Fish Passage Assessment and Recommended Treatment Options for Los Padres National Forest Stream Crossings on Davy Brown and Munch Creeks

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and
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Project Description

The scope of this project encompasses a site assessment, evaluation and characterization of existing fish passage, geomorphic and hydrologic conditions, and development of recommendations for improving fish passage conditions at three low-water road-stream crossings (also referred to as fords) maintained by Los Padres National Forest (LPNF) and located within the Sisquoc River basin (Figure 1). Results from the assessments and the recommendations are provided in this Technical Report.

The three on-Forest crossings are:

1. Lower Sunset Valley Road Crossing on Davy Brown Creek, (H-150'59-3), 34° 46' 17.76" N, 119° 56' 39.58" W
2. Upper Sunset Valley Road Crossing on Davy Brown Creek, (H-150'59-2), 34° 45' 37.19" N, 119° 57' 14.27" W, and,
3. Munch Creek Crossing at Davy Brown Campground (H-150'59-1), 34° 45' 29.72" N, 119° 57' 17.87" W

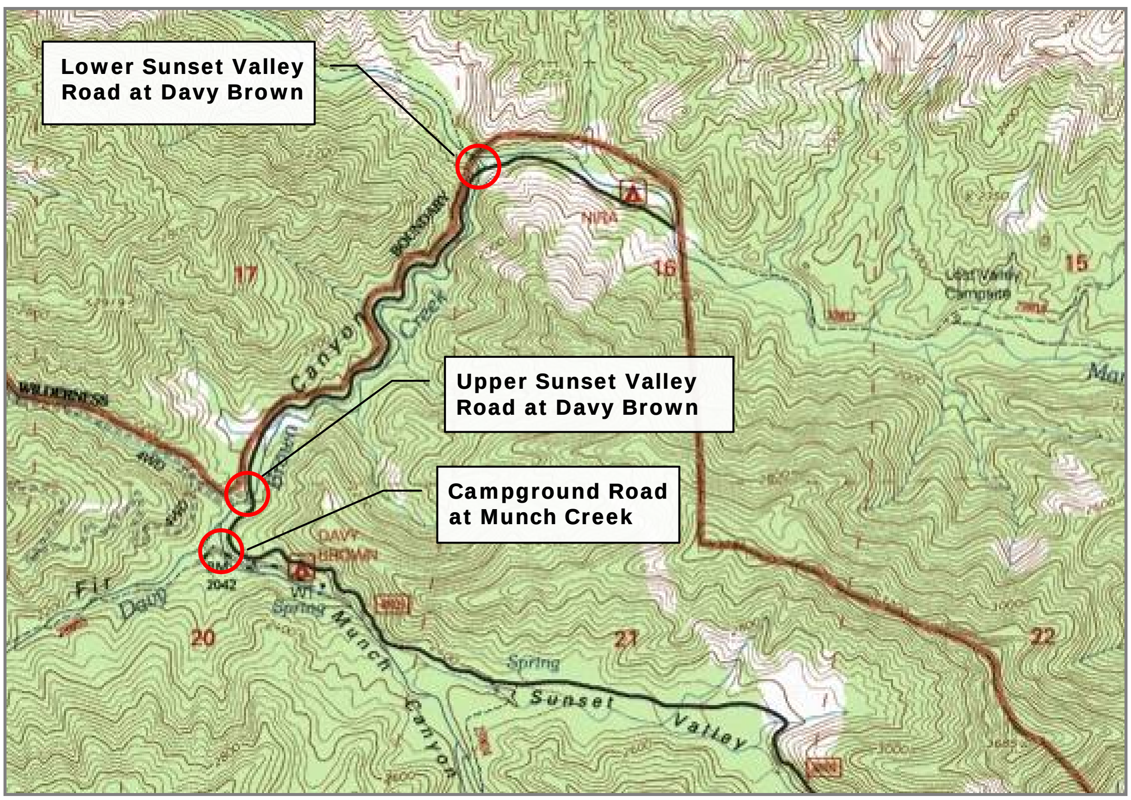


Figure 1 – Location of three low-water crossings (fords) assessed for fish passage and crossing treatments within the Los Padres National Forest. Bald Mountain USGS Topographic Quadrangle.

Sunset Valley Road is also referred to as Forest Route 8N09. All three of these crossings were identified as partial barriers to endangered southern steelhead trout, *Oncorhynchus mykiss,* in the 2003 report prepared by Matt Stoecker, titled Steelhead Migration Barrier Assessment and Recovery Opportunities for the Sisquoc River, California. No other barriers are known to occur in the Davy Brown Creek basin.

Recommendations for the two sites on Davy Brown Creek focus on improving fish passage while maintaining a vehicular crossing that meets current road safety standards. Recommendations for the Munch Creek crossing focus on removal only, with no replacement crossing.

Ecological Significance of Davy Brown Creek for Southern Steelhead Trout

Davy Brown Creek is a tributary to Manzana Creek, which is the largest tributary of the Sisquoc River. The Sisquoc River joins the Cuyama River to form the Santa Maria River, which flows west to the Pacific Ocean near the town of Guadalupe. The Santa Maria River is the northernmost watershed in the Southern California Steelhead Distinct Population Segment (DPS) that supports the endangered southern steelhead. In 1945 the California Department of Fish and Game (CDFG) biologist Leo Shapovalov identified the steelhead run in the Santa Maria River as the second largest in Santa Barbara County (behind the Santa Ynez River), and the Sisquoc River as the primary steelhead spawning tributary (Shapovalov, 1944a; 1944b; 1945). A recent report, Steelhead Migration Barrier Assessment and Recovery Opportunities for the Sisquoc River (Stoecker, 2003), identifies over 200 stream miles occurring within the productive Sisquoc River drainage where steelhead have been consistently documented for over a century. The Sisquoc River contains no mainstem fish migration barriers, making the habitat in this basin critical to recovery of southern steelhead populations.

As early as 1879, steelhead were documented in the Sisquoc and Santa Maria Rivers with adult steelhead runs reported into the 1940s, and periodic adult steelhead observations into the late 1990s following years with higher flows (Stoecker, 2003). Following the large flows of the 1998 El Niño winter, several adult steelhead measuring between 20 and 28 inches were observed and photographed by Los Padres National Forest and CDFG biologists (Stoecker, 2003).

During the fall of 2005, a CDFG funded study of the Sisquoc River's steelhead trout population revealed the significance of habitat within the Davy Brown

Figure 2 – Adult steelhead observed in the Sisquoc River 2005. Photo: M. Stoecker

Figure 3 – Manzana Creek steelhead 2005. Photo: M. Stoecker

basin for southern steelhead spawning and rearing (Stoecker, 2006). Adult steelhead were observed in both the Sisquoc River and Manzana Creek during the survey (Figure 2 and Figure 3). Within the surveyed reaches of the Sisquoc River, Davy Brown Creek contained the greatest number of young-of-the-year (YOY) or 0+ age class steelhead and the highest percentage of YOY (63%). These findings highlight this tributary's excellent spawning habitat and high spawning productivity. This tributary also had the second highest overall observed steelhead density, indicating the excellent rearing habitat available. All age classes (0+ to 3+) were represented in this tributary, pointing to a healthy reproducing population over several consecutive years.

While conducting surveys on Davy Brown Creek during 2005, Doug Colfax (Davy Brown Campground Host for the Forest Service) reported that he observed "adult sea-run steelhead in the spring of 2005, after the high flows that were not here before the winter." He reported catching, measuring, and releasing "a square-tail steelhead measuring 17.5 inches from Munch Creek at the Davy Brown Campsite in April 2005." He also reported seeing other steelhead of similar size in Munch and Davy Brown Creeks in addition to one "large, silver, 22-inch steelhead in Manzana Creek just downstream from the Davy Brown Creek confluence" that spring. Mr. Colfax also reported catching adult steelhead between 18 and 24 inches in Manzana Creek in the 1960s and 1970s following large winter flow events similar to those encountered in 2005.

The Zaca Fire of 2007, which was the second largest in California history, burned much of the Sisquoc River watershed and caused massive erosion and subsequent sediment deposition, which eliminated pool habitat and trout occurrence throughout much of the Manzana Creek tributary (pers. obs. Stoecker 2008) (Figure 4). Davy Brown Creek and its tributaries were relatively unaffected by the more northern fire. As a result, habitat in Davy Brown and Munch Creek is still in excellent condition and is now more important than ever for the Sisquoc River's returning adult steelhead population and resident coastal rainbow trout. For several more years, if not decades, the aftermath of the Zaca Fire will likely continue to cause depressed habitat quality for trout and reduced a population size for much of the Sisquoc River watershed. Davy Brown Creek is critical cold-water refugia and provides possibly the best remaining habitat for fish in Manzana Creek to escape the fire-related elevated sediment loads and resulting elevated water temperatures. To provide all age classes of trout access to the high quality habitat available in Davy Brown and Munch Creek, it is essential to identify and remove road-stream crossings, and any other anthropogenic barriers, that hinder fish passage.

Figure 4 – Excessive sediment in Manzana Creek in 2009 following the 2007 Zaca Fire. Photo: M. Stoecker

Field and Assessment Methodology

Fieldwork was conducted during December 3rd and 4th 2008 and January 20th 2009 by Michael Love & Associates and Stoecker Ecological. Data collection consisted of site surveying, mapping, and describing the channel substrate using Wolman pebble counts, where appropriate.

The site assessment involved collecting sufficient information to (1) describe the crossing configuration relative to the road approaches and the stream channel, (2) assess existing fish passage conditions at each crossing, (3) evaluate the geomorphic characteristics of the channel upstream and downstream of each crossing (channel type and geometry, geomorphic stability, relative mobility of bed material), and (4) evaluate influence of the crossing on stream processes. Understanding gained through the site characterization was incorporated into the development of recommendations for improving fish passage at each crossing.

The site survey component of the project involved:

- Plan mapping of pertinent channel features at identified road crossings. Features included road approaches, outline of the existing concrete ford, channel alignment, thalweg location, active channel margins, and grade controlling features such as exposed bedrock and natural boulder steps.

- Characterizing streambed material using surface pebble counts in two locations and detailed sketches of boulder arrangements.

- Surveying cross sections at the tailwater control immediately downstream of the crossing, along the top of the low-water crossing, and at a reach representative of the natural channel geometry.

- Collecting detailed information at the crossing structures following the California Department of Fish and Game fish passage assessment protocol (CDFG, 2002).

Field Methods

Surveys were conducted using a Nikon Total Station to collect coordinate and elevation data for each channel reach. The horizontal and vertical datum at each site was assumed.

The survey data was used for plan mapping, plotting longitudinal profiles of the channel thalweg and road centerline, and plotting channel cross sections. This data was used for mapping, hydraulic analysis and concept level development of crossing alternatives. The survey was not intended to be used as a design level survey for construction or quantity and cost estimates.

Pebble counts were conducted following the Wolman method (Harrelson et al., 1994) to randomly record the size of 100 particles found on the surface of the active stream channel. Pebble counts were conducted at both the lower and upper Sunset Valley Road Crossings on Davy Brown Creek. Due to the large boulders and cemented nature of the substrate adjacent to the Munch Creek Crossing, a pebble count was not conducted, but ocular observations of sediment size were noted.

Plan mapping was performed using field drawings and survey points to create scaled, diagrammatic plans of the crossing structures and adjacent road and ground features.

Observations of steelhead trout/coastal rainbow trout (*O. mykiss*) while conducting site surveys are noted in the description of each crossing.

Peak Flow Hydrology

Estimates of peak flows associated with 2, 5, 10, 25, 50, and 100-year recurrence intervals were calculated using two standard methods. Results are summarized below and provided in more detail in Appendix A. The peak flow estimates were used for developing conceptual design alternatives for the stream crossings. They were also used to determine fish passage design flows for passage assessment.

None of the project streams has been gaged for flow. Two methods were used to estimate peak flows at the Davy Brown Creek and Munch Creek road-stream crossings and for Manzana Creek at the confluence with Davy Brown Creek:

1. Regional regression equations developed for the South Coast Region of California by the USGS (Waananen and Crippen, 1977) to predict the 2, 5, 10, 25, 50, and 100-year return period flows. Mean annual precipitation, a variable in the equations, was obtained from a regional isoheytal map produced by USDA-NRCS (1999).

2. Prediction of peak flows with 2, 5, 10, 25, 50, and 100-year recurrence intervals from four USGS gaging stations near the project sites (Table 1) using a Log-Pearson Type III (LP3) distribution as described in USGS Bulletin 17B (USGS, 1982).

The drainage area at each site was calculated and used to scale the peak flow estimates derived from the LP3 analysis and for use in the regression equations (Table 2). The drainage areas are:

Lower Sunset Valley Road at Davy Brown Creek = 7.8 mi^2,
Upper Sunset Valley Road at Davy Brown Creek = 6.9 mi^2,
Munch Creek Crossing at Davy Brown Campground = 2.7 mi^2,
Manzana Creek at Davy Brown Creek = 39.1 mi^2.

There is a significant variation in peak flows predicted using both methods. We chose to use predictions from the regional regression equations, as they yielded the higher estimates. This was done to provide a wider range of flows for fish passage design and to establish a more robust target for hydraulic design of replacement crossings.

Table 1 – USGS gage stations used to develop peak flow estimates for the Davy Brown Creek and Munch Creek road-stream crossing sites.

Site Name	Location		Drainage Area (mi^2)	Record Length (years)
USGS ZACA C NR BUELLTON CA	34°38'55"	120°11'00"	32.80	34
USGS ALAMO PINTADO C NR SOLVANG CA	34°37'06"	120°07'11"	29.40	32
USGS SANTA CRUZ C NR SANTA YNEZ CA	34°35'48"	119°54'28"	74.00	65
USGS ZACA C A BUELLTON CA	34°36'50"	120°11'30"	39.40	24

Table 2– Summary of two methods to determine peak flood frequency for the Davy Brown and Munch Creek crossings and Manzana Creek at Davy Brown Creek.

Road Stream Crossing and Method of Estimation	Return Period of Peak Flow					
	2 year (cfs)	5 year (cfs)	10 year (cfs)	25 year (cfs)	50 year (cfs)	100 year (cfs)
Lower Sunset Valley Road Crossing of Davy Brown Creek (drainage area = 7.8 mi^2)						
Regional Regression Equations Waananen & Crippen, 1977	92	361	714	1,564	2,463	3,477
Log Pearson Type 3 Using Annual Peak Flow Records	36	157	304	565	807	1,084
Upper Sunset Valley Road Crossing of Davy Brown Creek (drainage area = 6.9 mi^2)						
Regional Regression Equations Waananen & Crippen, 1977	84	327	644	1,408	2,214	3,122
Log Pearson Type 3 Using Annual Peak Flow Records	31	138	267	496	709	952
Munch Creek crossing in Davy Brown Campground (drainage area = 2.7 mi^2)						
Regional Regression Equations Waananen & Crippen, 1977	42	158	306	655	1,021	1,426
Log Pearson Type 3 Using Annual Peak Flow Records	12	54	104	193	276	370
Manzana Creek at Davy Brown Creek (drainage area = 31.2 mi^2)						
Regional Regression Equations Waananen & Crippen, 1977	293	1,248	2,547	5,760	9,221	13,227
Log Pearson Type 3 Using Annual Peak Flow Records	178	785	1,519	2,824	4,038	5,422

Fish Passage Assessment Methodology and Criteria

A fish passage analysis of each crossing was performed following methods outlined in Part IX of the California Department of Fish and Game Salmonid Stream Habitat Restoration Manual (CDFG, 2003) and in the US Forest Service National Inventory and Assessment Procedure for Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings (Clarkin, 2005). The assessment focused on passage conditions for adult and juvenile steelhead/rainbow trout.

Fish Passage Design Flows

The low and high fish passage design flows define the flow range within which conditions at the crossing should be suitable for upstream passage for a specific species and life stage. Both NOAA Fisheries (2001) and California Department of Fish and Game (2002) have recommended fish passage design flow criteria for juvenile rainbow trout, adult rainbow trout, and adult steelhead. These are defined in terms of exceedance flows, which are derived from an annual flow duration curve based on mean daily flows. Alternately, high fish passage flows can be defined as a percentage of the 2-year return flow.

To develop a flow duration curve for the project site, exceedance flows for the four gaged streams were scaled to the drainage area at each crossing and then averaged to estimate the fish passage design flows (Appendix B). When compared to the alternate method based on percentage of the 2-year return flow, the exceedance flows predicted considerably smaller estimates of the high passage design flows. Given the infrequency of high flow events in this region, it is critical to provide free passage for adult steelhead at higher flows so they can reach their spawning grounds before flows recede and the streams become too shallow. Therefore, for all three sites the CDFG Alternate method was used to determine low and high fish passage flows (**Table 3**).

Fish Passage Criteria

Water depths, water velocities and water surface drops are hydraulic conditions affecting fish passage. They were evaluated using hydraulic criteria prescribed by CDFG, which are relatively conservative and meant to represent the needs and abilities of the weaker individual fish within the population. Many individual fish are able to swim through shallower water, swim faster, and leap further than weaker individual fish protected by the CDFG criteria listed in Table 4. Therefore, it is not uncommon for some fish to pass through stream crossings that fail to meet fish passage criteria.

Table 3 – Estimated fish passage design flows for Davy Brown and Munch Creek, based on CDFG (2002) and NOAA Fisheries (2001) criteria. Fish passage flows were estimated using the CDFG Alternate method to provide the greatest range of migration flows.

	Low Passage Design Flow for All Evaluated Crossings	
Species & Lifestage	**Criteria**	**Flow**
Juvenile Salmonids	Greater of 95% Exceedance Flow or 1 cfs	**1 cfs**
Adult Rainbow Trout	Greater of 90% Exceedance Flow or 2 cfs	**2 cfs**
Adult Steelhead	Greater of 50% Exceedance Flow or 3 cfs	**3 cfs**

	High Fish Passage Design Flow			
Species & Lifestage	**Criteria***	**Lower Sunset Valley Road**	**Upper Sunset Valley Road**	**Munch Creek**
Juvenile Rainbow Trout	10% of 2-Year return flow	**9.2 cfs**	**8.4 cfs**	**4.2 cfs**
Adult Rainbow Trout	30% of 2-Year return flow	**27.6 cfs**	**25.2 cfs**	**12.6 cfs**
Adult Steelhead	50% of 2-Year return flow	**46 cfs**	**42 cfs**	**21 cfs**

* CDFG Alternate high passage flow based on the 2-year return flow at the site. The 2-Year return flow determined using South Coast Regression Equations.

Table 4– CDFG and NOAA Fisheries fish passage criteria for culverts less than 60 ft, used in the assessment of the Davy Brown and Munch Creek low-water crossings.

Fish Passage Criterion	Juvenile Salmonids	Adult Resident Rainbow Trout	Adult Steelhead
Minimum Water Depth	0.3 ft	0.5 ft	0.8 ft
Maximum Water Velocity	1.0 ft/s	4.0 ft/s	6.0 ft/s
Maximum Water Surface Drop	0.5 ft	1.0 ft	1.0 ft

Fish Passage Analysis

Hydraulic conditions used to assess fish passage over the fords were predicted using a cross section analysis assuming uniform flow. Each of the crossings is constructed of smooth concrete and a roughness value (Manning's n) of 0.013 was applied.

The drop at each crossing was determined using a stage-discharge rating curve developed for the downstream tailwater channel cross section and across the downstream edge of the ford.

Results from the fish passage assessment are summarized in subsequent sections.

Overview of Proposed Crossing Types for Sunset Valley Road

For the two Sunset Valley Road crossings, the primary objective of this study is to identify conceptual approaches to replace or modify the existing crossings to improve fish passage and maintain channel stability, while maintaining or improving road safety. Investigation of the appropriate crossing structures for each site was guided by the following documents:

Low-water Crossings: Geomorphic, Biological and Engineering Design Considerations (USFS, 2006)

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings (USFS, 2008)

California Salmonid Stream Habitat Restoration Manual Part XII: Fish Passage Design and Implementation (CDFG, 2009)

These documents represent the current state of the practice for meeting road management objectives while providing aquatic organism passage and minimizing impacts to channel stability and aquatic habitat.

Two types of crossings were found appropriate for the Sunset Valley Road crossings: Vented low-water crossings and bridge crossings. The following describes each type of crossing and the design guidance used to evaluate their compatibility with site conditions and project objectives.

Low-water Crossings

Fords are a common technique for crossing streams on low volume roads. The existing road crossings at each site are categorized as "unvented improved low-water crossings," also known as concrete fords (Figure 5). The driving surface is armored and designed to be overtopped. There are no culverts (vents) under the road to keep the roadway dry during low-flows. Armored fords frequently cause backwatering and formation of a depositional area in the upstream channel. The shallow and swift flow over the smooth flat road surface frequently impedes or prevents upstream movement of fish and other aquatic organisms. These higher velocities over the road surface also tend to scour the downstream channel, creating a drop at the crossing that further impedes fish passage.

Vented Fords

A vented ford is a type of low-water crossing that elevates the roadway above the streambed with culverts (vents) that enable lower, frequently occurring flows to pass beneath the roadway. This is intended to keep the roadway dry and safe for vehicular traffic over a wider range of flows. The vents can be circular or box culverts. The driving surface over the vent can be paved or fitted with a removable grate to permit clearing of sediment and debris after large flow events. If the conveyance area provided by the vents under the roadway is not large enough, they tend to rapidly plug with sediment and debris and become ineffective.

A vent opening that approximates or exceeds the width, depth and conveyance area of the bankfull channel is considered to have a high vent-area ratio (VAR) (CDFG, 2009; USFS, 2006). A common type of high VAR ford is a series of box culverts that approaches or matches the stream width and bankfull depth. This type of low-water crossing is designed to minimize backwatering during commonly occurring sediment transport flows, thus having minimal impact on channel processes. The cross-sectional area of the roadbed, curbs, and any other flow obstructions should be minimized to reduce upstream backwatering and downstream scour at flows exceeding the capacity of the vents.

Embedding the vents allows for maintaining bedload inside the crossing, thus creating a natural bottom that promotes passage for a wide variety of aquatic organisms (Figure 6). Design of embedded crossings follows the *stream simulation* methodology, which assumes that a crossing designed to simulate the geomorphic characteristics of the natural channel should present no more of an obstacle to aquatic organisms than the adjacent natural channel (USFS, 2008).

As part of the design process, the embedded vents should be designed to function as desired throughout a range of potential channel profiles. This requires a geomorphic evaluation of the channel and an assessment of the range of channel bed elevations that might be anticipated throughout the life of the structure. This includes considering the possibility of future channel incision and the potential amount of channel aggradation to be expected following a large fire or other disturbance.

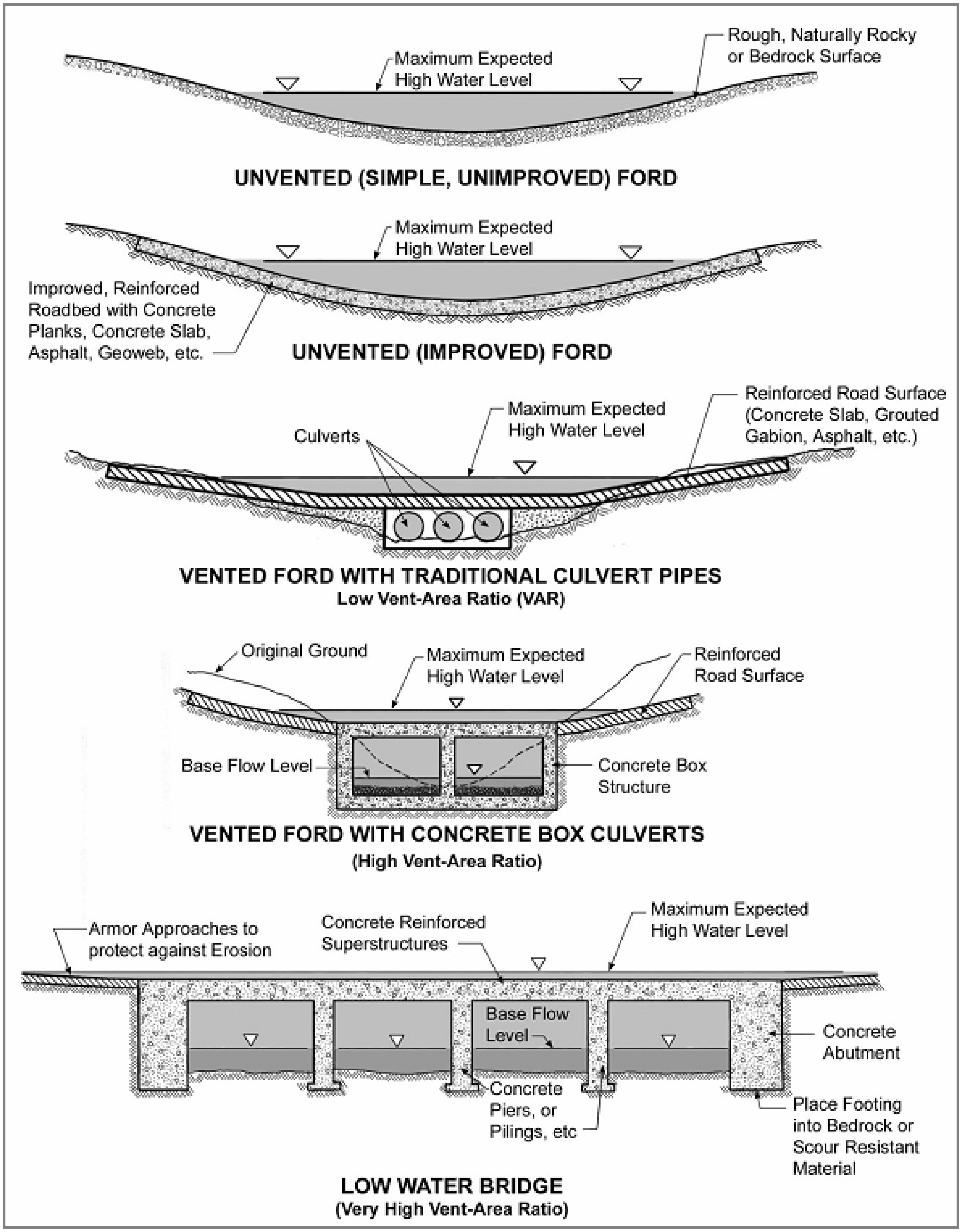


Figure 5 – Basic low-water crossing types. From *Low-water Crossings: Geomorphic, Biological, and Engineering Design Considerations* (USFS, 2006)

Figure 6 – Example of a Vented Ford type low-water crossing on the Ouachita National Forest, Arkansas. From the *FishXing Case Studies website* (http://www.stream.fs.fed.us/fishxing/).

Road Safety Considerations

Fords are typically designed to provide vehicle access when wet, however flows with a depth greater than 1 foot of depth over the crossing are considered *dangerous* and flows with a depth greater than 2 feet are considered *very dangerous* (USFS, 2006). Common safety measures at fords include proper signage that notifies traffic of the ford and low curbs along the downstream edge of the structure. Conventional guardrails cannot be placed along most low-water crossing structures because they will act as trash racks when overtopped and are easily damaged during high flows. Low curbs are recommended for identifying the edge of the roadway and keeping traffic on the structure. Curbs can be 6 to 10-inch high timbers raised to 12 inches on blocks or 15-inch high concrete curbs that are interrupted to avoid diverting the flow when the structure is overtopped (USFS, 2006).

Limitations

Vented fords sized to the bankfull channel can still pose significant safety risks to traffic when overtopped by large, infrequently occurring, flood events. If multiple vents are used to span the bankfull channel, debris tends to catch on the walls separating the culverts within the active channel. These crossings may require regular maintenance to unclog debris and remove sediment that collects at the inlet. In addition, if a vented ford becomes blocked with debris during steelhead migration flows, it can prevent steelhead from migrating upstream to spawn. When on a fish-bearing stream, permits may be required to conduct maintenance activities.

Channel Spanning Bridge

Crossing a channel with a bridge is often the preferred option for reduced maintenance, year-round vehicular access and unimpeded passage of fish and other aquatic and terrestrial organisms utilizing the stream channel. A common design standard for bridges is to convey the 100-year return flow under the bridge with 1-foot of freeboard to allow for passage of floating debris.

Prefabricated bridges are commonly used for spans of 65 feet and less. A prefabricated bridge can be quickly assembled and placed on finished abutments using a crane. Concrete abutments can be cast-in-place with footings that extend below the depth of channel scour (Figure 7). Alternately, the bridge can be placed on precast concrete blocks set on each bank above the design flood level.

The type of abutment and scour protection used influences the span required beyond the top width of the channel. Block abutments require the widest span because they are placed on top of the channel banks, with a setback of at least 5 to 10 feet for drainage and stability. Precast block abutments require no concrete work but rely on stable banks. The narrowest span can be achieved using vertical concrete abutments that extend below the predicted scour depth for the site. Concrete formwork for full height abutments is more costly than the block abutments. Geotechnical investigation for any abutment design is generally recommended.

Prefabricated bridges are typically assembled using either steel I-beams that support the road deck or pre-stressed concrete stringers laid side-by-side. Typically, the steel I-beam thickness is 2 to 3 feet plus the road deck, whereas concrete stringers can be 1 foot thick. For crossings with limited clearance, concrete stringers can provide additional freeboard without further elevating the roadway.

Figure 7 – Completed bridge installation for fish passage on Carpinteria Creek 2009.

Further investigation is needed to verify that a bridge with the required span could be transported to the site considering the steep and winding road. Transportation of bridge segments using a skycrane (helicopter) may be possible and could be investigated.

Individual Site Assessments and Recommended Treatments

A qualitative geomorphic assessment of the channel reach was conducted using field observations, survey data, characterization of streambed substrate, and hydraulic geometry of the channel. This included drawing plan maps and plotting the channel profile and cross sections. Hydraulic analyses of channel cross sections were used to describe the channel's hydraulics and the mobility of the streambed material. Information gained from this assessment was used to guide the development of recommendations for treating the existing fish passage problems at each crossing.

Cross section and channel hydraulics were calculated using the WinXSPro Cross Section model (USFS, 2005), which utilizes Manning's equation to predict flow and depth. WinXSPro uses a variety of methods to determine channel roughness. We used the user-defined roughness method to calculate hydraulic conditions on the low-water crossing assuming a Manning's n = 0.013 for the concrete ford. For the channel hydraulics we used the Thorne and Zevenberger method of estimating channel roughness, which utilizes the particle size as measured in the field, and Jarrett's method, which is based on water surface slope and hydraulic geometry of the channel. To evaluate capacity of the vents and road overtopping we utilized the HY-8 culvert analysis program developed by the Federal Highways Administration (FHWA, 1985).

Lower Sunset Valley Road at Davy Brown Creek

The existing crossing at Lower Sunset Valley Road (H-150'59-3) is located just upstream of the confluence of Davy Brown Creek and Manzana Creek. The crossing is located approximately 0.5 miles from the Nira Campground, in the Los Padres National Forest (Figure 1). The crossing is adjacent to a parking lot at the Manzana Creek trailhead as shown in Figure 8, 9 and Figure 10.

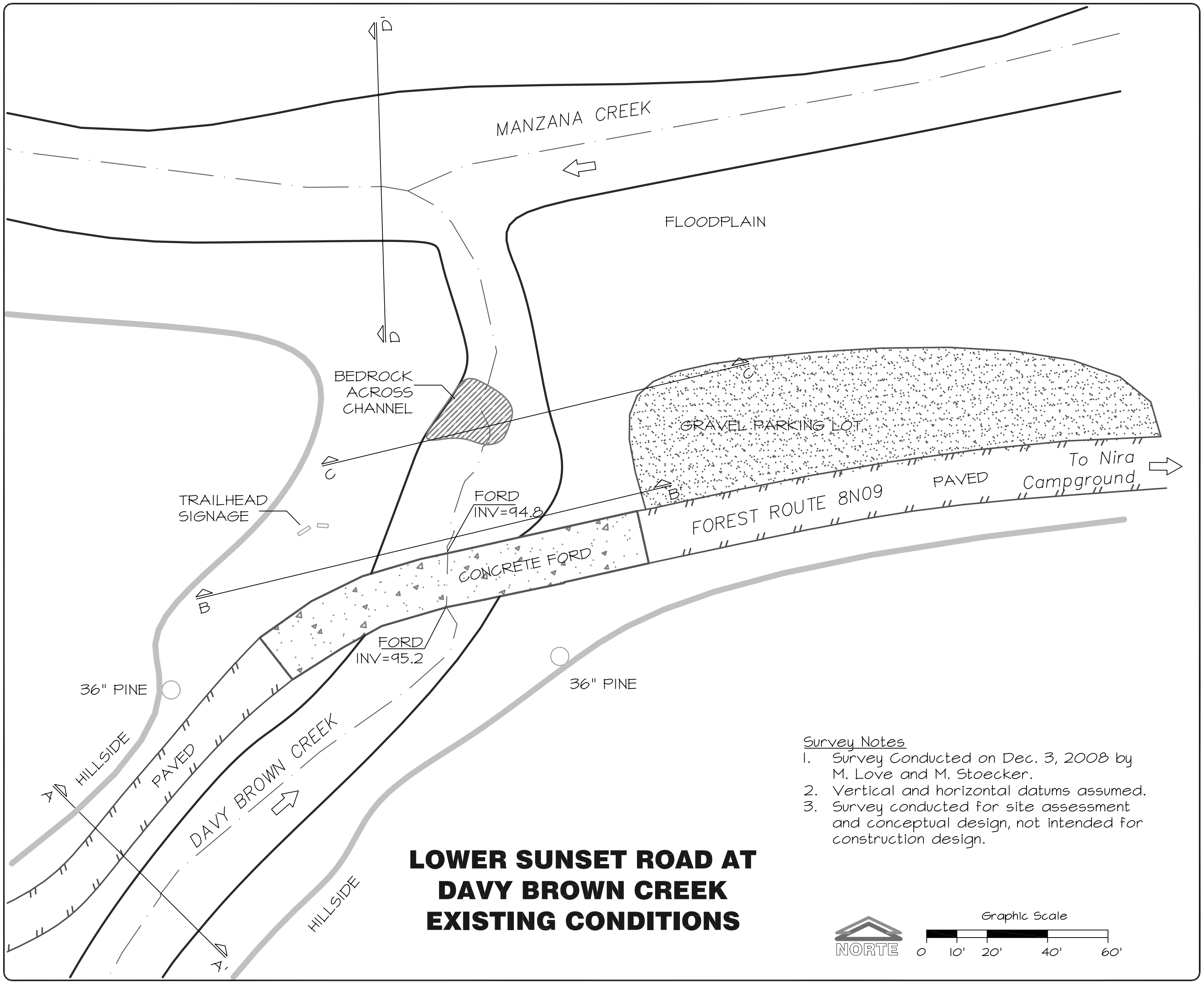
The site is frequently used as a trailhead access point for both hiking and horseback riding. Because the trail and parking lot are located on opposite sides of the creek, pedestrians are required to cross the wetted ford or walk through the channel at this location. The crossing has a smooth surface that is slippery due to aquatic algal growth. The crossing is a potential pedestrian/equestrian hazard due to its slippery surface.

The low-water crossing is an 18-foot wide concrete ford and extends approximately 130 feet in length. The concrete appears to be in good condition with minimal downstream scour. The approach road is asphalt. Heading north, the road runs along the left side (facing downstream) of the steep and narrow Davy Brown Creek canyon before turning sharply and crossing the stream. The approach road along the left side of the stream is built on a bench into the hill slope, with side-cast fill along the outside edge that extends into and constricts the channel. A summary of the crossing dimensions and channel cross sections are provided in Appendix C.

Currently the crossing is overtopped with a depth of 1 foot at a flow of approximately 970 cfs, which is just greater than the 10-year return flow.

Figure 8 – Lower Sunset Valley Road at Davy Brown Creek (H-150′59-3). The 18-foot wide concrete low-water ford is located 130 feet upstream of the confluence with Manzana Creek. The trailhead is visible in the foreground and the trailhead parking lot is seen at the top of the photo.

Figure 9 – Drop at the downstream edge of the low-water crossing on the lower Sunset Valley Road crossing at Davy Brown Creek.



LOWER SUNSET ROAD AT DAVY BROWN CREEK EXISTING CONDITIONS

Survey Notes
1. Survey Conducted on Dec. 3, 2008 by M. Love and M. Stoecker.
2. Vertical and horizontal datums assumed.
3. Survey conducted for site assessment and conceptual design, not intended for construction design.

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Los Padres National Forest
Davy Brown Creek
Fish Passage Assessment

DATE	April 2009
DESIGN	Llanos / Love
DRAWN	Llanos
FIGURE	10

Geomorphic Assessment

Upstream within the vicinity of the crossing the right bank is a steep valley wall, while the left bank is formed by constructed fill material from the road on the left bank approach. Approximately 90 feet upstream of the crossing, a road slip-out along the left bank is actively contributing sediment to the channel. The gradient within this section of channel is flat and within the hydraulic influence of the crossing. Farther upstream, the channel is dominated by boulder steps that form the channel bed structure. The boulders within the steps are largely cemented together. The cementation is apparently derived from precipitates from the stream due to water chemistry.

A channel reference reach was selected upstream of the lower Sunset Valley Road crossing site for use in developing recommendations for crossing treatments. The reference reach can be classified as a boulder step-pool channel with steps spaced roughly 20 feet apart and drops from 0.8 to 1.8 feet. The active and bankfull channel widths were measured at 25 feet and 30 feet, respectively. Rocks that formed the steps ranged form 18 to 26 inches in diameter. Cross section A was surveyed in this reach to describe the hydraulic conditions in the channel. The overall slope of the stable channel, excluding the concrete ford, is three percent. A pebble count of the reference channel reach upstream of the crossing revealed the following distribution of particle sizes:

D_{35} = 1.5 inches
D_{50} = 3.5 inches
D_{84} = 10 inches
D_{100} = 27 inches

Downstream of the crossing, the channel is characterized by cobbles and a bedrock cascade that forms a knickpoint in the channel profile. This reach of the channel has been widened by scour from flow over the existing ford. Cross sections B and C were surveyed in the downstream reach at the tailwater control of the crossing and at the bedrock, respectively.

Dominant riparian vegetation is Sycamore, Willow and Mule Fat. No fish were observed at the time of the survey.

To facilitate evaluation of crossing alternatives, the range of potential channel profiles through the crossing site due to aggradation and degradation was evaluated. This range was defined by a high and low potential profile. The existing tailwater control provides a likely upper limit of channel bed aggradation, while the exposed bedrock in the channel downstream of the crossing provides a stable knickpoint that represents the lowest likely elevation for streambed adjustment. Both profiles have 2.8% channel slopes, and they are offset by approximately 1 foot of vertical adjustment (Figure 11).

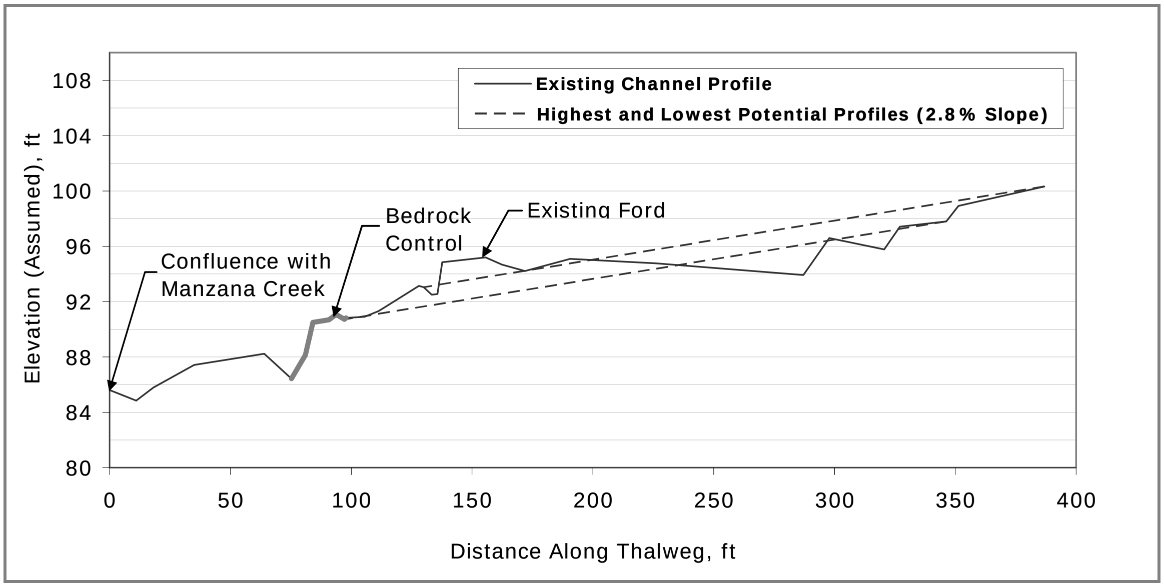


Figure 11 – Channel profile Davy Brown Creek at the lower Sunset Valley Road crossing. The highest and lowest design profiles were estimated to describe an estimate of the potential vertical adjustment of the channel that may occur if the ford is replaced.

Manzana Creek at Confluence with Davy Brown Creek

Massive fine sediment deposits along Manzana Creek, due to erosion from the Zaca Fire, were observed both upstream and downstream of the confluence with Davy Brown Creek. Pools observed during the previous fish passage assessment in this reach are now filled with fine sediment.

Sedimentation from fire and the resulting degraded habitat conditions in Manzana Creek reinforce the importance of providing access for fish and aquatic organisms from Manzana Creek into Davy Brown Creek, which contains high quality habitat unaffected by the fire. Spawning and rearing conditions in Manzana Creek will likely be negatively impacted by the sedimentation for several years and Davy Brown provides a high quality habitat sanctuary for spawning and rearing *O. mykiss* at this time.

A cross section (Cross section D) and longitudinal profile was surveyed in Manzana Creek at the confluence with Davy Brown Creek to determine the backwater effects of Manzana Creek on the lower Sunset Valley Road crossing during large flood events. The channel slope of Manzana Creek at the confluence was found to be 1.0%. The cross section in Manzana Creek was modeled assuming uniform flow and using Jarrett's method for channel roughness to predict water surface elevation during the 100-year return flow. At a 100-year flow of 13,227 cfs the water depth was predicted to be 13.9 feet in Manzana Creek, which translates to an elevation of 99.4 feet at the crossing. This is roughly 4.5 feet above the low point on the existing ford.

Fish Passage Conditions

Fish passage conditions of the lower Sunset Valley Road Crossing (H-150'59-3) were evaluated as outlined in the previous section (*Fish Passage Assessment Methodology and Criteria*). The fish passage assessment showed that the crossing fails to meet fish passage criteria for all evaluated life stages of rainbow trout/steelhead (Table 5). Based on the fish passage assessment and field observations, we conclude that for adult trout the primary impediment to upstream migration is the lack of depth across the wide flat concrete ford. These shallow depths likely do not prevent adult trout from migrating upstream at moderate and high flows, since adult salmonids are regularly observed swimming in short bursts across short reaches of shallow flow with their body partially exposed above the water.

The crossing is suspected of being a complete barrier to upstream movement of juvenile trout due to a combination of excessive water velocity, insufficient water depths and water surface drops across the downstream edge of the crossings.

Table 5 – Existing fish passage conditions at the lower Sunset Valley Road Crossing on Davy Brown Creek

Fish Species and Age Class	Fish Passage Design Flow	Water Depth	Water Velocity	Water Surface Drop
Conditions at the Low Fish Passage Design Flow				
Juvenile Trout	1 cfs	0.04 ft	1.60 ft/s	1.48 ft
Adult Rainbow Trout	2 cfs	0.06 ft	1.96 ft/s	1.41 ft
Adult Steelhead Trout	3 cfs	0.07 ft	2.24 ft/s	1.36 ft
Conditions at High Fish Passage Design Flow				
Juvenile Trout	9.2 cfs	0.12 ft	3.13 ft/s	1.21 ft
Adult Rainbow Trout	27.6 cfs	0.19 ft	4.26 ft/s	0.93 ft
Adult Steelhead Trout	46 cfs	0.24 ft	5.10 ft/s	0.74 ft

Recommended Treatments

To improve fish passage and overall ecological connectivity (unimpeded passage of water, sediment, and debris) at the lower Sunset Valley Road (H-150'59-3) crossing we examined two crossing types in detail: a bridge and a vented ford.

Hydraulic analysis was conducted for the representative cross section surveyed upstream of the crossing (Cross section A) and for a proposed cross section at the road crossing. Wetted widths and depths were evaluated at various flows to size replacement structures.

Bridge Crossing

We evaluated the suitability of the lower Sunset Valley Road crossing for a bridge with a slight modification to the existing crossing alignment (Figure 12).

A new channel shape for a bridge crossing was designed for conveyance of the 100-year flood flow in Davy Brown Creek (Figure 14). The channel under the bridge would have a bottom width of 33 feet, top width of 50 feet, 1:1 (h:v) side slopes and a 2.8% channel slope. The width of the new channel at the bridge will allow for lateral adjustment of the channel and provide a gradual transition from the confined upstream channel to the less confined channel downstream as it enters the floodplain of Manzana Creek.

We estimated the water surface elevation in the channel under the bridge using Manning's equation with a roughness value of 0.06, representative of the roughness created by large boulders steps. This analysis predicts a depth of flow of 7.9 feet during the 100-year flow of 3,477 cfs. The resulting water surface elevation would be higher than the backwater effect created by the 100-year flow in Manzana Creek.

Using the design slope of 2.8% and a channel bed at the high design profile would place the channel bottom at 93.8 feet at the inlet of the bridge crossing. Accommodating the 100-year flow plus 1 foot of freeboard would require the bottom of the bridge deck to be approximately 7.5 feet above the existing ford at an elevation of 102.7 feet. The top of the road deck would be located 1.0 to 3.0 feet higher than the bottom of the bridge deck, depending on the type of bridge used and the thickness of road surface applied.

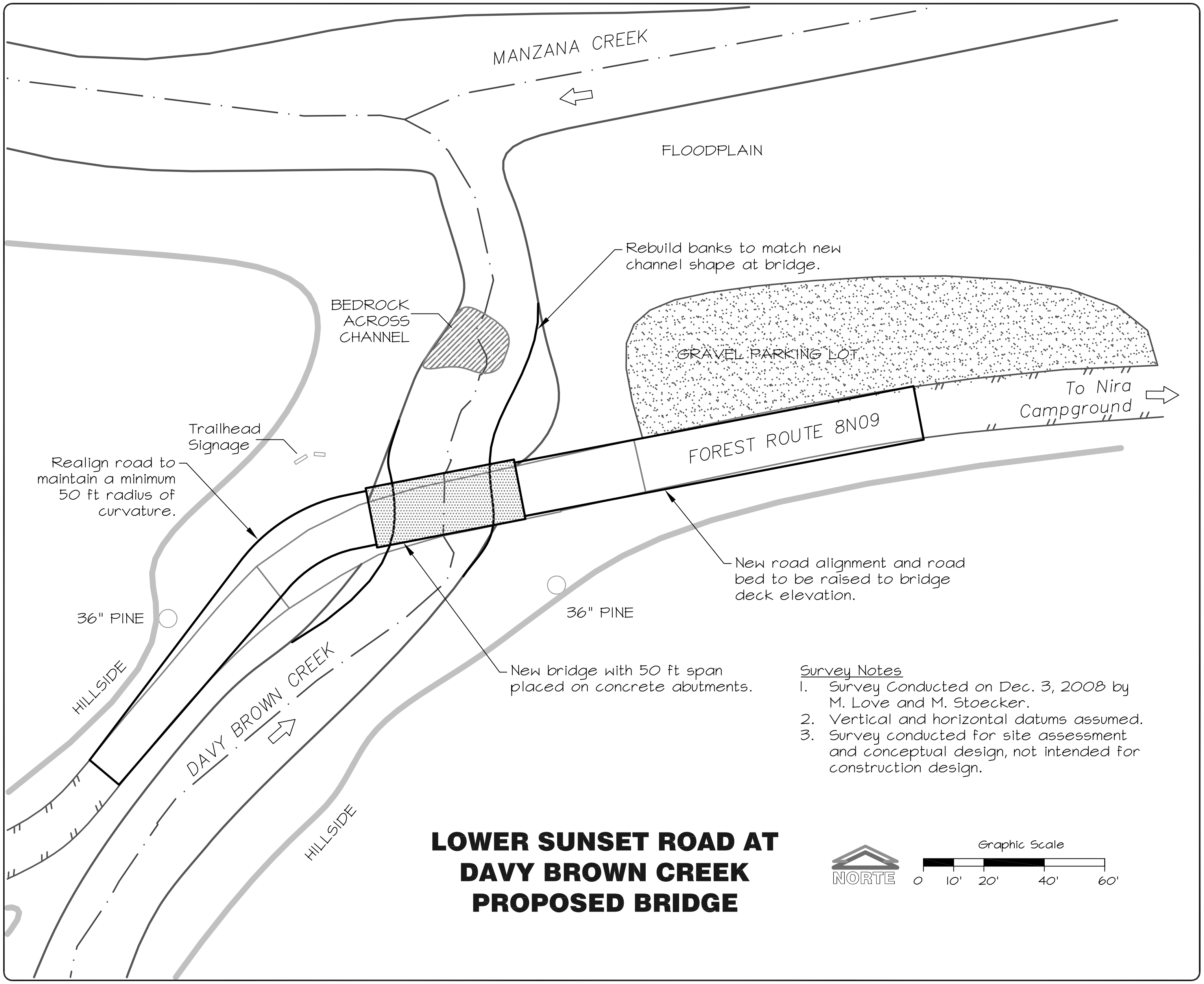
Placing a bridge at this site would involve considerable work to properly align and raise the road to meet the new bridge deck elevation. The criteria we used for locating the bridge crossing and road alignment was based on maintaining grades in and out of the crossing at less than 10% and horizontal curves that have a minimum radius of 50 ft to provide access for large trucks (USFS, 2006b). The bridge proposed in this preliminary analysis would place the top of the road deck approximately 8.5 to 10.5 feet above the existing concrete ford, depending on the thickness of the bridge deck. This requires raising the roadbed and providing 130 feet of new road surface on the left bank approach and 150 feet on the right bank approach. The current condition of the left bank approach road would need to be examined further to verify the practicality of raising and supporting a higher roadbed. The road would need to be closed or a temporary crossing upstream of the existing crossing would need to be installed.

Using vertical abutments placed at the edge of the channel and footed below the predicted scour depth or on bedrock would enable the use of a bridge with a 50 foot span. A short span minimizes the sharpness of the turn in the road along the left bank bridge approach. Using precast block footings set back from top of bank on one or both banks may also be feasible, but would require a longer bridge and may affect the horizontal curvature of the road approach on the left bank. Additionally, it may not be feasible to transport a longer bridge to the site. The feasibility and cost of hauling a prefabricated bridge to the site should be further evaluated before selecting this option for the site.

Vented Ford

A modified version of stream simulation methodology (USFS, 2008) was used to size the box culverts that make up the vents. For the lower Sunset Valley Road crossing a vented ford composed of three box culverts that are each 12 ft wide and 6 ft high and embedded a minimum of 1 foot would accommodate the existing 30-foot bankfull width, bankfull depth, and associated flow area found in the upstream channel (Figure 13).

The alignment of a new vented ford at this site would require the boxes to be skewed with the road surface since the road crossing is not perpendicular to the stream (Figure 13). Having a skewed alignment, as shown, would likely require forming the box culverts in place. Additional concrete work would also be required to armor the approaches of the road to prevent scour when the ford is



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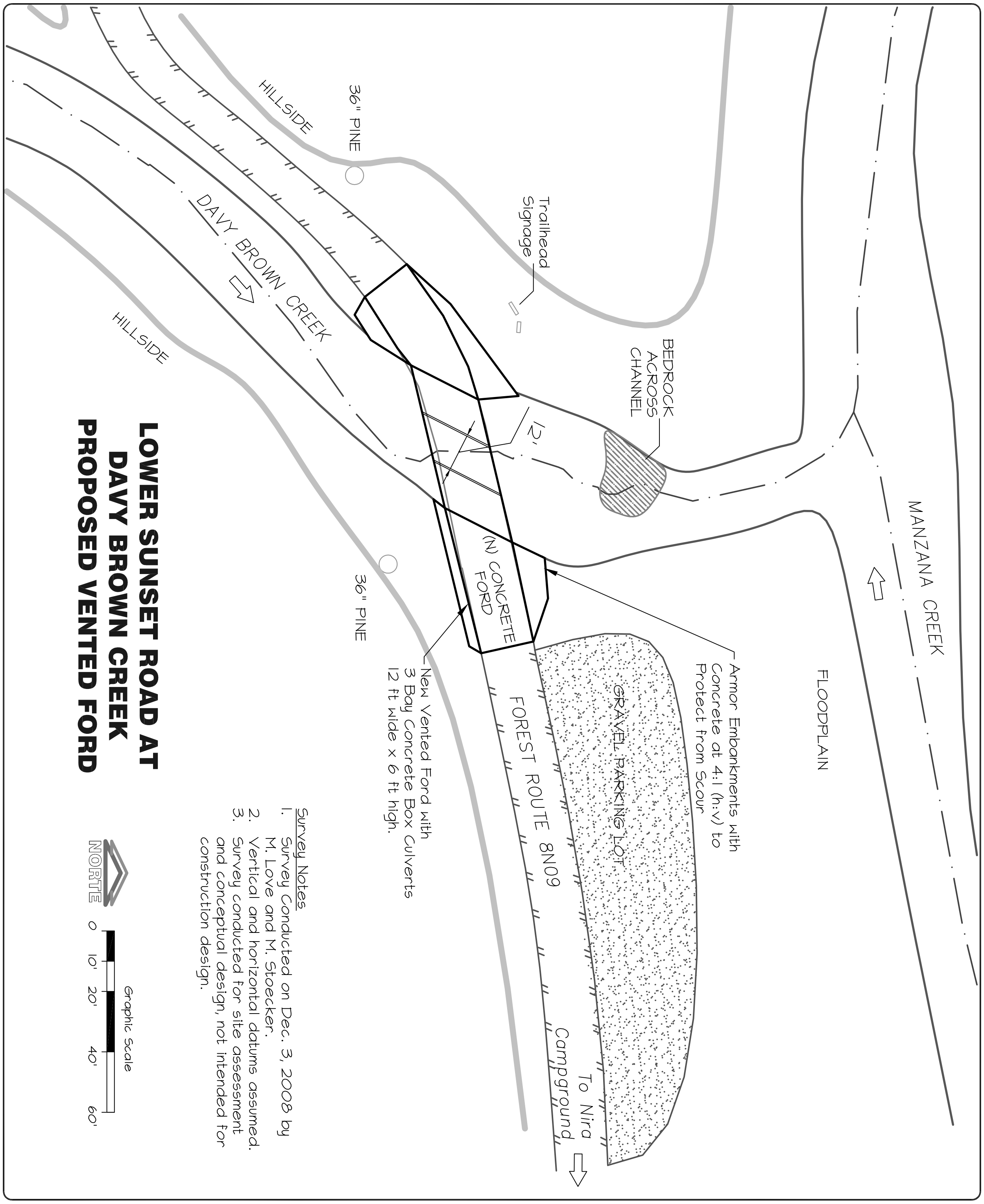
Los Padres National Forest
Davy Brown Creek
Fish Passage Assessment

DATE: April 2009
DESIGN: Llanos / Love
DRAWN: Llanos
FIGURE: 12



DATE	April 2009
DESIGN	Llanos / Love
DRAWN	Llanos
FIGURE	13

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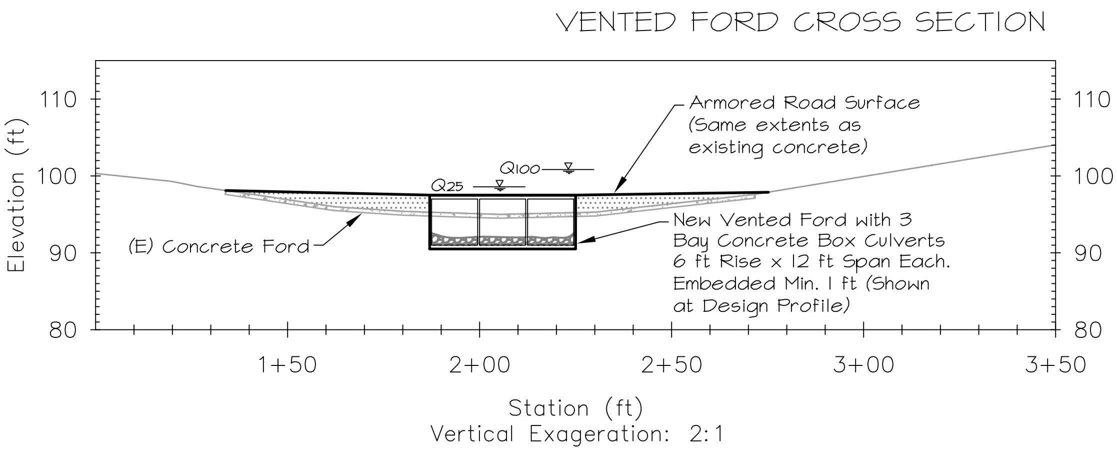

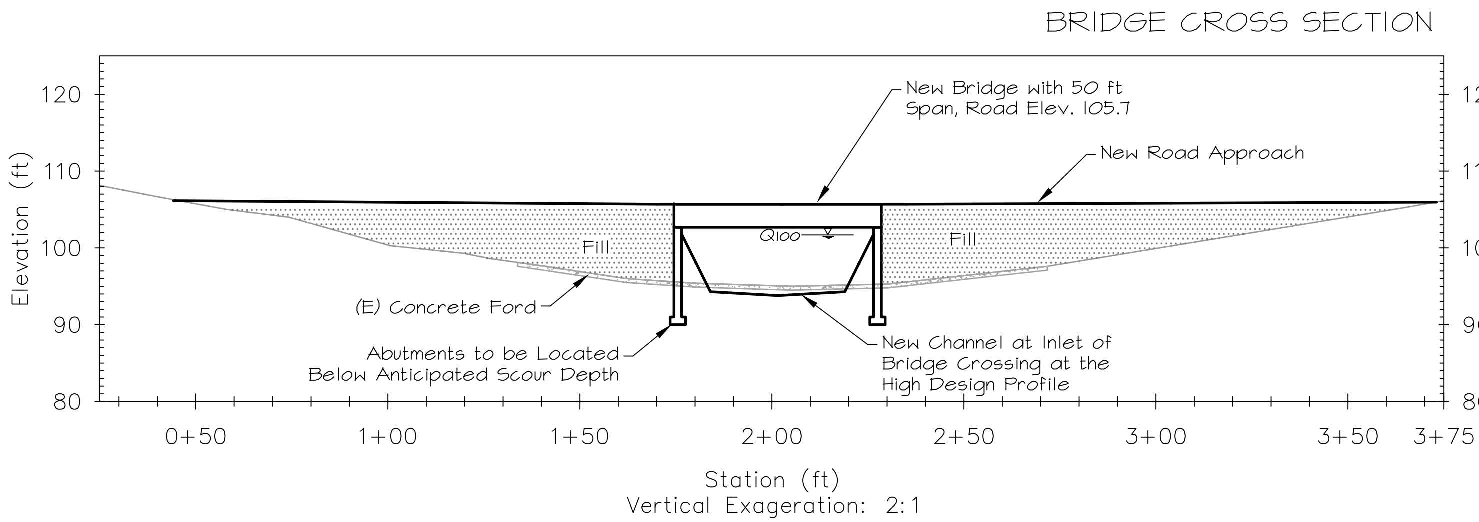

LOWER SUNSET ROAD AT DAVY BROWN CREEK PROPOSED CROSS SECTIONS

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Davy Brown Creek
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DATE	April 2009
DESIGN	Llanos / Love
DRAWN	Llanos
FIGURE	14

overtopped. Rock for scour protection may also be necessary at the downstream ends of the armored approaches to protect the banks when the ford is overtopped. Like the bridge crossing, the road would need to be closed or a temporary crossing upstream of the existing crossing would need to be installed.

We analyzed a new vented ford at the crossing as a single 36-foot wide by 6-foot high box culvert set at the design slope of 2.8 %, and embedded a minimum of 1.0 foot. A Manning's roughness coefficient of 0.060 was used for the boulder/cobble channel bed. The capacity was evaluated using the US Federal Highways culvert software, HY-8 (see Appendix for a summary of the hydraulic calculations). Because a vented ford is constructed as a box culvert, we assumed that the road surface would be directly on top of the box culverts and require a concrete thickness of 1 foot.

For the capacity analysis, the culvert was placed at the low design profile elevation with one foot of embedment. We then looked at two streambed conditions: one at the low design profile and one at the high design profile. The higher bed profile was simulated by embedding the vented ford 2.4 feet.

At the low design profile, flow would just submerge the culvert soffit at 965 cfs, overtop the road at 1,318 cfs and overtop the road with a depth of 1 ft at approximately 1,840 cfs (Appendix D).

If the channel bed aggrades to the high design profile at the crossing, the capacity of the culverts would be reduced. Flow would submerge the soffit at 620 cfs, overtop the road at 896 cfs and overtop the road with a depth of 1 ft at approximately 1,550 cfs.

Under both scenarios, the road would not be overtopped until well above the 5-year return flow. This would support uninterrupted transport of sediment through the culvert vents and retention of bed material along the bottom of the culvert. The potential would remain for debris to catch on the culvert inlet, which could interrupt sediment transport and flow conveyance.

Upper Sunset Valley Road at Davy Brown Creek

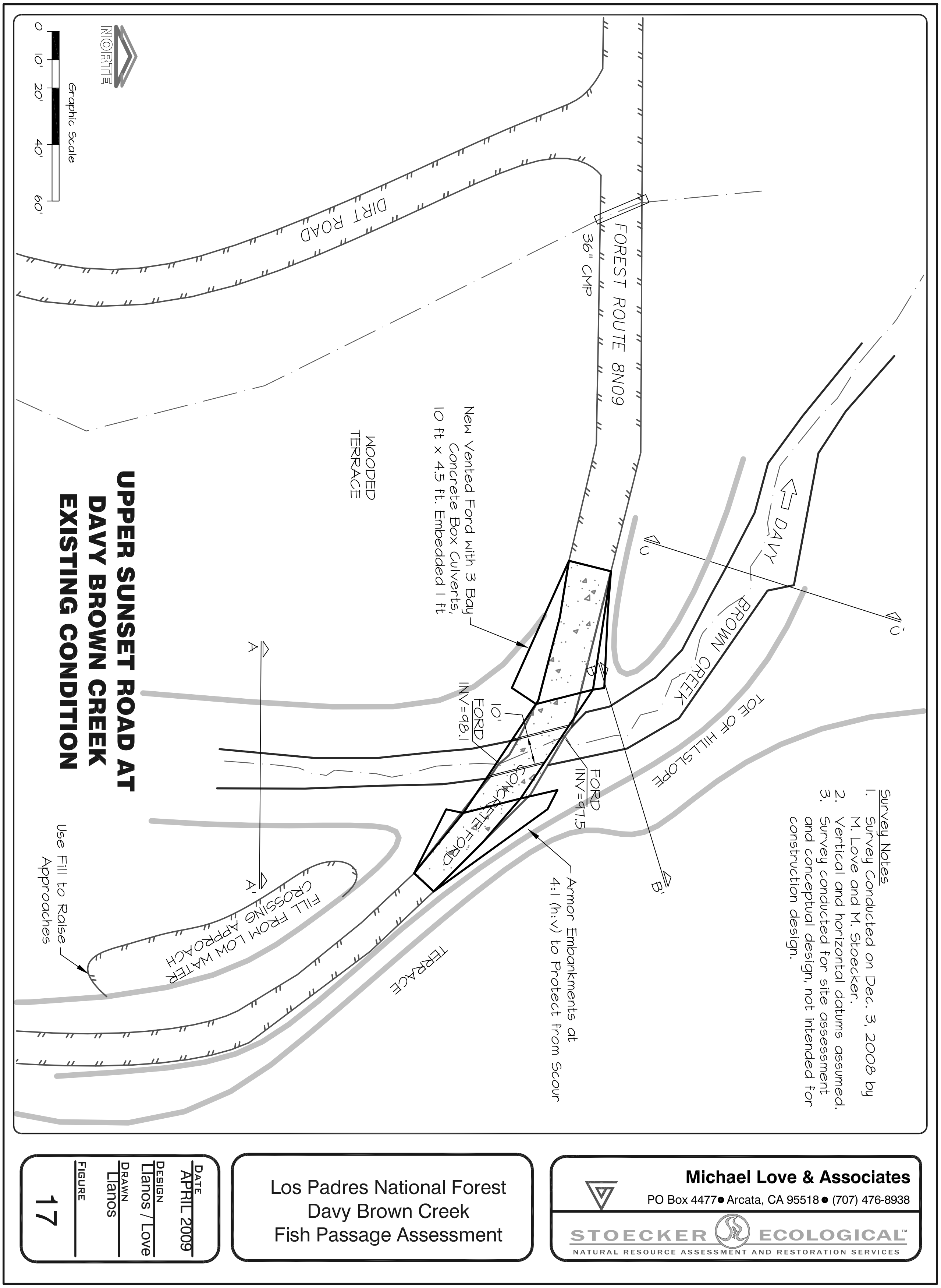
The existing crossing at upper Sunset Valley Road (H-150'59-2) is located approximately 1.2 miles upstream of the lower Sunset Valley Road crossing, in the Los Padres National Forest (Figure 1).

The existing low-water crossing is an 18-foot wide concrete ford that extends approximately 240 feet in length. The approach road is along a bend and dips approximately 9 feet vertically through a road cut in the right bank terrace (Figure 15 and Figure 17). Currently the crossing is overtopped with a depth of 1 foot at a flow of 486 cfs, which is slightly higher than the 10-year return flow.

Figure 15 – Upper Sunset Valley Road (H-150'59-2) at Davy Brown Creek looking toward the right bank terrace where the approach road was cut. The 18-foot wide concrete low-water ford is located 1.2 miles upstream of the lower Sunset Valley Road crossing.

A small channel runs parallel to Davy Brown Creek along the left bank and flows through a rusted and undersized 3-foot diameter culvert approximately 125 feet north of the lower crossing site (Figure 16). The culvert is squashed and shows evidence of recent sediment removal at the inlet. This culvert should be replaced with a larger diameter culvert, but was not analyzed as part of this study.

Figure 16 – Side channel culvert located approximately 125 -ft from the Upper Sunset Valley Road crossing. The culvert has a 3-ft diameter and is rusted, showing signs of regular sediment removal at the inlet. During high flows water diverted from the ford re-enter the channel at this location.


UPPER SUNSET ROAD AT
DAVY BROWN CREEK
EXISTING CONDITION
NORTE
Graphic Scale
0 10' 20' 40' 60'
DIRT ROAD
FOREST ROUTE 8N09
36" CMP
WOODED TERRACE
New Vented Ford with 3 Bay Concrete Box Culverts, 10 ft x 4.5 ft. Embedded 1 ft
DAVY BROWN CREEK
C
C'
B
B'
A
A'
10' FORD INV=98.1
FORD INV=97.5
CONCRETE FORD
TOE OF HILLSLOPE
Armor Embankments at 4:1 (h:v) to Protect from Scour
TERRACE
FILL FROM LOW WATER CROSSING APPROACH
Use Fill to Raise Approaches
Survey Notes
1. Survey Conducted on Dec. 3, 2008 by M. Love and M. Stoecker.
2. Vertical and horizontal datums assumed.
3. Survey conducted for site assessment and conceptual design, not intended for construction design.
DATE APRIL 2009
DESIGN Llanos / Love
DRAWN Llanos
FIGURE 17
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Geomorphic Assessment

Cross sections were surveyed downstream of the crossing in a representative reach of the boulder step channel (cross section C), at the tailwater control of the crossing (cross section B), and upstream at potential bridge alignment location (cross section A).

The channel at the upper Sunset Valley Road crossing is characterized by boulder steps and a 5% channel slope (Figure 18). The active channel and bankfull widths at the surveyed cross sections C and A were 15 feet and 30 feet respectively. The steps in the reach downstream of the crossing have pool depths up to 1.5 feet, which provide excellent fish habitat. Steps are spaced approximately 20 feet apart and are comprised of rock that is 15 to 36 inches in diameter. A pebble count revealed the following distribution of particle sizes:

D_{35} = 2.6 inches
D_{50} = 4.3 inches
D_{84} = 17 inches
D_{100} = 36 inches

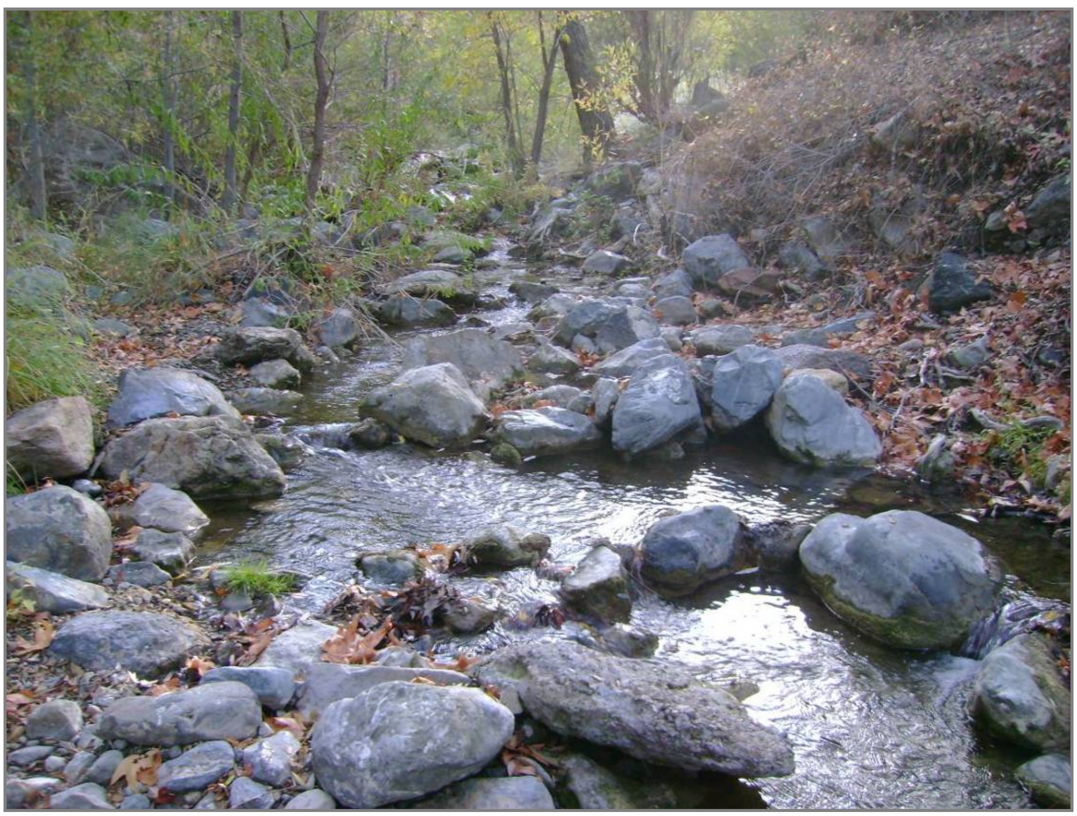


Figure 18 – Boulder step channel immediately downstream of the upper Sunset Valley Road crossing. The channel is at 5% slope and contains boulder steps spaced 20 feet apart on average.

The channel slope immediately upstream of the crossing is nearly flat for approximately 100 feet before continuing its ascent through a boulder step channel. This section of low slope is possibly due to the crossing functioning as a knickpoint that prevents vertical channel adjustments, or possible historic modifications to the channel.

Downstream and upstream of the crossing the creek has dense riparian canopy cover comprised of Alder, Sycamore, Live Oak, Maple and Willow. Large woody debris and undercut banks are present along this reach. High densities of ants and moderate densities of caddis larvae and mayfly nymphs were also present. Five juvenile steelhead (4-6") and 15 Arroyo chub (3-5") were observed within the 100 feet of habitat upstream of the crossing. Two juvenile steelhead (5-6") were observed in the scour pool immediately downstream of the crossing.

Fish Passage Conditions

Fish passage conditions were evaluated for the upper Sunset Valley Road (H-150'59-2) crossing as outlined in the previous section (*Fish Passage Assessment Methodology and Criteria*). The fish passage assessment showed that the crossing fails to meet fish passage criteria for all evaluated life stages of rainbow trout/steelhead (Table 6). Based on the fish passage assessment and field observations, we conclude that for adult trout the primary impediment to upstream migration is the lack of depth across the wide flat concrete ford at low flows. These shallow depths likely do not prevent adult trout from migrating upstream at moderate and high flows, since adult salmonids are regularly observed swimming in short bursts across short reaches of shallow flow with their body partially exposed above the water.

Table 6 – Existing fish passage conditions at upper Sunset Valley Road Crossing on Davy Brown Creek

Fish Species and Age Class	Fish Passage Design Flow	Water Depth	Water Velocity	Water Surface Drop
Conditions at the Low Fish Passage Design Flow				
Juvenile Trout	1.0 cfs	0.07 ft	1.98 ft/s	0.90 ft
Adult Rainbow Trout	2.0 cfs	0.10 ft	2.51ft/s	0.71 ft
Adult Steelhead Trout	3.0 cfs	0.11 ft	2.79 ft/s	0.58 ft
Conditions at High Fish Passage Design Flow				
Juvenile Trout	8.4 cfs	0.16 ft	3.99 ft/s	0.13 ft
Adult Rainbow Trout	25.2 cfs	0.26 ft	5.79 ft/s	0.0 ft
Adult Steelhead Trout	42.0 cfs	0.33 ft	6.80 ft/s	0.0 ft

The crossing is suspected of being a complete barrier to upstream movement of juvenile trout due to a combination of excessive water velocity, insufficient water depths and water surface drops across the downstream edge of the crossings.

Recommended Treatments

To improve sediment transport and overall ecological connectivity at the upper Sunset Valley Road (H-150'59-2) crossing of Davy Brown Creek, we examined two crossing types in detail: a vented ford and a bridge.

For the upper Sunset Valley Road crossing a stable grade was estimated using the downstream channel, assuming the coarse bed material stored upstream of the existing crossing will be mobilized. A channel bed slope of 4.2 % was used for streambed and vented ford design (Figure 19). Our preliminary design analysis used the design profile and resultant channel elevations.

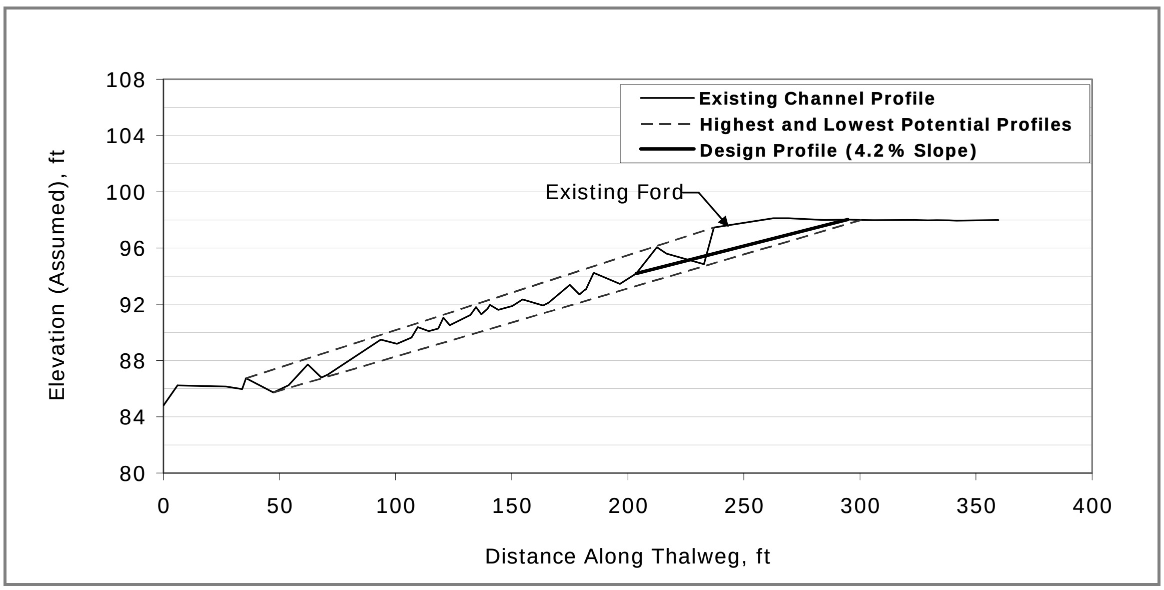


Figure 19 – Existing Davy Brown Creek channel profile at the upper Sunset Valley Road crossing. The highest and lowest profiles were estimated to describe the potential vertical adjustment of the channel if the ford was replaced.

Bridge

We evaluated the suitability of the upper Sunset Valley Road crossing for a bridge with a slight modification to the existing crossing alignment and an alignment further upstream (Figure 20).

A new channel shape for a bridge crossing was designed for conveyance of the 100-year flood flow in Davy Brown Creek. The channel under the bridge would have a bottom width of 40 feet, top width of 50 feet, 1:1 (h:v) side slopes and a

4.2% channel slope (Figure 22) . The width of the new channel at the bridge will allow for minor lateral channel adjustment.

We estimated the water surface elevation in the channel using Manning's Equation with a roughness coefficient of 0.06, representative of large rock used for scour control. This analysis predicts a depth of flow of 5.35 feet during the 100-year return flow of 3,122 cfs.

Bridge at Current Road Alignment

Because the existing road dips down through a road cut to the stream crossing, there are certain advantages to locating a bridge at the current crossing location. The dip in the road would allow the construction of bridge abutments with a minimum of excavation. Abutments could be formed in-place and then backfilled to bring the road elevation up to the level of the surrounding terrace. Material that appears to be from the original road cut is currently stockpiled on the terrace next to the road approach and could be used to build the road up to the new elevation. The road would need to be closed or a temporary crossing upstream of the existing crossing would need to be installed.

Using the design slope of 4.2% would place the channel bottom at 96.7 feet at the crossing. Accommodating the 100-year flow plus one foot of freeboard would require the bottom of the bridge deck to be located approximately 4.9 feet above the existing ford.

Using vertical abutments above the 100-year water surface elevation would enable the use of a bridge with a 50-foot span.

Where practical, 10% is the recommended maximum approach grade for new crossings. Currently the right bank approach is at 12% and the left bank approach is at 8%. Placing a bridge at the required road elevation would create a shorter approach on the right bank because the existing road cut would be filled. The left bank approach would require fill that slopes down to match the existing road.

Bridge at New Road Alignment

Realigning the road to cross the stream 85 feet upstream of the current crossing was also examined in the field. This option would require realigning up to 400 feet of the roadway through the area upstream of the existing crossing. The current channel shape does not contain the 100-year flow within its banks, requiring the bridge be placed above the top of banks to achieve adequate freeboard.

At this time, it is unknown if realigning the road to accommodate a new crossing location is feasible due to the environmental impacts and property ownership.

Vented Ford

A vented ford almost identical to one that was sized for the lower Sunset Valley Road crossing could be utilized at the upper Sunset Valley Road crossing. The sizing process was identical and yielded a similar crossing.

For the upper Sunset Valley Road crossing a vented ford composed of three 10 feet wide by 4.5 feet high box culverts embedded 1 foot would accommodate the existing channel width and flow area (Figure 21). Providing a total span of 30 feet should provide adequate width to accommodate the 30-foot bankfull channel width.

We analyzed a new vented ford at the crossing as a single 30-foot wide by 4.5 ft high box culvert set at the design slope of 4.2 %, and embedded a minimum of 1.0 foot. A Manning's roughness of 0.060 was used for the boulder and cobble dominated channel bed. The capacity was evaluated using the US Federal Highways culvert software, HY-8 (see Appendix for a summary of the hydraulic calculations). Because a vented ford is constructed as a box culvert, we assumed that the road surface would be directly on top of the box culverts and require a concrete thickness of 1 foot.

For the capacity analysis, the culvert was placed at the design profile elevation and embedded 1 foot.

At the design profile, flow would just submerge the inlet soffit at 500 cfs, overtop the road at 717 cfs and overtop the road with a depth of 1 ft at approximately 1,134 cfs. Under this scenario, the road would not be overtopped until well above the 5-year return flow (Appendix E).

Similar to the lower Sunset Valley Road crossing, the alignment of a new vented ford would likely require the boxes to be skewed with the road surface because the road crossing is not perpendicular to the stream (Figure 21). Having a skewed alignment as shown would likely require forming the box culverts in place. Additional concrete work would also be required to armor the approaches of the road to prevent scour when the ford is overtopped. Rock for scour protection may also be necessary at the downstream ends of the armored approaches to protect the banks when the ford is overtopped. Like the bridge crossing, the road would need to be closed or a temporary crossing upstream of the existing crossing would need to be installed.

A new vented ford could be located within the extent of the existing crossing. The roadbed would be higher, decreasing the approach grades and reducing road closures during high flows.

With the higher road profile, flow may be diverted down the road at flows greater than approximately 1,200 cfs. Were this to occur, flow would be directed to the adjacent channel located 125 feet down the road, and would enter Davy Brown Creek downstream of the 3-foot culvert under Sunset Valley Road.

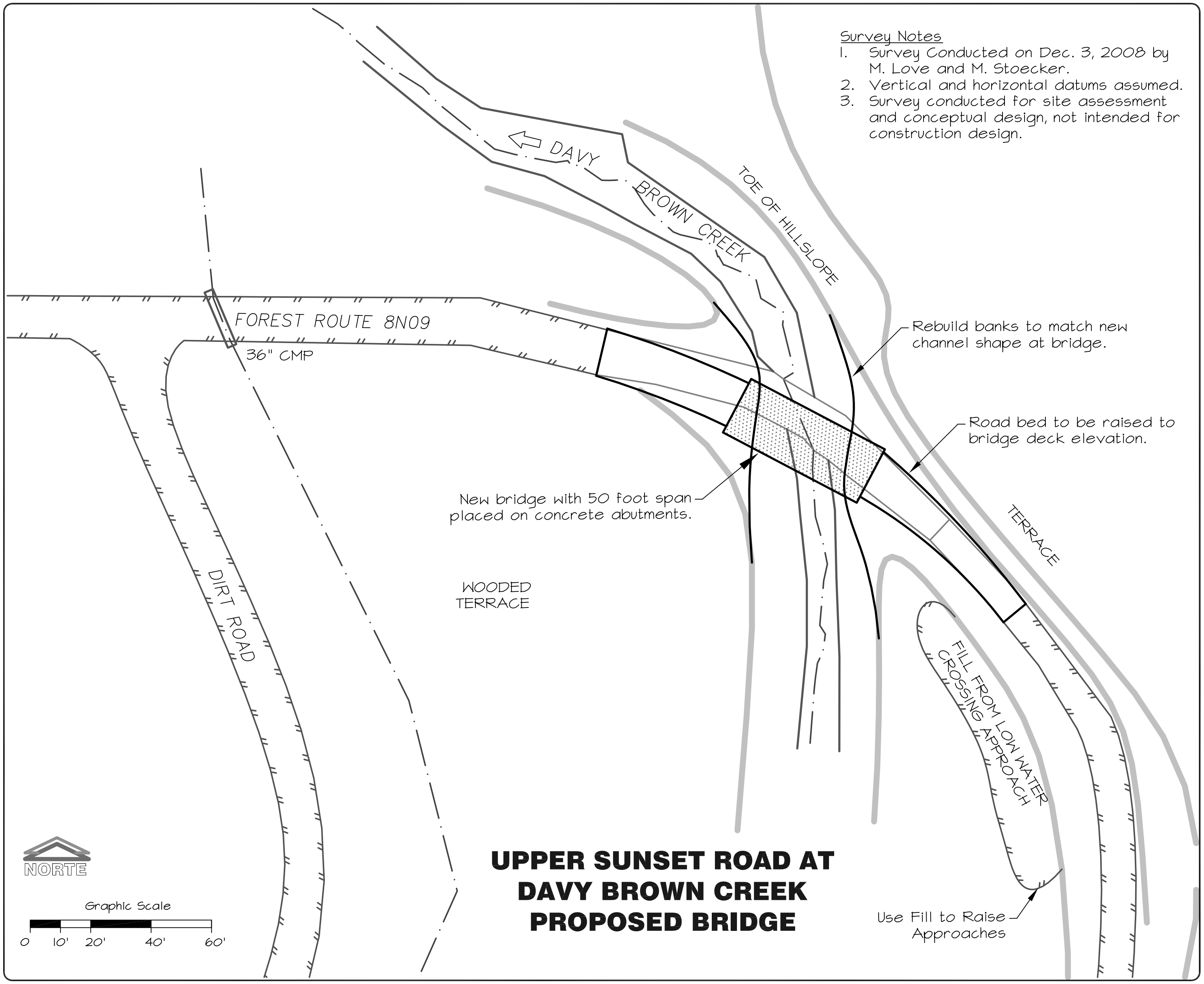
Other Treatments Considered for the Sunset Valley Road Crossings

In addition to the bankfull vented ford and bridge crossing types described above, we considered two other crossing alternatives: modifying the existing crossing to create a vented ford, and replacement with a channel spanning arch culvert. They are described in brief in the following sections. Neither was developed to the conceptual design level due to identified problems that make them unworkable for the site configuration and fish passage objectives.

Modifying Existing Crossing

In some cases modifying the crossing by cutting and reforming a box culvert to create a vented ford (Figure 23) is a relatively low cost alternative to complete replacement of a low-water crossing. If the added vent is not sized to have a high VAR or a width that approximates the bankfull channel width, then the modification is designed for fish passage based on hydraulic design criteria (velocities and depth requirements). The invert of the vent is set low enough such that the downstream channel backwaters it to provide adequate depth and low enough water velocities for fish passage.

This option was considered at both the lower and upper Sunset Valley Road crossings. However, the existing channel-road configuration makes installation of a vent into the existing ford problematic. Any vent installed into the existing ford would only have a two-foot high opening at best. In addition, the maximum span for a single concrete vent is typically 12 feet, which is much narrower than the existing channel width. Therefore, this type of modification would be highly susceptible to clogging with the large bedload present throughout the channel. This type of crossing would require routine



UPPER SUNSET ROAD AT DAVY BROWN CREEK PROPOSED BRIDGE

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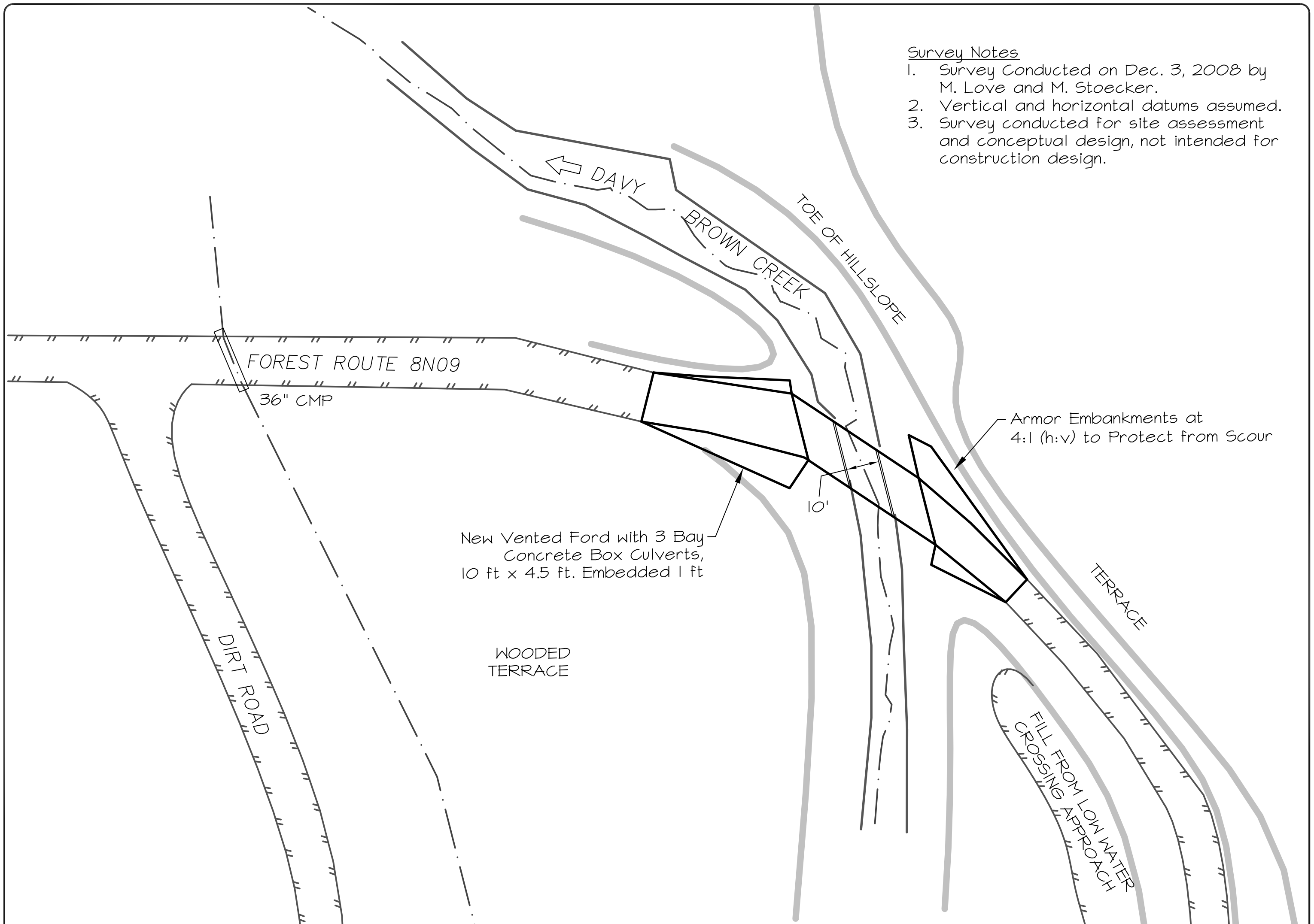
Davy Brown Creek
Fish Passage Assessment

DATE	APRIL 2009
DESIGN	Llanos / Love
DRAWN	Llanos
FIGURE	20



UPPER SUNSET ROAD AT DAVY BROWN CREEK PROPOSED VENTED FORD

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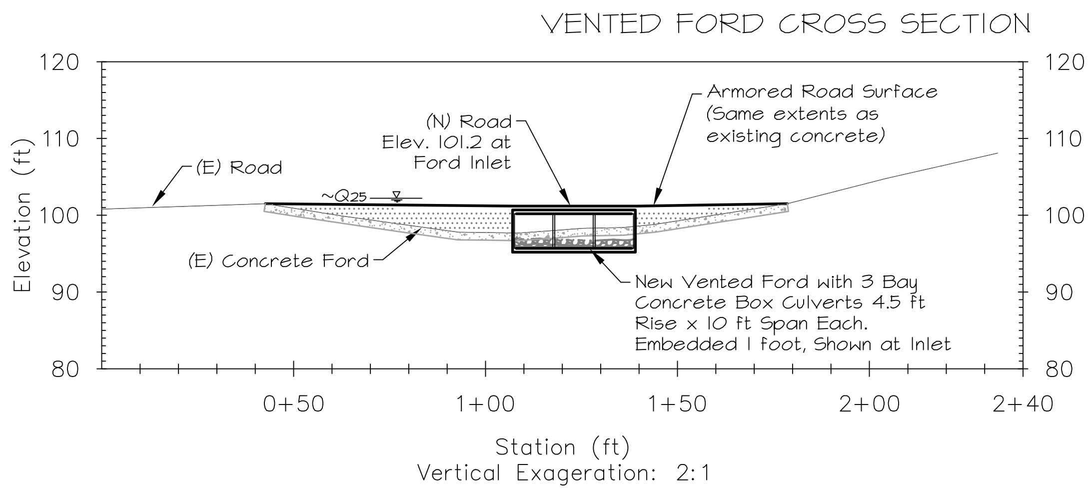
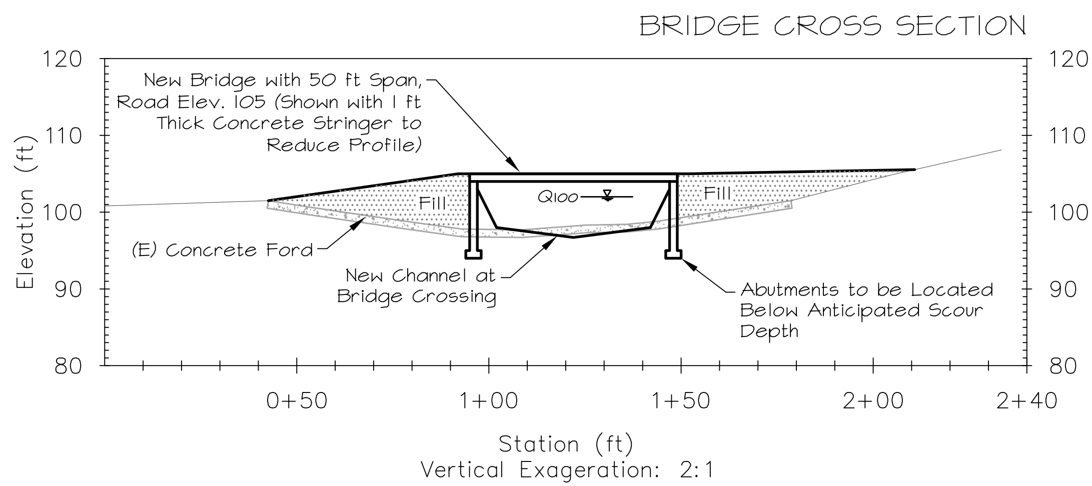
Davy Brown Creek
Fish Passage Assessment

DATE	APRIL 2009
DESIGN	Llanos / Love
DRAWN	Llanos
FIGURE	21





UPPER SUNSET ROAD AT
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PROPOSED CROSS SECTIONS

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Davy Brown Creek
Fish Passage Assessment

DATE	APRIL 2009
DESIGN	Llanos / Love
DRAWN	Llanos
FIGURE	22

Figure 23 – Example of modifying an existing low-water crossing by cutting and forming a new box to create a vented ford. The crossing is designed using hydraulic criteria for fish passage and will not retain a natural streambed. The grate is removable to clear debris that may accumulate during high flows.

maintenance and, when clogged with sediment, create impassible conditions for upstream migrating fish. Therefore, modification of the existing fords was not considered further.

Full Spanning Arch

We also considered utilizing a full spanning arch at each Sunset Valley Road crossing. An arch would be sized using the same criteria as a bridge, to provide adequate width to accommodate the bankfull channel and adequately sized to convey the 100-year return flow without submerging the inlet. An arch also requires a minimum of 2 feet of fill be placed over the crossing to form the roadbed.

Because both crossings are located in an existing dip in the road, an arch could be easily constructed without much excavation and the overall span could be reduced when compared to a bridge. An arch can also more easily accommodate a bend in the road at the crossing location. However, because arch culverts rest on footings placed in or adjacent to the active channel, they are susceptible to scour. Therefore, footings must often extend below the predicted scour depth, often requiring considerable excavation and concrete formwork. At both Sunset

Valley Road crossings, the size of arch required to convey the 100-year flow needs to be much wider and/or higher than the existing channel banks. This made using an arch culvert at both sites problematic. They require substantial raising of the road profile beyond the existing fords and approaches to prevent high flows from flanking the culvert and overtopping the adjacent road. Therefore, use of arch culverts at the two crossings was not considered further.

Munch Creek Crossing

The existing Munch Creek crossing (H-150'59-1) in the Davy Brown Campground is located approximately 0.3 miles upstream of the upper Sunset Valley Road Crossing on Forest Route 8N09a, in the Los Padres National Forest (Figure 1).

The existing low-water crossing is a concrete ford 13 feet wide and approximately 55 feet long (Figure 24). The drop across the downstream end of the ford is about 2.5 feet during low flows (Figure 25). The approach road is through the campground from the entrance on Sunset Valley Road. The road at the crossing approaches are in disrepair and mostly composed of broken asphalt. There appears to be a waterline that crosses the ford along the downstream end connected to a hose bib on the left bank. It is unknown if this line is in service or needed for future use.

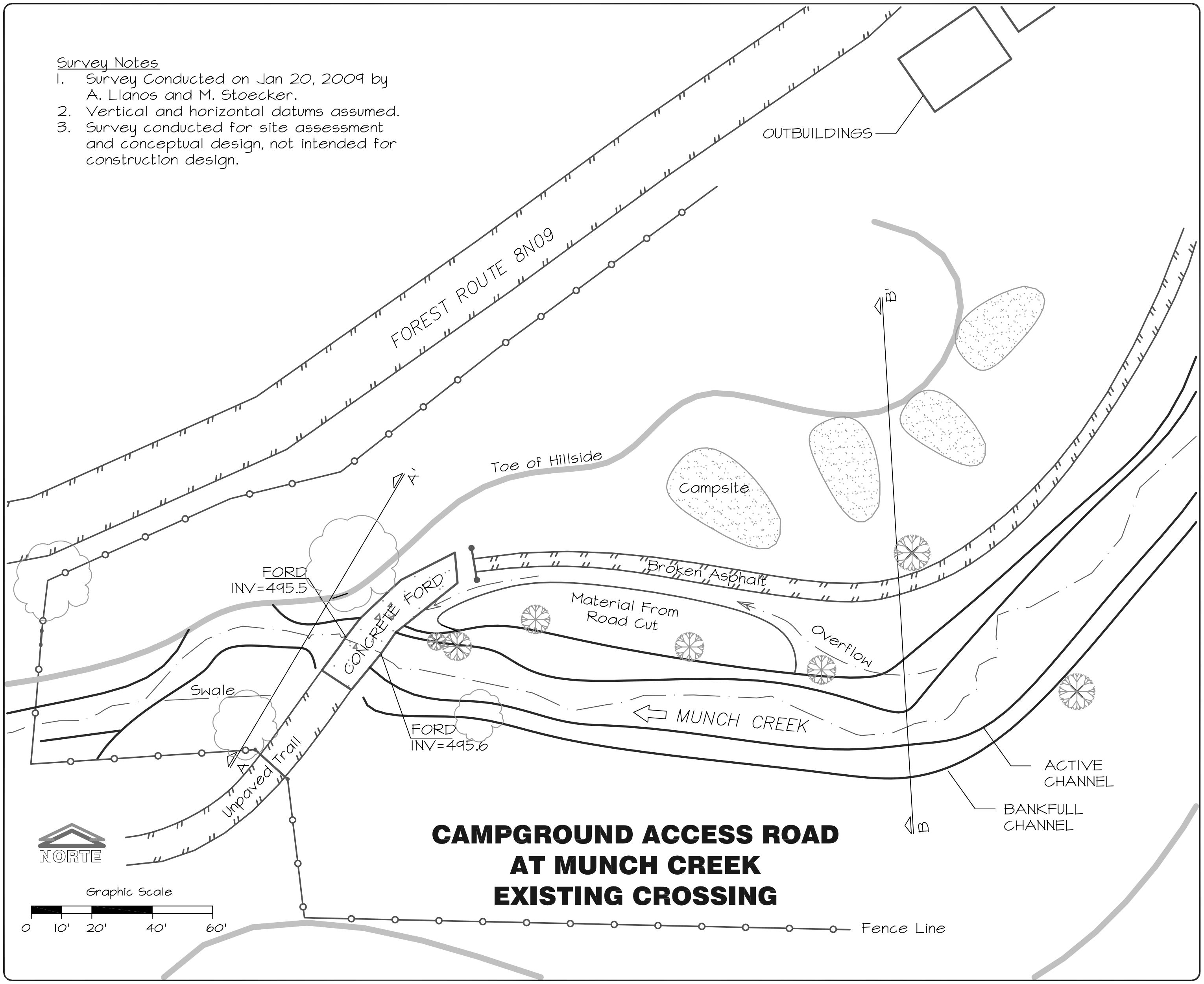
Currently the crossing is overtopped with a depth of 1 foot at a flow of 123 cfs, just less than the 5-year return flow.

Geomorphic Assessment

The channel at the Munch Creek crossing is characterized by a series of boulder steps immediately upstream of the crossing (Figure 26) with a channel slope of 6.4% and an incised channel for about 200 feet downstream of the crossing with a slope of 2.4%. The residual drop at the crossing is 2.8 feet.

The upstream channel shape is dominated by large boulder clusters that form distinct steps and pools. Steps are spaced between 12 and 37 feet, forming pools from 0.8 to 2.0 feet deep. Boulder steps appear to be formed by large "keystone" rocks that provide anchoring for smaller boulders to form clusters that span the channel, creating drops and pools.

The right bank is well defined by a levee, likely formed by material from the road cut at the right bank approach. The substrate in the channel is highly cemented, which precluded conducting a pebble count at this site.



CAMPGROUND ACCESS ROAD AT MUNCH CREEK EXISTING CROSSING

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NATURAL RESOURCE ASSESSMENT AND RESTORATION SERVICES

Los Padres National Forest
Davy Brown Creek
Fish Passage Assessment

DATE APRIL 2009
DESIGN Llanos / Love
DRAWN Llanos
FIGURE 24

Figure 25 –Munch Creek crossing (H-150'59-1) is an abandoned 13-foot wide concrete low-water ford. Complete removal is recommended.

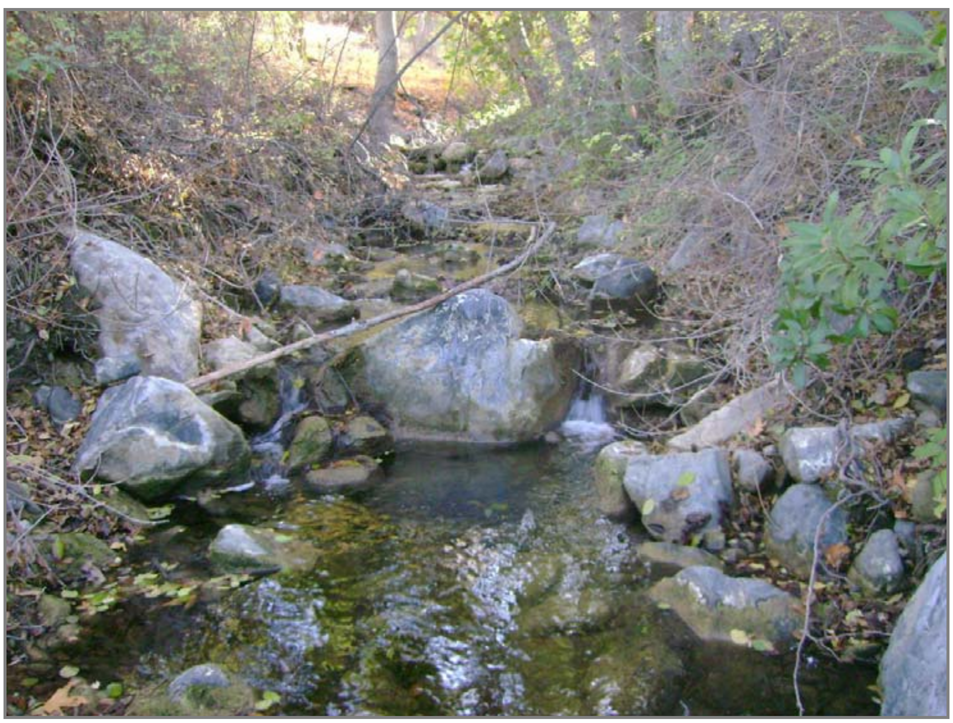


Figure 26 – Typical boulder step feature in the Munch Creek channel at the campground. Boulder steps form the primary channel feature upstream of the crossing. Pools ranged from 0.8 to 2 feet deep below boulder steps.

At 160 feet upstream of the crossing, the channel appears to be aggraded, forming braids and tighter spacing of steps with smaller drops. At this location there is evidence of overbank flow being diverted down the road, around the levee on the right bank, and re-entering the channel at the crossing. The aggradation along the upstream portion of the reach suggests that the steps in the channel may have formed at an elevation slightly higher than the original channel, possibly due to the ford acting as a knickpoint.

The riparian vegetation at the crossing is predominately pine, alder, sycamore and a few oaks. Seven juvenile rainbow trout / steelhead (3-11") were observed within the 150 feet of habitat upstream of the crossing. Two juvenile steelhead (5-6") were observed in the scour pool immediately downstream of the crossing.

The hydraulic analysis of the channel was conducted for the representative cross section (Cross Section B) that was surveyed upstream of the crossing in a boulder cascade section of the channel. The active channel width and depth are approximately 13 ft and 1.4 feet respectively, corresponding to a flow of 21 cfs. The 2-year return flow for the channel is estimated to be 42 cfs and corresponds to a depth of about 1.8 feet in the channel.

Fish Passage Conditions

Fish passage conditions were evaluated as outlined in the previous section (*Fish Passage Assessment Methodology and Criteria*). The fish passage assessment of the Munch Creek crossing (H-150'59-1) found that the crossing fails to meet fish passage criteria for all evaluated life stages of rainbow trout/steelhead (Table 7). Based on the fish passage assessment and field observations, we conclude that for adult trout the primary impediments to upstream migration are the drop over the downstream edge of the ford and the lack of depth across the wide flat concrete ford at low to moderate flows. At higher flows, the drop over the ford reduces to nothing. The shallow depths likely do not prevent adult trout from migrating upstream at moderate and high flows.

The crossing is suspected of being a complete barrier to upstream movement of juvenile trout due to a combination of excessive water velocity, insufficient water depths and the large water surface drops across the downstream edge of the crossings.

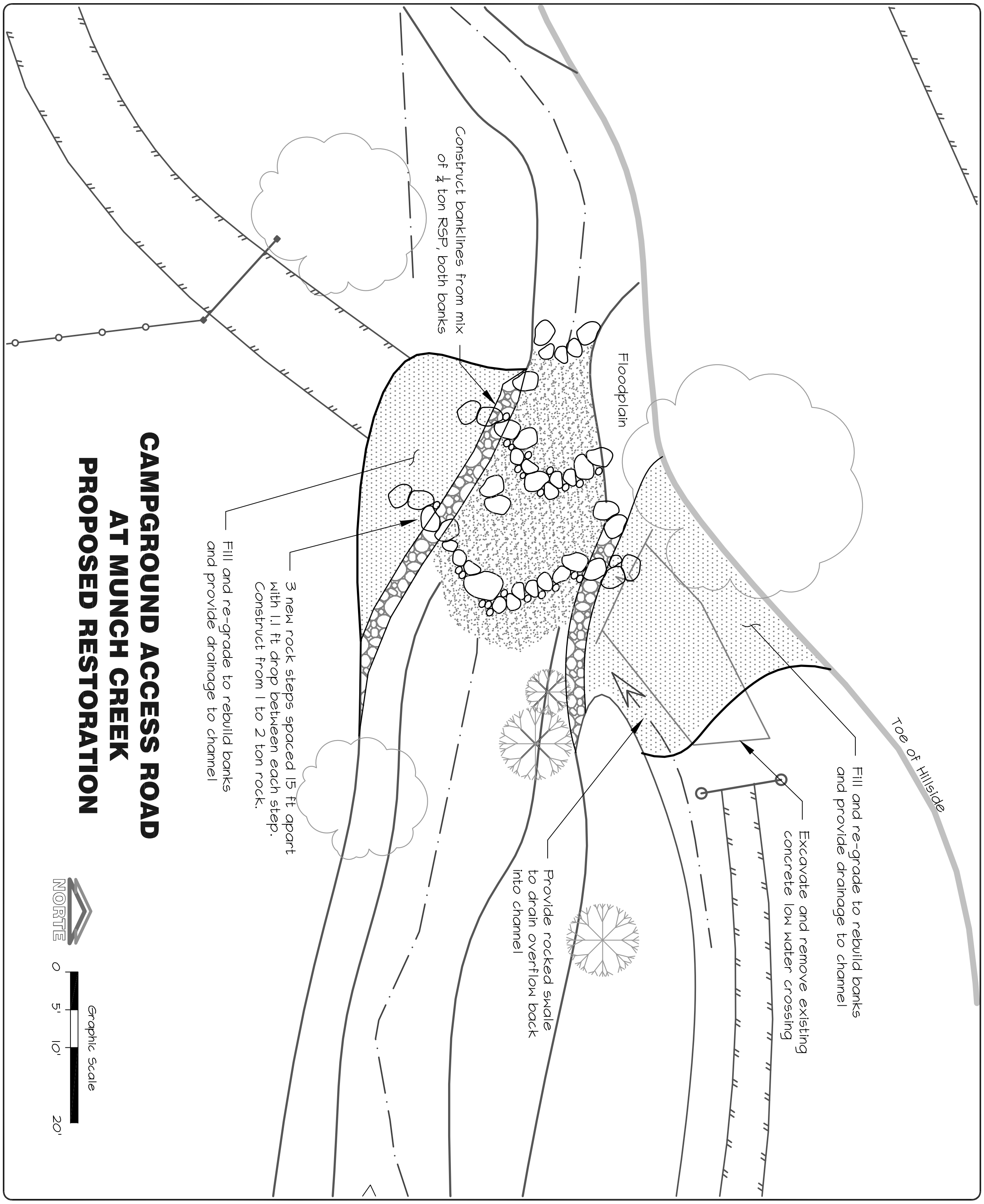
Table 7– Existing fish passage conditions at the Munch Creek crossing.

Fish Species and Age Class	Fish Passage Design Flow	Water Depth	Water Velocity	Water Surface Drop
Conditions at the Low Fish Passage Design Flow				
Juvenile Trout	1.0 cfs	0.17 ft	1.98 fps	2.51 ft
Adult Rainbow Trout	2.0 cfs	0.21 ft	2.29 fps	2.21 ft
Adult Steelhead Trout	3.0 cfs	0.25 ft	2.59 fps	1.97 ft
Conditions at High Fish Passage Design Flow				
Juvenile Trout	4.2 cfs	0.28 ft	2.79 fps	1.66 ft
Adult Rainbow Trout	12.6 cfs	0.42 ft	3.66 fps	0.51 ft
Adult Steelhead Trout	21 cfs	0.52 ft	4.17 fps	0.0 ft

Recommended Treatments

To improve sediment transport and overall ecological connectivity at the Munch Creek Crossing (H-150'59-1) we considered complete removal of the existing ford and restoration of the channel. Because the crossing is located at a significant break in slope, placement of natural grade control in the channel is recommended. The upstream boulder step channel was used as a reference for a new channel where the crossing would be removed.

We propose to create a series of three boulder steps that are similar in size and function to the boulder steps of the upstream channel (Figure 27). Steps should be placed 15 feet apart with a drop of 1.1 feet at each step (Figure 28). The rock steps would be built within the excavated area of the crossing, which will facilitate rock placement and proper installation of rocks to maintain stability. Unlike typical rock weirs, these steps are not intended to be immobile but rather to function as the other large rocks in channel to form complex flow patterns and bed form. They would be sized and placed to have similar stability characteristics as the existing naturally formed steps, with the large rock becoming mobilized when the upstream natural steps mobilize. Following the analog of the reference channel, placing a few large "keystone" rocks will provide anchor points for rocks to naturally form steps. These large keystones can be 2 to 3-ton sized rock. The rest of the steps will be constructed from a mix of ¼-ton to 1-ton sized rock. When possible, such as at the most downstream step, naturally occurring boulders should be used in the step construction.



DATE	APRIL 2009
DESIGN	Llanos / Love
DRAWN	Llanos
FIGURE	25

Los Padres National Forest
Davy Brown Creek
Fish Passage Assessment

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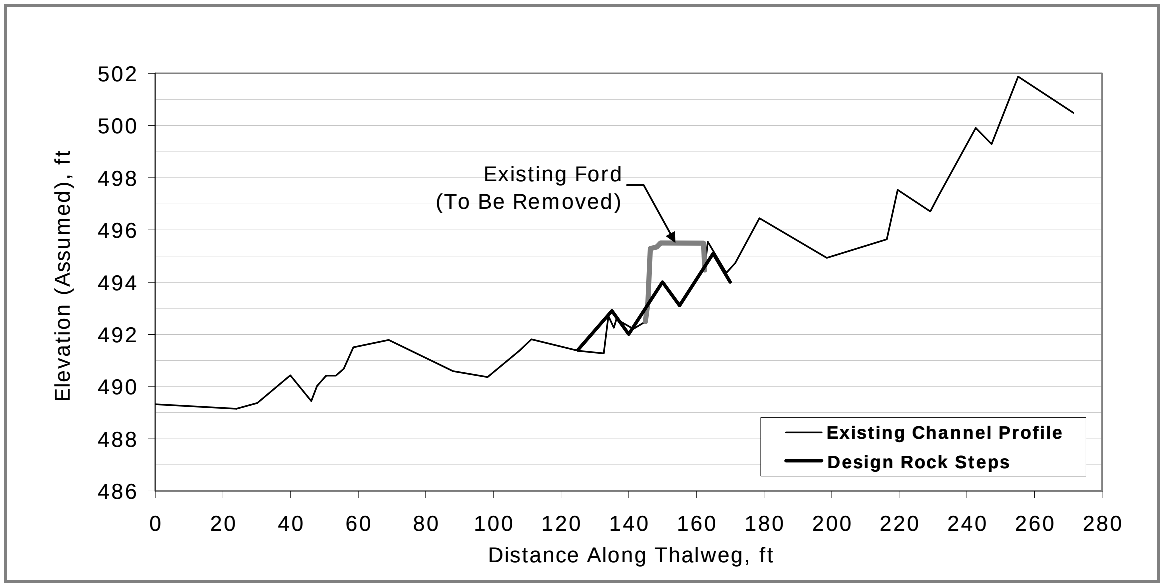

Figure 28 – Longitudinal profile for Munch Creek at the existing concrete ford. A new series of three rock steps with 1.1-foot drops can replace the crossing to provide fish passage and match the upstream channel morphology.

The rock steps should have "U" shaped plan forms with the apexes pointing upstream, and with crests that slope to the center of the channel in section view. This orientation will help concentrate flow to the center of the channel to form pools and protect the banks from excessive scour. Tapering the crest to the center of the channel also improves fish passage conditions by providing a distinct plunging nape for leaping.

The banks along the new section of channel will need to be built up and reinforced with a mix of ¼-ton rock. To match the existing channel morphology the banks should be 2 to 3 feet high from the channel center and slope at 6%, blending to the existing downstream and upstream banks.

The existing approaches to the crossing were cut through the original channel banks creating a low spot along each bank. The banks should be rebuilt with grading that provides positive drainage to the channel.

The three newly created step pools will provide additional, high quality habitat for steelhead trout and provide for unimpeded migration into this important spawning and rearing tributary.

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Appendix A.

Peak Flow Hydrology

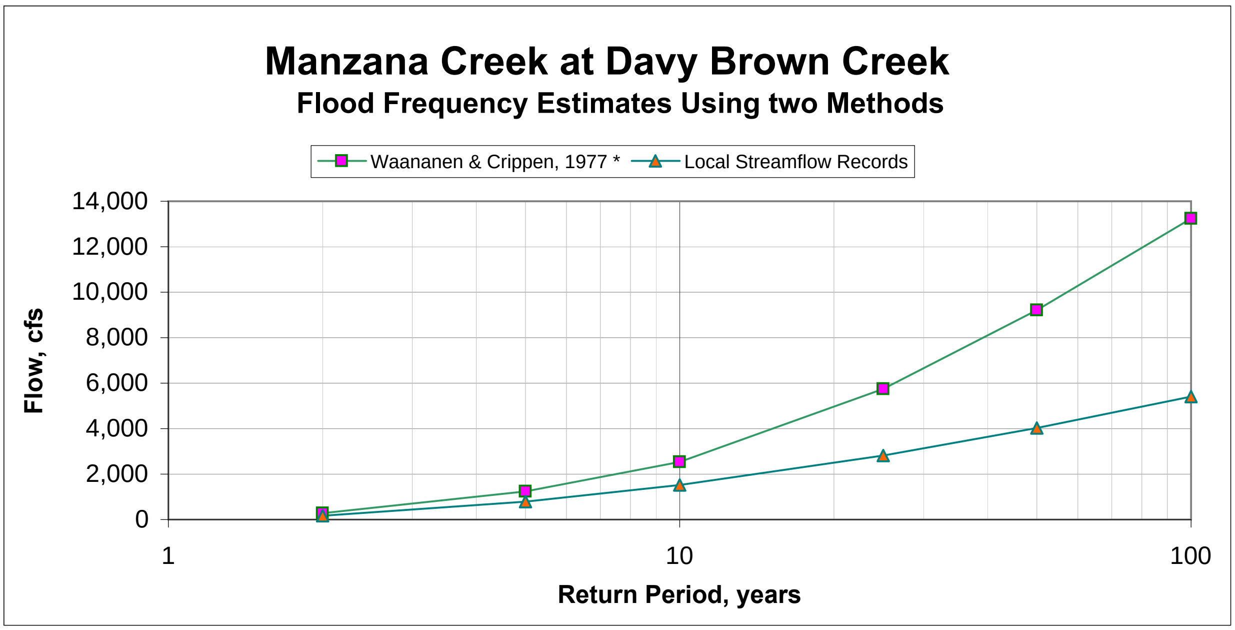
Manzana Creek

Summary of Peak Flow Calculations

Manzana Creek at the confluence of Davy Brown (includes Davy Brown)

Drainage Area (mi^2) = **39.1**
Mean Annual Precip. (in/yr) = **22.0**

Method	Q-2yr (cfs)	Q-5yr (cfs)	Q-10yr (cfs)	Q-25yr (cfs)	Q-50yr (cfs)	Q-100yr (cfs)
Waananen & Crippen, 1977 *	293	1,248	2,547	5,760	9,221	13,227
Local Streamflow Records						
Average	178	785	1,519	2,824	4,038	5,422
Mimium Estimate	40	185	399	876	1,434	2,207
Maximum Estimate	469	1,669	2,824	4,507	5,813	7,675



* Estimates using regional regression equations developed for the South Coast Region of California by the USGS (Waananen and Crippen, 1977):

South Coast Region (SC)

$Q_2 = 0.14 * A^{0.72} * p^{1.62}$

$Q_5 = 0.40 * A^{0.77} * p^{1.69}$

$Q_{10} = 0.63 * A^{0.79} * p^{1.75}$

$Q_{25} = 1.10 * A^{0.81} * p^{1.81}$

$Q_{50} = 1.50 * A^{0.82} * p^{1.85}$

$Q_{100} = 1.95 * A^{0.83} * p^{1.87}$

A = drainage area (mi2),
p = mean annual precipitation (in/yr),

Lower Davy Brown Creek

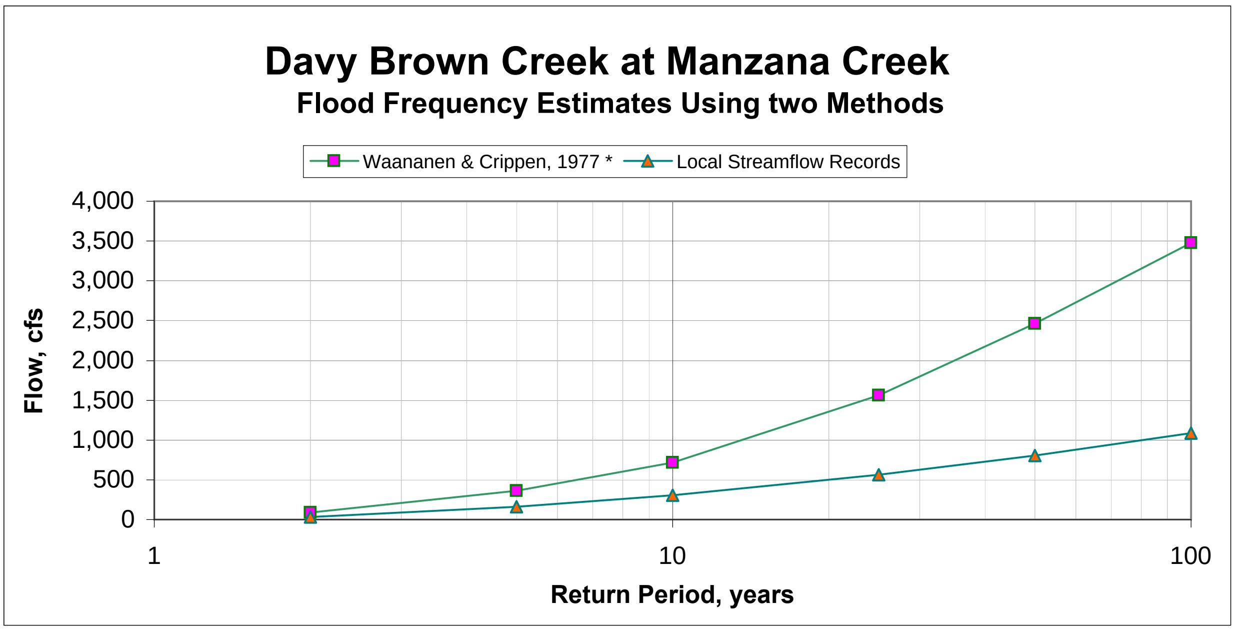
Summary of Peak Flow Calculations

Davy Brown Creek - at Manzana Creek

Drainage Area (mi^2) = **7.8**

Mean Annual Precip. (in/yr) = **22.0**

Method	Q-2yr (cfs)	Q-5yr (cfs)	Q-10yr (cfs)	Q-25yr (cfs)	Q-50yr (cfs)	Q-100yr (cfs)
Waananen & Crippen, 1977 *	92	361	714	1,564	2,463	3,477
Local Streamflow Records						
Average	36	157	304	565	807	1,084
Mimium Estimate	8	37	80	175	287	441
Maximum Estimate	94	334	565	901	1,162	1,534



* Estimates using regional regression equations developed for the South Coast Region of California by the USGS (Waananen and Crippen, 1977):

South Coast Region (SC)

$Q_2 = 0.14 * A^{0.72} * p^{1.62}$

$Q_5 = 0.40 * A^{0.77} * p^{1.69}$

$Q_{10} = 0.63 * A^{0.79} * p^{1.75}$

$Q_{25} = 1.10 * A^{0.81} * p^{1.81}$

$Q_{50} = 1.50 * A^{0.82} * p^{1.85}$

$Q_{100} = 1.95 * A^{0.83} * p^{1.87}$

A = drainage area (mi2),
p = mean annual precipitation (in/yr),

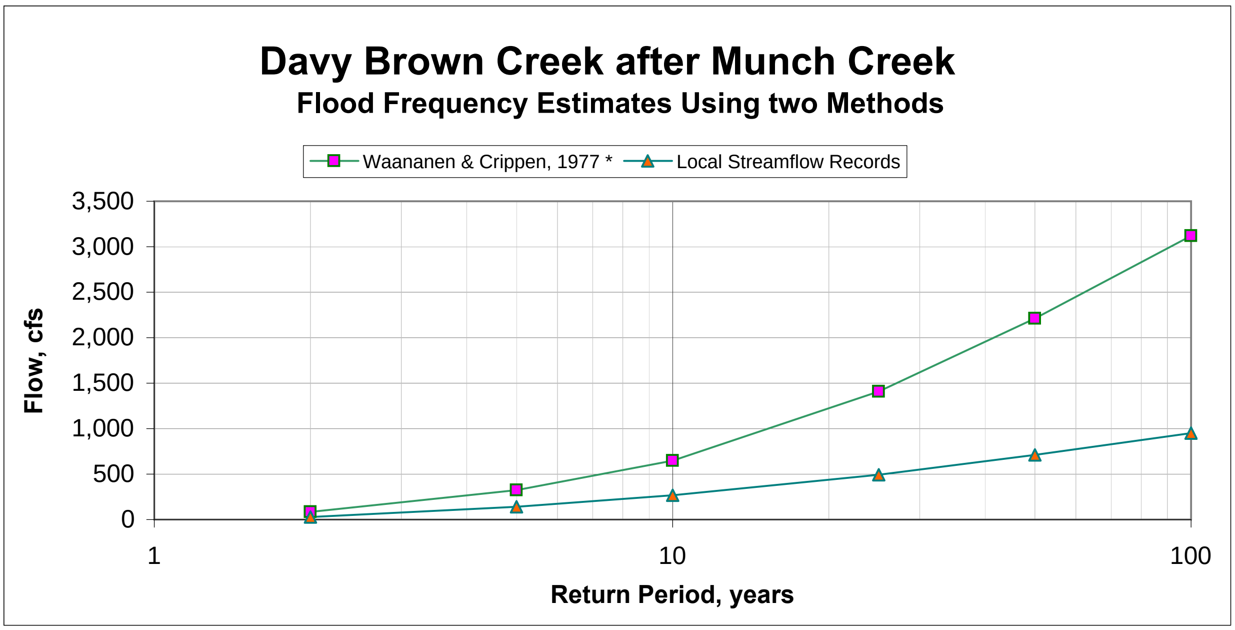
Upper Davy Brown Creek

Summary of Peak Flow Calculations

Davy Brown Creek - Upper Drainage

Drainage Area (mi^2) = **6.9**
Mean Annual Precip. (in/yr) = **22.0**

Method	Q-2yr (cfs)	Q-5yr (cfs)	Q-10yr (cfs)	Q-25yr (cfs)	Q-50yr (cfs)	Q-100yr (cfs)
Waananen & Crippen, 1977 *	84	327	644	1,408	2,214	3,122
Local Streamflow Records						
Average	31	138	267	496	709	952
Mimium Estimate	7	33	70	154	252	388
Maximum Estimate	82	293	496	791	1,021	1,348



* Estimates using regional regression equations developed for the South Coast Region of California by the USGS (Waananen and Crippen, 1977):

South Coast Region (SC)

$Q_2 = 0.14 * A^{0.72} * p^{1.62}$
$Q_5 = 0.40 * A^{0.77} * p^{1.69}$
$Q_{10} = 0.63 * A^{0.79} * p^{1.75}$
$Q_{25} = 1.10 * A^{0.81} * p^{1.81}$
$Q_{50} = 1.50 * A^{0.82} * p^{1.85}$
$Q_{100} = 1.95 * A^{0.83} * p^{1.87}$

A = drainage area (mi2),
p = mean annual precipitation (in/yr),

Munch Creek

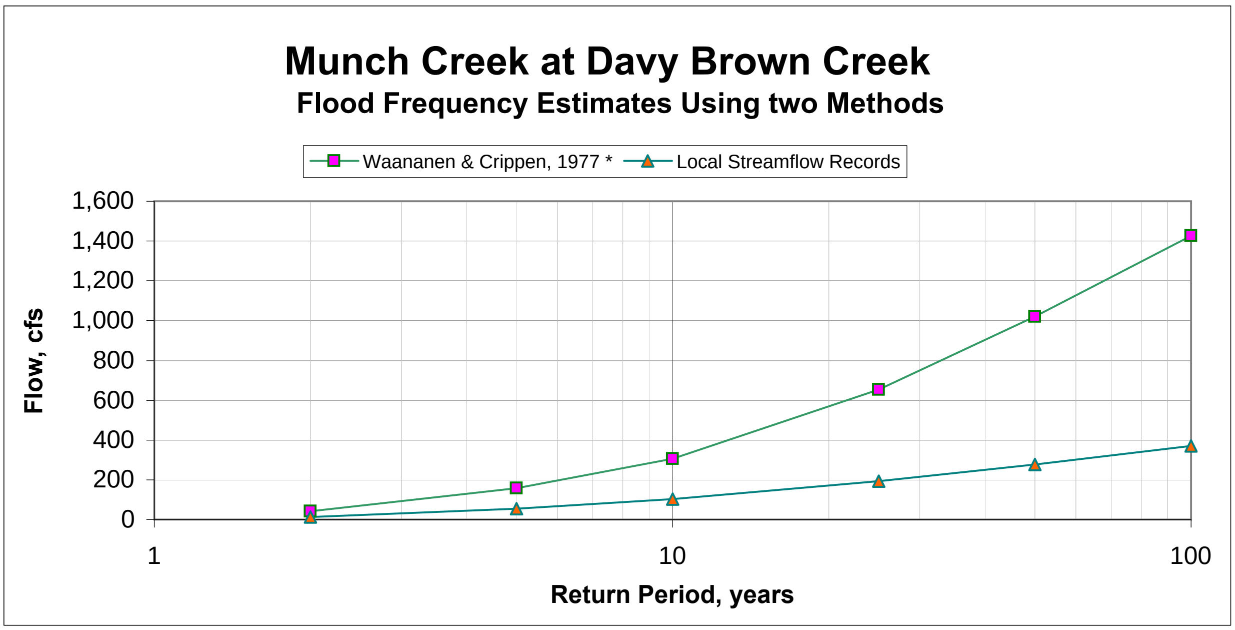
Summary of Peak Flow Calculations

Davy Brown Creek - Munch Creek

Drainage Area (mi^2) = **2.7**

Mean Annual Precip. (in/yr) = **22.0** 20-24

Method	Q-2yr (cfs)	Q-5yr (cfs)	Q-10yr (cfs)	Q-25yr (cfs)	Q-50yr (cfs)	Q-100yr (cfs)
Waananen & Crippen, 1977 *	42	158	306	655	1,021	1,426
Local Streamflow Records						
Average	12	54	104	193	276	370
Mimium Estimate	3	13	27	60	98	151
Maximum Estimate	32	114	193	308	397	524



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South Coast Region (SC)

$Q_2 = 0.14 * A^{0.72} * p^{1.62}$

$Q_5 = 0.40 * A^{0.77} * p^{1.69}$

$Q_{10} = 0.63 * A^{0.79} * p^{1.75}$

$Q_{25} = 1.10 * A^{0.81} * p^{1.81}$

$Q_{50} = 1.50 * A^{0.82} * p^{1.85}$

$Q_{100} = 1.95 * A^{0.83} * p^{1.87}$

A = drainage area (mi2),
p = mean annual precipitation (in/yr),

Manzana Creek, Santa Barbara County, CA

Flood Frequency Analysis Based on Local Streamflow Records

Peak flows associated with the 2-yr, 25-yr, 50-yr, and 100-yr recurrence intervals were estimated using a Log-Pearson type **III** distribution as described in Bulletin 17B (Guidelines for Determining Flood Flow Frequency, USGS, 1982).

Site Name	Location		Drainage Area (mi^2)	Record Length (yrs)	Recurrence Interval of Peak Flows 2-yr (cfs/mi^2)	5-yr (cfs/mi^2)	10-yr (cfs/mi^2)	25-yr (cfs/mi^2)	50-yr (cfs/mi^2)	100-yr (cfs/mi^2)
USGS ZACA C NR BUELLTON CA	34°38'55"	120°11'00"	32.80	34	1	11	25	54	85	121
USGS ALAMO PINTADO C NR SOLVANG CA	34°37'06"	120°07'11"	29.40	32	4	22	48	97	143	197
USGS SANTA CRUZ C NR SANTA YNEZ CA	34°35'48"	119°54'28"	74.00	65	12	43	72	115	149	182
USGS ZACA C A BUELLTON CA	34°36'50"	120°11'30"	39.40	24	1	5	10	22	37	57

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Min	1	5	10	22	37	57
Max	12	43	72	115	149	197
Average	5	20	39	72	103	139

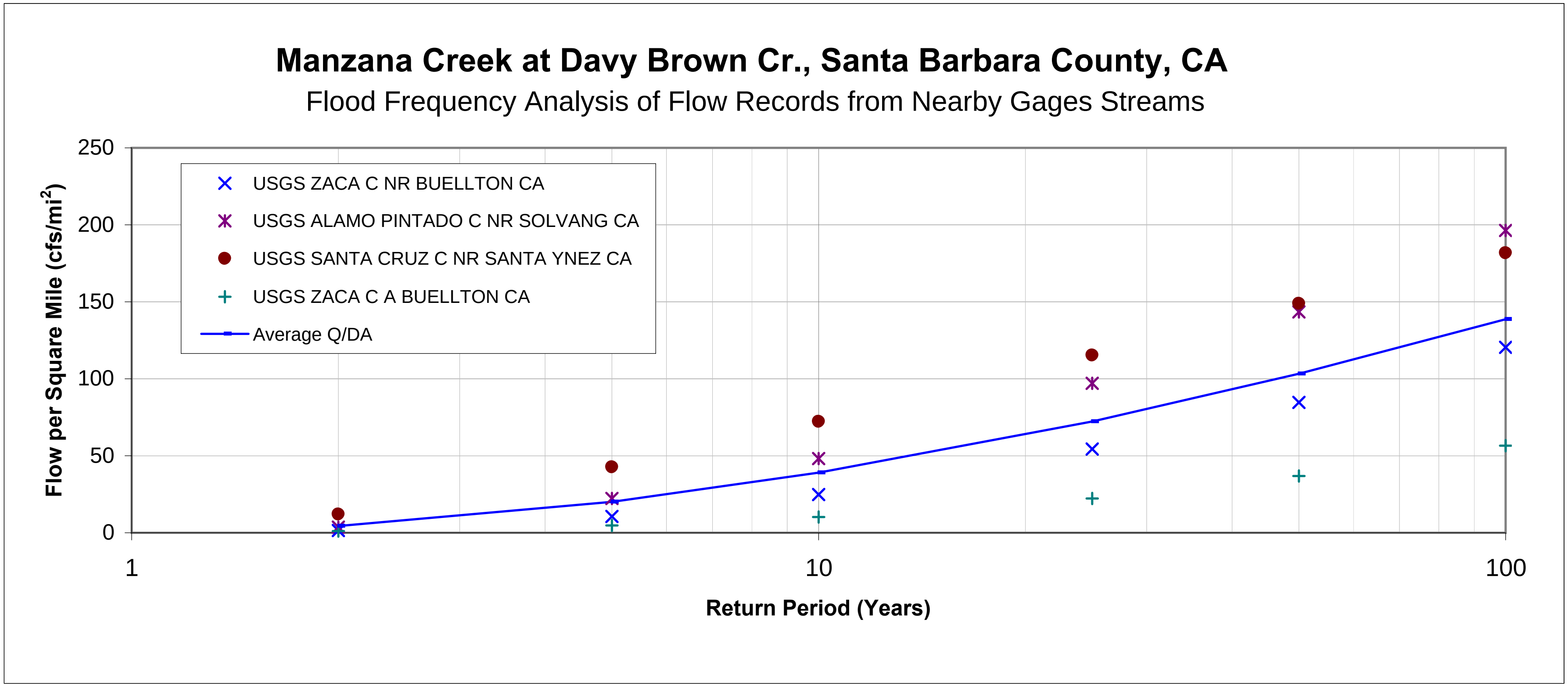
Peak Flow Estimates:

Peak flows for project site estimated from local streamflow records, adjusted by drainage area.

Manzana Creek at the confluence of Davy Brown (includes Davy Brown)

Drainage Area = 39.06 mi^2

	Q 2-yr	Q 5-yr	Q 10-yr	Q 25-yr	Q 50-yr	Q 100-yr
Average (cfs)	**178**	**785**	**1,519**	**2,824**	**4,038**	**5,422**
Minimum (cfs)	**40**	**185**	**399**	**876**	**1,434**	**2,207**
Maximum (cfs)	**469**	**1,669**	**2,824**	**4,507**	**5,813**	**7,675**



Manzana Creek at Davy Brown Cr., Santa Barbara County, CA
Flood Frequency Analysis of Flow Records from Nearby Gages Streams
250
200
150
100
50
0
Flow per Square Mile (cfs/mi2)
1
10
100
Return Period (Years)
USGS ZACA C NR BUELLTON CA
USGS ALAMO PINTADO C NR SOLVANG CA
USGS SANTA CRUZ C NR SANTA YNEZ CA
USGS ZACA C A BUELLTON CA
Average Q/DA

Davy Brown Creek, Santa Barbara County, CA

Flood Frequency Analysis Based on Local Streamflow Records

Peak flows associated with the 2-yr, 25-yr, 50-yr, and 100-yr recurrence intervals were estimated using a Log-Pearson type III distribution as described in Bulletin 17B (Guidelines for Determining Flood Flow Frequency, USGS, 1982).

Site Name	Location		Drainage Area (mi^2)	Record Length (yrs)	Recurrence Interval of Peak Flows 2-yr (cfs/mi^2)	5-yr (cfs/mi^2)	10-yr (cfs/mi^2)	25-yr (cfs/mi^2)	50-yr (cfs/mi^2)	100-yr (cfs/mi^2)
USGS ZACA C NR BUELLTON CA	34°38'55"	120°11'00"	32.80	34	1	11	25	54	85	121
USGS ALAMO PINTADO C NR SOLVANG CA	34°37'06"	120°07'11"	29.40	32	4	22	48	97	143	197
USGS SANTA CRUZ C NR SANTA YNEZ CA	34°35'48"	119°54'28"	74.00	65	12	43	72	115	149	182
USGS ZACA C A BUELLTON CA	34°36'50"	120°11'30"	39.40	24	1	5	10	22	37	57

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Min	1	5	10	22	37	57
Max	12	43	72	115	149	197
Average	5	20	39	72	103	139

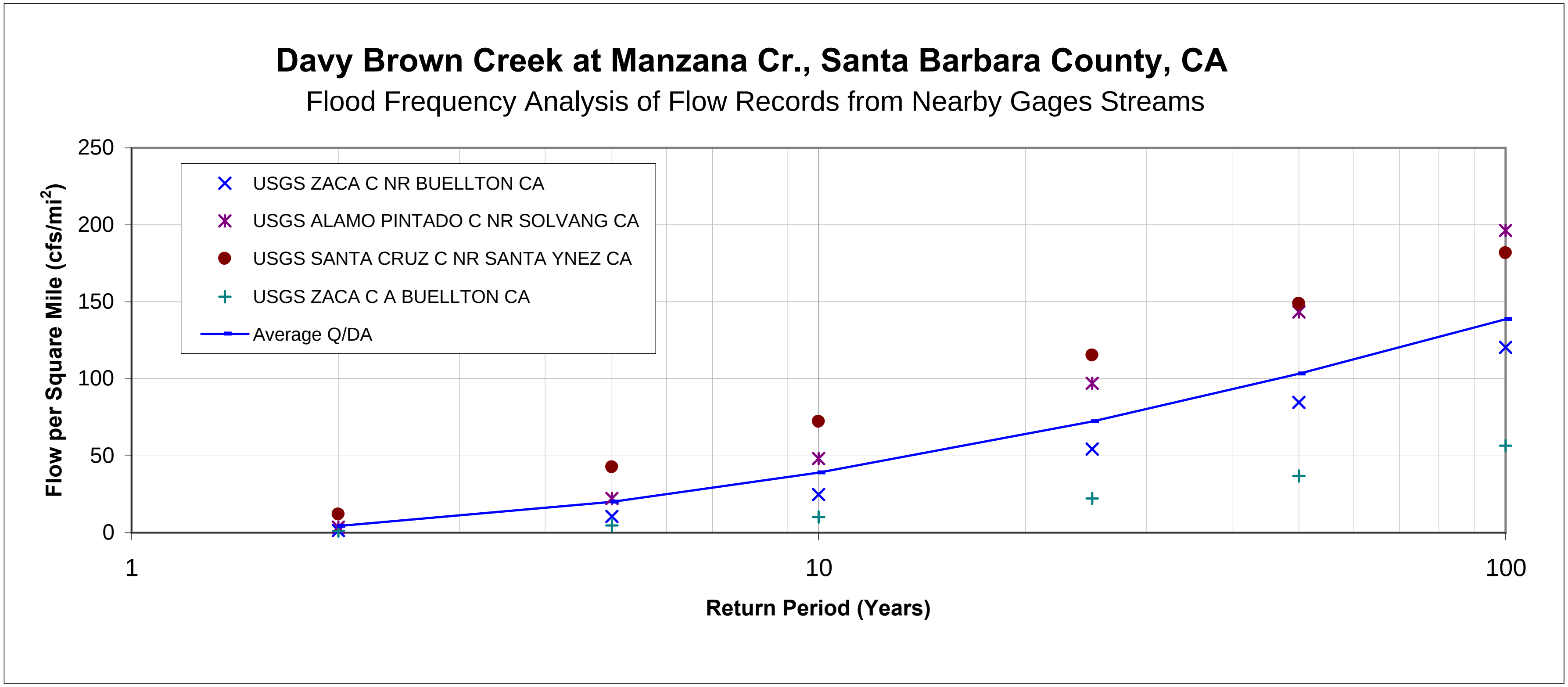
Peak Flow Estimates:

Peak flows for project site estimated from local streamflow records, adjusted by drainage area.

Davy Brown Creek - at Manzana Creek

Drainage Area = 7.81 mi^2

	Q 2-yr	Q 5-yr	Q 10-yr	Q 25-yr	Q 50-yr	Q 100-yr
Average (cfs)	36	157	304	565	807	1,084
Minimum (cfs)	8	37	80	175	287	441
Maximum (cfs)	94	334	565	901	1,162	1,534


Davy Brown Creek at Manzana Cr., Santa Barbara County, CA
Flood Frequency Analysis of Flow Records from Nearby Gages Streams
Flow per Square Mile (cfs/mi^2)
250
200
150
100
50
0
1
10
100
Return Period (Years)
USGS ZACA C NR BUELLTON CA
USGS ALAMO PINTADO C NR SOLVANG CA
USGS SANTA CRUZ C NR SANTA YNEZ CA
USGS ZACA C A BUELLTON CA
Average Q/DA

Davy Brown Creek, Santa Barbara County, CA

Flood Frequency Analysis Based on Local Streamflow Records

Peak flows associated with the 2-yr, 25-yr, 50-yr, and 100-yr recurrence intervals were estimated using a Log-Pearson type III distribution as described in Bulletin 17B (Guidelines for Determining Flood Flow Frequency, USGS, 1982).

Site Name	Location		Drainage Area (mi^2)	Record Length (yrs)	Recurrence Interval of Peak Flows 2-yr (cfs/mi^2)	5-yr (cfs/mi^2)	10-yr (cfs/mi^2)	25-yr (cfs/mi^2)	50-yr (cfs/mi^2)	100-yr (cfs/mi^2)
USGS ZACA C NR BUELLTON CA	34°38'55"	120°11'00"	32.80	34	1	11	25	54	85	121
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USGS ZACA C A BUELLTON CA	34°36'50"	120°11'30"	39.40	24	1	5	10	22	37	57

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Min	1	5	10	22	37	57
Max	12	43	72	115	149	197
Average	5	20	39	72	103	139

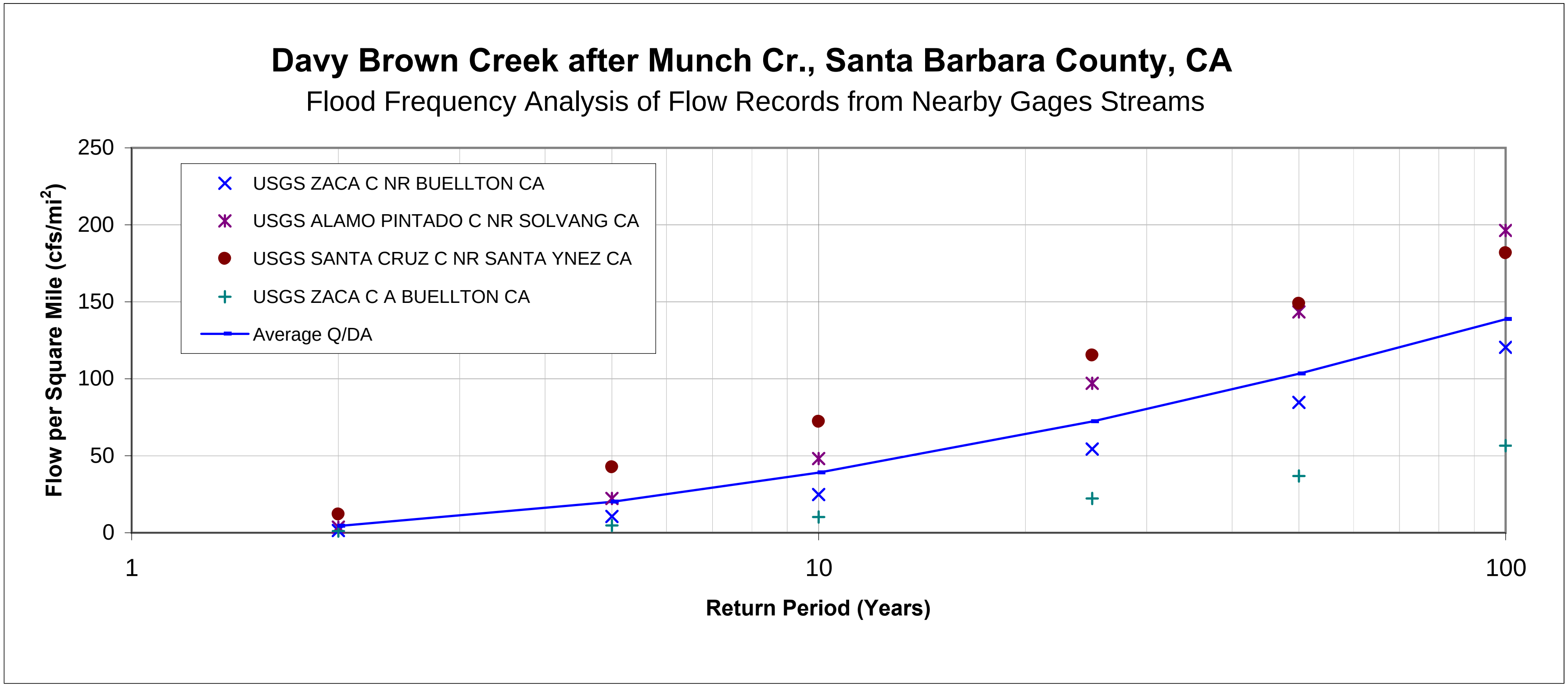
Peak Flow Estimates:

Peak flows for project site estimated from local streamflow records, adjusted by drainage area.

Davy Brown Creek - Upper Drainage

Drainage Area = 6.86 mi^2

	Q 2-yr	Q 5-yr	Q 10-yr	Q 25-yr	Q 50-yr	Q 100-yr
Average (cfs)	**31**	**138**	**267**	**496**	**709**	**952**
Minimum (cfs)	**7**	**33**	**70**	**154**	**252**	**388**
Maximum (cfs)	**82**	**293**	**496**	**791**	**1,021**	**1,348**


Davy Brown Creek after Munch Cr., Santa Barbara County, CA
Flood Frequency Analysis of Flow Records from Nearby Gages Streams
Flow per Square Mile (cfs/mi^2)
250
200
150
100
50
0
1
10
100
Return Period (Years)
USGS ZACA C NR BUELLTON CA
USGS ALAMO PINTADO C NR SOLVANG CA
USGS SANTA CRUZ C NR SANTA YNEZ CA
USGS ZACA C A BUELLTON CA
Average Q/DA

Davy Brown Creek, Santa Barbara County, CA

Flood Frequency Analysis Based on Local Streamflow Records

Peak flows associated with the 2-yr, 25-yr, 50-yr, and 100-yr recurrence intervals were estimated using a Log-Pearson type III distribution as described in Bulletin 17B (Guidelines for Determining Flood Flow Frequency, USGS, 1982).

					Recurrence Interval of Peak Flows					
Site Name	Location		Drainage Area (mi^2)	Record Length (yrs)	2-yr (cfs/mi^2)	5-yr (cfs/mi^2)	10-yr (cfs/mi^2)	25-yr (cfs/mi^2)	50-yr (cfs/mi^2)	100-yr (cfs/mi^2)
USGS ZACA C NR BUELLTON CA	34°38'55"	120°11'00"	32.80	34	1	11	25	54	85	121
USGS ALAMO PINTADO C NR SOLVANG CA	34°37'06"	120°07'11"	29.40	32	4	22	48	97	143	197
USGS SANTA CRUZ C NR SANTA YNEZ CA	34°35'48"	119°54'28"	74.00	65	12	43	72	115	149	182
USGS ZACA C A BUELLTON CA	34°36'50"	120°11'30"	39.40	24	1	5	10	22	37	57

Min	1	5	10	22	37	57
Max	12	43	72	115	149	197
Average	5	20	39	72	103	139

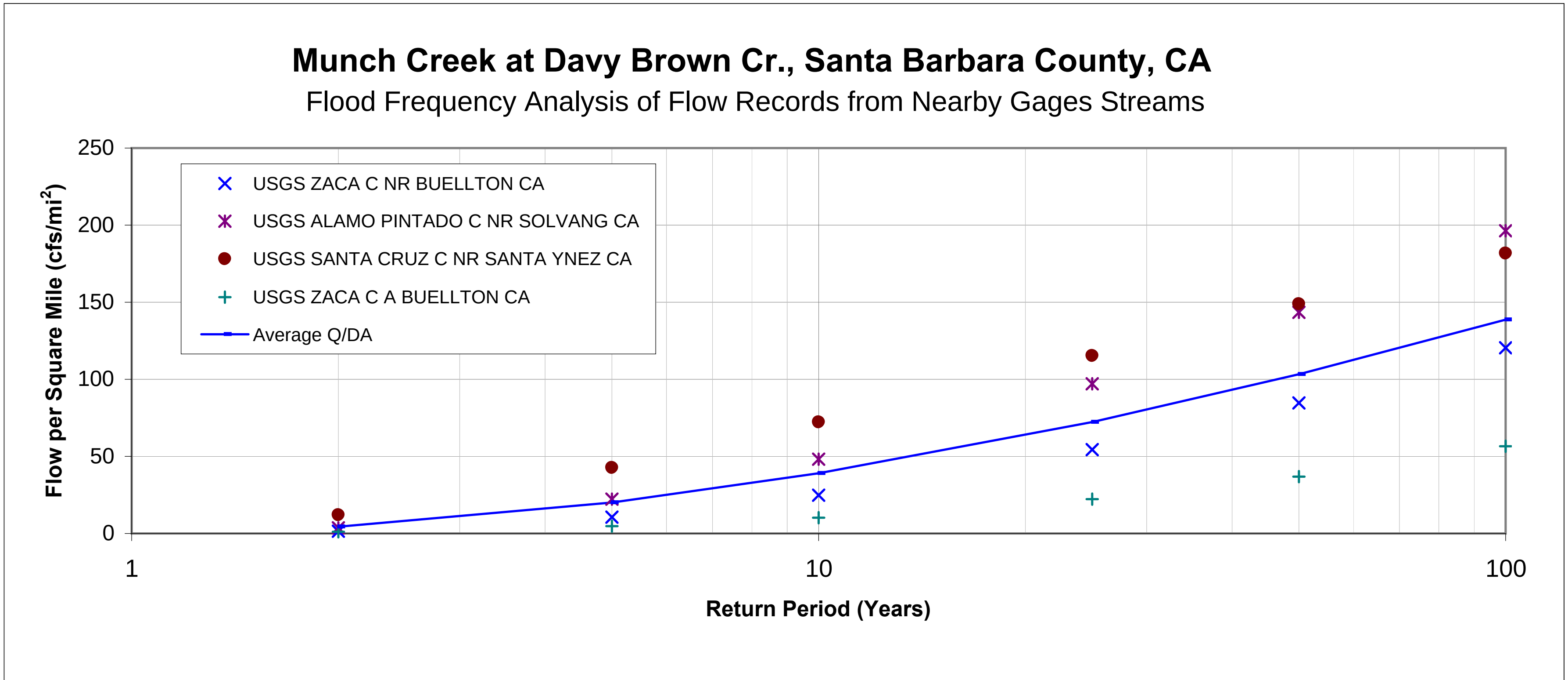
Peak Flow Estimates:

Peak flows for project site estimated from local streamflow records, adjusted by drainage area.

Davy Brown Creek - Munch Creek

Drainage Area = 2.67 mi^2

	Q 2-yr	Q 5-yr	Q 10-yr	Q 25-yr	Q 50-yr	Q 100-yr
Average (cfs)	**12**	**54**	**104**	**193**	**276**	**370**
Minimum (cfs)	**3**	**13**	**27**	**60**	**98**	**151**
Maximum (cfs)	**32**	**114**	**193**	**308**	**397**	**524**


Munch Creek at Davy Brown Cr., Santa Barbara County, CA
Flood Frequency Analysis of Flow Records from Nearby Gages Streams
Flow per Square Mile (cfs/mi2)
250
200
150
100
50
0
1
10
100
Return Period (Years)
USGS ZACA C NR BUELLTON CA
USGS ALAMO PINTADO C NR SOLVANG CA
USGS SANTA CRUZ C NR SANTA YNEZ CA
USGS ZACA C A BUELLTON CA
Average Q/DA

Flood Frequency based on Annual Maximum Series

USGS ALAMO PINTADO C NR SOLVANG CA

Station # 11128250

Drainage Area sq. mi **29.4**

Location: **34°37'06"** **120°07'11"** **NAD27**

WY	Date of Peak	Discharge (cfs)	RANK	Recurrence Interval (years)	Dischage (cfs)	Discharge (cms)	log-discharge (cfs)
	1/25/1969	10.32	1	33.00	3680	104	3.57
	12/21/1970	12	2	16.50	900	25	2.95
	12/27/1971	0.75	3	11.00	865	24	2.94
	1/18/1973	466	4	8.25	863	24	2.94
	1/7/1974	93	5	6.60	812	23	2.91
	3/7/1975	40	6	5.50	724	21	2.86
	9/28/1976	8.8	7	4.71	615	17	2.79
	1/2/1977	7	8	4.13	486	14	2.69
	2/9/1978	724	9	3.67	466	13	2.67
	3/27/1979	106	10	3.30	462	13	2.66
	2/19/1980	397	11	3.00	397	11	2.60
	3/5/1981	139	12	2.75	222	6	2.35
	4/11/1982	42	13	2.54	180	5	2.26
	12/25/1982	900	14	2.36	139	4	2.14
	12/25/1983	126	15	2.20	126	4	2.10
	12/19/1984	40	16	2.06	106	3	2.03
	1990	0	17	1.94	93	3	1.97
	3/18/1991	865	18	1.83	88	2	1.94
	2/12/1992	615	19	1.74	73	2	1.86
	3/10/1995	863	20	1.65	62	2	1.79
	2/20/1996	486	21	1.57	54	2	1.73
	12/22/1996	180	22	1.50	42	1	1.62
	2/3/1998	3680	23	1.43	40	1	1.60
	3/20/1999	73	24	1.38	40	1	1.60
	2/23/2000	222	25	1.32	36	1	1.56
	3/5/2001	462	26	1.27	12	0	1.08
	11/24/2001	54	27	1.22	10.32	0	1.01
	12/19/2002	36	28	1.18	8.8	0	0.94
	2/26/2004	62	29	1.14	8.4	0	0.92
	2/21/2005	812	30	1.10	7	0	0.85
	4/5/2006	88	31	1.06	0.75	0	-0.12
	10/13/2006	8.4	32	1.03	0.01	0	-2.00

Number of Years, n =	32		
Skewness =	4.05	4.05	-1.66
Mean=	363	10	1.90
Std Dev=	676	19	1.07

Peaks Flow Frequency

From USGS Data

Station # 11128250

Generalized Skew=	**-0.30**	A=	-0.02238
Station Skewness (log Q)=	-1.66	B=	0.50873
Station Mean (log Q)=	1.90	MSE (station skew) =	0.52558
Station Std Dev (log Q)=	1.07		
Weighted Skewness (G_W)=	**-0.80**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.96561	7
1.5	0.667	-0.31672	36
2.0	0.500	0.13131	110
2.33	0.429	0.29901	166
5.0	0.200	0.85611	658
10	0.100	1.16648	1,416
25	0.040	1.44981	2,852
50	0.020	1.60843	4,219
100	0.010	1.73577	5,778

Values From K-Table for Linear interpolation

Weighted Skewnes	-0.80	-0.70	-0.80
P	K	K	K
0.9	-1.33640	-1.33294	-1.33626
0.8	-0.77986	-0.79022	-0.78029
0.7	-0.41309	-0.42851	-0.41373
0.6	-0.12199	-0.13901	-0.12270
0.500	0.13199	0.11578	0.13131
0.429	0.29961	0.28516	0.29901
0.200	0.85607	0.85703	0.85611
0.100	1.16574	1.18347	1.16648
0.040	1.44813	1.48852	1.44981
0.020	1.60604	1.66325	1.60843
0.010	1.73271	1.80621	1.73577

Flood Frequency based on Annual Maximum Series

USGS ZACA C NR BUELLTON CA

Station # 11129800

Drainage Area sq. mi **32.80**

Location: **34°38'55"** **120°11'00"** **NAD27**

WY	Date of Peak	Discharge (cfs)	RANK	Recurrence Interval (years)	Dischage (cfs)	Discharge (cms)	log-discharge (cfs)
	5/16/1905	0	1	35.00	1390	39	3.14
	11/19/1963	8	2	17.50	1070	30	3.03
	11/12/1964	8	3	11.67	743	21	2.87
	2/6/1966	6	4	8.75	512	14	2.71
	12/6/1966	191	5	7.00	496	14	2.70
	3/13/1968	1	6	5.83	484	14	2.68
	2/24/1969	1390	7	5.00	246	7	2.39
	3/4/1970	9	8	4.38	236	7	2.37
	12/21/1970	3	9	3.89	233	7	2.37
	12/27/1971	5	10	3.50	205	6	2.31
	1/18/1973	205	11	3.18	191	5	2.28
	3/30/1974	16	12	2.92	142	4	2.15
	2/2/1975	48	13	2.69	123	3	2.09
	9/29/1976	45	14	2.50	103	3	2.01
	1/6/1977	14	15	2.33	96	3	1.98
	3/4/1978	743	16	2.19	52	1	1.72
	3/29/1979	28	17	2.06	48	1	1.68
	2/19/1980	96	18	1.94	45	1	1.65
	3/5/1981	142	19	1.84	32	1	1.51
	6/12/1905	0	20	1.75	28	1	1.45
	3/19/1991	233	21	1.67	28	1	1.45
	2/15/1992	512	22	1.59	16	0	1.20
	1/25/1995	496	23	1.52	14	0	1.15
	2/20/1996	103	24	1.46	12	0	1.08
	1/24/1997	52	25	1.40	9.8	0	0.99
	2/3/1998	1070	26	1.35	9	0	0.95
	2/9/1999	28	27	1.30	8	0	0.90
	2/23/2000	246	28	1.25	8	0	0.90
	3/5/2001	484	29	1.21	6	0	0.78
	11/24/2001	9.8	30	1.17	5	0	0.70
	12/20/2002	32	31	1.13	3	0	0.48
	2/25/2004	12	32	1.09	1	0	0.00
	1/9/2005	236	33	1.06	0.01	0	-2.00
	4/5/2006	123	34	1.03	0.01	0	-2.00

Number of Years, n =	34		
Skewness =	2.45	2.45	-1.44
Mean=	194	5	1.52
Std Dev=	321	9	1.19

Peaks Flow Frequency

From USGS Data

Station # 11129800

Generalized Skew=	**-0.30**	A=	-0.08931
Station Skewness (log Q)=	-1.44	B=	0.56674
Station Mean (log Q)=	1.52	MSE (station skew) =	0.40689
Station Std Dev (log Q)=	1.19		
Weighted Skewness (G_W)=	**-0.78**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.96631	2
1.5	0.667	-0.31864	14
2.0	0.500	0.12936	47
2.33	0.429	0.29727	75
5.0	0.200	0.85623	346
10	0.100	1.16861	815
25	0.040	1.45467	1,786
50	0.020	1.61531	2,774
100	0.010	1.74462	3,954

Values From K-Table for Linear interpolation

Weighted Skewnes	-0.80	-0.70	-0.78
P	K	K	K
0.9	-1.33640	-1.33294	-1.33584
0.8	-0.77986	-0.79022	-0.78154
0.7	-0.41309	-0.42851	-0.41559
0.6	-0.12199	-0.13901	-0.12475
0.500	0.13199	0.11578	0.12936
0.429	0.29961	0.28516	0.29727
0.200	0.85607	0.85703	0.85623
0.100	1.16574	1.18347	1.16861
0.040	1.44813	1.48852	1.45467
0.020	1.60604	1.66325	1.61531
0.010	1.73271	1.80621	1.74462

Flood Frequency based on Annual Maximum Series

USGS ZACA C A BUELLTON CA

Station # 11130000

Drainage Area sq. mi **39.40**

Location: **34°36'50"** **120°11'30"** **NAD27**

WY	Date of Peak	Discharge (cfs)
	3/3/1941	874
	12/28/1941	44
	1/22/1943	340
	2/22/1944	225
	2/2/1945	32
	3/29/1946	21
	11/20/1946	8
	3/24/1948	0.4
	3/4/1949	185
	12/8/1949	88
	10/26/1950	6.8
	1/15/1952	622
	12/30/1952	70
	1/19/1954	8
	1/9/1955	24
	1/26/1956	23
	5/11/1957	8.3
	4/3/1958	273
	2/21/1959	30
	2/1/1960	8
	1/26/1961	5
	2/11/1962	560
	3/28/1963	49
	1/26/1964	5

RANK	Recurrence Interval (years)	Dischage (cfs)	Discharge (cms)	log-discharge (cfs)
1	25.00	874	25	2.94
2	12.50	622	18	2.79
3	8.33	560	16	2.75
4	6.25	340	10	2.53
5	5.00	273	8	2.44
6	4.17	225	6	2.35
7	3.57	185	5	2.27
8	3.13	88	2	1.94
9	2.78	70	2	1.85
10	2.50	49	1	1.69
11	2.27	44	1	1.64
12	2.08	32	1	1.51
13	1.92	30	1	1.48
14	1.79	24	1	1.38
15	1.67	23	1	1.36
16	1.56	21	1	1.32
17	1.47	8.3	0	0.92
18	1.39	8	0	0.90
19	1.32	8	0	0.90
20	1.25	8	0	0.90
21	1.19	6.8	0	0.83
22	1.14	5	0	0.70
23	1.09	5	0	0.70
24	1.04	0.4	0	-0.40

Number of Years, n =	24		
Skewness =	2.03	2.03	-0.18
Mean=	146	4	1.57
Std Dev=	233	7	0.82

Peaks Flow Frequency

From USGS Data

Station # 11130000

Generalized Skew=	**-0.30**	A=	-0.31574
Station Skewness (log Q)=	-0.18	B=	0.89366
Station Mean (log Q)=	1.57	MSE (station skew) =	0.22104
Station Std Dev (log Q)=	0.82		
Weighted Skewness (Gw)=	**-0.23**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.98681	6
1.5	0.667	-0.40251	17
2.0	0.500	0.03820	40
2.33	0.429	0.21390	56
5.0	0.200	0.85075	187
10	0.100	1.25436	402
25	0.040	1.66909	884
50	0.020	1.92854	1,446
100	0.010	2.15599	2,227

Values From K-Table for Linear interpolation

Weighted Skewnes	-0.30	-0.20	-0.23
P	K	K	K
0.9	-1.30936	-1.30105	-1.30352
0.8	-0.82377	-0.83044	-0.82846
0.7	-0.48600	-0.49927	-0.49533
0.6	-0.20552	-0.22168	-0.21688
0.500	0.04993	0.03325	0.03820
0.429	0.22492	0.20925	0.21390
0.200	0.85285	0.84986	0.85075
0.100	1.24516	1.25824	1.25436
0.040	1.64329	1.67999	1.66909
0.020	1.88959	1.94499	1.92854
0.010	2.10294	2.17840	2.15599

Flood Frequency based on Annual Maximum Series

USGS SANTA CRUZ C NR SANTA YNEZ CA

Station # 11124500

Drainage Area sq. mi **74.00**

Location: 34°35'48" 119°54'28" **NAD27**

WY	Date of Peak	Discharge (cfs)	RANK	Recurrence Interval (years)	Dischage (cfs)	Discharge (cms)	log-discharge (cfs)
	12/28/1941	472	1	66.00	7050	200	3.85
	2/22/1944	2500	2	33.00	5800	164	3.76
	2/2/1945	2700	3	22.00	5480	155	3.74
	3/30/1946	1300	4	16.50	5060	143	3.70
	11/20/1946	910	5	13.20	4820	136	3.68
	4/10/1948	19	6	11.00	4520	128	3.66
	3/11/1949	140	7	9.43	4360	123	3.64
	2/6/1950	1160	8	8.25	3980	113	3.60
	3/2/1951	1.5	9	7.33	3960	112	3.60
	1/15/1952	2690	10	6.60	3580	101	3.55
	1/13/1953	261	11	6.00	3200	91	3.51
	1/24/1954	1540	12	5.50	3110	88	3.49
	2/17/1955	168	13	5.08	3100	88	3.49
	1/26/1956	2040	14	4.71	2700	76	3.43
	1/13/1957	559	15	4.40	2690	76	3.43
	4/3/1958	3580	16	4.13	2620	74	3.42
	2/16/1959	930	17	3.88	2500	71	3.40
	2/1/1960	918	18	3.67	2220	63	3.35
	12/2/1960	35	19	3.47	2160	61	3.33
	2/9/1962	4520	20	3.30	2040	58	3.31
	2/9/1963	398	21	3.14	2030	57	3.31
	4/1/1964	145	22	3.00	1800	51	3.26
	4/9/1965	308	23	2.87	1690	48	3.23
	12/29/1965	2030	24	2.75	1650	47	3.22
	12/6/1966	5800	25	2.64	1540	44	3.19
	3/8/1968	472	26	2.54	1400	40	3.15
	2/24/1969	7050	27	2.44	1380	39	3.14
	3/1/1970	910	28	2.36	1300	37	3.11
	11/29/1970	1100	29	2.28	1290	37	3.11
	12/25/1971	436	30	2.20	1160	33	3.06
	1/18/1973	2160	31	2.13	1100	31	3.04
	1/7/1974	648	32	2.06	930	26	2.97
	3/7/1975	1400	33	2.00	918	26	2.96
	2/9/1976	234	34	1.94	910	26	2.96
	5/9/1977	71	35	1.89	910	26	2.96
	2/9/1978	5060	36	1.83	868	25	2.94
	3/28/1979	673	37	1.78	735	21	2.87
	2/16/1980	2620	38	1.74	681	19	2.83
	3/4/1981	735	39	1.69	673	19	2.83
	4/1/1982	681	40	1.65	648	18	2.81
	3/1/1983	3960	41	1.61	599	17	2.78
	12/25/1983	1290	42	1.57	595	17	2.77
	2/9/1985	256	43	1.53	559	16	2.75
	2/14/1986	1650	44	1.50	472	13	2.67
	3/6/1987	203	45	1.47	472	13	2.67
	2/28/1988	1800	46	1.43	436	12	2.64
	2/9/1989	211	47	1.40	398	11	2.60
	2/18/1990	1.9	48	1.38	313	9	2.50
	3/19/1991	3100	49	1.35	308	9	2.49
	2/12/1992	4820	50	1.32	272	8	2.43
	2/23/1993	3200	51	1.29	261	7	2.42
	2/20/1994	313	52	1.27	256	7	2.41
	3/10/1995	3110	53	1.25	234	7	2.37
	2/20/1996	1690	54	1.22	211	6	2.32
	1/23/1997	2220	55	1.20	203	6	2.31
	2/23/1998	4360	56	1.18	168	5	2.23
	2/9/1999	272	57	1.16	145	4	2.16
	2/21/2000	595	58	1.14	140	4	2.15
	3/5/2001	3980	59	1.12	71	2	1.85
	12/30/2001	44	60	1.10	44	1	1.64
	3/15/2003	868	61	1.08	35	1	1.54
	2/25/2004	599	62	1.06	19	1	1.28
	2/21/2005	5480	63	1.05	6.8	0	0.83
	1/2/2006	1380	64	1.03	1.9	0	0.28
	1/28/2007	6.8	65	1.02	1.5	0	0.18

Number of Years, n =	65		
Skewness =	1.31	1.31	-1.52
Mean=	1612	46	2.83
Std Dev=	1684	48	0.78

Peaks Flow Frequency

From USGS Data

Station # 11124500

Generalized Skew=	**-0.30**	A=	-0.06500
Station Skewness (log Q)=	-1.52	B=	0.54567
Station Mean (log Q)=	2.83	MSE (station skew) =	0.31004
Station Std Dev (log Q)=	0.78		
Weighted Skewness (G_W)=	**-0.90**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.95895	121
1.5	0.667	-0.29956	397
2.0	0.500	0.14812	889
2.33	0.429	0.31373	1,197
5.0	0.200	0.85425	3,161
10	0.100	1.14705	5,351
25	0.040	1.40706	8,539
50	0.020	1.54867	11,014
100	0.010	1.65977	13,449

Values From K-Table for Linear interpolation

Weighted Skewness	-1.00	-0.90	-0.90
P	K	K	K
0.9	-1.34039	-1.33889	-1.33890
0.8	-0.75752	-0.76902	-0.76898
0.7	-0.38111	-0.39729	-0.39724
0.6	0.08763	-0.10486	-0.10421
0.500	0.16397	0.14807	0.14812
0.429	0.32740	0.31368	0.31373
0.200	0.85161	0.85426	0.85425
0.100	1.12762	1.14712	1.14705
0.040	1.36584	1.40720	1.40706
0.020	1.49188	1.54886	1.54867
0.010	1.58838	1.66001	1.65977

Appendix B.

Fish Passage Flows

USGS Gaged Streams near Davy Brown Creek. Exceedance flows are given in per unit drainage area.

Station Number	Station Name	Drainage Area (sq. miles)	Record Length (years)	Coverage (WY)	H (Altitude Index per 1,000 ft)	P (Precipitation (in/yr))	Latitude	Longitude	95% Exceedence Discharge (cfs/mi^2)	90% Exceedence Discharge (cfs/mi^2)	50% Exceedence Discharge (cfs/mi^2)	10% Exceedence Discharge (cfs/mi^2)	5% Exceedence Discharge (cfs/mi^2)	2% Exceedence Discharge (cfs/mi^2)	1% Exceedence Discharge (cfs/mi^2)
11130000	ZACA C A BUELLTON CA	39.4	22	1941-1963			34.61388889	120.1861111	0.00	0.00	0.00	0.00	0.01	0.15	0.53
11129800	ZACA C A BUELLTON CA	32.8	46	1963-2009			34.64859614	-120.1843172	0.00	0.00	0.00	0.02	0.11	0.37	0.73
11128250	ALAMO PINTADO C NR SOLVANG CA	29.4	39	1970-2009			34.61831975	-120.120703	0.00	0.00	0.00	0.10	0.17	0.51	1.36
11124500	SANTA CRUZ C NR SANTA YNEZ CA	74	68	1941-2009			34.5966563	-119.9087519	0.00	0.00	0.02	0.46	1.09	2.53	4.32
	Summary - Average of exceedance flows								**0.00**	**0.00**	**0.01**	**0.14**	**0.34**	**0.89**	**1.74**
	Flows - Lower Davy Brown Creek: at Manzana Creek								**0.00**	**0.00**	**0.04**	**1.13**	**2.69**	**6.94**	**13.57**
	Flows - Upper Davy Brown Creek: after Munch Creek								**0.00**	**0.00**	**0.04**	**0.99**	**2.36**	**6.10**	**11.91**
	Flows - Munch Creek: at Davy Brown Creek								**0.00**	**0.00**	**0.01**	**0.39**	**0.92**	**2.37**	**4.63**

Criteria for determining fish passage flows at stream crossings

	Exceedance Flows	
Species and Age Class	**Lower Fish Passage Flow ***	**Upper Fish Passage Flow**
Adult Anadromous Salmonids	50% EP or 3 cfs	1%
Non-Anadromous Adult Salmonids	90% EP or 2 cfs	5%
Juvenile Salmonids	95% EPor 1 cfs	10%

* Use the greater of the two for determining the lower fish passage flow

	Lower Davy Brown Creek 7.81 sq mi		Upper Davy Brown Creek 6.86 sq mi		Munch Creek 2.67 sq mi	
	Exceedance Flows		Exceedance Flows		Exceedance Flows	
Species and Age Class	**Lower Fish Passage Flow (cfs)**	**Upper Fish Passage Flow (cfs)**	**Lower Fish Passage Flow (cfs)**	**Upper Fish Passage Flow (cfs)**	**Lower Fish Passage Flow (cfs)**	**Upper Fish Passage Flow (cfs)**
Adult Anadromous Salmonids	**3**	**13.6**	**3**	**11.9**	**3**	**4.6**
Non-Anadromous Adult Salmonids	**2**	**2.7**	**2**	**2.4**	**2**	**0.9**
Juvenile Salmonids	**1**	**1.1**	**1**	**1.0**	**1**	**0.4**

**Fish Passage flows along Davy Brown Creek based on average exceedance flows from 4 local stream gages and normalized by drainage area.*

Alternate Fish Passage Flows	Lower Davy Brown Creek 92	Q2 (cfs)	Upper Davy Brown Creek 84	Q2 (cfs)	Munch Creek 42	Q2 (cfs)
Species and Age Class	**Percent of 2-yr Recurrence Interval Flow**	**Upper Fish Passage Flow (cfs)**		**Upper Fish Passage Flow (cfs)**		**Upper Fish Passage Flow (cfs)**
Adult Anadromous Salmonids	50%	46.0		42.0		21.0
Non-Anadromous Adult Salmonids	30%	27.6		25.2		12.6
Juvenile Salmonids	10%	9.2		8.4		4.2

**Alternate High Fish Passage Flows from DFG, 2001*
***Q2 Determined from South Coast Regression Equations. (greater than LPIII estimates)*

Flow Duration Table for Gaged Streams within and near Davy Brown Creek. The average of the exceedance flows is used to estimate the fish passage flows.

Percent Time Flow is Equalled or Exceeded	ZACA C A BUELLTON CA	ZACA C A BUELLTON CA	ALAMO PINTADO C NR SOLVANG CA	SANTA CRUZ C NR SANTA YNEZ CA	Minimum Flow	Maximum Flow	Average Flow	Minimum Flow at Lower Davy Brown Ck	Maximum Flow at Lower Davy Brown Ck	Average Flow at Lower Davy Brown Ck	Minimum Flow at Upper Davy Brown Ck	Maximum Flow at Upper Davy Brown Ck	Average Flow at Upper Davy Brown Ck	Minimum Flow at Munch Ck	Maximum Flow at Munch Ck	Average Flow at Munch Ck
	(cfs/mi^2)	(cfs/mi^2)	(cfs/mi^2)	(cfs/mi^2)	(cfs/mi^2)	(cfs/mi^2)	(cfs/mi^2)	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
1%	0.533	0.732	1.361	4.324	0.533	4.324	1.737	4.162	33.764	13.565	3.655	29.655	11.915	1.422	11.534	4.634
2%	0.152	0.366	0.510	2.527	0.152	2.527	0.889	1.189	19.731	6.940	1.044	17.330	6.096	0.406	6.740	2.371
5%	0.005	0.107	0.170	1.095	0.005	1.095	0.344	0.040	8.546	2.687	0.035	7.507	2.360	0.014	2.919	0.918
10%	0.000	0.018	0.102	0.459	0.000	0.459	0.145	0.000	3.587	1.131	0.000	3.151	0.994	0.000	1.225	0.386
15%	0.000	0.006	0.058	0.257	0.000	0.257	0.080	0.000	2.005	0.625	0.000	1.761	0.549	0.000	0.685	0.214
20%	0.000	0.002	0.041	0.162	0.000	0.162	0.051	0.000	1.266	0.400	0.000	1.112	0.352	0.000	0.433	0.137
25%	0.000	0.000	0.030	0.115	0.000	0.115	0.036	0.000	0.897	0.282	0.000	0.788	0.248	0.000	0.306	0.096
30%	0.000	0.000	0.020	0.085	0.000	0.085	0.026	0.000	0.665	0.206	0.000	0.584	0.181	0.000	0.227	0.070
35%	0.000	0.000	0.015	0.062	0.000	0.062	0.019	0.000	0.485	0.150	0.000	0.426	0.132	0.000	0.166	0.051
40%	0.000	0.000	0.010	0.045	0.000	0.045	0.014	0.000	0.348	0.106	0.000	0.306	0.093	0.000	0.119	0.036
45%	0.000	0.000	0.005	0.031	0.000	0.031	0.009	0.000	0.243	0.071	0.000	0.213	0.062	0.000	0.083	0.024
50%	0.000	0.000	0.002	0.019	0.000	0.019	0.005	0.000	0.148	0.042	0.000	0.130	0.037	0.000	0.050	0.014
55%	0.000	0.000	0.000	0.011	0.000	0.011	0.003	0.000	0.088	0.022	0.000	0.077	0.019	0.000	0.030	0.007
60%	0.000	0.000	0.000	0.007	0.000	0.007	0.002	0.000	0.053	0.013	0.000	0.046	0.012	0.000	0.018	0.005
65%	0.000	0.000	0.000	0.004	0.000	0.004	0.001	0.000	0.031	0.008	0.000	0.027	0.007	0.000	0.010	0.003
70%	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.008	0.002	0.000	0.007	0.002	0.000	0.003	0.001
75%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
85%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
95%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
98%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99.5%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix C.

Stream Crossing Summaries

STREAM CROSSING SUMMARY SHEET

Site: Lower Sunset Valley Road at Davy Brown Creek
Road: Sunset Valley Road / Cachuma Road

General Information

Survey Date:	12/03/08
Survey Team:	Mike Love, Matt Stoecker
Stream Name:	Davy Brown Creek
Land Ownership:	LPNF
7.5 Minute Quad Name:	Bald MT
Lattitude:	34^o 46' 17.76" N
Longitude:	119^o 56' 39.58'' W
Tributary to:	Manzana Ck, Sisquoc River

Crossing Information

Shape:	Low water crossing	
Material:	Concrete	
Roughness (n):	0.013	
Inlet Type:	n/a	
Outlet Type:	Drop	
Length:	18	ft
Constant Slope:	1.9%	
Residual Outlet Depth:	1.7	ft
Depth over ford = 1 ft:	966	cfs

Hydrology

Drainage Area: 7.8 mi^2

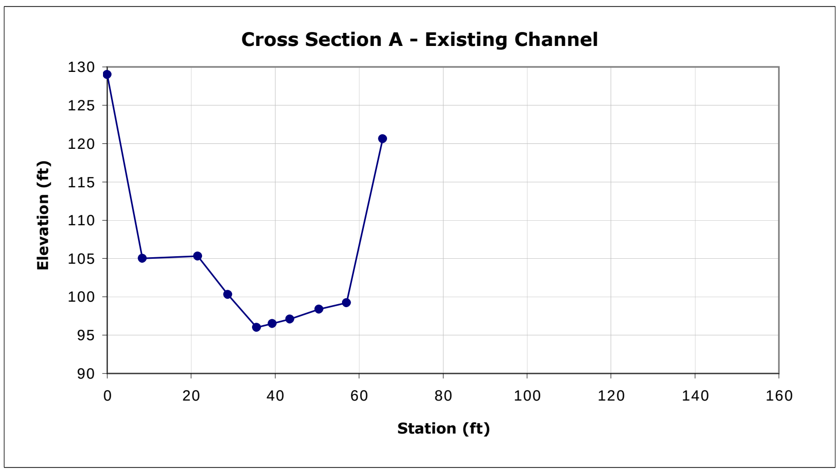
Estimated Flow*:

2-yr	92 cfs
5-yr	361 cfs
10-yr	714 cfs
25-yr	1,564 cfs
50-yr	2,463 cfs
100-yr	3,477 cfs

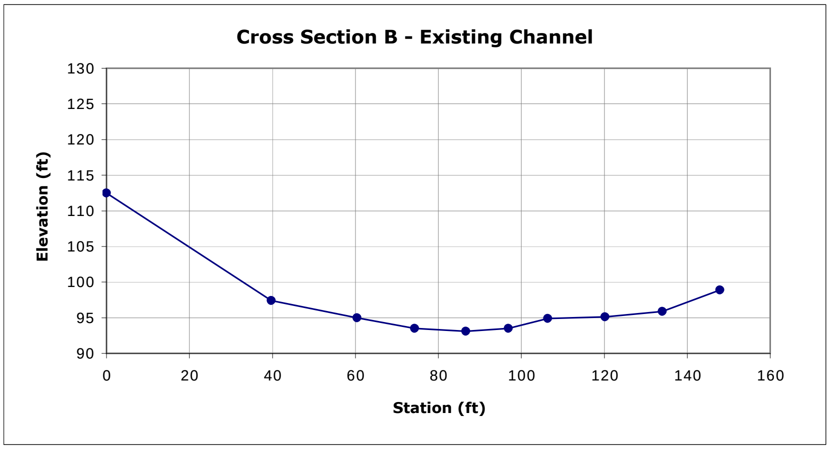
**Regional Regression Equations, Waananen & Crippen, 1977*

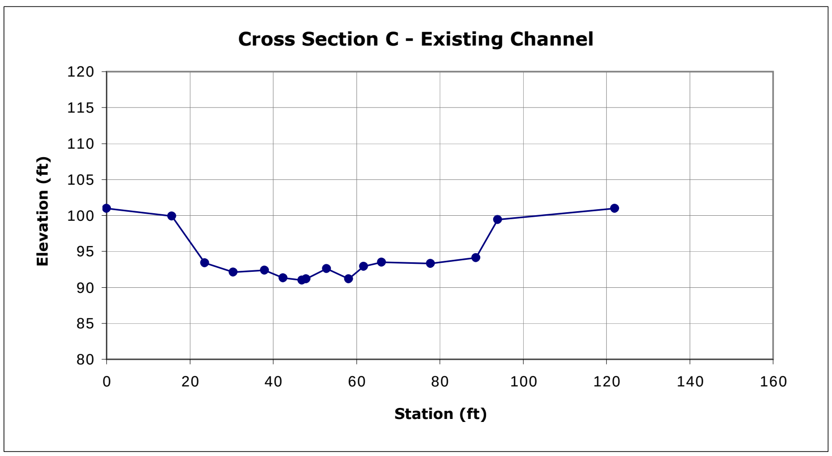
Channel Characteristics

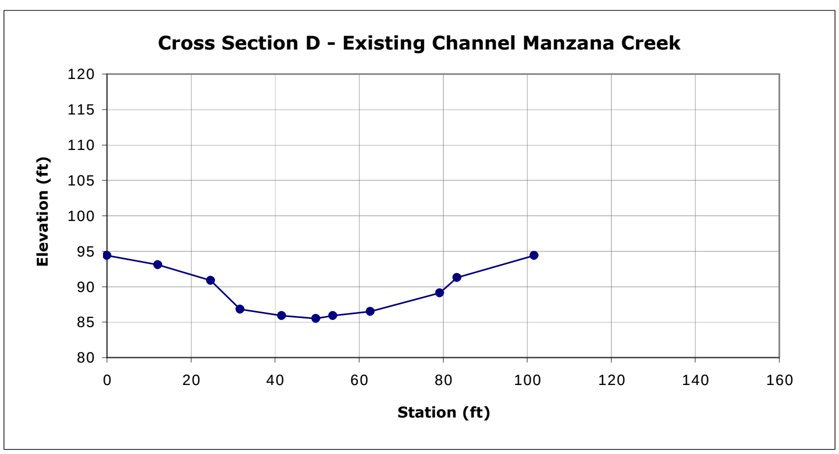
Mean Reach Slope:	2.8%
Bankfull Width:	30 ft
Active Channel Width:	25 ft



Site: Lower Sunset Valley Road at Davy Brown Creek
Road: Sunset Valley Road / Cachuma Road







STREAM CROSSING SUMMARY SHEET

Site: Upper Sunset Valley Road at Davy Brown Creek
Road: Sunset Valley Road / Cachuma Road

General Information

Survey Date:	12/03/08	7.5 Minute Quad Name:	Bald MT
Survey Team:	Mike Love, Matt Stoecker	Lattitude:	34° 45' 37.19" N
Stream Name:	Davy Brown Creek	Longitude:	119° 57' 14.27'' W
Land Ownership:	LPNF	Tributary to:	Manzana Crk, Sisquoc River

Crossing Information

Shape:	Low water crossing	
Material:	Concrete	
Roughness (n):	0.013	
Inlet Type:	n/a	
Outlet Type:	Drop	
Length:	20	ft
Constant Slope:	2.6%	
Residual Outlet Depth:	1.4	ft
Depth over ford = 1 ft:	486	cfs

Hydrology

Drainage Area: 6.9 mi^2

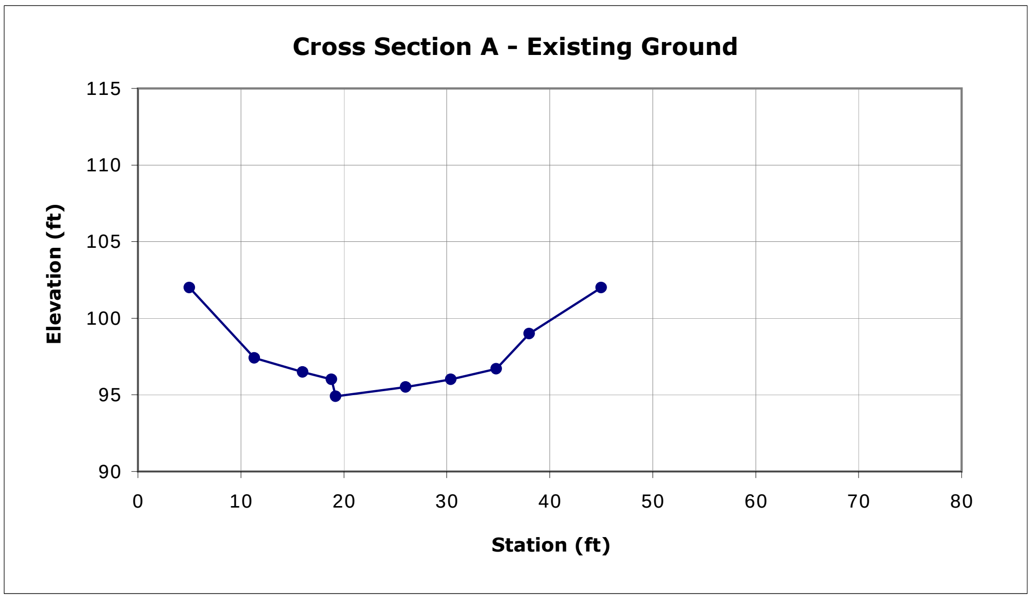
Estimated Flow*:

2-yr	84 cfs
5-yr	327 cfs
10-yr	644 cfs
25-yr	1,408 cfs
50-yr	2,214 cfs
100-yr	3,122 cfs

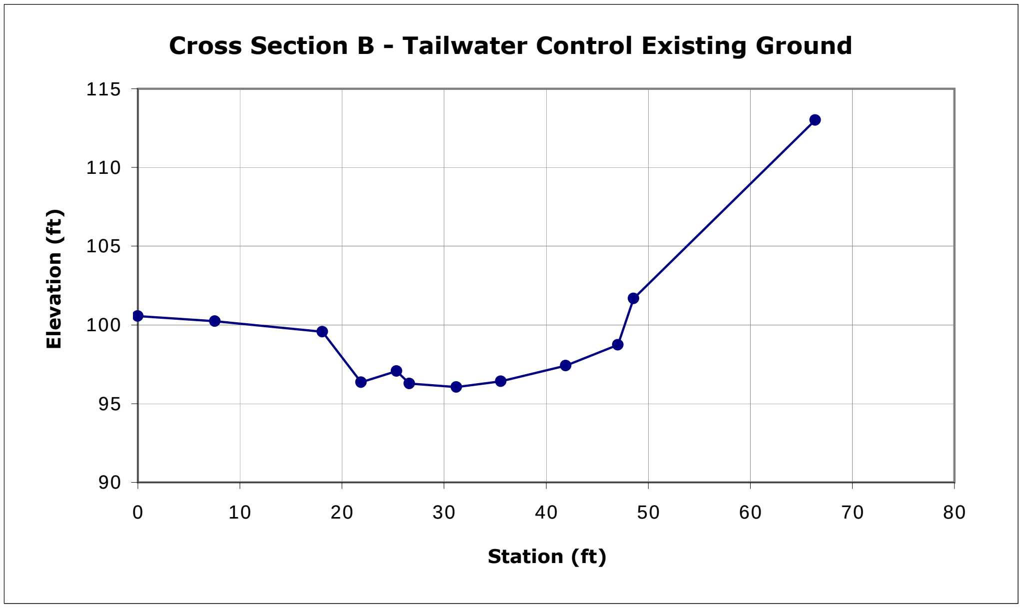
**Regional Regression Equations, Waananen & Crippen, 1977*

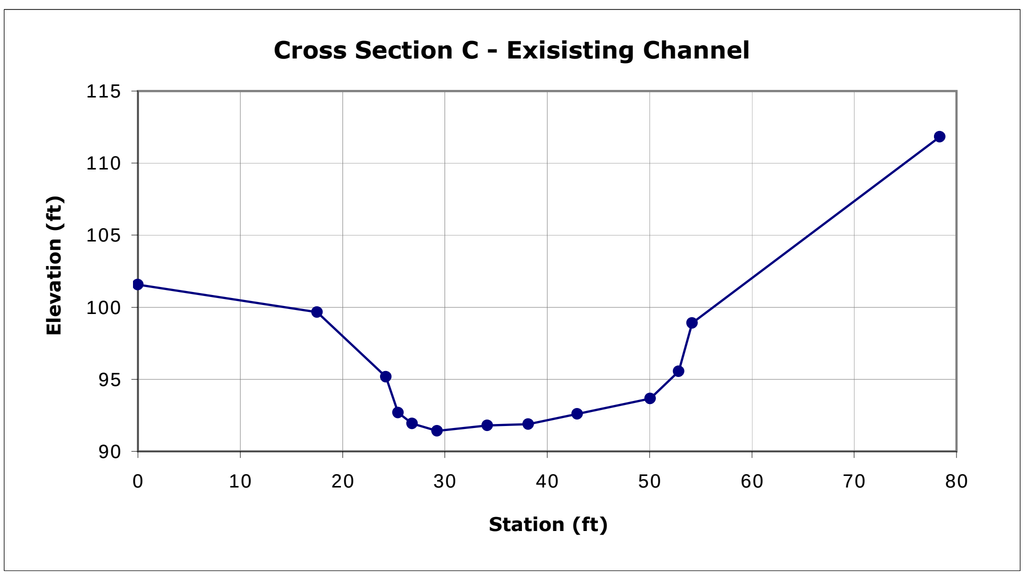
Channel Characteristics

Mean Reach Slope:	5.3%
Bankfull Width:	35 ft
Active Channel Width:	15 ft



Site: Upper Sunset Valley Road at Davy Brown Creek
Road: Sunset Valley Road / Cachuma Road





STREAM CROSSING SUMMARY SHEET

Site: Campground Access Road at Munch Creek
Road: Sunset Valley Road / Cachuma Road

General Information

Survey Date: 01/20/09
Survey Team: Antonio Llanos, Matt Stoecker
Stream Name: Davy Brown Creek
Land Ownership: LPNF

7.5 Minute Quad Name: Bald MT
Lattitude: 34° 45' 29.72" N
Longitude: 119° 57' 17.87'' W
Tributary to: Davy Brown Ck, Manzana Ck, Sisquoc River

Crossing Information

Shape:	Low water crossing	
Material:	Concrete	
Roughness (n):	0.013	
Inlet Type:	n/a	
Outlet Type:	Drop	
Length:	13	ft
Constant Slope:	0.8%	
Residual Outlet Depth:	2.8	ft
Depth over ford = 1 ft:	123	cfs

Hydrology

Drainage Area: 2.7 mi^2

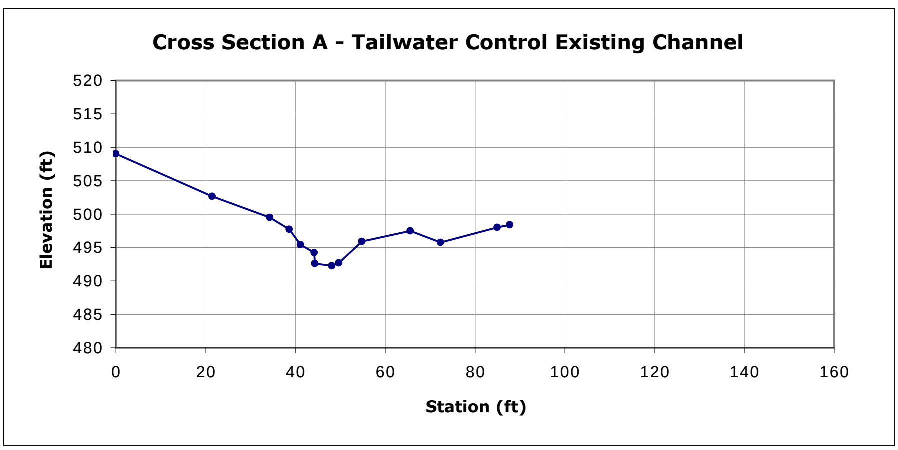
Estimated Flow*:

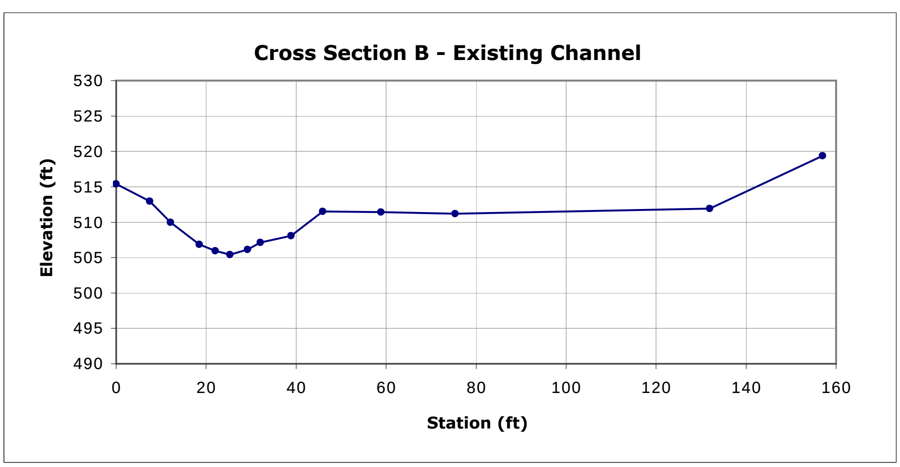
2-yr	42 cfs
5-yr	158 cfs
10-yr	306 cfs
25-yr	655 cfs
50-yr	1,021 cfs
100-yr	1,426 cfs

**Regional Regression Equations, Waananen & Crippen, 1977*

Channel Characteristics

Mean Reach Slope:	6.4%
Bankfull Width:	30 ft
Active Channel Width:	20 ft





Appendix D.

Lower Sunset Valley Road
Proposed Vented Ford Hydraulic Analysis

HY-8 Culvert Analysis Report

Table 1 - Culvert Summary Table: Lower Davy Brown (Design Profile, Embedded 1 ft)

Total Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Headwater Description
965	97.4	4.7	5.0	3-M1t	3.2	2.8	4.3	3.0	6.2	HW/D= 1 (headwater depth submerges soffit)
1318	98.4	5.9	6.0	7-M1t	3.9	3.5	4.7	3.4	7.7	Headwater Overtops road
1840	99.4	6.6	7.0	4-FFf	4.2	3.8	5.0	4.0	8.3	Road Submerged 1 ft

Table 2 - Culvert Summary Table: Lower Davy Brown (High Design Profile, Embedded 2.4 ft)

Total Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Headwater Description
620	97.4	3.48	3.6	3-M1t	2.41	2.1	2.45	2.55	7.02	HW/D= 1 (headwater depth submerges soffit)
896	98.4	4.5	4.6	3-M2t	3.1	2.7	2.9	3.0	8.7	Headwater Overtops road
1550	99.4	5.5	5.6	3-M2t	3.7	3.3	3.6	3.7	9.4	Road Submerged 1 ft

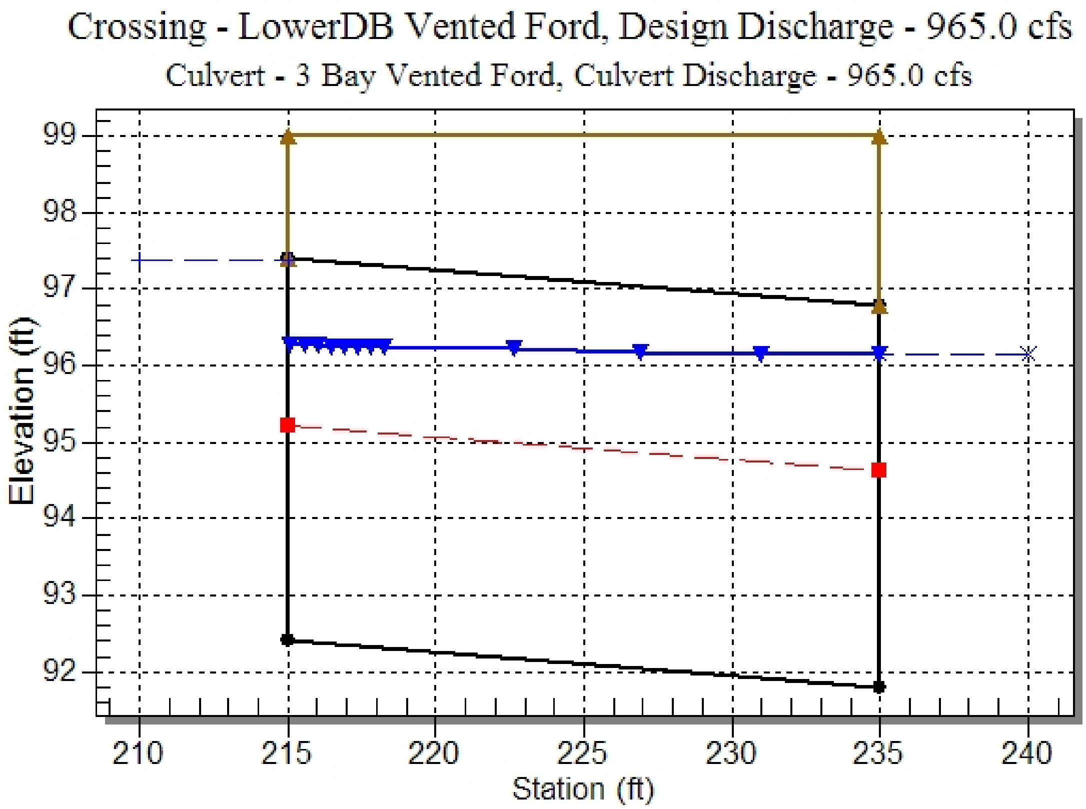
****

Inlet Elevation (invert): 92.40 ft,   Outlet Elevation (invert): 91.80 ft

Culvert Length: 20.01 ft,   Culvert Slope: 0.0300

****

Water Surface Profile Plot for Culvert: 3 Bay Vented Ford



Site Data - 3 Bay Vented Ford

Site Data Option: Culvert Invert Data

Inlet Station: 215.00 ft

Inlet Elevation: 93.80 ft

Outlet Station: 235.00 ft

Outlet Elevation: 93.20 ft

Number of Barrels: 1

Culvert Data Summary - 3 Bay Vented Ford

Barrel Shape: Concrete Box

Barrel Span: 36.00 ft

Barrel Rise: 5.00 ft

Barrel Material: Concrete

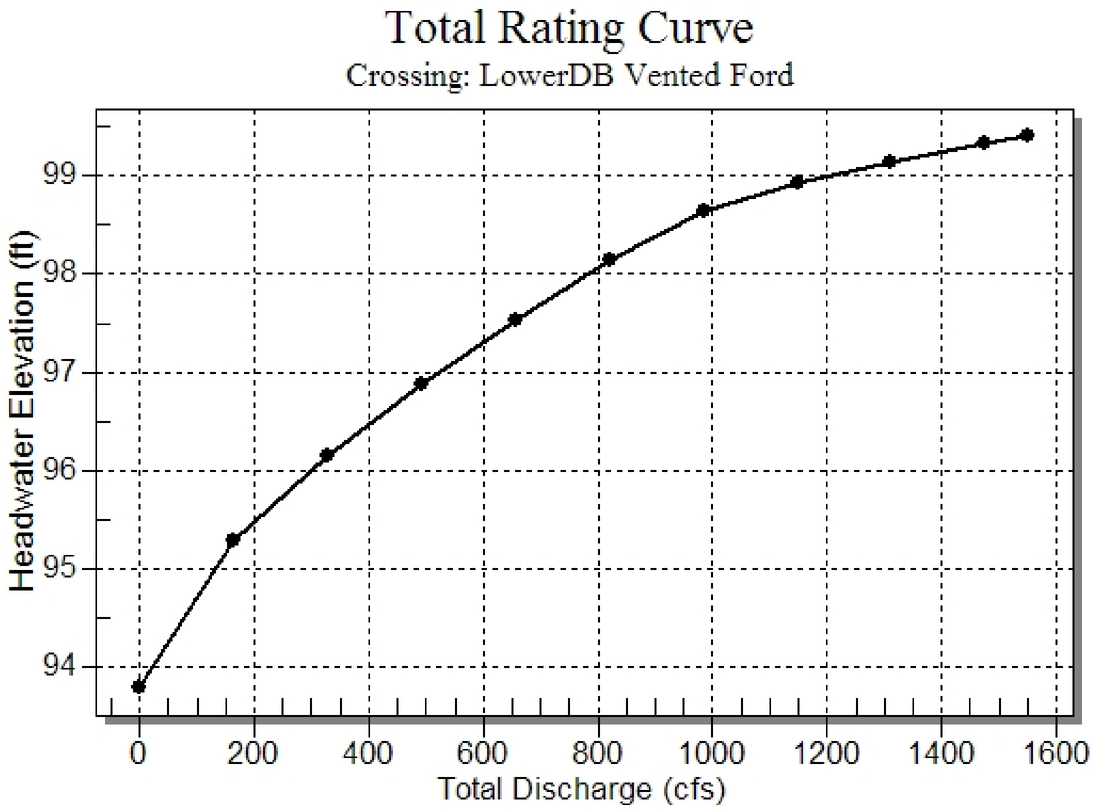
Barrel Manning's n: 0.0600

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90º) Headwall

Inlet Depression: None

Rating Curve Plot for Crossing: LowerDB Vented Ford



Roadway Data for Crossing: LowerDB Vented Ford

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
1	122.00	99.00
2	188.00	98.40
3	224.00	98.40
4	290.00	99.00

Roadway Surface: Paved

Roadway Top Width: 20.00 ft

Appendix E.

Upper Sunset Valley Road
Proposed Vented Ford Hydraulic Analysis

HY-8 Culvert Analysis Report

Table 1 - Culvert Summary Table: Upper Davy Brown (Design Profile, Embedded 1 ft)

Total Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Headwater Description
500	100.2	3.4	3.5	7-M1t	2.2	2.1	2.7	2.8	6.1	HW/D= 1 (headwater depth submerges soffit)
717	101.2	4.5	4.5	7-M1t	2.7	2.6	3.2	3.3	7.4	Headwater Overtops road
1134	102.2	4.9	5.5	4-FFf	2.8	2.8	3.5	4.1	7.5	Road Submerged 1 ft

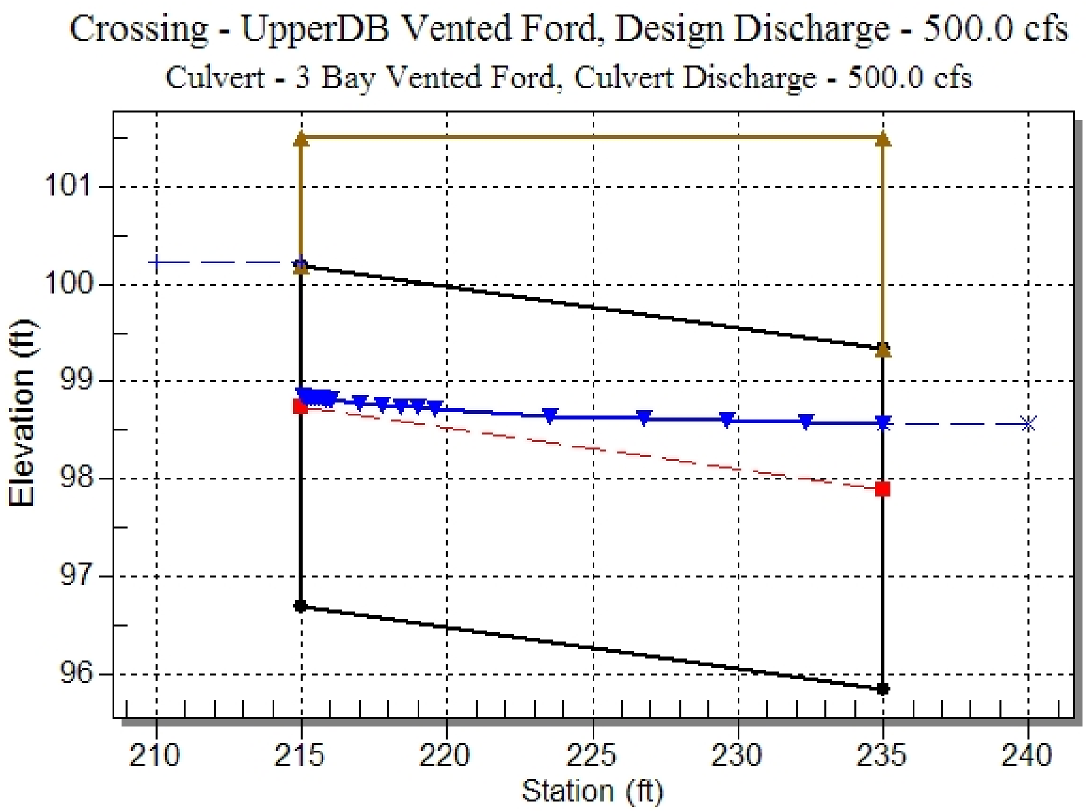
****

Inlet Elevation (invert): 96.68 ft,   Outlet Elevation (invert): 95.84 ft

Culvert Length: 20.02 ft,   Culvert Slope: 0.0420

****

Water Surface Profile Plot for Culvert: 3 Bay Vented Ford



Site Data - 3 Bay Vented Ford

Site Data Option: Culvert Invert Data

Inlet Station: 215.00 ft

Inlet Elevation: 96.68 ft

Outlet Station: 235.00 ft

Outlet Elevation: 95.84 ft

Number of Barrels: 1

Culvert Data Summary - 3 Bay Vented Ford

Barrel Shape: Concrete Box

Barrel Span: 30.00 ft

Barrel Rise: 3.50 ft

Barrel Material: Concrete

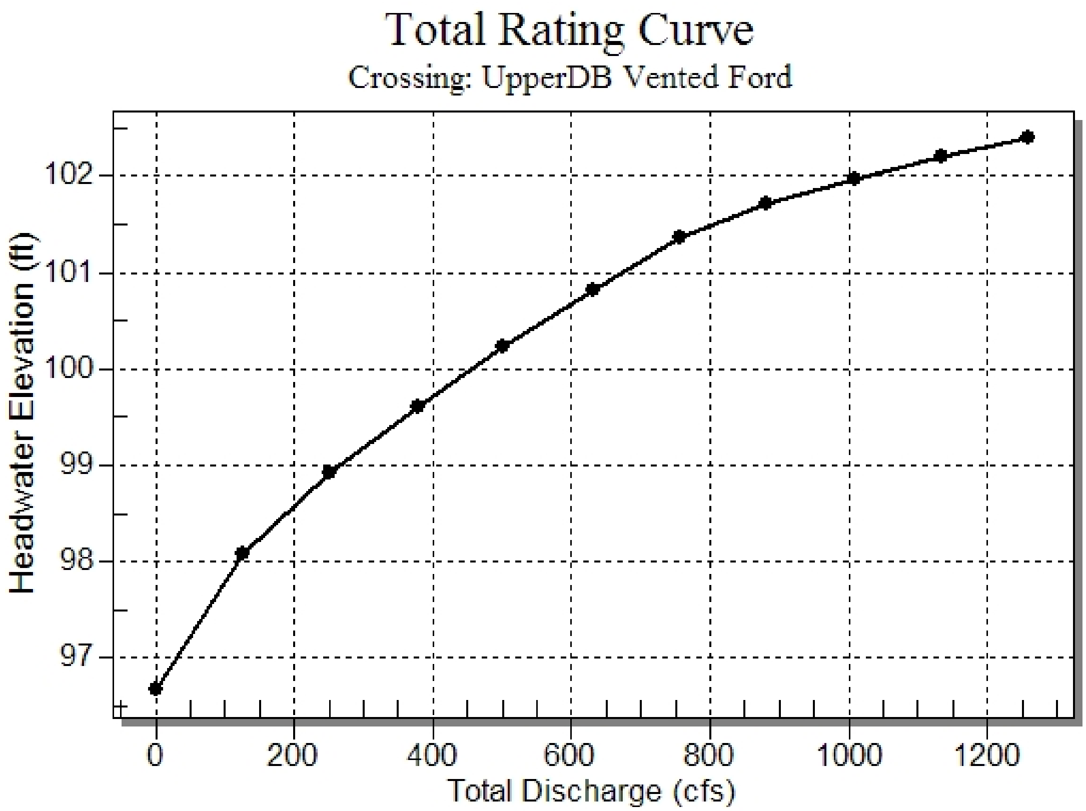
Barrel Manning's n: 0.0600

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90º) Headwall

Inlet Depression: None

Rating Curve Plot for Crossing: UpperDB Vented Ford



Roadway Data for Crossing: UpperDB Vented Ford

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
1	42.60	101.50
2	108.00	101.20
3	138.00	101.20
4	178.60	101.50
5	204.40	104.80
6	233.40	108.10

Roadway Surface: Paved

Roadway Top Width: 20.00 ft