American River Basin: Antelope Creek Improvement Project

Attachment 7: Economic Analysis – Flood Damage Reduction Costs and Benefits

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Summary

Phases 1 and 2 of the Antelope Creek Improvement Project (Project) site are located adjacent to Interstate 80, north of Atlantic Street on Antelope Creek in the City of Roseville. The proposed project concept is to construct two in-channel embankments and/or weirs spanning the main channel with culverts that have capacity for low to moderate flows. The embankments and/or weirs will detain higher flows to reduce peak flow rates downstream from the Project site. The locations of the structures are just upstream of the railroad bridge and Atlantic Street, at an existing bike path culvert, just downstream from Roseville Parkway. The Project is currently at a conceptual design stage, and the detailed designs will be developed at a later date. This evaluation assumes that arch structures would be used for the culverts to provide a natural stream bottom and that the embankment/weir at the bike path location would replace an existing culvert with one with more capacity. The structures would be designed to be overtopped in flood events.

The purpose of the Project is to reduce peak flows downstream from the project site. The Project is separated into three phases: Phase 1 involves construction of a new structure near Atlantic Street; Phase 2 involves replacement of the existing bike path crossing with a flow control structure that would improve low flow conveyance and increase the volume impounded before being overtopped; and Phase 3 is a water supply and water quality project at the upstream Clover Valley Reservoir and does not have any flood damage benefits. Figure 1 through Figure 3 show the locations of the flood-related phases of the Project and a conceptual layout of the proposed weir/embankments.

The structure near Atlantic Street was modeled as a 10- to 12-foot high embankment on the floodplain with a Conspan Arch culvert with a span of 32 feet and a rise of 7.5 feet. The second weir will replace the existing bike bridge, raising the bridge deck about four to six feet. An embankment or wall will tie in the crest of the new structure to existing ground to limit overtopping to the desired area. The model assumed that the two existing 6.5-foot diameter culverts will be replaced with a Conspan Arch with a span of 20 feet and a rise of seven feet.

Figure 1: Proposed Project Location

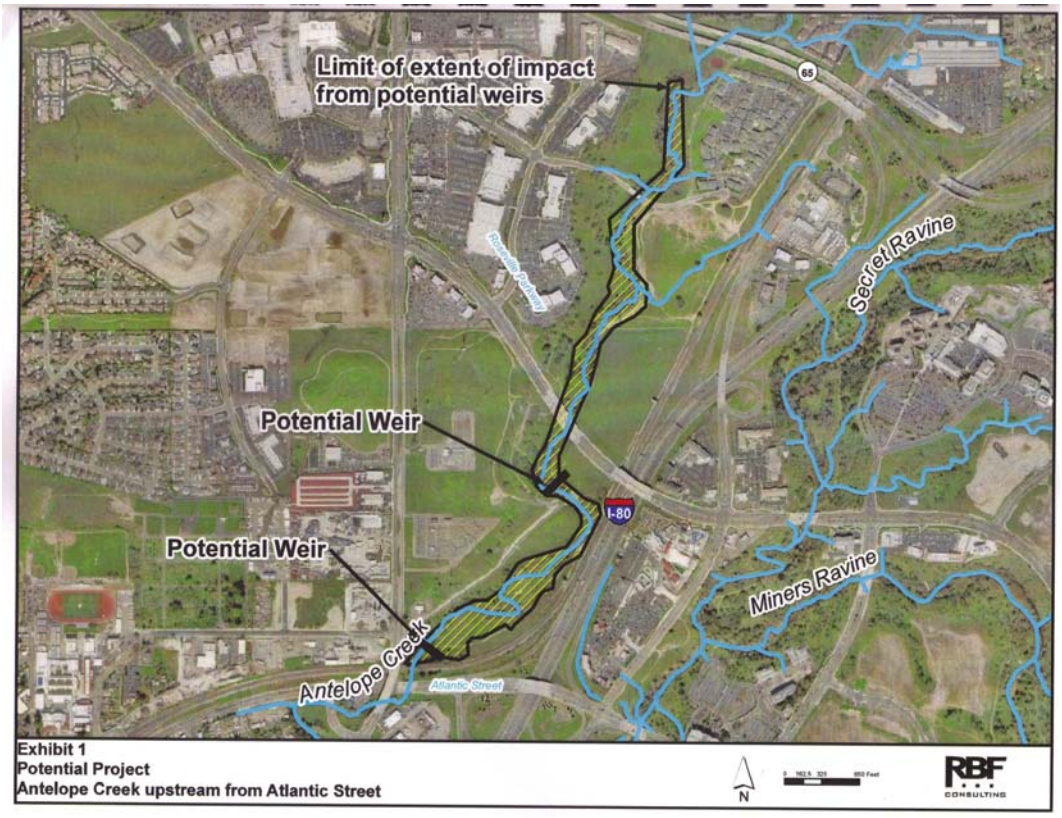
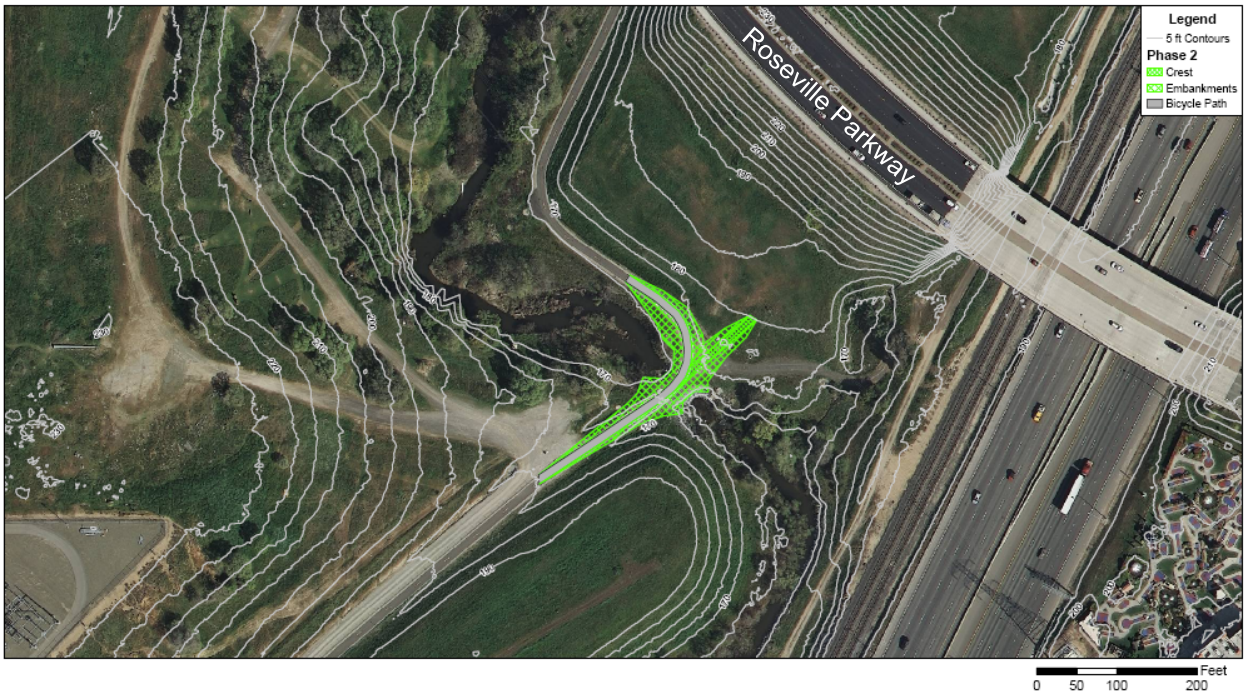


Figure 2: Conceptual Layout of Phase 1 - Construction of a New Structure near Atlantic Street

Figure 3: Conceptual Layout of Phase 2 - Replacement of the Existing Bike Path Crossing Downstream from Roseville Parkway



Costs

As documented in Attachment 4, the budgetary estimate for the Project is $5,839,747. Table 1 augments the costs presented in Attachment 4 with projected future operations, maintenance and replacement costs. The total present value of the project is $4,666,609 and is based on a 50-year project life cycle, which is consistent with the life cycle assumed in the flood damage reduction benefit analysis.

Table 1: Annual Cost of Project (referenced as Table 10 in Exhibit C of the Proposition 1E Grant PSP)

Annual Cost of Project Project: Antelope Creek Improvement Project									
	Initial Costs	Operations and Maintenance Costs						Discounting Calculations	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
YEAR	Grand Total cost From Attachment 4 Project 5 (row (i), column (d))	Admin	Operation	Maintenance	Replacement	Other	Total Costs (a) +...+ (f)	Discount Factor	Discounted Costs (g) x (h)
2009							$0.00	1.000	$0
2010							$0.00	0.943	$0
2011	$ 443,268						$443,268	0.890	$394,509
2012	$ 859,636						$859,636	0.840	$722,094
2013	$ 2,463,835						$2,463,835	0.792	$1,951,357
2014	$ 2,073,008			$2,000	$2,000		$2,077,008	0.747	$1,551,525
2015				$2,000	$2,000		$4,000.00	0.705	$2,820
2016				$2,000	$2,000		$4,000.00	0.665	$2,660
2017				$2,000	$2,000		$4,000.00	0.627	$2,508
2018				$2,000	$2,000		$4,000.00	0.592	$2,368
2019				$2,000	$2,000		$4,000.00	0.558	$2,232
2020				$2,000	$2,000		$4,000.00	0.527	$2,108
2021				$2,000	$2,000		$4,000.00	0.497	$1,988
2022				$2,000	$2,000		$4,000.00	0.469	$1,876
2023				$2,000	$2,000		$4,000.00	0.442	$1,768
2024				$2,000	$2,000		$4,000.00	0.417	$1,668
2025				$2,000	$2,000		$4,000.00	0.394	$1,576
2026				$2,000	$2,000		$4,000.00	0.371	$1,484
2027				$2,000	$2,000		$4,000.00	0.350	$1,400
2028				$2,000	$2,000		$4,000.00	0.331	$1,324
2029				$2,000	$2,000		$4,000.00	0.312	$1,248
2030				$2,000	$2,000		$4,000.00	0.294	$1,176
2031				$2,000	$2,000		$4,000.00	0.278	$1,112
2032				$2,000	$2,000		$4,000.00	0.262	$1,048

Annual Cost of Project Project: Antelope Creek Improvement Project									
	Initial Costs	Operations and Maintenance Costs						Discounting Calculations	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
YEAR	Grand Total cost From Attachment 4 Project 5 (row (i), column (d))	Admin	Operation	Maintenance	Replacement	Other	Total Costs (a) +...+ (f)	Discount Factor	Discounted Costs (g) x (h)
2033				$2,000	$2,000		$4,000.00	0.247	$988
2034				$2,000	$2,000		$4,000.00	0.233	$932
2035				$2,000	$2,000		$4,000.00	0.220	$880
2036				$2,000	$2,000		$4,000.00	0.207	$828
2037				$2,000	$2,000		$4,000.00	0.196	$784
2038				$2,000	$2,000		$4,000.00	0.185	$740
2039				$2,000	$2,000		$4,000.00	0.174	$696
2040				$2,000	$2,000		$4,000.00	0.164	$656
2041				$2,000	$2,000		$4,000.00	0.155	$620
2042				$2,000	$2,000		$4,000.00	0.146	$584
2043				$2,000	$2,000		$4,000.00	0.138	$552
2044				$2,000	$2,000		$4,000.00	0.130	$520
2045				$2,000	$2,000		$4,000.00	0.123	$492
2046				$2,000	$2,000		$4,000.00	0.116	$464
2047				$2,000	$2,000		$4,000.00	0.109	$436
2048				$2,000	$2,000		$4,000.00	0.103	$412
2049				$2,000	$2,000		$4,000.00	0.097	$388
2050				$2,000	$2,000		$4,000.00	0.092	$368
2051				$2,000	$2,000		$4,000.00	0.087	$348
2052				$2,000	$2,000		$4,000.00	0.082	$328
2053				$2,000	$2,000		$4,000.00	0.077	$308
2054				$2,000	$2,000		$4,000.00	0.073	$292
2055				$2,000	$2,000		$4,000.00	0.069	$276
2056				$2,000	$2,000		$4,000.00	0.065	$260
2057				$2,000	$2,000		$4,000.00	0.061	$244
2058				$2,000	$2,000		$4,000.00	0.058	$232

Annual Cost of Project

Project: Antelope Creek Improvement Project

	Initial Costs	Operations and Maintenance Costs						Discounting Calculations	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
YEAR	Grand Total cost From Attachment 4 Project 5 (row (i), column (d))	Admin	Operation	Maintenance	Replacement	Other	Total Costs (a) +...+ (f)	Discount Factor	Discounted Costs (g) x (h)
2059				$2,000	$2,000		$4,000.00	0.054	$217
2060				$2,000	$2,000		$4,000.00	0.051	$205
2061				$2,000	$2,000		$4,000.00	0.048	$193
2062				$2,000	$2,000		$4,000.00	0.046	$182
2063				$2,000	$2,000		$4,000.00	0.043	$172
2064				$2,000	$2,000		$4,000.00	0.041	$162
Total Present Value of Discounted Costs (Sum of Column (i))									$4,666,609

Comments:
All three phases of the project are passive projects that do not have regular administrative or operational costs.

Maintenance and replacement costs are included because the ALERT-type stream level and precipitation gauges that will be installed as part of the flood control improvements will require periodic maintenance and replacement. The National Weather Service's Weather Service Hydrology Handbook No. 2 notes that maintenance and life-cycle replacement costs each run around 10% of capital investment per year. For these calculations, 5% of the capital investment associated with the gauges is attributed to maintenance and the other 5% to replacement.

The "Without Project" Baseline

Antelope Creek is a perennial creek draining the northeast portion of the Dry Creek watershed. The mainstem is approximately 9.5 miles long and the watershed area is 21.4 square miles. The Antelope Creek system is composed of approximately 12.4 miles of intermittent tributaries in addition to the main tributary, Clover Valley Creek.

Antelope Creek and Miners Ravine combine with Clover Valley Creek and Secret Ravine, respectively, near Interstate 80 and Atlantic Street in Roseville to form Dry Creek. Cirby Creek, made up of the combination of Cirby and Linda Creeks and Strap Ravine, joins Dry Creek just upstream of Riverside Avenue in Roseville. Downstream of Roseville, just downstream of Elverta Road, Dry Creek branches into North Dry Creek and Dry Creek and forms Cherry Island in the Rio Linda area. Without the proposed project, the City of Roseville and unincorporated areas of Placer County will continue to be repeatedly damaged during storm events as a result of bank overtopping.

Flood Damage Reduction Benefits

This section describes the Flood Damage Reduction Analysis (FDRA) that was completed for the Project and presents the Expected Annual Damage (EAD) benefits that would result from the completion of the Project.

Hydrology and Hydraulic Analysis

Detailed hydrology and hydraulic models were developed for the *2010 Update to the Dry Creek Watershed Flood Control Study* (Plan Update). Hydrology models were developed for various levels of build-out in the Dry Creek watershed. This analysis used the 2007 existing conditions hydrology. As stipulated in Exhibit E (page 41, note 1) of the *Proposal Solicitation Package, Integrated Regional Water Management, Proposition 1E, Round 1* (DWR, August 2010), both Without Project and With Project conditions are assessed based on existing conditions hydrology.

The Plan Update hydrology uses cloudburst centering per the Placer County Flood Control and Water Conservation District's (District's) hydrology procedures. The centerings are based on various locations and angle combinations. The Plan Update identified seven critical storm centerings that produced nearly all peak flows at key locations throughout the watershed. Three of the critical storm centerings, centered at locations in the Antelope Creek and Secret Ravine watersheds, produce the maximum peak flows at locations downstream from the Project site. The three critical storm centerings are AC5I at 0°, SE40M at 30°, and SE40N at 0°. Details related to the hydrology are available in the Plan Update.

An extensive unsteady-state HEC-RAS model was created for the Plan Update using existing models. The existing conditions HEC-RAS geometry that includes the District's Miners Ravine Off-Channel Detention Basin was used as the basis for the baseline (Without Project) conditions for this analysis. The model datum is NGVD 29. Maximum peak stages and maximum peak flows for each of the three centerings for the 10-year, 25-year, 50-year, and 100-year flow conditions were generated for the Without Project flow conditions, Project Phase 1 flow conditions, and Project Phase 2 flow conditions. Project Phase 2 flow conditions reflect both Phase 1 and Phase 2 being complete. For each recurrence interval and Project condition scenario, the maximum peak stage produced by the maximum of the three critical centerings was tabulated for use in the FDRA.

Table 2 lists peak stages at five example locations on Dry Creek, downstream of the Project site for each of the five recurrence intervals for the Without Project, Phase 1, and Phase 2 flow conditions.

Table 2: Maximum Peak Flood Stage at Sample Locations for Various Scenarios

Without Project					
Recurrence Interval		10	25	50	100
Location	HEC-RAS River Station	Peak Stage (ft)	Peak Stage (ft)	Peak Stage (ft)	Peak Stage (ft)
Near Bernice Avenue	81041.20	145.2	147.1	148.4	150.0
Royer Park	77943	136.9	139.9	140.9	142.0
Near Earl Avenue	74433.10	131.1	133.2	134.4	135.3
Near Riverside Avenue	73756.6	129.7	131.7	132.8	133.4
Vernon Street	70071.60	124.0	126.1	127.2	129.2
Near Billy Mitchell Blvd	52140	93.9	95.7	96.5	97.3
Phase 1					
Recurrence Interval		10	25	50	100
Location	HEC-RAS River Station	Peak Stage (ft)	Peak Stage (ft)	Peak Stage (ft)	Peak Stage (ft)
Near Bernice Avenue	81041.20	145.1	147.0	148.2	149.8
Royer Park	77943	136.8	139.5	140.7	141.8
Near Earl Avenue	74433.10	131.0	133.1	134.3	135.1
Near Riverside Avenue	73756.6	129.6	131.6	132.7	133.3
Vernon Street	70071.60	124.0	126.0	127.1	129.1
Near Billy Mitchell Blvd	52140	93.9	95.6	96.5	97.2
Phase 2					
Recurrence Interval		10	25	50	100
Location	HEC-RAS River Station	Peak Stage (ft)	Peak Stage (ft)	Peak Stage (ft)	Peak Stage (ft)
Near Bernice Avenue	81041.20	145.0	146.8	148.0	149.6
Royer Park	77943	136.7	139.2	140.6	141.4
Near Earl Avenue	74433.10	130.9	133.0	134.2	135.0
Near Riverside Avenue	73756.6	129.6	131.5	132.6	133.2
Vernon Street	70071.60	123.9	125.9	126.9	129.1
Near Billy Mitchell Blvd	52140	93.9	95.6	96.4	97.1

Due to its proximity to locations of flood prone properties, Dry Creek at Vernon Street became, and continues to be used as a reference location for flood impacts in the Dry Creek watershed. Figure 4 and Figure 5 illustrate the location of flood prone properties that could benefit from the proposed project, and Vernon Street at Dry Creek. Figure 6 presents the 100-year flow hydrographs for the existing conditions, Phase 1, and Phase 2 scenarios for the SE40N° 0 centering that generates maximum peak flow rates at Vernon Street. The maximum peak flow rate is reduced by about 530 cubic feet per second (cfs) following completion of Phase 1 and by about 1,000 cfs following completion of Phase 2.

Figure 4: Dry Creek Watershed Groups and Flood Prone Properties with Potential Benefits

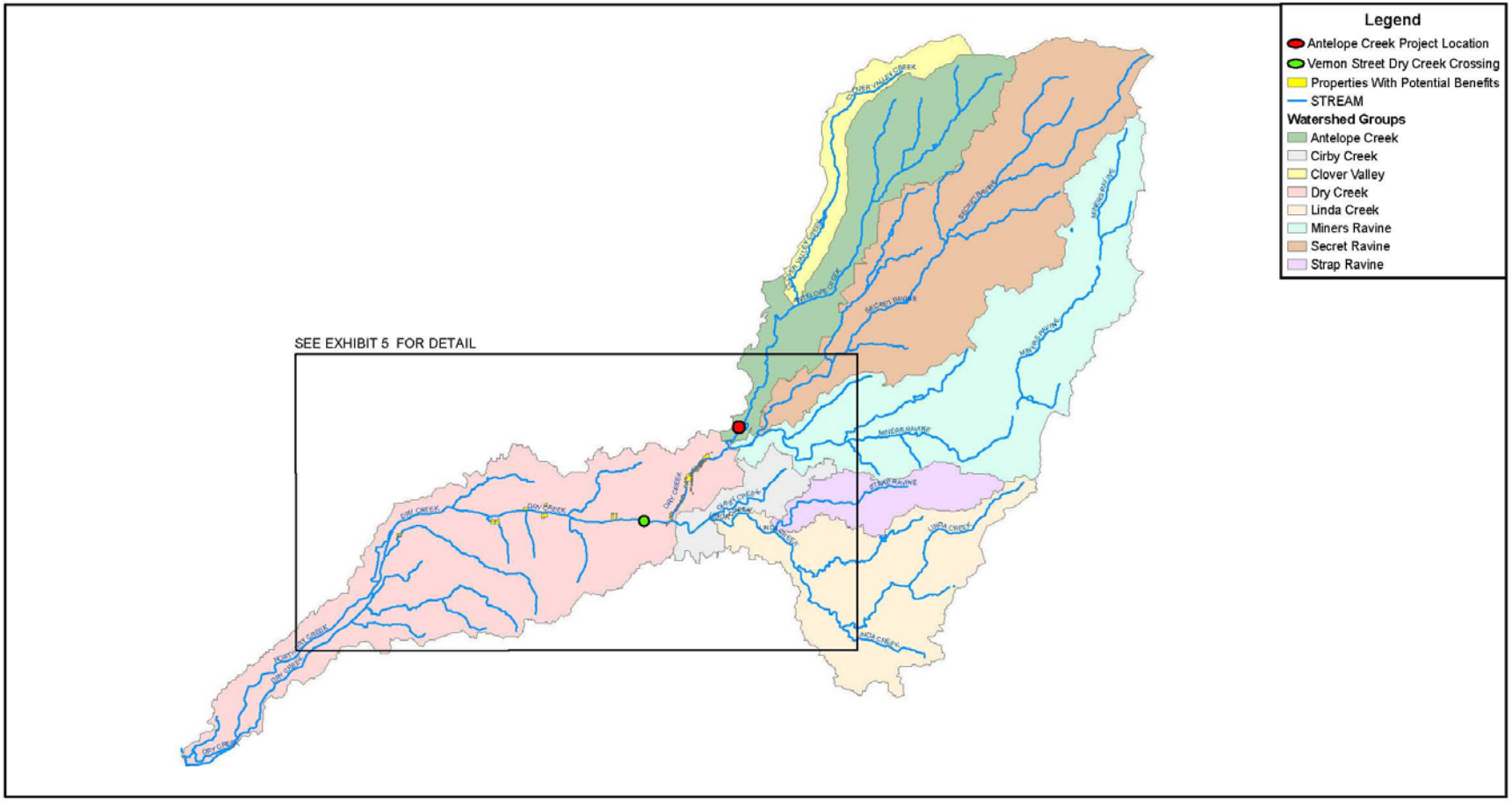


Figure 5: Detail of Project Area and Flood Prone Properties with Potential Benefits

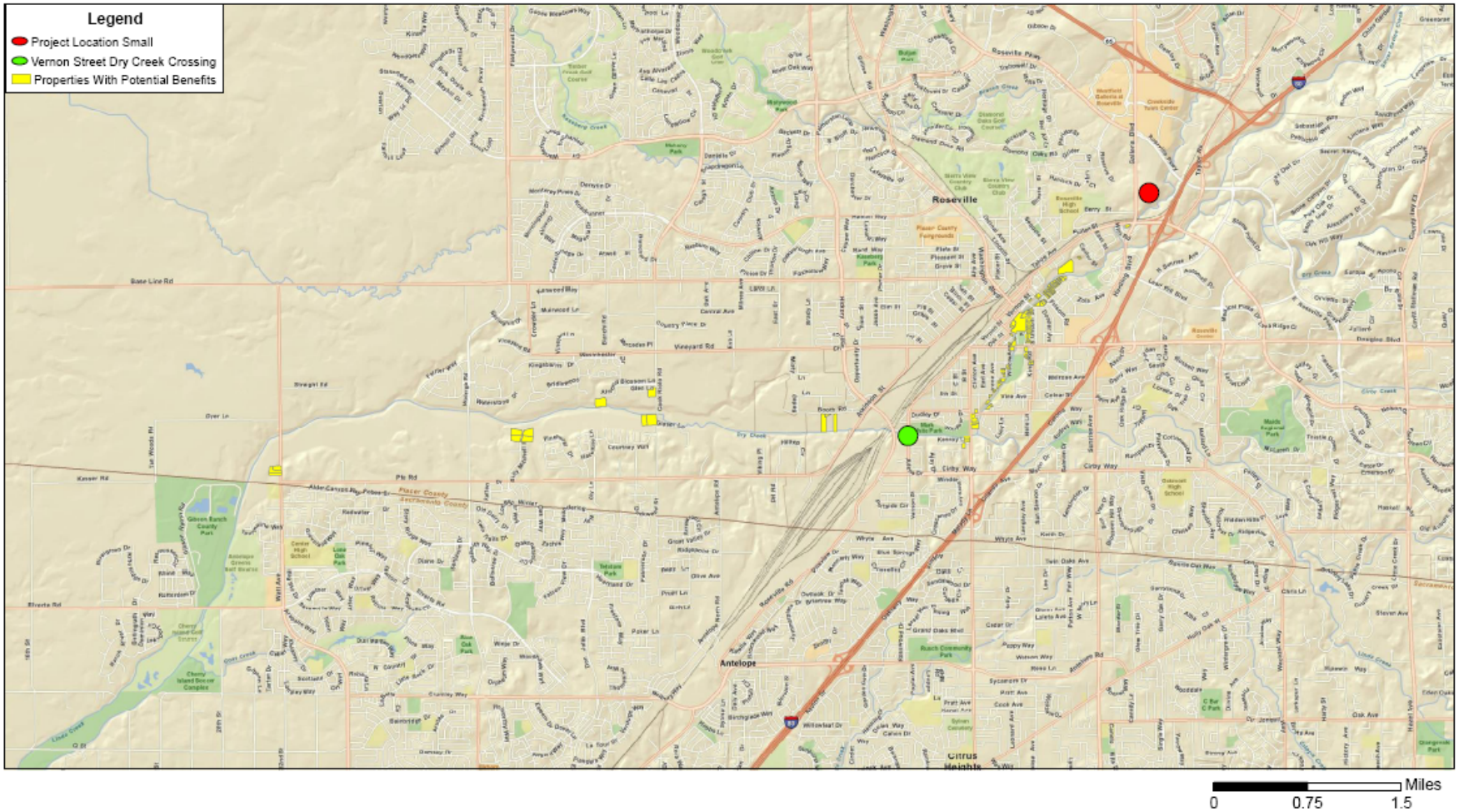
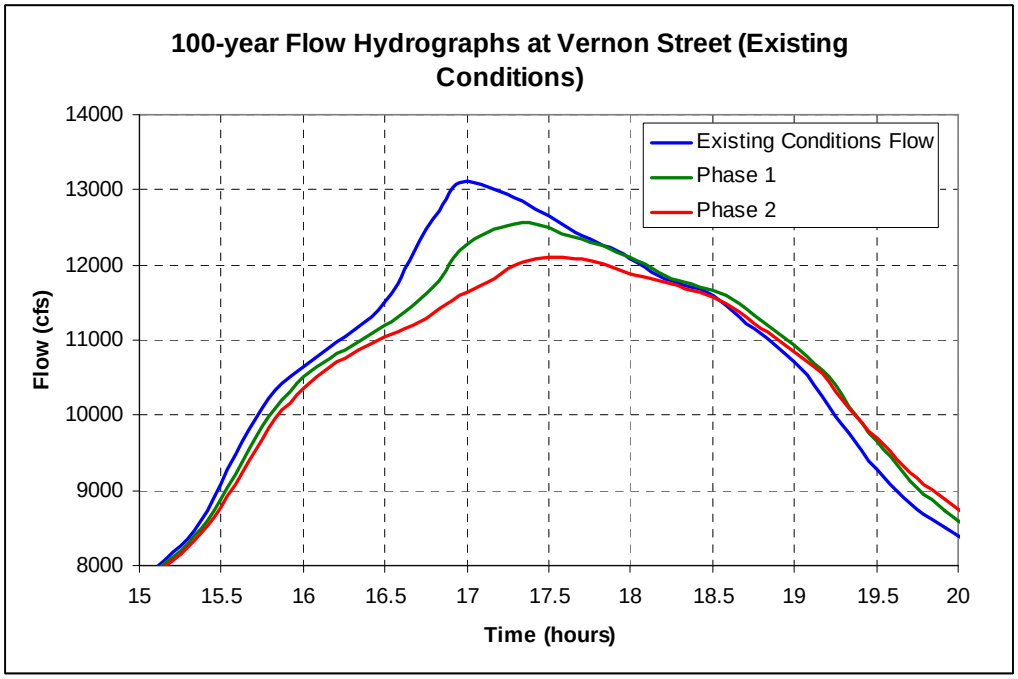


Figure 6: Flow **Hydrographs** for Vernon Street



Flood Prone Properties

Information about parcels that have experienced flood damage was provided by the District and included separate databases for parcels within the City of Roseville and for parcels in unincorporated Placer County. The Placer County database contains high water marks for the 1995 flood event and flood depths for the 1983, 1986, and 1995 flood events. The District also provided 2008 LiDAR data (from the California Department of Water Resources [DWR]) in NAVD 88. By using the databases provided by the District and the LiDAR data, a total of 128 flood prone parcels were identified downstream of the Project.

Finished floor or lowest living area elevations were available for most parcels from the City of Roseville and Placer County flood prone parcel databases. Finished floor elevations were estimated from 2008 LiDAR and converted to the model datum for elevations were not available in the databases. Google Earth street view was also used to determine if finished floor elevations appeared to be close to ground elevations or if structures were raised. Finished floor elevations for 13 parcels were estimated in this manner.

The building size was also available from the databases for most buildings. For 21 buildings without an available building size, an estimate was obtained from Zillow.com, which acquires building size from publicly available records. For properties where the building size could not be acquired, the size was estimated using aerial imagery.

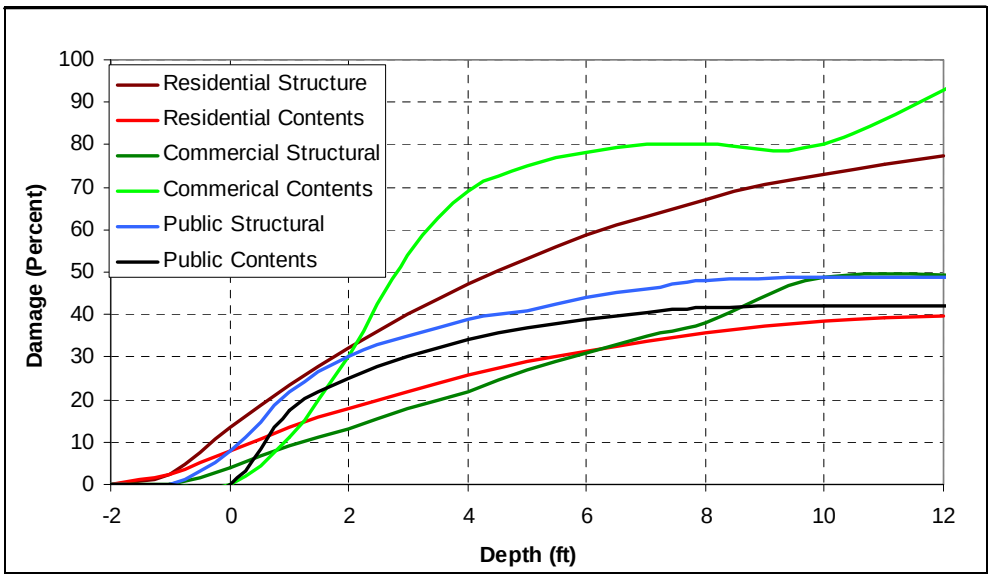
The database from the City of Roseville listed an estimated 1997 property value of $83.90 per square foot for living space and $22.10 per square foot for garage space. For the 2010 estimate, the property values were estimated to be $130 per square foot of living space and $30 per square foot of garage space.

Flood Damage Analysis

The flood damage analysis (FDA) was completed using HEC-FDA, a computer program developed by the US Army Corps of Engineers (USACOE). HEC-FDA uses the stage and discharge data produced in HEC-RAS and structure information to develop damage-stage relationships and combines the damage-stage functions with discharge-exceedance probability and stage-discharge relationships. The model then applies a Monte Carlo simulation process to compute expected annual damage while accounting for uncertainty (See HEC-FDA User's Manual).

Depth damage curves published by both USACOE and FEMA were used in the FDA (See USACE Economic Guidance Memorandum—EGM 04-01, *Generic Depth-Damage Relationships*, October 2003). The depth damage curves for residential, commercial, and public buildings are presented in Figure 7. All residential buildings are assumed to be 1-story without a basement.

Figure 7: Depth vs. Damage Curves



The structure value to content value ratio was assumed to be 0.50 for residential, commercial, and public buildings. Contents of structures may include equipment, furnishings, raw materials, and commercial inventory. A factor of plus or minus 0.25 feet was applied to the 100-year stage data to account for uncertainty.

HEC-FDA produced an expected annual damage result based on the structural damage curves and flood model described in this memo. The EAD based on structural damage only is presented in Table 3.

Table 3: Expected Annual Damage Based on Structural Damage Curves

Scenario	Expected Annual Damage	Expected Annual Damage Reduced
Without Project	$101,000	--
Phase 1	$97,000	$4,000
Phase 2	$89,000	$12,000

The event damage for structural damage only for the 2-, 10-, 25-, 50-, and 100-year recurrence intervals is presented in Table 4.

Table 4: Event Damage for Structural Damage Only (referenced as Table 11 in Exhibit C of the Proposition 1E Grant PSP)

Hydrologic Event	Event Probability	Event Damage Without Project	Event Damage With Project Phase 1	Phase 1 Event Benefit	Event Damage With Project Phase 2	Phase 2 Event Benefit
10-year	0.10	$179,000	$176,000	$3,000	$172,000	$7,000
25-year	0.04	$745,000	$718,000	$27,000	$656,000	$89,000
50-year	0.02	$1,689,000	$1,679,000	$10,000	$1,527,000	$162,000
100-year	0.01	$2,505,000	$2,415,000	$90,000	$2,202,000	$303,000

Figure 8 presents the loss-probability curves. The expected annual damage reduction is the area between the curves.

Figure 8: Loss vs. Probability Curves

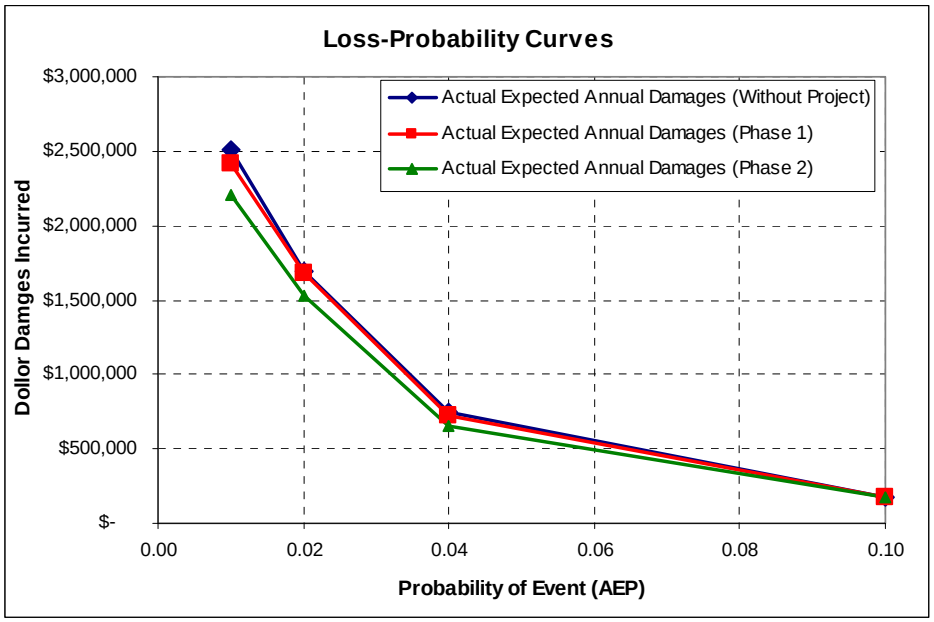


Table 5 presents the present value of future benefits of the Project, assuming an analysis period of 50 years with a 6% discount rate, consistent with DWR standard practice. The results are presented in the following section.

Table 5: Present Value of Expected Annual Damage Benefits (Structural Damage Only) (Referenced as Table 12 in Exhibit C of the Proposition 1E Grant PSP)

Expected Annual Damage Without Project	$101,000
Expected Annual Damage with Phase 1	$97,000
Expected Damage Benefit	$4,000
Expected Annual Damage with Phase 2	$89,000
Expected Damage Benefit	$12,000
Present Value Coefficient	15.76
Present Value of Future Benefits (Phase 1)	***$64,000***
Present Value of Future Benefits (Phase 2)	***$190,000***

Adjustments to Flood Damage Analysis Results

Several adjustments were made to the EAD values to account for various non-building damages, such as clean-up and other non-structural costs that can be considered to be proportional to structural damage. Some of the additional adjustment factors were taken from the *Flood Rapid Assessment Model (F-RAM) Development* (DWR, November 2008). These adjustments include:

- **Vehicle damage:** Street flooding can cause vehicle damage as flood waters rise above the vehicle floorboards. There is a used car lot on Riverside Avenue that has the potential for flood damage, and other vehicles would likely be damaged in the event of a flood. A small reduction in peak flood stage in a given event could cause a major reduction in automobile damage if flows remain below automobile floorboards. Assuming 100 vehicles would be damaged during a 100-year flood event with the vehicles experiencing 30% damage, and assuming an average vehicle value of $10,000, an estimate of $300,000 in vehicle damage may be expected for the 100-year flow event, representing 12% of the estimated 100-year event structural damage.
- **Roadway inundation damage***:* A value of $30,000 per mile of inundated minor road is assumed in F-RAM. Using a conservative assumption of two miles of inundated minor roads (in the areas that would receive benefit from the Project) for the 100-year flood event, about $60,000 of damage to minor roads is expected. This is about 2% of the estimated 100-year event structural damage. Damage reduction benefit can be assumed to be proportional to structural damage reduction benefit.

- **Bridge overtopping***:* Seven bridges are overtopped in the existing condition 100-year flood event downstream from the Project. While the Project does not prevent any of these bridges to be overtopped in the existing conditions 100-year flood event, the height of overtopping may be reduced. Also, the new Cook Riolo Road bridge is not indicated as being overtopped in the existing condition 100-year flood event, but the Plan Update does indicate that it would be overtopped in the 100-year flood event based on unmitigated build-out in the Dry Creek watershed. The Project may prevent the bridge from being overtopped for the 100-year build-out conditions, however, this study is based on existing hydrology and no bridge-related damage reduction was included for Cook Riolo Road. Furthermore, the benefit due to reduced overtopping of the other bridges is assumed to be negligible.
- **Other Factors:** Costs related to other factors include emergency response services, loss of business income, temporary relocation, transportation system disruptions, loss of public services, damage to landscaping, and damage to other infrastructure (e.g. sewer and power are not included in the structural damage estimates). Based on F-RAM documentation, indirect damages can be estimated as 25% of the direct damages to residential and commercial structures.

Factors for non-structural damage indicate that total damage can be expected to be at least 37% higher than structural damage based on property damage alone, not including loss of business to commercial and industrial enterprises, costs of flooding disruption to utilities (gas, electricity, water, sewerage, telecommunications and postal services), and costs imposed on public services, such as education and health services. To provide a reasonable comprehensive estimate for the flood reduction benefit of the project, the EAD for each scenario was increased by 50%. Table 6 presents the EAD adjusted by 50% to account for non-structural and indirect damages.

Table 6: Expected Annual Damage Adjusted for Non-Structural Factors

Scenario	Expected Annual Damage	Expected Annual Damage Reduced
Without Project	$ 151,000	--
Phase 1	$ 145,000	$ 6,000
Phase 2	$ 134,000	$ 17,000

Table 7 presents the present value of future benefits of the Project, assuming an analysis period of 50 years with a 6% discount rate, consistent with DWR standard practice.

Table 7: Expected Annual Damage Adjusted to Include Non-Structural Factors (Referenced as Table 12 in Exhibit C of the Proposition 1E Grant PSP)

Expected Annual Damage Without Project	$151,000
Expected Annual Damage with Phase 1	$145,000
Expected Damage Benefit	$6,000
Expected Annual Damage with Phase 2	$134,000
Expected Damage Benefit	$17,000
Present Value Coefficient	15.76
Present Value of Future Benefits (Phase 1)	***$95,000***
Present Value of Future Benefits (Phase 2)	***$268,000***

Qualitative Benefits

In addition to the monetized benefits, the Antelope Creek Improvement Project will mitigate all impacts of planned future development. The developments are expected to increase runoff in Antelope Creek by 900 cfs and this project will reduce the peak flow by 1,000 cfs. With this project, it is expected that no other flood mitigation project will be required for the Antelope Creek in response to planned future development.

Conclusion

Even though Phases 1 and 2 of the Project would provide a significant flow reduction in a 100-year storm event, this reduction corresponds to only a relatively small (less than one-half foot) reduction in peak flood stage at key locations. Based on the HEC-FDA results, multiplied by 1.5 to account for non-structural and indirect damages, the present value of the expected benefit of Phase 1 is $95,000 and the expected benefit of the complete Project with Phase 2 is $268,000.

Though these results alone do not provide justification for the cost of the proposed project, other factors, such as increased benefit of other potential future regional projects and reducing measures necessary to provide 100-year protection to properties help justify the cost. Additionally, there are few potentially feasible regional flood reduction projects in the Dry Creek watershed, and the Antelope Creek Improvement Project was identified as being the most cost effective of the options available. Finally, the Project includes additional benefits besides flood reduction; these benefits which also help to justify the cost are presented in Attachments 8 and 9 (Water Supply Benefits and Water Quality and Other Benefits, respectively).

Supporting Documentation

The following supporting documents are included in Attachment 3 of this Proposal:

- *Antelope Creek Water Efficiency and Flood Control Project Flood Damage Reduction Analysis* (RBF Consulting, December 28, 2010)
- *Miners Ravine Off-Channel Detention Basin Facility Mitigation Monitoring Plan* (Placer County Flood Control and Water Conservation District, January 2006)
- *Draft Update to the Dry Creek Watershed Flood Control Plan* (Placer County Flood Control and Water Conservation District, November 2010) - See separately bound document