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STOECKER ECOLOGICAL
NATURAL RESOURCE ASSESSMENT AND RESTORATION SERVICES

Technical Memorandum

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Subject: Horse Creek 2011 Post Dam Removal Monitoring Survey

1 PURPOSE OF MEMORANDUM

This technical memorandum documents geomorphic changes to Horse Creek and its confluence with the Sisquoc River in response to the October 2006 removal of a small dam on lower Horse Creek. It also reviews the appropriateness of methods and assumptions used to predict geomorphic response as part of the pre dam-removal environmental assessment. Findings are intended to aid in developing methods for predicting geomorphic response associated with future small dam removal projects.

2 BACKGROUND

On October 20, 2006 a defunct dam located on Horse Creek, a tributary to the Sisquoc River within Santa Barbara County, was demolished using explosives. Sediments stored behind the dam were left in-place to be regraded by the stream. The 4.5 foot tall and 60 foot wide dam was built in 1968 in the Los Padres National Forest (LPNF) on the edge of the San Rafael Wilderness Boundary. The following winter the region experienced a large flood event, estimated to have between a 10 and 25-year return period. Anecdotal and field evidence suggests that the basin behind the dam completely filled-in with sediment during the first few years after construction. Over time the downstream channel incised below the dam creating an overall drop of more than 8 feet over the dam face.

2.1 Pre Project Geomorphic and Biological Assessments

The dam removal project was initiated as an effort to improve upstream passage for fish and other aquatic organisms. Horse Creek and the Sisquoc River are designated critical habitat for the Federally Endangered Southern Steelhead. An aquatic habitat assessment of the 21.8

square mile Horse Creek watershed in 2005 (Stoecker, 2005 – **Attachment 1**) identified up to 18.9 miles of stream potentially suitable as salmonid habitat.

As part of the environmental assessment for the dam removal, Michael Love & Associates (MLA) and Stoecker Ecological (SE) conducted a geomorphic assessment of the proposed dam removal project (MLA, September 7, 2005 – **Attachment 2**). As part of the study, the channel profile and cross sections were surveyed to document the pre-project condition of the stream channel and estimate the potential sediment delivery to the Sisquoc River. The pre-project survey found the small impoundment formed by the dam was completely filled-in with sediment. The sediment wedge from the dam appeared to extend over 1,000 feet upstream. The study estimated that roughly 15,400 cubic yards of the sediment stored behind the dam could likely be released following dam removal, and the stored sediment would likely be released relatively quickly during large flow events.

2.2 2007-2008 Post Dam Removal Geomorphic Monitoring

In July 2006, shortly before the dam was demolished, a wildfire burned approximately 2,000 acres (approximately 15%) of the upper Horse Creek watershed (Per. Com., Kevin Copper, Forest Biologist, LPNF). On June 26th 2007, Stoecker Ecological conducted a post-project assessment (**Attachment 3)** and determined that after the first post removal winter, which experienced extremely low precipitation (6.27 inches fell at nearby Rancho Sisquoc, which has a 62 year average of 16.16 inches) and no significant flow events, little sediment behind the former dam was mobilized. In 2007 an incision measuring 7.5 feet wide and 4 feet deep extended 21 feet upstream from the removed dam site. This represented mobilization of an estimated 19 cubic yards of stored material.

The second year following demolition (Water Year 2008) the Sisquoc River and its tributaries experienced several large flow events, with the Sisquoc River peaking at 12,800 cfs; exceeding a 5-year return period . In April of 2008, the channel was resurveyed at the dam removal site and found that only approximately 120 cubic yards of material had been mobilized from behind the removed dam (MLA & SE, 2008 – **Attachment 4**). The overall conclusion was that while demolition of the dam removed a significant impediment to fish passage, significant mobilization of the stored upstream sediment had yet to occur. The 2008 report recommended conducting periodic reconnaissance of the site and follow-up monitoring after observing substantial geomorphic change.

2.3 2009 La Brea Fire

In August 2009 the 90,000 acre La Brea wildfire burned nearly the entire Horse Creek watershed.

2.4 2010 Site Reconnaissance

On December 19th, 2010 the USGS streamflow gaging station Sisquoc River near Garey (Station No. 11140000) recorded a peak flow of 9,940 cfs (from provisional data). This peak flow on the Sisquoc River has a corresponding return period of approximately 5 years. Five days later as flow receded, Matt Stoecker of Stoecker Ecological conducted a 2-day kayak reconnaissance trip down Manzana Creek to the Sisquoc River and Horse Creek to visually assess channel changes at the former dam site. Field observations from this reconnaissance trip are documented in *Sisquoc River and Horse Creek Dam Removal Site Observations and Float* (Stoecker, 2010 – **Attachment 5**). Qualitative observations were made and photographs clearly showed the anticipated "natural channel regrade" event has occurred. A large delta of deposited sediment had formed at the mouth of Horse Creek, with aggradation present in the channel below the old dam. This event shifted the course of the Sisquoc River approximately 200 feet to the south, around the new Horse Creek delta. Observations show that the channel upstream of the removed dam had widened considerably and incised, transporting a substantial portion of the sediment stored behind the dam. These qualitative observations triggered the October 2011 post-project geomorphic survey documented in this memorandum.

3 PURPOSE OF GEOMORPHIC MONITORING

Continued monitoring of the channel's response to demolition of the dam is expected to provide information useful in planning for future dam removal projects. Some of the questions that this geomorphic monitoring attempts to answer include:

- Accuracy of methods used to estimate the volume and rate of stored sediment released and the resulting alignment.
- Channel alignment changes relative to the pre project and historic location.
- Effect of soil cementation and root structure of riparian vegetation on sediment transport and channel shape
- The nature of sediment release in drier hydrologic and high frequency fire regimes.
- Relative impact of sediment release from the dam removal in comparison to fire related sediment transport.

A better understanding of these channel dynamics will help improve analysis and decision-making for future barrier removal projects.

4 ACTIVITIES

4.1 Geomorphic Mapping

On October 4th and 5th, 2011 Matt Stoecker of SE, and Michael Love and Antonio Llanos of MLA resurveyed the channel profile and cross sections originally established in 2004. The survey was conducted using a total station and GPS coordinates to reoccupy benchmarks set during the previous monitoring efforts. Benchmarks (rebar located at each cross section) were relocated where possible to overlay current and previous surveys. The survey included a longitudinal profile of the channel that extended from the confluence with the Sisquoc River to 3,780 feet upstream of the demolished Horse Creek Dam for a total length of 5,000 feet. The left and right edges of the active channel were surveyed from the Sisquoc River to approximately 800 feet upstream of the removed dam. Tops of terraces associated with the stored sediment behind the dam were also surveyed within the 800 foot reach upstream of the dam. Further upstream channel widths and bank heights were measured at corresponding thalweg survey points. Six channel cross sections were resurveyed. Additional detail of the delta formed at the confluence with the Sisquoc River was mapped using aerial photographs available from Google Earth.

Plots of the profile and cross sections and GPS coordinates of the cross section monuments are provided in **Attachment 6**.

4.2 Channel Bed Material Measurements

To characterize the size distribution of the streambed material and compare it to the pre dam removal distribution, two Wolman pebble counts were conducted. One was conducted in the channel approximately 200 feet upstream of the removed dam, and close to the location of the 2004 pebble count. The other pebble count was conducted approximately 400 feet downstream of the removed dam. Both counts involved measuring the intermediate axis on 100 pebbles deposited within the bed of the active channel.

4.3 Aquatic Organism Survey

As part of the this field effort, staff from the California Department of Fish and Game (CDFG) preformed snorkel surveys in Horse Creek. Their surveys extended approximately 1.3 miles upstream of the removed dam. The reach lacked deep scour pools, likely due to the influx of sediment resulting from the 2009 La Brea fire. No salmonids were observed in the surveyed reach of Horse Creek. Moderate to high density of arroyo chub (*Gila orcuttii*) was observed in the lower reaches of Horse Creek and high density of speckled dace (*Rhinichthys osculus*) were observed throughout the surveyed reach. They also snorkel surveyed a large pool in the Sisquoc River at the confluence with Horse Creek that was formed by a beaver dam. They observed a high density of *O. mykiss* within the large pool, including three fish that were approximately 9 to 14 inches in size. The CDFG file letter documenting the snorkel survey is provided in **Attachment 7**.

4.4 Hydrologic Analysis

An analysis of flows in the Sisquoc River at Geary (USGS Station No. 11140000) and in smaller near-by gaged streams was conducted to aid in characterizing the magnitude and frequency of the flow events that occurred between the April 2008 and the October 2010 geomorphic surveys. This involved a statistical analysis of available peak flow data from nearby gaging stations. Only streams with no significant flow impairments were used. Procedures outlined in Bulletin 17B (USGS, 1982) were employed to estimate recurrence intervals of peak flows. Additionally, monthly rainfall records for Rancho Sisquoc were obtained. Results are provided in **Attachment 8**.

5 FINDINGS AND OBSERVATIONS

The sediment stored upstream of the demolished dam has mobilized significantly since the pre-project survey. Additionally, the channel appears to have a dramatic increase in sediment load resulting from erosion and runoff related to the 2009 La Brea fire.

A photo-log of the site is provided in **Attachment 9**.

5.1 Channel Adjustments

5.1.1 Planform

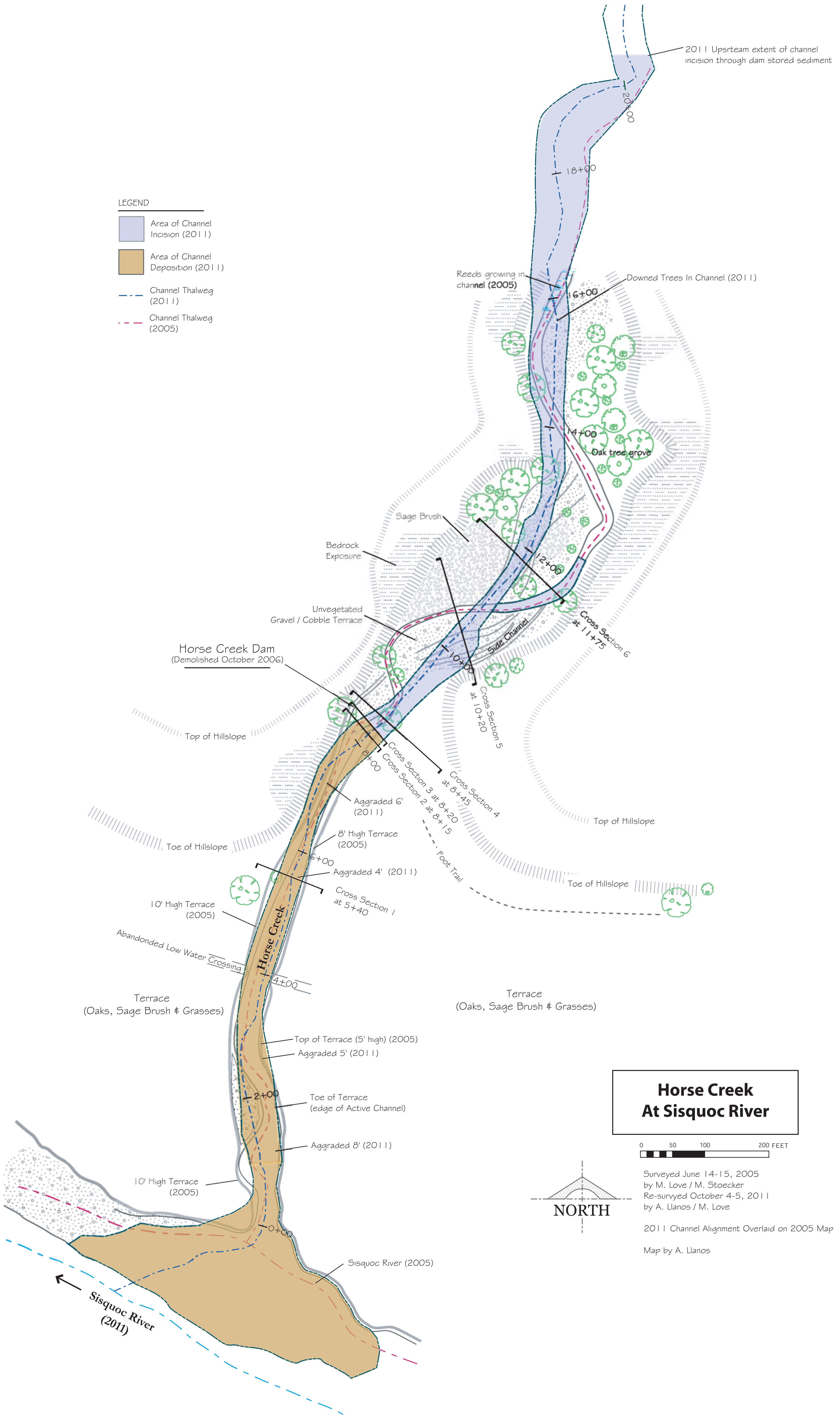
The channel immediately upstream of the removed dam had realigned its planform geometry (Figure 5-1). In the 2005 survey the channel made two tight meanders in the low-gradient depositional zone between the dam and approximately 600 feet upstream. This reach of channel had a sinuosity ratio of 1.3, considered sinuous, and a slope of 1.8 percent. The sinuous channel was very shallow, undefined and showed evidence of many overflow and side channels, likely active during high flow events. When remapped in 2011, the channel had abandoned the meanders and attained a nearly straight alignment. The decrease in sinuosity reduced the channel length by approximately 170 feet, and the overall channel slope had increased to 2.5 percent. Much of the abandoned meandering channel remains perched on the alluvial benches adjacent to the new channel. This suggests the current channel alignment resulted from an avulsion near station 14+00, where a side-channel was mapped in 2005, rather than lateral migration through erosion of the banks. Within the upper meander, the channel incised and widened before becoming abandoned.

Upstream of the dam influence a large amount of bedload appears to have been deposited on the overflow benches since 2008, presumably in response to the 2009 La Brea Fire. The channel and adjacent benches show signs of wide-spread aggradation followed by the channel incising through these aggraded sediments. In numerous locations the channel appeared to have also migrated laterally through these deposited sediments.

Since the 2008 survey, an alluvial fan has formed at the confluence with the Sisquoc River, shifting the thalweg of the river approximately 200 feet to the south. An aerial image from June 2010 shows that the fan developed prior to the high flows of Water Year 2011 (Figure 5-2). Therefore, the fan development occurred between April 2008 and June 2010. Based on the aerial image, we estimate that the alluvial fan is 1.5 acres in size and nearly 400 feet in width. Compared to field measurements and observations, the fan appears to have changed little between June 2010 and October 2011.

5.1.2 Channel Profile

Examining the full length of the 2011 surveyed channel profile (***Figure 5-3***), four distinct channel reaches can be discerned based on channel slope. At the downstream end is the alluvial fan with a convex profile, typical of this type of landform. The average slope of the fan is 4.2%. Upstream of the alluvial fan the channel is confined between steep channel banks and the channel profile is concave in shape. The first reach upstream of the fan is 1,300 feet in length and extends nearly 500 feet upstream of the removed dam. It has an average slope of 1.7 percent. The next upstream reach is 1,050 feet in length and has an average slope of 2.5 percent. The last reach extends to the upstream end of the survey, is 2,240 feet in length and has a nearly constant slope of 3.0%.



Horse Creek At Sisquoc River

Surveyed June 14-15, 2005
by M. Love / M. Stoecker
Re-surveyed October 4-5, 2011
by A. Llanos / M. Love

2011 Channel Alignment Overlaid on 2005 Map

Map by A. Llanos

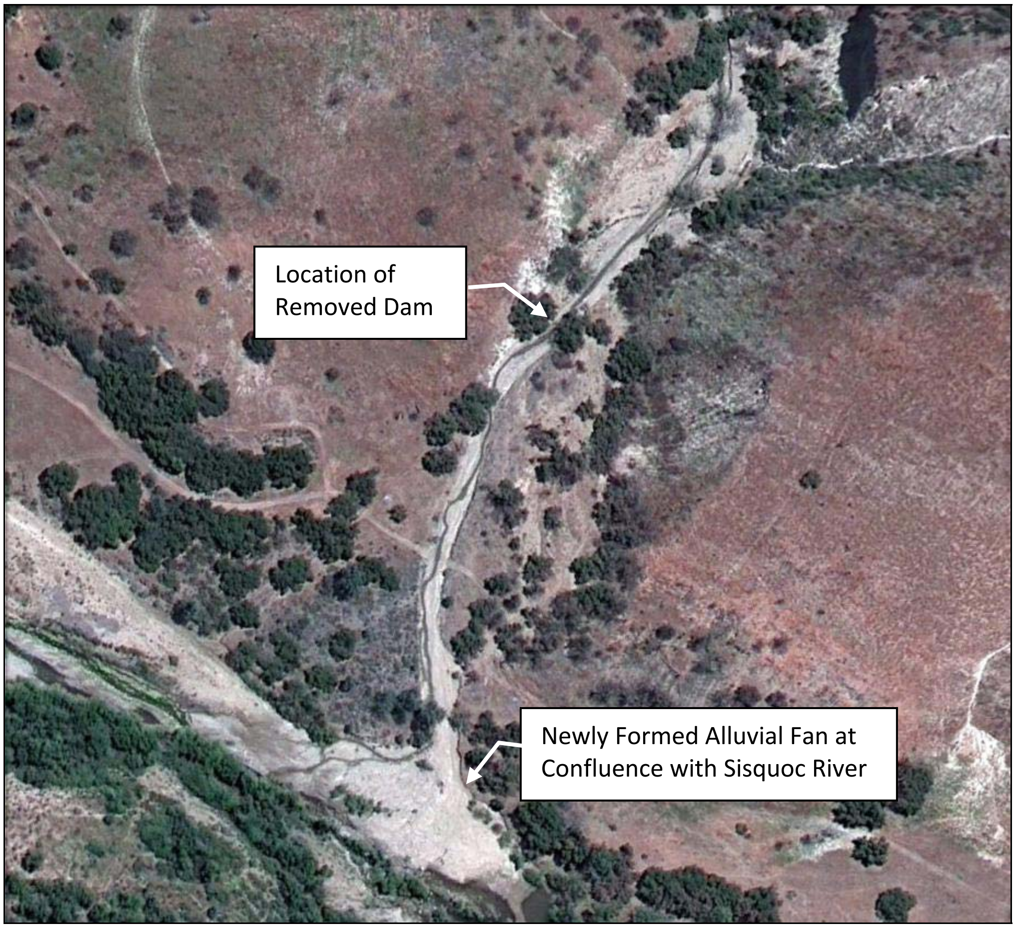


Figure 5-2. Aerial image of newly formed Horse Creek alluvial fan formed at the confluence with the Sisquoc River (Source: *Google Earth*, June, 2010).

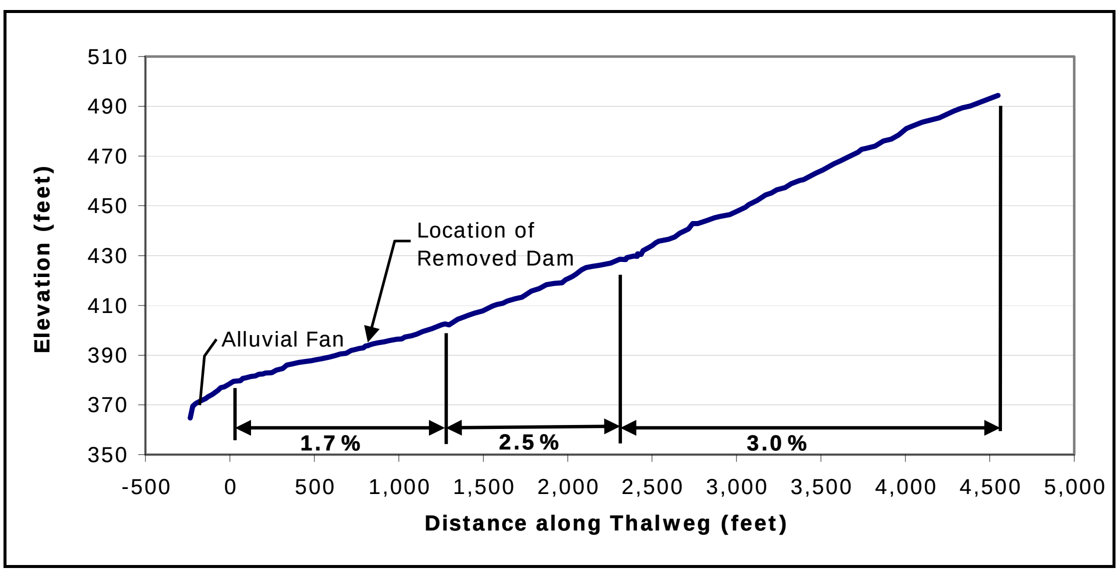


Figure 5-3. Horse Creek 2011 thalweg profile with average reach slopes. Elevation based on assumed vertical datum. Overlaying 2005 Profile onto 2011 Profile

Because alignment upstream of the dam changed between the 2005 and 2011 surveys, the two profiles can not be directly overlaid. Instead, the 2005 channel elevations were superimposed onto the 2011 alignment at locations that the two alignments cross (Figure 5-4)

Profile Changes Upstream of Removed Dam

The channel thalweg profile surveyed in 2011 clearly shows that the channel has regraded through much of the stored channel sediments, and the knickpoint observed in 2008 is no longer present. From the dam removal site to about station 20+80 the post dam removal channel bed is lower than pre dam removal. At 20+80, near the upstream end of the 2005 surveyed profile, the two profiles intersect. Therefore, between the removed dam and 20+80 the net vertical channel adjustment is downward. The incision through dam stored sediments extends from the removed dam to nearly 1,270 feet upstream. Depth of incision through much of this length averages between 4 and 7 feet.

The pre-project channel profile does not extend upstream of station 20+80, so no direct comparison of pre-project and 2011 conditions can be made. The 2011 observations of the channel upstream of this point suggest that it experienced wide-spread aggradation in the channel and overbank areas since 2008 due to high sediment loads. The channel appears to be re-incising through these recently deposited sediments.

Profile Changes Downstream of Removed Dam

Downstream of the dam the channel bed aggraded approximately 4 feet but maintains nearly the same slope as surveyed in 2005, prior to dam removal. The channel bed elevation is now 2 feet lower than the exposed footing of the removed dam, as surveyed in 2005. This suggests that in 1968, when the dam was constructed, the channel bed was even higher then it was in its aggraded state in 2011. The aggradation of the channel bed has also lead to the formation of an alluvial fan at the confluence with the Sisquoc River.

5.1.3 Channel Cross Sections

Comparison of the channel cross sections between 2005 and 2011 shows substantial changes. Upstream of the dam the new channel incised through the stored sediments, forming a relatively consistent bottom width of 30 to 35 feet (Figure 5-5). The exposed banks of the incised channel are composed of cobble and gravel mixed with sand. These banks are oversteepened to slopes exceeding 0.5:1 (Horizontal:Vertical). The bank material is able to maintain these nearly vertical side-slopes due to natural cementation within the sand-gravel-cobble matrix found within the sediments stored behind the dam. This cementation was noted in the 2008 report as slowing the rate of headward migration of the knick-point after removal of the dam. This type of cementation was not as prominent in the alluvium exposed in banks upstream of the dam stored sediments.

The smaller channel present in the 2011 survey at Cross Section 6 is located in the meandering channel mapped in 2005 and 2008. The 2011 cross section shows that this channel incised nearly 6 feet before being abandoned.

All six of the surveyed channel cross sections are provided in **Attachment 6**.

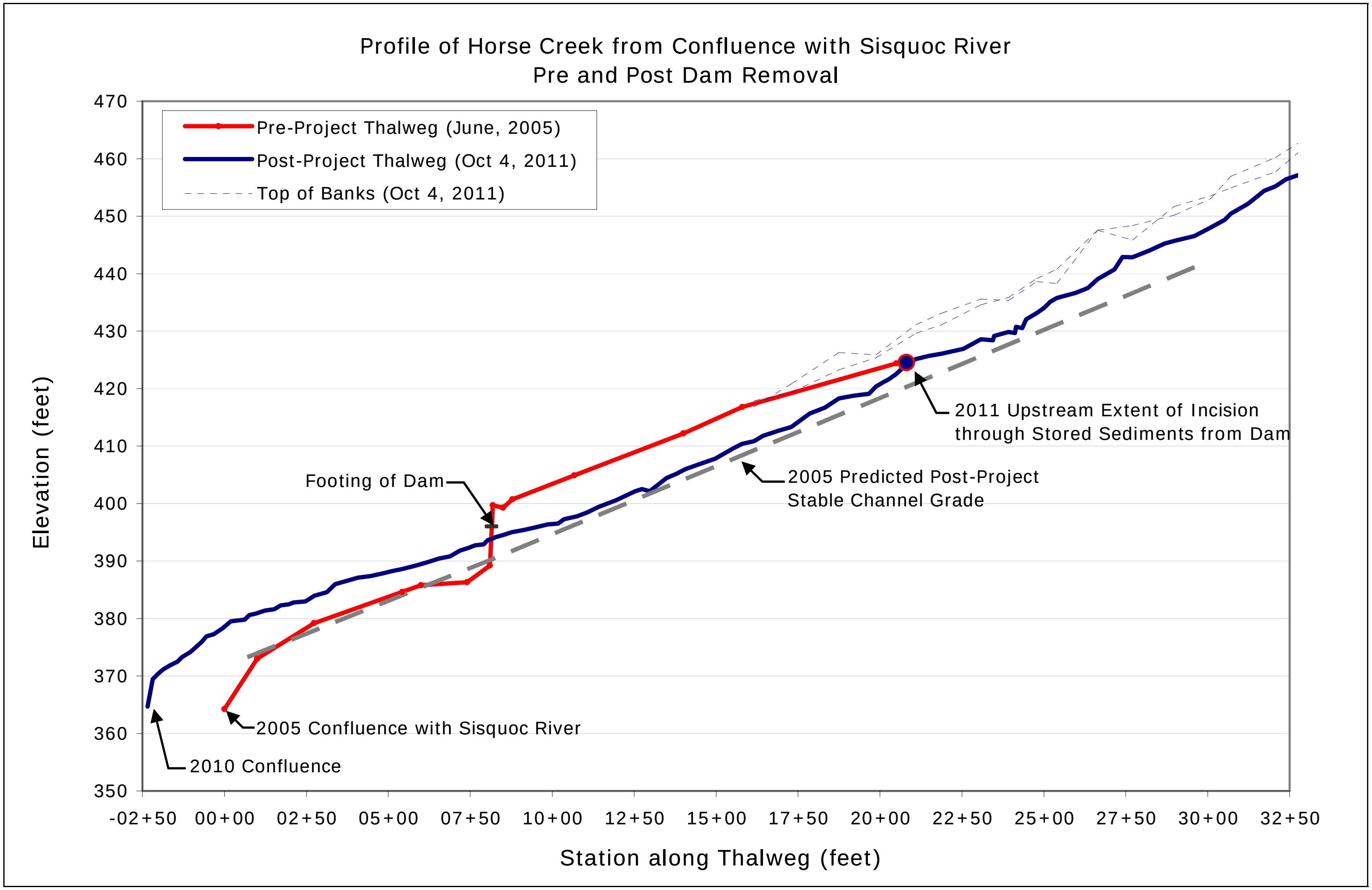


Figure 5-4. Profile of Horse Creek from 2005 (pre dam removal) and 2011 (post dam removal). Elevation based on assumed vertical datum.

5.2 Sediment Released and Deposited

Headward migrating incision has mobilized sediment stored behind the removed dam. Based on the longitudinal profiles and 2011 visual observations, the release of dam stored sediments extend from the removed dam to 1,260 feet upstream, where the pre and post project profiles intersect at station 20+80 (Figure 5-3). Additional sediment (approximately 530 cubic yards) was released through headward migrating incision of the upstream meander prior to its abandonment (Figure 5-1). Using the channel cross sections and the Average End-Area Method, the volume of dam stored sediment released between 2006 and 2011 is estimated to be 11,700 cubic yards.

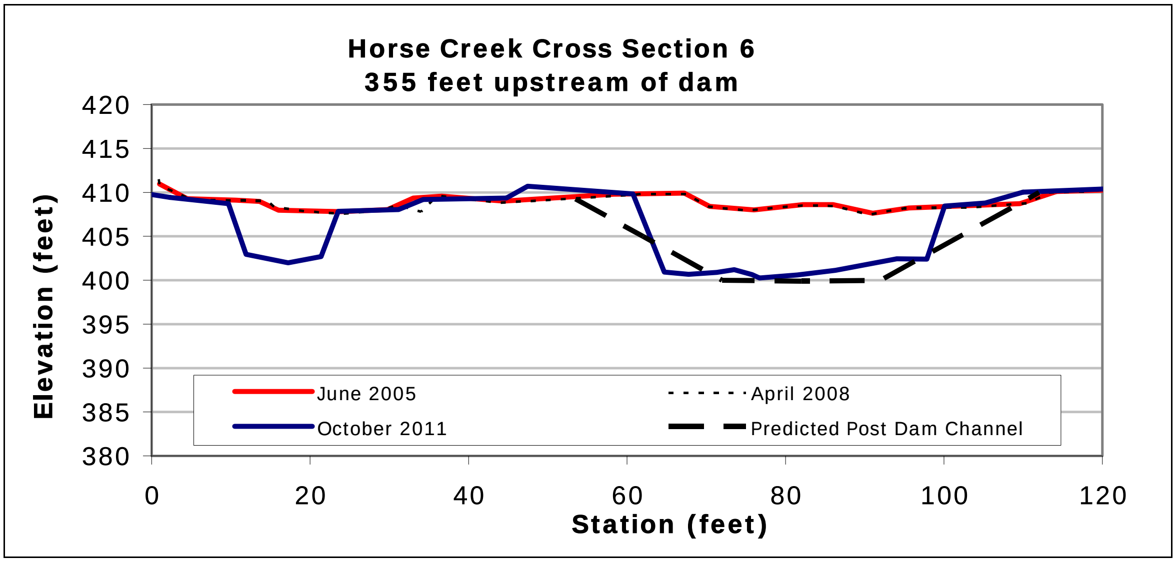


Figure 5-5. Monitoring Cross Section 6, located at 11+75 along the 2011 alignment.

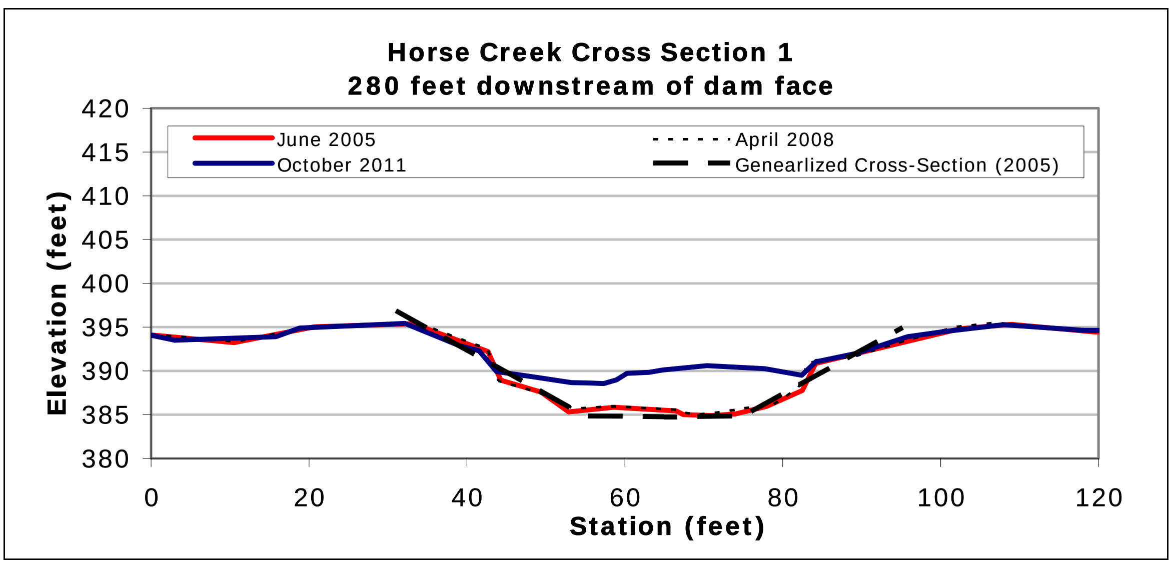


Figure 5-6. Monitoring Cross Section 1, located at 5+40 along the 2011 alignment.

Material delivered to the channel downstream of the dam includes both sediment stored from behind the dam and sediment delivered from the 2009 La Brea fire. Deposition of this sediment within the channel downstream of the removed dam has caused channel bed aggradation and has formed an alluvial fan at the confluence with the Sisquoc River. Using the Average End-Area Method, the volume of material deposited within the 800 foot long reach between the dam and the apex of the fan is 5,650 cubic yards. Estimating the volume of sediment comprising the alluvial fan is difficult given limited pre project survey of that area and the parabolic shape of the fan. As an order of magnitude approximation, the average depth of aggradation is 8 feet based on the profile and the surface area of the fan is approximately 1.5 acres (960 square feet). The product of these dimensions results in an estimated 280 cubic yards of sediment forming the alluvial fan.

The net volume of sediment released from behind the removed dam verses deposited downstream in Horse Creek and on the alluvial fan between the 2005 and 2011 surveys is summarized in Table 5-1. In total, the net volume of stored sediment transported to the Sisquoc River is approximately 5,800 cubic yards. This does not account for the apparent large load of sediment transported to lower Horse Creek and the Sisquoc River that originated upstream of the dam stored sediments.

Table 5-1. Estimated volume of sediment released from behind the removed dam and deposited in the downstream channel and alluvial fan between 2005 and 2011.

Channel Reach	Sediment Released (-) and Deposited (+)
Upstream of Dam (Station 8+20 to 20+80)	-11,700 CY
Channel Downstream of Dam (Station 15+00 to 8+15)	+5,650 CY
Alluvial Fan at Sisquoc River	+280 CY
Net Volume	**-5,770 CY**

5.3 Comparison to Predicted Values

The current estimate of dam stored sediments released at the time of the October 2011 survey is 78 percent of the pre-project estimated volume of 15,400 cubic yards (MLA, 2005). The original estimate was based on the downstream channel cross-section and slope a projected upstream through the deposited sediments behind the dam, following the previous meandering alignment. The cross-sectional shape of the incision through the stored sediments was based on Cross Section 1 surveyed in 2005, but generalized into a trapezoidal shape. The trapezoid section had a bottom width of 20 feet and side-slopes of 2:1 (Horizontal:Vertical), as shown in Figure 5-6. In general, this generalized cross section under estimated the bottom width and, as of now, overestimated the degree the banks would layback (Figure 5-5). However, the overall cross sectional area of the 2005 predicted and 2011 measured channel shape is similar.

The sinuous channel alignment surveyed upstream of the dam in 2005 was approximately 170 feet longer than the less sinuous 2011 channel alignment. Using the 2005 alignment to predict the length of channel regrade, rather than the more straight alignment seen in 2011, overestimated the sediment volume to be released by approximately 1,500 cubic yards. Subtracting this volume from the original prediction yields an estimated release of 13,900 cubic yards of sediment. This is closer to the estimated volume released between 2005 and 2011 of 11,700 cubic yards.

5.4 Size Distribution of Stored and Released Bed Material

The size distribution of bed material upstream of the dam pre-project (2005) and post project (2011) were similar (Figure 5-7). Additionally, the post project (2011) size distribution of bed material in the aggraded channel downstream of the removed dam had a similar distribution as found in the upstream channel. For all three samples, the D50 was coarse gravel (16-32 mm) and the D84 was small cobble (64 – 128 mm).

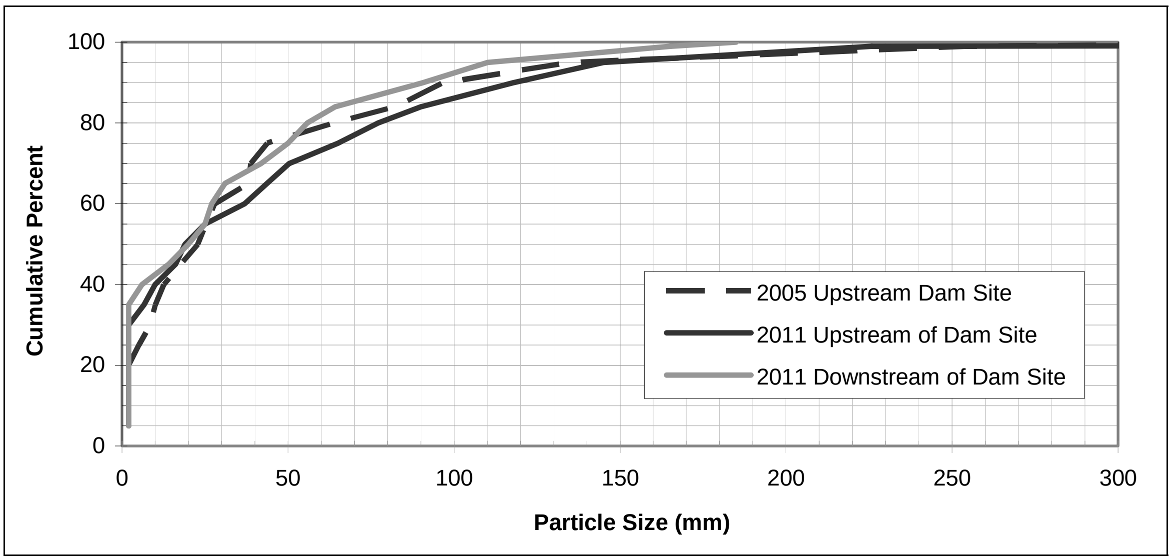


Figure 5-7. Distribution of bed material pre and post dam removal, measured using Wolman Pebble Count Methodology.

5.5 Rainfall and Streamflow Magnitude and Frequency since Dam Removal

Examination of monthly and annual rainfall records at Rancho Sisquoc since dam removal in October 2006 shows that Water Year 2010 and 2011 were both above normal (Table 5-2). The rainfall for December of 2011, totaling 11.74 inches, was reported to have a return period exceeding 1,000-years (Santa Barbara County, 2011).

Peak flow events corresponding to rainfall were examined using the gaging record for the Sisquoc River near Garey and Santa Cruz Creek near Santa Ynez. Santa Cruz Creek, which drains into Lake Cachuma and has a drainage area of 74.0 square miles, which is about 3 times the size of the 21.8 square mile Horse Creek watershed. The Santa Cruz Creek watershed, 16 miles south-southeast of Horse Creek, has similar aspect and elevations as the Horse Creek watershed. Therefore, the return period of peak flows measured at this gaging station are considered a reasonable approximation to those that occur in Horse Creek.

Examining peak flows on the Sisquoc River near Garey, the largest peak flow to occur post dam removal was in 2008, with a return period of 6-years. This was also the largest peak flow on the Santa Cruz Creek near Santa Ynez since dam removal, with an approximate return period of 35-years. Interestingly, the post dam removal monitoring survey conducted in April 2008 found almost no mobilization of the stored sediments behind the removed dam despite the significant flow event.

Water Year 2009 was very dry, with peak flows throughout the region having less than a 1.5-year return period (**Attachment 8**). Water Year 2010, the year that much of the dam stored sediments mobilized and the alluvial fan formed at the Horse Creek confluence, produced peak flows throughout the region having return periods of only 2- to 3-years. Although these regional return periods are much less than in Water Year 2008, it is suspected that the widespread burning of the Horse Creek watershed by the August 2009 La Brea fire caused a dramatic increase in peak flows and sediment load in Horse Creek during Water Year 2010.

Water year 2011 experienced peak flows in the Sisquoc River that were slightly less than 2008, and had a return period of approximately 5-years. The peak flow data for Santa Cruz Creek is not currently available from the USGS.

Table 5-2. Rainfall and streamflow statistics for Water Years following dam removal.

	Water Year				
Gaging Station	2007	2008	2009	2010	2011
Rancho Sisquoc Precipitation[1]					
Total Annual Rainfall (Percent of Normal*)	6.27 in (39%)	14.13 (87%)	10.88 (67%)	18.66 (115%)	26.37 (163%)
Monthly Maximum (Month)	1.37 in (Dec)	8.93 in (Jan)	5.25 in (Feb)	5.87 in (Jan)	11.74 in (Dec)
Sisquoc River Near Garey[2]					
Peak Flow (Return Period)	0 (1-year)	12,800 cfs (6-year)	398 cfs (1.3-year)	5,510 cfs (2.5-year)	9,940 cfs (5-year)
Santa Cruz C NR Santa Ynez[3]					
Peak Flow (Return Period)	6.8 cfs (1-year)	10,200 cfs (35-year)	470 cfs (1.5-year)	1,860 cfs (3-year)	Not Available

** Normal (average) rainfall is 16.16 in based on 62-year record*
[1] Santa Barbara Gaging Rainfall Station No. 415
[2] USGS Streamflow Gaging Station No. 11140000
[3] USGS Streamflow Gaging Station No. 11124500

5.6 Fish Passage Conditions

The project successfully removed the 9 foot tall dam that was a complete barrier to all salmonids and other fish species. Additional knickpoints upstream of the dam that may have impeded fish passage have also been eliminated since demolition of the dam. The April 2008 post-project survey identified a knickpoint located 40 feet upstream of the removed dam that had a 3.7 foot vertical drop, suspected of creating a partial barrier to adult steelhead. The surveyed channel profile in October 2011 found that the knickpoint was no longer present and that the channel slope had relaxed to a more stable grade.

Fish passage conditions for adult and juvenile steelhead and other aquatic organisms were qualitatively assessed by comparing the morphology of the newly regraded channel to the upstream reaches that were unaffected by the removed dam. Based on these 2011 observations, the channel reaches immediately upstream and downstream of the removed dam were as passable by fish and other aquatic organisms as the natural channel upstream of the influence of the dam. The newly incised channel upstream of the removed dam and the aggraded downstream channel had similar channel widths and bed morphology as the channel surveyed upstream of the dam's influence.

The alluvial fan at the mouth of Horse Creek had a steeper slope than the upstream channel. However, the channel on the fan was well defined, with steps and pools, making it passable by salmonids. Additionally, during elevated flows in the Sisquoc River, the steepest sections of the channel on the fan become backwatered, further improving fish access to Horse Creek.

6 DISCUSSION

6.1 Improving the Prediction of Released Sediment

The channel is believed to still be processing stored sediments from behind the removed dam, and the volume of sediment released will undoubtedly increase as the banks lay-back, and the channel could further incise. Even so, there are several lessons that can be learned regarding estimating sediment releases from small dams in this type of setting based on the 2011 observations.

As noted in the original pre-project study (MLA, 2005), assuming the channel will incise through stored sediments along the sinuous channel alignment caused by the dam will likely over-estimate the volume to be released. A more accurate estimate of sediment release for Horse Creek would have been to use a straight alignment based on the alignment and width between canyon walls and sinuosity of the natural channel upstream of the dam's influence.

During the channel regrading process existing or newly formed channels may become abandoned and may incise prior to their abandonment. Sediment released from these abandoned channels can be a substantial contribution to the overall volume of released sediment (4.5% in Horse Creek) and should be considered.

Field evidence suggests that the channel incised through recently formed depositional terraces. Alluvial terraces supporting mature oak groves and sycamore trees, suggesting that they were formed prior to dam construction, remained intact. Only two mature oak trees were observed to have fallen as a result of the channel incision.

Soil cementation, if present at a potential dam removal site, should be considered when predicting the rate of headward migrating incision through stored sediments. This may affect the type of treatments appropriate for the site. The 2008 Horse Creek survey found that this cementation was impeding the mobilization of stored sediments and creating a persistent knickpoint that could partially block upstream fish passage. If the 2009 La Brea fire had not occurred and changed the runoff characteristics of the watershed, it is uncertain if the channel would have regraded enough to eliminate the knickpoint during the 2010 and

2011 water years. In these situations, it may be prudent to regrade a pilot channel through the stored sediments to provide assurance that fish passage will be provided in the short and medium term.

6.2 Sediment Release and Fire Regime

The amount of sediment stored behind a small dam should be considered in context with the fire regime and associated sediment load of the stream. This may assist in characterizing the environmental impact of a sediment release associated with a dam removal. The Horse Creek Watershed is predominately covered by chaparral. In this region of the Los Padres National Forest, the natural fire rotation intervals are reported to be between 30 and 40-years (Keeley and Fotheringham, 2001). Large sediment loads and high peak flows commonly follow large fires. In many situations, the stored sediments behind a small dam may only contribute a small fraction to the overall bedload released during a post-fire runoff event.

The triggering event for sediment release following dam removal may be highly dependent on the occurrence of fires within the watershed. Even though 2008 likely produced at least a 5-year peak flow in Horse Creek, only a minor amount of sediment was released during that event. The 2009 La Brea fire burned most of the Horse Creek watershed and likely generated a larger peak flow than was inferred from the 2010 peak flows measured at gaged streams in the region. It was these presumably larger peak flows that initiated the rapid mobilization of the stored sediments.

The 2010 and 2011 flows appear to have transported a large amount of sediment originating from upstream of the dam's influence. As a result, the volume of stored sediment released during these two years is likely a small fraction of the overall sediment moved by Horse Creek and delivered to the Sisquoc River. Observations of the aggraded channel well upstream of the removed dam's influence suggest that Horse Creek will be processing the fire-related sediment load for some time, further diminishing the downstream impacts associated with the release of the dam stored sediments.

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ATTACHMENTS:

1. *Horse Creek Dam Removal Project Salmonid Habitat Survey* (Stoecker, 2005)
2. *Stream Channel Assessment for Horse Creek Dam Removal Project (*MLA, 2005)
3. *Horse Creek Dam Removal – Post Project Survey* (Stoecker, 2007)
4. *Horse Creek Post Dam Removal Monitoring Survey* (MLA & SE, 2008)
5. *Sisquoc River and Horse Creek Dam Removal Site Observations and Float* (Stoecker, 2010)
6. *2011 Channel Cross Sections and Profile*
7. *CDFG File Letter: 2011 Snorkel Survey Results*
8. *Horse Creek Hydrology*
9. *2011 Horse Creek Photo Log*

Attachment 1

Horse Creek Dam Removal Project Salmonid Habitat Survey

Horse Creek Dam Removal Project
Salmonid Habitat Survey

September 15, 2005

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Funded by:
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Community-Based Restoration Program Partnership

Table of Contents

Background

The Santa Barbara based Community Environmental Council retained Stoecker Ecological to conduct a site analysis of the Horse Creek Dam, an assessment of upstream salmonid habitat conditions, and to assistance Los Padres National Forest personnel with stakeholder-based dam removal plan development. The dam was built in 1969 and is located on Horse Creek approximately 850 feet upstream from the Sisquoc River confluence within the Los Padres National Forest, San Rafael Wilderness Area, and Sisquoc River Wild and Scenic River Corridor. The obsolete dam was identified as an impassable barrier to fish migration and recommended for removal in *Steelhead Migration Barrier Assessment and Recovery Opportunities for the Sisquoc River, California* (Stoecker 2003). The removal of Horse Creek Dam has been identified as a desirable restoration project by the Forest Service as part of their Sisquoc River Wild and Scenic River management planning process.

Horse Creek Dam

In coordination with Los Padres National Forest personnel, Community Environmental Council received a grant from American Rivers/NOAA Fisheries to further assess removal of Horse Creek Dam. The Forest Service has agreed to act as the lead agency for permitting and actual dam removal coordination. The Forest Service also provided an administrative pass and gate keys for vehicle access close to Horse Creek Dam near the Manzana Schoolhouse at the Manzana Creek and Sisquoc River confluence. Mike Love and Associates was contracted to oversee the dam site survey and to characterize the existing physical channel conditions, evaluate anticipated channel response associated with removal of the dam, and characterize the streams hydrology through estimation of peak flows and associated recurrence intervals. Matt Stoecker and Mike Love conducted the dam site survey June 14-15, 2005. Mike Love and Associates produced a technical memorandum titled *Stream Channel Assessment for Horse Creek Dam Removal Project* dated September 7, 2005 that details the dam site analysis findings. Los Padres Forest Service personnel have conducted non-fishery related biological surveys at the dam site during the spring and summer of 2005 and visited Stoecker and Love during the June 15, 2005 dam site survey. The following report summarizes salmonid habitat conditions observed on Horse Creek during two days of surveying on June 19-20, 2005 by Stoecker and Allen.

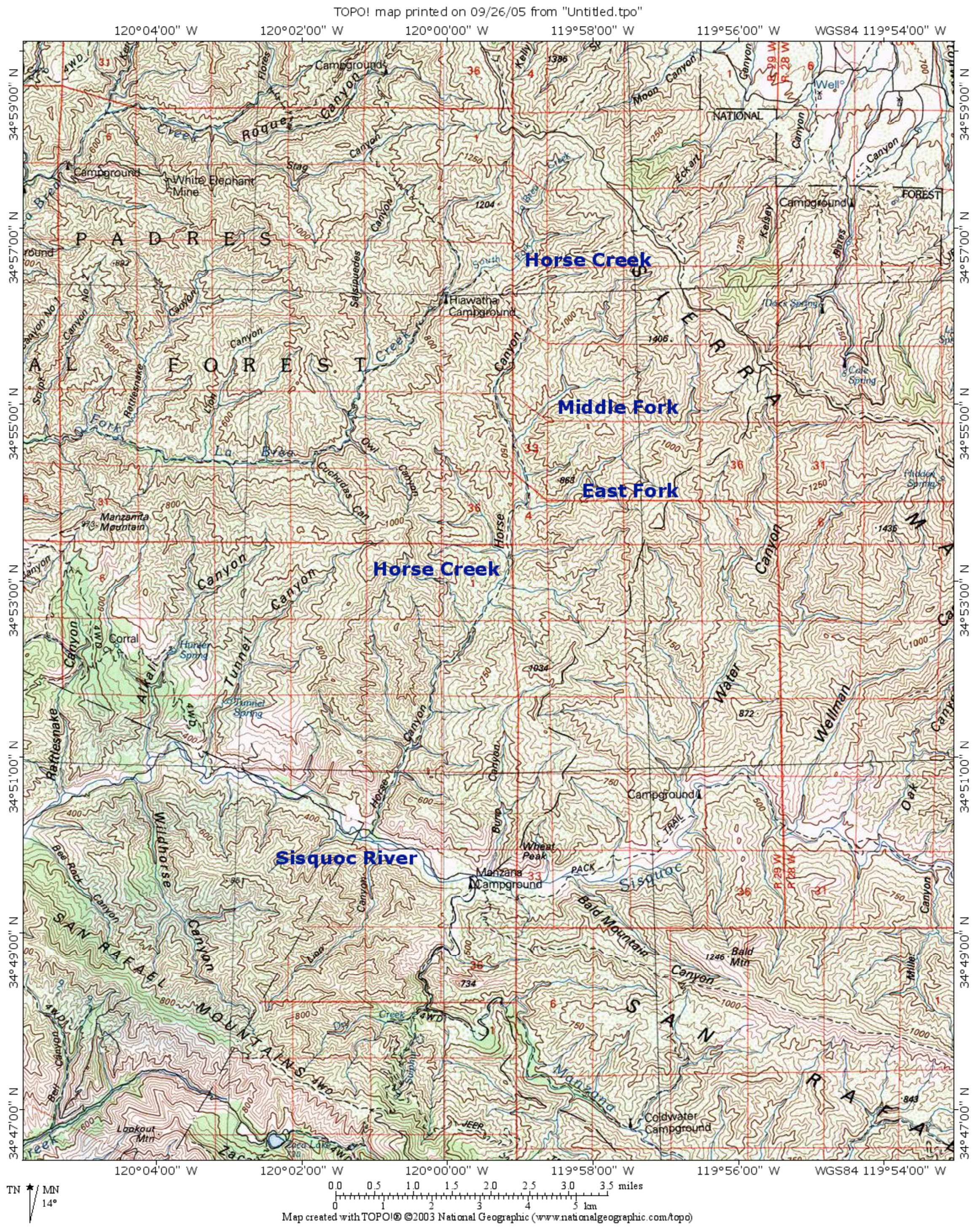
Scope of Work

The objectives of the survey were to identify the natural limits to upstream steelhead migration that would be encountered with the removal of the Horse Creek Dam, to assess basic salmonid habitat conditions, and to document any fish species observed. The habitat survey extended from the Horse Creek confluence at the Sisquoc River upstream and included the upper mainstem of Horse Creek and both the Middle and East Forks of Horse Creek.

Survey Results

Survey results are summarized below for the mainstem of Horse Creek, the East Fork Horse Creek, and the Middle Fork Horse Creek. Within these reaches the habitat description and photographs are organized in the order they were observed from the downstream end of the reach to the upstream survey limit. For the purposes of this report, the mainstem of Horse Creek extends from the Sisquoc River upstream along "Horse Canyon" as defined on USGS 7.5 minute quad maps. The East Fork Horse Creek confluence with the mainstem occurs approximately 6.1 miles upstream of the Sisquoc River. The Middle Fork Horse Creek confluence with the mainstem occurs approximately 7.15 miles upstream of the Sisquoc River. Both East and Middle Forks are unnamed tributaries on the USGS 7.5 minute quad maps. The mainstem of Horse Creek was surveyed for approximately 8.7 miles upstream of the Sisquoc River. The East Fork of Horse Creek was surveyed for 1.1 miles upstream of Horse Creek. The Middle Fork of Horse Creek was surveyed for 1.0 mile upstream of Horse Creek. A total of 10.8 miles of stream were ground surveyed within the Horse Creek drainage.

Horse Creek Drainage Map



Mainstem of Horse Creek

Downstream of the dam, Horse Creek provides limited salmonid rearing habitat of poor to fair quality due to the lack of pools, maximum water depth of less than 2 feet, low riparian canopy cover, and low instream cover. Adequately sized spawning substrate occurs in moderate abundance downstream of the dam with substrate embeddedness averaging 50%.

Looking downstream of the dam

Upstream of the dam, the wetted stream width measured between 5-12 feet and small pools up to 2 feet 6 inches in depth were observed. Shallow runs and riffles are the dominant habitat type with pocket water and small pools occurring to a lesser extent. The substrate consists mainly of cobbles and small boulders. Riparian canopy cover increases upstream of the dam and emergent vegetation also increases the available instream cover. Salmonid rearing habitat conditions are mostly fair upstream of the dam with several smaller pools that would provide good salmonid rearing habitat. Fair spawning substrate conditions occur with moderate substrate embeddedness and a moderate amount of adequately sized substrate.


Scour pool 950 feet upstream of dam


Bedrock scour pool approximately 1 mile upstream of dam


Stream habitat approximately 2.5 miles upstream of dam

Surface flow of approximately 2.0 c.f.s. was observed to occur continuously from the Sisquoc River confluence upstream for 5.0 miles to near the 1800-foot elevation. At this location a prolific groundwater source occurs and appears to supply all summer surface flows to lower Horse Creek.

Groundwater resurfacing and dry channel upstream

Upstream of the groundwater source, Horse Creek was observed to be dry for 1.1 miles to 100 feet upstream of the East Fork Horse Creek confluence. Approximately 100 feet upstream of the East Fork Horse Creek confluence, a short reach of Horse Creek was observed to have trickling flows mixed with short dry reaches and several small pools. This wetted reach extended for only 0.05 miles and contained one bedrock scour pool measuring 2 feet 6 inches deep. Water temperature measured 67 degrees Fahrenheit. The pool and adjacent wetted reaches would provide adequate, but limited summer rearing habitat for salmonids.

Habitat approximately 250 feet upstream of the East Fork

The Horse Creek channel remained dry for 0.9 miles upstream to 250 feet downstream of the Middle Fork where surface flows of 1 c.f.s were observed upstream to the Middle Fork. The Middle Fork supplied all surface flows into this portion of Horse Creek. Water temperature was measured at 65 degrees Fahrenheit and fair spawning and rearing habitat was observed. Beginning immediately upstream of the Middle Fork, the mainstem of Horse Creek was dry for 1.15 miles upstream to near the 2400-foot elevation.

Dry channel upstream of the Middle Fork

Upstream of the previously mentioned dry stream reach, trickling flow of less than 0.1 c.f.s was observed along with isolated pockets of shallow water and short dry reaches. Salmonid rearing habitat conditions were poor in this upper reach of Horse Creek due to sporadic surface flows, and shallow water depth. These variable surface flow conditions continued upstream to the upper extent of the survey approximately 8.7 miles upstream from the Sisquoc River.

Isolated pool in upper Horse Creek

Streambed substrate embeddedness on the mainstem of Horse Creek was observed to average 50% and varied from a low of 40% to a high of 60%. Substrate embeddedness values observed were not optimal for salmonid spawning in many locations, but several reaches associated with scour pools or confined reaches with accelerated water velocities contained adequate embeddedness values for spawning. In addition, embeddedness values observed during this mid-June survey are expected to be higher than substrate conditions encountered during ideal late winter and spring salmonid spawning season. By mid June, percent substrate embeddedness has likely increased significantly due to increased fine sediment deposition and incremental algal growth. Adequately sized spawning substrate was present in low to moderate abundance throughout the Horse Creek drainage and overall spawning conditions during late winter and spring are expected to be fair. Spawning conditions in a given year are likely variable and highly dependant upon natural events such as fire, erosion, and rainfall patterns.

Southern steelhead (*Oncorhynchus mykiss*) were not observed in the Horse Creek drainage. Arroyo Chub (*Gila orcutti*) ranging from 1.5 to 4 inches in total length were observed sporadically in low densities from the Sisquoc River upstream 4.0 miles. One Arroyo Chub was observed downstream of the dam. No fish species were observed upstream of the lower 4 miles of Horse Creek.

Arroyo Chub downstream of Horse Creek Dam

Along the 8.7 miles of the mainstem Horse Creek that were surveyed, no physical features within the stream channel were observed that would prevent upstream adult steelhead migration with adequate surface flows present. It is difficult to estimate the natural upstream limit of migration for steelhead on the mainstem of Horse Creek due to the lack of surface flows observed in several reaches and presence of thick vegetation in the channel of the uppermost surveyed reaches. While obvious waterfall or steep gradient type barriers were not present in the 8.7 miles of the mainstem surveyed, upstream migration may be limited by inadequate surface flows in multiple reaches. The dry reaches observed downstream of the East Fork and between the East Fork and Middle Fork appear to carry sufficient surface flow for upstream migration during winter flows, as determined by the extent of substrate scour, waterline marks observed on adjacent bedrock and channel banks, and debris caught in adjacent vegetation. The dry reach upstream of the Middle Fork, however, appears to convey low winter flows and chaparral-type vegetation was observed growing in the channel. Riparian vegetation associated with perennial reaches was absent and streambed substrate appeared highly permeable. The upper Horse Creek drainage is small upstream of the Middle Fork and adequate surface flows for upstream migration may be lacking during some years. Especially wet years may provide sufficient flow and limited upstream migration. The stream channel becomes a very small gully by mile 8.7 and is densely vegetated with thick brush limiting upstream survey access. It was determined based on USGS 7.5 minute topographic maps that steelhead migration could not extend past mile 9.7, where excessive stream gradient occurs.

East Fork Horse Creek

The lower 0.6 miles of the East Fork Horse was dry. Upstream of the dry reach, variable stream flow conditions occurred for 0.1 mile with trickling flow less than 0.1 c.f.s mixed with dry reaches.

Dry channel on East Fork upstream of Horse Creek

Surface flow of less than 0.2 c.f.s was observed 0.7 miles upstream of the mainstem of Horse Creek and continued past the upstream limit of the survey 1.0 mile upstream of Horse Creek. Water temperature was measured at 64 degrees Fahrenheit. Poor to fair rearing habitat was observed due to the shallow water depth, low instream cover, and highly limited habitat size. Adequate spawning substrate was present in low abundance and substrate embeddedness was moderate. No fish species were observed in the 1.0 mile of stream surveyed on the East Fork.

Near upper survey limit of the East Fork

Dry channel conditions along the lower 0.6 miles of the East Fork limit fish passage during most or all of a given year, depending on stream flows. Approximately 0.5 miles upstream from the mainstem of Horse Creek a 6-foot tall bedrock and boulder cascade was observed. This cascade would likely limit upstream fish passage depending on the amount of surface flow encountered during a given flow year. Waterlines suggest the downstream pool may fill 2 to 3 feet in depth leaving a 3 to 4-foot jump for fish. Such a scenario is near the upper limitation of adult steelhead jump capabilities, but may be possible during high stream flows when the downstream pool is at it's deepest.

6-Foot bedrock drop 0.5 mile upstream on the East Fork

With adequate surface flows and migration over the 6-foot cascade, steelhead may be able to migrate upstream of the upper survey limit 1.0 mile upstream of the mainstem of Horse Creek. The stream channel becomes densely vegetated with thick brush 1.0 mile upstream from Horse Creek, limiting upstream survey access. It was determined based on USGS 7.5 minute topographic maps that steelhead migration could not extend more than 4.6 miles upstream on the East Fork due to excessive stream gradient observed near the 3600-foot elevation.

Middle Fork Horse Creek

The Middle Fork of Horse Creek was observed to have the greatest surface flow upstream from flows observed on the lower 5 miles of Horse Creek. At the confluence with the mainstem, the Middle Fork was discharging approximately 1.0 c.f.s of stream flow with a temperature of 65 degrees Fahrenheit. The surface flow only continued upstream for 0.15 miles before abruptly ending. Fair to good salmonid rearing habitat was observed in this reach with moderate instream cover, 50-75% riparian canopy cover, and pool depth to 2 feet. Adequately sized spawning substrate was moderately abundant and substrate embeddedness measured 45%.

Middle Fork flow immediately upstream of Horse Creek

Dry channel conditions were observed upstream of the reach with surface flow for approximately 0.25 miles. Trickling flows of approximately 0.1 c.f.s combined with dry reaches were observed upstream to the upper survey limit. No fish species were observed on the Middle Fork.

Near the upper survey limit on the Middle Fork

The stream channel becomes densely vegetated with thick brush 1.1 miles upstream from Horse Creek, limiting upstream survey access. With adequate surface flows, steelhead may be able to migrate upstream of the upper survey limit 1.1 miles upstream of the mainstem of Horse Creek. It was determined based on USGS 7.5 minute topographic maps that steelhead migration could not extend more than 3.1 miles upstream on the mainstem of the Middle Fork due to excessive stream gradient observed near the 3240-foot elevation. Two smaller tributaries that enter the Middle Fork from the east may also be accessible. The downstream, unnamed tributary may provide 1.1 miles of accessible habitat before excessive gradient prevents upstream passage near the 2880-foot elevation and the second unnamed tributary may provide an additional 0.4 miles of habitat before excessive gradient prevents upstream passage near the 3040-foot elevation.

Salmonid Habitat and Population Recovery Conclusions

Adequate rearing and spawning habitat to support *O. mykiss* was observed in the Horse Creek drainage. With the removal of Horse Creek Dam it is anticipated that fish populations will be able to naturally recolonize all historically accessible habitat within the Horse Creek basin. Of the 10.5 stream miles surveyed, 5.2 miles were observed to have surface flow, 1.3 miles were observed to have variable stream flow conditions, and 4.0 miles were dry. The highest quality salmonid habitat was observed in the lower 5.0 miles of Horse Creek, the lower 0.15 miles of the Middle Fork of Horse Creek, and the 0.05 miles of Horse Creek upstream of the East Fork Horse Creek. These reaches provide fair to good summer rearing habitat conditions for salmonids. Adequate spawning substrate occurs throughout the surveyed reaches in low to moderate abundance and provide sufficient habitat conditions during spawning season.

It is possible that adequate migration conditions during wet years could allow *O. mykiss* to migrate upstream of the upper survey limits of this project. An additional 8.4 miles of stream were identified upstream of the upper survey limits to the estimated upstream natural barriers to steelhead migration. This potential additional habitat could increase the total quantity of habitat available for steelhead to 18.9 miles. Upstream natural limits were estimated by locating where the stream sustains a slope of 10-15% using CDFG barrier estimation methods and based on stream slope assessment of USGS 7.5 minute topographic maps.

The presence of a diversity of age classes of Arroyo Chub in the lower 4.0 miles of Horse Creek suggest the occurrence of perennial stream habitat over the last several years. Due to the presence of the impassable Horse Creek Dam, this Arroyo Chub population could not have migrated upstream from the Sisquoc River without human transplantation. It is assumed that the Arroyo Chub population has likely occurred in Horse Creek for many years and was likely present before the dam was built. Adequate habitat conditions for Arroyo Chub were observed in the lower 4 miles of Horse Creek where they were observed.

O. mykiss coexist with Arroyo Chub in the Sisquoc River and tributaries such as Manzana Creek and both species likely occurred in Horse Creek upstream of the dam before it was built. It is possible that following the construction of the dam, factors such as fire-related erosion and elevated sediment transportation in the stream, prolonged drought, excessive water temperatures, and possibly fishing pressure could have eliminated the *O. mykiss* population. With the impassable dam near the mouth of the creek, *O. mykiss* have likely not been able to recolonize the drainage since that time. It is expected that following the removal of Horse Creek Dam, *O. mykiss* and other aquatic species prevented from upstream migration, will naturally recolonize this drainage. It should be noted that natural events such as fires and prolonged droughts may have historical eliminated fish populations from all or parts of Horse Creek in the past and similar conditions will surely occur in the future. However, with the removal of Horse Creek Dam, unrestricted migration from the Sisquoc River to the natural upstream limits of Horse Creek will allow fish populations to naturally recolonize the tributary when conditions are adequate.

Successful steelhead recovery to Horse Creek, the Sisquoc River, and the Santa Maria River watershed is highly dependant on improving steelhead migration conditions on the Santa Maria River downstream. Unfavorable flow releases from Twitchell Dam on the Cuyama River, increased groundwater pumping near Santa Maria, and gravel extraction operations in the river channel have all negatively impacted the now endangered Santa Maria/Sisquoc River steelhead population (Stoecker 2003). Improved stream flow conditions for steelhead migration between the ocean and the Sisquoc River are needed to ensure successful steelhead recovery to Horse Creek, the Sisquoc River, and Santa Maria River watershed.

References

California Department of Fish and Game 2002. *California Salmonid Stream Habitat Restoration Manual*. State of California Resources Agency Department of Fish and Game Third Edition Volume II February 2002.

Love, Michael, Llanos, Antonio 2005. *Stream Channel Assessment for Horse Creek Dam Removal Project.* Prepared for Stoecker Ecological. September 7, 2005

Stoecker, Matt W., J. Stoecker 2003. *Steelhead Migration Barrier Assessment and Recovery Opportunities for the Sisquoc River, California*. Submitted to and funded by the Coastal Conservancy. January 2003.

Attachment 2

Stream Channel Assessment for Horse Creek Dam Removal Project

Attachment 3

Horse Creek Dam Removal – Post Project Survey

July 17, 2007

Horse Creek Dam Removal - Post Project Survey

Matt Stoecker, Biologist, Stoecker Ecological

Background

Following the successful removal of Horse Creek Dam in October, 2006 Stoecker Ecological returned to the former dam site on June 26, 2007 to assess channel configuration changes and specifically fish passage effectiveness. The following brief summary and accompanying photographs describe conditions encountered approximately 9 month after the dam was removed. In addition, large adult *O. mykiss* were observed in the mainstem Sisquoc River upstream of Horse Creek and are described.

Channel Configuration Changes

On May 11, 2007 Kevin Cooper, LPNF Biologist, sent an e mail informing project participants that he and Tom Murphey had returned to the dam site to remove remaining culvert pieces and pull tamarisk. In addition Kevin noted " the creeks and rivers hardly responded to the small amount of rain this year, so we did not expect to see much (at the dam), and we did not. Rancho Sisquoc reported 7 inches for the year and the river did not (reportedly) flow on the surface at the ranch. On the way up, we noticed that the river looked even lower than it did last fall, and that even the finest sediments were not transported. As soon as we stepped into Horse Canyon creek, we saw a skiff of black ash that had been transported down from the wildfire that burned in upper Horse Canyon watershed, so there was some movement of water and sediment, probably only because the area had burned. At the dam itself, there was about a 4 foot nick at the water course that had walked back about 20 meters (likely intended to be feet not meters) into the dam sediments, and above that, nothing appears to have changed."

Attached photographs from Kevin showed the notch in the deposited sediment and the remains of a piece of the former dam's concrete footing that was perched approximately 2.5 feet above the downstream substrate.

Upon returning to the dam site on June 26th, we observed similar conditions as described by Kevin, with a wedge measuring 7.5 feet wide and 4 feet deep extending 21 feet upstream to heavily mineralized pre-dam channel substrate. The mobilized sediment wedge had deposited immediately downstream of the dam creating a mound of substrate where the former scour pool occurred. The concrete footing was undercut with approximately 0.15 c.f.s. flowing underneath it. Using heavy boulders nearby, we were able to break the remaining concrete footing in half and remove it from the channel that was incising upstream through the sediment. Following removal of the footing, the wedge-shaped notch was measured to be 6.5 feet tall at the site of the former dam with the same width and upstream incision lengths stated above.

Using these measurements (21 x 6.5 x 7.5), we find that the amount of sediment mobilized in the first winter is approximately 512 cubic feet or just under 19 cubic yards. This amount of sediment represents only 0.12% of the total estimated sediment to be mobilized (15,400 cubic yards) with removal of the dam.

The following photographs show the channel incising through the deposited sediment behind the former dam.

Looking upstream at incising channel from below former dam site.

Looking across incision from river right side.


Looking downstream from the top of the incising channel.

Fish Passage

Due to the low rainfall year following dam removal and lack of connectivity between the Sisquoc River and the ocean there was no opportunity for adult steelhead to migrate to the former dam site. It appears that limited surface flow on Horse Creek allowed at least four Arroyo chub to migrate upstream from the Sisquoc River or downstream from upper Horse Creek to where they were observed 70 feet below the former dam site. Only one Arroyo chub, which was much larger than these 1-2 inch fish was observed in the downstream channel prior to dam removal.

Prior to removal of the remaining concrete footing slab, surface flow was forced under the slab and down a steep cascade with no fish passage opportunities during low to moderate flows. While the overall slope up the notch measured just over 3%, a large boulder in the middle of the notch half way up the slope caused a steeper slope at the downstream end that measured 6%. The upstream 12 feet of the incised channel had a mild slope of 1%. During the survey fish passage was not possible due to lack of water depth and excessive velocity down the steep incising slope of sediment deposits. However, there are numerous impassable riffles and cascades naturally at this time of year and with observed low flows. With the next significant rain and flow event the incising channel is expected to “lay down” upstream and quickly establish a slope of around 2-3% and allow for unimpeded upstream steelhead migration.

Adult steelhead and other wildlife observations

While hiking from Manzana Schoolhouse downstream to Horse Creek several large *O. mykiss* were observed in the Sisquoc River. During previous surveying efforts through this reach in 2001 and 2005 no *O. mykiss* were observed. Immediately downstream from the Manzana Schoolhouse campground outhouse and where the dry Manzana Creek channel enters the Sisquoc River, two *O. mykiss* with estimated lengths of 7 and 15 inches were observed while snorkeling in an isolated pool. The boulder scour pool measured over 7 feet deep with no surface inflow or outflow. Thousands of Arroyo chub were also present in this pool in addition to three Southwest pond turtles.

Pool with 7 and 15 inch *O. mykiss*.

An additional 1000 feet downstream from the above mentioned scour pool surface flows resumed and a small pool measuring 4 feet deep occurred upstream of a small beaver dam and in association with adjacent undercut banks. Four *O. mykiss* ranging from 11 to 17 inches in length were observed while snorkeling this pool.

11 and 14 inch *O. mykiss* in beaver dam pool plus small Arroyo chub.

One additional *O. mykiss* with an estimated length of 13 inches was observed from the bank approximately 2000 feet downstream from the Manzana Creek confluence. This fish disappeared into a thick root mass and could not be observed underwater.

Thousands of Arroyo chub were observed in all stream reaches with surface flow and isolated pool between Manzana Creek and Horse Creek. Two golden eagles were observed flying down the Sisquoc valley past the mouth of Horse Creek.

Three red-legged frogs were observed within the 1200 feet upstream of the former dam site on Horse Creek while investigating upstream.

Attachment 4

Horse Creek Post Dam Removal Monitoring Survey

Michael Love & Associates
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STOECKER ECOLOGICAL
NATURAL RESOURCE ASSESSMENT AND RESTORATION SERVICES

July 31, 2008

To: Mary Larson
Senior Fisheries Biologist
California Department of Fish and Game

Subject: Horse Creek Post Dam Removal Monitoring Survey- 2008
PSMFC Contract No. A06-S2 / Grant Agreement No. P0610528

Dear Mary,

We have completed a post dam removal monitoring survey and establishment of long term monitoring benchmarks at the Horse Creek Dam Site. The findings are summarized in this document.

Our overall conclusion is that while demolition of the dam removed a significant impediment to fish passage, significant mobilization of the stored upstream sediment has yet to occur. Since demolition of the dam in October 2006, a small wedge of sediment has eroded and a kickpoint with a 3.7-foot drop has formed. The slower than expected channel incision is likely a result of the wide shallow upstream channel, naturally cemented channel substrate, stabilization of sediment from root networks, and increased sediment delivery from the watershed due to the 2006 wildfire in the Horse Creek basin.

At this time there remains a barrier to upstream migrating salmonids, but the knickpoint and associated drop should become more passable in time as additional material mobilizes and the headcut retreats upstream, reducing the channel gradient.

For your reference the project reach coordinates are listed in the report and are:
Downstream (N 34° 50' 7.27" / W 120° 1 '5.94") and Upstream (N 34° 50' 21.92" / W 120° 1' 0.27")

It has been a pleasure working on this project.

Sincerely,

Antonio Llanos, P.E.
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Background

On October 20, 2006 a defunct dam located on Horse Creek, a tributary to the Sisquoc River within Santa Barbara County was demolished using explosives. The 4.5 foot tall and 60 foot wide dam was built in 1968 in the Los Padres National Forest (LPNF) on the edge of the San Rafael Wilderness Boundary. The following winter the region experienced a large flood event, estimated to have between a 10 and 25-year return period. Anecdotal and field evidence suggests that the basin behind the dam completely filled-in with sediment during the first few winters. Over time the downstream channel incised below the dam creating an overall drop of more than 8 feet over the dam face.

Horse Creek and the Sisquoc River are designated critical habitat for the Federally Endangered Southern Steelhead. The dam removal project was initiated as an effort to improve upstream passage for fish and other aquatic organisms.

In preparation for the dam removal, Stoecker Ecological (SE) and Michael Love & Associates (MLA) conducted a geomorphic assessment of the proposed dam removal project (MLA, September 7, 2005). As part of the study, the channel profile and cross sections were surveyed to document the pre-project condition of the stream channel and estimate the potential sediment delivery to the Sisquoc River. The pre-project survey found the small basin formed by the dam was filled-in completely with sediment. The sediment wedge from the dam extends over 1,000 feet upstream. The study estimated that roughly 15,400 cubic yards of sediment stored behind the dam would be released following dam removal, and the stored sediment would likely be mobilized relatively quickly during large flow events. In July 2006, shortly before the dam was demolished, a wildfire burned approximately 2,000 acres within the upper portions of the Horse Creek watershed (Per. Com., Kevin Copper, Forest Biologist, LPNF).

The final implemented project involved demolition of the dam using explosives and allowing natural sediment transport processes to regrade the upstream channel. On June 26th 2007, Stoecker Ecological conducted a post-project survey and determined that after the first winter, which experienced extremely low precipitation (only 7 inches fell at nearby Rancho Sisquoc) and no significant flow events, very little sediment behind the former dam was mobilized. In 2007 an incision measuring 7.5 feet wide and 4 feet deep extended 21 feet upstream. This represented mobilization of an estimated 19 cubic yards of stored material.

The second year following demolition (water year 2008) the Sisquoc River and its tributaries experienced several large flow events, as demonstrated by observed field evidence and recorded peak flows in other streams and rivers within the region.

This memorandum documents the follow-up survey conducted by SE and MLA in 2008 to quantify changes to the channel following the second winter since removal of the dam and establish benchmarks for future monitoring efforts.

Purpose of Geomorphic Monitoring

Continued monitoring of the channel's response to demolition of the dam is expected to provide information useful in planning for future dam removal projects. Some of the questions this geomorphic monitoring may assist in answering include:

- How accurate were the methods used to estimate the volume and rate of sediment mobilized and the resulting shape of the channel upstream of the dam?

- What is the nature of sediment release in drier hydrologic regimes? Much of the information currently available about sediment release from dam removal originates from areas with wetter hydrologic regimes. The Horse creek site represents one of the only studied dam removals in the drier southern California climate.

- Will the channel reestablish its historic location, and how long will it take?

- Was the decision to allow uncontrolled release of the stored sediments appropriate, or should other methods be used to address channel response? If stored material is left in place, but does not rapidly flush downstream, impacts to downstream habitat are limited but a passage impediment may still remain for an unknown duration of time.

- How should the effect of soil cementation and root structure be considered in the assessment of sediment removal?

A better understanding of these channel dynamics will help improve analysis and decision-making for future barrier removal projects.

Survey Methods

On April 17th and 18th, 2008 Matt Stoecker of SE and Antonio Llanos of MLA resurveyed the channel profile and cross sections established in 2004. The survey was conducted using the tape and level method. Previous benchmarks were relocated to overlay current and previous surveys. Rebar was installed at the ends of each of the six cross sections to provide permanent benchmarks for future surveys. The longitudinal profile of the channel extended 1,300 feet, from the confluence with the Sisquoc River to 460 feet upstream of the demolished Horse Creek Dam. All six cross sections were resurveyed.

Plots of the profile and cross sections and GPS coordinates of the cross section monuments are provided.

Measured Channel Changes

The sediment stored upstream of the demolished dam remains largely unchanged since the pre-project survey. Headward migrating incision of the channel extends about 40 feet upstream of the old dam face (Figure 1). The newly incised channel has an average slope of 7.5% and width of 14 feet. At the upstream end of this incising channel is a distinct knickpoint with a 3.7 foot vertical drop.

Figure 1 – New channel incised through the dam deposits. Photo was taken from approximately 20 feet from the old dam face. The knickpoint is characterized by a 3.7 feet drop and a 7.5 % channel slope for 45 feet.

Figure 2 – Newly exposed stratigraphy of sediments stored immediately upstream of the demolished Horse Creek Dam.

Calculated using the end-area method, an estimated 120 cubic yards of sediment has been released since the dam was demolished. This represents less than 1 percent of the estimated 15,400 cubic yards of stored sediment expected to be mobilized. Some of this material has been deposited immediately downstream but most of it appears to have been transported out of Horse Creek. The depositional area extends approximately 35 feet downstream of the demolished dam, filling in the plunge pool and forming a short section of braided channel.

Observations of the banks along the newly incised channel reveal the cemented nature of the material stored behind the dam and network of fine roots. The cementation is likely a result of the high mineral content of the water. The incision through the upstream sediment also revealed the vertical layering of the material as it deposited behind the dam (Figure 2). The bottom most layer is about 9 inch thick and consists of coarse relatively clean gravels. The elevation at the top of this layer is close to the elevation of the assumed pre-dam channel bed at this location, as shown in the pre-demolition report (MLA, 2005). The bottom layer is overlaid with a 15 inch thick layer of coarse cobbles and gravels mixed with fine sediment. This is presumed to be the initial material deposited after construction of the dam in 1968, and may have all been delivered during the single large flood event in January 1969 that followed the Wellman fire of 1966. On top of this layer is a 15 inch thick layer of fine sediment that may have been delivered shortly after the dam was constructed. It is overlaid by a 30 inch thick layer dominated by coarse gravels and cobbles. This stratification is common behind dams, as the larger material initially deposits at the upstream end of the basin and fines settle near the dam. As the basin fills in, larger material is more easily transported downstream to the dam site.

During the survey Red-legged and Pacific Tree frogs were both observed utilizing habitat at the former dam site.

Discussion

The Zaca Wildland Fire in July and August of 2007 burned a significant portion of the Sisquoc Basin, but none of the Horse Creek Watershed. While assessing the impacts of the fire was not a part of this study, the impacts to the mainstem Sisquoc River were noteworthy. The highly erosive soils of the basin have supplied large quantities of sediment to the mainstem as evidenced by the uniform channel bed, sand covered river bars, and infilling of pools with fine material along Manzana Creek and the Sisquoc River at Horse Creek.

Although Horse Creek experienced large flows during the winter of 2008, as clearly indicated by field evidence and USGS gage information for Sisquoc River, there was only limited channel adjustments and mobilization of the stored materials. There are several possible reasons for the lower than expected sediment mobilization.

The wide braided channel upstream of the dam site reduces stream power, limiting its ability to erode and transport sediment. The upstream channel is shallow and shows clear evidence of recent flow in side channels along both valley edges.

The surrounding hillslopes provided a high sediment load after the 2006 fire in the Horse Creek Basin, as evident by the veneer of fine grain material newly deposited over the coarse gravel bars upstream of the dam. Transport of these sediments may have exceeded the sediment transport capacity of the channel, reducing its ability to erode the channel bed.

Additionally, the cemented nature of the sediment upstream of the demolished dam, likely caused by high mineral content in the water, requires additional force to mobilize the streambed.

Future Monitoring Efforts

With benchmarks established at the ends of each cross section, future monitoring efforts will be able to quantify changes to the channel and volume of sediment mobilized. We recommend follow-up monitoring occur in the spring following significant storm events. Periodical reconnaissance of the site could also be a useful indicator for monitoring. Significant channel changes observed by US Forest Service, DFG, or others working in the area should serve as a trigger to mobilize a new survey.

Conclusions

Field observations and results from the survey suggest that it will take some time for the channel to readjust and mobilize the sediment stored behind the dam. At this time, the knickpoint at the head of the incision is still a barrier to migrating salmonids, but should become passable in time as the material mobilizes.

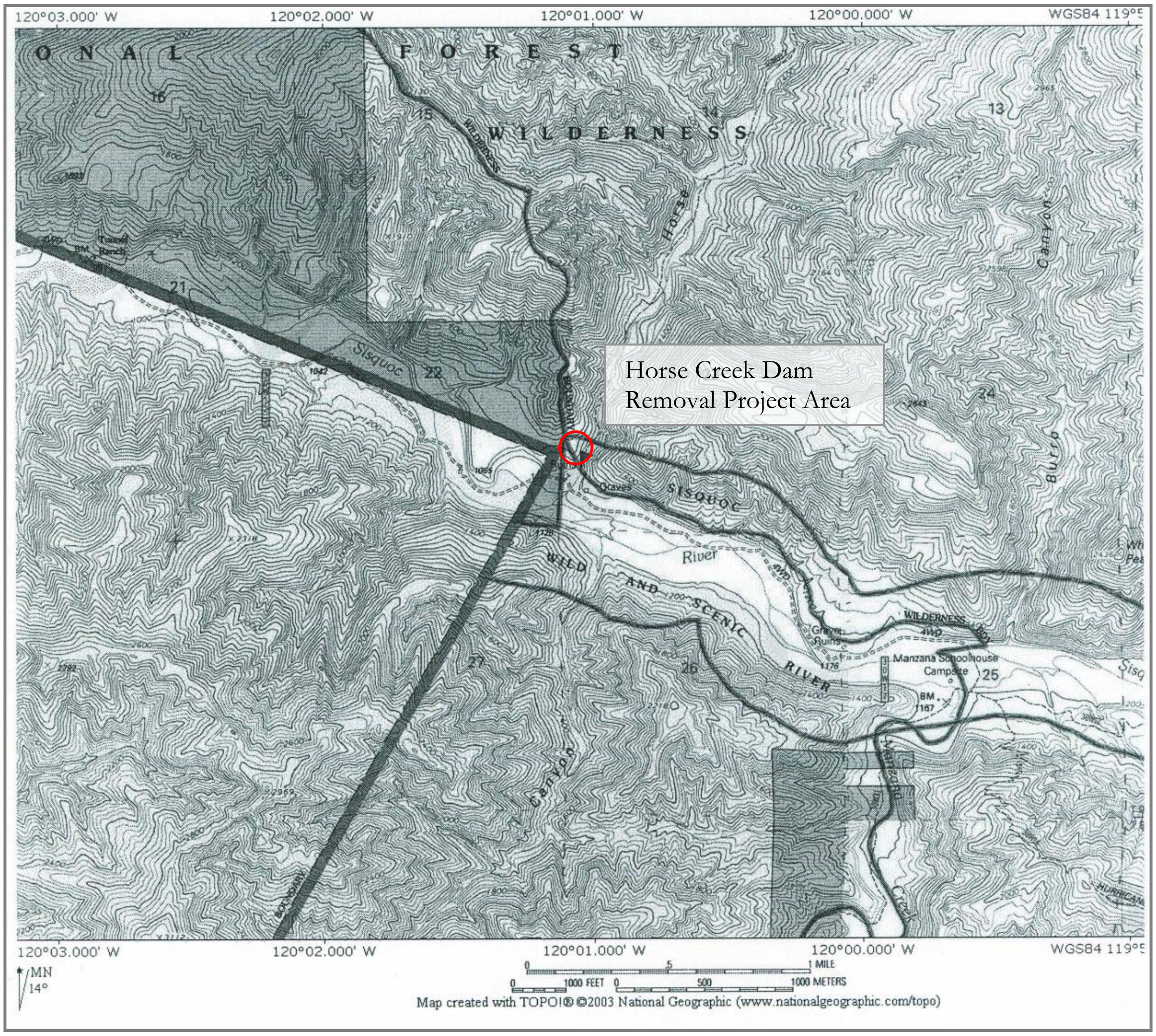
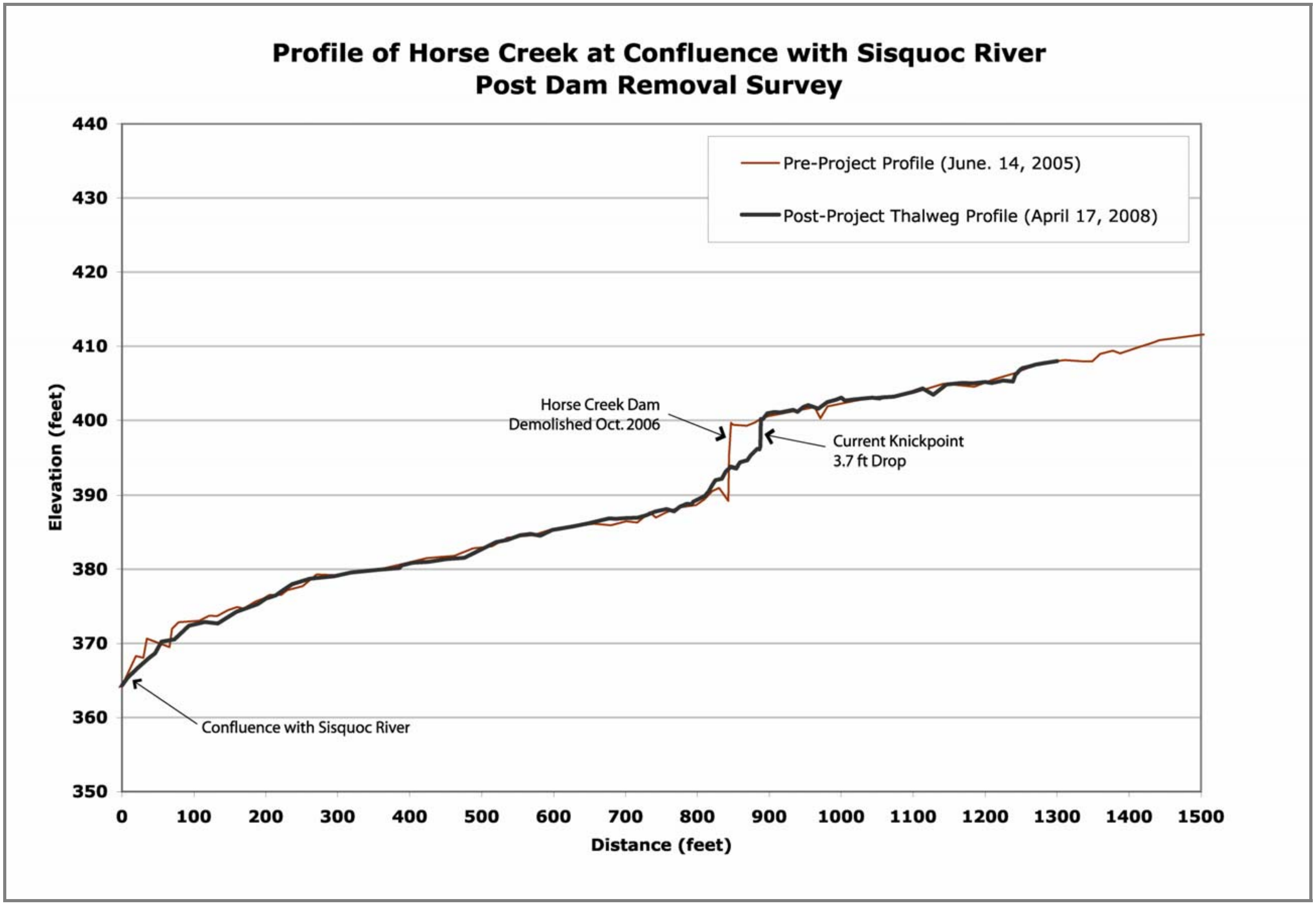


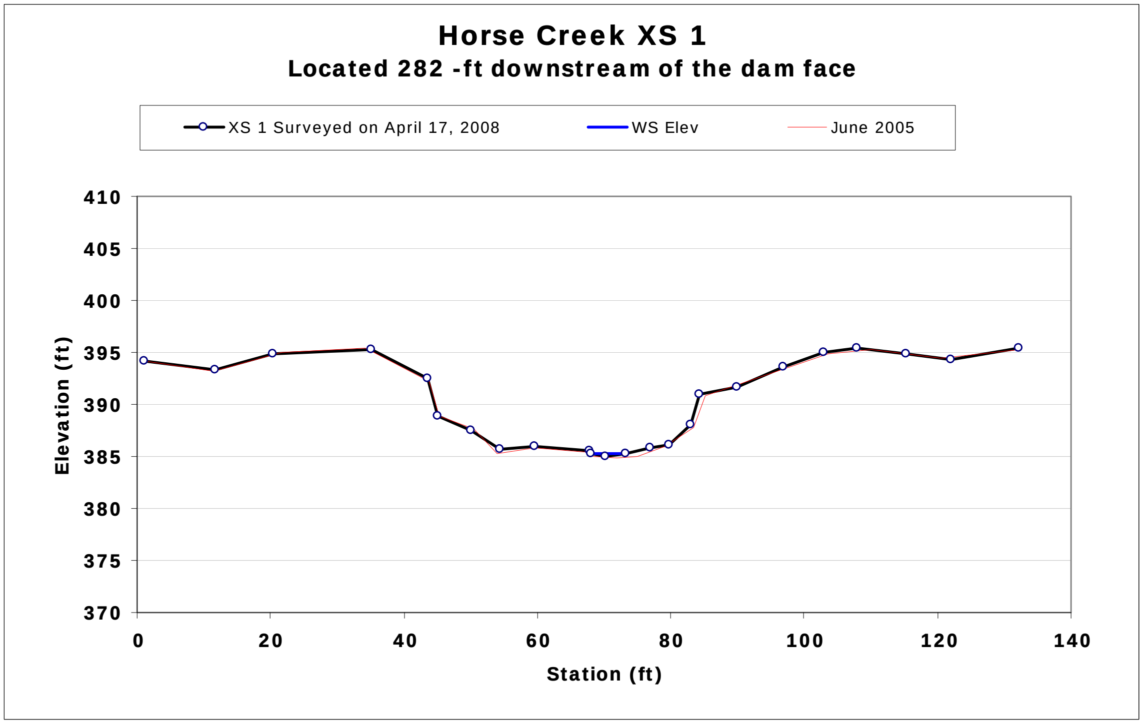
Figure – USGS Topographic map of Project Area

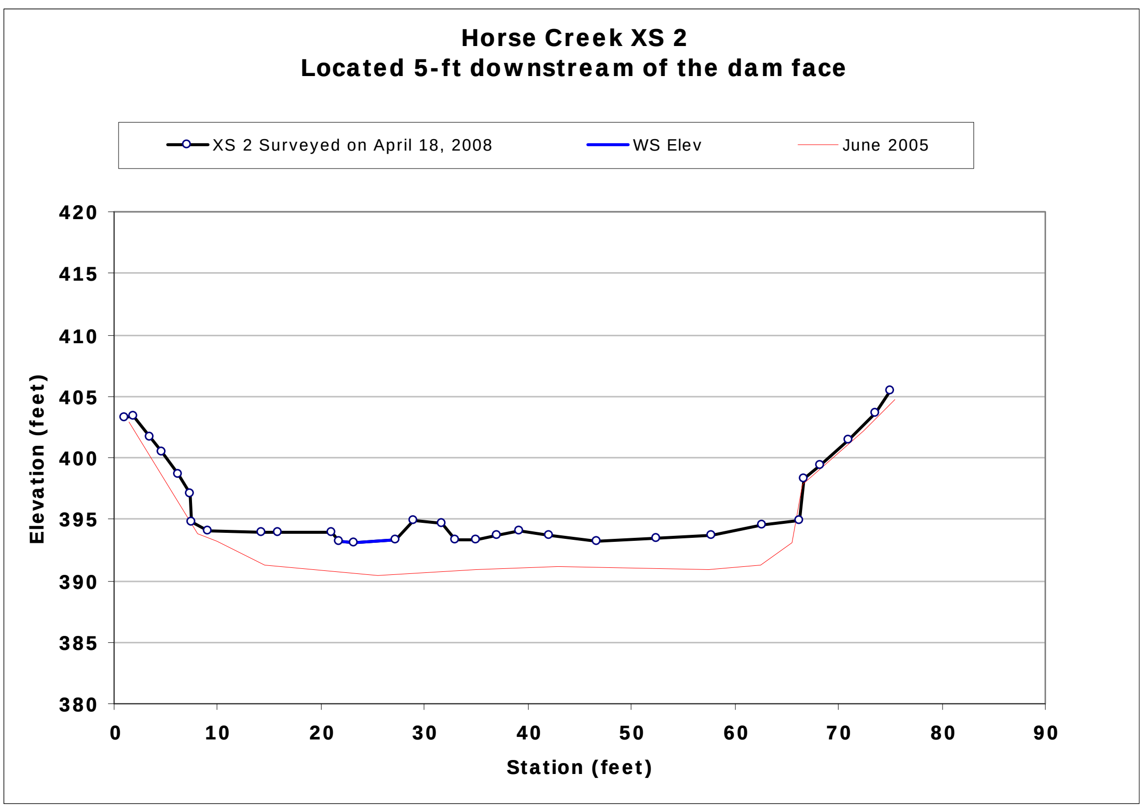
PLACE PLAN MAP HERE

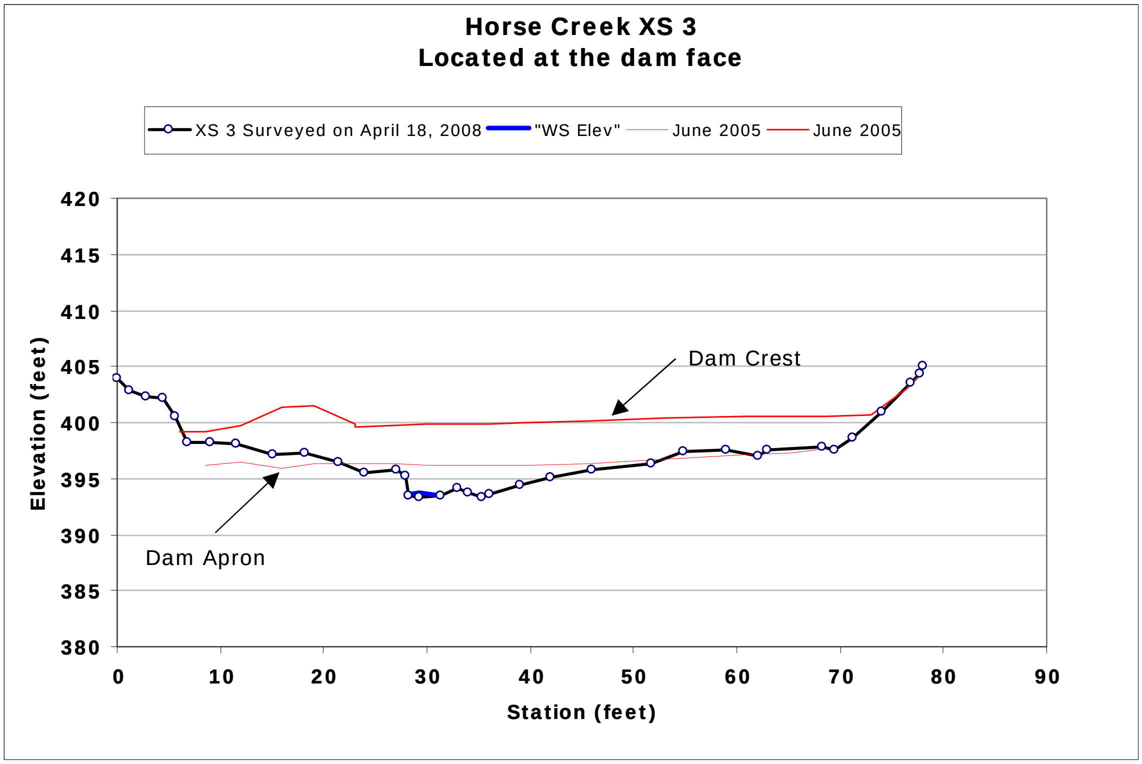

Profile of Horse Creek at Confluence with Sisquoc River
Post Dam Removal Survey
Pre-Project Profile (June. 14, 2005)
Post-Project Thalweg Profile (April 17, 2008)
Horse Creek Dam
Demolished Oct. 2006
Current Knickpoint
3.7 ft Drop
Confluence with Sisquoc River
Elevation (feet)
Distance (feet)
440
430
420
410
400
390
380
370
360
350
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

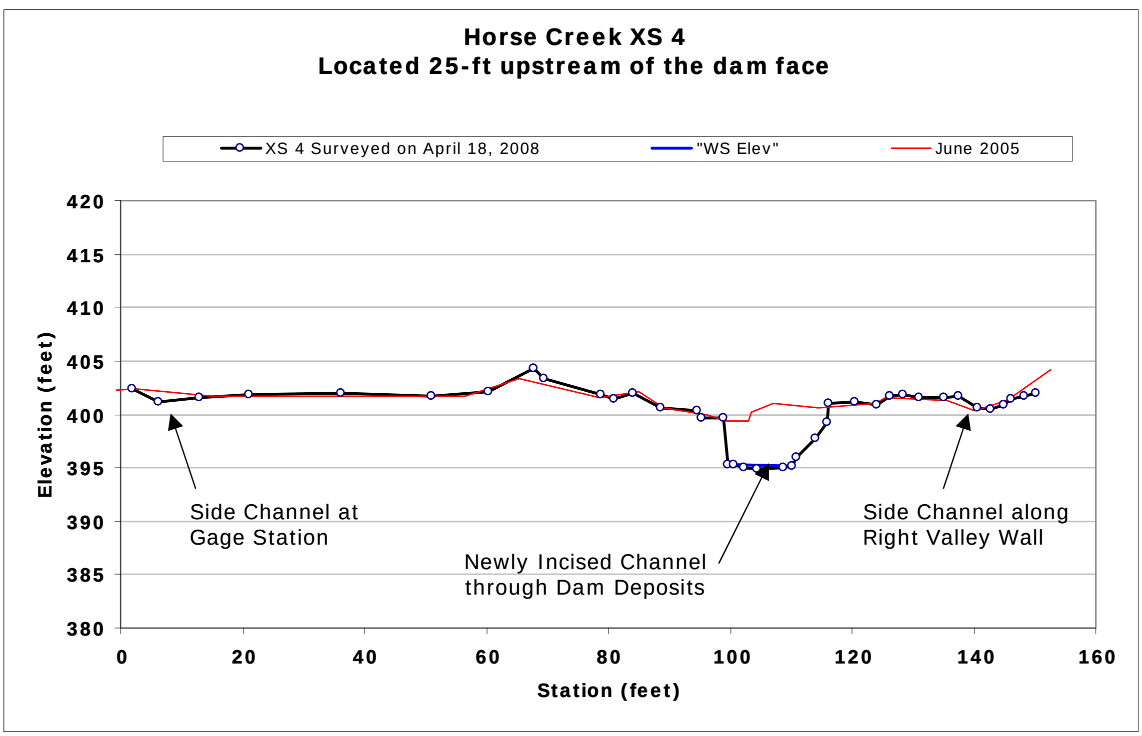
Post Dam Removal Survey Monumented Cross Sections

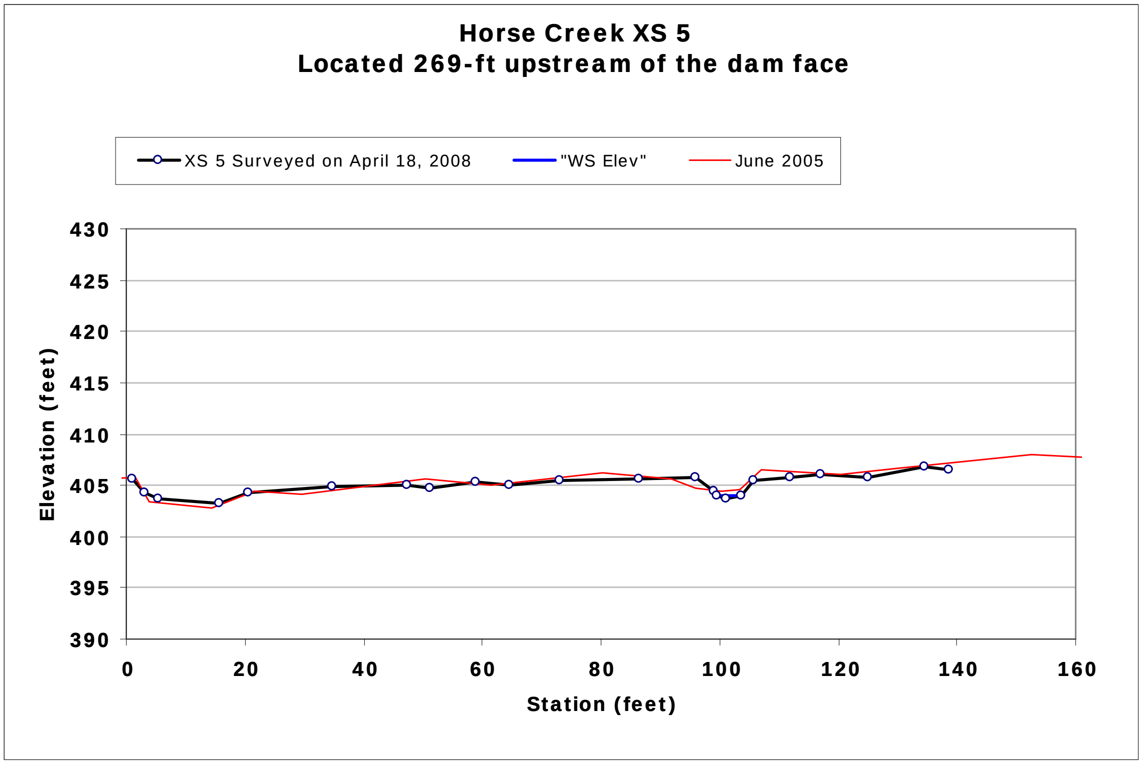
(All Cross Sections are Left to Right Bank as Looking Downstream)

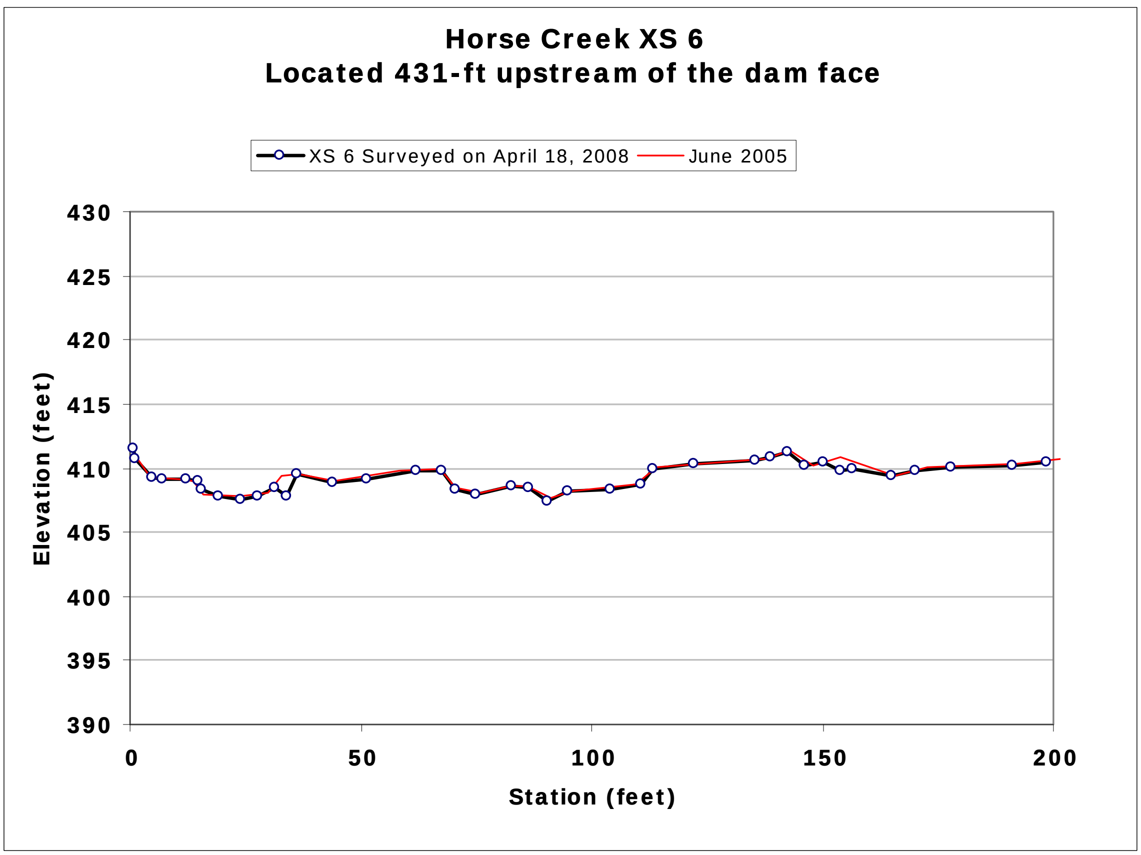





Horse Creek XS 3
Located at the dam face
XS 3 Surveyed on April 18, 2008
"WS Elev"
June 2005
June 2005
Dam Crest
Dam Apron
Elevation (feet)
Station (feet)
420
415
410
405
400
395
390
385
380
0
10
20
30
40
50
60
70
80
90


Horse Creek XS 4
Located 25-ft upstream of the dam face
XS 4 Surveyed on April 18, 2008
"WS Elev"
June 2005
Side Channel at
Gage Station
Newly Incised Channel
through Dam Deposits
Side Channel along
Right Valley Wall
Elevation (feet)
Station (feet)
420
415
410
405
400
395
390
385
380
0
20
40
60
80
100
120
140
160


Horse Creek XS 5
Located 269-ft upstream of the dam face
XS 5 Surveyed on April 18, 2008
"WS Elev"
June 2005
Elevation (feet)
430
425
420
415
410
405
400
395
390
0
20
40
60
80
100
120
140
160
Station (feet)


Horse Creek XS 6
Located 431-ft upstream of the dam face
XS 6 Surveyed on April 18, 2008
June 2005
Elevation (feet)
430
425
420
415
410
405
400
395
390
0
50
100
150
200
Station (feet)

Coordinates of Cross Section Rebar Monuments

Cross Section		Latitude	Longitude	Elevation	Bearing
XS 1	LB Pin	N 34° 50' 12.2"	W 120° 1' 3.6"	394.51	108°
	RB Pin	N 34° 50' 12.6"	W 120° 1' 5.1"	395.73	
XS 2	LB Pin			403.58	318°
	RB Pin	N 34° 50' 14.9"	W 120° 1' 3.2"	403.59	
XS 3	LB Pin	Wooden Stake		403.37	320°
	RB Pin	N 34° 50' 15.1"	W 120° 1' 3.0"	405.23	
XS 4	LB Pin	N 34° 50' 14.1"	W 120° 1' 1.5"	402.72	314°
	RB Pin	N 34° 50' 15.1"	W 120° 1' 2.9"	402.34	
XS 5	LB Pin	N 34° 50' 18.0"	W 120° 1' 1.9"	406.02	328°
	RB Pin	N 34° 50' 16.3"	W 120° 1' 2.0"	406.86	
XS 6	LB Pin	N 34° 50' 16.9"	W 120° 1' 0.1"	411.09	311°
	RB Pin	N 34° 50' 18.1"	W 120° 1' 0.4"	410.92	

Notes:
Pin = Rebar monument located at each edge of cross section
Bearing = compass bearing from left to right bank of cross section
LB / RB = Left Bank / Right Bank
All elevations on top of rebar pin

Up and Downstream Coordinates for Project Area

Project Reach Coordinates	Latitude	Longitude
Downstream	N 34° 50' 7.27"	W 120° 1 '5.94"
Upstream	N 34° 50' 21.92"	W 120° 1' 0.27"

Notes:
WGS84 Coordinate System

Attachment 5

Sisquoc River and Horse Creek Dam Removal Site Observations and Float

Sisquoc River and Horse Creek dam removal site observations and float

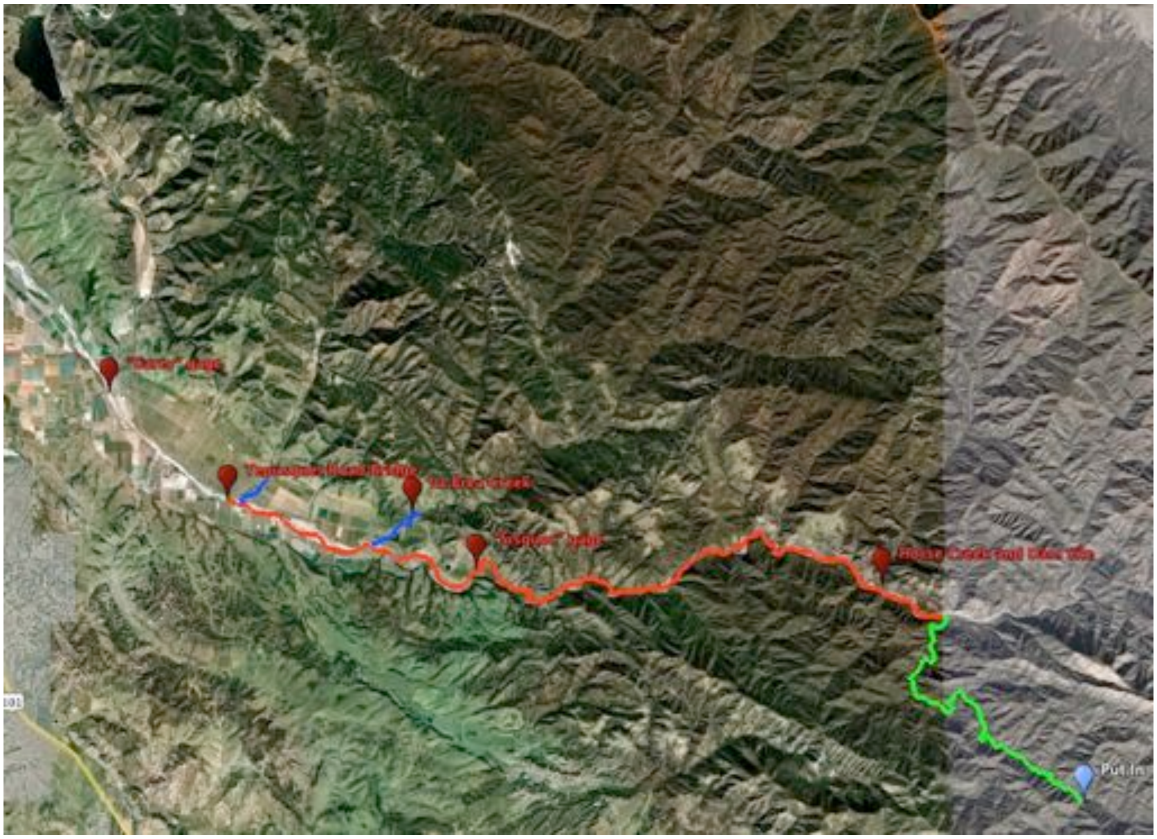
December 23-24, 2010
Matt Stoecker, Biologist, Stoecker Ecological

On December 23rd 2010, myself, and Garrett Kababik, co-owner of Paddle Sports in Carpinteria, kayaked from the Manzana Creek and Davy Brown Creek confluence downstream on Manzana Creek and the Sisquoc River to the Tepusquet Road bridge. Besides the adventure, primary goals of the exploration were to 1) observe elevated stream flows on Manzana Creek, the Sisquoc River, and the Cuyama and Santa Maria Rivers with respect to surface flow depth and steelhead migration opportunities 2) access the remote former Horse Creek Dam (removed in 2006) site during higher flows and assess the level of sediment flushing from deposits behind the dam and fish passage potential into Horse Creek 3) if possible to snorkel a few locations and look for steelhead. This trip and report are not apart of any project or contract, but rather personal interest in the watershed, ongoing projects and restoration efforts, and related projects I am involved with (Davy Brown Creek fish passage projects at instream crossings, Horse Creek Dam removal monitoring, and Santa Maria River steelhead recovery efforts).

We had originally planned to float all the way to the Suey Crossing Road bridge on the Santa Maria River near the City of Santa Maria, in order to assess inflow from the Cuyama River and Santa Maria River mainstem flows down to Suey Crossing. This objective was cut short due to my paddle breaking in half on lower Manzana, just a couple of miles upstream of the Sisquoc River confluence. We used alder, willow, and mulefat branches to brace and piece back together my paddle twice in order to make it out, but this delayed our progress downstream and forced a take out at Tepusquet Road bridge late on the 24th. We were able to briefly assess Horse Creek and the former dam site where major geomorphic changes have taken place since the dam was removed in the Fall of 2006 and even follow up surveys as recent as April of 2008. A description of these changes follows with photos. Water clarity was not adequate to snorkel survey the Manzana or the Sisquoc during this float.

The following description of the float is accompanied by still images I took and we both documented the float with helmet and deck-mounted video cameras (GoPro HD) and are in the process of editing close to 10 hours of video from the float into a short 7-10 minute video.

The below satellite image shows our float and some key locations mentioned. From the "Put In" at the Davy Brown and Manzana Creek confluence (lower right), down Manzana Creek on day 1 (green), down the Sisquoc River on day 2 (red) past "Horse Creek and Dam Site", "Sisquoc" gage, "La Brea Creek" (blue), "Tepusquet Creek" (blue), and take out at "Tepusquet Road Bridge". Downstream I included the "Garey gage" location upstream of the Cuyama River (Twitchell Reservoir can be seen in the upper left corner).



December 23rd

Davy Brown Creek-

After leaving one car at the Suey Crossing Bridge at around 8:30 am we drove to the put-in at the Davy Brown Creek and Manzana Creek confluence. On the way, we crossed both Sunset Valley Road instream crossings on Davy Brown Creek, for which Michael Love and Associates and I recently finished a fish passage assessment report and recommended treatment options. Both crossings conveyed flow across the concrete surface with a maximum depth of 4 inches and both were near the limit of adequate adult steelhead passage across the shallow depths. Both crossings had high flow debris on the road indicating that water depth over the crossings had exceeded 2 feet in the preceding days. Jump heights at the downstream lip of these crossings was 4 and 10 inches respectively for the upper and lower crossings. It was clear that the two crossings were already presenting limitations to upstream steelhead passage due to shallow depth while the rest of Davy Brown Creek that was observed contained more than sufficient depth and adequate pathways for adult steelhead to migrate upstream. As described in surveys and analysis of these crossings (and the Munch Creek crossing upstream) with Michael Love and Associates, these crossings limit upstream passage during moderate and low flows and collectively (with the upstream Munch Creek crossing) cause upstream delays for migrating steelhead in the important Davy Brown Creek basin. Fish passage conditions observed during these moderate flows reinforce the need to continue coordinating with the Forest Service to remove the Munch Creek crossing and bridge or modify the two Davy Brown Crossings.

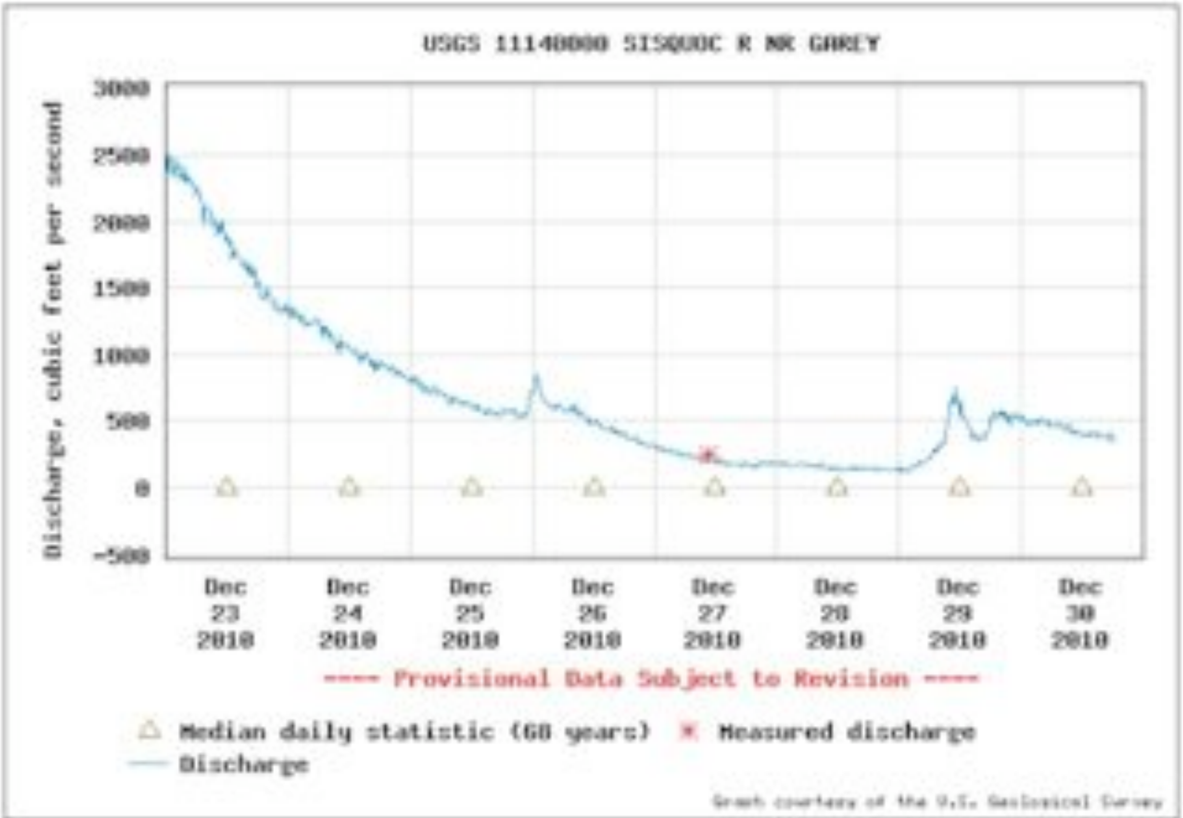
Upper Davy Brown Creek Crossing heading towards Nira Campground

Lower Davy Brown Creek Crossing immediately upstream from Manzana Creek

Measured gage flows during our float (USGS)-

We put in at the Manzana and Davy Brown Creek confluence at 11:00 am on Dec 23rd following the first big flow event of the new 2011 water year. The USGS "Garey" stream flow gage on the lower Sisquoc River recorded a peak flow of almost 10,000 c.f.s on Dec 19th. This gage was reading approximately 2000 c.f.s. at the time of our put-in and dropped to just under 1000 c.f.s. by the time we took out at the Tepusquet Road bridge the next day. The USGS graph below shows the falling hydrograph of the Sisquoc River at the "Garey" gage during the two days of our float and following 6 days. Unlike the other, remote, upstream "Sisquoc" USGS gage (upstream of La Brea Creek), the accessible "Garey" gage appears to be reading accurate flow measurements, with 4 separate "Measured discharge" efforts by USGS during this end-of-2010 storm event. Calibration measurements were taken on 12/19, 12/20, 12/22, and 12/27. The 12/27 measurement is identified as a red star on below graph.

The remote and seasonally inaccessible "Sisquoc" gage appears to be recording measurements that are erroneous and appears to be in need of significant re-calibration or maintenance. The "Sisquoc" gage recorded flows of less than 200 c.f.s. at our put in time and around 50-60 c.f.s. when we passed the "Sisquoc" gage at 1:01 pm on Dec. 24th. While La Brea, Tepusquet, and a couple smaller creeks enter the Sisquoc between the "Sisquoc" gage and the downstream "Garey" gage, their combined flow does not come close to explaining the dramatic 10x difference in flows between the two fairly close gages. In fact, the Sisquoc River appeared almost equal in volume at the "Sisquoc" gage than it did at the "Garey" gage just 3 hours later. There is no way that the Sisquoc River was flowing anywhere close to 50-60 c.f.s. when we floated past the "Sisquoc" gage, as recorded by USGS. At 50-60 c.f.s. we would have been carrying our kayaks and we floated high over the most submerged "Sisquoc" gage weir at flows that I would estimate between 500-900 c.f.s. Due to the lack of water visibility this estimated is based on approximating wetted channel width, velocity, and limited depth measurements with my paddle. For past, present, and future flow analysis of the Sisquoc River I recommend that caution be used with the "Sisquoc" gage measurements in particular and that immediate requests be made for USGS staff to accurately calibrate both gages and assess discrepancies.



Hydrograph during and after our float from the USGS gaging station at Garey Bridge

Manzana Creek-

Manzana Creek was moving fast, and continuous Class II and III+ rapids (possibly a couple IV- rapids) moved us downstream quickly. We had to portage several tree strainers blocking the channel and one fence crossing just upstream of Manzana Schoolhouse Camp at the downstream edge of the private in-holding. We were able to float the rest.

Davy Brown Ck. (bottom left) flowing into Manzana Ck. (flowing right to upper left)

Manzana Creek near Coldwater Campsite

My paddle broke around mile 7 at 1:15 pm and we spent some time putting it back together with an alder branch and athletic tape and making it down to the Sisquoc River by about 3:00pm.


Fence crossing at private property near Manzana Schoolhouse

Abundant depth for upstream adult steelhead passage was observed throughout the float down Manazana Creek, including depths to over 6 feet, and shallow, critical riffles could not be easily identified at these flows, nor any features that would limit upstream steelhead passage. The shallowest areas observed had numerous pathways exceeding one foot in depth and no jumps would be required to move upstream. It was good to see that scouring flows have reestablished many of the deep pools that were filled in during previous years following the Zaca Fire and high erosion.

End of day 1 at confluence of Sisquoc River and Manzana Ck. (top right, behind Garrett)

Sisquoc River upstream of Horse Creek-

At the Sisquoc River and Manzana Creek confluence we decided to camp instead of racing the fading light and trying to reach Horse Creek as originally planned. The flow on the Sisquoc River, upstream of the confluence, appeared to be approximately 50% greater than the inflow from Manzana Creek. The Sisquoc was a noticeably darker brown compared to the brownish-green of Manzana Creek indicating a higher suspended sediment load, which may be related to the recent burn area. Upstream of the confluence, at the Manzana Schoolhouse Campsite, Manzana Creek was observed to drop 1 inch from 4:00pm on Dec. 23rd to 7:00am the next morning and the creek appeared more green and with improved clarity from around 3 inches the previous day to around 6 inches in the morning.

Morning of day 2 at the Sisquoc River (left) and Manzana Creek (right) confluence

Horse Creek and former dam site-

We arrived at Horse Creek at 8:30am on Dec. 24th. I was only able to run up Horse Creek approximately 2000 feet, quickly take some photos, and make limited observations as we needed get downstream 20 miles with a broken paddle before dark. Upon approaching Horse Creek Canyon, while floating down the Sisquoc River, I noticed that most of the Sisquoc River was cutting through a new channel towards river-left (south) away from the former alignment that was cutting into the mouth of Horse Creek to the north, as observed on surveys from 2002 until 2008. No personal observation of Horse Creek was made between April 2008 and this float, however the newly formed channel appeared very recently cut and steep walls were even observed calving off into the undermining flows. At the confluence of Horse Creek, the channel morphology changes of the Sisquoc River and lower Horse Creek, since 2008, were dramatic. Horse Creek was flowing a deep brown into the much lighter brown of a branch of the Sisquoc River. A huge delta of deposited sediment had extended the mouth of Horse Creek over 200 hundred feet out into the former Siquoc River channel in a large fan with a varying radius.

A brown Horse Creek (bottom and lower left) flowing into a braid of the Sisquoc River

Freshly deposited sediment ranging in size from boulders to fine silt, in addition to large trees and stumps, were deposited in this new delta at the mouth of Horse Creek. The lack of vegetation growing on the delta and fresh silt deposits indicated that this recent high flow event had caused much, or all, of the observed delta deposits. The subsiding flow of Horse Creek emerged from the canyon and turned immediately right (west) as it hit the elevated delta deposit and carved along the edge of the deposits and into the Sisquoc River downstream approximately 200 feet from the former mouth.


New Horse Creek mouth looking upstream and new sediment deposits (right)

As described in previous Horse Creek dam removal reports completed with Michael Love and Associates (see Stoecker Ecological website to download), the former mouth of Horse Creek dropped steeply into the Sisquoc River over a boulder cascade and it was determined that the Sisquoc River channel was cutting north into the mouth of Horse Creek and causing headcutting upstream to the dam. This latest high flow event has reversed the previous condition and extended the mouth of Horse Creek over 200 feet into the Sisquoc River channel. The steep boulder cascade at the mouth of Horse Creek is gone and steelhead migration opportunities into the creek have been improved as the gradient has been reduced across the newly deposited sediment delta. The new Horse Creek channel now transitions more moderately across the long delta deposits and into the Sisquoc River, which has carved a new channel to the south.


Looking downstream at lower Horse Creek from middle of deposits (kayak at confluence)

Upstream of the new delta deposits, Horse Creek channel conditions have changed dramatically as well. The upstream channel has straightened, widened, and appears to have aggraded significantly since the last survey in 2008. Virtually all vegetation between the top of banks was stripped away and the substrate was dominated by newly deposited silt and sand.

Looking up Horse Creek from former mouth toward the historic chimney (upper left)

The Horse Creek channel at the former dam site has also changed dramatically. Post dam removal surveys in April of 2008 measured a 3.7-foot tall knickpoint 40 feet upstream of the former dam site with a 14-foot wide channel cut into the sediment deposits and a steep, 7.5% slope. Between the dam removal in October 2006 and April 2008 surveys barely any of the sediment deposited behind the former dam had been mobilized during the two mild winters. With the recent large flushing flows, the channel has now doubled in width to approximately 28 feet and downcut over 6 feet deep into the dam deposits as much of the deposited sediments have flushed out.

100 feet downstream of the former Horse Creek Dam site looking upstream

Garrett standing at the former Horse Creek Dam cross section, looking upstream


Looking downstream at the former dam site (at the large live oak on the right)

No knickpoint was observed upstream for the approximately 1200 feet observed and a mild gradient occurs upstream. Some sediment also flushed from the “old” river-left (east) dry channel surveyed in 2008, but this may have occurred in 2009 as the channel had young, foot-tall vegetation growing in it. Signs of the recent fire in Horse Canyon were observed with both charred and living riparian trees upstream of the dam site in various stages of falling into the creek channel or stabilizing the new channel banks.

~200 feet upstream of the former dam site with Horse Creek (left) and dry channel (right)

~ 800 ft. upstream of the former dam. Note downcutting of the channel into dam deposits

These dramatic changes to lower Horse Creek and the confluence with the Sisquoc River are likely a combination of both high flows moving large amounts of the dam-deposited sediments as well as the recent fire, erosion, and elevated sediment transport. The contribution of elevated sedimentation from the fire seemed apparent at the next Sisquoc River tributary downstream, Tunnel Creek, which had a similar and recent sediment deposit and delta at the mouth. Due to the dramatic geomorphological changes at the former dam site on Horse Creek and relationship to the Sisquoc River, as well as for documenting the upstream steelhead passage effectiveness and possible recolinization, a third, post-dam removal survey should be completed in mid 2011.

Sisquoc River below Horse Creek-

The high suspended sediment load from Horse Creek turned the Sisquoc River a darker brown as we floated downstream and portaged around several large, cross-channel, tree strainers. Some of these trees are partially burned and there are some excellent large woody debris features and associated scour pools on both the Sisquoc and Manzana. Only a few miles below Horse Creek my wood-splinted paddle broke again at the original breaking point. We spent about an hour cutting and shaping a large forked willow branch and two pieces of smaller mulefat to the full length of the paddle. I drilled two holes in each paddle blade to wrap emergency rope around the entire paddle and branches and then lengthwise between the paddle blades to tension it all together. The result was a bulky, beast of a paddle rig. It wasn't pretty, but I was able to paddle the next 15 or so miles to the Tepusquet Road bridge.

The Sisquoc River was full, fast, and beautiful through the Rancho Sisquoc property all the way downstream to the USGS "Sisquoc" gage. As noted above, the river was discharging far more than the 50-60 cfs recorded on the USGS website.

USGS “Sisquoc” gage upstream of La Brea Creek

“Sisquoc” gage weir exposed at left (river-right) and submerge ~3/4 of channel width

Fortunately, the concrete gage weir, just downstream of the "Sisquoc" gage was mostly submerged and did not present a fish passage impediment under flows observed, or higher. While some of the weir was approximately 12 inches above the observed water elevation on the far river-river side, most of the span was submerged and does not appear to much higher than streambed grade. No jump was needed for fish to swim over the weir at flows observed. A low-flow fish passage assessment of this structure should be conducted to determine the fish passage severity of the weir during lower flows. No excessively shallow reaches were observed that would limit fish passage during observed flows upstream of the "Sisquoc" gage.

Below the "Sisquoc" gage, the river became less confined and opened up into the upper limits of what is labeled the "Santa Maria Valley" on USGS 7.5 minute topographical maps. The river becomes braided in sections and agricultural operations are observed first on the north and then both sides of the valley.

La Brea Creek (upper left and middle) flows into Sisquoc River (flowing right to bottom)

La Brea Creek enters from the north and added a fair amount of highly turbid flow to the Sisquoc River. Below La Brea Creek, as the valley continues to widen and the river becomes more braided in reaches, there were two locations (near the Sisquoc Ranch and near the Kelley Creek confluence) where shallow riffles were observed to be taking shape and could be appropriate "critical riffle" survey locations for assessing limitations to low flow steelhead migration. At the flows observed, however, these shallow riffles conveyed enough flow and depth for us to kayak over them with only sporadic scraping on the bottom. Multiple migration pathways with one foot, or more, of depth occurred across these riffles. No reaches on the entire Sisquoc River were observed to be excessively shallow for adult steelhead migration (or kayaking) at the flows encountered, but a reduction of 50% of the observed flow would be expected to seriously limit or prevent upstream adult steelhead migration. Critical riffle surveys at these locations during lower flows could aid in determining migration flow limitations at these locations.

Dozens of large, plastic and metal culvert pipes were observed in the river channel downstream of the Sisquoc Ranch. These culverts appear to be discarded from the earthfill and culvert crossings that span the Sisquoc River during lower flows and are flushed out during high flows. Continued efforts should be made to discourage such invasive and wasteful practices in the future as has been accomplished with the installation of the new Tepusquet Road Bridge crossing and elimination of one of these former earth-fill culvert crossings. In addition, dozens of large white pipes were observed coming from the river-right bench into the Sisquoc River valley floor. It appears that these pipes may be connecting uphill agricultural operations to wells in the river bottom and/or carrying agricultural run-off into the river.

Sisquoc River looking upstream from our take out at Tepusquet Road Bridge

Tepusquet Creek flowed relatively clear into the Sisquoc River upstream of the Tepusquet Road bridge. As mentioned in previous reports, I believe it is important to address the numerous steelhead migration barriers on Tepusquet Creek to provide access from the Sisquoc River. Currently, fish passage barriers block upstream migration to almost all of Tepusquet Creek with impassable barriers occurring just upstream of the mouth. In addition to being a potentially important spawning and rearing stream, as well as having historic steelhead documentation and contemporary rainbow trout occurrence, this creek may be a critically important refuge tributary for upstream and downstream migrating steelhead on the Sisquoc River. With access provided, Tepusquet Creek could provide a relatively clearwater refuge for fish to hold in between adequate migration flows on the Sisquoc River, if turbidity levels in the Sisquoc River are excessively elevated, and as a safe lower-river holdover location for fish unable to make the connection between the ocean or headwaters as this flashy river subsides and becomes to shallow. A Tepusquet Creek Valley community-based effort (along with the County and Forest Service) is recommended to assist residents in developing improved and safe road crossings while providing access for steelhead. Most of the Tepusquet Creek steelhead migration barriers identified in our 2004 report are private driveway crossings, County road crossings, and small private dams and ponds.

Tepusquet Ck. (top) flows relatively clear into a northern branch of the Sisquoc River

Looking downstream on the Sisquoc River from the Tepusquet Road Bridge

From the Tepusquet Road bridge, it appeared that adequate water depth for upstream adult steelhead migration occurred as far downstream as could be observed (approximately ¼ mile). This observation was made at 4:00 pm on Dec 24th and a downstream "Garey" gage flow estimate of approximately 900 c.f.s. This flow estimate of 900 c.f.s. seemed about right when we took out at Tepusquet Road bridge.

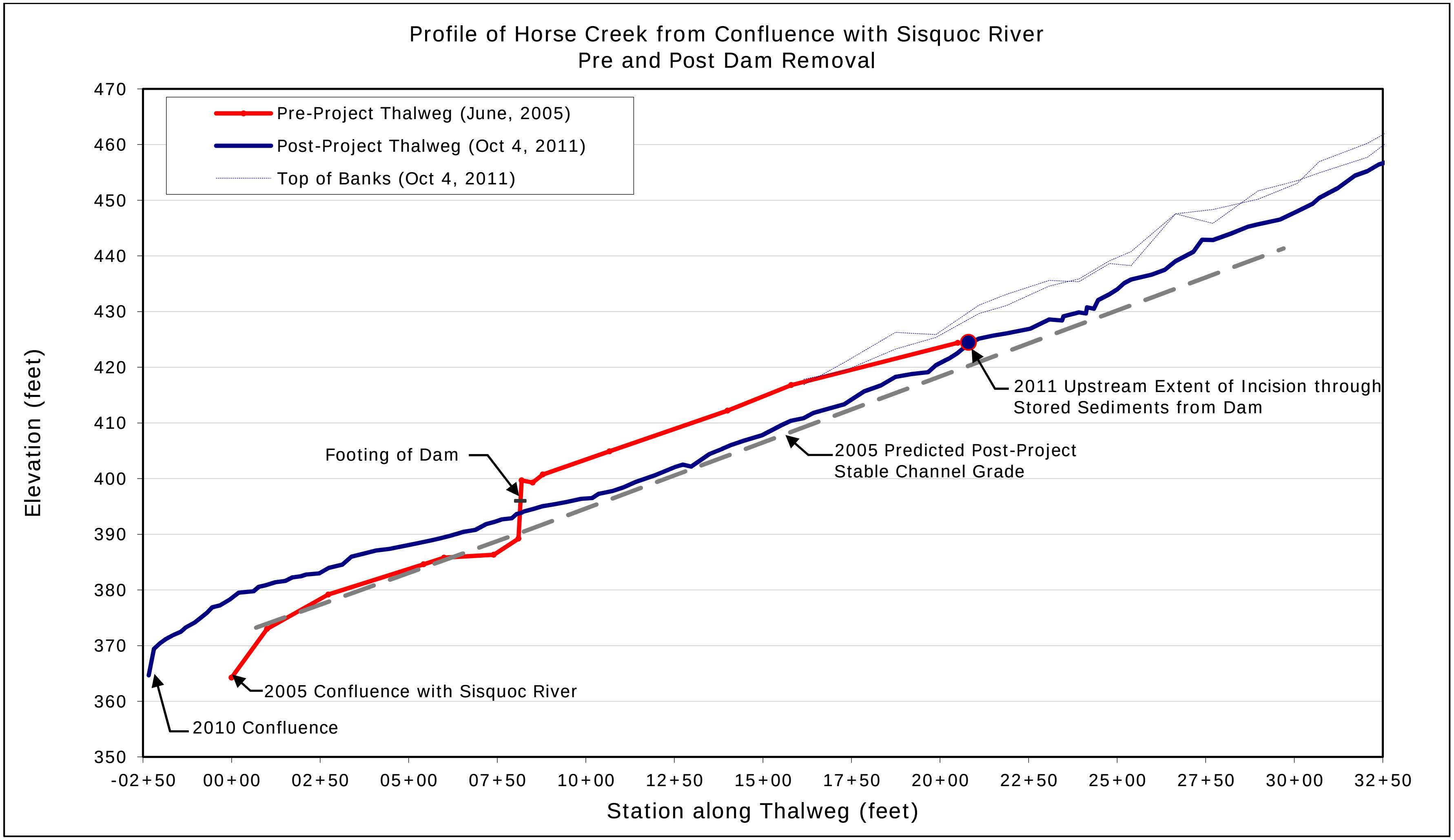
While I had hoped we would make it to the Suey Crossing bridge and observed the Cuyama River and upper Santa Maria River flows and conditions, we were feeling good about even making it down from Manzana Creek with a broken paddle. Lesson learned; bring a spare breakdown paddle for remote floats like this one!

Barely home in time for the holiday dinner and checking out the "willow-reinforced" paddle repair that got me down the Sisquoc

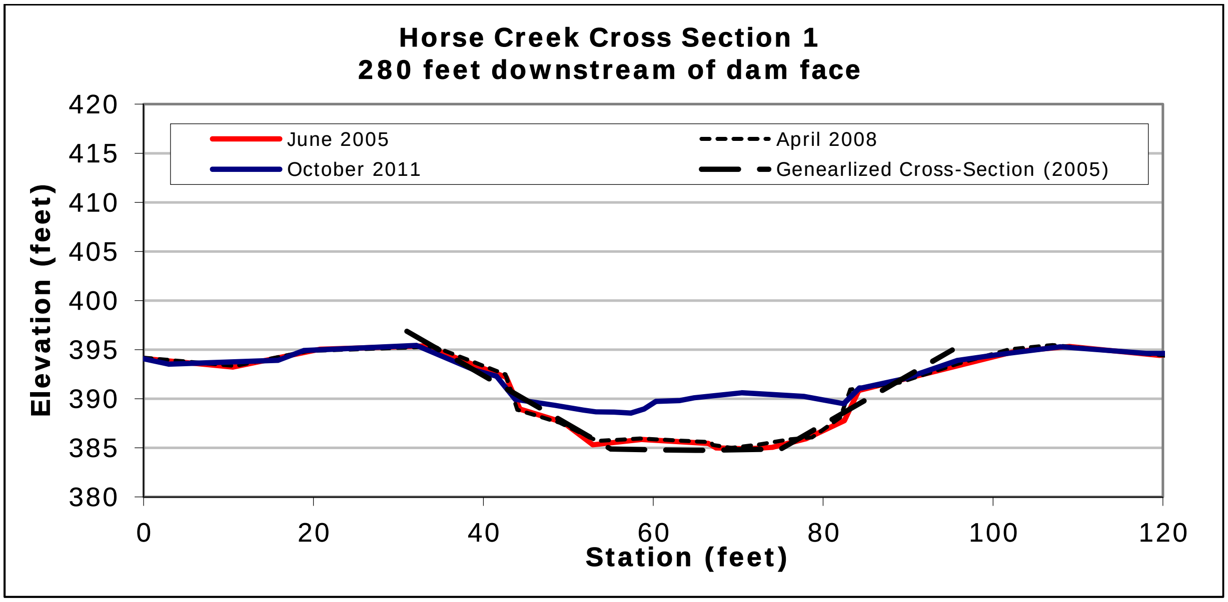
Once again I was amazed and impressed by the wildness of the Sisquoc River. We saw bobcats, a golden eagle, many kingfishers, bear and cougar tracks, hawks, and as usually not one person. From it's source at nearly 7000 feet on the flanks of Big Pine Mountain to the Santa Maria River mouth at the Pacific, the combined Sisquoc and Santa Maria River remain one of the last and longest free-flowing rivers in California. Not one dam or impassable anthropogenic steelhead migration barrier occurs between the ocean and the natural upstream limit of migration on the Sisquoc River. While undammed, the flows of the Santa Maria River are manipulated by releases from Twitchell Dam and groundwater withdrawals from local agricultural operations. By working effectively together, all of the stakeholders in the Santa Maria River watershed can ensure the most efficient and reliable use of a limited water supply while improving and protecting the natural heritage of this shared river.

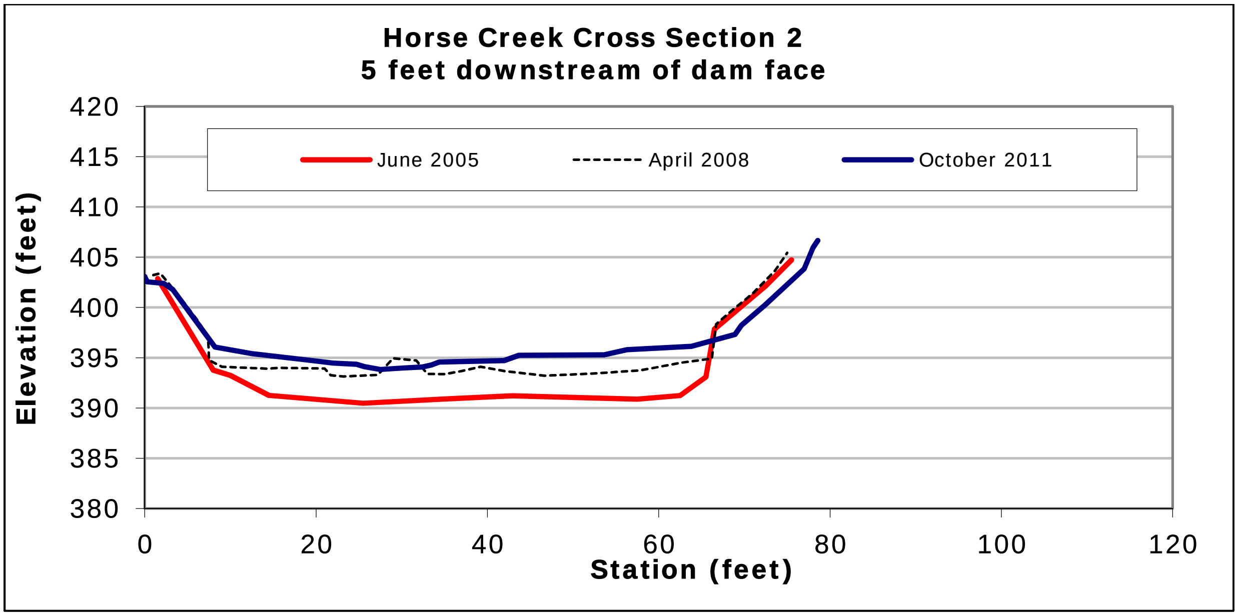
Attachment 6

2011 Channel Cross Sections and Profile

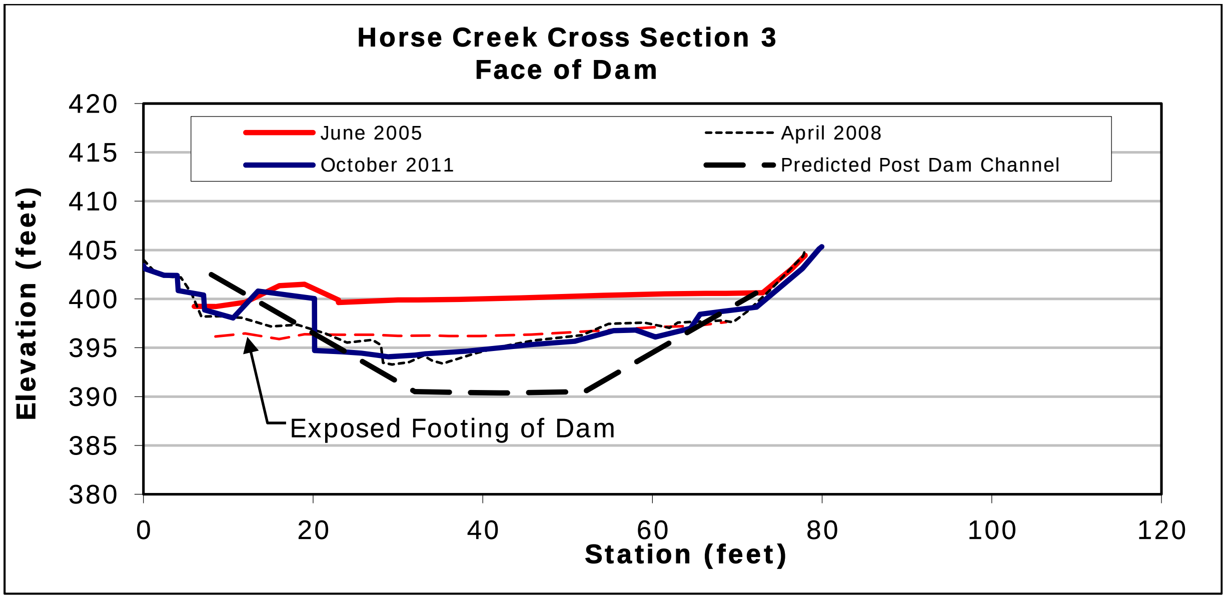


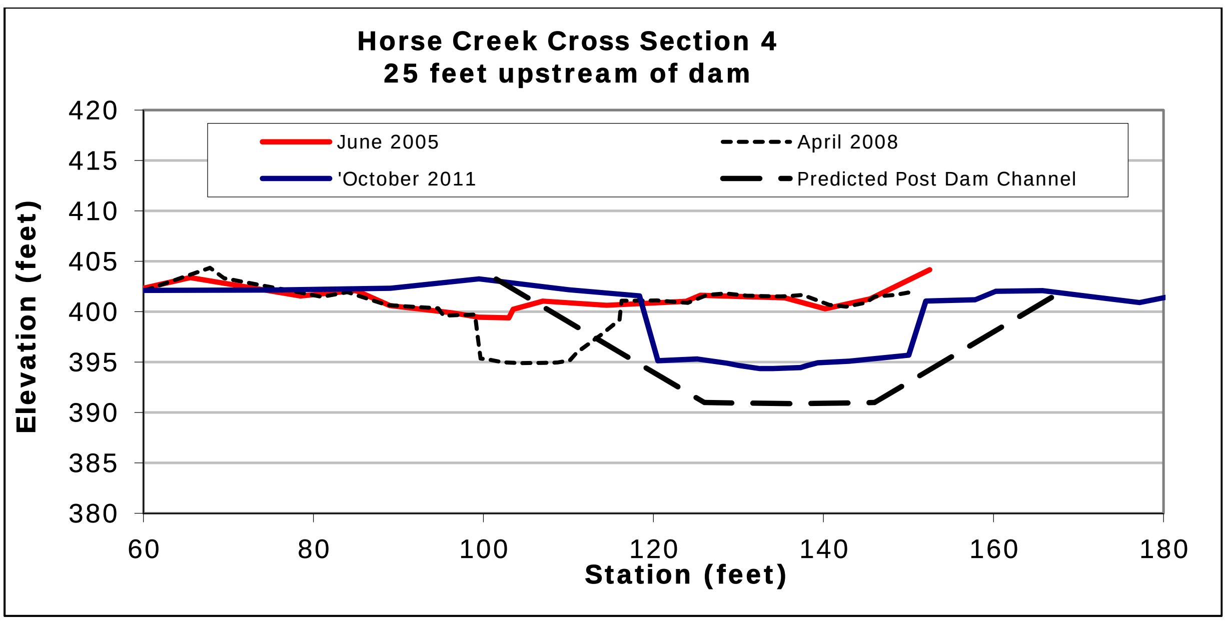
Michael Lover & Associates
Stoecker Ecological

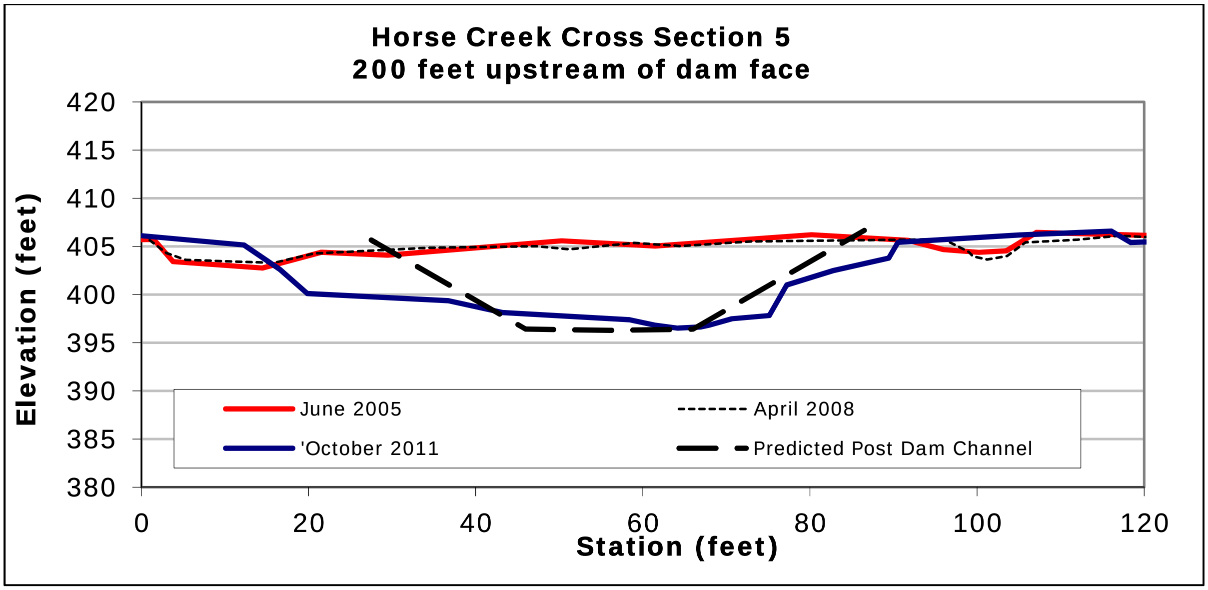


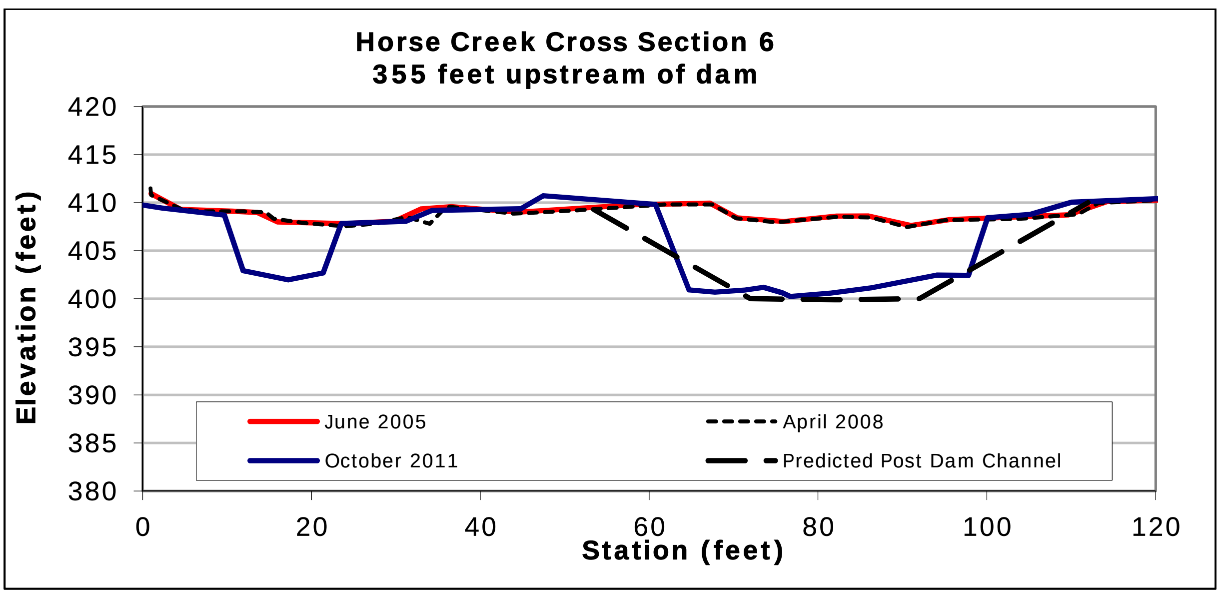


Michael Lover & Associates
Stoecker Ecological


Horse Creek Cross Section 3
Face of Dam
June 2005
April 2008
October 2011
Predicted Post Dam Channel
Elevation (feet)
420
415
410
405
400
395
390
385
380
0
20
40
60
80
100
120
Station (feet)
Exposed Footing of Dam


Horse Creek Cross Section 4
25 feet upstream of dam
June 2005
April 2008
'October 2011
Predicted Post Dam Channel
Elevation (feet)
420
415
410
405
400
395
390
385
380
60
80
100
120
140
160
180
Station (feet)


Horse Creek Cross Section 5
200 feet upstream of dam face
Elevation (feet)
420
415
410
405
400
395
390
385
380
0
20
40
60
80
100
120
Station (feet)
June 2005
April 2008
'October 2011
Predicted Post Dam Channel


Horse Creek Cross Section 6
355 feet upstream of dam
Elevation (feet)
420
415
410
405
400
395
390
385
380
0
20
40
60
80
100
120
Station (feet)
June 2005
April 2008
October 2011
Predicted Post Dam Channel

Coordinates of Cross Section Rebar Monuments

Cross Section		Latitude	Longitude	Elevation	Bearing
XS 1	LB Pin	N 34° 50' 12.2"	W 120° 1' 3.6"	394.51	108°
	RB Pin	N 34° 50' 12.6"	W 120° 1' 5.1"	395.73	
XS 2	LB Pin			403.58	318°
	RB Pin	N 34° 50' 14.9"	W 120° 1' 3.0"	403.59	
XS 3	LB Pin	Wooden Stake		403.37	320°
	RB Pin	N 34° 50' 15.1"	W 120° 1' 3.0"	405.23	
XS 4	LB Pin	N 34° 50' 14.1"	W 120° 1' 1.5"	402.72	314°
	RB Pin	N 34° 50' 12.6"	W 120° 1' 5.1"	402.34	
XS 5	LB Pin	N 34° 50' 18.0"	W 120° 1' 1.9"	406.02	328°
	RB Pin	N 34° 50' 16.3"	W 120° 1' 2.0"	406.86	
XS 6	LB Pin	N 34° 50' 16.9"	W 120° 1' 0.1"	411.09	311°
	RB Pin	N 34° 50' 18.1"	W 120° 1' 0.4"	410.92	

Notes:

Pin = Rebar monument located at each edge of cross section
Bearing = compass bearing from left to right bank of cross section
LB / RB = Left Bank / Right Bank
All elevations on top of rebar pin

Up and Downstream Coordinates for Project Area

Project Reach Coordinates	Latitude	Longitude
Downstream	N 34° 50' 7.27"	W 120° 1 '5.94"
Upstream	N 34° 50' 21.92"	W 120° 1' 0.27"

Attachment 7

CDFG File Letter: 2011 Snorkel Survey Results

State of California -The Natural Resources Agency
DEPARTMENT OF FISH AND GAME
1416 9th Street
Sacramento, CA 95814
http://www.dfg.ca.gov

EDMUND G. BROWN JR., *Governor*
CHARLTON H. BONHAM, Director

February 27, 2012

Michael Love, P.E.
Michael Love & Associates, Inc.
427 F Street, Suite 223
Eureka, CA 95501
mlove@h2odesigns.com
707-476-8938

Don Baldwin
California Department of Fish and Game
830 S Street
Sacramento, CA 95811
dbaldwin@dfg.ca.gov
916-445-1921

RE: CDFG Horse Creek Post-Dam Removal Snorkel Survey Results

Snorkel surveys were conducted by CDFG on Horse Creek to document presence/absence of *Oncorhynchus mykiss* post dam removal. Snorkel surveyors were conducted by Don Baldwin and Jill Taylor. Mary Larson assisted surveyors carrying gear, taking photos, marking GPS points and note taking. Survey was conducted on 4 October 2011. Due to rain event no survey was conducted on 5 October 2011 as planed. Approximately 1.5 – 2 miles of Horse Creek were surveyed. Flows were low, coble dominant with high algal growth. All sections of stream deep enough (pools, runs) to snorkel were surveyed.

No *O. mykiss* were observed in survey reach of Horse Creek. There was a moderate to high density of arroyo chub (*Gila orcuttii*) in the lower reach of Horse Creek. There was a high density of speckled dace (*Rhinichthys osculus*) through out entire reached surveyed. Other species observed were Pacific treefrog (*Hyla regilla*) through out reach and Southwestern pond turtle (*Clemmys marmorata pallida*) near confluence of the Sisquoc River.

At the dam removal site the stream has degraded down to natural stream bed elevation opening the entire Horse Creek watershed to anadromous fish. Habitat was fair for *O. mykiss* spawning and fair to poor for rearing. There was a lack of deep scour pools in survey reach. Habitat was dominated by shallow, coble riffles. The first major tributary from the confluence was on river right and deposits a large volume of sediment to Horse Creek. This may be the result of fire effects on the stream. There are many miles of stream and tributaries above survey reach that should be surveyed before habitat quality can be quantified. The quality *O. mykiss* spawning and rearing habitat may be further upstream near the headwaters and in the many tributaries of Horse creek. There were no fish passage impediments observed in the survey reach of Horse Creek.

The Sisquoc River at confluence of Horse Creek is a long pool created by a beaver dam approximately 150-200 feet downstream of Horse Creek. A snorkel survey was conducted in the beaver pool. The bottom 2/3 of pool ranges form 1-4 feet deep lined with willows. In the steep bank on river left is an active beaver den. The upper 1/3 of pool is lined with willows and large woody debris (LWD) in mid channel spanning pool from bank to bank. This LWD in upper pool may be remanence of an old beaver dam, causing much scour under the LWD creating high quality fish refuge habitat. Max depth of pool under LWD was approximately 8 feet. At top of pool on river left is under cut bank. This beaver activity has created high quality spawning and rearing habitat in the Sisquoc River at the mouth of Horse Creek.

There was a high density of arroyo chub and speckled dace through beaver pool. Three *O. mykiss* were observed holding under the LWD in the deepest part of the pool. These fish were approximately 9-14 inches in length. Two held under LWD in deep pool while one swam upstream and held under the undercut bank on river left. Fish were documented with still images and video. Two Southwestern pond turtles were observed on LWD in beaver pool.

Attachment 8

Horse Creek Hydrology

Horse Creek

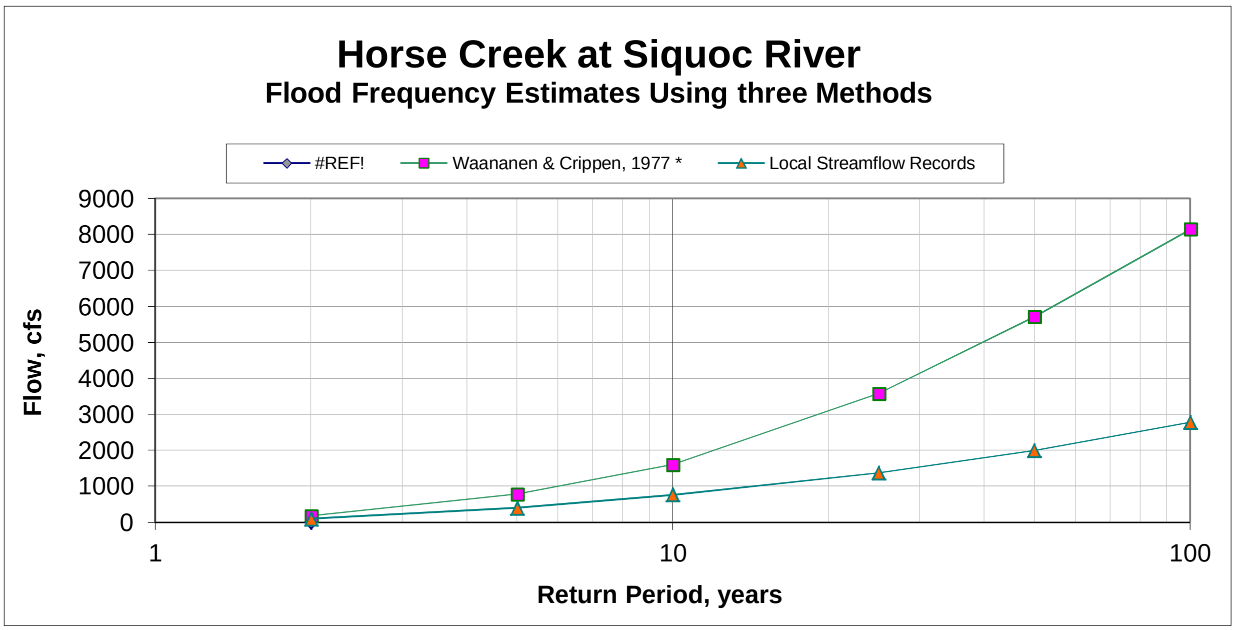
Summary of Peak Flow Calculations

Horse Creek at Siquoc River

Drainage Area (mi^2) = **21.8**

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 *	193	797	1,607	3,592	5,716	8,152
Local Streamflow Records						
Average	104	406	765	1,381	2,005	2,781
Mimium Estimate	22	104	223	489	800	1,232
Maximum Estimate	275	973	1,643	2,614	3,366	4,103



* 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),

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Horse Creek at Siquoc River, 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	37	2	8	18	41	70	114
USGS ALAMO PINTADO C NR SOLVANG CA	34°37'06"	120°07'11"	29.40	35	4	17	37	70	107	152
USGS SANTA CRUZ C NR SANTA YNEZ CA	34°35'48"	119°54'28"	74.00	68	13	45	75	120	154	188
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	13	45	75	120	154	188
Average	5	19	35	63	92	128

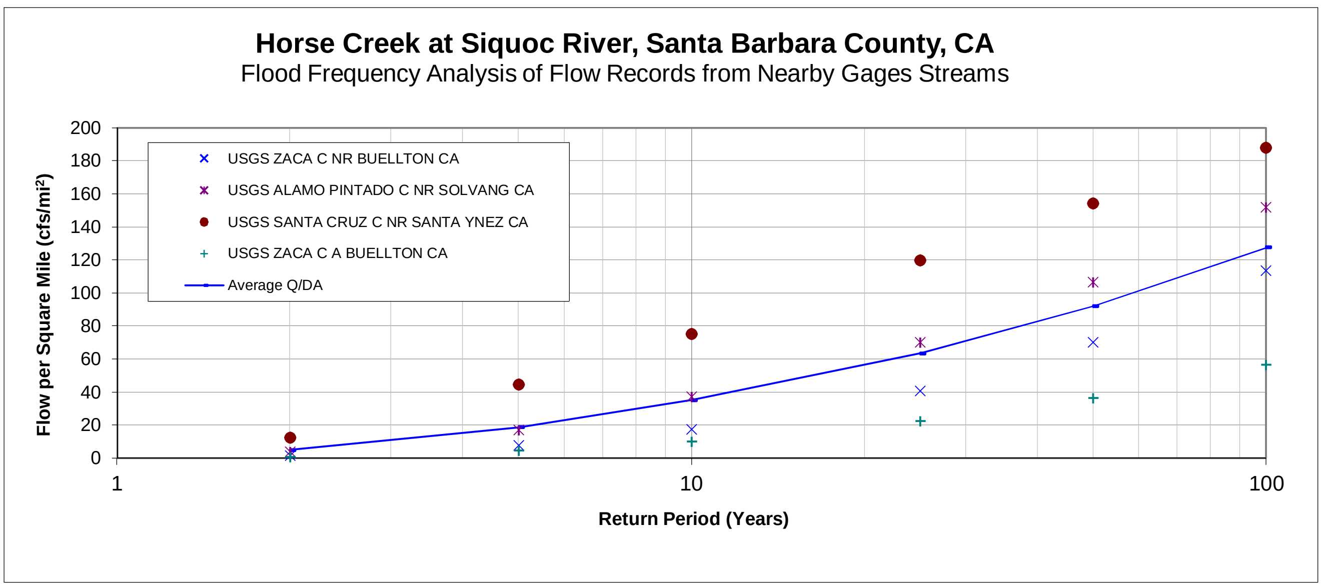
Peak Flow Estimates:

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

Horse Creek at Siquoc River

Drainage Area = 21.8 mi^2

	Q 2-yr	Q 5-yr	Q 10-yr	Q 25-yr	Q 50-yr	Q 100-yr
Average (cfs)	104	406	765	1,381	2,005	2,781
Minimum (cfs)	22	104	223	489	800	1,232
Maximum (cfs)	275	973	1,643	2,614	3,366	4,103



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	36.00	3680	104	3.57
	12/21/1970	12	2	18.00	900	25	2.95
	12/27/1971	0.75	3	12.00	865	24	2.94
	1/18/1973	466	4	9.00	863	24	2.94
	1/7/1974	93	5	7.20	812	23	2.91
	3/7/1975	40	6	6.00	724	21	2.86
	9/28/1976	8.8	7	5.14	615	17	2.79
	1/2/1977	7	8	4.50	486	14	2.69
	2/9/1978	724	9	4.00	466	13	2.67
	3/27/1979	106	10	3.60	462	13	2.66
	2/19/1980	397	11	3.27	397	11	2.60
	3/5/1981	139	12	3.00	302	9	2.48
	4/11/1982	42	13	2.77	222	6	2.35
	12/25/1982	900	14	2.57	180	5	2.26
	12/25/1983	126	15	2.40	139	4	2.14
	12/19/1984	40	16	2.25	126	4	2.10
	1990	0	17	2.12	106	3	2.03
	3/18/1991	865	18	2.00	94	3	1.97
	2/12/1992	615	19	1.89	93	3	1.97
	3/10/1995	863	20	1.80	88	2	1.94
	2/20/1996	486	21	1.71	73	2	1.86
	12/22/1996	180	22	1.64	62	2	1.79
	2/3/1998	3680	23	1.57	54	2	1.73
	3/20/1999	73	24	1.50	42	1	1.62
	2/23/2000	222	25	1.44	40	1	1.60
	3/5/2001	462	26	1.38	40	1	1.60
	11/24/2001	54	27	1.33	36	1	1.56
	12/19/2002	36	28	1.29	12	0	1.08
	2/26/2004	62	29	1.24	10.32	0	1.01
	2/21/2005	812	30	1.20	8.8	0	0.94
	4/5/2006	88	31	1.16	8.4	0	0.92
	10/13/2007	8.4	32	1.13	7	0	0.85
	1/28/2008	302	33	1.09	1.6	0	0.20
	2/16/2009	1.6	34	1.06	0.75	0	-0.12
*	1/20/2010	94	35	1.03			

Number of Years, n =	35		
Skewness =	4.18	4.18	-0.58
Mean=	353	10	1.98
Std Dev=	657	19	0.84

Peaks Flow Frequency

From USGS Data

Station # 11128250

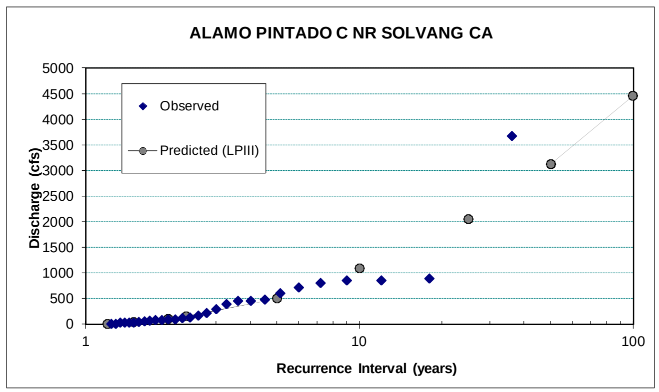
Generalized Skew=	**-0.30**	A=	-0.28372
Station Skewness (log Q)=	-0.58	B=	0.78958
Station Mean (log Q)=	1.98	MSE (station skew) =	0.19351
Station Std Dev (log Q)=	0.84		
Weighted Skewness (G_W)=	**-0.47**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.98088	14
1.5	0.667	-0.36747	47
2.0	0.500	0.07803	112
2.33	0.429	0.25098	157
5.0	0.200	0.85609	508
10	0.100	1.25253	1,095
25	0.040	1.57899	2,063
50	0.020	1.79422	3,132
100	0.010	1.97727	4,467

Values From K-Table for Linear interpolation

Weighted Skewness	-0.50	-0.40	-0.47
P	K	K	K
0.9	-1.32309	-1.31671	-1.32116
0.8	-0.80829	-0.81638	-0.81074
0.7	-0.45812	-0.47228	-0.46240
0.6	-0.17261	-0.18916	-0.17761
0.500	0.08302	0.06651	0.07803
0.429	0.25558	0.24037	0.25098
0.200	0.85653	0.85508	0.85609
0.100	1.26180	1.23114	1.25253
0.040	1.56740	1.60574	1.57899
0.020	1.77716	1.83361	1.79422
0.010	1.95472	2.02933	1.97727



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	38.00	1390	39	3.14
	11/19/1963	8	2	19.00	1070	30	3.03
	11/12/1964	8	3	12.67	743	21	2.87
	2/6/1966	6	4	9.50	512	14	2.71
	12/6/1966	191	5	7.60	496	14	2.70
	3/13/1968	1	6	6.33	484	14	2.68
	2/24/1969	1390	7	5.43	246	7	2.39
	3/4/1970	9	8	4.75	233	7	2.37
	12/21/1970	3	9	4.22	205	6	2.31
	12/27/1971	5	10	3.80	191	5	2.28
	1/18/1973	205	11	3.45	142	4	2.15
	3/30/1974	16	12	3.17	103	3	2.01
	2/2/1975	48	13	2.92	96	3	1.98
	9/29/1976	45	14	2.71	52	1	1.72
	1/6/1977	14	15	2.53	48	1	1.68
	3/4/1978	743	16	2.38	45	1	1.65
	3/29/1979	28	17	2.24	32	1	1.51
	2/19/1980	96	18	2.11	28	1	1.45
	3/5/1981	142	19	2.00	28	1	1.45
	6/12/1905	0	20	1.90	16	0	1.20
	3/19/1991	233	21	1.81	14	0	1.15
	2/15/1992	512	22	1.73	12	0	1.08
	1/25/1995	496	23	1.65	9.8	0	0.99
	2/20/1996	103	24	1.58	9	0	0.95
	1/24/1997	52	25	1.52	8	0	0.90
	2/3/1998	1070	26	1.46	8	0	0.90
	2/9/1999	28	27	1.41	6	0	0.78
	2/23/2000	246	28	1.36	5	0	0.70
	3/5/2001	484	29	1.31	3	0	0.48
	11/24/2001	9.8	30	1.27	1	0	0.00
	12/20/2002	32	31	1.23			
	2/25/2004	12	32	1.19			
	1/9/2005	236	33	1.15			
	4/5/2006	123	34	1.12			
	2007	0	35	1.09			
	2008	0	36	1.06			
	2009	0	37	1.03			

Number of Years, n =	37		
Skewness =	2.29	2.29	-0.01
Mean=	208	6	1.71
Std Dev=	338	10	0.83

Peaks Flow Frequency

From USGS Data
Station # 11129800

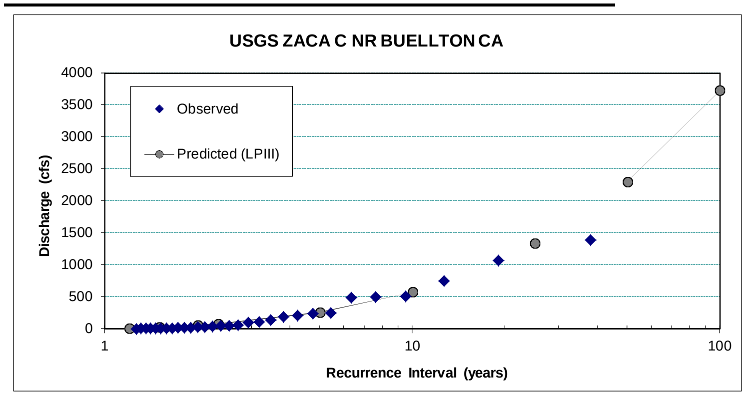
Generalized Skew=	**-0.30**	A=	-0.32903
Station Skewness (log Q)=	-0.01	B=	0.93686
Station Mean (log Q)=	1.71	MSE (station skew) =	0.13761
Station Std Dev (log Q)=	0.83		
Weighted Skewness (G_W)=	**-0.10**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.98817	8
1.5	0.667	-0.42028	23
2.0	0.500	0.01699	53
2.33	0.429	0.19374	74
5.0	0.200	0.84619	256
10	0.100	1.27010	574
25	0.040	1.71501	1,341
50	0.020	1.99852	2,303
100	0.010	2.25094	3,726

Values From K-Table for Linear interpolation

Weighted Skewnes	-0.20	-0.10	-0.10
P	K	K	K
0.9	-1.30105	-1.29178	-1.29198
0.8	-0.83044	-0.83639	-0.83626
0.7	-0.49927	-0.51207	-0.51179
0.6	-0.22168	-0.23763	-0.23728
0.500	0.03325	0.01662	0.01699
0.429	0.20925	0.19339	0.19374
0.200	0.84986	0.84611	0.84619
0.100	1.25824	1.27037	1.27010
0.040	1.67999	1.71580	1.71501
0.020	1.94499	1.99973	1.99852
0.010	2.17840	2.25258	2.25094



Michael Love Associates
P.O. Box 4477 Arcata CA 95518

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	69.00	10200	289	4.01
	2/22/1944	2500	2	34.50	7050	200	3.85
	2/2/1945	2700	3	23.00	5800	164	3.76
	3/30/1946	1300	4	17.25	5480	155	3.74
	11/20/1946	910	5	13.80	5060	143	3.70
	4/10/1948	19	6	11.50	4820	136	3.68
	3/11/1949	140	7	9.86	4520	128	3.66
	2/6/1950	1160	8	8.63	4360	123	3.64
	3/2/1951	1.5	9	7.67	3980	113	3.60
	1/15/1952	2690	10	6.90	3960	112	3.60
	1/13/1953	261	11	6.27	3580	101	3.55
	1/24/1954	1540	12	5.75	3200	91	3.51
	2/17/1955	168	13	5.31	3110	88	3.49
	1/26/1956	2040	14	4.93	3100	88	3.49
	1/13/1957	559	15	4.60	2700	76	3.43
	4/3/1958	3580	16	4.31	2690	76	3.43
	2/16/1959	930	17	4.06	2620	74	3.42
	2/1/1960	918	18	3.83	2500	71	3.40
	12/2/1960	35	19	3.63	2220	63	3.35
	2/9/1962	4520	20	3.45	2160	61	3.33
	2/9/1963	398	21	3.29	2040	58	3.31
	4/1/1964	145	22	3.14	2030	57	3.31
	4/9/1965	308	23	3.00	1860	53	3.27
	12/29/1965	2030	24	2.88	1800	51	3.26
	12/6/1966	5800	25	2.76	1690	48	3.23
	3/8/1968	472	26	2.65	1650	47	3.22
	2/24/1969	7050	27	2.56	1540	44	3.19
	3/1/1970	910	28	2.46	1400	40	3.15
	11/29/1970	1100	29	2.38	1380	39	3.14
	12/25/1971	436	30	2.30	1300	37	3.11
	1/18/1973	2160	31	2.23	1290	37	3.11
	1/7/1974	648	32	2.16	1160	33	3.06
	3/7/1975	1400	33	2.09	1100	31	3.04
	2/9/1976	234	34	2.03	930	26	2.97
	5/9/1977	71	35	1.97	918	26	2.96
	2/9/1978	5060	36	1.92	910	26	2.96
	3/28/1979	673	37	1.86	910	26	2.96
	2/16/1980	2620	38	1.82	868	25	2.94
	3/4/1981	735	39	1.77	735	21	2.87
	4/1/1982	681	40	1.73	681	19	2.83
	3/1/1983	3960	41	1.68	673	19	2.83
	12/25/1983	1290	42	1.64	648	18	2.81
	2/9/1985	256	43	1.60	599	17	2.78
	2/14/1986	1650	44	1.57	595	17	2.77
	3/6/1987	203	45	1.53	559	16	2.75
	2/28/1988	1800	46	1.50	477	14	2.68
	2/9/1989	211	47	1.47	472	13	2.67
	2/18/1990	1.9	48	1.44	472	13	2.67
	3/19/1991	3100	49	1.41	436	12	2.64
	2/12/1992	4820	50	1.38	398	11	2.60
	2/23/1993	3200	51	1.35	313	9	2.50
	2/20/1994	313	52	1.33	308	9	2.49
	3/10/1995	3110	53	1.30	272	8	2.43
	2/20/1996	1690	54	1.28	261	7	2.42
	1/23/1997	2220	55	1.25	256	7	2.41
	2/23/1998	4360	56	1.23	234	7	2.37
	2/9/1999	272	57	1.21	211	6	2.32
	2/21/2000	595	58	1.19	203	6	2.31
	3/5/2001	3980	59	1.17	168	5	2.23
	12/30/2001	44	60	1.15	145	4	2.16
	3/15/2003	868	61	1.13	140	4	2.15
	2/25/2004	599	62	1.11	71	2	1.85
	2/21/2005	5480	63	1.10	44	1	1.64
	1/2/2006	1380	64	1.08	35	1	1.54
	1/28/2007	6.8	65	1.06	19	1	1.28
	1/27/2008	10200	66	1.05	6.8	0.2	0.83
	12/15/2009	477	67	1.03	1.9	0.1	0.28
*	1/19/2010	1860	68	1.01	1.5	0.0	0.18

Number of Years, n =	68		
Skewness =	1.93	1.93	-1.49
Mean=	1725	49	2.85
Std Dev=	1954	55	0.78

Peaks Flow Frequency

From USGS Data

Station # 11124500

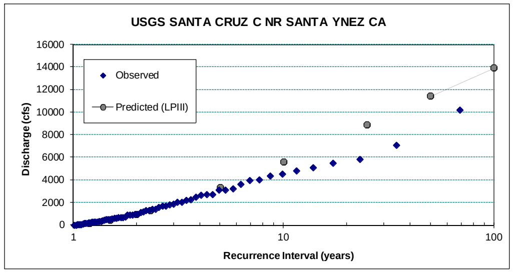
Generalized Skew=	-0.30	A=	-0.07289
Station Skewness (log Q)	-1.49	B=	0.55251
Station Mean (log Q)=	2.85	MSE (station skew) =	0.29318
Station Std Dev (log Q)=	0.78		
Weighted Skewness (G_w)=	**-0.90**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.95869	128
1.5	0.667	-0.29682	420
2.0	0.500	0.14871	934
2.33	0.429	0.31423	1,256
5.0	0.200	0.85415	3,304
10	0.100	1.14634	5,578
25	0.040	1.40555	8,874
50	0.020	1.54658	11,425
100	0.010	1.65715	13,928

Values From K-Table for Linear interpolation

Weighted Skewnes	-1.00	-0.90	-0.90
P	K	K	K
0.9	-1.34039	-1.33889	-1.33895
0.8	-0.75752	-0.76902	-0.76856
0.7	-0.38111	-0.39729	-0.39664
0.6	0.08763	-0.10486	-0.09717
0.500	0.16397	0.14807	0.14871
0.429	0.32740	0.31368	0.31423
0.200	0.85161	0.85426	0.85415
0.100	1.12762	1.14712	1.14634
0.040	1.36584	1.40720	1.40555
0.020	1.49188	1.54886	1.54658
0.010	1.58838	1.66001	1.65715



Michael Love Associates
P.O. Box 4477 Arcata CA 95518

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)	RANK	Recurrence Interval (years)	Dischage (cfs)	Discharge (cms)	log-discharge (cfs)
	3/3/1941	874	1	25.00	874	25	2.94
	12/28/1941	44	2	12.50	622	18	2.79
	1/22/1943	340	3	8.33	560	16	2.75
	2/22/1944	225	4	6.25	340	10	2.53
	2/2/1945	32	5	5.00	273	8	2.44
	3/29/1946	21	6	4.17	225	6	2.35
	11/20/1946	8	7	3.57	185	5	2.27
	3/24/1948	0.4	8	3.13	88	2	1.94
	3/4/1949	185	9	2.78	70	2	1.85
	12/8/1949	88	10	2.50	49	1	1.69
	10/26/1950	6.8	11	2.27	44	1	1.64
	1/15/1952	622	12	2.08	32	1	1.51
	12/30/1952	70	13	1.92	30	1	1.48
	1/19/1954	8	14	1.79	24	1	1.38
	1/9/1955	24	15	1.67	23	1	1.36
	1/26/1956	23	16	1.56	21	1	1.32
	5/11/1957	8.3	17	1.47	8.3	0	0.92
	4/3/1958	273	18	1.39	8	0	0.90
	2/21/1959	30	19	1.32	8	0	0.90
	2/1/1960	8	20	1.25	8	0	0.90
	1/26/1961	5	21	1.19	6.8	0	0.83
	2/11/1962	560	22	1.14	5	0	0.70
	3/28/1963	49	23	1.09	5	0	0.70
	1/26/1964	5	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

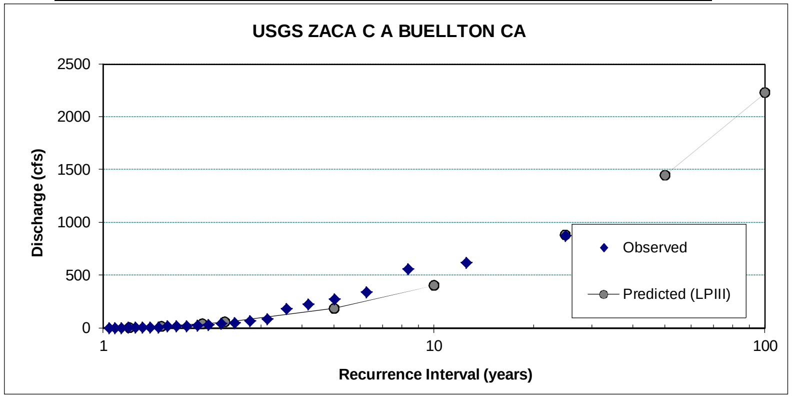
Generalized Skew=	**-0.30**	A=	-0.31574
Station Skewness (log Q)=	-0.18	B=	0.89366
Station Mean (log Q)=	1.57	MSE (station skew) =	0.22104
Station Std Dev (log Q)=	0.82		
Weighted Skewness (G_W)=	**-0.23**		

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 Skewness	-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 11140000 SISQUOC R NR GAREY

Drainage Area sq. mi **471** **mi^2**
Location: 34°53'38" **120°18'20"** **NAD27**

WY	Date of Peak	Discharge (cfs)	RANK	Recurrence Interval (years)	Dischage (cfs)	Discharge (cms)	log-discharge (cfs)
	3/5/1941	7000	1	69.00	33600	951	4.53
	4/22/1942	875	2	34.50	29500	835	4.47
	1/23/1943	13000	3	23.00	24500	694	4.39
	2/22/1944	6600	4	17.25	22600	640	4.35
	2/2/1945	5400	5	13.80	22200	629	4.35
	3/30/1946	4000	6	11.50	13000	368	4.11
	11/23/1946	900	7	9.86	12800	362	4.11
	1948	0	8	8.63	11000	311	4.04
	3/11/1949	50	9	7.67	10400	294	4.02
	2/6/1950	900	10	6.90	*9,940*	281	4.00
	1951	0	11	6.27	9520	270	3.98
	1/15/1952	8910	12	5.75	9280	263	3.97
	1/14/1953	480	13	5.31	8910	252	3.95
	2/17/1955	137	14	4.93	8550	242	3.93
	1/27/1956	2120	15	4.60	8000	227	3.90
	10/19/1956	105	16	4.31	7980	226	3.90
	4/3/1958	8000	17	4.06	7400	210	3.87
	2/11/1959	1000	18	3.83	7250	205	3.86
	1/12/1960	3.6	19	3.63	7200	204	3.86
	1961	0	20	3.45	7000	198	3.85
	2/10/1962	7200	21	3.29	6600	187	3.82
	2/10/1963	150	22	3.14	6390	181	3.81
	1964	0	23	3.00	5510	156	3.74
	4/10/1965	900	24	2.88	5400	153	3.73
	12/29/1965	1370	25	2.76	4000	113	3.60
	12/6/1966	22600	26	2.65	3980	113	3.60
	3/8/1968	2280	27	2.56	3860	109	3.59
	1/25/1969	24500	28	2.46	3560	101	3.55
	3/1/1970	1000	29	2.38	3400	96	3.53
	11/29/1970	1910	30	2.30	3060	87	3.49
	12/27/1971	748	31	2.23	3060	87	3.49
	2/11/1973	10400	32	2.16	2790	79	3.45
	1/7/1974	988	33	2.09	2490	71	3.40
	3/8/1975	2170	34	2.03	2300	65	3.36
	2/10/1976	389	35	1.97	2280	65	3.36
	1/6/1977	72	36	1.92	2170	61	3.34
	3/4/1978	22200	37	1.86	2120	60	3.33
	3/28/1979	2490	38	1.82	1910	54	3.28
	2/19/1980	7980	39	1.77	1860	53	3.27
	3/5/1981	3560	40	1.73	1370	39	3.14
	4/11/1982	3400	41	1.68	1180	33	3.07
	3/1/1983	33600	42	1.64	1060	30	3.03
	12/25/1983	2300	43	1.60	1000	28	3.00
	2/15/1986	3860	44	1.57	1000	28	3.00
	1987	0	45	1.53	988	28	2.99
	2/29/1988	2790	46	1.50	900	25	2.95
	1989	0	47	1.47	900	25	2.95
	1990	0	48	1.44	900	25	2.95
	3/19/1991	7250	49	1.41	875	25	2.94
	2/12/1992	8550	50	1.38	748	21	2.87
	2/23/1993	9520	51	1.35	480	14	2.68
	2/8/1994	1060	52	1.33	398	11	2.60
	2/20/1996	7400	53	1.30	389	11	2.59
	12/22/1996	3060	54	1.28	150	4	2.18
	2/3/1998	29500	55	1.25	137	4	2.14
	2/10/1999	1860	56	1.23	105	3	2.02
	2/21/2000	3980	57	1.21	72	2	1.86
	3/5/2001	11000	58	1.19	50	1	1.70
	2002	0	59	1.17			
	3/15/2003	3060	60	1.15			
	2/26/2004	1180	61	1.13			
	1/9/2005	9280	62	1.11			
	4/4/2006	6390	63	1.10			
	2007	0	64	1.08			
	1/5/2008	12800	65	1.06			
	2/16/2009	398	66	1.05			
*	1/19/2010	5510	67	1.03			
*	*12/19/2011*	*9,940*	68	1.01			

Number of Years, n =	68		
Skewness =	2.10	2.10	-0.70
Mean=	6036	171	3.43
Std Dev=	7377	209	0.66

Peaks Flow Frequency
From USGS Data
USGS 11140000 SISQUOC R NR GAREY

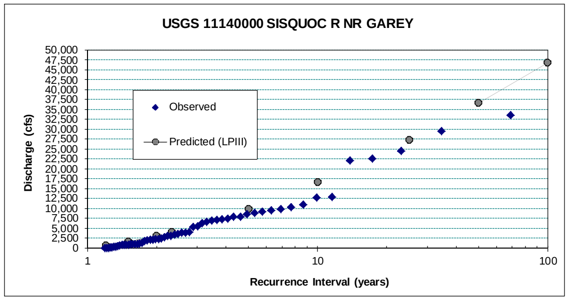
Generalized Skew=	**-0.30**	A=	-0.27375
Station Skewness (log Q)=	-0.70	B=	0.75718
Station Mean (log Q)=	3.43	MSE (station skew) =	0.12471
Station Std Dev (log Q)=	0.66		
Weighted Skewness (G_W)=	**-0.59**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.97643	611
1.5	0.667	-0.34989	1,577
2.0	0.500	0.09704	3,102
2.33	0.429	0.26829	4,020
5.0	0.200	0.85708	9,804
10	0.100	1.20930	16,712
25	0.040	1.53403	27,325
50	0.020	1.72866	36,690
100	0.010	1.89121	46,928

Values From K-Table for Linear interpolation

Weighted Skewness	-0.60	-0.50	-0.59
P	K	K	K
0.9	-1.32850	-1.32309	-1.32771
0.8	-0.79950	-0.80829	-0.80079
0.7	-0.44352	-0.45812	-0.44566
0.6	-0.15589	-0.17261	-0.15834
0.500	0.09945	0.08302	0.09704
0.429	0.27047	0.25558	0.26829
0.200	0.85718	0.85653	0.85708
0.100	1.20028	1.26180	1.20930
0.040	1.52830	1.56740	1.53403
0.020	1.72033	1.77716	1.72866
0.010	1.88029	1.95472	1.89121



Years with zero flow omited from analysis.
12/19/2010 provisional

Michael Love Associates
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Santa Barbara County - Flood Control District

123 E. Anapamu St., Santa Barbara, CA 93101
805.568.3440 - www.countyofsb.org/pwd

Official Monthly and Yearly Rainfall Record

(Monthly Depth Durations and Average Recurrence Intervals)

Station: 415 Station Type: Data Logger w/TB **Latitude: 345024 Longitude: 1201238**

Station Name: Rancho Sisquoc **Elevation (ft): 550 Rainfall (in.)**

WY	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	WY
1947-48	0.00	0.22	0.16	0.46	0.00	2.42	2.92	2.52	1.01	0.00	0.00	0.00	9.71
1948-49	0.00	0.00	0.00	3.01	1.15	2.00	3.75	0.15	1.04	0.00	0.00	0.00	11.10
1949-50	0.00	0.00	1.84	3.00	3.07	1.68	1.45	0.80	0.20	0.00	0.70	0.00	12.74
1951-52	0.00	0.76	1.26	4.52	6.54	1.00	7.43	0.69	0.08	0.00	0.00	0.00	22.28
1953-54	0.00	0.00	2.62	0.32	4.69	1.13	4.00	0.36	0.00	0.00	0.00	0.00	13.12
1954-55	0.00	0.00	1.28	3.37	4.33	1.63	0.35	1.34	1.26	0.00	0.00	0.00	13.56
1955-56	0.00	0.00	1.96	6.88	4.09	0.58	0.00	1.68	0.00	0.00	0.00	0.00	15.19
1956-57	0.00	0.46	0.00	0.25	3.15	3.15	0.55	1.20	1.50	0.18	0.00	0.00	10.44
1957-58	0.00	1.95	0.38	3.51	2.85	6.15	3.98	6.58	0.00	0.00	0.00	0.60	26.00
1958-59	0.75	0.00	0.27	0.30	2.56	4.39	0.00	1.37	0.00	0.00	0.00	0.00	9.64
1959-60	0.00	0.00	0.00	0.52	4.01	4.01	1.01	2.30	0.00	0.00	0.00	0.00	11.85
1960-61	0.45	0.63	3.61	1.17	1.05	0.10	1.10	0.40	0.27	0.00	0.00	0.00	8.78
1961-62	0.00	0.00	3.00	2.04	3.08	12.61	1.85	0.00	0.00	0.00	0.00	0.00	22.58
1962-63	0.00	1.48	0.00	0.21	0.35	4.93	3.30	2.80	0.38	0.05	0.00	0.16	13.66
1963-64	0.00	0.00	2.59	0.10	1.92	0.10	1.86	0.96	0.60	0.25	0.03	0.00	8.41
1964-65	0.00	2.03	3.22	2.03	1.33	0.41	1.72	4.59	0.00	0.00	0.00	0.00	15.33
1965-66	0.00	0.00	5.79	4.15	1.57	1.20	0.00	0.12	0.00	0.00	0.00	0.00	12.83
1966-67	0.22	0.00	2.45	5.39	3.72	0.46	2.61	6.87	0.17	0.27	0.00	0.00	22.16
1967-68	0.36	0.00	2.60	1.32	1.35	1.24	3.78	0.82	0.05	0.00	0.00	0.00	11.52
1968-69	0.00	1.93	1.00	2.17	9.75	8.68	1.42	1.80	0.10	0.00	0.00	0.00	26.85
1969-70	0.00	0.32	1.24	0.55	3.80	1.19	3.43	0.15	0.00	0.00	0.00	0.00	10.68
1970-71	0.00	0.07	3.37	4.07	0.76	0.36	0.53	0.93	0.99	0.00	0.00	0.00	11.08
1971-72	0.02	0.18	0.53	5.36	0.11	0.39	0.00	0.31	0.00	0.00	0.12	0.00	7.02
1972-73	0.00	0.43	4.95	1.39	4.86	6.03	4.12	0.00	0.00	0.00	0.00	0.00	21.78
1973-74	0.00	0.44	3.14	2.68	5.48	0.18	4.25	1.30	0.00	0.00	0.00	0.00	17.47
1974-75	0.07	1.75	0.20	3.96	0.14	3.82	4.94	1.43	0.00	0.00	0.00	0.00	16.31
1975-76	0.00	0.68	0.51	0.22	0.00	5.47	1.84	1.56	0.05	0.00	0.00	0.53	10.86
1976-77	5.14	0.20	0.49	0.62	2.46	0.18	1.85	0.00	2.08	0.03	0.00	0.00	13.05
1977-78	0.00	0.00	0.08	3.69	5.05	9.89	7.66	2.75	0.00	0.00	0.00	0.00	29.12
1978-79	2.03	0.00	1.73	1.73	4.70	4.35	4.18	0.00	0.10	0.00	0.00	0.00	18.82
1979-80	0.24	1.14	0.74	1.56	4.32	7.25	2.46	1.39	0.35	0.00	0.00	0.00	19.45
1980-81	0.00	0.00	0.00	0.55	4.79	2.65	5.37	0.66	0.00	0.00	0.00	0.00	14.02
1981-82	0.00	0.98	1.22	1.01	2.96	0.92	5.91	3.40	0.00	0.00	0.00	0.34	16.74
1982-83	0.49	1.99	4.85	1.94	8.21	5.02	9.96	2.94	0.26	0.00	0.00	0.34	36.00
1983-84	0.10	1.35	3.08	3.97	0.20	0.50	0.67	0.59	0.00	0.00	0.00	0.00	10.46
1984-85	0.00	0.94	3.47	4.04	0.69	1.48	2.17	0.06	0.00	0.00	0.00	0.18	13.03
1985-86	0.01	0.41	3.58	0.63	0.83	4.92	6.80	0.53	0.00	0.00	0.00	0.00	17.71
1986-87	0.95	0.00	0.75	1.28	1.73	1.54	3.60	0.11	0.00	0.00	0.00	0.00	9.96
1987-88	0.00	1.41	1.19	3.67	2.07	1.73	0.80	2.68	0.29	0.15	0.00	0.00	13.99
1988-89	0.00	0.00	1.24	4.99	0.46	1.25	0.73	0.37	0.44	0.00	0.00	0.00	9.48
1989-90	1.07	0.22	0.45	0.02	2.68	2.34	0.38	0.13	0.63	0.00	0.00	0.00	7.92
1990-91	0.64	0.00	0.22	0.50	1.11	1.67	13.11	0.14	0.00	0.00	0.00	0.00	17.39
1991-92	0.00	0.48	0.44	3.95	3.13	6.38	1.83	0.00	0.00	0.00	0.00	0.00	16.21
1992-93	0.00	1.00	0.05	3.01	7.54	7.39	4.72	0.00	0.20	0.16	0.00	0.00	24.07
1993-94	0.00	0.25	1.17	1.36	2.08	4.22	1.57	0.96	0.72	0.54	0.00	0.00	12.87
1994-95	0.09	0.77	1.88	1.55	13.63	2.84	9.05	0.46	1.00	0.95	0.00	0.00	32.22
1995-96	0.25	0.00	0.00	1.86	2.55	10.77	1.77	1.14	0.25	0.00	0.00	0.00	18.59
1996-97	0.00	2.72	2.38	5.05	5.68	0.19	0.00	0.00	0.00	0.00	0.11	0.00	16.13
1997-98	0.14	0.00	4.42	2.84	4.12	14.60	3.64	3.19	2.67	0.00	0.00	0.00	35.62
1998-99	0.30	0.05	1.82	1.25	2.43	1.49	5.79	1.55	0.00	0.00	0.00	0.11	14.79
1999-00	0.03	0.00	1.83	0.03	1.77	8.47	1.63	3.60	0.03	0.14	0.00	0.00	17.53
2000-01	0.00	1.95	0.00	0.08	5.78	4.60	5.09	1.70	0.00	0.00	0.04	0.00	19.24
2001-02	0.00	0.55	3.60	2.05	1.04	0.32	1.03	0.35	0.30	0.00	0.00	0.00	9.24
2002-03	0.00	0.00	2.98	4.72	0.04	2.02	1.56	1.58	1.09	0.00	0.00	0.00	13.99
2003-04	0.00	0.00	2.06	1.96	0.68	5.08	0.69	0.00	0.00	0.00	0.00	0.00	10.47
2004-05	0.00	4.45	0.37	5.40	6.35	4.12	2.71	0.48	1.68	0.00	0.00	0.00	25.56
2005-06	0.04	0.93	1.02	1.41	3.89	1.10	4.75	4.69	1.14	0.00	0.00	0.00	18.97
2006-07	0.00	0.39	0.22	1.37	0.87	2.42	0.44	0.56	0.00	0.00	0.00	0.00	6.27
2007-08	0.23	0.55	0.00	2.33	8.93	2.05	0.02	0.02	0.00	0.00	0.00	0.00	14.13
2008-09	0.00	0.15	1.93	1.71	0.66	5.25	0.82	0.22	0.07	0.05	0.00	0.02	10.88

Santa Barbara County - Flood Control District

123 E. Anapamu St., Santa Barbara, CA 93101
805.568.3440 - www.countyofsb.org/pwd

Official Monthly and Yearly Rainfall Record

(Monthly Depth Durations and Average Recurrence Intervals)

Station: 415 Station Type: Data Logger w/TB **Latitude: 345024 Longitude: 1201238**

Station Name: **Rancho Sisquoc** **Elevation (ft): 550 Rainfall (in.)**

WY	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	WY
2009-10	0.02	1.68	0.04	3.48	5.87	3.79	0.62	2.98	0.17	0.00	0.01	0.00	18.66
2010-11	0.00	1.68	1.46	11.74	1.22	3.28	6.10	0.19	0.42	0.28	0.00	0.00	26.37
Total	13.64	39.57	98.73	150.30	196.23	211.38	181.67	82.45	21.59	3.05	1.01	2.28	1001.90
N	62	62	62	62	62	62	62	62	62	62	62	62	62
Mean	0.22	0.64	1.59	2.42	3.17	3.41	2.93	1.33	0.35	0.05	0.02	0.04	16.16
Max	5.14	4.45	5.79	11.74	13.63	14.60	13.11	6.87	2.67	0.95	0.70	0.60	36.00
StdDev	0.71	0.85	1.46	2.07	2.68	3.18	2.69	1.53	0.56	0.15	0.09	0.12	6.74
CV	3.24	1.34	0.91	0.85	0.85	0.93	0.92	1.15	1.62	3.01	5.53	3.20	0.42
Reg CV	2.68	1.28	1.03	0.84	0.90	0.99	0.87	1.11	1.83	2.91	3.81	4.10	0.44
Reg Skew	3.80	1.80	1.40	1.00	1.60	1.10	1.10	1.70	2.60	3.60	4.40	4.80	1.10
FIC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Average Recurrence Intervals (in Years)

2	0.00	0.41	1.22	2.10	2.45	2.80	2.47	0.93	0.11	0.00	0.00	0.00	14.88
5	0.37	1.16	2.76	3.97	5.10	5.94	4.84	2.30	0.65	0.09	0.03	0.05	21.49
10	0.83	1.72	3.79	5.15	6.95	7.93	6.35	3.28	1.13	0.20	0.07	0.16	25.69
25	1.55	2.43	5.09	6.58	9.32	10.36	8.18	4.55	1.79	0.37	0.15	0.36	30.81
50	2.14	2.97	6.02	7.60	11.08	12.15	9.53	5.48	2.32	0.51	0.22	0.53	34.58
100	2.76	3.50	6.96	8.57	12.82	13.84	10.81	6.41	2.85	0.66	0.29	0.72	38.13
200	3.41	4.03	7.87	9.53	14.53	15.49	12.06	7.34	3.39	0.81	0.37	0.92	41.61
500	4.71	4.92	9.32	10.92	17.35	17.92	13.89	8.87	4.33	1.11	0.53	1.33	46.73
1000	4.96	5.25	9.96	11.65	18.46	19.17	14.84	9.46	4.68	1.17	0.55	1.40	49.36
10000	7.28	6.99	12.86	14.56	24.02	24.30	18.71	12.46	6.55	1.71	0.83	2.13	60.17

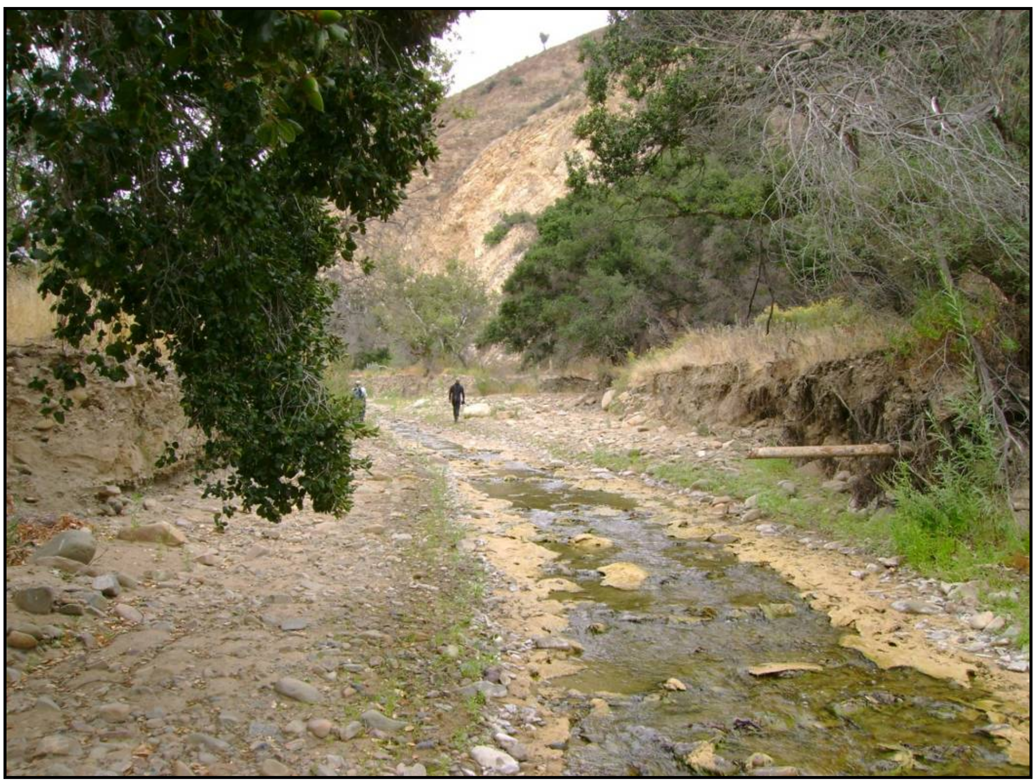
Attachment 9

2011 Horse Creek Photo Log

(STA 0+50) Looking downstream at new alluvial fan at mouth of Horse Creek at the Sisquoc River.

(STA 0+70) Looking upstream from alluvial fan at banks buried by deposition at approximate location of mouth in 2008.

(STA 5+30) Looking downstream at aggraded reach downstream of removed dam.



(STA 8+10) Looking upstream at location of removed Horse Creek Dam.

(STA 10+00) Looking downstream at location of removed Horse Creek Dam.

(STA 11+50) Looking upstream at incised channel upstream of the removed dam site.

(STA 14+50) Looking downstream at exposed bedrock in incised and widened channel.

(STA 15+00) Looking upstream at two oak trees fall into incised and widened channel.

(STA 38+00) Sediment deposition from recent fire deposited upstream of dam's influence.