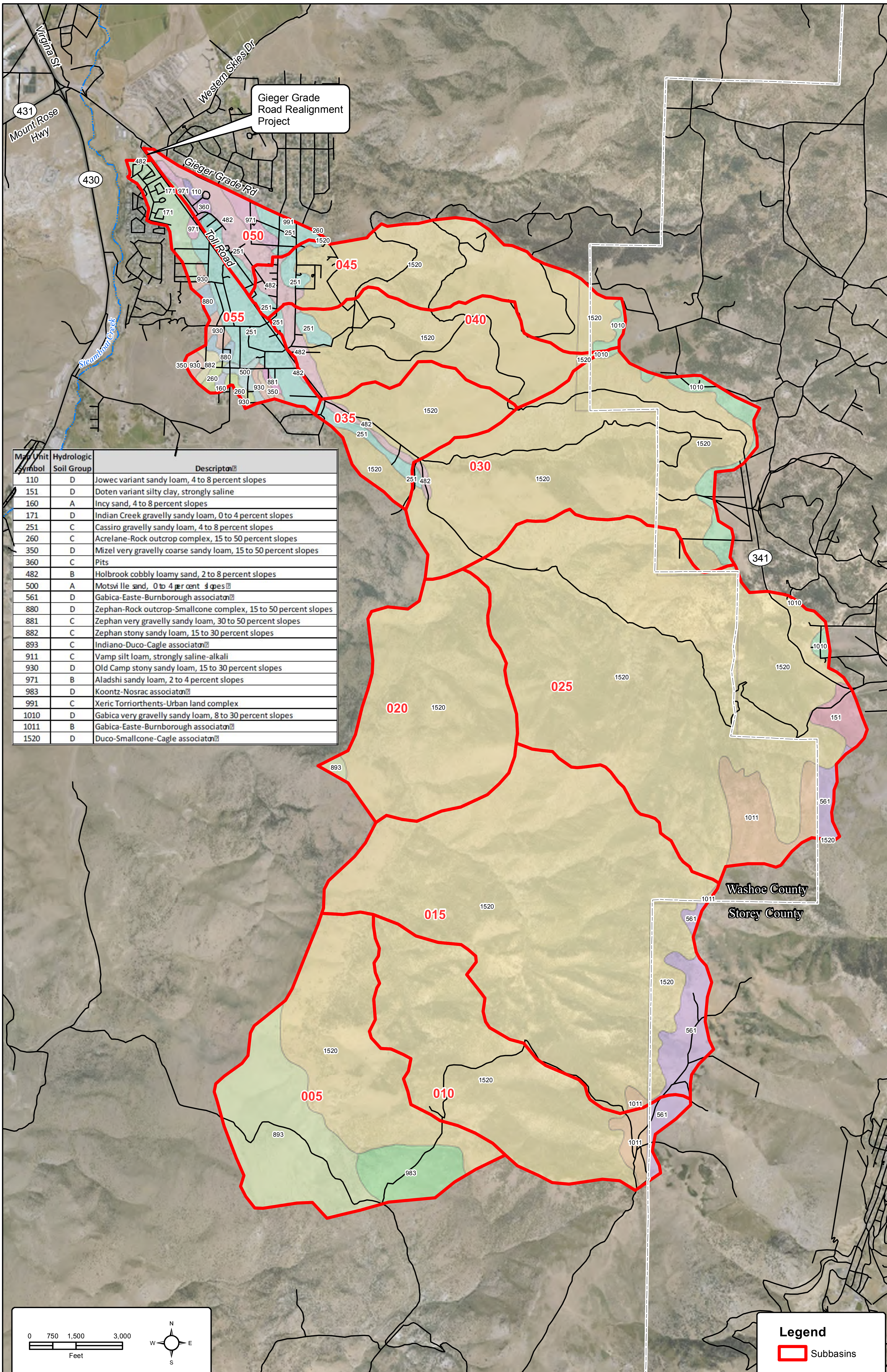


0 1,250 2,500 5,000 Feet; Kimley-Horn and Associates, Inc.	**Gieger Grade Road Realignment** **Bailey Canyon Creek Hydrologic Analysis**	**Washoe, County**
	Figure 2. Vicinity Map	



PROJECT NO. 092528005	Gieger Grade Road Realignment Bailey Canyon Creek Hydrologic Analysis Figure 3. Hydrology Map	SCALE(H):1"= 3000' SCALE(V): N/A	Kimley-Horn and Associates, Inc.
DRAWING NAME FIGURE03_HYDROLOGY.MXD		DESIGNED BY: TDD DRAWN BY: JAG CHECKED BY: LSM	Engineering, Planning and Environmental Consultants
		DATE: NOVEMBER 2011	5370 Kietzke Lane, Suite 201 Reno, NV 89511 (775) 787-7552

NO.	REVISION	BY	DATE	APPR.



Map Unit Symbol	Hydrologic Soil Group	Description
110	D	Jowec variant sandy loam, 4 to 8 percent slopes
151	D	Doten variant silty clay, strongly saline
160	A	Incy sand, 4 to 8 percent slopes
171	D	Indian Creek gravelly sandy loam, 0 to 4 percent slopes
251	C	Cassiro gravelly sandy loam, 4 to 8 percent slopes
260	C	Acrelane-Rock outcrop complex, 15 to 50 percent slopes
350	D	Mizel very gravelly coarse sandy loam, 15 to 50 percent slopes
360	C	Pits
482	B	Holbrook cobbly loamy sand, 2 to 8 percent slopes
500	A	Motsville sand, 0 to 4 percent slopes
561	D	Gabica-Easte-Burnborough association
880	D	Zephan-Rock outcrop-Smallcone complex, 15 to 50 percent slopes
881	C	Zephan very gravelly sandy loam, 30 to 50 percent slopes
882	C	Zephan stony sandy loam, 15 to 30 percent slopes
893	C	Indiano-Duco-Cagle association
911	C	Vamp silt loam, strongly saline-alkali
930	D	Old Camp stony sandy loam, 15 to 30 percent slopes
971	B	Aladshi sandy loam, 2 to 4 percent slopes
983	D	Koontz-Nosrac association
991	C	Xeric Torriorthents-Urban land complex
1010	D	Gabica very gravelly sandy loam, 8 to 30 percent slopes
1011	B	Gabica-Easte-Burnborough association
1520	D	Duco-Smallcone-Cagle association

PROJECT NO.
FIGURE04_SOILD.MXD
DRAWING NAME
092528005

Gieger Grade Road Realignment
Bailey Canyon Creek Hydrologic Analysis
Figure 4. Soils Map

SCALE(H):1"= 3000'
SCALE(V): N/A
DESIGNED BY: TDD
DRAWN BY: JAG
CHECKED BY: LSM
DATE: NOVEMBER 2011

Kimley-Horn and Associates, Inc.
Engineering, Planning and Environmental Consultants
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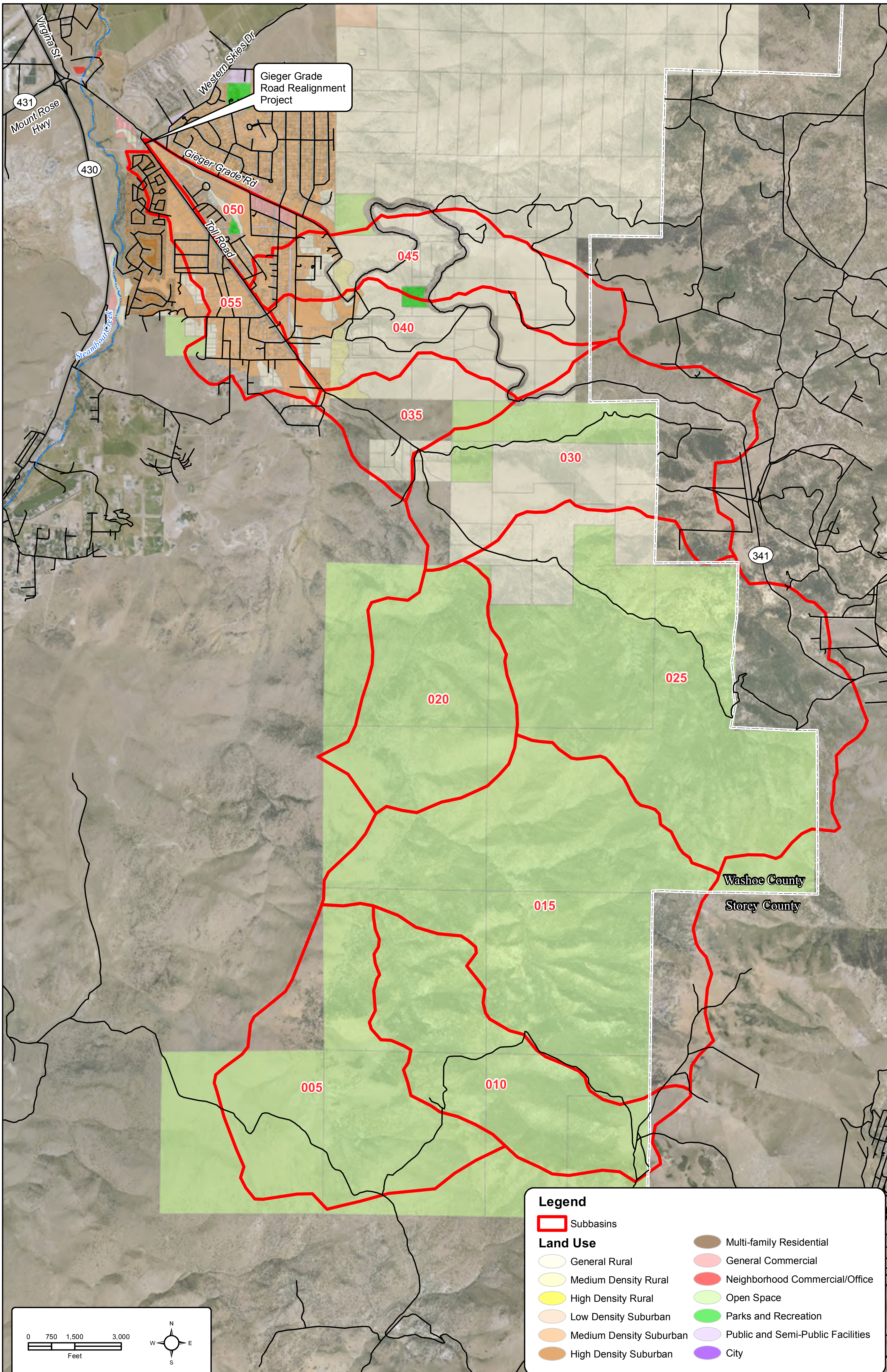
NO.	REVISION	BY	DATE	APPR.



PROJECT NO.
FIGURES_LANDUSE.MXD
DRAWING NAME
092528005

Gieger Grade Road Realignment
Bailey Canyon Creek Hydrologic Analysis
Figure 5. Land Use Map

SCALE(H):1"= 3000'
SCALE(V): N/A
DESIGNED BY: TDD
DRAWN BY: JAG
CHECKED BY: LSM
DATE: NOVEMBER 2011

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Engineering, Planning and Environmental Consultants
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NO.	REVISION	BY	DATE	APPR.

ATTACHMENTS:

1. Field Photographs
2. NOAA Atlas 14 Rainfall
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8. Flow Split Calculations
9. HEC-1 Model Output
10. Geiger Grade Road Realignment Exhibit

ATTACHMENT 1: FIELD PHOTOGRAPHS

At the top of the Geiger Summit, the eastern boundary of the Bailey Canyon Creek Watershed.

Typical vegetative cover high in the Bailey Canyon Creek Watershed

Slopes and vegetative cover along Geiger Grade Road

Close up view of typical vegetative cover in the higher elevations

Cover conditions of the mid-elevations of the Bailey Canyon Creek Watershed

Low elevation cover and slopes along Geiger Grade Road

Low elevation cover and slopes

Typical vegetation in Bailey Canyon Creek adjacent to Bain Spring Road

Bailey Canyon Creek adjacent to Toll Road and downstream of Bain Spring Road

Dual 8'x5' concrete box culverts at Bailey Canyon Creek crossing under Toll Road near Ravazza Road

12'x5' concrete box culvert at Bailey Canyon Creek crossing under Kivett Lane

Roadside ditch along south side of Toll Road (looking west)

ATTACHMENT 2: NOAA ATLAS 14 RAINFALL

NOAA Atlas 14, Volume 1, Version 5
Location name: Reno, Nevada, US*
Coordinates: 39.3550, -119.6890
Elevation: 5641ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval(years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.111** (0.095-0.131)	**0.138** (0.119-0.164)	**0.184** (0.157-0.218)	**0.226** (0.191-0.267)	**0.295** (0.242-0.350)	**0.357** (0.284-0.429)	**0.430** (0.332-0.524)	**0.519** (0.384-0.645)	**0.663** (0.461-0.847)	**0.795** (0.525-1.04)
10-min	**0.169** (0.145-0.199)	**0.210** (0.181-0.249)	**0.280** (0.239-0.332)	**0.344** (0.291-0.407)	**0.448** (0.368-0.533)	**0.543** (0.432-0.652)	**0.655** (0.505-0.797)	**0.790** (0.584-0.981)	**1.01** (0.701-1.29)	**1.21** (0.799-1.58)
15-min	**0.209** (0.180-0.247)	**0.261** (0.224-0.309)	**0.347** (0.296-0.411)	**0.426** (0.360-0.504)	**0.556** (0.456-0.661)	**0.673** (0.536-0.809)	**0.812** (0.626-0.987)	**0.979** (0.724-1.22)	**1.25** (0.869-1.60)	**1.50** (0.991-1.96)
30-min	**0.281** (0.243-0.332)	**0.351** (0.302-0.416)	**0.467** (0.398-0.553)	**0.574** (0.485-0.679)	**0.749** (0.615-0.890)	**0.906** (0.722-1.09)	**1.09** (0.842-1.33)	**1.32** (0.975-1.64)	**1.68** (1.17-2.15)	**2.02** (1.33-2.64)
60-min	**0.348** (0.300-0.411)	**0.434** (0.374-0.515)	**0.578** (0.492-0.685)	**0.710** (0.601-0.840)	**0.926** (0.761-1.10)	**1.12** (0.893-1.35)	**1.35** (1.04-1.65)	**1.63** (1.21-2.03)	**2.08** (1.45-2.66)	**2.50** (1.65-3.27)
2-hr	**0.462** (0.407-0.533)	**0.575** (0.508-0.663)	**0.731** (0.639-0.843)	**0.865** (0.748-0.998)	**1.07** (0.899-1.24)	**1.25** (1.03-1.46)	**1.45** (1.16-1.73)	**1.71** (1.33-2.06)	**2.15** (1.60-2.68)	**2.57** (1.84-3.27)
3-hr	**0.561** (0.498-0.636)	**0.698** (0.626-0.796)	**0.869** (0.770-0.989)	**1.01** (0.886-1.15)	**1.20** (1.04-1.38)	**1.37** (1.17-1.58)	**1.56** (1.30-1.83)	**1.81** (1.48-2.15)	**2.24** (1.78-2.72)	**2.64** (2.05-3.29)
6-hr	**0.808** (0.719-0.910)	**1.01** (0.899-1.14)	**1.24** (1.10-1.40)	**1.42** (1.25-1.61)	**1.66** (1.44-1.89)	**1.85** (1.58-2.12)	**2.03** (1.71-2.35)	**2.25** (1.86-2.64)	**2.58** (2.09-3.08)	**2.90** (2.31-3.52)
12-hr	**1.10** (0.976-1.24)	**1.38** (1.23-1.56)	**1.73** (1.53-1.96)	**2.01** (1.76-2.28)	**2.38** (2.06-2.71)	**2.66** (2.28-3.06)	**2.95** (2.48-3.43)	**3.23** (2.68-3.81)	**3.61** (2.91-4.34)	**3.92** (3.09-4.78)
24-hr	**1.39** (1.26-1.55)	**1.75** (1.59-1.95)	**2.22** (2.01-2.48)	**2.61** (2.35-2.90)	**3.14** (2.81-3.50)	**3.57** (3.17-3.98)	**4.02** (3.53-4.51)	**4.48** (3.90-5.07)	**5.12** (4.38-5.85)	**5.64** (4.75-6.51)
2-day	**1.71** (1.53-1.93)	**2.16** (1.93-2.43)	**2.77** (2.47-3.12)	**3.27** (2.91-3.69)	**3.98** (3.50-4.50)	**4.55** (3.97-5.16)	**5.15** (4.44-5.89)	**5.79** (4.94-6.68)	**6.68** (5.58-7.80)	**7.40** (6.07-8.76)
3-day	**1.90** (1.71-2.15)	**2.41** (2.16-2.72)	**3.13** (2.80-3.52)	**3.71** (3.31-4.19)	**4.55** (4.01-5.14)	**5.22** (4.56-5.92)	**5.95** (5.14-6.78)	**6.72** (5.73-7.71)	**7.81** (6.52-9.07)	**8.71** (7.14-10.2)
4-day	**2.10** (1.88-2.37)	**2.67** (2.39-3.01)	**3.48** (3.12-3.93)	**4.16** (3.70-4.68)	**5.12** (4.52-5.77)	**5.90** (5.16-6.67)	**6.75** (5.83-7.66)	**7.65** (6.52-8.74)	**8.94** (7.47-10.3)	**10.0** (8.21-11.7)
7-day	**2.49** (2.21-2.82)	**3.17** (2.81-3.60)	**4.18** (3.69-4.74)	**4.99** (4.40-5.67)	**6.14** (5.37-7.00)	**7.07** (6.13-8.08)	**8.07** (6.91-9.25)	**9.12** (7.73-10.5)	**10.6** (8.84-12.4)	**11.8** (9.71-14.0)
10-day	**2.80** (2.47-3.18)	**3.58** (3.17-4.07)	**4.72** (4.17-5.37)	**5.62** (4.94-6.40)	**6.88** (6.00-7.86)	**7.88** (6.82-9.02)	**8.94** (7.66-10.3)	**10.0** (8.51-11.6)	**11.6** (9.65-13.5)	**12.8** (10.5-15.0)
20-day	**3.57** (3.18-4.04)	**4.56** (4.06-5.17)	**5.98** (5.31-6.77)	**7.08** (6.27-8.01)	**8.57** (7.53-9.71)	**9.72** (8.48-11.1)	**10.9** (9.44-12.5)	**12.1** (10.4-13.9)	**13.8** (11.6-16.0)	**15.1** (12.6-17.7)
30-day	**4.22** (3.75-4.79)	**5.41** (4.80-6.13)	**7.07** (6.26-8.02)	**8.36** (7.37-9.47)	**10.1** (8.85-11.5)	**11.4** (9.96-13.0)	**12.8** (11.1-14.7)	**14.2** (12.2-16.4)	**16.1** (13.6-18.8)	**17.6** (14.7-20.7)
45-day	**5.05** (4.49-5.68)	**6.48** (5.75-7.28)	**8.46** (7.50-9.51)	**9.95** (8.79-11.2)	**11.9** (10.5-13.4)	**13.4** (11.7-15.1)	**14.9** (13.0-16.9)	**16.4** (14.2-18.7)	**18.4** (15.7-21.1)	**19.9** (16.8-23.0)
60-day	**5.89** (5.20-6.65)	**7.59** (6.70-8.55)	**9.91** (8.74-11.1)	**11.6** (10.2-13.0)	**13.7** (12.0-15.4)	**15.3** (13.3-17.3)	**16.8** (14.6-19.0)	**18.3** (15.8-20.8)	**20.2** (17.3-23.1)	**21.6** (18.4-24.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.
Please refer to NOAA Atlas 14 document for more information.

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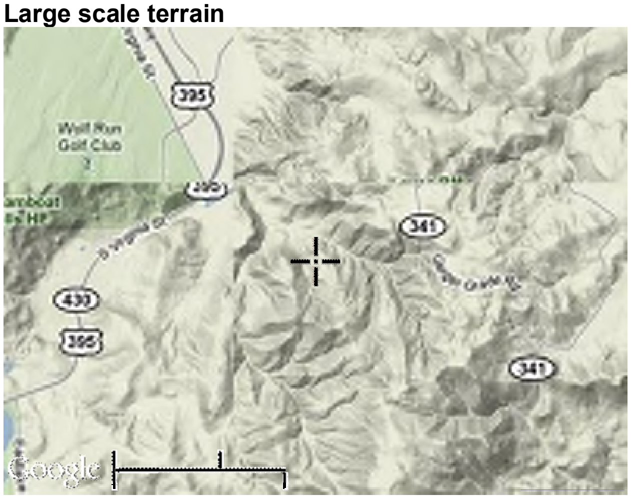
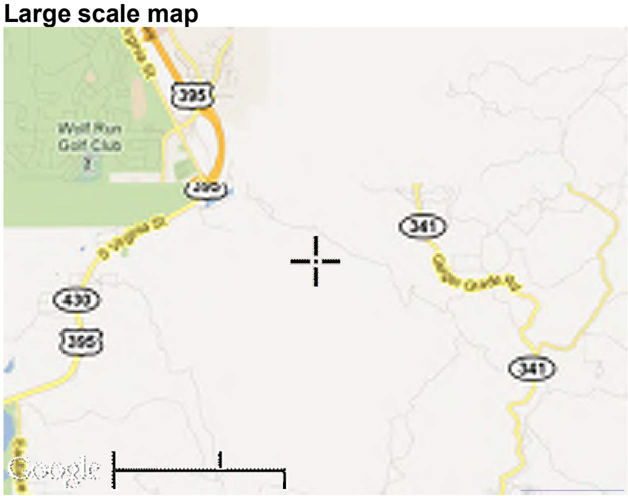
PF graphical

Large scale terrain



Large scale map



Large scale aerial

Back to Top

US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Office of Hydrologic Development
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

ATTACHMENT 3: TLAG CALCULATIONS

Project *Geiger Grade Relignment - Hydrology for Bailey Canyon Creek*
Subject **HEC-1 Input Parameters - LAG**
Designed by LSM Date 9/22/2011 Project No. 092528005
Checked by MAF Date 10/5/2011

Mean Basin Slope (Sc):

$$S_c = \left(\frac{L_c}{G}\right)^2$$

Mean slope equation from City of Tucson *Standards Manual for Drainage Design and Floodplain Management* (1998)

where S_c = Mean Basin Slope (ft/ft)
L_c = Length of Hydraulically Longest Watercourse (ft)

$$G = \left(\frac{\Delta L_1^3}{\Delta H_1}\right)^{1/2} + \left(\frac{\Delta L_2^3}{\Delta H_2}\right)^{1/2} + \left(\frac{\Delta L_3^3}{\Delta H_3}\right)^{1/2} + \left(\frac{\Delta L_4^3}{\Delta H_4}\right)^{1/2}$$

ΔL = Change in Length Factor (ft)
ΔH = Change in Elevation Factor (ft)

Subbasin	Segment	ΔL [ft]	USGE [ft]	DSGE [ft]	$(\Delta L^3/\Delta H)^{1/2}$ [ft]	S_c [ft/mi]
	Upper	1,396	6,725	6,600	4,665	
	Upper-Mid	2,427	6,600	6,320	7,145	
	Lower-Mid	3,006	6,320	6,020	9,515	
	Lower	7,085	6,020	5,720	34,431	
005	Subbasin	13,914	6,725	5,720	55,757	329
	Upper	3,406	7,720	7,160	8,400	
	Upper-Mid	3,764	7,160	6,360	8,165	
	Lower-Mid	2,329	6,360	6,080	6,717	
	Lower	5,178	6,080	5,720	19,635	
010	Subbasin	14,677	7,720	5,720	42,918	617
	Upper	1,044	7,680	7,480	2,385	
	Upper-Mid	2,154	7,480	6,800	3,834	
	Lower-Mid	5,773	6,800	6,000	15,508	
	Lower	4,992	6,000	5,560	16,815	
015	Subbasin	13,963	7,680	5,560	38,542	693
	Upper	846	6,520	6,200	1,375	
	Upper-Mid	3,095	6,200	5,520	6,603	
	Lower-Mid	4,356	5,520	5,280	18,558	
	Lower	4,157	5,280	5,120	21,192	
020	Subbasin	12,454	6,520	5,120	47,728	360
	Upper	2,198	7,420	6,850	4,316	
	Upper-Mid	6,506	6,850	5,640	15,087	
	Lower-Mid	3,416	5,640	5,320	11,160	
	Lower	3,665	5,320	5,120	15,690	
025	Subbasin	15,785	7,420	5,120	46,253	615

Project *Geiger Grade Relignment - Hydrology for Bailey Canyon Creek*
Subject **HEC-1 Input Parameters - LAG**
Designed by LSM | Date 9/22/2011 | Project No. 092528005
Checked by MAF | Date 10/5/2011

	Upper	996	6,490	6,360	2,757	
	Upper-Mid	5,400	6,360	5,440	13,081	
	Lower-Mid	3,031	5,440	5,160	9,972	
	Lower	2,659	5,160	4,970	9,947	
030	Subbasin	12,086	6,490	4,970	35,758	603
	Upper	759	5,960	5,600	1,103	
	Upper-Mid	912	5,600	5,280	1,540	
	Lower-Mid	2,248	5,280	4,960	5,958	
	Lower	3,515	4,960	4,834	18,562	
035	Subbasin	7,434	5,960	4,834	27,163	395
	Upper	1,216	6,480	6,240	2,738	
	Upper-Mid	1,570	6,240	5,840	3,109	
	Lower-Mid	6,183	5,840	4,940	16,205	
	Lower	3,494	4,940	4,732	14,319	
040	Subbasin	12,462	6,480	4,732	36,371	620
	Upper	2,574	6,560	6,000	5,518	
	Upper-Mid	4,585	6,000	5,200	10,975	
	Lower-Mid	3,818	5,200	4,806	11,886	
	Lower	3,307	4,806	4,689	17,583	
045	Subbasin	14,284	6,560	4,689	45,962	510
	Upper	6,616	4,689	4,588	53,547	
050	Subbasin	6,616	4,689	4,588	53,547	81
	Upper	9,986	4,840	4,588	62,860	
055	Subbasin	9,986	4,840	4,588	62,860	133

Notes:

Longest flowpath split up into segments of similar slope and slope calculated using City of Tucson methodology (1998)

Project *Geiger Grade Relignment - Hydrology for Bailey Canyon Creek*
Subject **HEC-1 Input Parameters - LAG**
Designed by LSM Date 9/22/2011 Project No. 092528005
Checked by MAF Date 10/5/2011

For drainage basins greater than one square mile:

$$TLAG = 22.1K_n\left(\frac{L\ L_c}{S^{0.5}}\right)^{0.33}$$

Lag Equation (710) from *Truckee Meadows Regional Drainage Manual* (2009)

where
TLAG = Lag Time (hr)
K_n = Manning's Roughness Factor for the Basin Channels
L = Length of the Longest Watercourse (mi)
L_c = Length Along Longest Watercourse Meastured Upstream to a Point Opposite the Centroid of the Basin (mi)
S = Representative (Average) Slope of the Longest Watercourse (ft/mi)

Subbasin	K_n [---]	L [mi]	L_c [mi]	S [ft/mi]	TLAG [hrs]
005	0.12	2.64	1.22	329	1.50
010	0.12	2.78	1.42	617	1.45
015	0.12	2.64	0.98	693	1.24
020	0.12	2.36	0.89	360	1.28
025	0.12	2.99	1.66	615	1.56
030	0.10	2.29	1.03	603	1.02
035	0.08	1.41	0.50	395	0.59
040	0.07	2.36	1.09	620	0.73
045	0.07	2.71	1.44	510	0.87
050	0.05	1.25	0.74	81	0.52
055	0.05	1.89	1.02	133	0.61

Notes:
Roughness factor K_n interpolated from Table 703 in *City of Sparks Hydrologic Criteria and Drainage Design Manual* (1998)

ATTACHMENT 4: COMPOSITE CURVE NUMBER CALCULATIONS

Project *Geiger Grade Relignment - Hydrology for Bailey Canyon Creek*
Subject **HEC-1 Input Parameters - Curve Number by Subbasin**
Designed by LSM Date 9/26/2011 Project No. 092528005
Checked by MAF Date 10/5/2011

Subbasin ID	Soil Area[1] [mi²]	HSG	Land Use	CN	Area*CN [mi²]	Composite CN	Notes/Assumptions[2]
	0.65	C	OS	80	51.8		Sagebrush with Grass Understory (Poor)
	1.02	D	OS	80	82.0		Pinyon-Juniper (Fair)
5	1.67				133.7	80	
	0.12	B	OS	51	6.2		Sagebrush with Grass Understory (Fair)
	1.19	D	OS	71	84.5		Pinyon-Juniper (Good)
10	1.31				90.8	69	
	0.02	B	OS	51	0.9		Sagebrush with Grass Understory (Fair)
	2.99	D	OS	71	212.0		Pinyon-Juniper (Good)
15	3.00				212.9	71	
	0.01	C	OS	80	1.1		Sagebrush with Grass Understory (Poor)
	1.17	D	OS	71	83.1		Pinyon-Juniper (Good)
20	1.18				84.2	71	
	0.22	B	OS	51	11.1		Sagebrush with Grass Understory (Fair)
	3.07	D	OS	71	217.8		Pinyon-Juniper (Good)
	0.09	D	GR	86	7.9		Farmsteads - buildings, lanes, driveways, etc.
25	3.38				236.9	70	
	0.01	B	GR	74	0.6		Farmsteads - buildings, lanes, driveways, etc.
	0.01	C	GR	82	0.5		Farmsteads - buildings, lanes, driveways, etc.
	0.07	D	GR	86	6.3		Farmsteads - buildings, lanes, driveways, etc.
	0.09	D	OS	85	7.4		Sagebrush with Grass Understory (Poor)
	0.17	D	OS	89	15.4		Pinyon-Juniper (Poor)
	0.37	D	OS	80	29.8		Pinyon-Juniper (Fair)
	1.02	D	OS	71	72.4		Pinyon-Juniper (Good)
	0.00	D	Paved	98	0.2		
30	1.74				132.7	76	
	0.00	B	GR	74	0.3		Farmsteads - buildings, lanes, driveways, etc.
	0.03	B	OS	35	1.2		Sagebrush with Grass Understory (Good)
	0.00	B	OS	41	0.0		Pinyon-Juniper (Good)
	0.02	C	GR	82	1.2		Farmsteads - buildings, lanes, driveways, etc.
	0.00	C	LDS	79	0.2		
	0.05	C	OS	47	2.3		Sagebrush with Grass Understory (Good)
	0.04	D	GR	83	3.0		Farmsteads - buildings, lanes, driveways, etc.
	0.02	D	OS	85	1.6		Sagebrush with Grass Understory (Poor)
	0.36	D	OS	89	31.8		Pinyon-Juniper (Poor)
	0.00	D	OS	71	0.0		Pinyon-Juniper (Good)
35	0.52				41.7	81	

Project *Geiger Grade Relignment - Hydrology for Bailey Canyon Creek*
Subject **HEC-1 Input Parameters - Curve Number by Subbasin**
Designed by LSM Date 9/26/2011 Project No. 092528005
Checked by MAF Date 10/5/2011

Subbasin ID	Soil Area[1] [mi²]	HSG	Land Use	CN	Area*CN [mi²]	Composite CN	Notes/Assumptions[2]
	0.02	B	GR	67	1.0		
	0.00	B	MDR	65	0.0		
	0.04	B	MDS	70	2.7		
	0.00	B	PSP	98	0.3		
	0.00	C	GR	77	0.0		
	0.00	C	MDR	77	0.0		
	0.04	C	MDS	80	2.8		
	0.00	C	PSP	98	0.0		
	0.60	D	GR	83	49.6		
	0.04	D	MDR	82	3.0		
	0.03	D	MDS	82	2.8		
	0.01	D	PR	88	0.8		
	0.05	D	OS	89	4.6		Pinyon-Juniper (Poor)
40	0.82				67.6	82	
	0.00	B	GR	67	0.1		
	0.04	B	MDS	70	3.0		
	0.00	B	PSP	98	0.1		
	0.00	C	GR	77	0.2		
	0.04	C	MDS	80	3.4		
	0.00	C	PSP	98	0.2		
	0.60	D	GR	83	50.1		
	0.02	D	MDR	82	1.5		
	0.04	D	MDS	82	2.9		
	0.10	D	OS	70	6.7		Sagebrush with Grass Understory (Fair)
	0.09	D	PSP	98	8.8		
	0.01	D	PR	88	0.8		
45	0.94				77.7	82	
	0.00	B	GC	92	0.4		
	0.02	B	GR	67	1.4		
	0.12	B	MDS	70	8.4		
	0.00	B	PR	77	0.4		
	0.00	B	PSP	98	0.3		
	0.02	C	GC	94	1.6		
	0.00	C	GR	77	0.1		
	0.07	C	MDS	80	5.5		
	0.00	C	PSP	98	0.3		
	0.01	D	MDS	82	1.1		
	0.04	D	Paved	98	3.6		
50	0.29				22.9	79	

Project Geiger Grade Realignment - Hydrology for Bailey Canyon Creek
Subject HEC-1 Input Parameters - Curve Number by Subbasin
Designed by LSM Date 9/26/2011 Project No. 092528005
Checked by MAF Date 10/5/2011

Subbasin ID	Soil Area[1] [mi²]	HSG	Land Use	CN	Area*CN [mi²]	Composite CN	Notes/Assumptions[2]
	0.00	A	GR	48	0.0		
	0.02	A	MDS	54	1.0		
	0.02	A	OS	35	0.7		Sagebrush with Grass Understory (Good)
	0.00	B	GR	67	0.1		
	0.00	B	HDS	72	0.0		
	0.01	B	MDS	70	0.7		
	0.00	B	PSP	98	0.0		
	0.02	C	GR	77	1.3		
	0.00	C	LDS	79	0.2		
	0.20	C	MDS	80	16.3		
	0.04	C	OS	47	1.8		Sagebrush with Grass Understory (Good)
	0.00	C	PSP	98	0.3		
	0.02	D	GR	83	1.7		
	0.05	D	HDS	86	4.5		
	0.11	D	MDS	85	9.0		
	0.02	D	OS	55	1.2		Sagebrush with Grass Understory (Good)
	0.00	D	PSP	98	0.0		
	0.03	D	Paved	98	2.9		
55	0.54				41.5	77	

15.41 Total Contributing Area

[1] Soil areas within each subbasin from ArcGIS analysis

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

ATTACHMENT 5: SOIL PARAMETERS

NRCS Soils Data - Map Unit Areas by Subbasin

Basin ID	Map Unit Symbol	Hydr_Soil	Area (acres)	Area (mi^2)	Soil Survey	Soil Description
5	1520	D	545	0.85	NV628	Duco-Smallcone-Cagle association
5	893	C	404	0.63	NV628	Indiano-Duco-Cagle association
5	983	D	121	0.19	NV628	Koontz-Nosrac association
10	1520	D	760	1.19	NV628	Duco-Smallcone-Cagle association
10	1011	B	42	0.07	NV628	Gabica-Easte-Burnborough association
10	561	D	36	0.06	NV772	Gabica-Easte-Burnborough association
15	1520	D	1662	2.60	NV628	Duco-Smallcone-Cagle association
15	1011	B	3	0.00	NV628	Gabica-Easte-Burnborough association
15	1011	B	9	0.01	NV628	Gabica-Easte-Burnborough association
15	561	D	124	0.19	NV772	Gabica-Easte-Burnborough association
15	1520	D	123	0.19	NV772	Duco-Smallcone-Cagle association
20	1520	D	749	1.17	NV628	Duco-Smallcone-Cagle association
20	893	C	9	0.01	NV628	Indiano-Duco-Cagle association
25	1520	D	1578	2.47	NV628	Duco-Smallcone-Cagle association
25	1011	B	142	0.22	NV628	Gabica-Easte-Burnborough association
25	561	D	33	0.05	NV772	Gabica-Easte-Burnborough association
25	1010	D	11	0.02	NV772	Gabica very gravelly sandy loam, 8 to 30 percent slopes
25	151	D	47	0.07	NV772	Doten variant silty clay, strongly saline
25	1520	D	0	0.00	NV772	Duco-Smallcone-Cagle association
25	1520	D	351	0.55	NV772	Duco-Smallcone-Cagle association
30	1520	D	681	1.06	NV628	Duco-Smallcone-Cagle association
30	251	C	4	0.01	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
30	482	B	7	0.01	NV628	Holbrook cobbly loamy sand, 2 to 8 percent slopes
30	1010	D	84	0.13	NV772	Gabica very gravelly sandy loam, 8 to 30 percent slopes
30	1520	D	340	0.53	NV772	Duco-Smallcone-Cagle association
35	1520	D	286	0.45	NV628	Duco-Smallcone-Cagle association
35	251	C	28	0.04	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
35	482	B	17	0.03	NV628	Holbrook cobbly loamy sand, 2 to 8 percent slopes
40	1520	D	462	0.72	NV628	Duco-Smallcone-Cagle association
40	251	C	17	0.03	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
40	251	C	6	0.01	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
40	482	B	36	0.06	NV628	Holbrook cobbly loamy sand, 2 to 8 percent slopes
40	1010	D	1	0.00	NV772	Gabica very gravelly sandy loam, 8 to 30 percent slopes
40	1520	D	4	0.01	NV772	Duco-Smallcone-Cagle association
45	1520	D	480	0.75	NV628	Duco-Smallcone-Cagle association
45	251	C	11	0.02	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
45	251	C	19	0.03	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
45	482	B	30	0.05	NV628	Holbrook cobbly loamy sand, 2 to 8 percent slopes
45	1010	D	14	0.02	NV772	Gabica very gravelly sandy loam, 8 to 30 percent slopes
45	1520	D	49	0.08	NV772	Duco-Smallcone-Cagle association
50	110	D	4	0.01	NV628	Jowec variant sandy loam, 4 to 8 percent slopes
50	1520	D	1	0.00	NV628	Duco-Smallcone-Cagle association
50	171	D	4	0.01	NV628	Indian Creek gravelly sandy loam, 0 to 4 percent slopes
50	251	C	28	0.04	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
50	251	C	33	0.05	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
50	260	C	0	0.00	NV628	Acrelane-Rock outcrop complex, 15 to 50 percent slopes
50	360		4	0.01	NV628	Pits
50	482	B	71	0.11	NV628	Holbrook cobbly loamy sand, 2 to 8 percent slopes
50	971	B	27	0.04	NV628	Aladshi sandy loam, 2 to 4 percent slopes
50	971	B	12	0.02	NV628	Aladshi sandy loam, 2 to 4 percent slopes
50	991		1	0.00	NV628	Xeric Torriorthents-Urban land complex
55	160	A	4	0.01	NV628	Incy sand, 4 to 8 percent slopes
55	171	D	77	0.12	NV628	Indian Creek gravelly sandy loam, 0 to 4 percent slopes
55	251	C	148	0.23	NV628	Cassiro gravelly sandy loam, 4 to 8 percent slopes
55	260	C	9	0.01	NV628	Acrelane-Rock outcrop complex, 15 to 50 percent slopes
55	260	C	9	0.01	NV628	Acrelane-Rock outcrop complex, 15 to 50 percent slopes

Basin ID	Map Unit Symbol	Hydr_Soil	Area (acres)	Area (mi^2)	Soil Survey	Soil Description
55	350	D	4	0.01	NV628	Mizel very gravelly coarse sandy loam, 15 to 50 percent slopes
55	350	D	0	0.00	NV628	Mizel very gravelly coarse sandy loam, 15 to 50 percent slopes
55	482	B	4	0.01	NV628	Holbrook cobbly loamy sand, 2 to 8 percent slopes
55	500	A	17	0.03	NV628	Mottsville sand, 0 to 4 percent slopes
55	880	D	10	0.01	NV628	Zephan-Rock outcrop-Smallcone complex, 15 to 50 percent slopes
55	880	D	9	0.01	NV628	Zephan-Rock outcrop-Smallcone complex, 15 to 50 percent slopes
55	881	C	5	0.01	NV628	Zephan very gravelly sandy loam, 30 to 50 percent slopes
55	882	C	10	0.02	NV628	Zephan stony sandy loam, 15 to 30 percent slopes
55	930	D	1	0.00	NV628	Old Camp stony sandy loam, 15 to 30 percent slopes
55	930	D	8	0.01	NV628	Old Camp stony sandy loam, 15 to 30 percent slopes
55	930	D	8	0.01	NV628	Old Camp stony sandy loam, 15 to 30 percent slopes
55	930	D	13	0.02	NV628	Old Camp stony sandy loam, 15 to 30 percent slopes
55	930	D	7	0.01	NV628	Old Camp stony sandy loam, 15 to 30 percent slopes
55	971	B	6	0.01	NV628	Aladshi sandy loam, 2 to 4 percent slopes

ATTACHMENT 6: LAND USE CALCULATIONS

Table 3: Land Use Compatibility Matrix

	LDR	MDR	HDR	LDS/ LDS 2	MDS/ MDS 4	HDS	LDU	MDU	HDU	PR	PSP	GC	NC	TC	I	GR/ GRR	OS
LDR		H	H	M	M	M	L	L	L	H	M	L	L	L	L	H	H
MDR			H	H	M	M	M	L	L	H	M	L	L	L	L	M	H
HDR				H	H	M	M	M	L	H	M	L	L	L	L	M	H
LDS/ LDS 2					H	H	M	M	M	H	M	L	L	L	L	M	H
MDS/ MDS 4						H	H	M	M	H	M	L	L	L	L	M	H
HDS							H	H	M	H	M	L	M	M	L	M	H
LDU								H	H	H	H	M	M	L	L	M	H
MDU									H	H	H	M	M	L	M	L	H
HDU										H	H	M	M	M	M	L	H
PR											H	H	H	H	M	H	H
PSP												H	H	H	H	M	H
GC													H	H	M	L	H
NC														H	M	L	H
TC															M	L	H
I																L	M
GR/ GRR																	H
OS																	H

H - High Compatibility: Little or no screening or buffering necessary.

M - Medium Compatibility: Some screening and buffering necessary.

L - Low Compatibility: Significant screening and buffering necessary.

Regulatory Zones

Residential

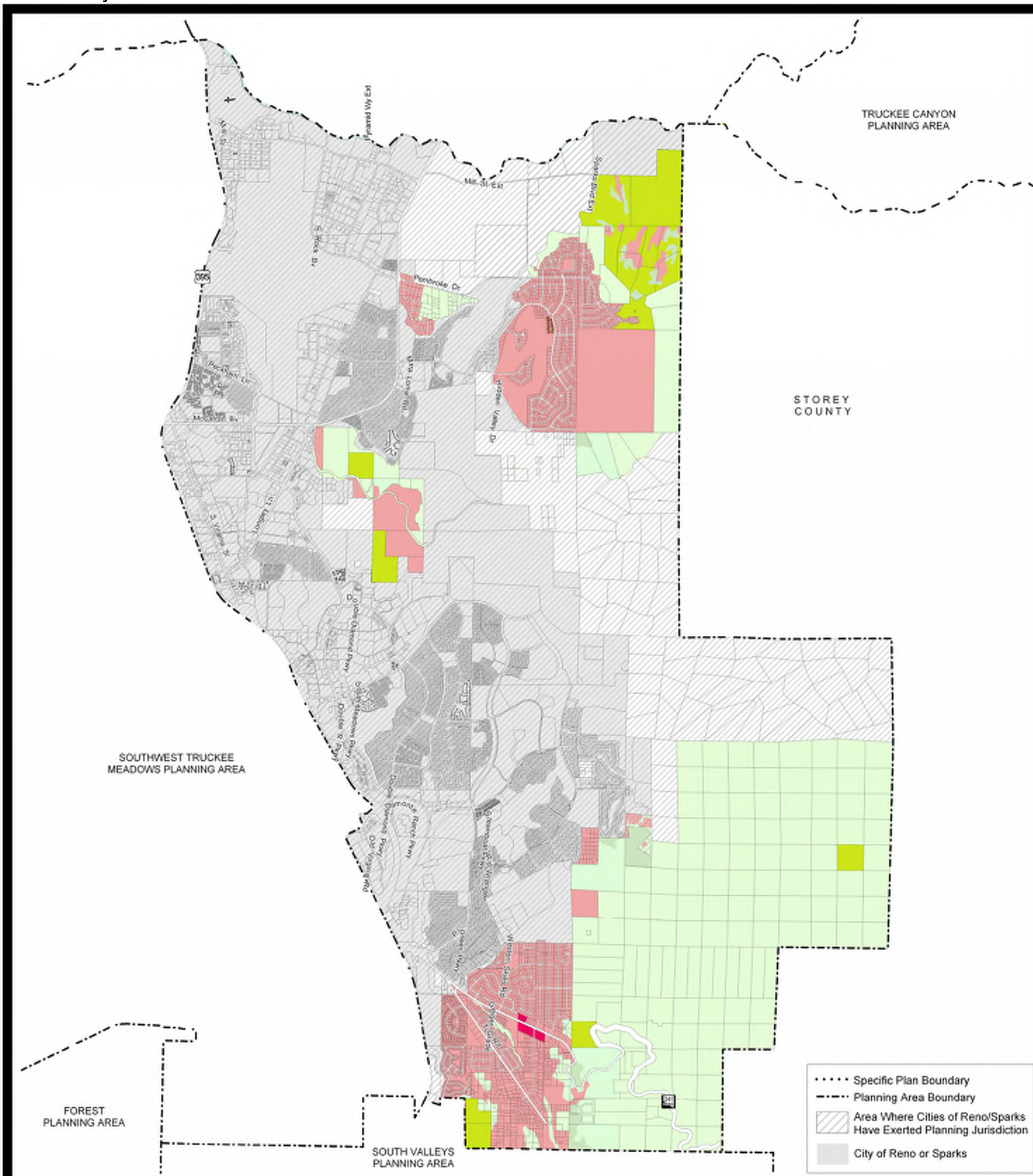
LDR - Low Density Rural
MDR - Medium Density Rural
HDR - High Density Rural
LDS/LDS 2 - Low Density Suburban
MDS/MDS 4 - Medium Density Suburban
HDS - High Density Suburban
LDU - Low Density Urban
MDU - Medium Density Urban
HDU - High Density Urban

Non-Residential

PR - Parks and Recreation
PSP - Public and Semi-Public Facilities
GC - General Commercial
NC - Neighborhood Commercial/Office
TC - Tourist Commercial
I - Industrial
GR - General Rural
GRR - General Rural Residential
OS - Open Space

Note: Plans for the amount of screening and buffering shall be made to the satisfaction of Washoe County Department of Community Development staff before completion of project review.

Source: Washoe County Department of Community Development



SOUTHEAST

MASTER PLAN MAP

- RURAL
- RURAL RESIDENTIAL
- SUBURBAN RESIDENTIAL
- URBAN RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- OPEN SPACE

PC Date: April 5, 2011
BCC Date: May 10, 2010
RPC Date: July 13, 2011

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N

0 1,200 2,400 4,800
Feet

CERTIFICATION:
THIS DOCUMENT HAS BEEN REVIEWED AND APPROVED AS AN ACCURATE REPRESENTATION OF THE ADOPTED MASTER PLAN MAPS OF WASHOE COUNTY, NEVADA, BY THE WASHOE COUNTY COMMUNITY DEVELOPMENT DEPARTMENT.

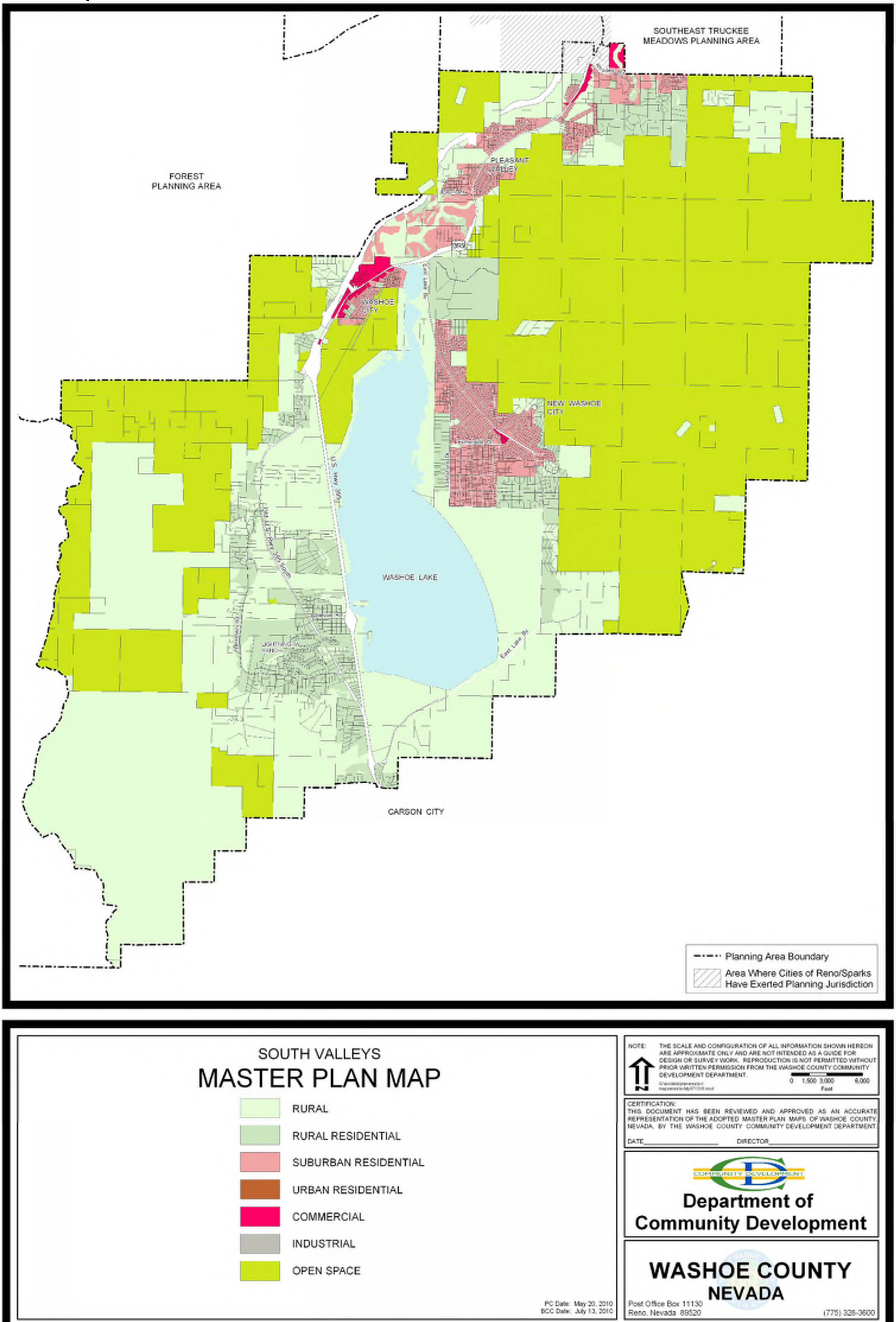
DATE____________ DIRECTOR____________

COMMUNITY DEVELOPMENT

Department of Community Development

WASHOE COUNTY
NEVADA

Post Office Box 11130
Reno, Nevada 89520
(775) 328-3600


SOUTHEAST TRUCKEE MEADOWS PLANNING AREA
FOREST PLANNING AREA
PLEASANT VALLEY
WASHOE CITY
NEW WASHOE CITY
WASHOE LAKE
U.S. Hwy 395
East Lake Bv
CARSON CITY
Planning Area Boundary
Area Where Cities of Reno/Sparks Have Exerted Planning Jurisdiction
SOUTH VALLEYS
MASTER PLAN MAP
RURAL
RURAL RESIDENTIAL
SUBURBAN RESIDENTIAL
URBAN RESIDENTIAL
COMMERCIAL
INDUSTRIAL
OPEN SPACE
PC Date: May 20, 2010
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Department of Community Development
WASHOE COUNTY
NEVADA
Post Office Box 11130
Reno, Nevada 89520
(775) 328-3600

Washoe County Land Use Data - Land Use Areas by Subbasin

005	*OS*	129	0.20
005	OS	941	1.47
010	*OS*	34	0.05
010	OS	804	1.26
015	*OS*	246	0.38
015	OS	1675	2.62
020	OS	0	0.00
020	*GR*	1	0.00
020	OS	756	1.18
025	*OS*	453	0.71
025	GR	251	0.39
025	OS	1459	2.28
030	*OS*	503	0.79
030	GR	400	0.62
030	OS	211	0.33
030	RDS	1	0.00
035	*OS*	133	0.21
035	GR	152	0.24
035	LDS	4	0.01
035	MDR	10	0.02
035	MDS	2	0.00
035	OS	29	0.05
035	RDS	0	0.00
040	*OS*	33	0.05
040	GR	392	0.61
040	MDR	23	0.04
040	MDS	69	0.11
040	PR	6	0.01
040	PSP	2	0.00

Subbasin ID	Land Use Code[1]	Area (acres)	Area (mi^2)
045	*PSP*	114	0.18
045	GR	388	0.61
045	MDR	11	0.02
045	MDS	77	0.12
045	OS	4	0.01
045	PR	6	0.01
045	PSP	2	0.00
050	*OS*	24	0.04
050	GC	13	0.02
050	GR	14	0.02
050	MDS	128	0.20
050	PR	3	0.00
050	PSP	3	0.01
055	*OS*	63	0.10
055	GR	25	0.04
055	HDS	33	0.05
055	LDS	1	0.00
055	MDS	216	0.34
055	OS	7	0.01
055	PSP	2	0.00

[1] Land use codes in italics represent areas outside of the master planned area limits. Land use codes were assigned for the purpose of this study based on topography, existing land use and adjacent land use.

ATTACHMENT 7: MUSKINGUM-CUNGE CHANNEL ROUTING

Project *Geiger Grade Relignment - Hydrology for Bailey Canyon Creek*
Subject **Manning's N Calculation**
Designed by Date Project No.
Checked by Date

where

n = Manning's n
n_0 = base value of n for a straight, uniform channel
n_1 = value for surface irregularities
n_2 = value for variations in channel cross section
n_3 = value for obstruction
n_4 = value for vegetation
m = adjustments for meanders

R015							0.073
R025							0.078
R030							0.100
R035							0.108
R040							0.073
R045							0.086
R050							0.053
R055							0.045

References:

Ven Te Chow, *Open Channel Hydraulics* , 1959.
Table 802, TMRDM

Project *Geiger Grade Relignment - Hydrology for Bailey Canyon Creek*
Subject **HEC-1 Input Parameters - Routing Reaches**
Designed by MAF Date 9/27/2011 Project No. 092528005
Checked by LSM Date 10/5/2011

Muskingum-Cunge Routing Data (RD Record in HEC-1)

Routing Reach	Length [ft]	USGE [ft]	DSGE [ft]	Slope [ft/ft]	Manning's n	Bottom Width [ft]	Side Slopes [XX:1]
R015	3,529	5720	5560	0.045	0.073	100	2
R025	9,817	5560	5120	0.045	0.078	50	2
R030	4,069	5120	4960	0.039	0.100	25	3
R035	3,714	4960	4834	0.034	0.108	70	4
R040	3,539	4834	4730	0.029	0.073	30	50
R045	1,734	4730	4690	0.023	0.086	30	50
R050	5,748	4690	4588	0.018	0.053	20	2
R055	9,490	4834	4588	0.026	0.045	8	10

Notes:

Elevations from USGS Quadrangle Maps

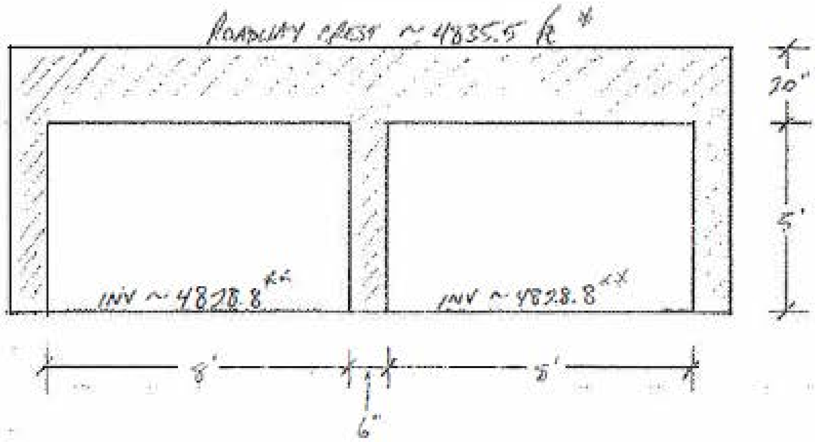
Bottom width and side slopes estimated from typical cross sections cut in ArcGIS

ATTACHMENT 8: FLOW SPLIT CALCULATIONS

SPLIT FLOW NOTES AT TOLL ROAD U/S OF INTERSECTION BETWEEN TOLL ROAD + PAVAZZA ROAD

CULVERT CROSSING NOTES FROM 9/16/11 SITE VISIT (SEE ATTACHED AERIAL + PHOTOGRAPHS)

2 - 8 ft x 5 ft CONCRETE BOX CULVERTS: (NOT TO SCALE!)

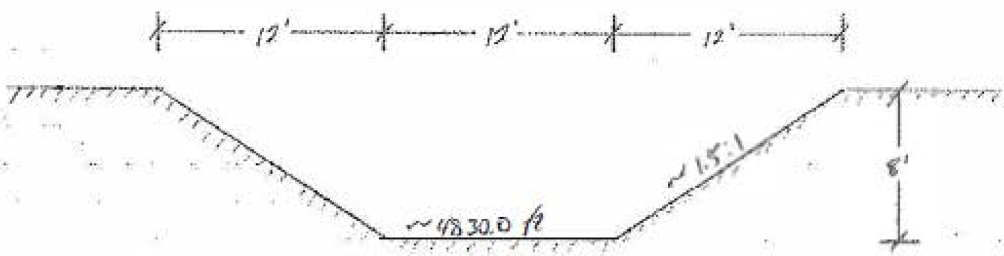


* NOTE: ELEVATIONS FROM COUNTY TOPOGRAPHY - 2 ft CONTOUR DATA, DATED 2007

** NOTE: SOME SEDIMENT BUILDUP AT U/S ENTRANCE FOR INV.
U/S INV = 4829.0
D/S INV = 4828.6

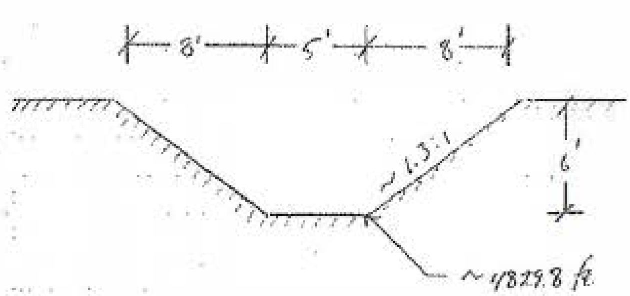
CULVERT LENGTH ~ 53'

APPROXIMATE U/S CHANNEL GEOMETRY:



CHANNEL SLOPE ~ 0.0250 ft/ft

APPROXIMATE D/S CHANNEL GEOMETRY:



CHANNEL SLOPE ~ 0.0130 ft/ft

Aerial Source: Google Maps (accessed 10/3/2011)

Photo: Bailey Canyon Creek Culvert Crossing at Toll Road. Looking downstream (northwest) at 2-8’x5’ Concrete Box Culverts. (Photo Date: 9/16/2011)

Photo: Bailey Canyon Creek Culvert Crossing at Toll Road. Looking upstream (southeast) at upstream channel. (Photo Date: 9/16/2011)

Photo: Bailey Canyon Creek Culvert Crossing at Toll Road. Looking downstream (northwest) at downstream channel. (Photo Date: 9/16/2011)

SPLIT FLOW NOTES AT TOLL RD U/S OF INTERSECTION BETWEEN TOLL RD + BANAZZA RD

DETERMINE DIVERSION RATING CURVE AT TOLL ROAD

FROM HY-8 ANALY, CULVERT CAPACITY AT OVERTOPPING IS 510 cfs (OVERTOPPING AT ELEVATION 4835.5)

SEE ATTACHED EXHIBIT FOR NORMAL DEPTH CROSS SECTION AT TOLL ROAD TO DETERMINE OVERTOPPING DEPTH, AND D/S OF TOLL ROAD TO DETERMINE FLOW SPLITS.

1) SECTION 1 REFLECTS THE UPSTREAM CHANNEL WHERE FLOW EXITS THE CHANNEL, AND CONTINUES BOTH OVER TOLL ROAD IN BAILEY CANYON CREEK AND ALONG TOLL ROAD.

→ FLOW EXITS THE CHANNEL AT ~ 4835.5. CHANNEL CAPACITY = 1,306 cfs
CULVERT CAPACITY = 510 cfs
Δ = 796 cfs

→ FOR FLOW 2,000 cfs, ELEVATION = 4837.60 $Q_{CHANNEL}$ 1,490 cfs
$Q_{CULVERT}$ 510 cfs

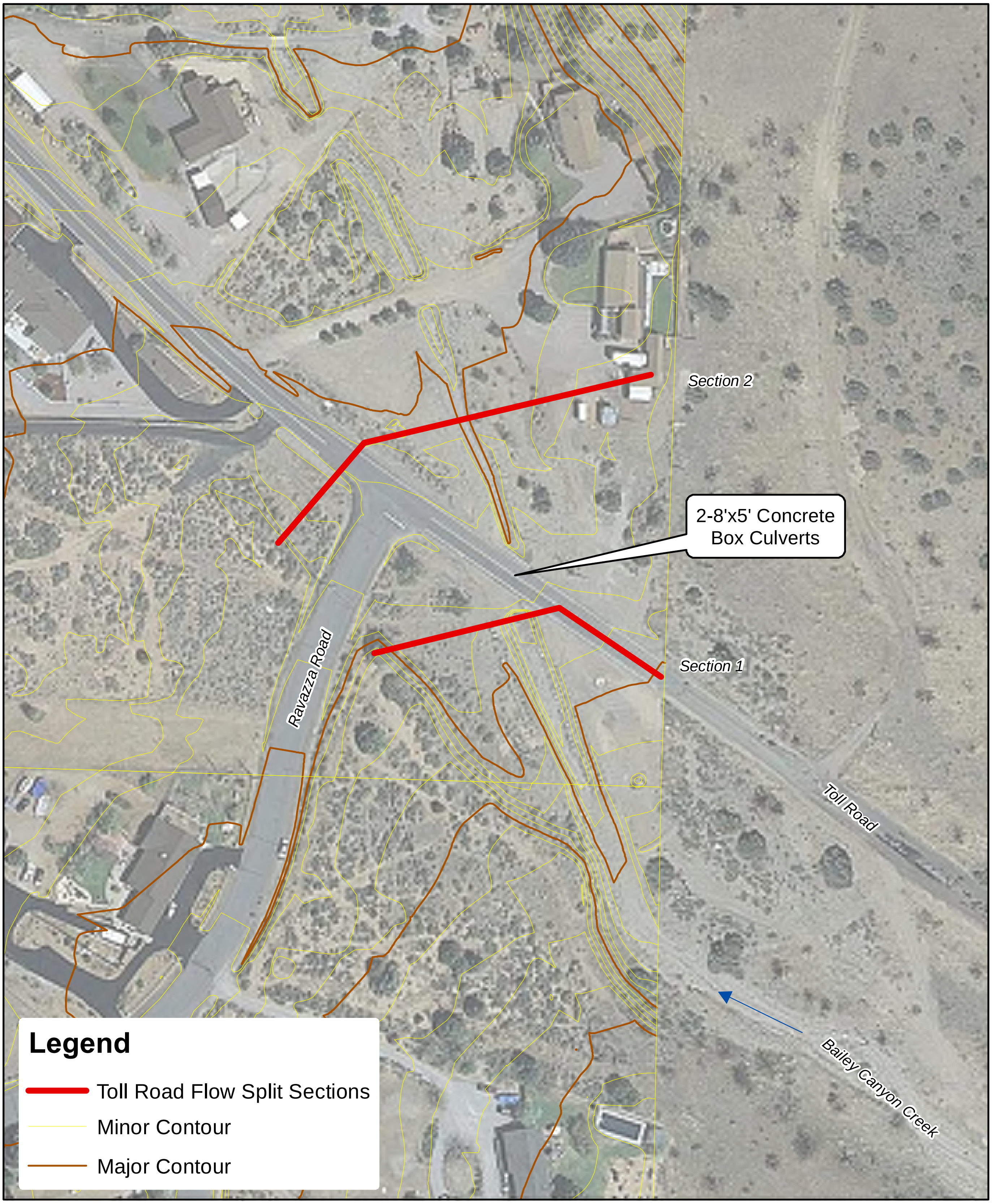
→ FOR FLOW 2,500 cfs, ELEVATION 4837.98 $Q_{CHANNEL}$ = 1,990 cfs
$Q_{CULVERT}$ = 510 cfs

* ONCE FLOW EXITS THE BAILEY CANYON CREEK CHANNEL, IT OVERTOPS TOLL ROAD. FLOW SPLITS → MOST CONTINUES IN BAILEY CANYON CREEK, THE REST FLOWS ALONG TOLL ROAD (ON BOTH SIDES)

2) SECTION 2 REFLECTS BAILEY CANYON CREEK DOWNSTREAM OF TOLL ROAD, AND INCLUDES FLOW ALONG TOLL ROAD

→ "CROSS SECTION FOR FULL SECTION 2" SHOWS APPROXIMATE DIVIDE OF FLOW SPLIT. "CROSS SECTION FOR SECTION 2 AT BAILEY CANYON CREEK" SHOWS SECTION THAT STAYS IN BAILEY CANYON CREEK. "CROSS SECTION FOR SECTION 2 ALONG TOLL ROAD" SHOWS SECTION THAT DIVERTS TO TOLL ROAD.

→ SEE ATTACHED TABLE FOR DIVERSION RATING CURVE



0 30 60 120 Feet

2

Kimley-Horn and Associates, Inc.

Gieger Grade Road Realignment
Bailey Canyon Creek Hydrologic Analysis

Washoe, County

Toll Road Split Flow Exhibit

Cross Section for Section 1

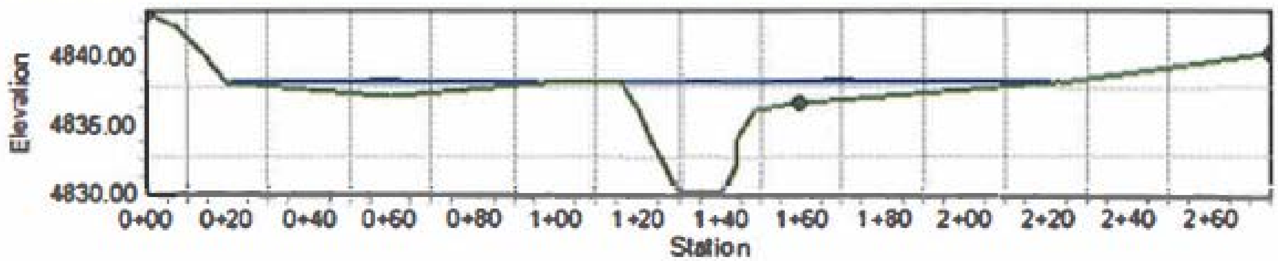
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	7.98	ft
Discharge	2500.00	ft³/s

Cross Section Image



BAILEY CANYON CREEK u/s OF TOLL ROAD. (u/s OF BOX CULVERTS)

HY-8 Culvert Analysis Report

Table 1 - Summary of Culvert Flows at Crossing: Toll Road

Rating Curve Plot for Crossing: Toll Road

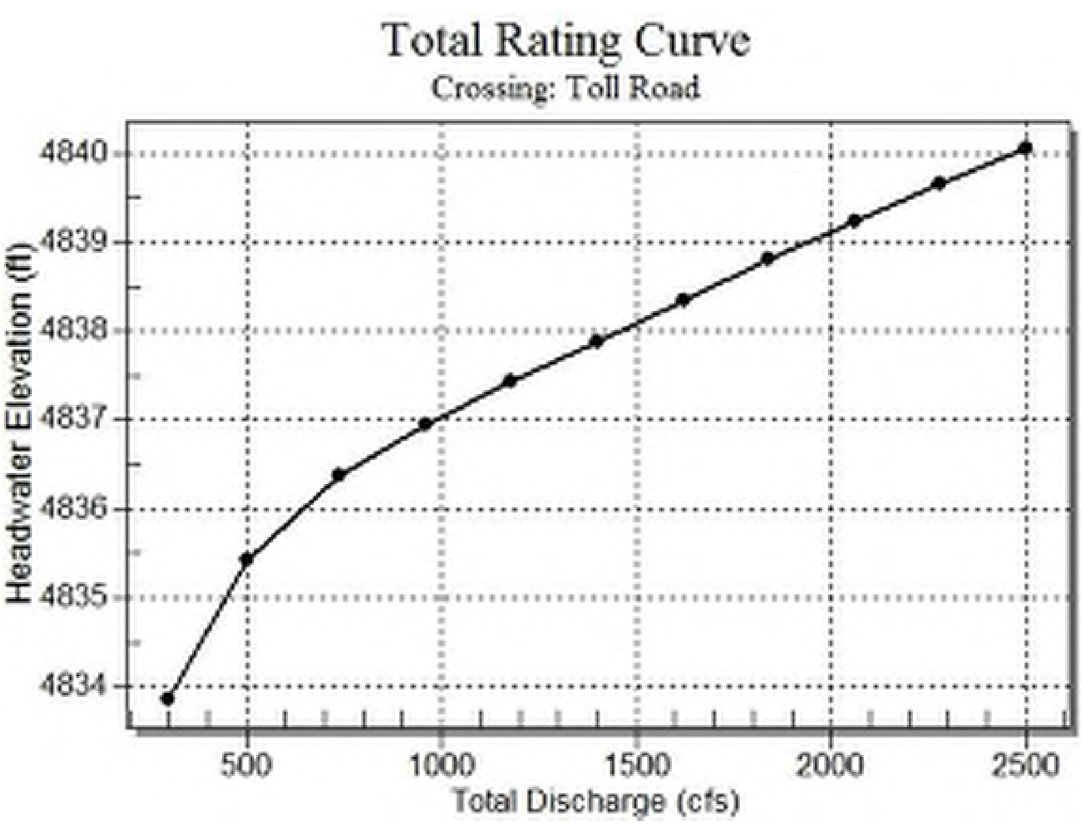


Table 2 - Culvert Summary Table: Culvert 1

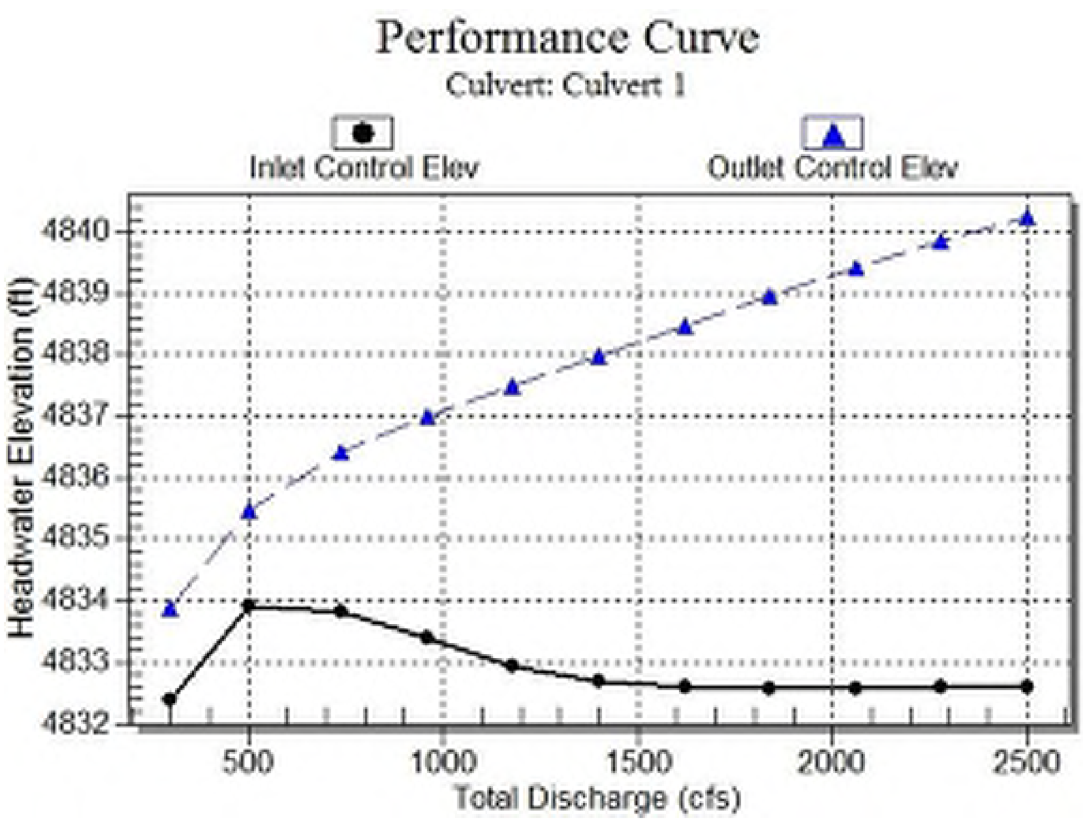
****

Inlet Elevation (invert): 4829.00 ft, Outlet Elevation (invert): 4828.60 ft

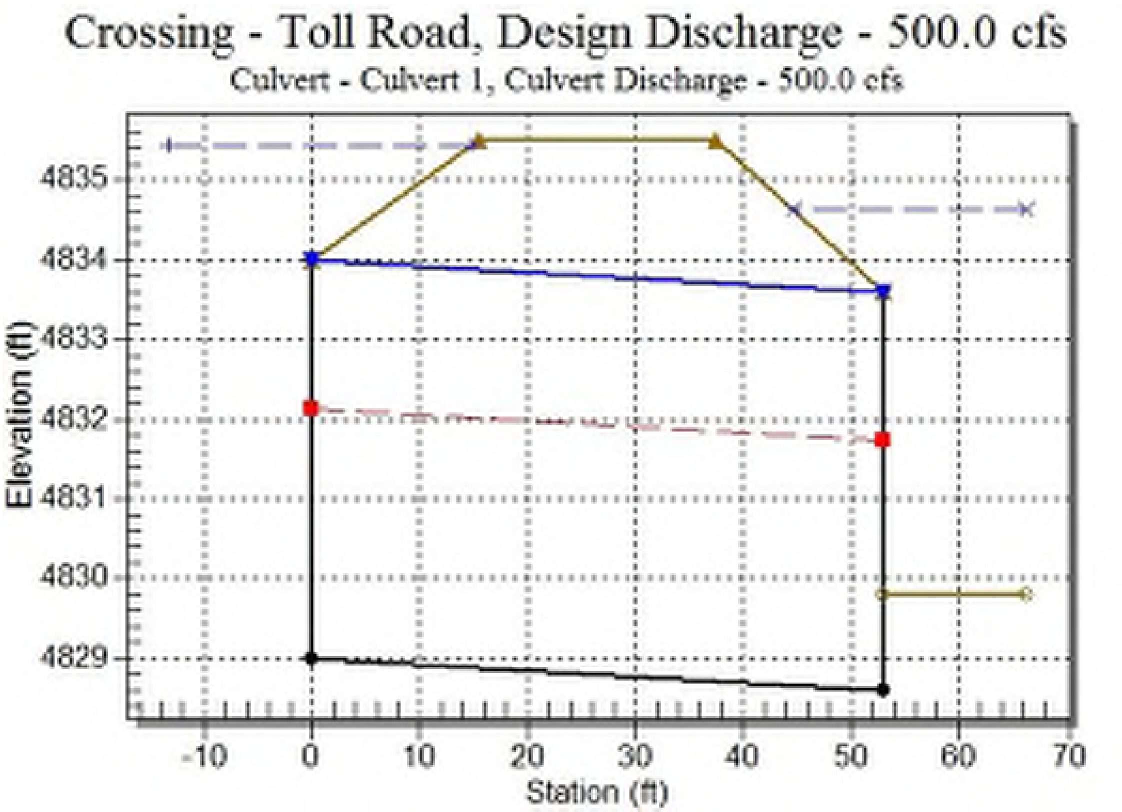
Culvert Length: 53.00 ft, Culvert Slope: 0.0075

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4829.00 ft

Outlet Station: 53.00 ft

Outlet Elevation: 4828.60 ft

Number of Barrels: 2

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 5.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: 1:1 Bevel (45º flare) Wingwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: Toll Road)

Tailwater Channel Data - Toll Road

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 ft

Side Slope (H:V): 1.30 (_:1)

Channel Slope: 0.0130

Channel Manning's n: 0.0350

Channel Invert Elevation: 4829.80 ft

Roadway Data for Crossing: Toll Road

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 4835.50 ft

Roadway Surface: Paved

Roadway Top Width: 22.00 ft

Cross Section for Full Section 2

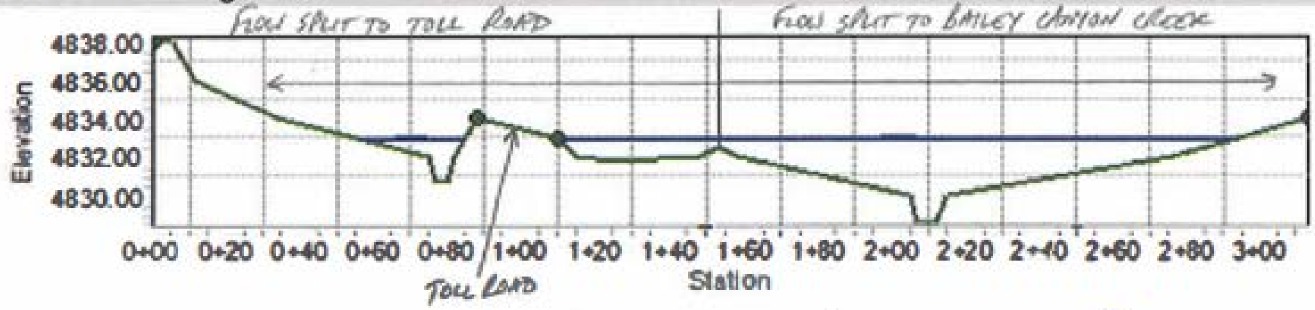
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	4.21	ft
Discharge	2500.00	ft³/s

Cross Section Image



BAILEY CANYON CREEK D/S OF TOLL ROAD (D/S OF BOX CULVERTS)

Cross Section for Section 2 at Bailey Canyon Creek

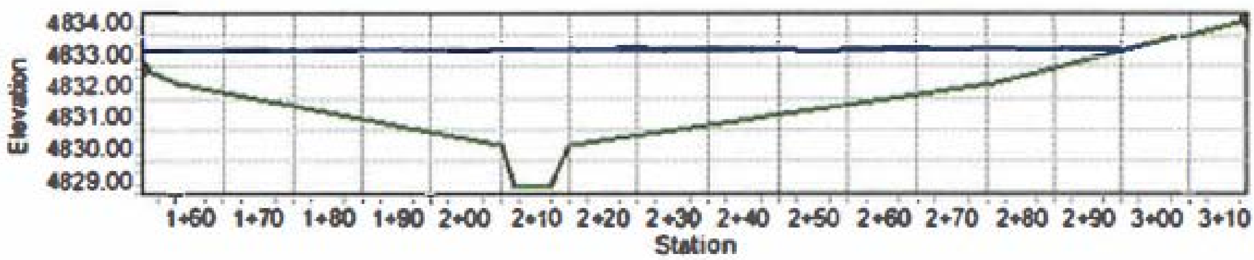
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	4.32	ft
Discharge	2500.00	ft³/s

Cross Section Image



FLOW SPLIT SECTION TO BAILEY CANYON CREEK

Rating Table for Section 2 at Bailey Canyon Creek

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	4.32	ft

Section Definitions

Station (ft)	Elevation (ft)
1+53	4832.50
1+58	4832.00
2+05	4830.00
2+07	4828.70
2+12	4828.70
2+15	4830.00
2+76	4832.00
3+13	4834.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+53, 4832.50)	(3+13, 4834.00)	0.035

Water Surface Elevation (ft)	Discharge (ft³/s)	Velocity (ft/s)	Flow Area (ft²)	Wetted Perimeter (ft)	Top Width (ft)
4828.00					
4828.50					
4829.00	4.15	2.48	1.67	6.30	6.15
4829.50	22.76	4.35	5.23	8.48	8.08
4830.00	55.18	5.66	9.75	10.65	10.00
4830.50	88.81	4.13	21.50	37.67	37.00

Rating Table for Section 2 at Bailey Canyon Creek

Input Data

Water Surface Elevation (ft)	Discharge (ft³/s)	Velocity (ft/s)	Flow Area (ft²)	Wetted Perimeter (ft)	Top Width (ft)
4831.00	226.03	4.83	46.75	64.69	64.00
4831.50	489.90	5.73	85.50	91.71	91.00
4832.00	913.17	6.63	137.75	118.73	118.00
4832.50	1580.08	7.89	200.31	133.02	132.25
4833.00	2459.84	9.15	268.75	142.78	141.50
4833.50	3514.16	10.28	341.81	152.55	150.75
4834.00	4743.51	11.31	419.50	162.31	160.00

Cross Section for Section 2 along Toll Road

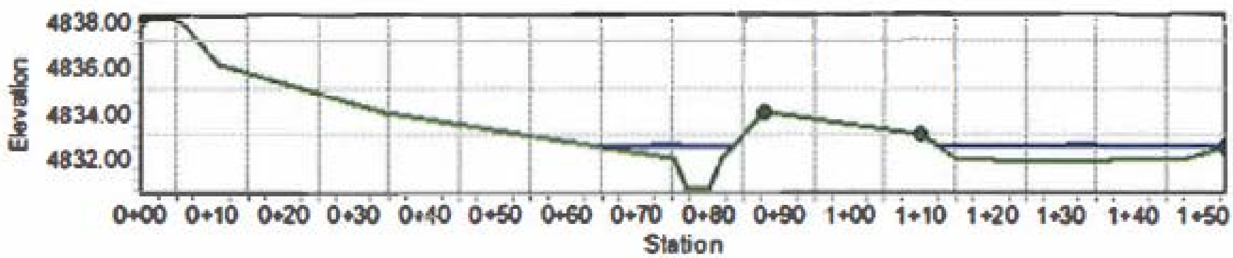
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	1.80	ft
Discharge	143.71	ft³/s

Cross Section Image



Rating Table for Section 2 along Toll Road

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	1.80	ft

Section Definitions

Station (ft)	Elevation (ft)
0+00	4838.00
0+05	4838.00
0+11	4836.00
0+34	4834.00
0+75	4832.00
0+77	4830.70
0+80	4830.70
0+82	4832.00
0+88	4834.00
1+10	4833.00
1+15	4832.00
1+26	4831.80
1+48	4832.00
1+53	4832.50

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 4838.00)	(0+88, 4834.00)	0.035
(0+88, 4834.00)	(1+10, 4833.00)	0.015
(1+10, 4833.00)	(1+53, 4832.50)	0.035

Water Surface Elevation (ft)	Discharge (ft³/s)	Velocity (ft/s)

Rating Table for Section 2 along Toll Road

Input Data

Elevation (ft)	Discharge (ft^3/s)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
4830.00					
4830.50					
4831.00	2.50	2.40	1.04	4.10	3.92
4831.50	13.97	4.13	3.38	5.94	5.46
4832.00	22.75	2.32	9.80	40.77	40.00
4832.50	143.71	4.15	34.61	60.19	59.25
4833.00	380.30	5.61	67.80	75.08	73.50
4833.50	748.76	6.79	110.24	98.44	96.25
4834.00	1301.17	7.93	164.05	121.79	119.00

Diversion Rating Table for Flow Split at Toll Road Near Intersection of Toll Road and Ravazza Road*

Elevation	Split to Bailey Canyon Creek[1,2] (cfs)	Split to Toll Road[1,3] (cfs)	Total Flow (cfs)
4828.0	0	0	0
4828.5	0	0	0
4829.0	4	0	4
4829.5	23	0	23
4830.0	55	0	55
4830.5	89	0	89
4831.0	225	0	225
4831.5	490	0	490
4832.0	913	23	936
4832.5	1580	144	1724
4833.0	2460	380	2840
4833.5	3514	749	4263
4834.0	4744	1301	6045

[1]No flow travels along Toll Road until flow overtops the culvert capacity of 510 cfs.

[2]From Rating Table for "Cross Section for Section 2 at Bailey Canyon Creek"

[3]From Rating Table for "Cross Section for Section 2 along Toll Road".

*Note that this rating table was developed referencing Sections 1 and 2 shown in the split flow exhibit attached. Section 1 reflects the upstream channel to establish the culvert capacity ONLY. Once the culvert capacity is reached, flow overtops section 1 and overtops Toll Road. Section 2 represents the actual split where flow divides between Toll Road and Bailey Canyon Creek.

Potential Flow Split at Geiger Grade Road

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.01390	ft/ft
Normal Depth	7.40	ft

Section Definitions

Station (ft)	Elevation (ft)
0+00	4605.00
0+19	4604.00
0+26	4602.00
0+54	4602.00
1+10	4602.00
1+16	4602.00
1+48	4602.00
1+70	4600.00
2+16	4598.00
2+26	4596.00
2+31	4594.50
2+38	4594.50
2+39	4596.00
2+41	4598.00
2+42	4600.00
2+47	4602.00
2+63	4603.50
2+99	4603.30
3+08	4602.00
3+48	4602.00
4+58	4602.70

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient

Potential Flow Split at Geiger Grade Road

Input Data

Start Station	Ending Station	Roughness Coefficient
(0+00, 4605.00)	(1+48, 4602.00)	0.045
(1+48, 4602.00)	(2+63, 4603.50)	0.035
(2+63, 4603.50)	(2+99, 4603.30)	0.015
(2+99, 4603.30)	(3+08, 4602.00)	0.015
(3+08, 4602.00)	(4+58, 4602.70)	0.035

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge		3288.35	ft³/s
Elevation Range	4594.50 to 4605.00 ft		
Flow Area		311.17	ft²
Wetted Perimeter		101.43	ft
Hydraulic Radius		3.07	ft
Top Width		97.65	ft
Normal Depth		7.40	ft
Critical Depth		8.06	ft
Critical Slope		0.01630	ft/ft
Velocity		10.57	ft/s
Velocity Head		1.74	ft
Specific Energy		9.14	ft
Froude Number		1.04	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

Potential Flow Split at Geiger Grade Road

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	7.40	ft
Critical Depth	8.06	ft
Channel Slope	0.01390	ft/ft
Critical Slope	0.01630	ft/ft

Cross Section for Irregular Section - 1

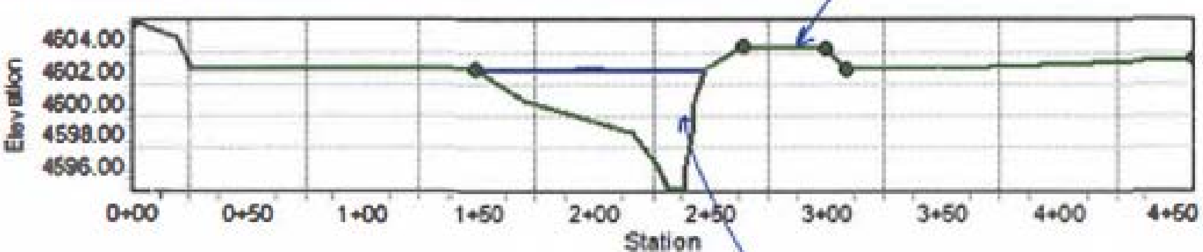
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.01390	ft/ft
Normal Depth	7.40	ft
Discharge	3288.35	ft³/s

Cross Section Image



DISCHARGE MUST EXCEED 3,288 cfs TO RESULT IN SPLIT FLOW

ATTACHMENT 9: HEC-1 MODEL OUTPUT

```
1*****************************************                                                   ***************************************
 *                                       *                                                   *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *   U.S. ARMY CORPS OF ENGINEERS      *
 *               JUN   1998              *                                                   *   HYDROLOGIC ENGINEERING CENTER     *
 *            VERSION 4.1                *                                                   *         609 SECOND STREET           *
 *                                       *                                                   *      DAVIS, CALIFORNIA 95616        *
 *  RUN DATE   06OCT11  TIME  17:48:01   *                                                   *          (916) 756-1104             *
 *                                       *                                                   *                                     *
 *****************************************                                                   ***************************************





                                               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




           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


1                                                    HEC-1 INPUT                                              PAGE  1

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

             1           ID      GEIGER GRADE ROAD REALIGNMENT
             2           ID      Model for Bailey Canyon Creek Watershed
             3           ID      Existing Conditions
             4           ID
             5           ID      Prepared for the Regional Transportation Commission
             6           ID      of Washoe County
             7           ID
             8           ID      Prepared by Kimley-Horn and Associates, Inc.
             9           ID      KHA Project Number 092528005
            10           ID      September 2011
            11           ID
            12           ID      MODELING PARAMETERS
            13           ID      - 100 Year 24 Hour Storm Event
            14           ID      - NOAA Atlas 14 Rainfall Data
            15           ID      - SCS Unit Hydrograph
            16           ID      - SCS Curve Number Method
            17           ID      - Muskingum-Cunge Routing Method
            18           ID
            19           ID      Topographic and land use data received from Washoe County September 2011
            20           ID
            21           ID      Diversion data obtained from capacity analysis of split flow using normal
            22           ID      depth
            23           ID
            24           ID      MODELING NOMENCLATURE
            25           ID      SUBBASIN HYDROGRAPH:
            26           ID         Example: 005    - the most upstream subbasin
            27           ID
            28           ID      SUBBASIN DIVERSION:
            29           ID         Example: D040 - flow is diverted northeast towards combination point CP
            30           ID         Example: DO55 - flow is diverted northwest towards combination point CP
            31           ID
            32           ID      ROUTE HYDROGRAPH:
            33           ID         Example: RCP030 - flow is routed towards CP030
            34           ID
            35           ID      COMBINE HYDROGRAPH:
            36           ID         Example: CP035  - combine flow at concentration point 035
            37           ID
            38           ID
            39           ID      PREFIXES FOR MODELING OPERATIONS
            40           ID         D      Divert flow
            41           ID         R      Routing flow
            42           ID         CP     Combination point
            43           ID   ***************************************************************************
            44           IT       5       0       0     400
            45           IO       5
            46           JR    PREC    0.98
                         *DIAGRAM
                         *

            47           KK     005
            48           KM   Runoff hydrograph for subbasin 005
            49           BA    1.67
            50           PH                   0.430   0.812    1.35    1.45    1.56    2.03    2.95    4.02
            51           LS              80
            52           UD    1.50
                         *
1                                                    HEC-1 INPUT                                              PAGE  2

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


            53           KK     010
            54           KM   Runoff hydrograph for subbasin 010
            55           BA    1.31
            56           LS              69
```

```
             57          UD    1.45
                         *

             58          KK   CP010
             59          KM   Combine runoff hydrographs from subbasins 005 and 010
             60          HC       2
                         *

             61          KK    R015
             62          KM   Route combined hydrograph at CP010 to CP015
             63          RD    3529   0.045   0.073            TRAP     100       2
                         *

             64          KK     015
             65          KM   Runoff hydrograph for subbasin 015
             66          BA    3.00
             67          LS             71
             68          UD    1.24
                         *

             69          KK   CP015
             70          KM   Combine routed hydrograph from CP010 with runoff hydrograph
             71          KM   from subbasin 015
             72          HC       2
                         *

             73          KK    R025
             74          KM   Route combined hydrograph at CP015 to CP025
             75          RD    9817   0.045   0.078            TRAP      50       2
                         *

             76          KK     020
             77          KM   Runoff hydrograph for subbasin 020
             78          BA    1.18
             79          LS             71
             80          UD    1.28
                         *

             81          KK     025
             82          KM   Runoff hydrograph for subbasin 025
             83          BA    3.38
             84          LS             70
             85          UD    1.56
                         *
1                                               HC-1 INPUT                                             PAGE  3

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


             86          KK   CP025
             87          KM   Combine routed hydrograph from CP015 with runoff hydrographs from
             88          KM   subbasins 020 and 025
             89          HC       3
                         *

             90          KK    R030
             91          KM   Route combined hydrograph at CP025 to CP030
             92          RD    4069   0.039   0.100            TRAP      25       3
                         *

             93          KK     030
             94          KM   Runoff hydrograph for subbasin 030
             95          BA    1.74
             96          LS             76
             97          UD    1.02
                         *

             98          KK   CP030
             99          KM   Combine routed hydrograph from CP025 with runoff hydrograph
            100          KM   from subbasin 030
            101          HC       2
                         *

            102          KK    R035
            103          KM   Route combined hydrograph at CP030 to CP035
            104          RD    3714   0.034   0.108            TRAP      70       4
                         *

            105          KK     035
            106          KM   Runoff hydrograph for subbasin 035
            107          BA   0.517
            108          LS             81
            109          UD    0.59
                         *

            110          KK   CP035
            111          KM   Combine routed hydrograph from CP030 with runoff hydrograph
            112          KM   from subbasin 035
            113          HC       2
                         *

            114          KK    D040
            115          KM   Flow diversion at the intersection of Toll Road and Ravazza Road.
            116          KM   Bailey Canyon Creek runoff crosses Toll Road in 2-8x5 concrete box
            117          KM   culverts.  When the road overtops, the majority continues down Bailey
            118          KM   Canyon Creek.  The remainder flows northeast along Toll Road.
            119          KM   The split was determined by modeling the culvert in HY-8 to get the
            120          KM   capacity.  Normal depth cross sections were used to determine the amount
            121          KM   of flow along Toll Road.  All measurements were taken on site
            122          KM   in September 2011.
            123          DT    D055
            124          DI       0     510     913    1580    2460    3514
            125          DQ       0       0      23     144     380     749
```

```
                          *
1                                                     HEC-1 INPUT                                             PAGE  4

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


            126           KK    R040
            127           KM   Route portion of the Bailey Canyon Creek runoff that crosses Toll
            128           KM   Road in culvert to CP040
            129           RD    3539   0.029   0.073            TRAP      30      50
                          *

            130           KK     040
            131           KM   Runoff hydrograph for subbasin 040
            132           BA   0.821
            133           LS             82
            134           UD    0.73
                          *

            135           KK   CP040
            136           KM   Combine routed hydrograph from CP035 with runoff hydrograph
            137           KM   from subbasin 040
            138           HC       2
                          *

            139           KK    R045
            140           KM   Route combined hydrograph at CP040 to CP045
            141           RD    1734   0.023   0.086            TRAP      30      50
                          *

            142           KK     045
            143           KM   Runoff hydrograph for subbasin 045
            144           BA   0.943
            145           LS             82
            146           UD    0.87
                          *

            147           KK   CP045
            148           KM   Combine routed hydrograph from CP040 with runoff hydrograph
            149           KM   from subbasin 045
            150           HC       2
                          *

            151           KK    R050
            152           KM   Route combined hydrograph at CP045 to CP050
            153           RD    5748   0.018   0.053            TRAP      20       2
                          *

            154           KK     050
            155           KM   Runoff hydrograph for subbasin 050
            156           BA   0.290
            157           LS             79
            158           UD    0.52
                          *
1                                                     HEC-1 INPUT                                             PAGE  5

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


            159           KK   CP050
            160           KM   Combine routed hydrograph from CP045 with runoff hydrograph
            161           KM   from subbasin 050
            162           HC       2
                          *

            163           KK    Toll
            164           KM   Retrieve diverted runoff from CP035 that flows in Toll Road
            165           DR    D055
                          *

            166           KK    R055
            167           KM   Route diverted hydrograph from CP035 in Toll Road to CP055
            168           RD    9490   0.026   0.045            TRAP       8      10
                          *

            169           KK     055
            170           KM   Runoff hydrograph for subbasin 055
            171           BA   0.542
            172           LS             77
            173           UD    0.61
                          *

            174           KK   CP055
            175           KM   Combine routed hydrograph from CP035 with runoff hydrograph
            176           KM   from subbasin 055 on the west side of Toll Road
            177           HC       2
                          *

            178           KK   CP055
            179           KM   Combine hydrograph from CP050 with combined hydrograph at CP055
            180           HC       2
            181           ZZ
1
                 SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE      (V) ROUTING         (--->) DIVERSION OR PUMP FLOW

   NO.      (.) CONNECTOR       (<---) RETURN OF DIVERTED OR PUMPED FLOW

    47         005
                 .
                 .
    53           .         010
```

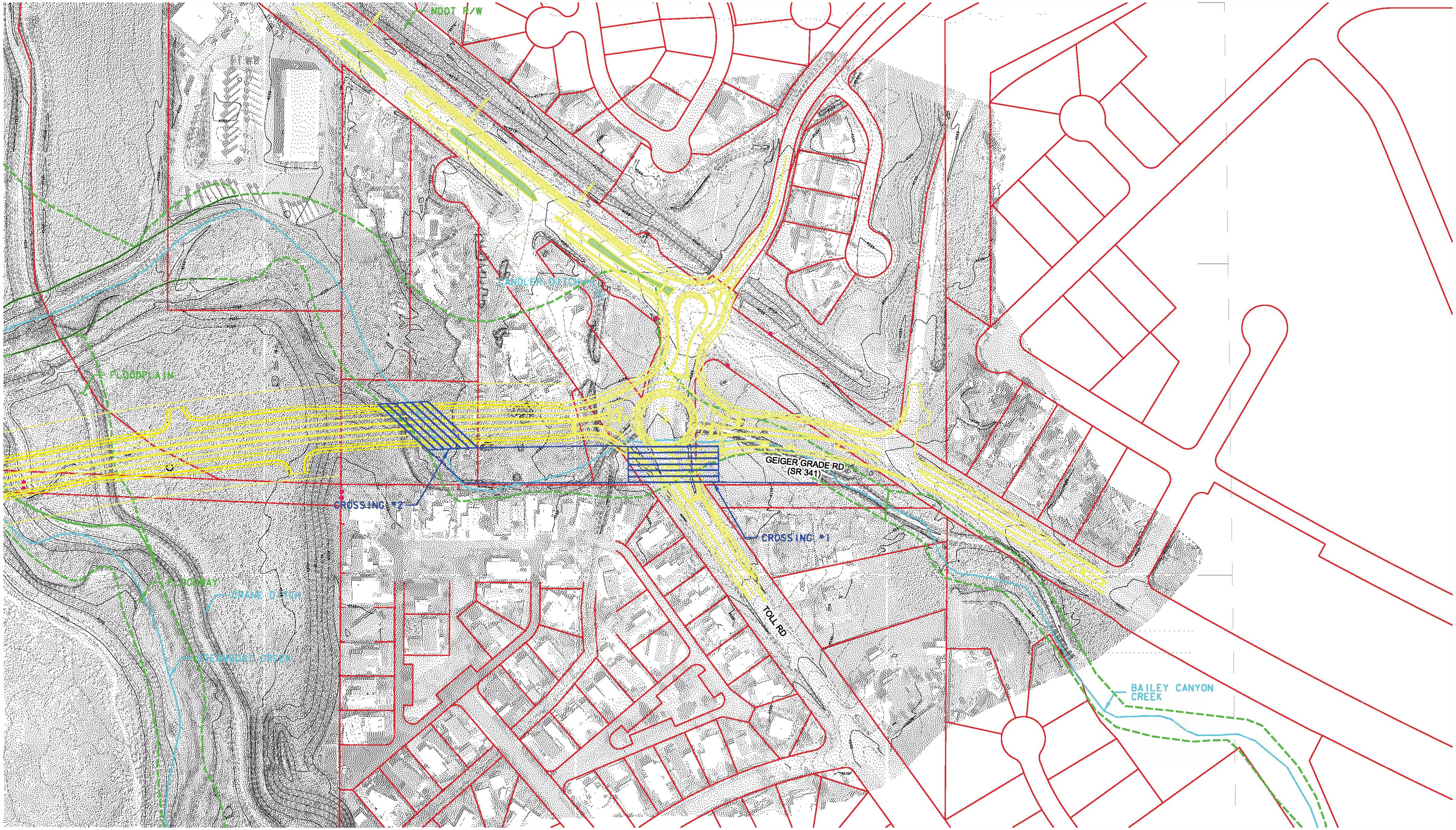
```
                 .           .
                 .           .
    58       CP010............
                 V
                 V
    61        R015
                 .
                 .
    64           .         015
                 .           .
                 .           .
    69       CP015............
                 V
                 V
    73        R025
                 .
                 .
    76           .         020
                 .           .
                 .           .
    81           .           .         025
                 .           .           .
                 .           .           .
    86       CP025........................
                 V
                 V
    90        R030
                 .
                 .
    93           .         030
                 .           .
                 .           .
    98       CP030............
                 V
                 V
   102        R035
                 .
                 .
   105           .         035
                 .           .
                 .           .
   110       CP035............
                 .
                 .
   123           .------->    D055
   114        D040
                 V
                 V
   126        R040
                 .
                 .
   130           .         040
                 .           .
                 .           .
   135       CP040............
                 V
                 V
   139        R045
                 .
                 .
   142           .         045
                 .           .
                 .           .
   147       CP045............
                 V
                 V
   151        R050
                 .
                 .
   154           .         050
                 .           .
                 .           .
   159       CP050............
                 .
                 .
   165           .           .<-------    D055
   163           .        Toll
                 .           V
                 .           V
   166           .        R055
                 .           .
                 .           .
   169           .           .         055
                 .           .           .
                 .           .           .
   174           .       CP055............
                 .           .
                 .           .
   178       CP055............

 (***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1*****************************************                                                   ***************************************
 *                                       *                                                   *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *    U.S. ARMY CORPS OF ENGINEERS     *
 *               JUN   1998              *                                                   *    HYDROLOGIC ENGINEERING CENTER    *
 *            VERSION 4.1                *                                                   *          609 SECOND STREET          *
 *                                       *                                                   *       DAVIS, CALIFORNIA 95616       *
 *  RUN DATE   06OCT11  TIME  17:48:01   *                                                   *           (916) 756-1104            *
 *                                       *                                                   *                                     *
 *****************************************                                                   ***************************************
```

```


                          GEIGER GRADE ROAD REALIGNMENT
                          Model for Bailey Canyon Creek Watershed
                          Existing Conditions

                          Prepared for the Regional Transportation Commission
                          of Washoe County

                          Prepared by Kimley-Horn and Associates, Inc.
                          KHA Project Number 092528005
                          September 2011

                          MODELING PARAMETERS
                          - 100 Year 24 Hour Storm Event
                          - NOAA Atlas 14 Rainfall Data
                          - SCS Unit Hydrograph
                          - SCS Curve Number Method
                          - Muskingum-Cunge Routing Method

                          Topographic and land use data received from Washoe County September 2011

                          Diversion data obtained from capacity analysis of split flow using normal
                          depth

                          MODELING NOMENCLATURE
                          SUBBASIN HYDROGRAPH:
                             Example: 005    - the most upstream subbasin

                          SUBBASIN DIVERSION:
                             Example: D040 - flow is diverted northeast towards combination point CP
                             Example: DO55 - flow is diverted northwest towards combination point CP

                          ROUTE HYDROGRAPH:
                             Example: RCP030 - flow is routed towards CP030

                          COMBINE HYDROGRAPH:
                             Example: CP035  - combine flow at concentration point 035


                          PREFIXES FOR MODELING OPERATIONS
                             D      Divert flow
                             R      Routing flow
                             CP     Combination point
                       ****************************************************************************

   45 IO          OUTPUT CONTROL VARIABLES
                        IPRNT          5  PRINT CONTROL
                        IPLOT          0  PLOT CONTROL
                        QSCAL         0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          5  MINUTES IN COMPUTATION INTERVAL
                        IDATE      1    0  STARTING DATE
                        ITIME       0000  STARTING TIME
                           NQ        400  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE      2    0  ENDING DATE
                       NDTIME       0915  ENDING TIME
                       ICENT          19  CENTURY MARK

                     COMPUTATION INTERVAL     .08 HOURS
                          TOTAL TIME BASE   33.25 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
                      .98
1


               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
                                                       .98

 HYDROGRAPH AT
+                    005      1.67     1   FLOW         428.
                                           TIME        13.58

 HYDROGRAPH AT
+                    010      1.31     1   FLOW         195.
                                           TIME        13.58

  2 COMBINED AT
+                  CP010      2.98     1   FLOW         623.
                                           TIME        13.58

 ROUTED TO
+                   R015      2.98     1   FLOW         622.
```

```
                                       TIME        13.75

 HYDROGRAPH AT
+                  015      3.00     1   FLOW         568.
                                         TIME        13.33

  2 COMBINED AT
+                CP015      5.98     1   FLOW        1161.
                                         TIME        13.50

 ROUTED TO
+                 R025      5.98     1   FLOW        1162.
                                         TIME        13.75

 HYDROGRAPH AT
+                  020      1.18     1   FLOW         220.
                                         TIME        13.42

 HYDROGRAPH AT
+                  025      3.38     1   FLOW         499.
                                         TIME        13.75

  3 COMBINED AT
+                CP025     10.54     1   FLOW        1861.
                                         TIME        13.75

 ROUTED TO
+                 R030     10.54     1   FLOW        1862.
                                         TIME        13.83

 HYDROGRAPH AT
+                  030      1.74     1   FLOW         504.
                                         TIME        13.08

  2 COMBINED AT
+                CP030     12.28     1   FLOW        2186.
                                         TIME        13.67

 ROUTED TO
+                 R035     12.28     1   FLOW        2185.
                                         TIME        13.75

 HYDROGRAPH AT
+                  035       .52     1   FLOW         280.
                                         TIME        12.67

  2 COMBINED AT
+                CP035     12.80     1   FLOW        2238.
                                         TIME        13.75

 DIVERSION TO
+                 D055     12.80     1   FLOW         320.
                                         TIME        13.75

 HYDROGRAPH AT
+                 D040     12.80     1   FLOW        1918.
                                         TIME        13.75

 ROUTED TO
+                 R040     12.80     1   FLOW        1918.
                                         TIME        13.92

 HYDROGRAPH AT
+                  040       .82     1   FLOW         398.
                                         TIME        12.83

  2 COMBINED AT
+                CP040     13.62     1   FLOW        2017.
                                         TIME        13.92

 ROUTED TO
+                 R045     13.62     1   FLOW        2019.
                                         TIME        14.00

 HYDROGRAPH AT
+                  045       .94     1   FLOW         402.
                                         TIME        12.92

  2 COMBINED AT
+                CP045     14.56     1   FLOW        2157.
                                         TIME        13.92

 ROUTED TO
+                 R050     14.56     1   FLOW        2157.
                                         TIME        14.08

 HYDROGRAPH AT
+                  050       .29     1   FLOW         158.
                                         TIME        12.58

  2 COMBINED AT
+                CP050     14.85     1   FLOW        2179.
                                         TIME        14.08

 HYDROGRAPH AT
+                 Toll       .00     1   FLOW         320.
                                         TIME        13.75

 ROUTED TO
+                 R055       .00     1   FLOW         321.
                                         TIME        14.08

 HYDROGRAPH AT
```

```
+                   055       .54     1   FLOW         242.
                                          TIME        12.67

  2 COMBINED AT
+                 CP055       .54     1   FLOW         362.
                                          TIME        14.08

  2 COMBINED AT
+                 CP055     15.39     1   FLOW        2541.
                                          TIME        14.08
1
                                          SUMMARY OF KINEMATIC WAVE - MUSKINGUM-CUNGE ROUTING
                                              (FLOW IS DIRECT RUNOFF WITHOUT BASE FLOW)
                                                                                 INTERPOLATED TO
                                                                              COMPUTATION INTERVAL
           ISTAQ    ELEMENT      DT       PEAK    TIME TO     VOLUME      DT       PEAK    TIME TO     VOLUME
                                                    PEAK                                     PEAK

                                (MIN)     (CFS)      (MIN)     (IN)     (MIN)     (CFS)     (MIN)       (IN)

          FOR PLAN = 1  RATIO=  .00
              R015  MANE        5.00    622.42    825.00      1.65      5.00    622.42    825.00       1.65


 CONTINUITY SUMMARY (AC-FT) - INFLOW= .2622E+03 EXCESS= .0000E+00 OUTFLOW= .2622E+03 BASIN STORAGE= .1277E-01 PERCENT ERROR=    .0


          FOR PLAN = 1  RATIO=  .00
              R025  MANE        5.00   1162.23    825.00      1.50      5.00   1162.23    825.00       1.50


 CONTINUITY SUMMARY (AC-FT) - INFLOW= .4770E+03 EXCESS= .0000E+00 OUTFLOW= .4771E+03 BASIN STORAGE= .2829E-01 PERCENT ERROR=    .0


          FOR PLAN = 1  RATIO=  .00
              R030  MANE        5.00   1862.12    830.00      1.41      5.00   1862.12    830.00       1.41


 CONTINUITY SUMMARY (AC-FT) - INFLOW= .7923E+03 EXCESS= .0000E+00 OUTFLOW= .7924E+03 BASIN STORAGE= .1613E-01 PERCENT ERROR=    .0


          FOR PLAN = 1  RATIO=  .00
              R035  MANE        5.00   2185.06    825.00      1.45      5.00   2185.06    825.00       1.45


 CONTINUITY SUMMARY (AC-FT) - INFLOW= .9488E+03 EXCESS= .0000E+00 OUTFLOW= .9488E+03 BASIN STORAGE= .4794E-01 PERCENT ERROR=    .0


          FOR PLAN = 1  RATIO=  .00
              R040  MANE        5.00   1917.82    835.00      1.40      5.00   1917.82    835.00       1.40


 CONTINUITY SUMMARY (AC-FT) - INFLOW= .9575E+03 EXCESS= .0000E+00 OUTFLOW= .9575E+03 BASIN STORAGE= .4143E-01 PERCENT ERROR=    .0


          FOR PLAN = 1  RATIO=  .00
              R045  MANE        5.00   2018.86    840.00      1.45      5.00   2018.86    840.00       1.45


 CONTINUITY SUMMARY (AC-FT) - INFLOW= .1052E+04 EXCESS= .0000E+00 OUTFLOW= .1052E+04 BASIN STORAGE= .4020E-01 PERCENT ERROR=    .0


          FOR PLAN = 1  RATIO=  .00
              R050  MANE        5.00   2156.92    845.00      1.49      5.00   2156.92    845.00       1.49


 CONTINUITY SUMMARY (AC-FT) - INFLOW= .1160E+04 EXCESS= .0000E+00 OUTFLOW= .1160E+04 BASIN STORAGE= .1268E+00 PERCENT ERROR=    .0


          FOR PLAN = 1  RATIO=  .00
              R055  MANE        4.00    321.08    844.00     -1.00      5.00    320.75    845.00      -1.00






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

ATTACHMENT 10: GEIGER GRADE ROAD REALIGNMENT EXHIBIT



Kimley-Horn
and Associates, Inc.

9/13/2011

GEIGER GRADE ROAD REALIGNMENT
BAILEY CANYON CREEK - OPTION 1

0' 50' 100' 200'

NORTH

RTC

Appendix B. HEC-HMS Model Support Data

Folders

GIS_Data
- Soils
  - soilmu_a_nv628.shp
  - soilmu_a_nv772.shp
- Watersheds
  - Subbasins.shp
  - KHA_Data
    - Miscellaneous shapefiles from Original Hydrologic Study

HECHMS_Data
- CurveNumber – HEC-HMS model converted from Original Hydrologic Study
- GA_ThreeInch – HEC-HMS Green and Ampt hydrologic model

SupportFiles
- BaileyCanyonHMSFlowComparisons.xlsx – Excel file used for results comparison
- GA_Detail.csv – Green and Ampt values averaged for HEC-HMS model per subbasin
- GA_Summary.csv - Green and Ampt values per subbasin extracted from soils/basin data

Soil data files available upon request

Contact NDOT Research at (775) 888-7000
info@dot.nv.gov and request

"Research Project 674-19-803 Soil Data"

Nevada Department of Transportation
Kristina L. Swallow, P.E. Director
Ken Chambers, Research Division Chief
(775) 888-7220
kchambers@dot.nv.gov
1263 South Stewart Street
Carson City, Nevada 89712