HYDRAULIC MODELING OF TRUCKEE CANAL ALLUVIAL FANS USING SRH-2D

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Abstract: Alluvial fans are gently sloping, fan-shaped landforms created over time by the deposition of sediment. Their gentle slope near mountainous regions attracts development in these flood-prone areas. The flow paths of flood events can change with each event, placing development at risk (National Research Council (NRC), 1996). Because of the uncertainty of flow paths and flood extent, many studies have been performed on alluvial fans in the arid west. Most of these studies focus on the flood elevations inside the alluvial fan and mitigation against such events. This study, however, is not focused on the flood elevations inside the alluvial fan; rather it is focused on the effect the alluvial fan has on the flood wave passing through and into a canal.

The Truckee Canal is located in western Nevada, approximately 35 miles east of Reno, Nevada, and adjacent to the City of Fernley. The areas adjacent to the canal are seven alluvial fans emanating from foothills to the west and southwest. The alluvial fans have complex networks of distributary channels that are constantly changing with each flood event as new sediment gets deposited. Infiltration and channel form within alluvial fans drastically varies longitudinally and laterally. These characteristics make flow modeling complex and requires two-dimensional flow modeling.

A two-dimensional hydraulic model SRH-2D (Lai Y., 2008) was used to model the 10-, 25-, 50-, and 100-year unsteady flow through the seven alluvial fans in the Truckee canal basin. SHR-2D has an unstructured hybrid mixed element mesh, which is based on the arbitrarily shared element method for geometric representation (Lai Y. , 2000). Mesh generation flexibility allows complex alluvial network of incised channels to be modeled in greater detail. SRH-2D applies gridded infiltration to model the losses within the alluvial fans. SRH-2D adopts very robust and stable numerical schemes with a seamless wetting-drying algorithm. Finally, SRH-2D uses a finite volume approach where mass balance accounting was performed to determine the validity of model results.

The model results indicated that basins with spares developed attenuate peak discharge and volume; however, the net effect of flow attenuation is lower than expected for developed alluvial fans. Development within the alluvial fans, however seemingly small, can affect the flow attenuation. The historic channels have been either preserved as they pass through developments, or new channels have been formed by road cuts. The result of this development has concentrated the flows so that the flood hydrograph passes through the alluvial fan before it has time to infiltrate into the soils.

INTRODUCTION

A team evaluating the flooding risk of the Truckee canal wanted to determine the hydrologic loadings for the 10-, 25-, 50-, and 100-year events. The loadings were achieved by coupling a one-dimensional rainfall-runoff modeled with a two-dimensional hydraulic model to simulate lateral inflow along the Truckee canal. A two dimensional hydraulic model was necessary to capture the flow dynamics of alluvial fans that have complex channel geometries and varying infiltration.

Project Location and Basin Description: The Truckee Canal is located in western Nevada, approximately 35 miles east of Reno, Nevada, and adjacent to the City of Fernley (Figure 1). The areas adjacent to the canal are seven alluvial fans emanating from foothills to the west and southwest. The alluvial fans have complex networks of distributary channels that are constantly changing with each flood event as new sediment gets deposited. Infiltration and channel form within alluvial fans drastically varies longitudinally and laterally. These characteristics make flow modeling complex and requires 2-D flow modeling.

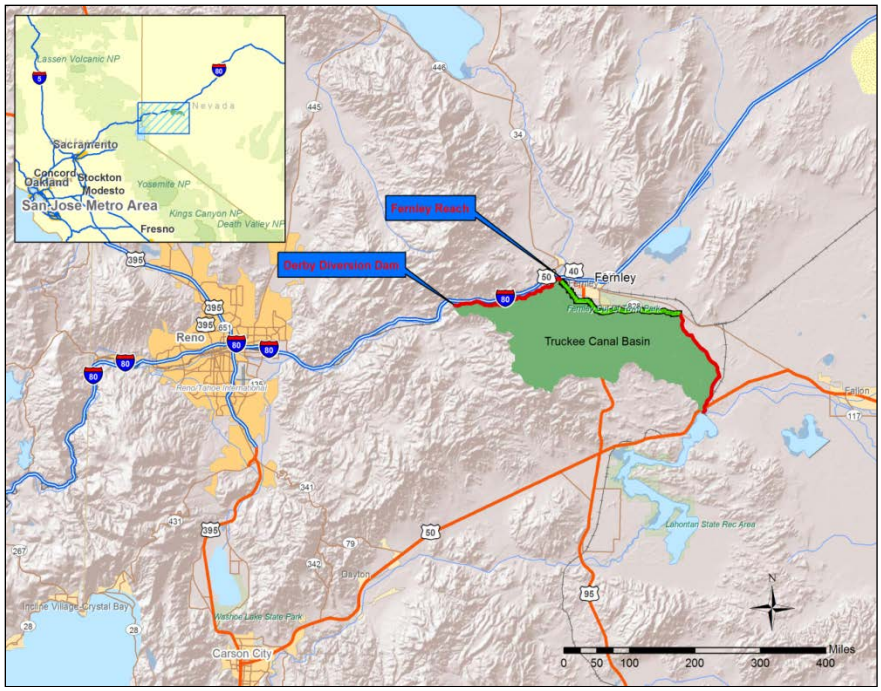

Figure 1 Vicinity map showing the location of the Truckee Canal drainage basin.

The basin area contributing to the Truckee Canal is mostly foothills draining from the south to the north. The Fernley area receives 5.91 inches of annual precipitation. Only the areas to the south of the canal contribute to the flood flows. The overall contributing area along the Truckee canal is approximately 100 mi^2. The alluvial fans are adjacent to the canal emanating from foothills to the west and southwest. The alluvial fans have complex network of distributary channels who's flow paths are in constant flux from sediment deposition. Alluvial fans have mid slopes around 0.016 ft/ft. Small washes inset into Holocene alluvial fans ranging from early to late Holocene in area. A broad distributary network of small incised channels can be found in the alluvial fan consisting of younger Holocene deposits. Alluvial fan channel beds at higher elevations contain predominately gravels and fine moving towards the fan mouth.

Model Selection: The one-dimensional hydrologic model HEC-1, Hydrological Engineering Center 1 (HEC-1) (U.S. Army Corps of Engineers, 1990) was used to model the tributary basins that provide the inflow hydrographs into the alluvial fans. HEC-1 simulates basin surface response to precipitation through a series of interconnect hydrologic and hydraulic components. USACE has superseded HEC-1 with Hydrologic Modeling System (HMS); however, this study chose HEC-1 because of the ability to automate the model and process multiple model runs. Additionally, the HEC-1 model can easily transform Reclamation dimensionless unit hydrographs (Cudworth, 1989). The Reclamation unit hydrograph converts dimensionless hydrographs into a unit hydrograph by three steps. First the basin area is calculated and the lag time is determined. Second, incremental rainfall is converted into incremental runoff while incorporating for losses due to soil infiltration. Third, incremental runoff is transformed into a flood hydrograph. The HEC-1 model simplifies the basin's response to rainfall by lumping parameters. HEC-1 model accurately captures the rainfall response for well-defined basins with incised channels such as those found in the Truckee Canal drainage basin.

The two-dimensional hydraulic model Sediment and River Hydraulics- 2D (SRH-2D) was selected to model the hydraulics within the alluvial fan. SRH2D is a two-dimensional (2D) fixed-bed depth averaged hydraulic model specifically focused on the flow hydraulics of river systems. SRH-2D adopts a zonal approach for coupled modeling of channels and floodplains; a river system is broken down into modeling zones (delineated based on natural features such as topography, vegetation, and bed roughness), each with unique parameters such as flow resistance. One of the major features of SRH-2D is the adoption of an unstructured hybrid mixed element mesh, which is based on the arbitrarily shared element method of Lai (Lai, 2000) for geometric representation. This meshing strategy is flexible enough to facilitate the implementation of the zonal modeling concept; it allows for greater modeling detail in areas of interest, and ultimately leads to increased modeling efficiency through a compromise between solution

accuracy and computing demand. The SRH-2D model is a Reclamation-developed model. The flexibility of the mesh generation allowed the complex alluvial network of incised channels to be modeled in greater detail. Because SRH-2D was developed at Reclamation, custom modifications were easily made to the source code to allow for losses in the alluvial fans.

DATA COLLECTION

Meteorology and Precipitation:

Precipitation Frequency Analysis: Precipitation magnitudes with an associated frequency of occurrence are used as input into the rainfall-runoff model to estimate flood frequency. To compute the precipitation frequency curve for the Truckee Canal watershed, the L-moments regional statistical analysis method was used (Hosking & Wallis, 1997). In regional analyses, it is assumed that additional information in space can account for lack of information in time. In other words, precipitation regional analyses allow for the user to substitute rain gauge observations from within a statistically (and climatically) homogeneous region for precipitation observations at a specific site (i.e., a rain gauge along the Truckee Canal). From this substitution, the user will obtain hundreds to thousands of observations as opposed to the approximate hundred observations (at best) available at-site.

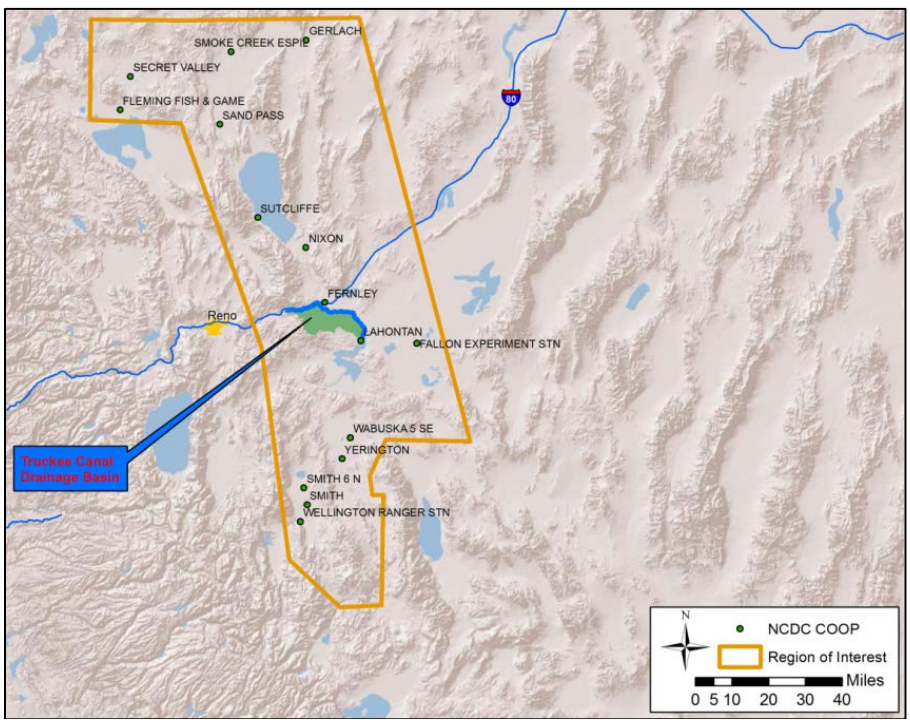

Figure 2 Fifteen NCDC COOP rain gauges with in the Truckee Canal drainage.

Climatically and Statistically Homogeneous Region: 15 NCDC COOP gauges were deemed climatically and statistically homogeneous and were used in the precipitation frequency analysis (Figure 2). These observations amounted to approximately 547 years of station data. The 24-hour annual maxima precipitation observations exhibit low variability of the L-moment ratios (i.e. L-Cv, L-skewness, and L-kurtosis; Table 1). Heterogeneity measures H1 and H2 were computed to assess the variability of station values of L-Cv and L-skewness, respectively. Measures of H1 and H2 (H1=-2.61 and H2=-0.97) confirmed that the chosen region was acceptably homogeneous.

Regional Growth Curve: For the Truckee Canal watershed, the Generalized Logistic (GLO) distribution, a unique form of the Kappa distribution, best describes the regional distribution of the 24-hour annual maxima precipitation dataset. The GLO distribution most closely represents the spread within the cloud of L-skewness and L-kurtosis pairs for the 15 gauges. The regional L-skewness and L-kurtosis estimates further suggest that the GLO distribution is the best-fit three-parameter probability distribution based on L-moment goodness-of-fit tests.

Table 1 L-moments for the 15 gauges in the homogeneous region, where L1 is the location (mean) and t3 is the skewness.

Location	ST	COOP	L1	L-Cv	t3
FLEMING FISH & GAME	CA	043087	1.08	0.1898	0.4341
SECRET VALLEY	CA	048074	0.97	0.2349	0.1384
FALLON EXPERIMENT STN	NV	262780	0.68	0.2137	0.1512
FERNLEY	NV	262840	0.90	0.2025	0.1755
GERLACH	NV	263090	0.86	0.2130	0.3258
LAHONTAN	NV	264349	0.73	0.2293	0.1871
NIXON	NV	265605	0.88	0.2118	0.1679
SAND PASS	NV	267261	0.97	0.2081	0.1832
SMITH	NV	267609	0.93	0.2392	0.2138
SMITH 6 N	NV	267612	0.86	0.2245	0.2199
SMOKE CREEK ESPIL	NV	267618	0.89	0.2544	0.2308
SUTCLIFFE	NV	267953	0.96	0.2350	0.4119
WABUSKA 5 SE	NV	268822	0.72	0.2323	0.1292
WELLINGTON RANGER STN	NV	268977	1.24	0.2259	0.3233
YERLINGTON	NV	269229	0.81	0.2375	0.2167

At-Site Precipitation-Frequency Relationship: The regional growth curve is next scaled by the mean of the 24-hour basin-average point (10 mi^2) precipitation (hereafter, referred to as the basin-average mean) to obtain a 24-hour basin-average point precipitation-frequency curve. This curve is representative of point precipitation with a common annual exceedance probability occurring throughout the watershed. The 24-hour basin-average mean for the contributing area of the Truckee Canal watershed is 0.96 inches.

The following equation is used to scale the regional growth curve by the basin-average mean to produce a site-specific precipitation-frequency relationship (Hosking and Wallis, 1997):

$$Q_i(F) = \hat{\mu}_i q(F) \tag{1}$$

Where Q_i is the at-site precipitation-frequency relationship, $\hat{\mu}_i$ is the at-site mean, and q(F) is the regional growth curve.

24-hour Basin-Average Precipitation Frequency: A fixed areal reduction factor (ARF) is applied throughout the frequency range to the 24-hour basin-average 10 mi^2 precipitation frequency relationship to obtain the basin-average precipitation frequency curve. Fixed ARFs were derived in NOAA Atlas 2 for Nevada for multiple area sizes and durations (Miller, Frederick, & Tracey, 1973). For the area size of the contributing portion of the Truckee Canal watershed (approximately 100 mi^2) at 24-hours, the scaling factor is 93.5%. Table 2 presents the precipitation estimates corresponding to these basin-average frequency curves at select return periods.

Table 2 Basin-average precipitation frequency estimates at select return periods.

1/AEP	All Season 24-hr Basin Average Precipitation (in)
5	1.281
10	1.536
25	1.913
50	2.245
100	2.628

Terrain: Watershed Sciences, Inc. (WS) collected Light Detection and Ranging (LiDAR) data for the alluvial areas on March 9, 2012. The data were combined with previously acquired LiDAR data in 2008 to ensure complete capture of the alluvial basins. The resulting Digital Terrain Model (DTM) achieved a resolution of 0.72 points per ft^2 with a vertical accuracy of 0.08 feet (Woolpert, Inc., 2012).

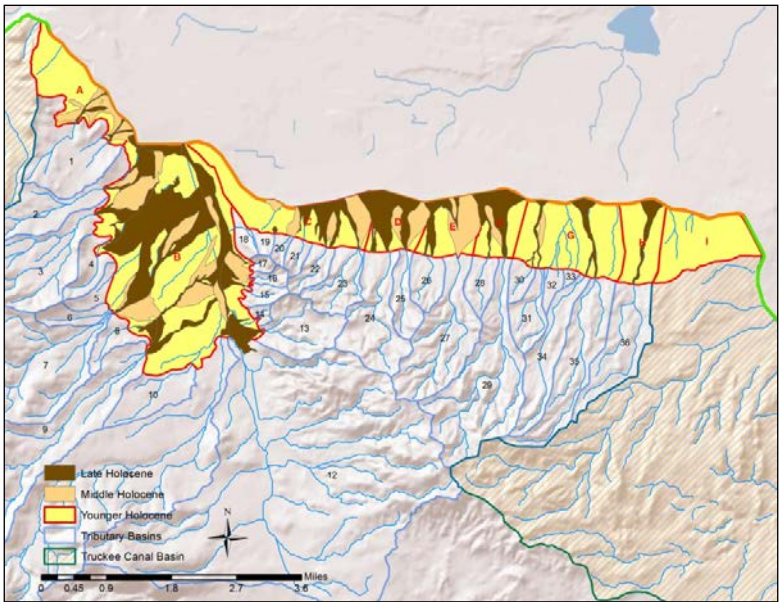

Figure 3 Geology of alluvial fans within the Truckee Canal drainage basin

Alluvial Fan Geology: The bedrock and surficial geology for the Truckee Canal drainage basin has been mapped at a 1:24,000 scale (Faulds & Ramelli, 2009; Faulds, J. E.; Ramelli, A. R.; Herny, C. D., 2008; Faulds, J. E.; Ramelli, A. R., 2005). The alluvial fan basins are comprised of three materials: Lake Lahontan deposits (younger Holocene), middle Holocene alluvial deposits, and old Holocene deposits. The Lake Lahontan deposits consist of gravel beach deposits, gravel deposits, silt deposits, tufa deposits, and silicified sands. In some locations the alluvial deposits may overlay the Lake Lahontan deposits. Locations of these deposits are shown in Figure 3. Because the alluvial deposits are the youngest material on the basin, it was assumed that these represent the locations of flow paths within the basins. When comparing the LiDAR data with the geologic map, the location of alluvial deposits were the same as locations of incised channels. The incised channel locations were also confirmed with a site visit. The channel areas of each sub-basin correlated to the alluvial deposits, and the out-of-bank floodplain areas correlated to Lake Lahontan deposits.

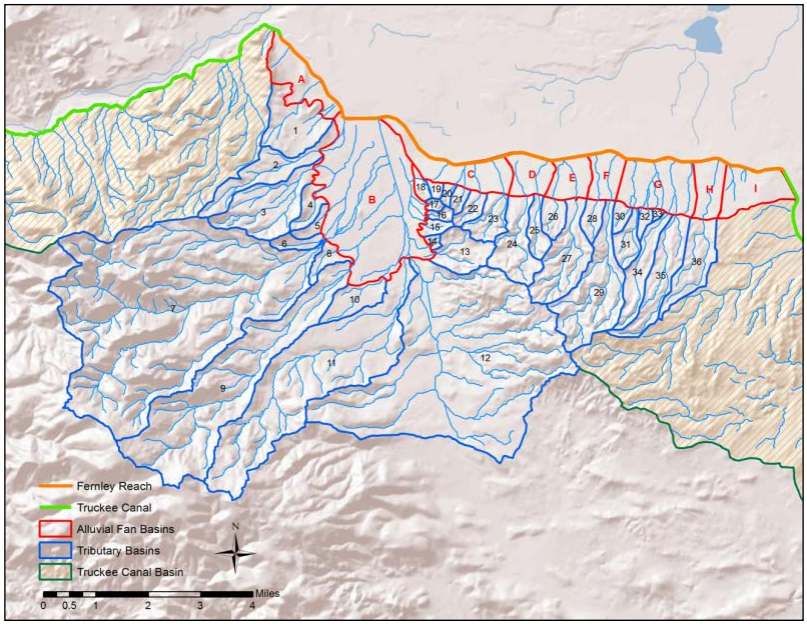

Figure 4 Tributary basins in the Truckee Canal drainage basin.

HEC-1 MODEL INPUTS

Sub-basin Delineation and Characteristics: The individual basins for the apexes of the alluvial fans along the Fernley Reach were determined initially using the national hydrology database (USGS, 2012) and further refined using 30m USGS DEM data (USGS, 2012). This method identified 36 tributary basins and is presented in Figure 3. The lag time was estimated for each sub-basin using methods outlined by the Reclamation Flood Hydrology Manual (Cudworth, 1989) and was calculated using the following equation.

$$Lag\ Time\ = C_t \left(\frac{L \times L_{ca}}{\sqrt{S}}\right)^{0.33} \tag{2}$$

Where L is the watercourse length (feet); L_{ca} is the length along the watercourse to a point opposite of the centroid of the basin (feet); S is the basin slope (feet per mile); and C_t is a constant. The length and slope parameters were estimated using ArcGIS (Environmental Systems Research Insitute (ESRI), 2011)). The value used for the constant, C_t, value of 2.6, corresponding to a Manning's roughness of about 0.1 (Chow, 1959).

Tributary Basin Loss Rates: The computation of loss rates requires consideration of many factors such as historic data, soils information, vegetation, and season. Near the end of a big storm, after the depressions have been filled and the soils within the watershed have been saturated, the difference between rainfall and runoff closely represents the minimum infiltration rate. For this study, the initial loss was assumed to be 0.5 in.

Hydrologic soil groups for each tributary basin were identified from NRCS county-level SSURGO database (Soil Survey Staff, Natural Resources Conservation Service). National Engineering Handbook Part 630 Chapter 7 (NEH) (Natural Resources Concervation Service, 2007) provides range of loss rates for each hydrologic soil group. Table 2 provides the NEH recommend soil loss rates and provides the loss rates selected in this study. The majority of tributary basins were comprised of more than one soil group type; therefore, losses rate of basins were calculated through area weighted method.

Table 3 Estimated soil loss rates for each hydrologic soil group.

Hydrologic Soil Group	Loss Rate (in/hr)		
	Low	High	Used in study
A	0.39	0.3	0.45
B	0.24	0.15	0.3
C	0.11	0.05	0.15
D	0.05	0.00	0.05

The majority of soils in the tributary basins in the Fernley reach are T*ype C* (moderately high potential runoff when thoroughly wet) and *Type D* (high runoff potential when thoroughly wet). Areas of *Type B* (moderately low runoff potential when thoroughly wet) can be found along some of the incised channel areas in basins 7 through 12 and more so in basins 18 through 33. Basins 1 through 6 are reported by NRCS to have exclusively *Type A* (low runoff potential when thoroughly wet), which appears to be a mistake in the NRCS soils reporting. The southern boundary for the *Type A* soils appears to follow a political boundary. Furthermore, the state-level NRCS STATSGO database notes this area as being generally *Type D* (NRCS, 2012).

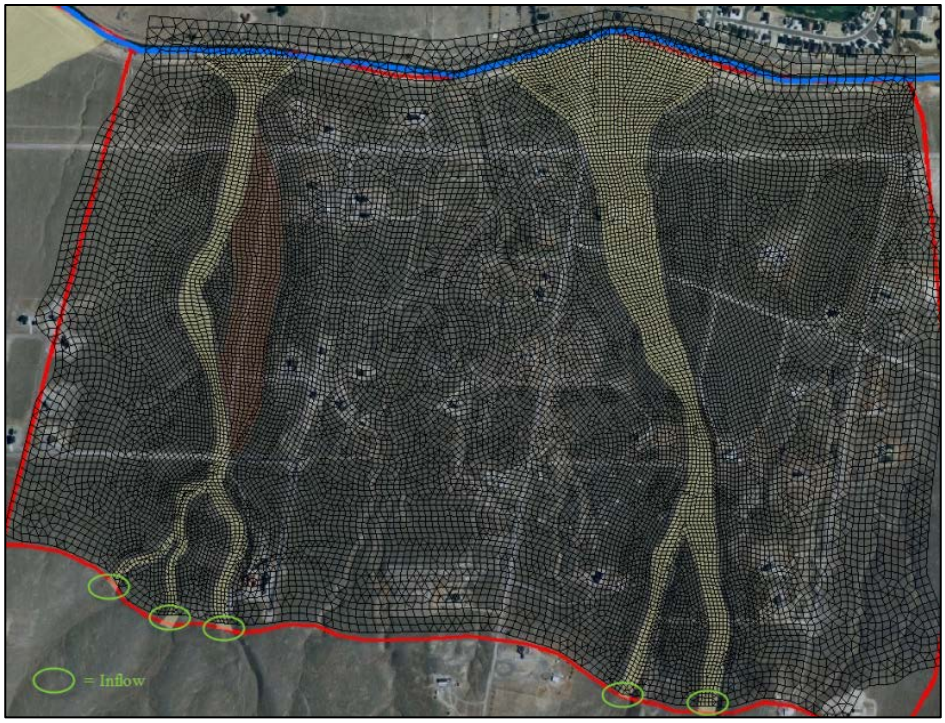

Figure 5 A typical mesh used for the alluvial fan basins. Quadrilaterals were used for younger alluvial channel materials whereas triangles were used from the older area. Alluvial fan basin G is depicted.

SRH-2D MODEL

Each alluvial fan sub-basin was modeled independently of one another. This occurred since terrain data was so robust and demanded large computational resources.

Mesh: Meshes were developed for each alluvial fan sub-basin using Surface Water Modeling Solution (SMS) version 10.1 (Aquaveo, Inc., 2012). The geologic map was imported into SMS to differentiate between in channel locations and out of channel locations. These boundaries were traced to form feature objects. For each feature object, the geologic material type was entered. For each identified identify a Manning's n roughness coefficient. The alluvial channel had no vegetation, so a manning's n of 0.045 was used. Outside of the channel areas were highly vegetated with greasewood and sagebrush; therefore, a Manning's n of 0.1 was used (Chow, 1959). The mesh types where selected for each feature object. The alluvial channels were assigned a quadrilateral mesh type, and the Lake Lahontan deposits were assigned a triangular mesh type. Quadrilateral meshes are used when flow is oriented in a general direction like river channels. Figure 5 illustrates a typical mesh used for this study. Table 4 summarizes the SRH-2D meshes used for alluvial fan basins B through H.

Table 4 SRH2D Alluvial fan mesh summary.

Alluvial Fan Basin	Number of quadrilateral elements	Area (ft^2)		Number of triangular elements	Area (ft^2)	
		Low	High		Low	High
B	19254	1089	24881	6580	613	8373
C	46645	290	19072	9114	110	5155
D	12791	560	1903	2374	191	5334
E	38783	139	263	9942	19	12547
F	16282	1044	2502	5508	137	1253
G	17195	905	8810	7541	1097	2864
H	7932	527	708	3235	237	60406

Infiltration: SRH-2D was modified for this study to account for soil losses in the alluvial areas. SRH2D subtracts a given water depth at the end of each time step using a constant loss rate. The majority of alluvial basins contain

hydrologic soil group *Type B* which has a loss rate between 0.15- to 0.45 in/hr. A loss rate of 0.27 in/hr was applied throughout the alluvial areas. A limitation of the SRH2D model is its inability to model rainfall. This means that rain fall over top of the alluvial fans could not be numerically modeled. The majority of contributing flow into the Truckee Canal Fernley Reach comes from the tributary basins; therefore, rainfall occurring over the alluvial areas was not considered to significantly affect the flood inflows. However, it was assumed that all rainfall would be absorbed in the initial losses which would account for the rainfall on the alluvial fans.

Hydrographs: Hydrographs developed from the HEC-1 model were used as inflow into the SRH2D models apex of the alluvial fans. The unsteady inflow condition was placed at the apex of each alluvial fan.

Boundary Conditions: There were no measurements of flow at the outlet of the alluvial fans to develop a rating curve for the boundary conditions. Therefore critical exits were selected as the downstream boundary conditions for the 7 alluvial fan models. This allowed the simulation of the flow across the alluvial fan with unknown water depth conditions on the downstream end. This was accomplished by artificially creating a 2:1 sloped edge along the downstream boundary. To prevent the effect of model instabilities that occur near critical flow boundaries, the boundary was placed approximately 400 ft from the canal bank.

RESULTS

HEC-1 Results: The peak discharge results of the 1-dimensional modeling for the 36 tributary basins along the Fernley Reach are presented in Table 4. The runoff response remains low for events ranging to the 100-yr events for these basins. Because of the low runoff, these basins were omitted in the 2-dimensional model due to their likelihood to create numerical instabilities from low water depths. Tributary basins 7, 9, 11 and 12 are the largest contributors along the Fernley Reach, accounting for about 50 percent of the volume for the extreme events. Alluvial fan basin I does not respond to the 100-yr or more common rainfall events because the loss rate (0.27 in/hr) is greater than the largest 100-yr incremental rainfall amount modeled for this study.

Table 5 Summary of 24-hour peak discharges from the tributary basins along the Truckee Canal Basin, Fernley Reach.

Tributary Basin	Area (mi^2)	24hr Peak Discharge (ft^3/s)			
		10-yr	25-yr	50-yr	100-yr
1	1.15	29	51	70	92
2	1.09	23	42	59	79
3	1.49	32	57	80	107
4	0.32	9	15	20	27
5	0.18	5	8	11	15
6	0.23	3	8	11	16
7	12.62	143	308	473	666
8	0.25	10	15	19	24
9	5.05	0	40	95	167
10	0.57	5	14	23	33
11	5.55	85	163	237	323
12	10.67	181	339	488	661
13	0.72	32	46	59	73
14	0.07	3	5	6	7
15	0.16	8	11	13	16
16	0.10	5	7	9	11
17	0.07	4	5	6	8
18	0.14	0	0	0	2
19	0.08	0	0	0	0
20	0.09	0	0	0	0
21	0.14	0	0	0	1
22	0.25	0	4	8	13
23	0.50	2	10	18	28
24	1.00	12	28	44	62
25	0.34	3	9	14	21
26	0.32	0	0	0	2
27	1.28	27	49	69	93
28	0.27	0	0	1	6
29	1.89	53	84	112	145
30	0.16	0	0	0	0
31	0.38	9	16	23	30
32	0.12	0	0	0	0
33	0.04	0	0	0	0
34	0.77	24	37	50	64
35	1.13	40	60	78	98
36	0.92	35	52	67	84
I	0.92	0	0	0	0

SRH-2D Results: Table 5, Table 6, Table 7, and Table 8 summarize the hydrograph peak discharges and volumes from the alluvial fans along the Fernley Reach for the 10-, 25-, 50-, and 100-yr return periods, respectively. A mass balance was computed for each model simulation. The percent error, summarized in Tables 5 through 8 was calculated by:

$$Percent\ Error = \frac{V_i - (V_o + V_{lost} + V_{surface})}{V_i} \times 100 \quad (3)$$

The overall error calculated by volume for SRH-2D was below 2 percent for all return periods. The percent error in the mass balance is one measure of the model error. The total percent mass balance error is the summation of the volume differences divided by the total inflow volume. All of the outflows listed in Tables 5 through 8 are lateral inflows along the Fernley Reach. Alluvial basin A (pour point 7) was not modeled because of the assumed 100-yr flood mitigation from the developed sub-division, which would result in no canal inflows. Alluvial basin I was not modeled in SRH-2D because it has no upstream contributing flows; therefore, it was modeled in HEC-1 similar to the tributary basins.

Table 6 10-year hydrologic event for alluvial fans long the Fernley reach.

Alluvial Basin	**Peak Discharge (ft^3/s)**		**48-hr Volume (ac-ft)**				**Difference (V_{in}-(V_o+V_i+V_s))**	**Percent Error**
	Inflow (Q_i)	**Outflow (Q_o)**	**Inflow (V_{in})**	**Outflow (V_o)**	**Loss (V_i)**	**Surface (V_s)**		
B	474	221	169	50	109	13	-3.66	-2.17%
C	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	15	9	3	1	2	0	0.24	7.96%
E	27	6	7	0.2	6.9	0.6	-0.61	-8.66%
F	53	25	19	5	12	1	1.68	8.69%
G	73	55	25	13	10	0	1.45	5.91%
H	35	20	12	4	7	1	1.07	8.99%
TOTAL			235				0.17	0.07%

Table 7 25-year hydrologic event for the alluvial fans long the Fernley reach

Alluvial Basin	**Peak Discharge (ft^3/s)**		**60-hr Volume (ac-ft)**				**Difference (V_{in}-(V_{out}+V_i+V_s))**	**Percent Error**
	Inflow (Q_i)	**Outflow (Q_o)**	**Inflow (V_{in})**	**Outflow (V_{out})**	**Loss (V_i)**	**Surface (V_s)**		
B	981	707	441	221	201	14	5.06	1.15%
C	14	6	3	1	2	0	-0.24	-9.60%
D	37	23	10	5	5	0	0.57	5.55%
E	49	19	18	12.6	12.6	6.0	-13.57	-76.87%
F	84	69	38	16	18	2	2.14	5.65%
G	113	94	49	30	15	0	3.76	7.72%
H	52	40	23	11	10	1	1.14	5.00%
Total			**581**				**-1.14**	**-0.20%**

Table 8 50-year hydrologic event for the alluvial fans long the Fernley reach.

Alluvial Basin	**Peak Discharge (ft^3/s)**		**60-hr Volume (ac-ft)**				**Difference (V_{in}-(V_{out}+V_i+V_s))**	**Percent Error**
	Inflow (Q_i)	**Outflow (Q_o)**	**Inflow (V_{in})**	**Outflow (V_{out})**	**Loss (V_i)**	**Surface (V_s)**		
B	1487	1191	778	476	278	16	8.00	1.03%
C	26	15	7	3	4	2	-2.10	-29.09%
D	58	38	21	11	8	1	1.08	5.24%
E	69	51	29	6.4	16.2	2.5	4.40	14.92%
F	113	86	59	31	24	2	2.73	4.60%
G	149	133	77	54	20	0	3.20	4.15%
H	67	54	36	19	13	1	2.38	6.62%
Total			**1008**				**19.68**	**1.95%**

Table 9 100-year hydrologic event for the alluvial fans long the Fernley reach.

Alluvial Basin	Peak Discharge (ft^3/s)		60-hr Volume (ac-ft)				Difference (V_{in}-(V_{out}+V_i+V_s))	Percent Error
	Inflow (Q_i)	Outflow (Q_o)	Inflow (V_{in})	Outflow (V_{out})	Loss (V_i)	Surface (V_s)		
B	2089	1790	1209	841	340	18	10.31	0.85%
C	41	24	14	7	7	5	-5.54	-39.68%
D	83	54	35	21	12	1	1.64	4.67%
E	93	73	44	17.3	18.4	3.9	4.62	10.45%
F	148	120	91	52	33	2	3.80	4.20%
G	191	172	117	86	27	0	3.42	2.93%
H	84	75	55	33	18	1	2.82	5.16%
Total			**1564**				**21.06**	**1.35%**

DISCUSSION

Alluvial fan flows can lose large amounts of water due to the flow spreading out and infiltrating into the ground over the mouth of the alluvial fan. This flow mechanism occurs in all of the alluvial fans to some extent; however, the net effect of flow attenuation is lower than expected for undeveloped alluvial fans. Development within the alluvial they pass through developments, or new channels have been formed by road cuts. The result of this development has concentrated the flows so that the flood hydrograph passes through the alluvial fan before it has time to infiltrate into the soils.

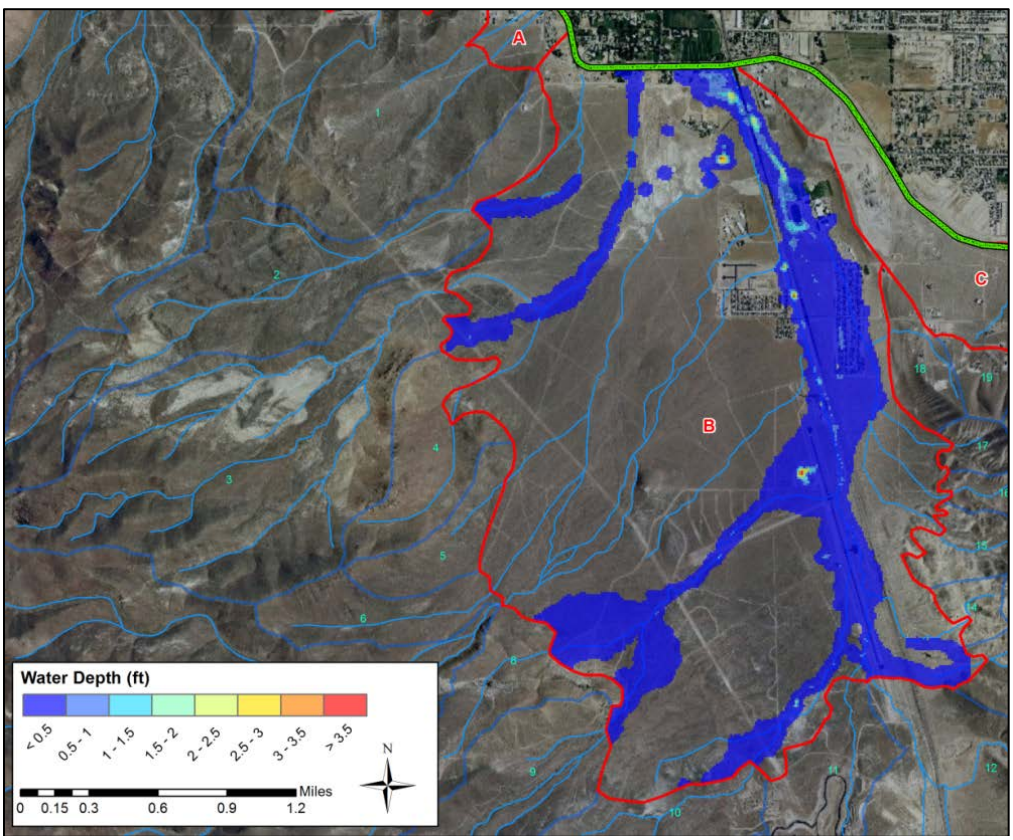

Figure 6 Alluvial basin B water depth got 100-year event at time t=10 hours.

Alluvial basin B is by far the largest flood contributor along the Fernley Reach and also the Truckee Canal. A total of 38.74 mi^2 contributes to 12 significant apexes identified along the apex boundary of alluvial basin B. Highway 95 bisects the basin from north to south providing a conduit for concentrated flow. This becomes apparent in viewing

the 100-yr event at hour 10, the peak of the water depths within the basin (Figure 6.). Aerial photographs of the basin also indicate dirt roads are within the historic incised channels to the west of Highway 95. Other development within the basin includes an airport and 2 subdivisions. Although seemingly insignificant in size, they contribute to the concentrated flows. These developments may provide an explanation why large floods have not been noticed in the past, because the recent developments have only recently increased the probability of larger magnitude floods into the Fernley Reach.

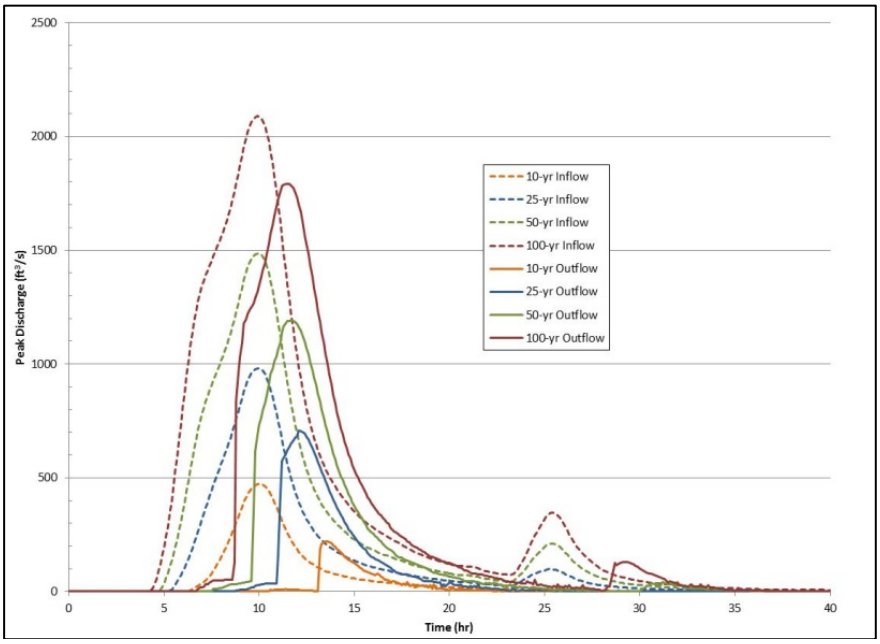

Figure 7 Flood Hydrographs attenuation for 10-, 25-, 50-, and 100-year events in alluvial basin B.

Despite the concentrated flow, a significant amount of the flood hydrograph is lost to water infiltrating into the soil. Figure 6 illustrates that some floods do not flow into the canal at all. Figure 7 illustrates the reduction of the peak inflow into alluvial basin B and the outflow into the right bank of the Fernley Reach. The peak discharge for alluvial basin B is reduced by 14% and 21% for the 100-yr and 50-yr flood events, respectively.

Alluvial basins C through H also show flood hydrograph attenuation, although not as much as expected in undeveloped alluvial channels. The more frequent events, however, did show an increasing amount of attenuation and losses. This is most likely due to less flow concentration within the alluvial fan area resulting in higher losses.

The ponded areas along the right bank in the Fernley Reach are representative of the ground topography in 2008. Material removed from the canal for cleaning since 2008 has changed the topography along the banks. The additional material would affect the amount of ponded water upstream of the canal and could cause additional losses into the soil to occur.

Minor numerical instabilities were noticed in the 2-dimensional model for the lower flow alluvial basins C through H. These instabilities were due to problems associated with SRH-2D when switching between wet and dry elements. Such instabilities are considered to be insignificant and did not affect the overall performance of the model.

CONCLUSION

It had been hypothesized that peak flooding flows within the Truckee canal basin were attenuated due to the adjacent alluvial fans. Classic one-dimensional hydrologic modeling is unable to capture the infiltration losses experience in alluvial fans since the surfaces are dynamic. To better understand the hydrology of the basin, a one-dimensional hydrologic model was coupled with a two-dimensional hydrologic model to simulate the 10-, 25-, 50-, and 100-year flows. This model was un-calibrated since there was no available data to calibrate toward. The model

uncertainty was determined through a mass balance analyses. It was found that only a 2% error in mass balance between the flows entering and leaving the two-dimensional model.

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