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Report

Smelter Creek Regional Flood Control Project

Douglas County, Nevada

Feasibility Engineering Study

October 20, 2015

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Feasibility Engineering Study

Final Report

October 20, 2015

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1 Background and Introduction

Smelter Creek is an intermittent or ephemeral stream that originates in the Pine Nut Mountains and flows through the Ruhenstroth subdivision, which is located in the southern parts of Carson Valley, Douglas County, Nevada. After passing through Ruhenstroth, the channel traverses westerly along the northern boundary of the subdivision crossing several roadways and through residential properties until it reaches a culvert under U.S. Highway 395 (Figure 1 – Project Vicinity Map). The watershed for Smelter Creek encompasses about 12.3 square miles and is shown on Figure 2 – Project Location Map. Smelter Creek is generally dry except during thunderstorms that produce runoff. However, after significant rainfall or local thunderstorms the wash can and does fill up quickly. The watershed of Smelter Creek experienced several large hydrologic events in recent years causing short duration, high-flow conditions to occur. Such storms occurred in 1986, 1997, 2005, and more recently in summer of 2014 and spring of 2015, each resulting in considerable damage to private property, roads, and drainage structures. Photographs taken to document flooding damage from June 11, 2015 storms are included in Appendix 1. During these events, dip sections of the roadways filled with water and sediment completely cutting off residents from access to or from their homes sometimes for several days. Additionally, following the flood event, the dip sections are left filled with 6 to 8 inches of accumulated sediment. The problem is exacerbated by lack of an adequate conveyance system resulting in an unstable flow path as well as routine overflowing of the streambed and shallow flooding of private properties lying downslope. According to the effective Flood Insurance Rate Map (FIRM), approximately 166 parcels are within the Special Flood Hazard Area (SFHA). As a result, homeowners within this area are required to carry flood insurance. Figure 3 – Effective FEMA FIRM depicts the extent of the effective floodplain boundaries

In order to alleviate flood risks to the downstream neighborhood, construction of an on-stream (Smelter Creek) regional flood control (detention) basin, just east of the Ruhenstroth subdivision on BLM managed land was first proposed in early 2011. R.O. Anderson Engineering (ROA) personnel, in partnership with the Douglas County, developed conceptual design plans, and submitted a proposed solution in the form of a hazard mitigation grant application to the Federal Emergency Management Agency (FEMA). Carson Water Subconservancy District (CWSD) retained ROA to perform a feasibility-level

Figure 1 – Project Vicinity Map

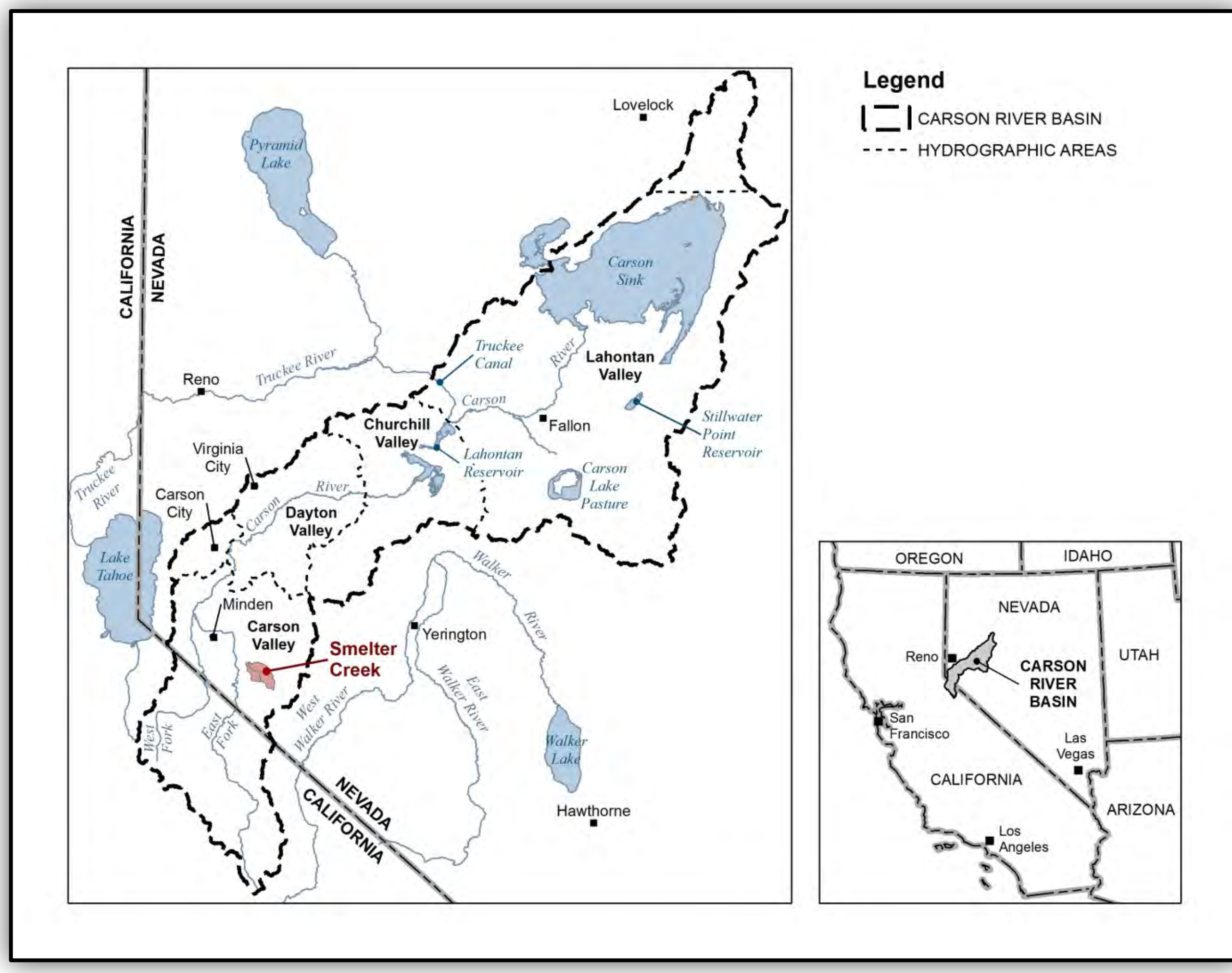


Figure 2 – Project Location Map

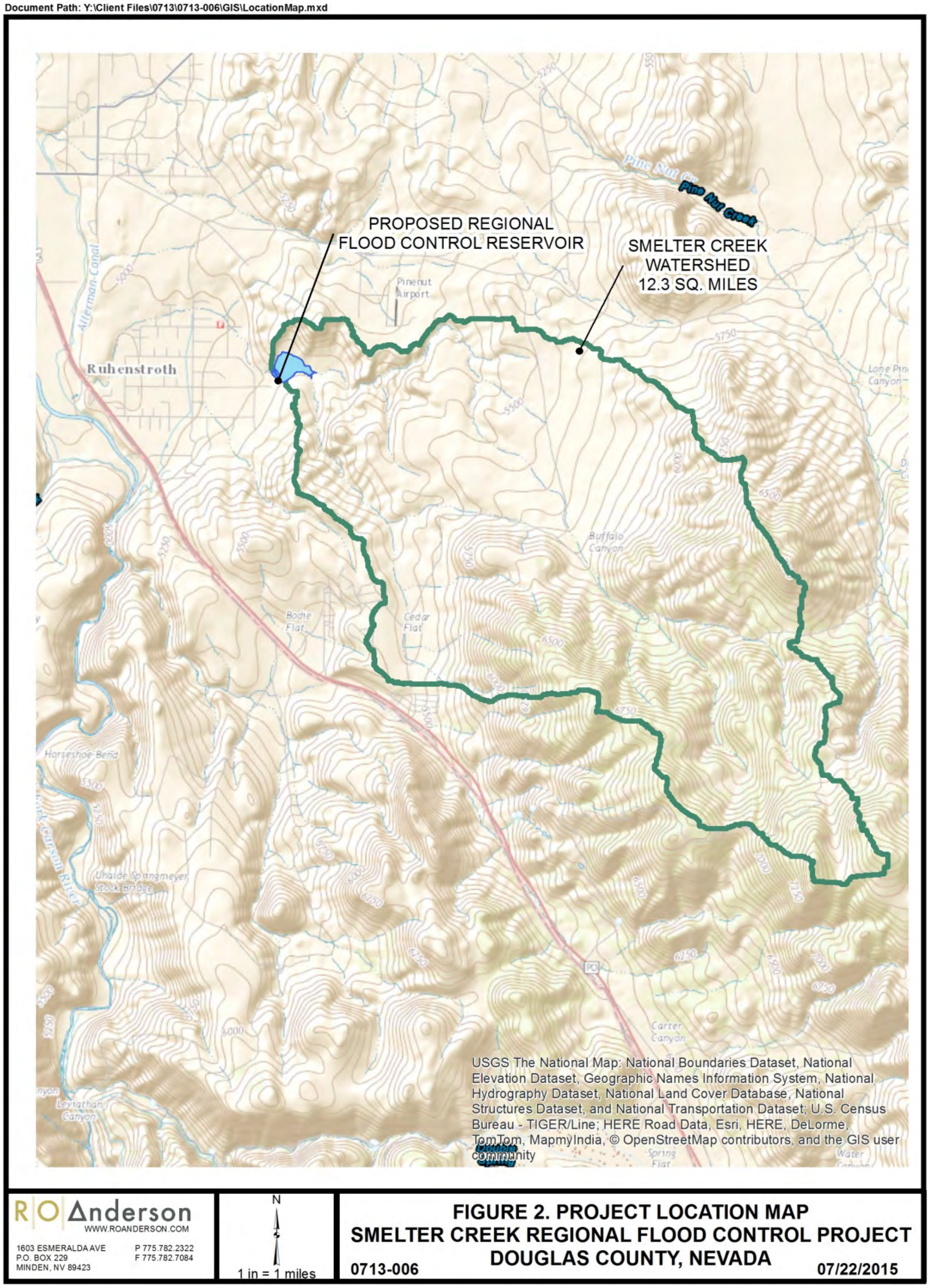
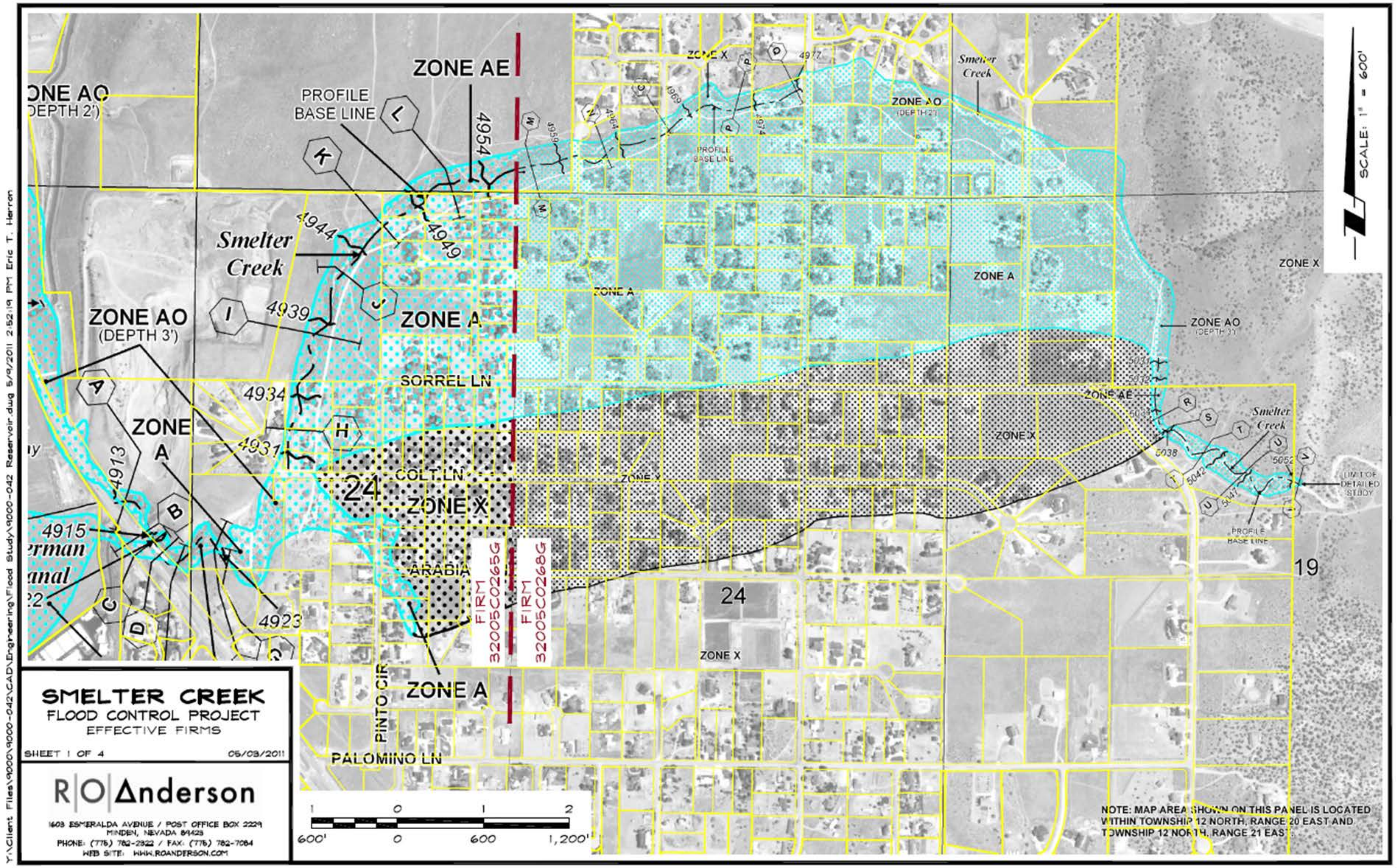


Figure 3 – Effective FEMA FIRM



study to identify alternative solutions to address and minimize future flooding resulting from severe hydrologic events that occur in the Smelter Creek Watershed.

The following specific tasks were included in the scope of services:

- Collect available topographic data for the study area from U.S. Geological Survey (USGS) National Map; Perform field surveys and aerial topographic surveys and construct a work map.
- Delineate Smelter Creek Watershed boundary, and perform hydrologic modeling to estimate runoff characteristics for 1-, 0.2-percent-annual-chance precipitation events.
- Size flood control reservoir outlet structures such that the peak flows resulting from the above-mentioned rainfall events are attenuated and reduced such that outflow from the proposed flood control structure is contained within the banks of Smelter Creek thereby reducing the floodplain footprint along the channel through the Ruhenstroth subdivision.
- Route proposed flood control structure outflow hydrograph downstream from the proposed flood control reservoir all the way to US-395, and delineate approximate floodplain boundaries. The resulting floodplain boundary will be used to assess the number of structures / parcels that could potentially be removed from the regulatory floodplain.
- Perform earthwork calculations, develop engineer's estimate of probable costs to design, permit and ultimately construct the embankment structure, outlet works and necessary appurtenances.
- Prepare a draft report with supporting exhibits for CWSD's, and other public agencies' (stakeholders) review and comment.
- Participate in and present the results of this study at the Carson River Coalition River Corridor Working Group Meeting and one general public meeting.
- Address comments and feedback received from stakeholders and the public and finalize the report.

Section 2 of this report describes criteria used to develop hydrologic model, and also presents the results of hydrologic modeling. Section 3 of the report includes results of hydraulic modeling, and presents floodplain boundary delineations. Section 4 of the report includes a detailed discussion of the basis of design, alternatives considered, a comparison of the alternatives, along with the presentation of the engineer's estimate of probable construction costs for this regional flood control facility. Section 5 of the report contains the findings and conclusions of this study.

2 Hydrologic Modeling

This section of the report describes procedures and methodology used for the development of watershed model using the U.S. Army Corps of Engineers' (USACE) Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS V 4.0) software. HEC-HMS is the next generation Windows version of the popular HEC-1 program, developed by the USACE. It is capable of modeling various catchments' components such as infiltration / evapotranspiration losses, runoff transformations, and a variety of open channel routing methods. HEC-HMS method provides both peak flow and the total volume of runoff and is appropriate method to use when modeling large watersheds that include large conveyance facilities and storage facilities. The following precipitation return interval events were used while preparing the hydrologic modeling.

- 1-percent annual chance of exceedance (100-year event)
- 0.2-percent-annual-chance of exceedance (500-year event)
- ½-Probable Maximum Precipitation (½-PMP)

2.1 HEC-HMS Model Setup

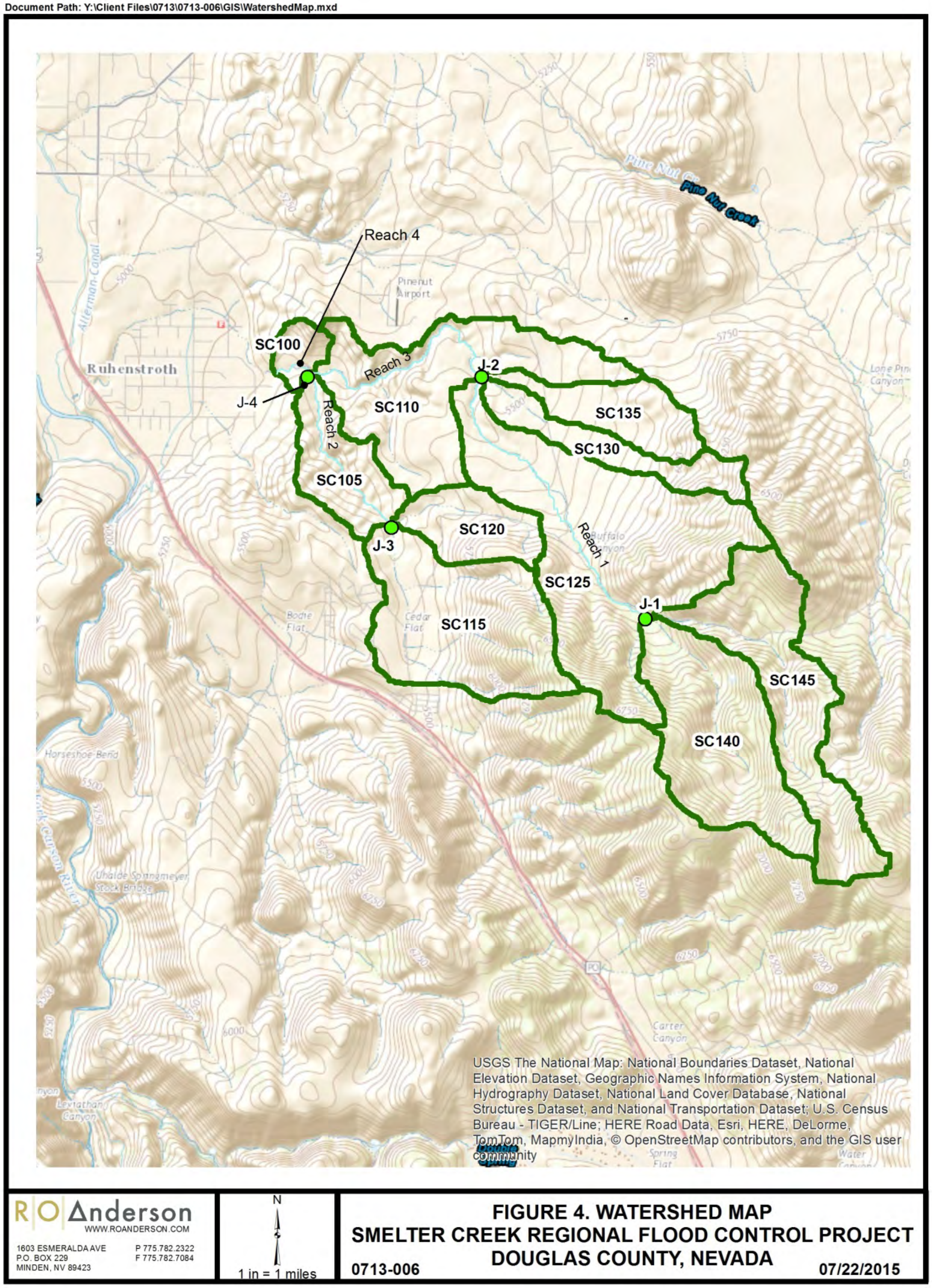
The first step in the development of a hydrologic model is to delineate the contributing watershed boundary. A DEM was created from the topographic data and HEC-GeoHMS tools were used in ESRI's ArcGIS environment to delineate contributing watershed. The total drainage area of the contributing watershed is approximately 12.3 square miles.

To perform detailed hydrologic analyses of the study area, the 12.3 square mile drainage area was subdivided into ten sub-basins based on distinct topographic characteristics. The runoff from these sub-basins is routed downstream, and the flow is added at the junction of sub-basins as shown in Figure 4 – Watershed Map.

Once the sub-basins were delineated, the next step in the development of the hydrologic model was to estimate the parameters used to build the components of the model. After sub-basin delineation, ArcGIS and HEC-GeoHMS were used to develop modeling input parameters and develop the connectivity schematic for the HEC-HMS model.

Figure 4 – Watershed Map

Document Path: Y:\Client Files\0713\0713-006\GIS\WatershedMap.mxd



A HEC-HMS hydrologic model consists of three basic components:

- *A Basin Model*, consisting of a physical representation of watersheds
- *A Meteorologic Model*, consisting of precipitation, evapotranspiration, and snowmelt data
- *A Control Specification*, consisting of information such as hydrologic simulations time span

2.1.A Basin Model:

In order to estimate excess runoff generated from any particular precipitation event the following input information is entered in the Basin Model of HEC-HMS:

- Loss Rate Parameters
- Transformation Parameters
- Base flow Parameters
- Reach Parameters
- Reservoir Parameters, if detention/retention ponds are being modeled

An assortment of different methods is available in HEC-HMS to physically represent these parameters. The following methodologies were used in developing the hydrologic model for the Smelter Creek watershed. A detailed description of estimation of these model parameters are discussed in the subsequent sections of this report:

- Loss Rate: Green-Ampt Method
- Transformation: Snyder Unit Hydrograph Method
- Reach Routing: Muskingum-Cunge Method
- Reservoir Routing: Outflow Structures

For this basin, base flow is assumed to be negligible and, therefore, not taken into account in developing these hydrologic models. The other model parameter estimation is described in the subsequent sections of this report.

2.1.A.1 Loss Rate Parameters

Watershed loss or abstraction is a term used to describe the collective precipitation losses throughout the watershed that occur during a storm. These losses play a significant role in rainfall-runoff modeling as they determine the amount of rainfall excess, or direct runoff, produced by the storm within the model. Typical losses abstracted from rainfall include:

- Soil infiltration
- Landscape interception
- Depression storage (aka: surface storage)
- Evaporation
- Evapotranspiration

The rainfall volume attributable to these losses is not converted to direct runoff. For this study losses such as evaporation, landscape, interception and evapotranspiration by vegetation are considered minor and were not included.

Depression storage, or initial loss, in a sub-basin is the process by which precipitation is abstracted by being retained in puddles, ditches, interception, and other natural or artificial depressions on the land surface. The water either evaporates or eventually contributes to soil moisture by infiltration. Depression storage, in inches over the sub-basin area or computational cell, is subtracted from rainfall and reduces the contribution to runoff. Land use characteristics are used to help quantify estimates of depression storage.

Infiltration is the process by which precipitation is abstracted by seeping into the soil below the land surface. Soil infiltration was estimated using the Green-Ampt method. The Green - Ampt method applies Darcy's law and principle of conservation of mass to estimate infiltration. The method works under the assumption that water enters the soil as a sharp, vertical wetting front that travels as a function of the hydraulic conductivity.

The Green-Ampt infiltration function (in rate form) is

$$f = K_s\left(1 + \frac{\Psi\theta}{F}\right)$$

Where f is the infiltration rate (capacity, L/T), F is the cumulative infiltration (L), K_s is the saturated hydraulic conductivity (L/T), Ψ is the soil suction at the wetting front (L), and θ is the dimensionless soil moisture deficit of the soil at the beginning of the storm.

Parameters (K_s, Ψ, θ) were determined using the protocol defined by Maricopa County, Arizona (Engineering Division, Flood Control District of Maricopa County, 2010). The basic approach is to estimate a weighted saturated hydraulic conductivity by computing the area-weighted mean logarithm (equivalent to computing the area-weighted geometric mean) and then using that value to enter the table in the Maricopa County manual to choose the suction (Ψ) and soil moisture deficit (θ) parameters. Table 1 – Weighted-Average Green-Ampt Parameters below shows a summary of Green-Ampt parameters calculated for each sub-basin: Figure 5 – Soils Map shows NRCS soils overlaid on the sub watersheds of Smelter Creek watershed.

Table 1 – Weighted-Average Green-Ampt Parameters

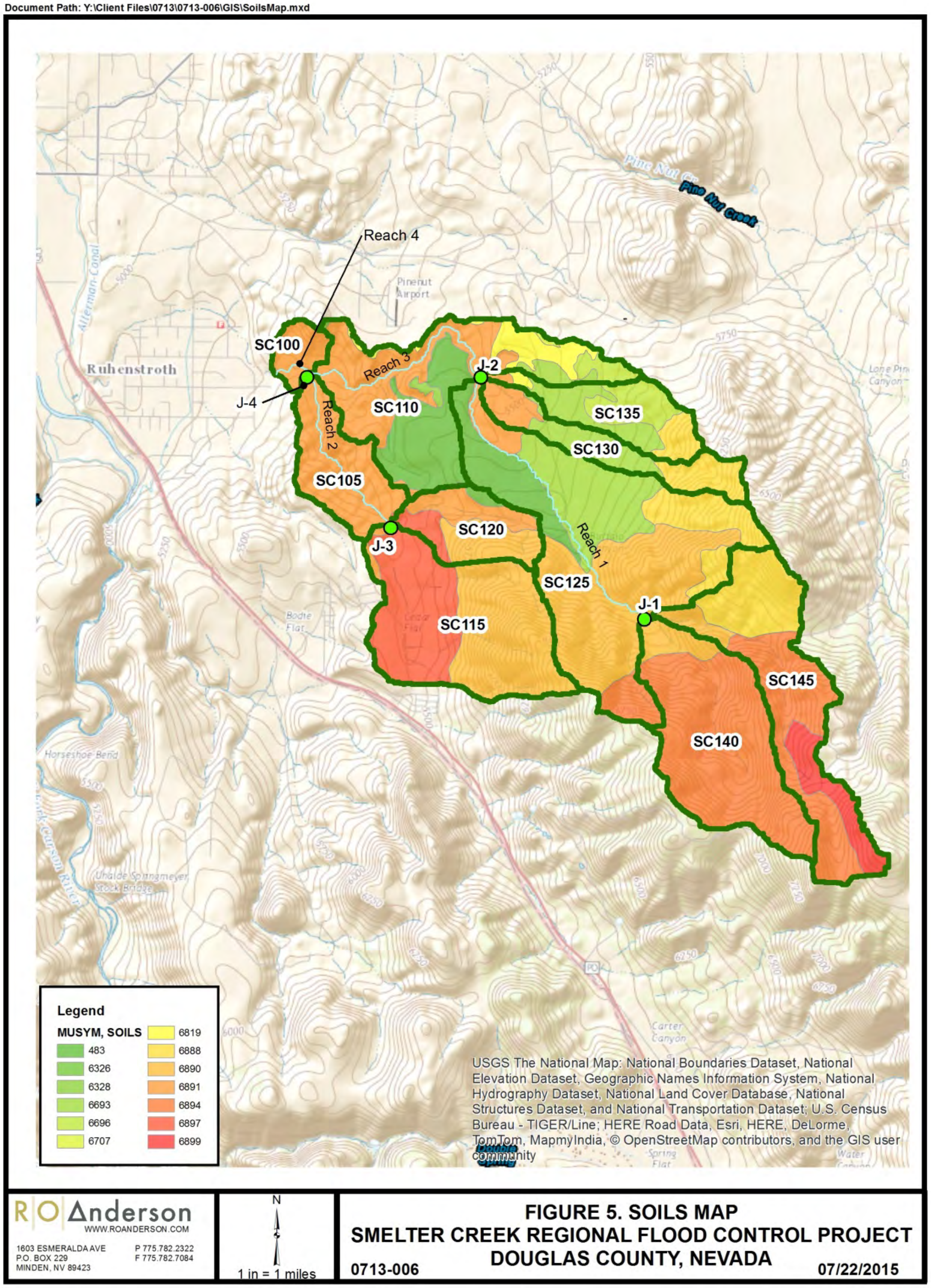
Subwatershed	K_S (in/hr)	Ψ (in)	θ[1]
SC100	0.40	4.30	0.35
SC105	0.40	4.30	0.35
SC110	0.62	4.20	0.35
SC115	1.18	2.50	0.35
SC120	0.93	3.30	0.35
SC125	0.89	3.40	0.35
SC130	0.40	4.30	0.35
SC135	0.39	4.37	0.35
SC140	1.20	2.40	0.35
SC145	0.96	3.20	0.35

[1]Dimensionless Parameter

2.1.A.2 Transformation Parameters

Rainfall transformation, as it relates to rainfall-runoff modeling, refers to the process of converting excess rainfall into storm-water runoff – typically in the form of a runoff hydrograph. HEC-HMS has a total of eight different transform methods available. The choices include various unit hydrograph methods, a kinematic wave implementation, and a linear quasi-distributed method. Out of all the available transformation methods within HEC-HMS, Snyder Unit Hydrograph (UH) method was selected to perform runoff transformation calculations. The Snyder UH method was selected because of its

Figure 5 – Soils Map



wide spread use in the mountainous watersheds, and the reliable input parameters available for this particular region. Other available rainfall transformation methods, such as the SCS UH and the Clark UH were considered but known limitations of each made the Snyder UH a better selection.

The Snyder UH method, as proposed by F.F. Snyder in 1938, was developed from studies of basins in the Appalachian Mountain region and uses a synthesized hydrograph approach derived from specific physical watershed measurements (Johnstone, 1949). The method calculates flow values using a Snyder lag time as presented in the following equations:

$$Q_p = \frac{640 C_p A}{L_g}$$

where

Q_p= peak runoff (cfs)

C_p= empirical storage or peaking coefficient,

A = watershed or sub-basin area (mi^2), and

L_g = standard Snyder basin lag time (hr).

and

$$L_g = C_t (L L_c)^{0.3}$$

where

C_t = empirical landform coefficient,

L = length of the watershed main stem from divide to outlet (mi), and

L_c = length along the main stem to a point nearest (perpendicular) to the watershed centroid (mi).

Snyder UH is based on five input parameters – three of which are directly measurable from the watershed. The two remaining parameters (C_p and C_t) are empirically based and usually subjectively derived. It is recommended that values for these two parameters be developed through model calibrations from gaged watersheds. Currently, the Smelter Creek watershed does not contain gages, therefore it was decided to use published values for these parameters, which is discussed later in this section.

Complications with using referenced sources of C_t parameter values have been reduced since the inception of the Snyder UH method. The method has been studied, modified, and regionalized by the USACE, US Bureau of Reclamation (USBR), and others. In 1944, the

Los Angeles District of the USACE introduced a modification to the original Snyder standard basin lag time by including the slope of the longest watercourse – a sixth physical watershed parameter (Cudworth, 1989). Subsequently, the USBR has studied, synthesized, calibrated, and further modified the Snyder standard lag time equation into the form used in this restudy, which is:

$$L_g = 26K_n\left(\frac{LL_c}{\sqrt{S}}\right)^{0.33}$$

where

K_n = an average Manning's *n* roughness coefficient for the principal watercourse of the watershed set to reflect hydraulic conditions during flood events and

S = overall or average slope of the longest watercourse of the watershed reflecting average conditions (ft/mi).

The primary modification in this form of the Snyder lag time equation is the conversion of the *Ct* parameter into the factor of 26 times average Manning's *n* roughness coefficient, K_n. Most hydrologic modelers have an intuitive or educated sense of appropriate Manning's *n* values – versus the subjective selection of the widely ranging C_t landform parameter.

Runoff using the Snyder UH method is estimated using the following parameters:

- Empirical storage or peaking coefficient, C_p
- Watershed or sub-basin area (mi^2), A
- Length of the watershed main stem from divide to outlet (mi), L
- Length along the main stem to a point nearest (perpendicular) to the watershed centroid (mi), L_c
- Average Manning's roughness coefficient for the principal watercourse of the watershed, K_n
- Average slope of the longest watercourse (ft/mi), S

Early studies developed from the use of the Snyder UH method produced a fairly narrow band of peaking coefficient, C_p, values, ranging from 0.4 to 0.8 (Bedient, 1992). For this study, peaking coefficients are set near the middle of the published range at 0.50. Watershed area, watercourse lengths and slopes were determined using ArcGIS tools. Table 2 – Snyder Unit Hydrograph Parameters lists estimated model parameters.

Table 2 – Snyder Unit Hydrograph Parameters

Subbasin	Area (sq. Miles)	Length of Longest Water Course "L" (mile)	Length Along Longest Water Course Nearest to Centroid "L_c" (mile)	High Point (ft)	Low Point (ft)	Elevation Diff (ft)	Slope of Longest Water Course (ft/mile)	UH Peaking Coefficient (C_t)	Manning's n	USBR Method Lag Time (hrs)
SC100	1.74	0.79	0.27	5,420.00	5,060.00	360.00	456.79	0.5	0.11	0.62
SC105	0.19	1.95	0.99	5,465.00	5,085.00	380.00	194.77	0.5	0.11	1.49
SC110	2.93	3.79	1.22	5,800.00	5,085.00	715.00	188.84	0.5	0.11	2.00
SC115	0.59	3.05	1.03	6,225.00	5,350.00	875.00	286.58	0.5	0.11	1.64
SC120	0.63	1.86	0.83	6,000.00	5,350.00	650.00	350.00	0.5	0.11	1.26
SC125	0.67	4.26	2.23	6,890.00	5,380.00	1,510.00	354.80	0.5	0.11	2.28
SC130	0.59	2.80	1.36	6,670.00	5,380.00	1,290.00	460.90	0.5	0.11	1.62
SC135	1.71	2.28	1.41	6,212.00	5,380.00	832.00	364.85	0.5	0.11	1.59
SC140	1.62	2.99	1.43	7,617.00	5,964.00	1,653.00	553.43	0.5	0.11	1.63
SC145	1.59	4.10	1.80	7,700.00	5,964.00	1,736.00	423.28	0.5	0.11	2.04

2.1.A.3 Reach Parameters

A reach is an element of the watershed with one or more inflow and only one outflow. Inflow comes from other elements in the basin model. Outflow is computed using one of 7 different routing methods that simulate open channel flow. Given the predominantly natural terrain and limited land uses in the study area, the Muskingum-Cunge 8-point routing method was selected, and is appropriate. The Muskingum-Cunge routing method is a combination of the conservation of mass and the iterative diffusion of the conservation of momentum at every time step within the channel (USACE, 2009). The following parameters need to be estimated in order to use Muskingum-Cunge routing method:

- Channel length,
- Channel average slope,
- Manning's *n* roughness coefficient for the channel and overbank areas, and
- Eight-point cross-section of channel and effective overbank flow areas.

ArcGIS was utilized to determine average reach cross-sections, channel lengths, and average slopes for each of the reaches defined in the study area. It is important to note that for the Muskingum-Cunge method, the Manning's *n* values are selected to reflect average conditions throughout the entire routing reach. The Manning's *n* values selected for the routing reaches in the HEC-HMS model range from 0.04 to 0.05 in the channels and from 0.055 to 0.08 in the overbank areas. A summary of the estimated Muskingum-Cunge parameters are shown in the Table 3 – Muskingum-Cunge Reach Parametets on the next page:

Table 3 – Muskingum-Cunge Reach Parametets

Reach	Length (ft)	Elevation U/S (ft)	Elevation D/S (ft)	Slope (ft/ft)	Mannig's n (Main Channel)	Mannig's n (Over Banks)
1	16,138	6,890.0	5,380.0	0.219	0.040	0.060
2	8,931	5,350.0	5,085.0	0.050	0.040	0.060
3	12,334	5,380.0	5,085.0	0.055	0.040	0.060
4	1,962	5,085.0	5,060.0	0.005	0.040	0.060

2.1.A.4 Reservoir Parameters

A reservoir element is added to model storage and resulting attenuation of peak flood flows resulting from various precipitation events. A reservoir element in the HEC-HMS model can be used to model reservoirs, lakes, and ponds, and may have one or more inflow and one computed outflow. Inflow into the reservoir element comes from other elements in the basin model. If there is more than one inflow, all inflow is added together before computing the outflow. It is assumed that the water surface in the reservoir pool is level.

While a reservoir element conceptually represents a natural lake, or a lake behind a dam, as in this case, the actual storage simulation calculations are performed by a routing method contained within the reservoir. Four different reservoir routing methods are available in HEC-HMS, and Outflow Structures routing method was chosen for this study. Outflow Structures routing method is designed to model reservoirs with a number of uncontrolled outlet structures. For example, a reservoir may have a spillway and several low-level outlet pipes. Low-level outlet was modeled as a 60-inch RCP culvert that allows for partially full or submerged flow that takes both Inlet and Outlet control conditions. In addition, a 20-ft wide spillway was included to pass flood flows over the dam top in a controlled manner. The spillway was modeled as a broad-crested spillway with a discharge coefficient of 3. The crest of the spillway was set such that it will only be used (discharge floodwaters) during 0.2-percent-annual-chance, and ½-PMP events. That is, the 1-percent annual chance of exceedance (100-year) event will be detained within the reservoir.

Several methods are available for defining the storage properties of the reservoir. Elevation-Area method was used for this study to define the characteristics of the proposed reservoir. The Elevation-Area data was extracted from the topographic data using ArcGIS 3-D Analyst and is graphically shown on Figure 6 – Reservoir Stage – Storage Volume

Curve The HEC-HMS automatically transforms provided elevation-area into an elevation-storage curve using the conic formula, and will compute the elevation-area-storage characteristics for each time interval.

In order for HEC-HMS to start reservoir transformation computations, initial conditions must be specified. Out of the two choices HEC-HMS provides to set initial condition, the pool elevation method was chosen, and the bottom of the proposed reservoir was used as the initial pool elevation. Tailwater was assumed to have no effect on the reservoir flow, and was, therefore, ignored. The following table summarizes low-level outlet and spillway characteristics considered:

Table 4 – Low-Level Outlet and Spillway Details

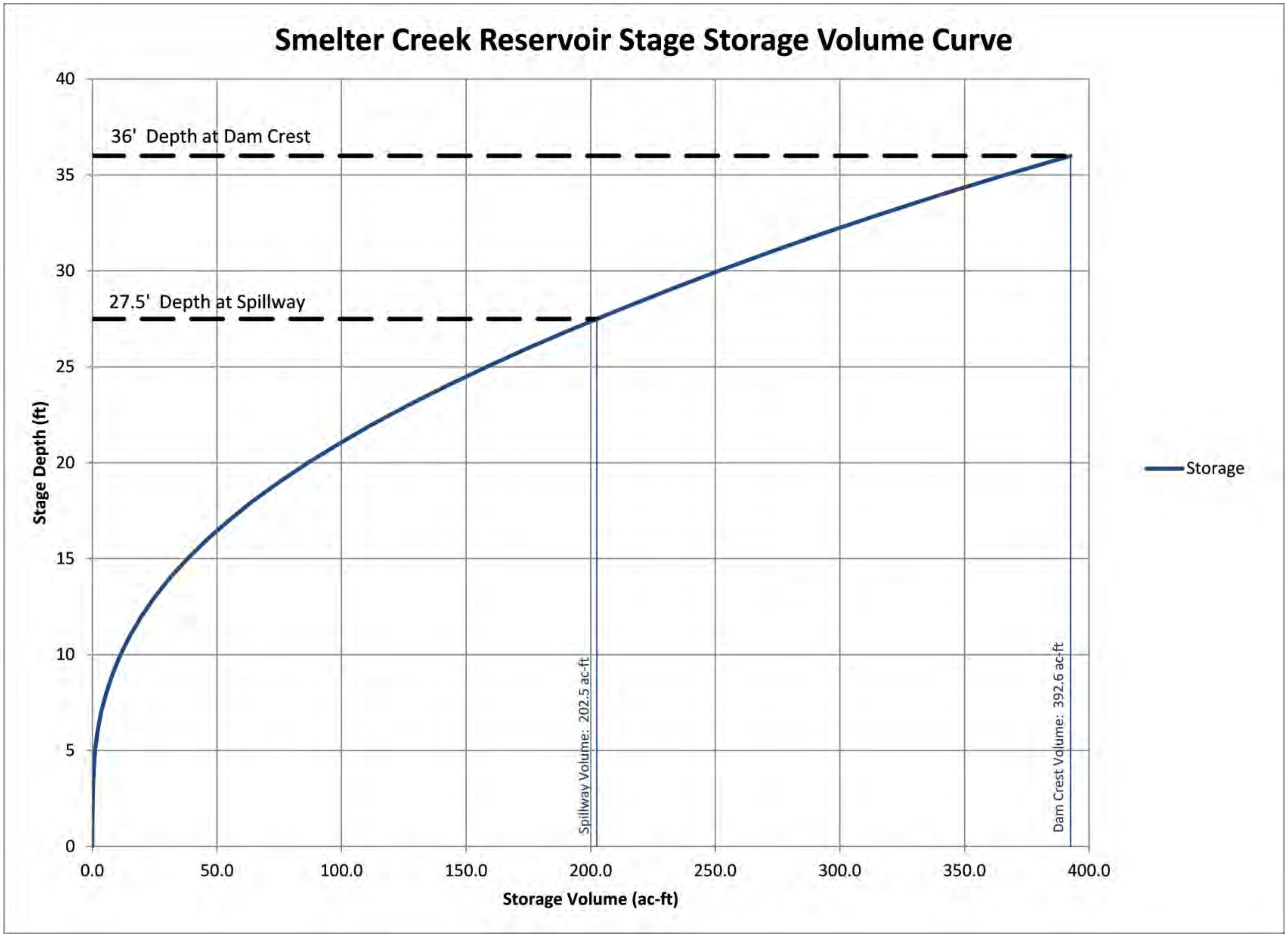
Embankment Details - Units: feet	
Primary Outlet IE_{IN}	5,086
Primary Outlet IE_{OUT}	5,082
Primary Outlet Size	5
Emergency Spillway Crest	5,113.5
Emergency Spillway Width	20
Top of Dam	5,122
Height of Dam	36

2.1.B Meteorologic Model:

In the Meteorologic Model, only the information pertaining to precipitation is entered. Out of several possible methods available to enter precipitation data, Specified Hyetograph Method was selected for use in developing the Meteorologic Model. Hypothetical design storms were developed using the NOAA Atlas 14 grids within ArcGIS to calculate an area-weighted average for each sub-basin for the 5, 10, 15, 30, 60-minute and 2, 3, 6, 12, and 24-hour rainfall depths for the 1-, and 0.2-percent-annual-chance precipitation events. For hydrologic modeling purposes, these rainfall depths were used to develop custom, balanced design storm hyetographs for each sub-basin within each watershed.

Prior to the development of individual rainfall hyetographs, an Area Reduction Factor (ARF) was applied to the rainfall depths for each sub-basin. When appropriate, the use of ARFs reduces the total rainfall depths for the given storm durations – with larger reductions

Figure 6 – Reservoir Stage – Storage Volume Curve



applied to the shorter duration and smaller reductions assigned to the longer durations. NOAA Atlas 14 does not address ARFs but its predecessor, NOAA Atlas 2, included curves for ARFs based on watershed area and storm durations (Miller, 1973). This information was used for the rainfall depths for the study area. Appendix 2 includes a summary table for the original NOAA Atlas 14 rainfall depths, the applicable NOAA Atlas 2 ARF values, and the resulting rainfall depths for each sub-basin.

The rainfall depths for the Probable Maximum Precipitation (PMP) were estimated using the protocol presented in Hydrometeorological Report 49 (U.S. Department of Commerce, 1984). The PMP calculations are presented in Table 5 – PMP Calculations and graphically depicted on Figure 7 – General Storm PMP Plot.

2.1.C Control Specifications:

Control specifications are one of the main components of the model, even though they do not contain much parameter data. Control specifications will govern the model simulation time, or the duration of the runoff. The duration of the simulation is defined by the starting date, starting time, ending date, and the ending time in the control specifications. The control specifications are selected so that it exceeds the duration of the rainfall specified in the meteorologic model.

2.2 Hydrologic Modeling Results

The HEC-HMS hydrologic model was used to determine storm-water hydrographs and peak flow rates for the 1- , 0.2-percent-annual-chance, and ½-PMP events under existing land use and watershed conditions for the entire study area. The model is based on the input parameters and modeling methodologies as described in detail in the previous sections of the report. Table 6 summarizes peak flow rates, and associate runoff volume for each rainfall event considered in this study for each sub-basin, including junctions, reaches of the model. Table 7 lists peak storage, peak elevation, along with the available freeboard in the proposed reservoir for each rainfall event modeled. Detailed printouts of the Hydrologic Modeling results for each storm event are included in Appendix 2.

It should be noted that the effective FIS lists peak flow (1,048 cfs) resulting from only 1-percent annual chance precipitation event for Smelter Creek watershed. The effective FIS does not, however, list the estimated discharge from the 0.2-percent annual chance flood.

Table 5 – PMP Calculations

Project # 0713-006
Client: CWSD

Smelter Creek Detention Ponds
Feasibility Engineering Study

Prepared: SG
Checked: ROA

Table 6.1. General -Storm PMP Computations for the Colorado River and Great Basin.

Drainage: Smelter Creek — Area: 12.6 Sq. Miles

Latitude: 38.86840 — Longitude: -119.62140 — of Basin Center

Month: October

Step	Description	Value	Unit	6	12	18	24	48	72	Unit
				Duration (hrs)						
A	Convergence PMP									
	1. Drainage average value (from one of the figures 2.5 to 2.16)	9.2	Inch							
	2. Reduction for barrier elevation (fig. 2.18)	50	%							
	3. Barrier elevation reduced PMP	4.6	Inch							
	4. Durational Variation (Figs. 2.25 to 2.27 & Table 2.7)			62	82	93	100	119	129	%
	5. Convergence PMP for indicated durations (Steps 3X4)			2.9	3.8	4.3	4.6	5.5	5.9	Inch
	6. Incremental 10 mi^2 PMP (Successive subtraction in step 5)			2.9	0.9	0.5	0.3	0.9	0.5	Inch
	7. Areal reduction (Select from figs 2.28 and 2.29)			100	100	100	100	100	100	%
	8. Aerially reduced PMP (Step 6 X Step 7)			2.9	0.9	0.5	0.3	0.9	0.5	Inch
	9. Drainage average PMP (accumulated values of step 8)			2.9	3.8	4.3	4.6	5.5	5.9	Inch
B	Orographic PMP									
	1. Drainage average orographic index (from figure 3.11 a to d)	2	Inch							
	2. Areal reduction (figure 3.20)	100	%							
	3. Adjustment for month (one of figs 3.12 to 3.17)	105	%							
	4. Aerially and seasonally adjusted PMP (Steps 1 X 2 X 3)	2.1	Inch							
	5. Durational variation (Table 3.9)			30	57	80	157	157	185	%
	6. Orographic PMP for given durations (Steps 4 X 5)			0.6	1.2	1.7	3.3	3.3	3.9	Inch
C.	Total PMP									
	1. Add Steps A9 and B6			3.5	5.0	6.0	7.9	8.8	9.8	Inch
	2. PMP for other durations from smooth curve fitted to plot of computed data									
	3. Comparison with local-storm PMP (see sec 6.3)									

Reference:
Hydrometeorological Report No. 49 - Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages, Reprinted 1984
U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Army Corps of Engineers

PMP.xlsx — R|O Anderson — General-Storm-PMP

Figure 7 – General Storm PMP Plot

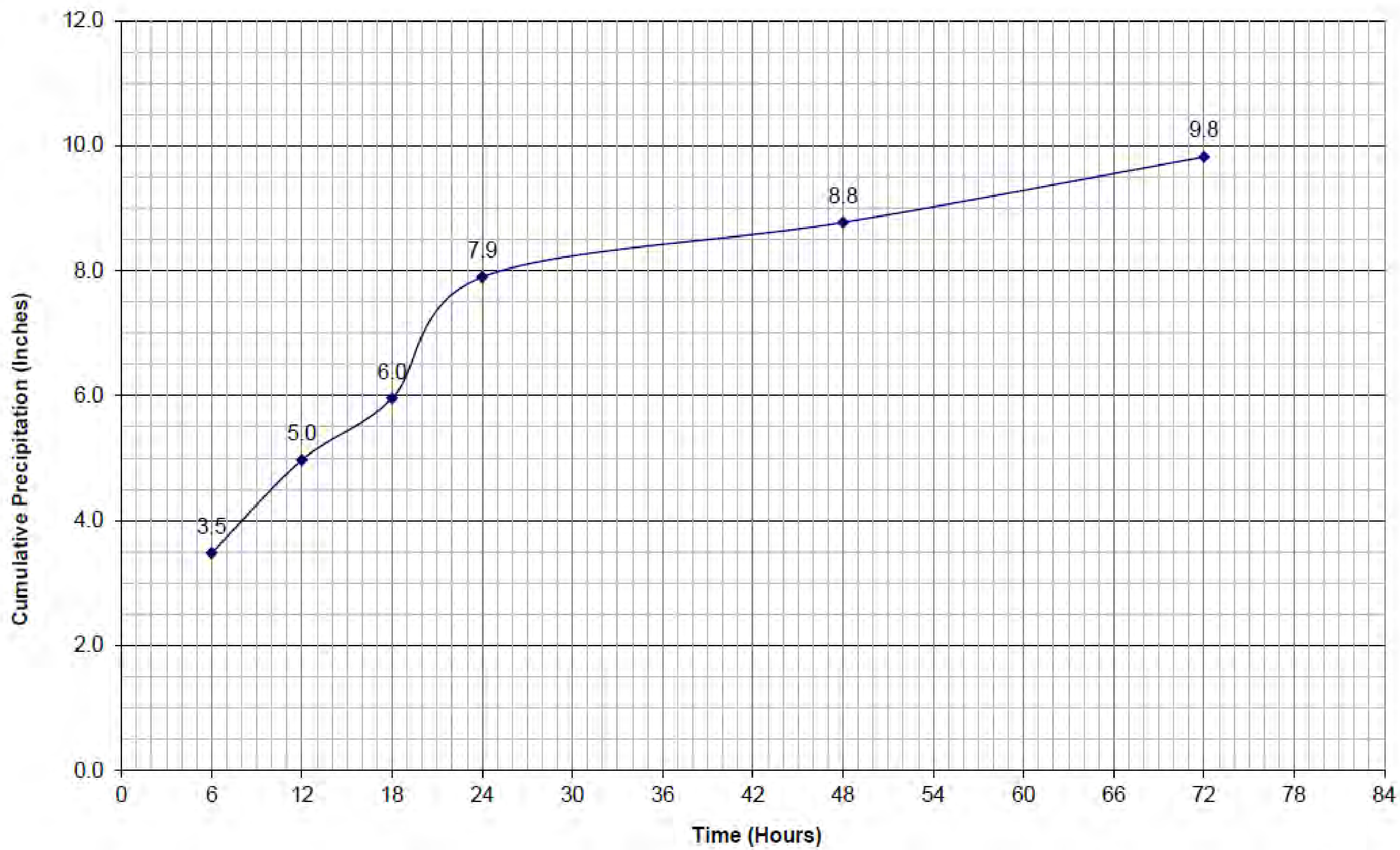


Table 6 – Summary of Hydrologic Modeling Results

	1-percent annual chance			0.2-percent annual chance		1/2-Probable Maximum Precipitation	
Hydrologic Element	Drainage Area (Sq. Miles)	Peak Discharge (cfs)	Volume (Acre-feet)	Peak Discharge (cfs)	Volume (Acre-feet)	Peak Discharge (cfs)	Volume (Acre-feet)
SC140	1.62	94.9	24.7	266.4	69.5	294.0	77.2
SC145	1.59	88.3	28.3	233.8	75.1	249.4	80.6
J-1	3.21	177.7	53	486.1	144.6	528.7	157.7
Reach-1	3.21	177.8	52.8	485.9	144.2	528.9	157.4
SC135	1.71	185.2	47.2	469.6	120.6	472.5	124.7
SC125	0.67	28	9.9	92.3	32.6	97.6	34.7
SC130	0.59	58.4	15.2	157.3	41.2	158.6	42.7
J-2	6.18	413.2	125.1	1133.3	338.6	1204.7	359.3
Reach-3	6.18	412.8	124.7	1133.2	337.9	1204.4	358.7
SC110	2.93	177.9	56	534.6	169.0	553.0	176.3
SC120	0.63	43.9	8.9	150.9	30.7	159.5	32.9
SC115	0.59	28.5	7.5	96.8	25.4	106.8	28.2
J-3	1.22	69.8	16.4	239.1	56.2	257.4	61.1
Reach-2	1.22	69.7	16.4	238.7	56.2	257.1	61.1
SC105	0.19	17.7	4.2	54.9	13.3	55.2	13.8
J-4	10.52	663.2	201.3	1926.9	576.4	2037.9	609.8
Reach-4	10.52	661.5	201	1923.8	575.8	2035.0	609.3
SC100	1.74	372.4	38.4	1133.5	121.7	1079.0	126.0
J-5	12.26	730	239.4	2182.9	697.6	2335.8	735.3
Reservoir	12.26	380.5	239.3	1114.5	607.0	1222.4	642.9

Table 7 – Reservoir Summary

Hydrologic Event	Peak Inflow (cfs)	Peak Storage (Acre-Feet)	Peak Elevation (Feet)	Freeboard (feet)
100-Year 24-Hour	730.0	67.1	5,104.3	17.7
500-Year 24-Hour	2,182.9	295.9	5,118.1	3.9
1/2 PMF	2,335.8	307.9	5,118.6	3.4

This hydrologic study estimated peak runoff resulting from 1-percent annual chance flood to be approximately 730 cfs, which is 318 cfs lower than the effective peak flow. The reduction of estimated peak discharge from the effective FIS (FEMA, January 2010) is generally consistent with the findings from more recent hydrologic models of other Pine Nut Mountain watersheds as documented by Manhard/Kimley-Horn in their work for Douglas County.

3 Hydraulic Modeling

A hydraulic model of the reach of Smelter Creek below the proposed regional flood control facility was developed using HEC-RAS. HEC-RAS is a one-dimensional hydraulic model developed by USACE and approved by FEMA to perform floodplain studies. The steady-state component of the model was applied in this analysis; hence, each water surface profile was computed with a single discharge that did not vary with time. The model is generally suitable for modeling stream networks where the stream flow along the channel is gradually varied, flow lines are parallel, and the channel profile slope has less than one foot of vertical drop in 10 longitudinal feet along the channel. The study reach generally meets these criteria; likewise, the one dimensional model results appear to reasonably estimate the water surface levels and flooding extent for the modeled flows.

3.1 HEC-RAS Model Development

The major inputs for an HEC-RAS model include flow, geometry, loss coefficients (Manning roughness, contraction and expansion coefficients), steady flow data, and upstream and/or downstream boundary conditions. Terrain geometry files for the one-dimensional HEC-RAS model were defined using a combination of aerial topography and field surveys that were organized into a GIS database. A TIN of the surface was generated using the filtered mass point data, and breaklines and elevation contours were created from the TIN. Using HEC-GeoRAS in conjunction with 3D Analyst add-on for ArcGIS, channel centerline and cross section data were extracted. Once the channel centerline and cross sections were established, the geometry was exported into HEC-RAS. Flow contraction or expansion between cross sections is a cause of energy loss that influences the calculated water surface elevation. In HEC-RAS, contraction and expansion coefficients are specified and are used as a term in the energy equation to account for these losses. Within the study reach, the contractions and expansions are relatively gradual and were, therefore, set to the values of 0.1 and 0.3, as recommended by HEC (USACE, 2005).

In HEC-RAS, Manning's Roughness Coefficient (Manning n) is used to calculate energy losses due to channel and overbank characteristics, such as surface roughness, vegetation, channel irregularities, and channel alignment. When corresponding discharge data and water level data are available, Manning n is calibrated (adjusted) to match observed data. The corresponding data were not available for the study reach; therefore, the Manning n was estimated from standard engineering references and previous modeling experience. Standard references include Chow (1959) and Barnes (1967). For the main stream channel, Manning's coefficient of 0.035 was selected that represents natural channels with stones and weeds, and Manning's coefficient of 0.055 was used to represent floodplains with scattered brush, and weeds.

To perform steady flow simulations, it is necessary to supply a steady flow and reach boundary conditions in the Steady Flow Data editor within HEC-RAS. A set of three steady flows to represent following conditions were included:

- Allowed outflow from the proposed flood control reservoir during 1-percent annual chance flood (380 cfs)
- Allowed outflow from the proposed flood control reservoir during 0.2-percent-annual-chance flood (1,115 cfs)
- Allowed outflow from the proposed flood control reservoir during ½-PMP event (1,275 cfs)

After the flow data have been entered into the Steady Flow Data editor, the next step is to enter boundary conditions. Boundary conditions are necessary to establish the starting water surface at the end of the river systems (upstream and downstream). A starting water surface is necessary in order for HEC-RAS to begin computations. In a subcritical flow regime, such as in this case boundary conditions are only necessary at the downstream end of the river system. HEC-RAS allows four types of boundary conditions, out of which Normal Depth boundary condition was selected for this study. For this type of boundary condition, energy slope estimation is required that will be used by HEC-RAS to perform normal depth calculations using Manning's equation. Typically, for sub-critical flow regimes the energy slope is assumed to approximate the slope of the water surface or the slope of the channel bottom at the downstream end of the model, which is approximately 0.009 ft/ft for this reach.

3.2 HEC-RAS Modeling Results

After all the required data were entered steady state flow simulations were performed to calculate water surface elevations at each of the cross section locations. The following observations were made after analyzing the model results:

- During the occurrence of 1-percent annual chance of flood (100-year), the proposed regional flood control facility would limit the outflow from the reservoir to approximately 380 cfs. The resulting flow is contained within the channel for the most part, although at some locations, the flow would escape the blanks, extending the width of the flood inundation boundaries. It is estimated that 3 structures will be within the primary floodplain as compared to 120 structures as shown on the effective Flood Insurance Rate Map (FIRM).
- During the occurrence of 0.2-percent-annual-chance flood (500-year), the proposed flood control reservoir attenuates peak flood flows and limits the outflow to approximately 1,115 cfs. The resulting flow will have wider flood inundation footprint, and therefore will impact more properties compared to that of 1-percent annual chance flood. In a hydrologic event of this magnitude, it is expected that the flow split might occur downstream from RS 11516, forcing some of the floodwater in a different direction along Sorrel Ln and Pinto Circle areas. It is estimated that 11 structures will be within the floodplain as compared to 206 structures as shown on the effective SFHA.
- During the occurrence of ½-PMF, the proposed flood control reservoir attenuates peak flood flow and limits the outflow to approximately 1,275 cfs, and will have wider floodplain than that of previous two scenarios.

Table **8** – Summary of HEC-RAS Results contains condensed results of HEC-RAS modeling. Detailed results, including cross section plots, profile plots are provided in Appendix 3.

3.3 Preliminary Floodplain Mapping

HEC-RAS model results were imported into ArcGIS environment to facilitate the generation of floodplain maps from exported HEC-RAS simulation results. Floodplain boundary and inundation depth data sets were created from exported cross sectional water surface elevations. The first step in the floodplain delineation process is to create a water surface TIN from the water surface elevations attached to each cross section. Utilizing the cross sectional cut lines as hard breaklines with constant elevation, water surface TIN for each profile was created using ArcGIS triangulation method. Floodplain delineation method rasterizes the water surface TIN using the Rasterization Cell Size and compares to the existing ground DTM. The floodplain is calculated where the water surface grid is higher than the existing terrain grid. The floodplain boundary feature class is created based on the depth grid. The floodplain boundary is, therefore estimated at the outline of the floodplain depth grid.

Table 8 **– Summary of HEC-RAS Results**

		380 cfs		1,115 cfs		1,275 cfs	
River Sta	Min Ch Elev (ft)	W.S. Elev (ft)	Vel Chnl (ft/sec)	W.S. Elev (ft)	Vel Chnl (ft/sec)	W.S. Elev (ft)	Vel Chnl (ft/sec)
15517	5087.74	5090.00	6.75	5091.25	8.57	5091.39	8.96
15017	5080.55	5082.97	7.34	5083.88	9.12	5084.01	9.50
14432	5071.90	5074.52	7.36	5075.57	9.95	5075.72	10.35
14017	5065.42	5067.83	6.61	5069.27	8.96	5069.52	9.29
13591	5060.25	5063.10	3.26	5064.59	5.07	5064.81	5.24
13464	5057.87	5060.29	5.82	5061.15	8.43	5061.27	8.98
13393	5057.12	5059.49	3.48	5060.53	5.31	5060.68	5.64
13345	5056.62	5058.81	6.00	5059.84	7.72	5060.11	7.47
13196	5054.33	5056.53	5.67	5058.00	8.07	5058.26	8.42
13128	5052.97	5055.40	6.78	5056.91	9.17	5057.15	9.59
13060	5052.24	5054.99	3.69	5056.67	5.10	5056.94	5.33
12985	5051.24	5053.90	6.89	5055.47	8.88	5055.70	9.26
12511	5043.63	5046.12	5.36	5046.88	7.65	5047.01	8.05
12049	5037.32	5039.72	5.22	5040.83	7.63	5041.05	7.92
11726	5032.58	5035.33	7.20	5037.03	8.71	5037.23	9.15
11516	5029.47	5033.94	4.24	5036.18	6.84	5036.49	7.23
11431	5028.43	5031.48	7.40	5033.29	9.40	5033.64	9.44
11368	5027.76	5030.77	6.10	5032.41	8.70	5032.67	9.11
11250	5026.28	5029.22	6.90	5030.91	8.99	5031.19	9.25
11119	5024.68	5029.07	3.45	5030.92	4.16	5031.20	4.23
10970	5022.78	5025.76	7.41	5027.55	9.50	5027.85	9.81
10868	5021.30	5024.33	6.32	5025.89	9.20	5026.11	9.75
10763	5019.11	5022.71	7.57	5024.53	9.46	5024.81	9.81
10664	5017.51	5020.98	7.95	5022.98	10.34	5023.24	10.89
10573	5016.28	5019.53	7.84	5021.55	9.66	5021.86	9.97
10520	5015.53	5018.72	7.77	5020.75	10.41	5021.10	10.74
10235	5008.42	5013.21	4.90	5014.88	8.57	5015.10	9.20
10145	5007.37	5010.05	7.72	5012.22	7.95	5012.43	8.18
10069	5006.15	5009.15	4.93	5010.21	8.85	5010.52	8.96
9940	5003.48	5009.05	2.84	5009.22	7.64	5009.50	3.83
9829	5002.64	5006.16	7.26	5007.55	4.05	5007.55	4.64
9622	5000.24	5003.33	8.01	5004.33	4.11	5004.33	4.70
9395	4997.42	4999.78	2.43	5000.17	5.43	5000.30	5.69
9135	4994.07	4996.88	5.26	4997.60	7.41	4997.71	7.67
8511	4987.46	4990.08	5.01	4990.63	6.26	4990.72	6.47
7567	4978.65	4981.10	5.36	4981.47	6.16	4981.56	6.32
7019	4973.85	4976.06	4.18	4976.86	5.23	4976.97	5.44
6520	4968.32	4971.37	4.89	4971.92	6.44	4972.01	6.64
5971	4962.93	4965.77	4.42	4966.39	6.30	4966.51	6.48
5552	4959.98	4961.68	5.15	4962.30	6.14	4962.38	6.45
4717	4949.32	4951.70	4.07	4952.46	5.59	4952.59	5.83
4021	4941.18	4944.84	4.47	4945.76	6.32	4945.90	6.65
3522	4938.02	4941.20	5.91	4942.27	7.09	4942.43	7.29
3018	4933.82	4937.47	5.53	4938.20	7.82	4938.30	8.21
2456	4930.41	4934.52	1.79	4934.87	4.29	4935.09	4.39
2249	4929.25	4932.93	8.67	4933.53	7.61	4933.53	8.68
1866	4927.19	4929.60	1.42	4930.17	2.85	4930.33	2.98
1628	4926.21	4927.53	6.10	4928.21	8.73	4928.34	9.10
1378	4922.50	4923.68	3.70	4924.39	5.74	4924.50	6.11
1061	4917.41	4919.31	5.05	4920.17	7.13	4920.34	7.37
790	4916.19	4917.81	2.26	4919.25	2.80	4919.51	2.90
614	4914.50	4916.83	5.31	4918.14	7.91	4918.35	8.31

Figure 8 – Post Project Flood Inundation Map depicts the preliminary floodplain boundary mapping for 1-, 0.2-percent, and ½-PMF events. The following observations were made comparing the floodplain maps with current FEMA effective FIRMs:

- During the 1-percent annual chance flood event, with the proposed regional flood control structure northeast of Ruhenstroth subdivision in place and operational, only 3 structures are expected to be located within the revised SFHA, compared to 120 structures in the current regulatory SFHA. It translates to 117 structures being removed from the regulatory SFHA.
- During the 0.2-percent-annual-chance flood event, with the proposed flood control reservoir northeast of Ruhenstroth subdivision in place and operational, only 11 structures are expected to be in the revised FIRM, compared to 206 structures within the limits of the 500-year floodplain. It translates to 195 structures being removed from the 500-year flood plain.

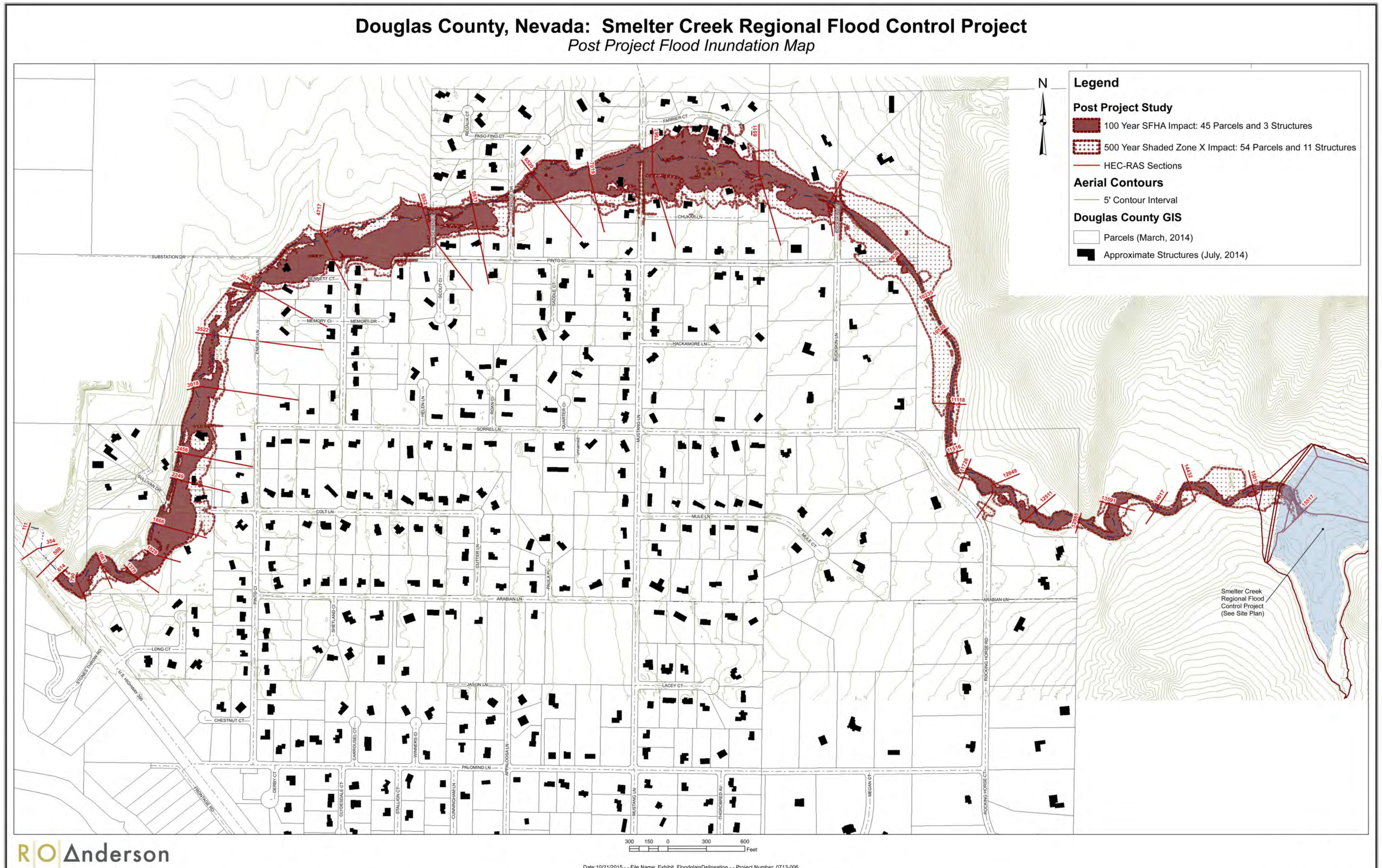


Figure 8 – Post Project Flood Inundation Map

4 Basis of Design, Flood Control Reservoir Layout and Engineer's Estimate of Probable Costs

4.1 Basis of Design

Representatives of Nevada Division of Water Resources, Bureau of Dam Safety were contacted to confirm the design inflow event that the proposed structure will be required to be designed to safely mitigate and control flood discharges from this watershed. From those discussions, the proposed structure will likely be characterized as a High Hazard Dam. The Design Inflow criteria will therefore be the ½-PMP event. That is, the proposed dam and its appurtenances must be sized to pass the ½-PMF through the proposed spillway with approximately three feet of freeboard before overtopping the dam structure.

The dam and reservoir were, therefore, sized to detain the inflow from a 1%-annual chance hydrologic event. The outlet was sized to control the outflow such that the number of downstream structures reasonably protected from flooding could be maximized. This criterion required an evaluation of the floodplain impacts downstream based on various outlet discharge rates. A 60-inch Reinforced Concrete Pipe (RCP) was selected as the outlet pipe, which, with an appropriate outlet structure, can effectively limit the discharge to the design estimate of 380 cfs. During final design, the capacity of the outlet structure and discharge pipe can be reviewed more fully to determine if additional restriction of the outlet discharge could result in all structures being removed from the floodplain.

4.2 Regional Flood Control Reservoir

In order to attenuate peak flood flows in Smelter Creek and protect the downstream properties in the Ruhenstroth subdivision, a regional flood control reservoir was proposed. ROA personnel performed preliminary study in early 2011, and identified potential location of the proposed flood control reservoir. The identified location was on property managed by the United State Department of the Interior, Bureau of Land Management (BLM). The plausibility of using the identified site for this purpose was investigated by Douglas County. Representatives of BLM confirmed that the proposed use (regional flood control) is eligible to obtain a right-of-way grant. The BLM representative suggested that before proceeding too far the county should undertake an archaeological/paleontological investigation to confirm that there are no cultural resources in this area. The County separately undertook and completed that investigation, which confirmed that no such resources were present with in the proposed site of the flood control reservoir.

During this feasibility engineering study, the hydrology of Smelter Creek watershed was further refined to obtain reasonable estimates of peak flood flows and associated flood volumes for 1-, 0.2-percent-annual-chance, and ½-PMF events. Six potential locations for the proposed regional flood control reservoir were initially identified. Stage-area curves were developed using available topographic data for each configuration. The stage-area data was used to define the reservoirs in HEC-HMS model, and the model was run with each reservoir added at a time. The modeling results suggested that the Alternative 4 reservoir configuration and location is desirable and more feasible when compared with other alternate locations, primarily because of the available storage area, and reduced cut / fill (earthwork) volumes.

During the review of the draft report, it was suggested that ROA further evaluate Alternative 3 reservoir location, which is located just upstream of the proposed Alternative 4 reservoir location. This final report includes site plans, engineer's probable construction cost estimate, and associated preliminary Benefit-Cost Analyses (BCA) for both Alternatives. It should be noted that the results of the hydrologic and hydraulic modeling included in this report refer to Alternative 3. Hydrologic and Hydraulic models of Alternative 4 and results are included in the attached digital media.

After the reservoir site was selected, HEC-HMS model was further refined by adding detailed information such as low-level outlet works, and spillway information. Detailed discussion of model parameter estimation and the results are presented in Section 2 – Hydrologic Modeling.

The proposed location of the regional flood control reservoirs was compared to the locations of USGS- documented earthquake faults (Quaternary Faults) and is included as Figure 9 – USGS Quaternary Fault Map. It is evident that there are no identified faults within the limits of the Alternative 4 dam and reservoir location. A portion of the reservoir area of the proposed Alternative 3 appears to fall within USGS moderately constrained fault location.

Conceptual layout of the proposed regional flood control reservoir along with the cross section is displayed on Figure 10 – Alternative 3 Site Plan. Alternative 3 provides 202.5 acre-feet of storage below the spillway elevation and a dam crest height of 5,112 feet, about

36 feet above the channel elevation of the site of the proposed dam. Alternative 4 provides 176.8 acre-feet of storage below the spillway elevation and a dam crest height of 5,093 feet, about 32 feet above the channel elevation of the site of the proposed dam.

Figure 9 – USGS Quaternary Fault Map

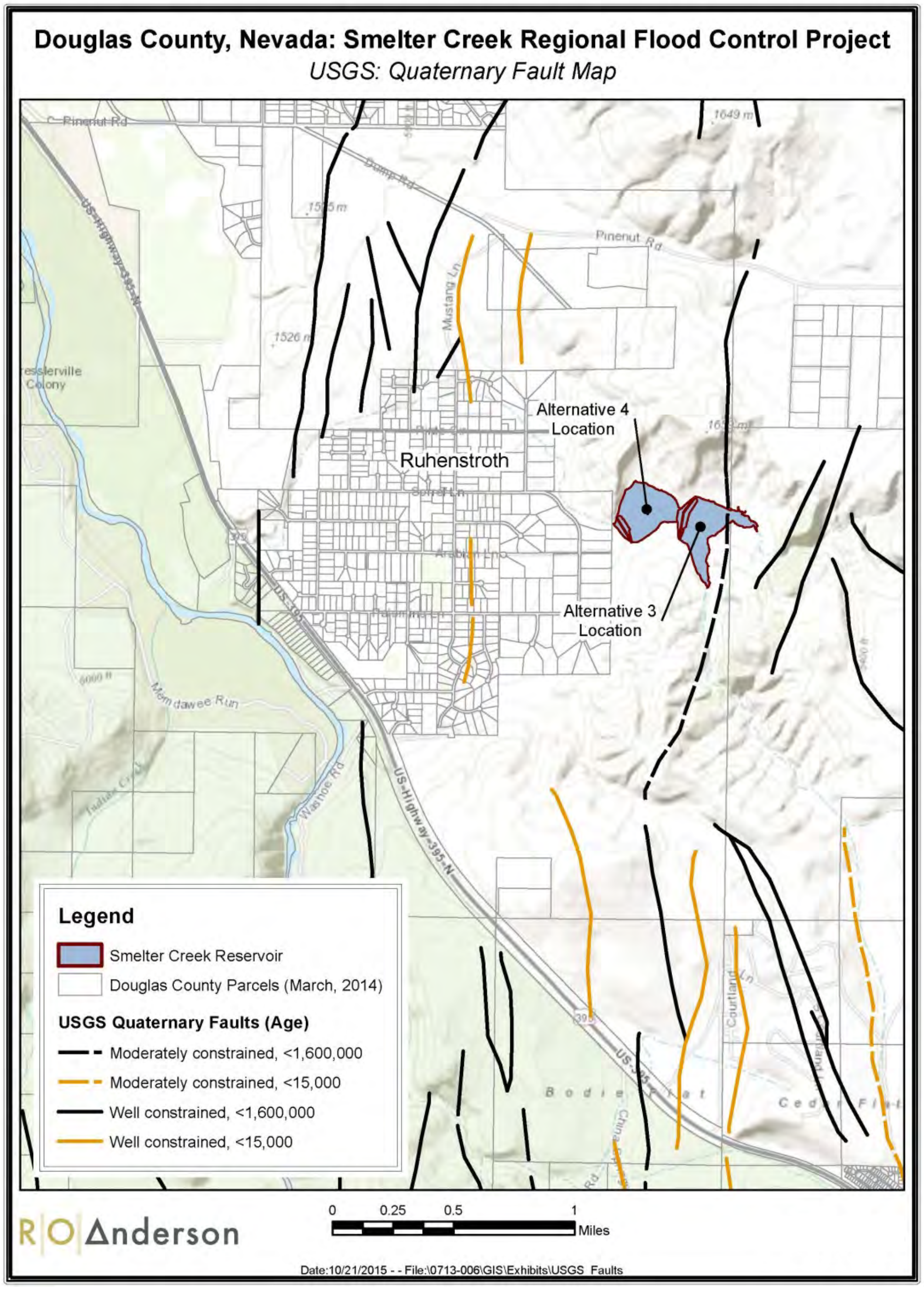


Figure 10 – Alternative 3 Site Plan

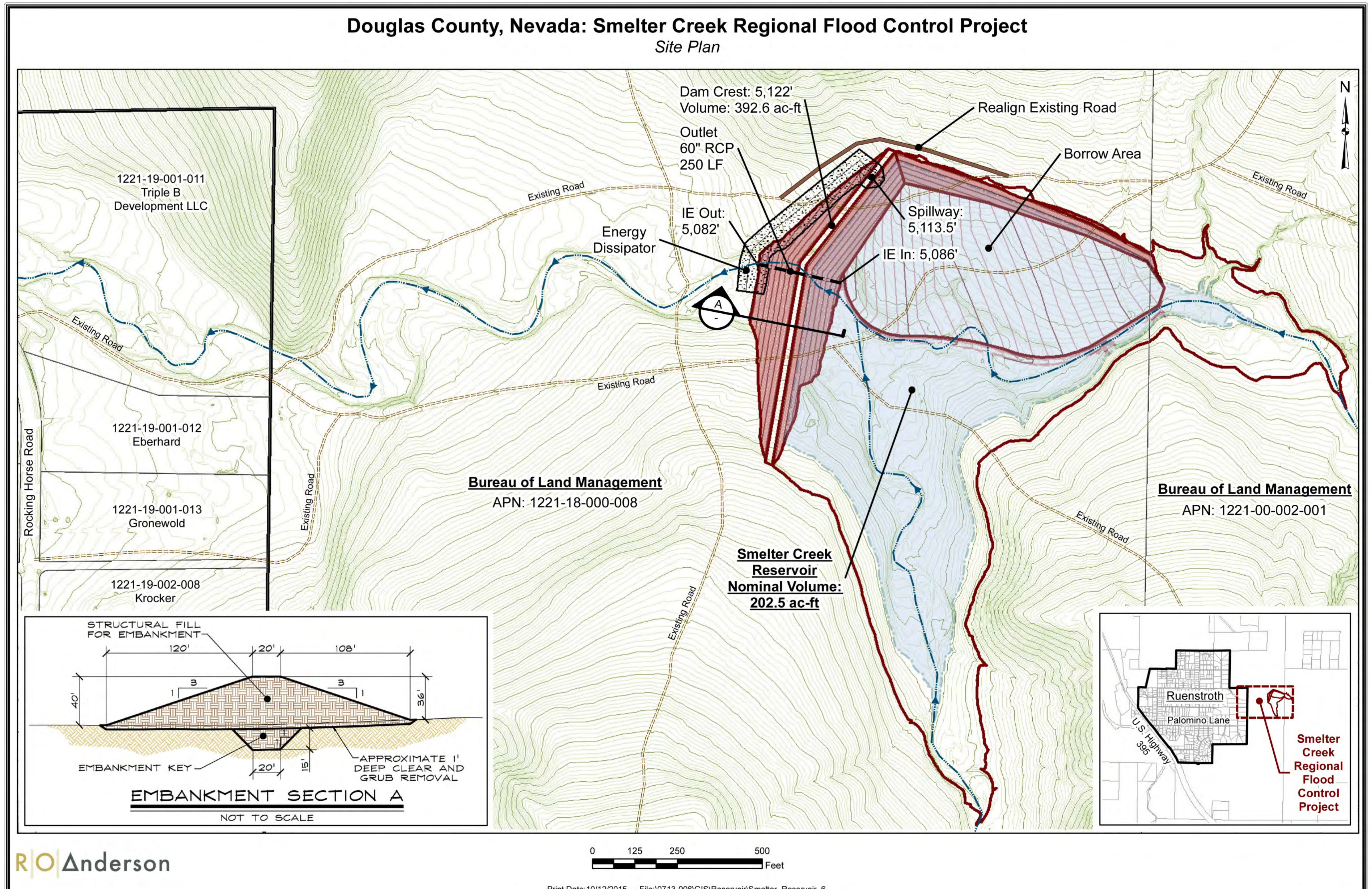
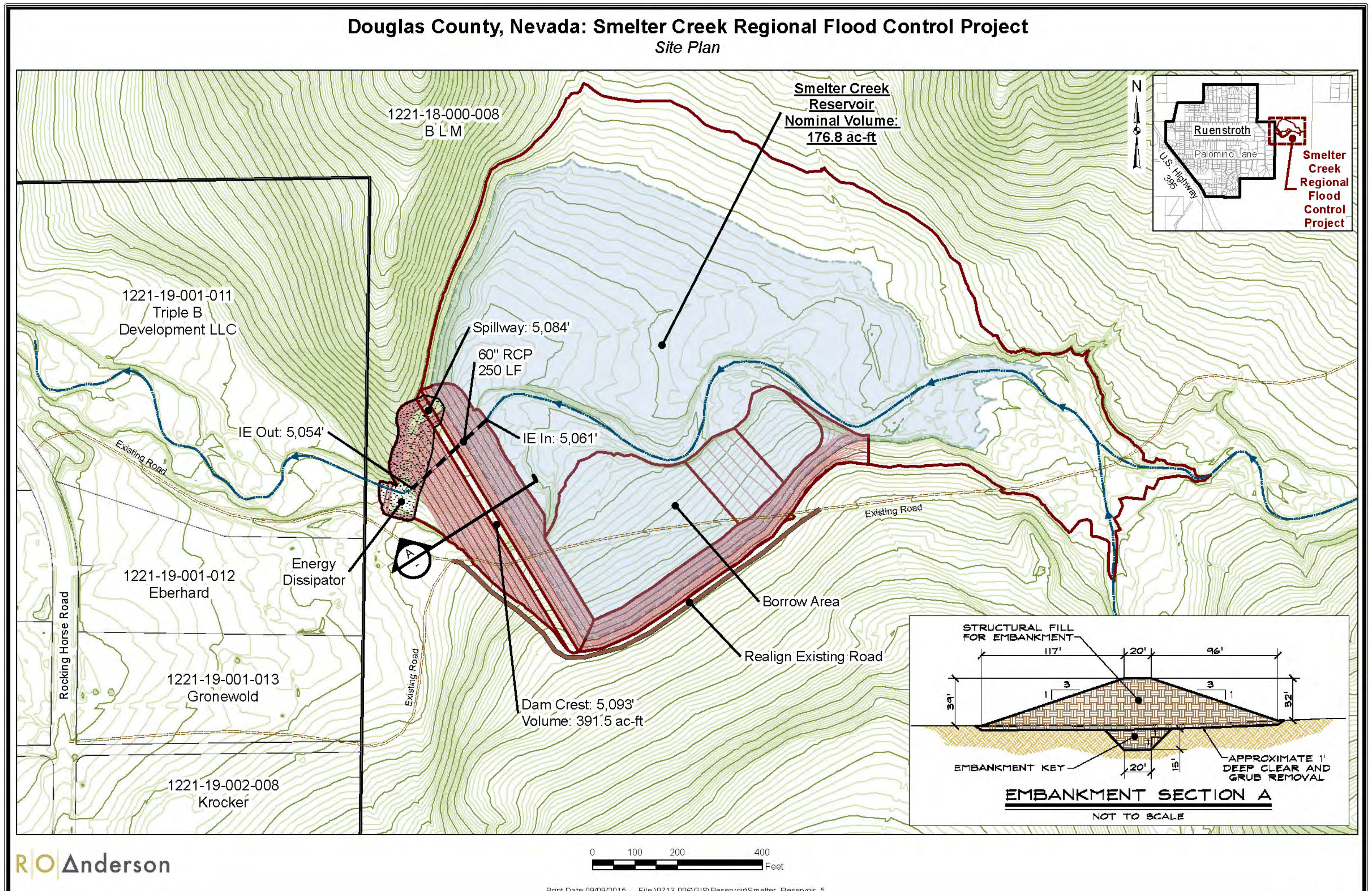


Figure 11 – Alternative 4 Site Plan



4.3 Engineer's Preliminary Estimate of Probable Cost and Benefit Cost Analyses

Using the schematic design, as shown in Figure 9 and Figure 10, an Engineer's Preliminary Estimate of Probable Costs has been developed for the two alternatives considered. The estimates for Alternate 3 and Alternative 4 are provided in Table 9 and Table 10, respectively. The preliminary estimate of probable costs for Alternative 3 is about $2,550,000, and for Alternative 4 is $3,170,000. These amounts include: an allowance ($277,200) for construction contingencies at 15% of the estimated probable construction costs; an allowance ($55,000) for land acquisition costs through BLM; an allowance ($240,000) for engineering design and permitting; and, an allowance ($125,000) for construction phase services.

The Smelter Creek Regional Flood Control facility, which serves to remove about 117 structures from the SFHA, is eligible for FEMA's Hazard Mitigation Grant Program. For eligible projects, this program currently provides a 75% grant to complete the design, permitting and construction of proposed flood control facilities. Presuming Douglas County determined to pursue and was successful in obtaining such a grant, the project cost distribution for Alternative 3 would be:

- Total Estimated Project Cost: $3,170,000
- Federal HMG Funds $2,377,750
- Required Local Match $792,250

Similarly, the project cost distribution for Alternative 4 would be:

- Total Estimated Project Cost: $2,550,000
- Federal HMG Funds $1,912,500
- Required Local Match $637,500

Several potential sources for deriving the required local match have been identified including:

- Formation of a Flood Control District specific to Smelter Creek pursuant to NRS 543.170-543.830.
- Formation of a local Assessment District of the benefitted properties.
- A combination of funding from the County and the members of local assessment district.

There may be other grant opportunities available (CDBG, etc.) to assist in achieving the required local match for this project.

As noted above, there are about 248 individual parcels impacted by the floodplains from Smelter Creek that would potentially benefit from the proposed flood control project. Assuming financing for the required match for Alternative 3 ($792,250) could be obtained at 5% interest rate for a term of 25 years, the annual payments would be about $55,600. The annual payment per benefitted parcel would then be approximately $225. Similarly, assuming financing for the required match for Alternative 4 ($637,500) could be obtained at 5% interest rate for a term of 25 years, the annual payments would be about $44,750. The annual payment per benefitted parcel would then be approximately $180.

In contrast, if the County was unsuccessful in obtaining federal grant assistance for this project, but used either a Flood Control District or a local Assessment District to fund the full cost for proposed Alternative 3 ($3,170,000) improvements, using the same financing terms, the projected annual payment would be about $222,500. The projected annual payment per benefitted parcel would then be about $900. Similarly, to fund the full cost for Alternative 4 ($2,550,000) improvements, using the same financing terms, the projected annual payment would be about $179,000. The projected annual payment per benefitted parcel would then be about $720.

A preliminary BCA was performed using FEMA BCA Version 5.2.1 tool for each of the two alternatives considered. This tool is a key mechanism for evaluating hazard mitigation grant applications and determining whether mitigation projects are eligible for Federal funding. To be eligible for Federal funding assistance, a BCA should show that the proposed project have a BCA ratio greater than 1.0, and prove that that the proposed project will reduce future damages and losses from natural disasters, such as flooding. FEMA considers reduction in losses or prevention of future damages as benefits of the proposed project, and these benefits should be quantified and at a minimum should outweigh the cost of the proposed project.

Primary input data required for performing BCA is probable construction cost estimate for the proposed flood mitigation project, which was obtained from the engineer's probable cost estimate. The other major element of BCA is quantification of estimated benefits realized from the construction of the proposed flood control reservoir project. The estimated benefits resulting from the implementation of the project can be derived from a variety of sources, such as collection, compilation of documentation of costs associated with expected damage to the structures; loss of use of utilities; loss of roadways and other public infrastructures; and costs incurred by public agencies for debris clean up, and necessary repairs to infrastructure as a direct result of flood damage. The majority of this information is generally available from various departments of Douglas County. This data is not readily available from the County at this time, and obtaining such detailed data from the County will be time consuming and requires input from several departments within the County. Therefore, for the purposes of calculating preliminary BCA, ROA personnel made some simplified assumptions to estimate potential benefits of the project. Examples of some of the simplified assumptions used include cost of cleaning up debris, and sediment buildup, replacement costs of infrastructure such as culverts, roadway, etc. These simplified assumptions are appropriate for use with preliminary estimate of BCA for conceptual level studies. Using this data, FEMA BCA tool was operated and BCA was estimated for the two alternatives under consideration. It was found that the Alternative 3 would result in BCA of 2.27, and Alternative 4 would result in slightly better BCA of 2.82.

Table 9 – Engineer's Preliminary Estimate of Probable Cost – Alternative 3

R O Anderson

ENGINEER'S PRELIMINARY ESTIMATE OF PROBABLE COSTS

Client:	CWSD	Estimated:	ROA
Project:	Smelter Creek Regional Flood Control Basin, 203 acre-feet	Checked:	
Description:	Preliminary Estimate of Probable Costs	Date:	12-Oct-15
File:	Y:\Client Files\0713\0713-006\Documents\Cost Estimate\[Smelter Creek 10_12_2015.xlsx]Cost Analysis		

ITEM	DESCRIPTION	QUANTITY		UNIT COST		TOTAL
DIVISION 1 - GENERAL REQUIREMENTS						
1	Mobilization, Demobilization, BMPs (15% of construction costs)	1	Lump Sum	$0.00	/LS	$311,700
				SUB TOTAL		**$311,700**
DIVISION 2 - SITE CONSTRUCTION						
1	Demolition & Abandonment	0	Lump Sum	$0.00	/LS	$0
2	Clear & Grub	14	Acres	$5,500.00	/Acre	$78,700
3	On-site Earthwork	90,000	Cubic Yards	$5.50	/CYDS	$495,000
4	Imported Fill	20,000	Cubic Yards	$15.00	/CYDS	$300,000
5	Rip-Rap- Spillway Channel	9,000	Cubic Yards	$30.00	/CYDS	$270,000
6	Rip-Rap - Dam Face	5,100	Cubic Yards	$30.00	/CYDS	$153,000
7	Roller Compacted Concrete - Spillway and Energy Dissipation Basin	12,000	Sq. Feet	$20.00	/SF	$240,000
8	Re-align Ex. Road	11,000	Sq. Feet	$4.75	/SF	$52,300
9	Regrade and Add Base to Existing Access Road	40,800	Sq. Feet	$3.00	/SF	$122,400
10	Revegetate Disturbed Areas	12	Acres	$2,200.00	/Acre	$26,400
11	Site Fencing & Access Gate	5,900	Lineal Feet	$25.00	/LF	$147,500
12	Construction Water	1	Lump Sum	$50,000.00	/LS	$50,000
				SUB TOTAL		**$1,935,300**
DIVISION 3 - CONCRETE						
1	Outlet Control Structure including Valving	1	Lump Sum	$50,000.00	/LS	$50,000
2	60" RCP, Gasketed	250	Lineal Feet	$265.00	/LF	$66,300
3	Flared End Section	1	Each	$1,500.00	/EA	$1,500
				SUB TOTAL		**$117,800**
DIVISION 5 - METALS						
1	Trash Rack/Miscellaneous Grating	1	Lump Sum	$10,000.00	/LS	$10,000
				SUB TOTAL		**$10,000**
DIVISION 17 - CONTROLS						
1	Water Level Transducer + SCADA Package	1	Lump Sum	$15,000.00	/LS	$15,000
				SUB TOTAL		**$15,000**

CONSTRUCTION SUB TOTAL	**$2,389,800**
CONTINGENCY AT 15% OF CONSTRUCTION[1]	**$358,500**
Land Acquisition, BLM Permitting + NEPA	**$55,000**
Engineering Design & Geotechnical Investigation	**$185,000**
Permitting - Dam Safety + Douglas County + NDEP Air Quality + CLOMR/LOMR	**$55,000**
Construction Phase Services including Construction Staking	**$125,000**
ENGINEERS PRELIMINARY ESTIMATE OF PROBABLE PROJECT COSTS (EXCL. FINANCING)	**$3,170,000**

[1] Contingency is for unknown items as a full design and permitting requirements are not now fully known.

Table 10 – Engineer's Preliminary Estimate of Probable Cost – Alternative 4

ENGINEER'S PRELIMINARY ESTIMATE OF PROBABLE COSTS R|O Anderson

Client:	CWSD	Estimated:	ROA
Project:	Smelter Creek Regional Flood Control Basin, 177 acre-feet	Checked:	
Description:	Preliminary Estimate of Probable Costs	Date:	12-Oct-15
File:	Y:\Client Files\0713\0713-006\Documents\Cost Estimate\[Cost Estimate Worksheet - Smelter Creek.xlsx]Cost Analysis		

ITEM	DESCRIPTION	QUANTITY		UNIT COST		TOTAL
DIVISION 1 - GENERAL REQUIREMENTS						
1	Mobilization, Demobilization, BMPs (15% of construction costs)	1	Lump Sum	$0.00	/LS	$241,100
				SUB TOTAL		**$241,100**
DIVISION 2 - SITE CONSTRUCTION						
1	Demolition & Abandonment	0	Lump Sum	$0.00	/LS	$0
2	Clear & Grub	10	Acres	$5,500.00	/Acre	$52,300
3	On-site Earthwork	70,000	Cubic Yards	$5.50	/CYDS	$385,000
4	Imported Fill	20,000	Cubic Yards	$15.00	/CYDS	$300,000
5	Rip-Rap- Spillway Channel	3,000	Cubic Yards	$30.00	/CYDS	$90,000
6	Rip-Rap - Dam Face	3,600	Cubic Yards	$30.00	/CYDS	$108,000
7	Roller Compacted Concrete - Spillway and Energy Dissipation Basin	12,000	Sq. Feet	$20.00	/SF	$240,000
8	Re-align Ex. Road	15,000	Sq. Feet	$4.75	/SF	$71,300
9	Regrade and Add Base to Existing Access Road	30,000	Sq. Feet	$3.00	/SF	$90,000
10	Revegetate Disturbed Areas	8	Acres	$2,200.00	/Acre	$17,600
11	Site Fencing & Access Gate	2,400	Lineal Feet	$25.00	/LF	$60,000
12	Construction Water	1	Lump Sum	$50,000.00	/LS	$50,000
				SUB TOTAL		**$1,464,200**
DIVISION 3 - CONCRETE						
1	Outlet Control Structure including Valving	1	Lump Sum	$50,000.00	/LS	$50,000
2	60" RCP, Gasketed	250	Lineal Feet	$265.00	/LF	$66,300
3	Flared End Section	1	Each	$1,500.00	/EA	$1,500
				SUB TOTAL		**$117,800**
DIVISION 5 - METALS						
1	Trash Rack/Miscellaneous Grating	1	Lump Sum	$10,000.00	/LS	$10,000
				SUB TOTAL		**$10,000**
				SUB TOTAL		**$0**
DIVISION 17 - CONTROLS						
1	Water Level Transducer + SCADA Package	1	Lump Sum	$15,000.00	/LS	$15,000
				SUB TOTAL		**$15,000**

CONSTRUCTION SUB TOTAL	**$1,848,100**
CONTINGENCY AT 15% OF CONSTRUCTION[1]	**$277,200**
Land Acquisition, BLM Permitting + NEPA	**$55,000**
Engineering Design & Geotechnical Investigation	**$185,000**
Permitting - Dam Safety + Douglas County + NDEP Air Quality + CLOMR/LOMR	**$55,000**
Construction Phase Services including Construction Staking	**$125,000**
ENGINEERS PRELIMINARY ESTIMATE OF PROBABLE PROJECT COSTS (EXCL. FINANCING)	**$2,550,000**

[1] Contingency is for unknown items as a full design and permitting requirements are not now fully known.

5 Findings and Conclusions

The Smelter Creek watershed has experienced several large hydrologic events in recent years, including the most recent events in 2014 and 2015 that caused unquantified damage to private property, roads, and drainage structures in the Ruhenstroth subdivision in Douglas County, Nevada. In order to alleviate flood risks to these downstream areas, construction of an on-stream (Smelter Creek) regional flood control reservoir, just east of the Ruhenstroth subdivision on BLM managed land was first proposed in early 2011. Subsequently, CWSD retained ROA to prepare a feasibility-level study to identify alternative solutions to alleviate future flooding resulting from severe hydrologic events that occur in Smelter Creek Watershed. The following is the summary of our findings and conclusions:

- The effective FIS lists only 1-percent annual chance peak flow for Smelter Creek watershed. This peak flow rate estimate was probably based on the hydrologic study that was performed in late 1980s using HEC-1, and may not accurately represent current land use characteristics or available hydrologic data generated since that former analysis was prepared. It is therefore, appropriate and prudent to evaluate the hydrology of this watershed and estimate 1-percent annual chance peak flows based on updated precipitation data developed by NOAA.
- The hydrologic study performed by ROA personnel and presented in this report used current NOAA precipitation data to build balanced design storm hyetographs for each sub-basin that takes area-reduction factors, altitude, etc. into consideration thereby producing reliable peak runoff estimates. In addition, the revised hydrologic study also includes estimated peak flows resulting from 0.2-percent-annual chance and ½ PMP events.
- This hydrologic study estimated peak runoff resulting from 1-percent annual chance flood to be approximately 730 cfs, which is 350 cfs lower than the effective peak flow (1,080 cfs). The proposed discharge entering the flood control reservoir during the occurrence of 0.2-percent-annual-chance event is approximately 2,183 cfs.
- General PMP rainfall depths were computed using HMR-49 guidelines, and the resulting rainfall data was used to construct a hyetograph that was applied uniformly over the entire watershed. The resulting hydrograph at the most downstream end of the watershed was taken and the ordinates of this flood hydrograph were divided in

half to obtain ½-PMF. The resulting ½-PMF was routed through the proposed flood control reservoir.

- While preparing this feasibility analysis, Nevada Division of Water Resources, Bureau of Dam Safety was contacted to confirm the design inflow event that the proposed structure will be required to be designed to safely mitigate. From those discussions, the proposed structure will likely be characterized as a High Hazard Dam. The Design Inflow criteria will therefore be the ½-PMP event. That is, the proposed dam and its appurtenances must be sized to pass the ½-PMF through the proposed spillway with approximately three feet of freeboard before overtopping.
- After reviewing the estimated peak flood flows from 1-, 0.2-percent, and ½-PMF events, four alternate flood control basin locations were considered, and a feasibility analysis was performed, which culminated in the selection of two potential locations for this regional flood control basin — Alternative 3 and Alternative 4.
- The embankment of the proposed Alternative 3 flood control structure is 36 feet high with a normal storage capacity of 202.5 acre-feet, and a storage capacity of 392.6 acre-feet at dam crest. The proposed flood control basin incorporates a 60-inch low-level primary outlet, and an emergency spillway with 20-ft bottom width.
- The embankment of the proposed Alternative 4 flood control structure is 32 feet high with a normal storage capacity of 176.8 acre-feet, and a storage capacity of 391.5 acre-feet at dam crest. The proposed flood control basin incorporates a 60-inch low-level primary outlet, and an emergency spillway with 20-ft bottom width.
- The primary and emergency outlet works were designed such that during the 1-percent annual chance flood, the outflow discharge is limited to 380 cfs through the 60-inch primary outlet; and, during 0.2-percent annual-chance flood and ½-PMF events, the emergency spillway safely conveys incoming flood flows with sufficient freeboard and some attenuation.
- The Engineer's Preliminary Estimate of Probable Costs for Alternative 3 is $3,170,000, and for Alternative 4 is $2,550,000, which amount includes allowances for construction contingencies, land acquisition, engineering design, permitting and construction phase services.
- A hydraulic model of downstream reach of Smelter Creek below the proposed flood control facility was developed using HEC-RAS. A set of three steady flow rates that represent discharges from the proposed reservoir during the occurrence of 1-, 0.2-

percent, and ½-PMF events were used to perform steady state flow simulations. The results of these simulations were processed in ArcGIS environment and preliminary floodplain boundary maps were produced.

- The resulting floodplain boundary maps were compared with FEMA effective FIRMs, and number of structures / parcels that may be removed from the SFHA was estimated. It is estimated that only 3 structures will remain in the revised SFHA compared to 120 structures that are currently in the effective SFHA for this area of Douglas County.
- Building an instream flood control basin on Smelter Creek with an estimated cost of $3.17 million dollars for Alternative 3 or $2.55 million dollars for Alternative 4 results in direct and substantial benefit to the residents of Ruhenstroth subdivision, particularly those within the regulatory floodplain of Smelter Creek. The project provides additional indirect benefits to the residents of Douglas County by reducing potential damage to public infrastructure such as roads and drainage structures in this area.
- The Smelter Creek Regional Flood Control project is eligible for FEMA's Hazard Mitigation Grant Program that currently provides 75% grants for qualified projects.
- If successful in obtaining a Hazard Mitigation Grant for this project, the required local match to complete Alternative 3 improvements is estimated to be $792,250. Assuming this amount could be funded through a Flood Control District (NRS 543.170-543.830, or a local Assessment District at an effective interest rate of 5% and a term of 25 years, the annual payments would be about $225/benefitted parcel. Without grant funding, using the same financing terms, the estimated annual payment is about $900 per benefitted parcel. These per parcel amounts, $225/year and $900/year, are understood to be less than what many of the homeowners impacted by this floodplain currently pay for flood insurance in this area.
- For Alternative 4, the required local match to complete the planned improvements is estimated to be $637,500. Assuming this amount could be funded through a Flood Control District (NRS 543.170-543.830, or a local Assessment District at an effective interest rate of 5% and a term of 25 years, the annual payments would be about $180/benefitted parcel. Without grant funding, using the same financing terms, the estimated annual payment is about $720 per benefitted parcel. These per parcel amounts, $180/year and $720/year, are understood to be less than what many of the

homeowners impacted by this floodplain currently pay for flood insurance in this area.

- Preliminary BCA shows a BCA of 2.27 for Alternative 3, and a slightly better BCA of 2.82 for Alternative 4.
- The proposed locations of the regional flood control basins were compared to the locations of USGS- documented earthquake faults (Quaternary Faults). There are no identified active faults within the limits of the proposed dam and reservoir.
- From these investigations, we conclude that the project is eminently feasible and worthy of pursuing further.

6 References

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7 Appendices

Appendix 1: June 6, 2015 Flooding Pictures

Appendix 2: HEC-HMS Modeling Input and Output

Appendix 3: HEC-RAS Modeling Results

APPENDIX 1
JUNE 6, 2015 FLOODING PHOTOGRAPHS

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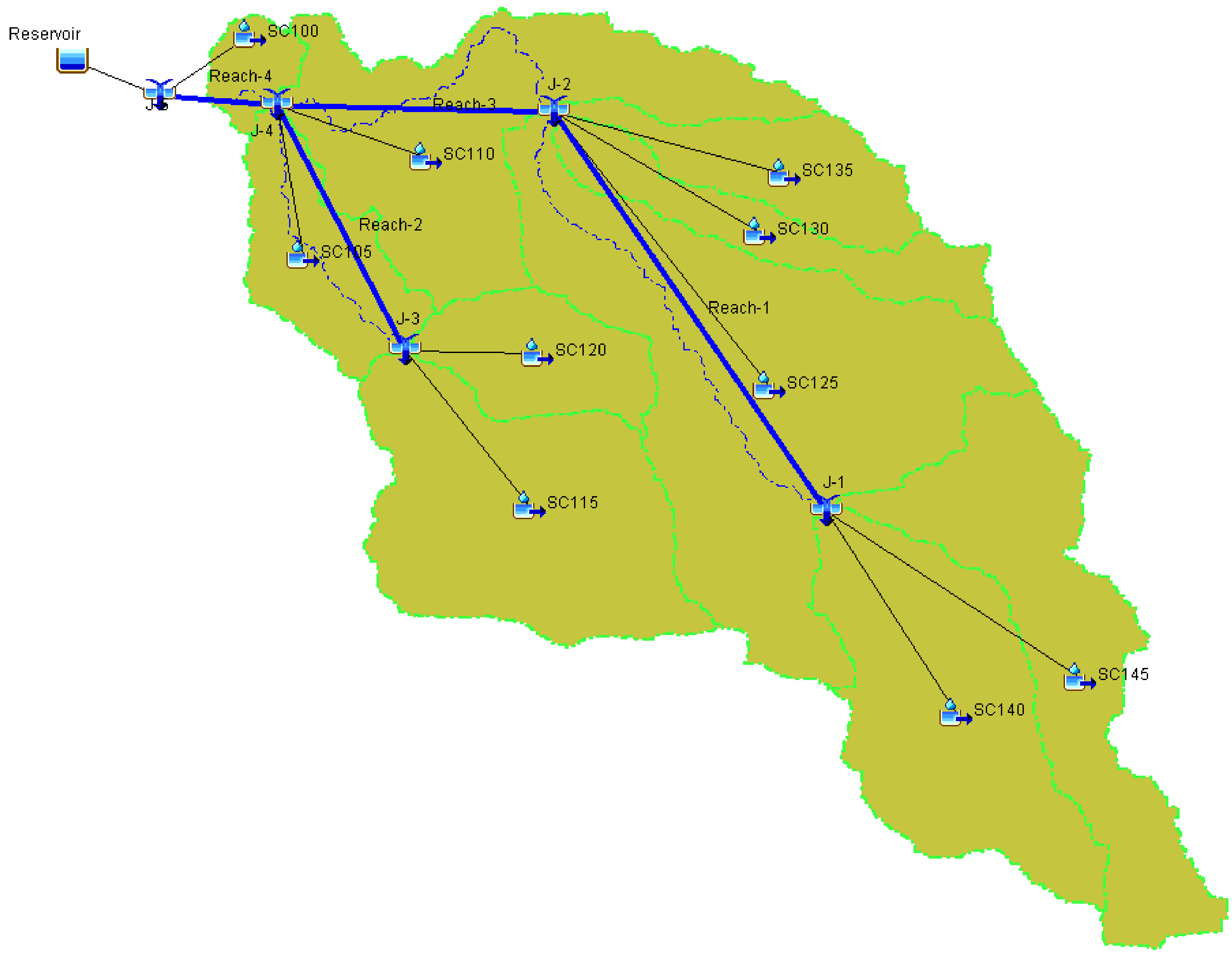
RO Anderson

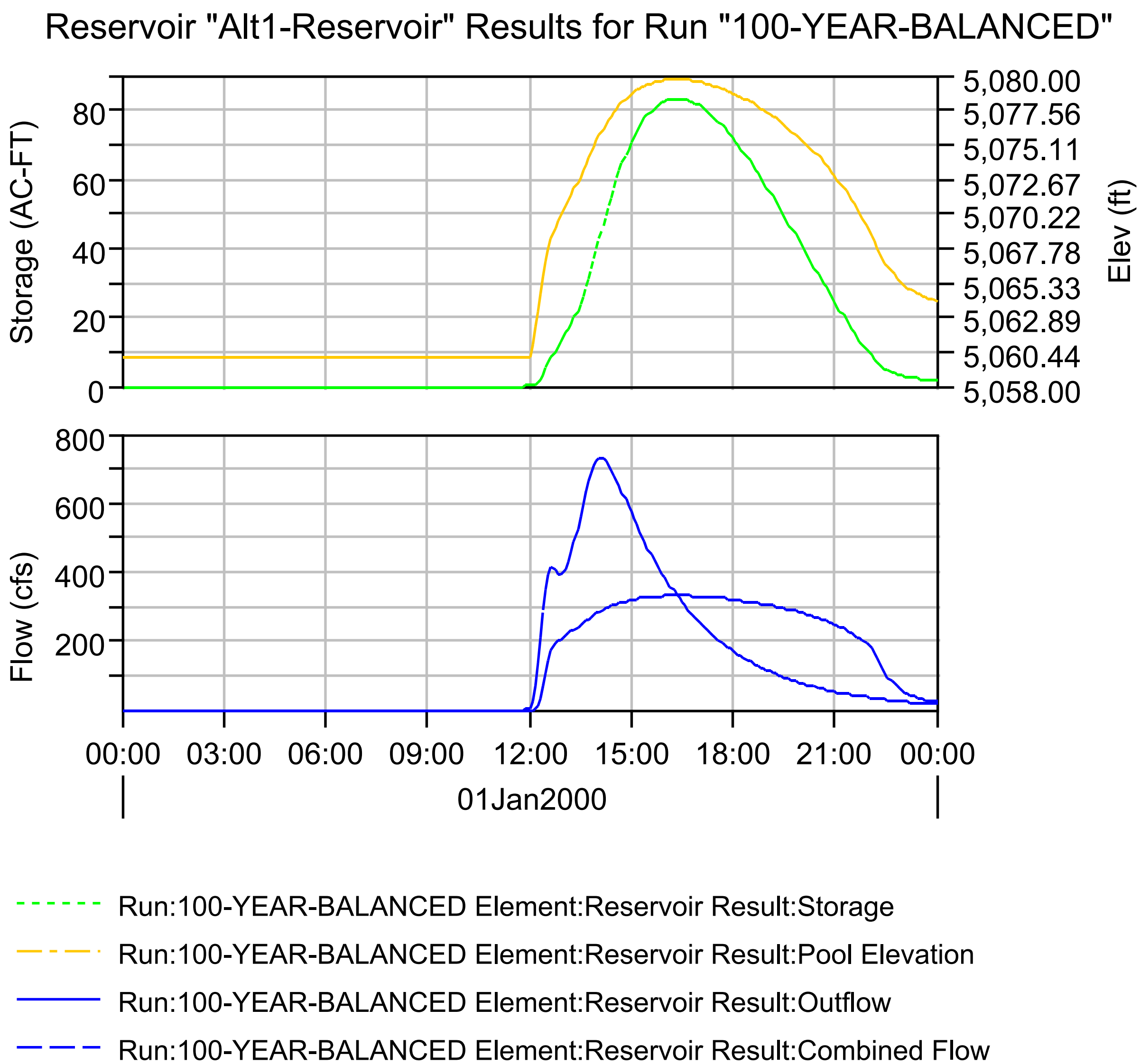
APPENDIX 2
HEC-HMS MODELING INPUT AND OUTPUT


Reservoir
SC100
Reach-4
J-5
J-4
Reach-3
J-2
SC110
SC135
SC130
Reach-2
SC105
Reach-1
J-3
SC120
SC125
J-1
SC115
SC145
SC140

Project: SmelterCreek Simulation Run: 100-YEAR-BALANCED

Start of Run: 01Jan2000, 00:00 Basin Model: Existing
End of Run: 02Jan2000, 00:00 Meteorologic Model: 100-YEAR-BALANC
Compute Time: 08Jul2015, 14:52:00 Control Specifications: 24-HOUR-CONTRO

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
SC140	1.62	94.9	01Jan2000, 13:35	24.7
SC145	1.59	88.3	01Jan2000, 14:00	28.3
J-1	3.21	177.7	01Jan2000, 13:45	53.0
Reach-1	3.21	177.8	01Jan2000, 14:10	52.8
SC135	1.71	185.2	01Jan2000, 13:35	47.2
SC125	0.67	28.0	01Jan2000, 14:15	9.9
SC130	0.59	58.4	01Jan2000, 13:35	15.2
J-2	6.18	413.2	01Jan2000, 13:50	125.1
Reach-3	6.18	412.8	01Jan2000, 14:10	124.7
SC110	2.93	177.9	01Jan2000, 13:55	56.0
SC120	0.63	43.9	01Jan2000, 13:15	8.9
SC115	0.59	28.5	01Jan2000, 13:35	7.5
J-3	1.22	69.8	01Jan2000, 13:20	16.4
Reach-2	1.22	69.7	01Jan2000, 13:40	16.4
SC105	0.19	17.7	01Jan2000, 13:30	4.2
J-4	10.52	663.2	01Jan2000, 14:05	201.3
Reach-4	10.52	661.5	01Jan2000, 14:10	201.0
SC100	1.74	372.4	01Jan2000, 12:40	38.4
J-5	12.26	730.0	01Jan2000, 14:05	239.4
Reservoir	12.26	357.7	01Jan2000, 16:20	239.2


Reservoir "Alt1-Reservoir" Results for Run "100-YEAR-BALANCED"
Storage (AC-FT)
0
20
40
60
80
Elev (ft)
5,058.00
5,060.44
5,062.89
5,065.33
5,067.78
5,070.22
5,072.67
5,075.11
5,077.56
5,080.00
Flow (cfs)
200
400
600
800
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
01Jan2000
Run:100-YEAR-BALANCED Element:Reservoir Result:Storage
Run:100-YEAR-BALANCED Element:Reservoir Result:Pool Elevation
Run:100-YEAR-BALANCED Element:Reservoir Result:Outflow
Run:100-YEAR-BALANCED Element:Reservoir Result:Combined Flow

Project: SmelterCreek Simulation Run: 100-YEAR-BALANCED
Reservoir:Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Existing
End of Run:	02Jan2000, 00:00	Meteorologic Model:	100-YEAR-BALANCED
Compute Time:	08Jul2015, 14:52:00	Control Specifications:	24-HOUR-CONTROL

Volume Units: AC-FT

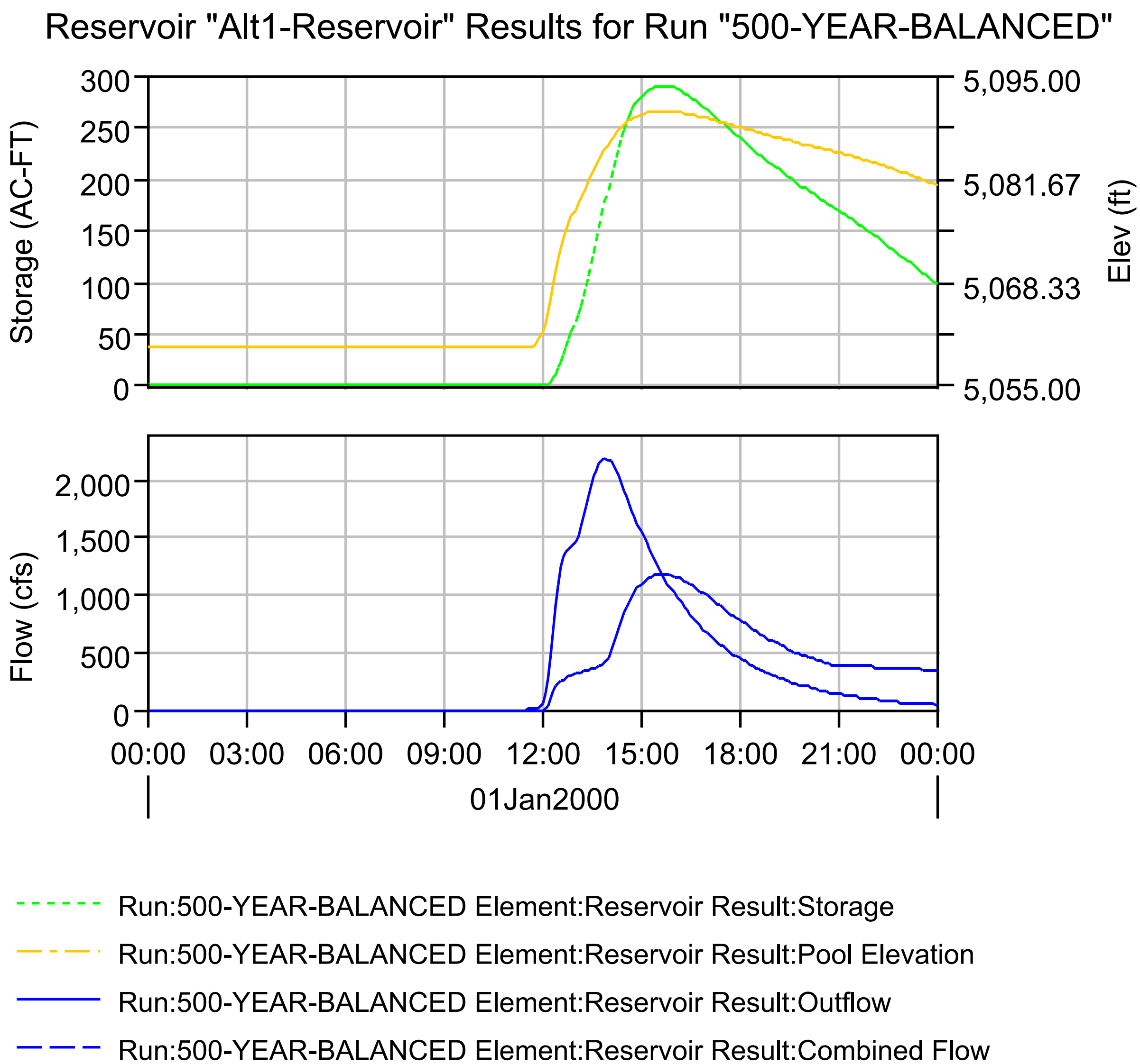
Computed Results

Peak Inflow:	730.0 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 14:05
Peak Discharge:	331.1 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 16:20
Inflow Volume:	239.4 (AC-FT)	Peak Storage:	83.4 (AC-FT)
Discharge Volume:	237.7 (AC-FT)	Peak Elevation:	5079.7 (FT)

Project: SmelterCreek Simulation Run: 500-YEAR-BALANCED

Start of Run: 01Jan2000, 00:00 Basin Model: Existing
End of Run: 02Jan2000, 00:00 Meteorologic Model: 500-YEAR-BALANC
Compute Time: 08Jul2015, 14:54:07 Control Specifications: 24-HOUR-CONTRO

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
SC140	1.62	266.4	01Jan2000, 13:35	69.5
SC145	1.59	233.8	01Jan2000, 14:00	75.1
J-1	3.21	486.1	01Jan2000, 13:45	144.6
Reach-1	3.21	485.9	01Jan2000, 14:05	144.2
SC135	1.71	469.6	01Jan2000, 13:35	120.6
SC125	0.67	92.3	01Jan2000, 14:15	32.6
SC130	0.59	157.3	01Jan2000, 13:35	41.2
J-2	6.18	1133.3	01Jan2000, 13:50	338.6
Reach-3	6.18	1133.2	01Jan2000, 14:05	337.9
SC110	2.93	534.6	01Jan2000, 13:55	169.0
SC120	0.63	150.9	01Jan2000, 13:15	30.7
SC115	0.59	96.8	01Jan2000, 13:35	25.4
J-3	1.22	239.1	01Jan2000, 13:20	56.2
Reach-2	1.22	238.7	01Jan2000, 13:35	56.2
SC105	0.19	54.9	01Jan2000, 13:30	13.3
J-4	10.52	1926.9	01Jan2000, 14:00	576.4
Reach-4	10.52	1923.8	01Jan2000, 14:05	575.8
SC100	1.74	1133.5	01Jan2000, 12:40	121.7
J-5	12.26	2182.9	01Jan2000, 13:55	697.6
Reservoir	12.26	1172.5	01Jan2000, 15:40	610.7


Reservoir "Alt1-Reservoir" Results for Run "500-YEAR-BALANCED"
Storage (AC-FT)
300
250
200
150
100
50
0
Elev (ft)
5,095.00
5,081.67
5,068.33
5,055.00
Flow (cfs)
2,000
1,500
1,000
500
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
01Jan2000
Run:500-YEAR-BALANCED Element:Reservoir Result:Storage
Run:500-YEAR-BALANCED Element:Reservoir Result:Pool Elevation
Run:500-YEAR-BALANCED Element:Reservoir Result:Outflow
Run:500-YEAR-BALANCED Element:Reservoir Result:Combined Flow

Project: SmelterCreek Simulation Run: 500-YEAR-BALANCED
Reservoir: Alt1-Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Existing
End of Run:	02Jan2000, 00:00	Meteorologic Model:	500-YEAR-BALANCED
Compute Time:	08Jul2015, 14:54:07	Control Specifications:	24-HOUR-CONTROL

Volume Units: AC-FT

Computed Results

Peak Inflow:	2182.9 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 13:55
Peak Discharge:	1181.2 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 15:40
Inflow Volume:	697.6 (AC-FT)	Peak Storage:	290.1 (AC-FT)
Discharge Volume:	598.4 (AC-FT)	Peak Elevation:	5090.4 (FT)

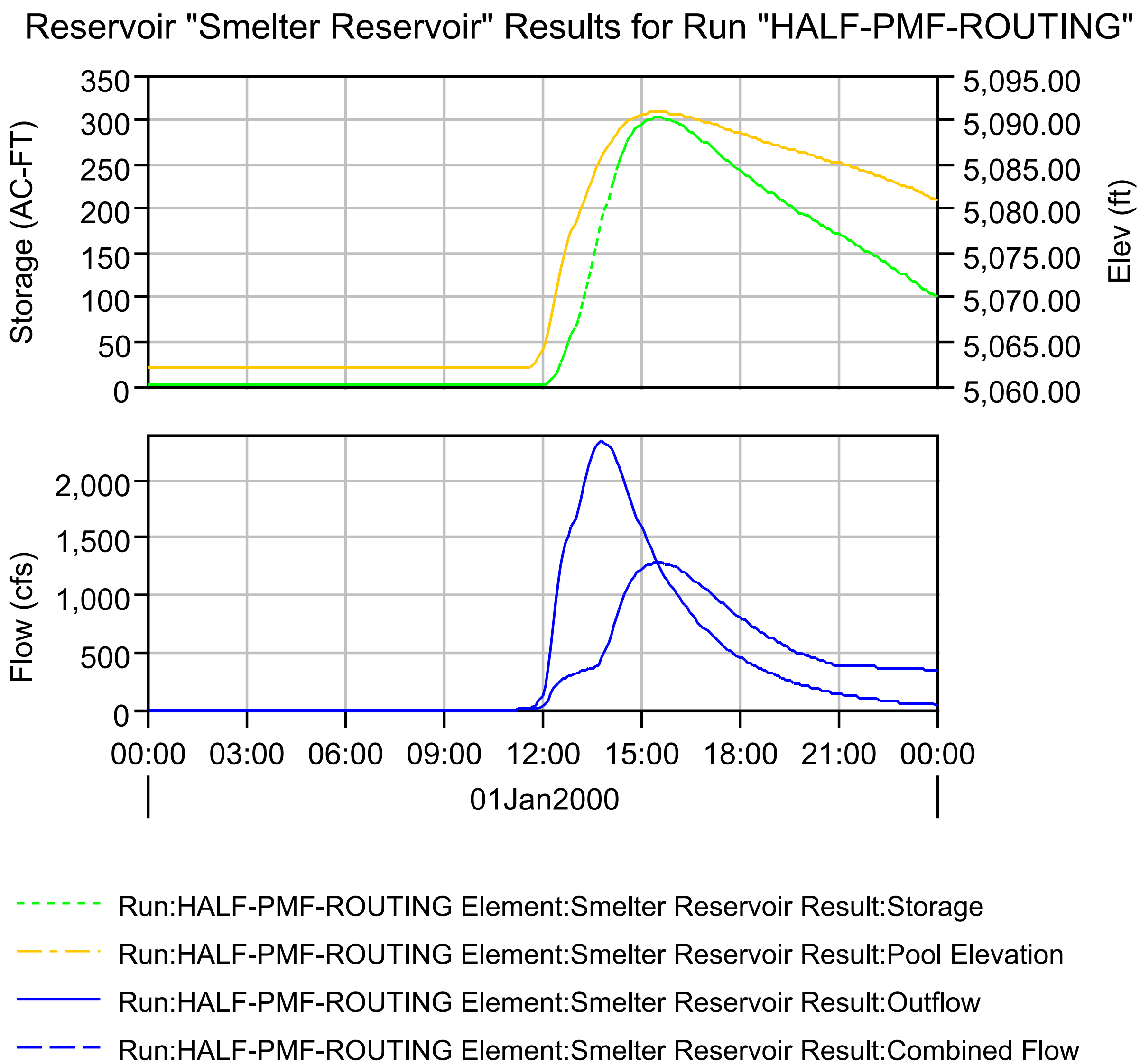
Project: SmelterCreek Simulation Run: HALF-PMF-ROUTING
Reservoir: Smelter Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Detention_Basin_Half_PMF
End of Run:	02Jan2000, 00:00	Meteorologic Model:	Dummy
Compute Time:	23Jul2015, 11:33:14	Control Specifications:	24-HOUR-CONTROL

Volume Units: AC-FT

Computed Results

Peak Inflow:	2335.8 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 13:50
Peak Discharge:	1283.7 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 15:30
Inflow Volume:	735.3 (AC-FT)	Peak Storage:	302.2 (AC-FT)
Discharge Volume:	635.1 (AC-FT)	Peak Elevation:	5090.8 (FT)


Reservoir "Smelter Reservoir" Results for Run "HALF-PMF-ROUTING"
Storage (AC-FT)
350
300
250
200
150
100
50
0
Elev (ft)
5,095.00
5,090.00
5,085.00
5,080.00
5,075.00
5,070.00
5,065.00
5,060.00
Flow (cfs)
2,000
1,500
1,000
500
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
01Jan2000
Run:HALF-PMF-ROUTING Element:Smelter Reservoir Result:Storage
Run:HALF-PMF-ROUTING Element:Smelter Reservoir Result:Pool Elevation
Run:HALF-PMF-ROUTING Element:Smelter Reservoir Result:Outflow
Run:HALF-PMF-ROUTING Element:Smelter Reservoir Result:Combined Flow

APPENDIX 3
HEC-RAS MODELING OUTPUT

Smelter Creek Regional Flood Control Project
Feasibility Engineering Study
Profile Output Table - 350cfs, 1,175cfs, 1,275 cfs

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Lower	15517	350	5087.74	5089.90	5089.80	5090.40	0.01797	6.66	70.10	65.32	1.04
Lower	15517	1175	5087.74	5091.30	5091.30	5092.00	0.01186	8.72	230.29	156.51	0.95
Lower	15517	1275	5087.74	5091.40	5091.39	5092.10	0.01199	8.96	243.89	158.22	0.96
Lower	15017	350	5080.55	5082.90	5082.90	5083.40	0.01117	7.12	83.41	117.16	0.88
Lower	15017	1175	5080.55	5083.90	5083.94	5084.50	0.01073	9.19	274.00	196.09	0.92
Lower	15017	1275	5080.55	5084.00	5084.01	5084.60	0.01113	9.50	287.26	197.43	0.94
Lower	14432	350	5071.90	5074.50	5074.50	5074.90	0.01073	6.86	91.07	98.15	0.86
Lower	14432	1175	5071.90	5075.60	5075.63	5076.30	0.01273	10.09	231.21	138.62	1.01
Lower	14432	1275	5071.90	5075.70	5075.72	5076.50	0.01292	10.35	243.42	139.35	1.02
Lower	14017	350	5065.42	5067.70	5067.74	5068.40	0.01690	6.51	53.78	41.70	1.01
Lower	14017	1175	5065.42	5069.40	5069.36	5070.60	0.01286	9.12	132.60	55.68	0.99
Lower	14017	1275	5065.42	5069.50	5069.52	5070.90	0.01252	9.29	141.78	57.17	0.98
Lower	13591	350	5060.25	5063.00		5063.10	0.00210	3.14	139.77	88.79	0.39
Lower	13591	1175	5060.25	5064.70		5065.00	0.00258	5.15	359.20	195.47	0.47
Lower	13591	1275	5060.25	5064.80		5065.10	0.00254	5.24	388.05	202.28	0.47
Lower	13464	350	5057.87	5060.20	5060.23	5060.60	0.01142	5.71	89.17	116.46	0.84
Lower	13464	1175	5057.87	5061.20	5061.20	5062.00	0.01287	8.58	208.67	128.16	0.98
Lower	13464	1275	5057.87	5061.30	5061.27	5062.10	0.01363	8.98	216.51	128.82	1.01
Lower	13393	350	5057.12	5059.40		5059.50	0.00377	3.39	151.35	135.33	0.49
Lower	13393	1175	5057.12	5060.60		5060.90	0.00452	5.45	331.47	168.65	0.59
Lower	13393	1275	5057.12	5060.70		5061.00	0.00462	5.64	347.67	169.83	0.60
Lower	13345	350	5056.62	5058.80	5058.76	5059.20	0.01088	5.84	84.62	116.47	0.83
Lower	13345	1175	5056.62	5059.90	5059.82	5060.50	0.00868	7.63	258.94	168.04	0.82
Lower	13345	1275	5056.62	5060.10		5060.70	0.00766	7.47	288.12	171.55	0.77
Lower	13196	350	5054.33	5056.50		5056.90	0.01054	5.50	63.68	44.36	0.81
Lower	13196	1175	5054.33	5058.10	5057.81	5059.10	0.00936	8.19	144.72	53.98	0.85
Lower	13196	1275	5054.33	5058.30	5057.96	5059.40	0.00923	8.42	153.17	54.88	0.85
Lower	13128	350	5052.97	5055.30	5055.32	5056.00	0.01709	6.63	52.75	39.84	1.02
Lower	13128	1175	5052.97	5057.00	5056.99	5058.40	0.01344	9.36	125.70	47.74	1.01
Lower	13128	1275	5052.97	5057.20	5057.15	5058.60	0.01322	9.59	133.35	48.60	1.01
Lower	13060	350	5052.24	5054.90		5055.10	0.00409	3.63	96.40	61.91	0.51

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Lower	13060	1175	5052.24	5056.80		5057.20	0.00347	5.18	226.70	75.01	0.53
Lower	13060	1275	5052.24	5056.90		5057.40	0.00348	5.33	239.05	75.94	0.53
Lower	12985	350	5051.24	5053.80	5053.79	5054.50	0.01479	6.70	53.06	37.69	0.97
Lower	12985	1175	5051.24	5055.50	5055.55	5056.70	0.01019	9.09	158.22	74.41	0.91
Lower	12985	1275	5051.24	5055.70	5055.70	5056.90	0.00992	9.26	169.99	75.35	0.90
Lower	12511	350	5043.63	5046.10	5046.08	5046.40	0.01956	5.19	84.83	122.71	1.01
Lower	12511	1175	5043.63	5046.90	5046.92	5047.70	0.01760	7.84	190.12	129.25	1.07
Lower	12511	1275	5043.63	5047.00	5047.01	5047.80	0.01731	8.05	201.32	129.97	1.07
Lower	12049	350	5037.32	5039.70	5039.40	5039.90	0.00972	5.07	92.88	115.62	0.77
Lower	12049	1175	5037.32	5040.90	5040.58	5041.60	0.00951	7.77	211.74	145.20	0.85
Lower	12049	1275	5037.32	5041.00	5040.70	5041.70	0.00923	7.92	225.76	147.78	0.84
Lower	11726	350	5032.58	5035.20	5035.23	5036.00	0.01546	7.08	51.43	35.72	1.00
Lower	11726	1175	5032.58	5037.10	5037.11	5038.20	0.01078	8.85	156.31	78.42	0.92
Lower	11726	1275	5032.58	5037.20	5037.23	5038.40	0.01090	9.15	165.74	79.28	0.93
Lower	11516	350	5029.47	5033.80		5034.10	0.00210	4.10	94.49	38.61	0.41
Lower	11516	1175	5029.47	5036.30		5037.00	0.00279	6.99	226.28	85.28	0.52
Lower	11516	1275	5029.47	5036.50		5037.20	0.00286	7.23	242.62	89.38	0.53
Lower	11431	350	5028.43	5031.40	5031.39	5032.20	0.01579	7.21	48.51	30.15	1.00
Lower	11431	1175	5028.43	5033.40	5033.42	5034.80	0.01351	9.44	124.51	45.78	1.01
Lower	11431	1275	5028.43	5033.60	5033.64	5035.00	0.01289	9.44	135.96	57.07	0.99
Lower	11368	350	5027.76	5030.70	5030.38	5031.20	0.00902	5.85	59.81	33.61	0.77
Lower	11368	1175	5027.76	5032.50	5032.36	5033.70	0.01112	8.86	132.58	48.57	0.93
Lower	11368	1275	5027.76	5032.70	5032.53	5034.00	0.01135	9.11	140.02	61.51	0.94
Lower	11250	350	5026.28	5029.10	5029.09	5029.80	0.01538	6.90	50.72	33.15	0.98
Lower	11250	1175	5026.28	5031.00	5031.01	5032.30	0.01303	9.09	129.19	75.10	0.99
Lower	11250	1275	5026.28	5031.20	5031.19	5032.50	0.01292	9.25	137.80	79.64	0.99
Lower	11119	350	5024.68	5028.90	5027.46	5029.10	0.00196	3.36	106.40	54.74	0.38
Lower	11119	1175	5024.68	5031.00	5029.43	5031.20	0.00162	4.18	432.72	205.40	0.37
Lower	11119	1275	5024.68	5031.20	5029.70	5031.40	0.00156	4.23	467.61	207.61	0.37
Lower	10970	350	5022.78	5025.70	5025.66	5026.50	0.01583	7.26	48.19	29.78	1.01
Lower	10970	1175	5022.78	5027.70	5027.66	5029.10	0.01135	9.64	130.45	55.59	0.95
Lower	10970	1275	5022.78	5027.80	5027.85	5029.30	0.01090	9.81	141.27	59.87	0.94

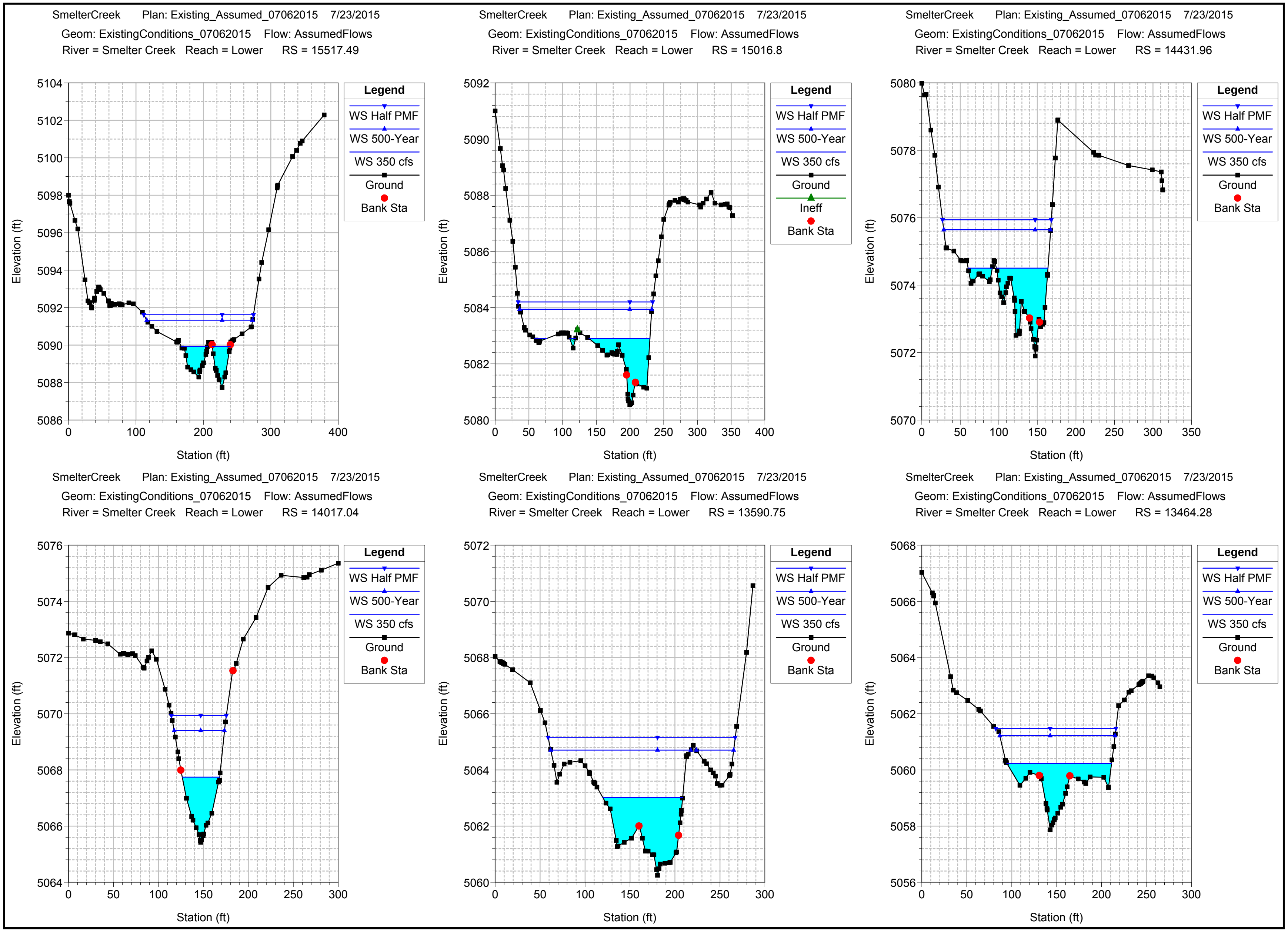
Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Lower	10868	350	5021.30	5024.20		5024.80	0.01042	6.17	56.72	32.30	0.82
Lower	10868	1175	5021.30	5026.00	5025.93	5027.30	0.01255	9.46	125.54	48.37	0.98
Lower	10868	1275	5021.30	5026.10	5026.11	5027.60	0.01249	9.75	132.81	50.29	0.99
Lower	10763	350	5019.11	5022.60	5022.56	5023.50	0.01586	7.59	46.09	26.18	1.01
Lower	10763	1175	5019.11	5024.60	5024.64	5026.10	0.01216	9.59	126.93	49.50	0.97
Lower	10763	1275	5019.11	5024.80	5024.81	5026.30	0.01181	9.81	135.67	51.16	0.97
Lower	10664	350	5017.51	5020.80	5020.82	5021.80	0.01322	7.92	46.15	31.17	0.95
Lower	10664	1175	5017.51	5023.10	5023.08	5024.50	0.00903	10.54	153.13	58.38	0.88
Lower	10664	1275	5017.51	5023.20	5023.24	5024.70	0.00920	10.89	162.42	59.76	0.90
Lower	10573	350	5016.28	5019.40	5019.40	5020.30	0.01517	7.61	45.99	25.13	0.99
Lower	10573	1175	5016.28	5021.70	5021.68	5023.20	0.01296	9.74	121.22	42.96	1.00
Lower	10573	1275	5016.28	5021.90	5021.86	5023.40	0.01262	9.97	128.98	44.95	0.99
Lower	10520	350	5015.53	5018.60	5018.60	5019.50	0.01564	7.66	45.70	25.92	1.01
Lower	10520	1175	5015.53	5020.90	5020.88	5022.50	0.00998	10.54	128.54	46.47	0.92
Lower	10520	1275	5015.53	5021.10	5021.10	5022.80	0.00966	10.74	138.99	48.47	0.92
Lower	10235	350	5008.42	5013.10	5011.65	5013.40	0.00333	4.74	73.80	25.20	0.49
Lower	10235	1175	5008.42	5015.00	5014.50	5016.10	0.00681	8.83	155.34	56.58	0.74
Lower	10235	1275	5008.42	5015.10	5014.73	5016.30	0.00718	9.20	163.42	58.84	0.77
Lower	10145	350	5007.37	5009.90	5009.93	5010.80	0.01574	7.58	46.17	26.41	1.01
Lower	10145	1175	5007.37	5012.30	5012.31	5013.20	0.00736	8.01	212.08	144.88	0.77
Lower	10145	1275	5007.37	5012.40	5012.43	5013.30	0.00731	8.18	230.14	148.78	0.77
Lower	10069	350	5006.15	5009.00	5008.47	5009.40	0.00632	4.88	71.71	40.42	0.65
Lower	10069	1175	5006.15	5010.30	5010.28	5011.60	0.01348	9.06	129.76	122.93	1.00
Lower	10069	1275	5006.15	5010.50	5010.52	5011.80	0.01337	8.96	142.31	157.82	0.99
Lower	9940	350	5003.48	5008.90	5007.00	5009.00	0.00116	2.80	161.57	420.47	0.29
Lower	9940	1175	5003.48	5009.30	5009.29	5010.10	0.00784	7.77	211.26	455.16	0.78
Lower	9940	1275	5003.48	5009.50	5009.50	5009.60	0.00178	3.83	689.21	493.22	0.38
Lower	9829	350	5002.64	5006.00	5005.82	5006.80	0.01104	7.06	49.55	135.86	0.86
Lower	9829	1175	5002.64	5007.50	5007.55	5007.70	0.00254	4.27	586.77	632.54	0.44
Lower	9829	1275	5002.64	5007.50	5007.55	5007.70	0.00300	4.64	586.77	632.54	0.47
Lower	9622	350	5000.24	5003.20	5003.20	5004.20	0.01486	7.87	44.50	335.29	0.99

Smelter Creek Regional Flood Control Project
Feasibility Engineering Study
Profile Output Table - 350cfs, 1,175cfs, 1,275 cfs

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Lower	9622	1175	5000.24	5004.30	5004.33	5004.50	0.00314	4.33	451.85	603.54	0.47
Lower	9622	1275	5000.24	5004.30	5004.33	5004.50	0.00370	4.70	451.85	603.54	0.51
Lower	9395	350	4997.42	4999.80	4999.78	4999.80	0.00195	2.24	241.50	275.24	0.34
Lower	9395	1175	4997.42	5000.20	4999.78	5000.40	0.00854	5.54	339.57	357.23	0.74
Lower	9395	1275	4997.42	5000.30	4999.78	5000.50	0.00852	5.69	358.90	370.75	0.75
Lower	9135	350	4994.07	4996.80	4996.83	4997.10	0.00727	5.14	121.27	197.32	0.69
Lower	9135	1175	4994.07	4997.60	4997.65	4998.10	0.00915	7.47	319.48	292.73	0.83
Lower	9135	1275	4994.07	4997.70	4997.71	4998.20	0.00934	7.67	336.94	295.57	0.84
Lower	8511	350	4987.46	4990.00	4989.81	4990.20	0.01031	5.18	118.75	245.87	0.78
Lower	8511	1175	4987.46	4990.70	4990.50	4990.90	0.00930	6.33	409.28	433.02	0.79
Lower	8511	1275	4987.46	4990.70	4990.56	4990.90	0.00937	6.47	433.12	439.12	0.80
Lower	7567	350	4978.65	4981.10	4981.04	4981.30	0.00854	4.97	131.88	343.55	0.73
Lower	7567	1175	4978.65	4981.50	4981.41	4981.70	0.01012	6.24	382.43	382.80	0.82
Lower	7567	1275	4978.65	4981.60	4981.41	4981.80	0.01004	6.32	404.91	384.64	0.82
Lower	7019	350	4973.85	4976.00	4975.86	4976.10	0.01033	4.37	143.24	213.77	0.76
Lower	7019	1175	4973.85	4976.90		4977.10	0.00706	5.30	391.80	301.46	0.69
Lower	7019	1275	4973.85	4977.00		4977.20	0.00711	5.44	411.55	302.33	0.70
Lower	6520	350	4968.32	4971.40	4971.37	4971.50	0.00804	4.50	160.88	252.71	0.68
Lower	6520	1175	4968.32	4971.90	4971.78	4972.20	0.01352	6.50	319.56	296.40	0.91
Lower	6520	1275	4968.32	4972.00	4971.83	4972.30	0.01341	6.64	338.79	300.39	0.91
Lower	5971	350	4962.93	4965.60	4965.61	4965.90	0.01103	5.41	137.72	256.97	0.81
Lower	5971	1175	4962.93	4966.40		4966.70	0.00796	6.32	372.09	301.04	0.75
Lower	5971	1275	4962.93	4966.50		4966.80	0.00805	6.48	392.18	304.18	0.76
Lower	5552	350	4959.98	4961.80	4961.65	4961.90	0.00778	3.84	172.66	287.65	0.66
Lower	5552	1175	4959.98	4962.30	4962.14	4962.60	0.01216	6.33	336.83	322.13	0.89
Lower	5552	1275	4959.98	4962.40	4962.19	4962.70	0.01202	6.45	356.52	323.26	0.89
Lower	4717	350	4949.32	4951.70	4951.61	4951.80	0.02095	4.04	115.36	212.38	0.97
Lower	4717	1175	4949.32	4952.50	4952.14	4952.80	0.01129	5.63	332.26	294.12	0.83
Lower	4717	1275	4949.32	4952.60	4952.22	4952.90	0.01140	5.83	351.58	300.88	0.84
Lower	4021	350	4941.18	4944.80	4943.92	4945.00	0.00549	4.33	80.76	102.04	0.60
Lower	4021	1175	4941.18	4945.80	4945.56	4946.30	0.00762	6.52	244.09	167.51	0.75
Lower	4021	1275	4941.18	4945.90	4945.66	4946.50	0.00747	6.65	262.67	173.60	0.75

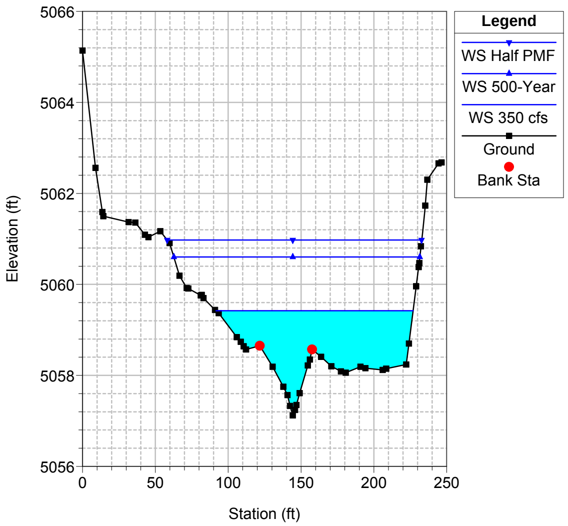
Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Lower	3522	350	4938.02	4941.10	4941.10	4941.60	0.00907	5.85	88.51	128.56	0.77
Lower	3522	1175	4938.02	4942.40		4942.80	0.00653	7.04	316.26	218.61	0.71
Lower	3522	1275	4938.02	4942.40		4942.90	0.00676	7.29	333.18	222.83	0.73
Lower	3018	350	4933.82	4937.40	4937.42	4937.80	0.00629	5.39	122.22	191.81	0.66
Lower	3018	1175	4933.82	4938.20	4938.21	4938.80	0.00991	8.15	297.81	251.13	0.86
Lower	3018	1275	4933.82	4938.30	4938.30	4938.80	0.00962	8.21	321.08	255.88	0.85
Lower	2456	350	4930.41	4934.40	4933.85	4934.40	0.00063	1.84	344.97	221.00	0.21
Lower	2456	1175	4930.41	4935.00	4933.88	4935.10	0.00283	4.35	488.26	257.21	0.45
Lower	2456	1275	4930.41	4935.10	4933.93	4935.20	0.00276	4.39	524.12	266.03	0.45
Lower	2249	350	4929.25	4932.80	4932.79	4933.90	0.01489	8.48	41.28	139.97	0.98
Lower	2249	1175	4929.25	4933.50	4933.53	4934.00	0.01091	8.02	268.73	198.28	0.86
Lower	2249	1275	4929.25	4933.50	4933.53	4934.10	0.01278	8.68	269.21	198.86	0.93
Lower	1866	350	4927.19	4929.60	4929.60	4929.60	0.00085	1.31	382.97	322.85	0.22
Lower	1866	1175	4927.19	4930.20	4929.60	4930.30	0.00245	2.90	597.55	354.77	0.40
Lower	1866	1275	4927.19	4930.30	4929.60	4930.40	0.00243	2.98	632.76	359.22	0.40
Lower	1628	350	4926.21	4927.50	4927.48	4927.80	0.02449	6.02	91.22	139.46	1.14
Lower	1628	1175	4926.21	4928.30	4928.26	4928.90	0.02252	8.86	203.75	150.17	1.22
Lower	1628	1275	4926.21	4928.30	4928.34	4929.00	0.02239	9.10	215.16	151.23	1.22
Lower	1378	350	4922.50	4923.60	4923.46	4923.80	0.00980	3.61	96.95	121.59	0.71
Lower	1378	1175	4922.50	4924.40	4924.26	4925.00	0.01097	5.87	200.06	131.39	0.84
Lower	1378	1275	4922.50	4924.50	4924.33	4925.10	0.01129	6.11	208.54	131.89	0.86
Lower	1061	350	4917.41	4919.30	4919.27	4919.60	0.01859	4.89	71.83	113.73	0.98
Lower	1061	1175	4917.41	4920.20	4920.23	4921.00	0.01402	7.25	168.93	160.21	0.97
Lower	1061	1275	4917.41	4920.30	4920.34	4921.20	0.01338	7.37	181.17	182.63	0.96
Lower	790	350	4916.19	4917.70		4917.80	0.00244	2.22	164.88	169.55	0.37
Lower	790	1175	4916.19	4919.30		4919.50	0.00119	2.84	455.27	190.69	0.30
Lower	790	1275	4916.19	4919.50		4919.60	0.00115	2.89	485.55	192.14	0.30
Lower	614	350	4914.50	4916.80	4916.45	4917.10	0.00900	5.16	84.41	62.10	0.75
Lower	614	1175	4914.50	4918.20	4917.82	4919.00	0.00901	8.07	197.93	100.55	0.84
Lower	614	1275	4914.50	4918.40	4917.97	4919.10	0.00900	8.31	211.38	105.71	0.85

Smelter CReek Flood Control Project
Feasibility Engineering Study
Cross Section Plots

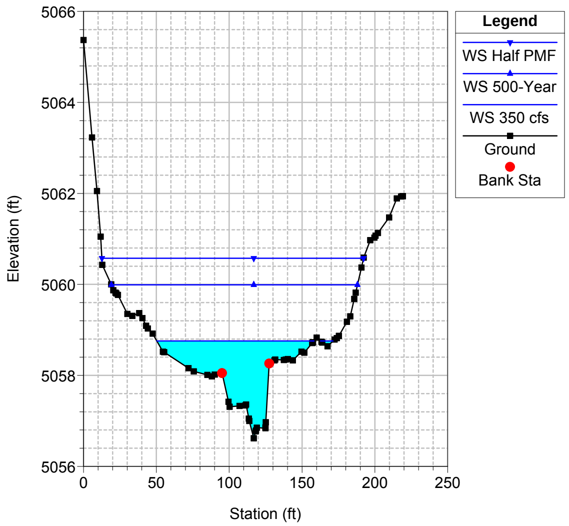


Smelter CReek Flood Control Project
Feasibility Engineering Study
Cross Section Plots

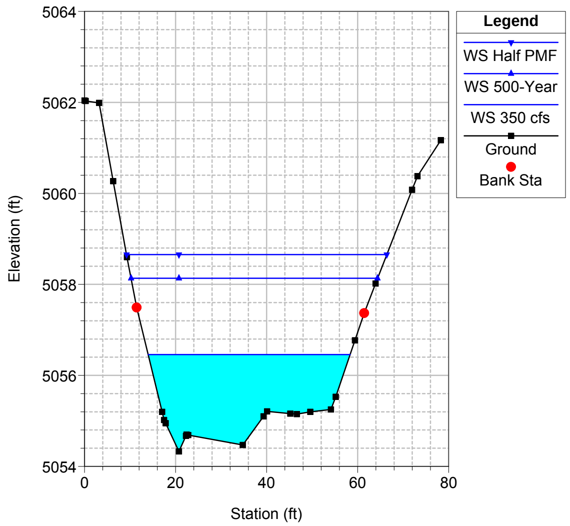
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 13393.39



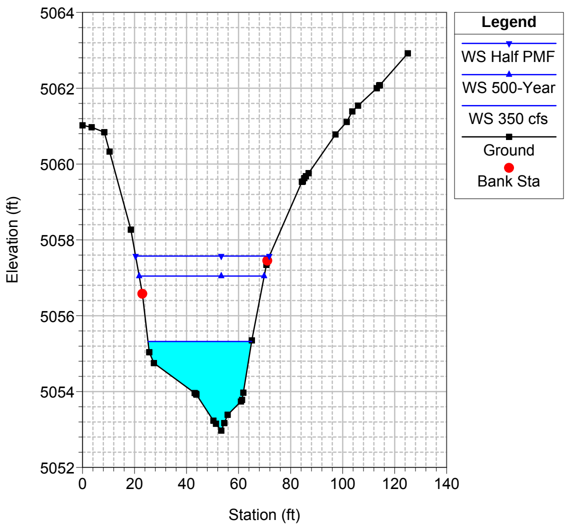
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 13344.68



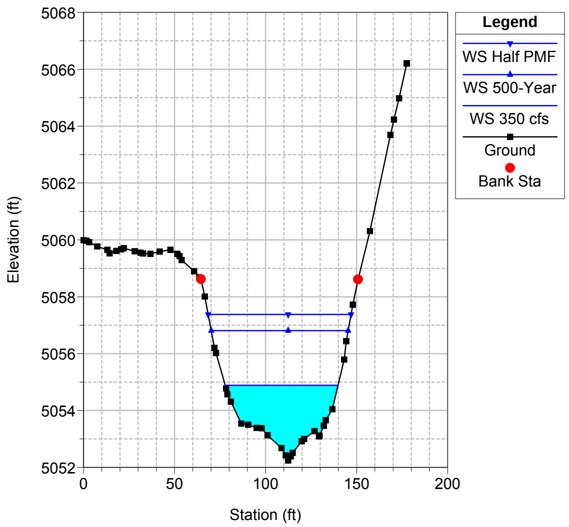
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 13196.07



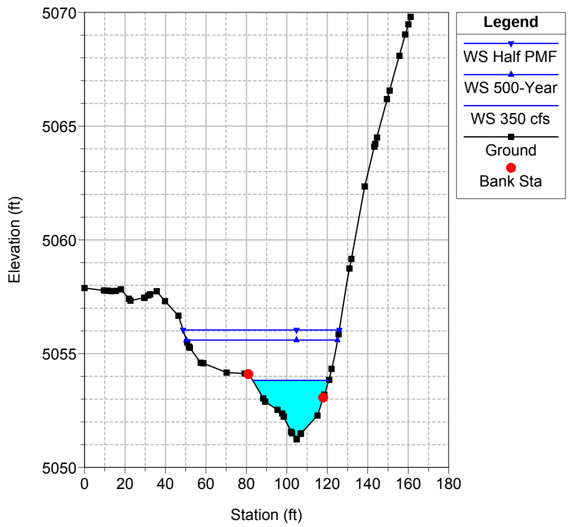
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 13128.05

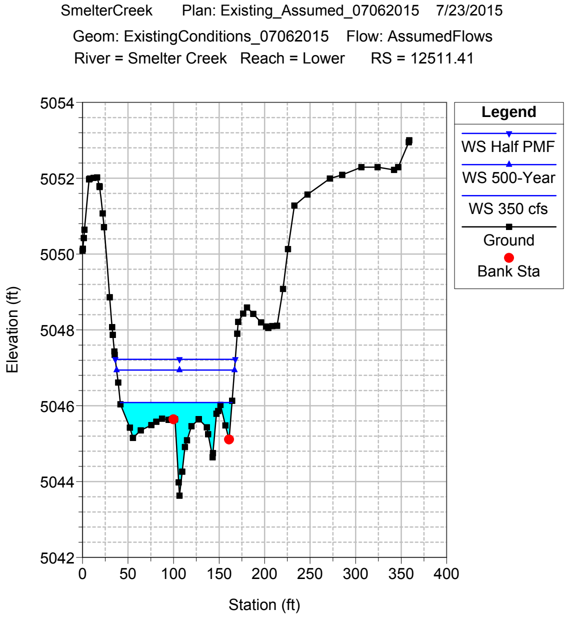


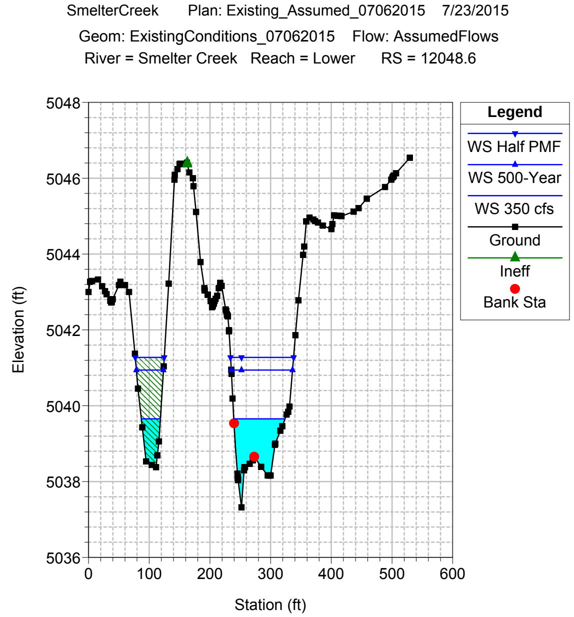
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 13059.71

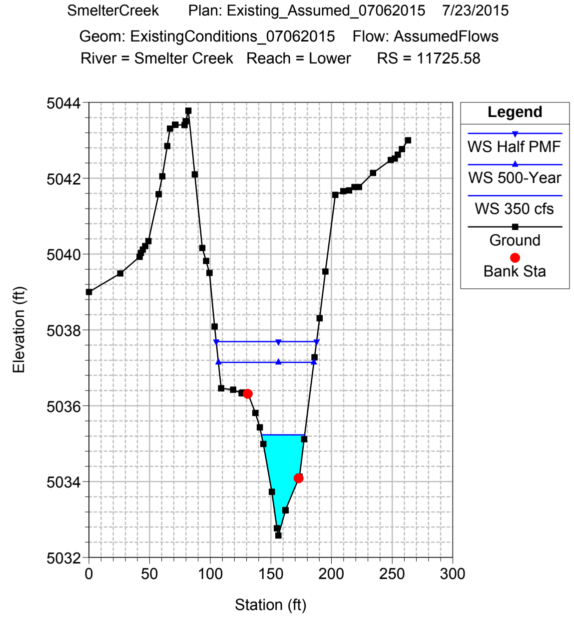


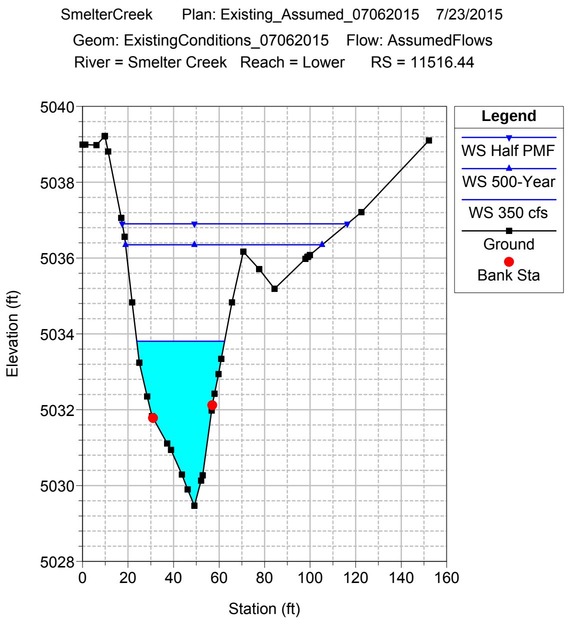
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 12984.69

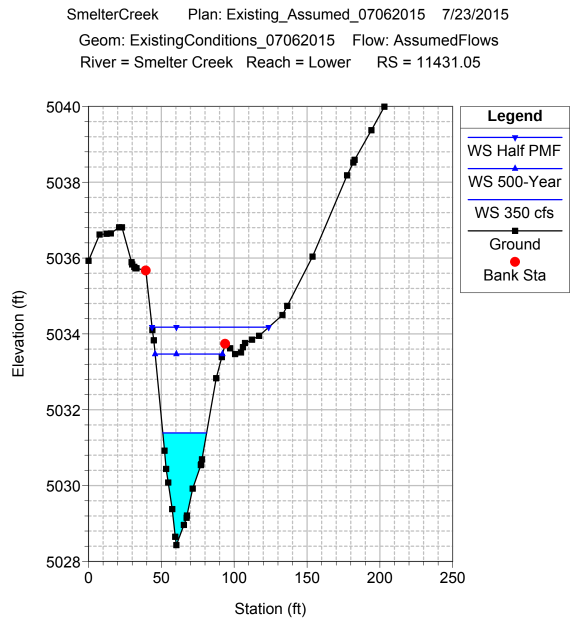


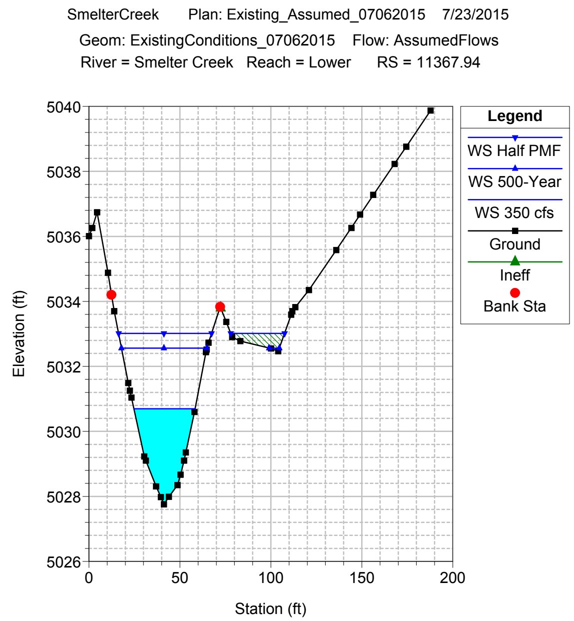

SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 12511.41
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)

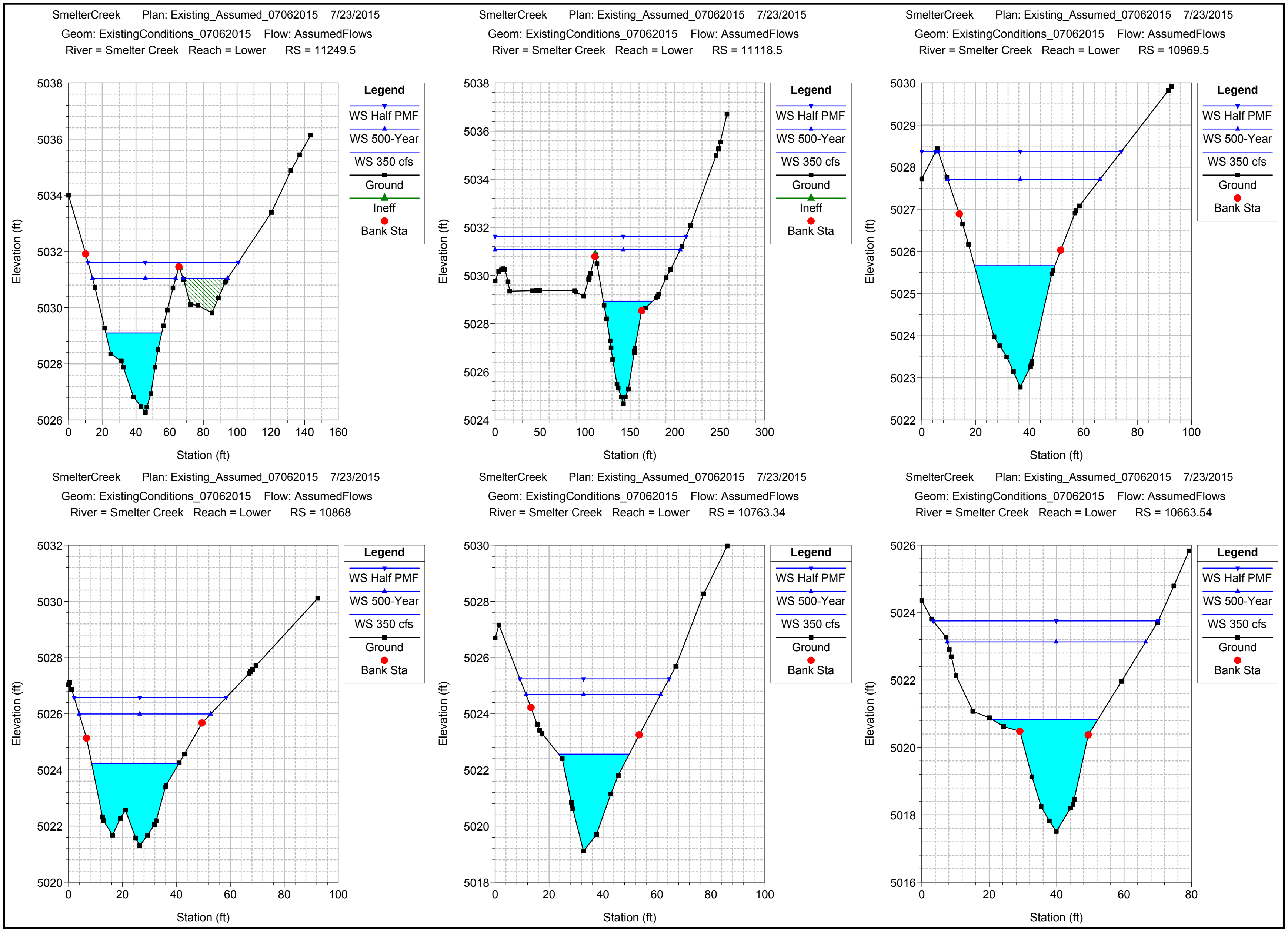

SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 12048.6
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 11725.58
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)


SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 11516.44
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)


SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 11431.05
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)

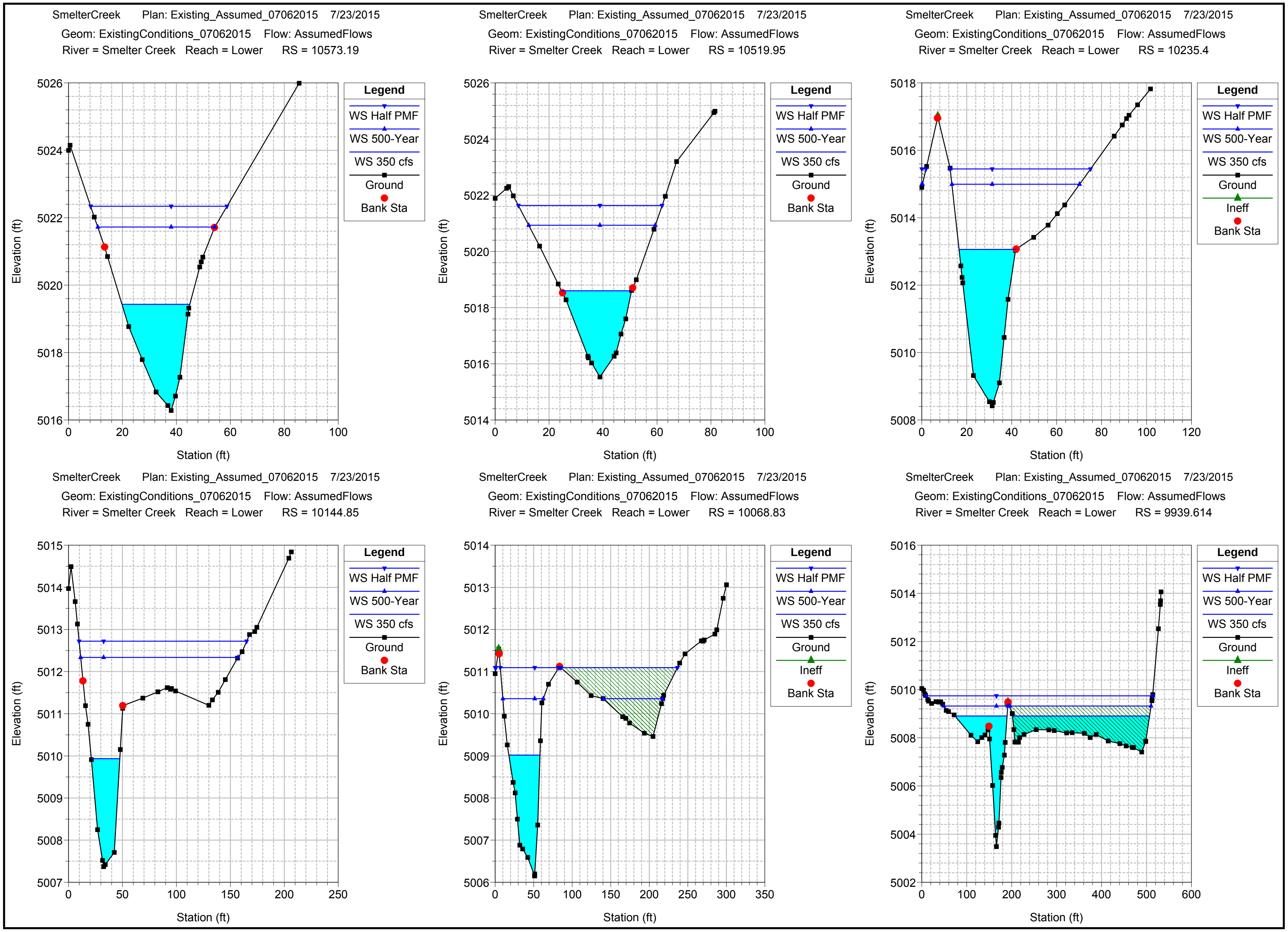

SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 11367.94
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 11249.5
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 11118.5
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 10969.5
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 10868
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 10763.34
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 10663.54

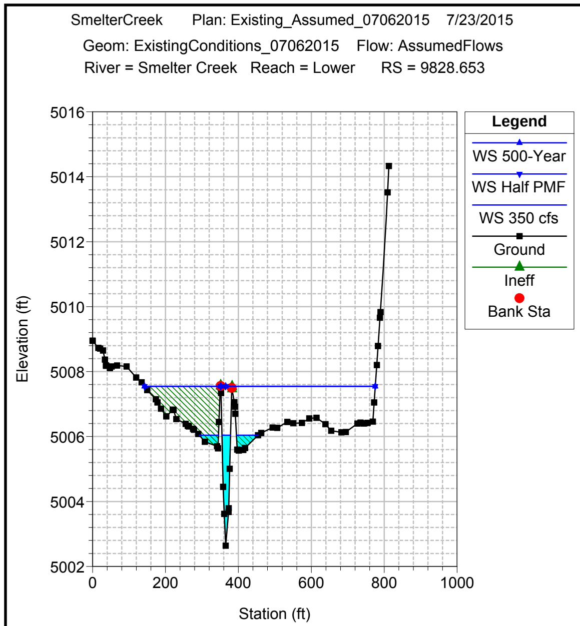
Project # 0713-006
Client: CWSD

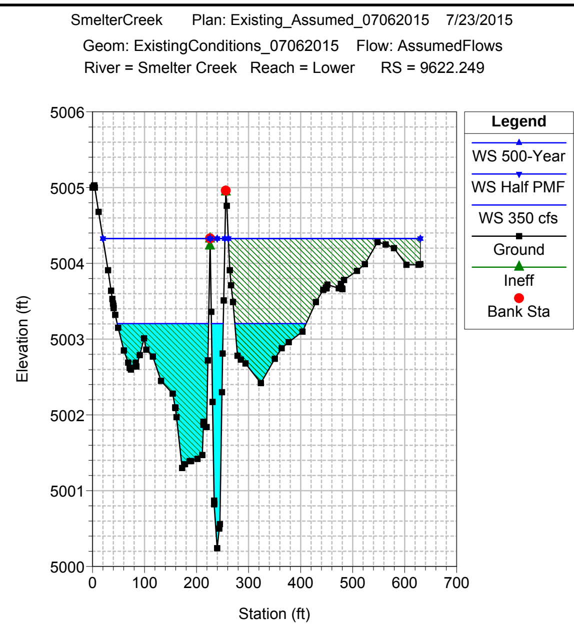
Smelter CReek Flood Control Project
Feasibility Engineering Study
Cross Section Plots

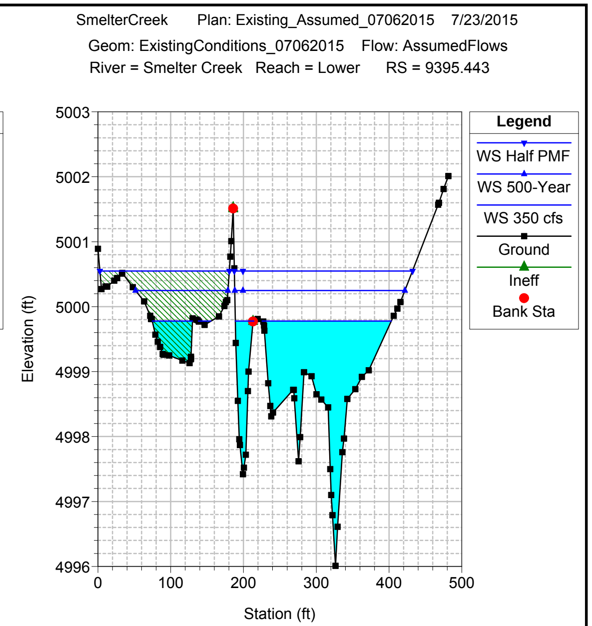
Prepared: SG
Checked: ROA

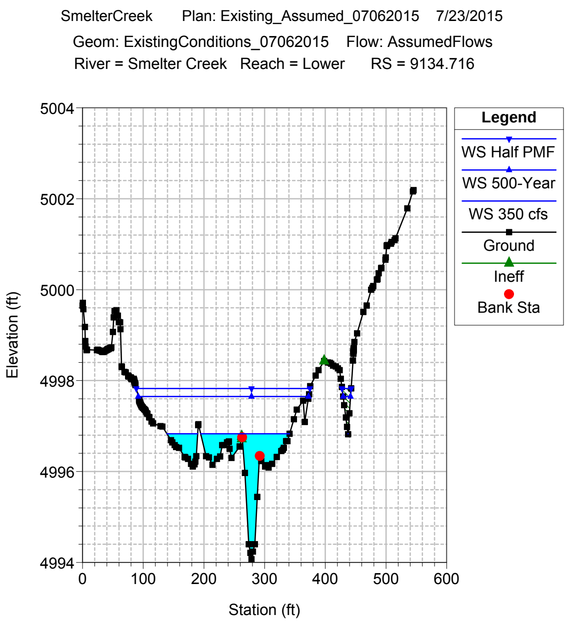


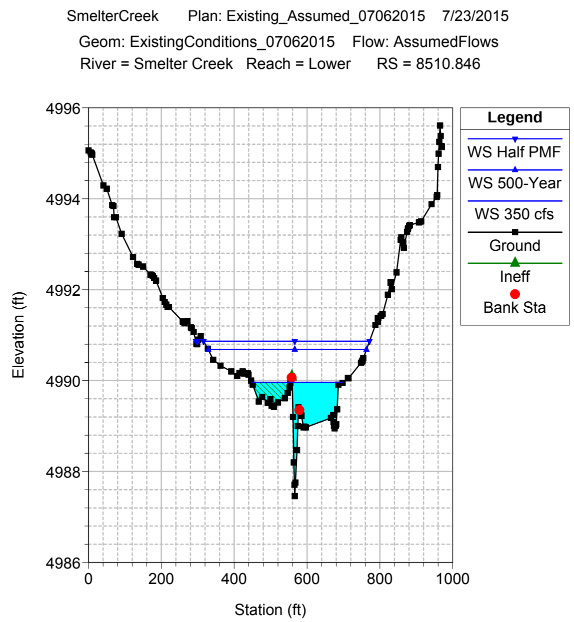
Smelter CReek Flood Control Project
Feasibility Engineering Study
Cross Section Plots

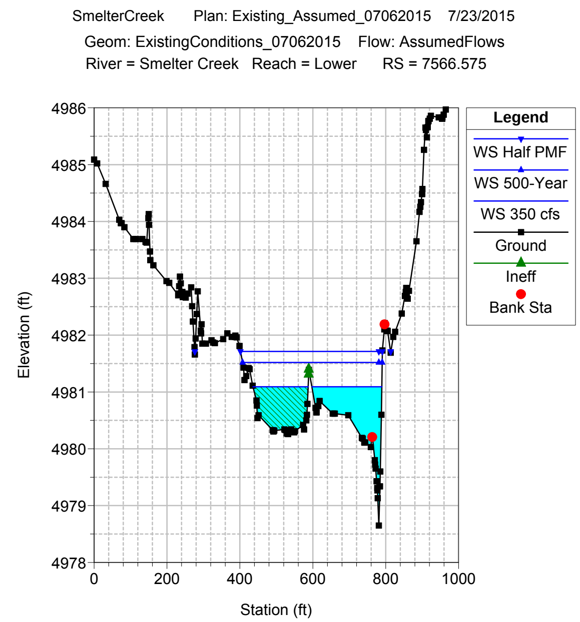


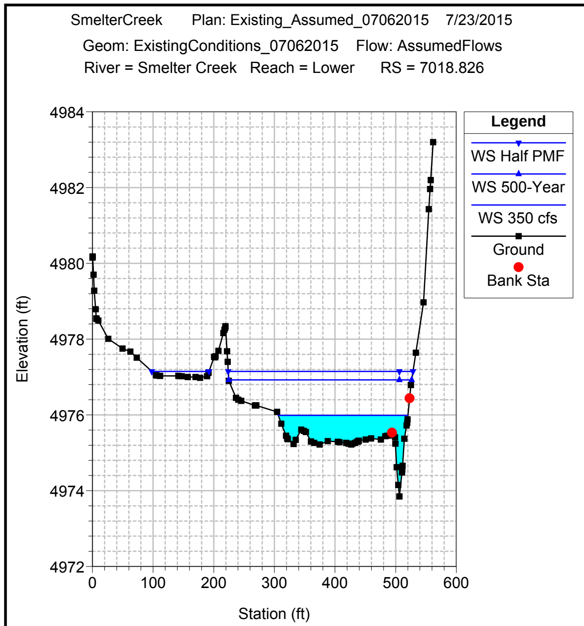




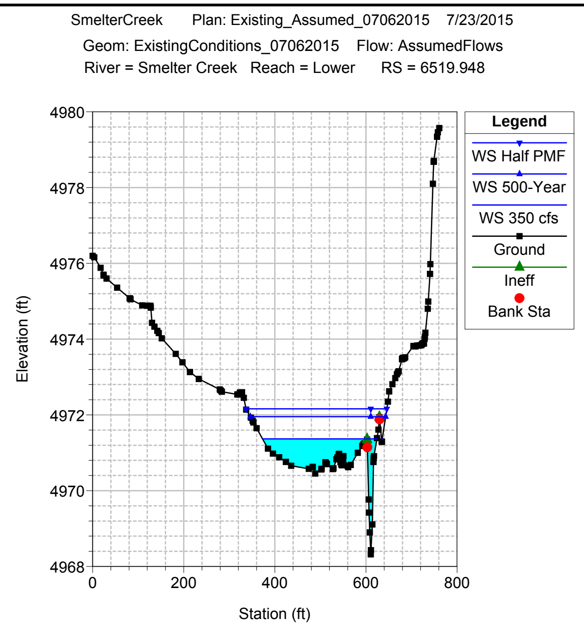




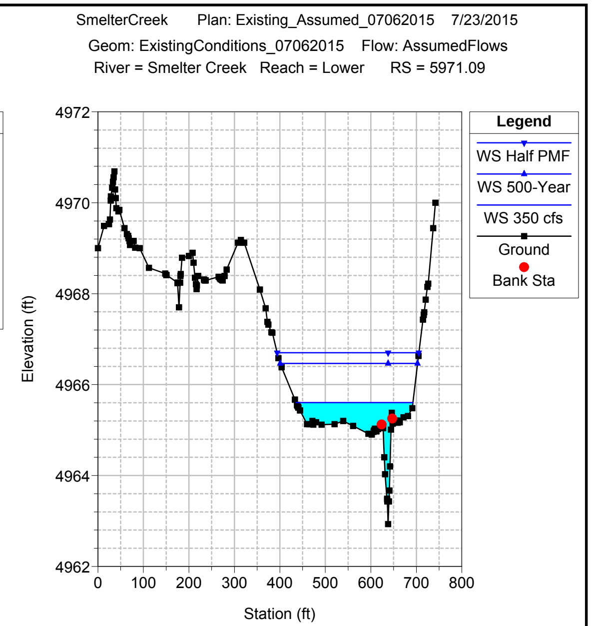




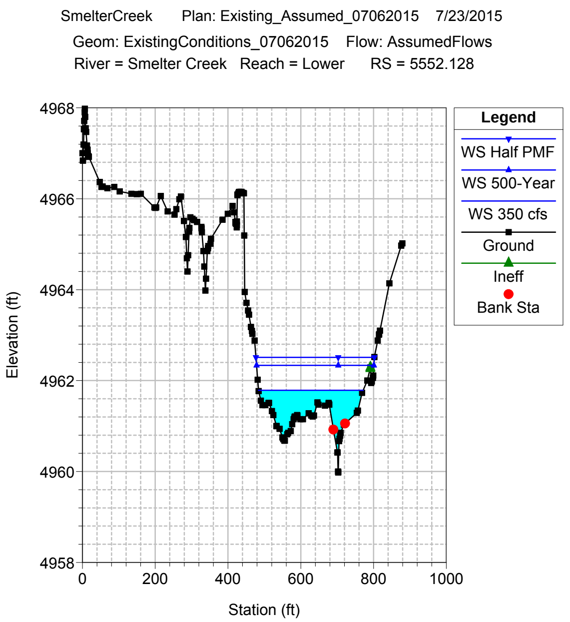
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 7018.826
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
4972
4974
4976
4978
4980
4982
4984
0
100
200
300
400
500
600



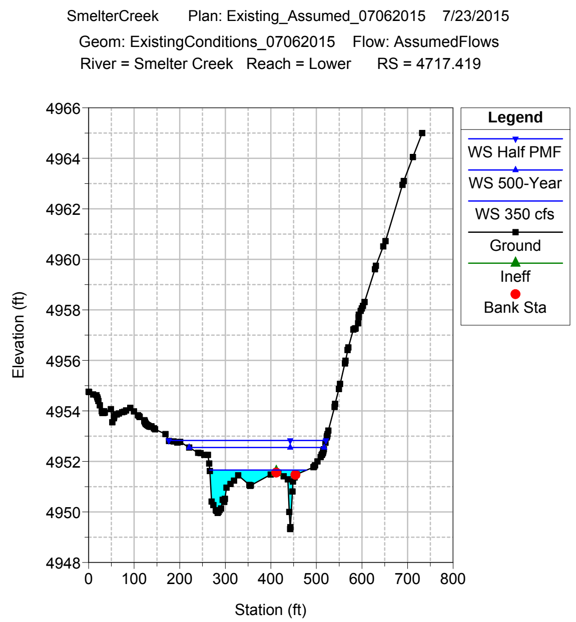
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 6519.948
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
4968
4970
4972
4974
4976
4978
4980
0
200
400
600
800



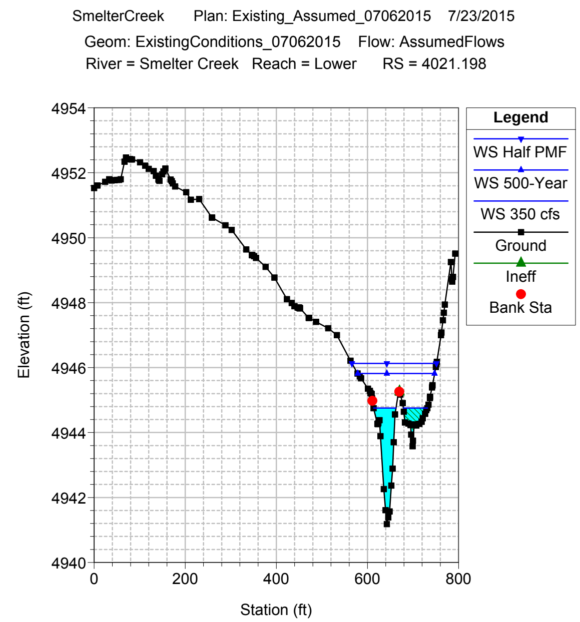
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 5971.09
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
4962
4964
4966
4968
4970
4972
0
100
200
300
400
500
600
700
800



SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 5552.128
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
4958
4960
4962
4964
4966
4968
0
200
400
600
800
1000

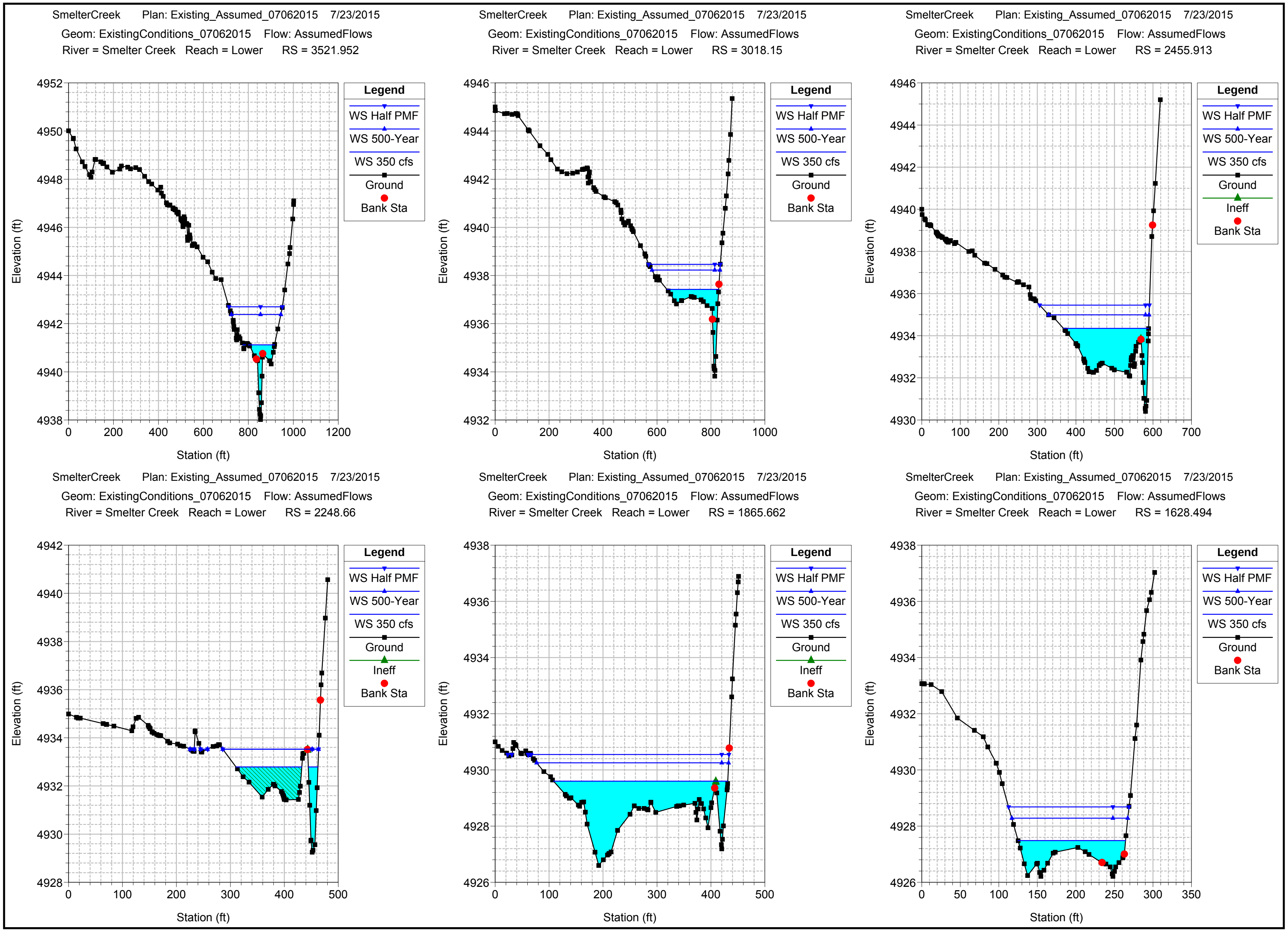


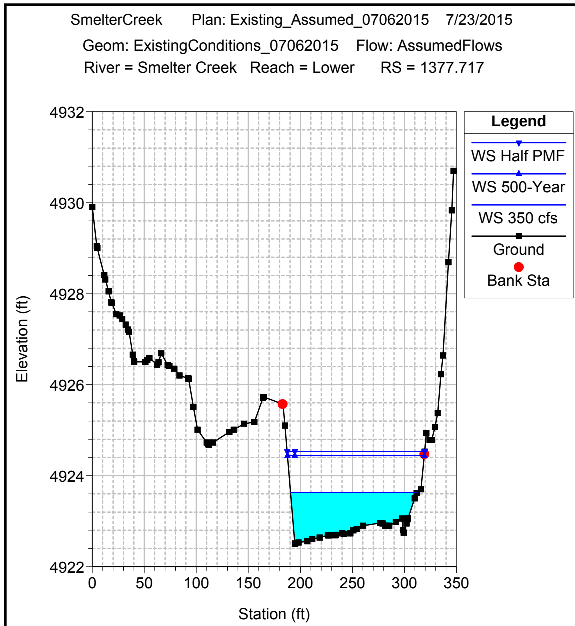
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 4717.419
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
4948
4950
4952
4954
4956
4958
4960
4962
4964
4966
0
100
200
300
400
500
600
700
800

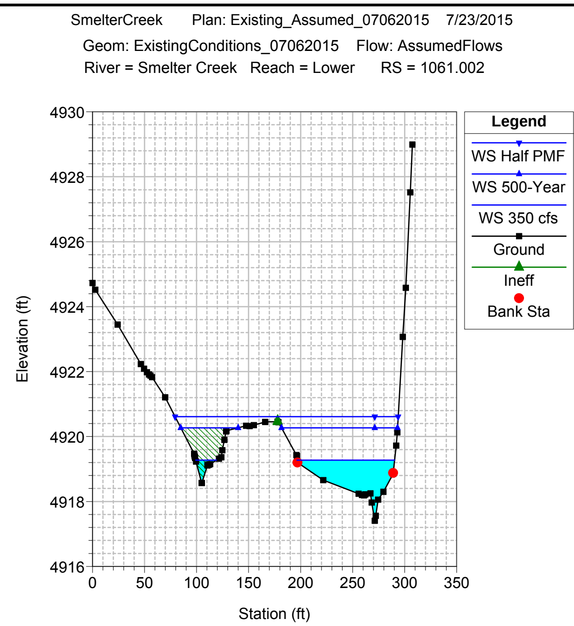


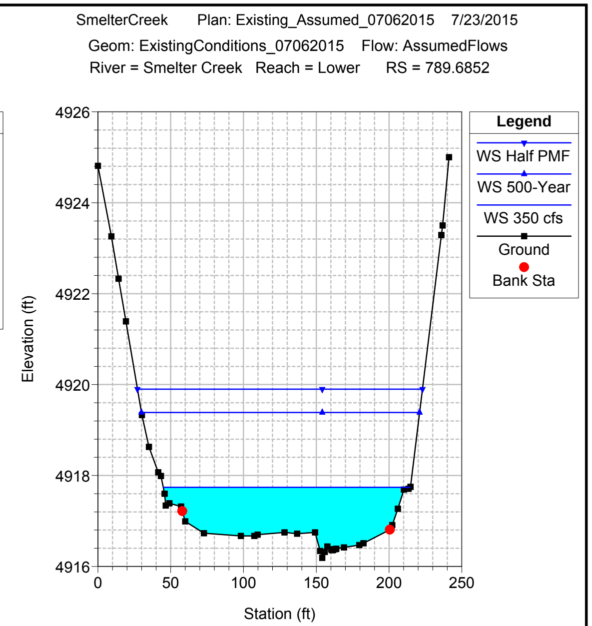
SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 4021.198
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
4940
4942
4944
4946
4948
4950
4952
4954
0
200
400
600
800

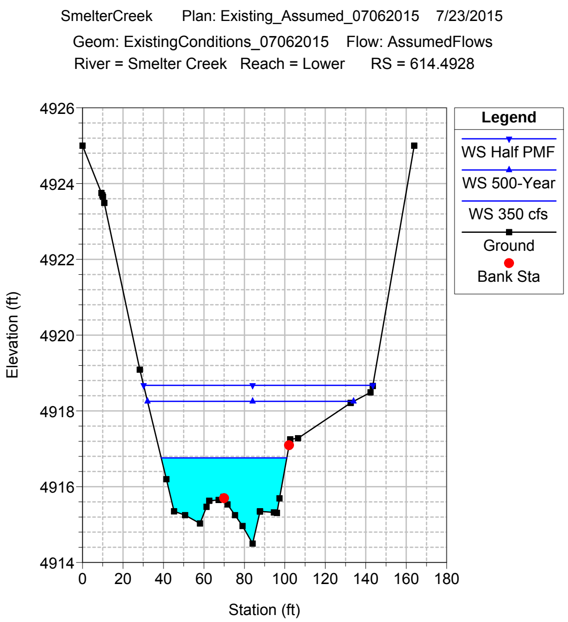
Smelter CReek Flood Control Project
Feasibility Engineering Study
Cross Section Plots




SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 1377.717
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
4932
4930
4928
4926
4924
4922
0
50
100
150
200
250
300
350


SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 1061.002
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
4930
4928
4926
4924
4922
4920
4918
4916
0
50
100
150
200
250
300
350


SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 789.6852
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
4926
4924
4922
4920
4918
4916
0
50
100
150
200
250


SmelterCreek Plan: Existing_Assumed_07062015 7/23/2015
Geom: ExistingConditions_07062015 Flow: AssumedFlows
River = Smelter Creek Reach = Lower RS = 614.4928
Legend
WS Half PMF
WS 500-Year
WS 350 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
4926
4924
4922
4920
4918
4916
4914
0
20
40
60
80
100
120
140
160
180

Smelter Creek Flood Control Project
Feasibility Engineering Study
Profile Plot

Project # 0713-006
Client: CWSD

Prepared: SG
Checked: ROA