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Monitoring channel change at the Sausal Creek Restoration Project, Oakland, California

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MONITORING CHANNEL CHANGE AT THE SAUSAL CREEK  
RESTORATION PROJECT, OAKLAND, CALIFORNIA

**FINAL DRAFT**

BY

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## **ABSTRACT**

Sausal Creek drains an urban watershed in the City of Oakland, California. In 2001, a portion of the creek was restored within Dimond Canyon, in part to create a stable channel profile, control erosion, and limit flood damage. Subsequent monitoring efforts to evaluate the effectiveness of the restoration project have been limited by inconsistent monitoring locations and methods. In this study, we investigated how channel morphology has changed within the creek since the 2001 as-built surveys and the fall 2005 post-project appraisal. We conducted cross-section surveys at eleven locations along the restoration project and found that channel morphology has not changed significantly since project implementation. However, we documented some channel scouring, which has decreased bed elevations and widened the channel along portions of the restored reach. To allow for repeatable future monitoring at the site, we installed durable markers at each of the surveyed cross-section locations.

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## INTRODUCTION

Sausal Creek is an urban creek in the City of Oakland, California that runs through a mixture of preserved open space and highly developed residential and commercial areas. Sausal Creek drains a 4.15 square-mile basin that extends from the western slopes of the Oakland Hills to San Francisco Bay (Figures 1- 2). Approximately 80% of the watershed area is developed, supporting a population of approximately 80,000 residents (Eagon and Largent [E&L], 2005; Friends of Sausal Creek [FoSC] Website, 2006).

The creek begins just below Highway 13 at the confluence of Shepherd and Palo Seco Creeks and extends approximately 3.7 miles to its outlet at a tidal slough between Oakland and Alameda. The upper 1.5 miles of Sausal Creek is a natural open channel within a preserved riparian corridor in Dimond Canyon (Figures 3 - 4), while the lower reach of the creek is mostly channelized or culverted (Figure 2; E&L, 2005). The Hayward fault runs through the watershed, leading to unstable bedrock geology caused by shearing forces of fault action (Lowe, 1998). Steep slopes in the upper watershed and shallow soils contribute to rapid runoff and high erosion rates within the creek (FoSC Website, 2006).

Logging in the 1850s and extensive urbanization since the early 1900s led to increased flood flows and erosion, which destabilized banks and threatened creek-side properties (Lowe, 1998; Owens-Viana, 1998). In the 1930s, the Works Progress Administration installed concrete and steel structures along the creek banks to prevent erosion. These control structures eventually failed and significant channel erosion continued due to increased watershed urbanization and natural landslides. In 1995, a major flood in Dimond Canyon brought community awareness to the degraded conditions of the creek and catalyzed political support to develop a more effective flood prevention strategy (E&L, 2005).

A local community group, Friends of Sausal Creek (FoSC), formed in 1996 to restore the creek with a focus on native plant revegetation, erosion control, bank stabilization and water quality monitoring (Chanse et al., 2003). In 2000, the Waterways Restoration Institute (WRI) and Wolfe Mason and Associates (WMA) were contracted to study and design a restoration project for a 600-foot reach of the creek in the lower portion of Dimond Canyon, beginning about 825 feet upstream of El Centro Avenue (Table 1). The designed restoration project had multiple key objectives, which included restoring a stable channel profile and meander sequence within the restoration reach, stabilizing channel banks, restoring native riparian plant species and improving the quality of habitat for terrestrial and aquatic species (WMA, 2000; Figure 5). The project was funded by the City of Oakland, California Coastal Conservancy and Alameda County Flood Control District and was implemented in the summer of 2001.

The restoration project involved the removal of failing in-stream concrete structures, re-contouring of stream-channel bed and banks and installation of rock weirs (Figures 6 – 9; E&L, 2005). The rock weirs were incorporated in the design for profile control, to define and maintain the low-flow channel and to create scour pools for in-stream habitat heterogeneity (WMA, 2000). Prior to construction, eleven cross-section surveys were conducted along the restoration reach to record pre-project conditions (Figure 5). Two-foot tall rebar markers were installed at each cross-section to facilitate future monitoring at the site (WMA, 2001).

In the fall of 2001, WRI conducted a post-project survey of the restoration site. WRI produced a long-profile survey and multiple cross-section surveys of the restoration reach. Where possible, they conducted cross-section surveys at the locations of the original rebar markers remaining from the pre-project survey (Goetting, 2001). In 2003, Chanse and Herron conducted a survey of revegetation as part of a U.C. Berkeley River Restoration Course (LA 227). They documented

increases in native plant cover and overall riparian plant diversity relative to pre-project conditions and reported a decrease in erosion along revegetated creek banks (Chanse and Herron, 2003).

In 2005, Eagon and Largent of LA 227 conducted a post-project appraisal at Sausal Creek, focusing on channel morphology, water quality, and aquatic insect diversity (Table 1). They surveyed eight cross-sections and a long-profile of the restored channel. They found the weirs to be successfully creating riffles and deep pools. They otherwise found no significant changes in channel morphology. They found an increase in vegetation, with a 50 percent increase of percent cover of vegetation in the first 18 months since the restoration project. They found no change in water quality or aquatic insects diversity from 2001 to 2005.

For each post-project monitoring effort, surveying creek cross-sections at consistent locations has been difficult. Sediment movement from the steep canyon slopes buried most of the original cross-section rebar markers and vegetation has concealed subsequent survey marker locations. In other cases, people using the trail may have removed survey markers along the creek. For these reasons, it has been difficult to evaluate the success of the restoration project in reaching design objectives of providing long-term erosion control and maintaining a stable channel morphology (WMA 2000).

## **PURPOSE**

The purpose of this study is to (1) determine how channel morphology has changed within the creek since the 2001 as-built surveys and the fall 2005 post-project appraisal and (2) establish permanent cross-section markers along the restoration project to allow for repeatable future monitoring at the site.

## **METHODS**

### *Cross Section Surveys*

We conducted cross section surveys at eleven marker locations (A – K). We used a self-leveling engineer's level and survey rod to measure ground surface elevations. We used a tape measure to record horizontal distances from the post marker along the cross-section transect perpendicular to the stream channel. We documented the location of distinctive landscape features, such as large trees, weirs, and other permanent man-made structures along the transect alignment. We adjusted surface elevations in reference to two manhole covers located on the trail south of the creek, approximately 650 feet and 1,270 feet in the upstream direction from El Centro Avenue. According to the 2001 construction documents, the elevations of the manholes are 227.8 feet and 240.2 feet, respectively (WMA, 2001). We did not conduct a long profile of Sausal Creek within the restoration project area because of time constraints.

Where possible, we compared channel elevation and shape from our survey data with the 2001 as-built surveys and surveys conducted by E&L in 2005 to determine significant changes in stream channel morphology. If past survey locations could not be determined in the field, we analyzed the fit of the past cross-section surveys with our survey data. Where necessary, we

shifted the horizontal distances of past surveys to align with our channel surveys to correct for differences in starting point locations along the cross-section.

### ***Cross Section Monitoring Locations***

The primary criterion we used for establishing cross-section marker locations was to align them as closely as possible with past surveys, so that it would be possible to compare cross-section data from past surveys with current creek conditions. In order to relocate monitoring stations at the site, we reviewed construction documents for the Sausal Creek Restoration Project (WMA, 2001). The construction drawings indicate that eleven cross sections (A – K) were established perpendicular to the stream prior project construction in order to monitor changes in channel morphology (Figure 5). The drawings note that each of the cross-section stations was marked with rebar stakes on the left bank of the creek corridor, with respect to the downstream flow direction.

We obtained as-built surveys conducted after completion of the restoration project on November 19, 2001 (Goetting, 2001) and reviewed the 2005 E&L post-project appraisal of the site. E&L were unable to locate rebar markers in their 2005 survey, likely because people had removed the markers or sediment eroded from hill slopes had buried the markers.

In the field, we used landscape features, construction documents, post-project surveys, and flagging pins left by E&L to determine approximate locations of the previous cross section surveys. We searched for original rebar markers with a metal detector. At each rebar location, we installed a 3-foot long, green aluminum fence post (Figure 10). In areas where we were not able to locate rebar markers, we used horizontal distances from the construction documents and post-project surveys to determine approximate locations for the original cross sections and marked the estimated location with a green post. In all locations, we installed the posts on the east side of

the trail, approximately 6-feet away from the trail's edge (Figure 11). We labeled each post with a letter (A-K) with a permanent marker on the top, right side of the post. We took photographs at each marker location and measured distances between markers and other distinctive, adjacent landscape features (e.g., trees and rock outcrops).

## **RESULTS**

Based on our comparisons of our survey data with past cross-section surveys, we found that only cross-sections J and K aligned with the 2005 E&L survey. Our survey locations were in alignment with as-built cross-sections C, H, I, and J, surveyed in 2001 by WRI. The remaining cross-section surveys were either not conducted in previous studies or were not in alignment with our survey locations (See Table 2 for summary of results). Overall, it appears that the creek channel morphology has not changed significantly. Minor changes observed at the surveyed cross-sections are discussed below.

### Cross Section A

We did not locate the original rebar marker for this cross-section and WRI did not conduct a survey of cross section A in 2001. The 2005 cross-section survey was conducted at an unknown location. Therefore, the 2006 survey establishes baseline conditions for cross section A (Figure 12 – 15). The post marker is located 546 feet along the trail from the northern edge of El Centro Road (Figure 13). The post is located on a 4-foot wide topographic bench, immediately above a rock outcrop. The rock is surrounded by herbaceous vegetation and is marked with the letter “A” in orange paint (Figure 15). The symbol “X3” has also been painted on the rock outcrop in black, located above the “A” and just down slope of the post marker. A buckeye tree (*Aesculus californica*), approximately 8 inches in diameter at breast height (dbh), is located a few feet above the post.

### Cross Section B

We did not locate the original rebar marker for cross-section B and the 2005 cross section was surveyed at an unreferenced location. The 2006 survey establishes baseline conditions (Figure 16). We established a new cross section location 26 feet from post marker A, along the trail in the upstream direction. A large seven-trunk bay laurel (*Umbellularia Californica*) is aligned on center with the cross-section post, approximately 12 feet up slope from the trail (Figure 17). A small (2-inch dbh) buckeye tree is rooted above a rock outcrop, 2 feet from the post in the upstream direction.

### Cross Section C

We did not locate the original rebar for cross-section C. However, the 2001 survey is in close alignment with the 2006 cross-section survey. E&L conducted a survey for cross-section C in 2005 at an unreferenced location. The channel banks appeared to remain stable between 2001 and 2006, while the bed has down-cut approximately 0.4 feet from the original surface elevation in 2001 (Figure 18). The upper left bank of the 2001 channel has been set back approximately 50 feet to create a wide terrace at the trail elevation. This change in the channel bank occurred after the 2001 as-built survey, when additional grading at the site was conducted to construct the pedestrian trail (Drew Goetting, Restoration Design Group, personal correspondence, April 2006).

We established a new permanent location for the cross section, 76 feet along the trail in the upstream direction from Cross Section B. The cross section is located at the opening of a wide clearing (Figure 19). Several large (3 to 4-foot diameter) logs have been placed around the perimeter of the clearing. A sewer manhole (56-000-63) is located along the cross section, on the west side of the trail (Figures 20 and 21). The manhole cover was partially covered by a few

inches of sediment at the time of our survey. The manhole is located 26.5 feet from the marker post, aligned with the cross section. The marker post is also in line with the end of a placed log, located on the east side of the clearing.

#### Cross Section D

We established a new location for cross-section D, as we were unable to relocate the original rebar and the 2005 transect markers (see Figures 22 and 24 for channel profile and conditions). The post marker for Cross Section D is located 111 feet along the trail past Cross Section C. The post is located past the clearing, on a moderately sloping surface that is covered by loose-leaf litter and sparse herbaceous vegetation (Figure 23). The post marker is fixed behind a two-trunk buckeye tree rooted on the slope above the trail.

#### Cross Section E

We did not locate the rebar for cross-section E and the 2005 survey was conducted in an unreferenced location. The 2006 survey establishes baseline conditions (Figure 25). A post marker was placed 200 feet from Cross Section D, along the trail in the upstream direction. The post marker is located immediately down slope from a large (3.5-foot dbh) two-trunk buckeye tree (Figure 26). The cross section is aligned with a rock weir in the stream (Figure 27). On the north bank of the stream, in alignment with the cross section, large limbs from a bay tree extend over the banks and stream (Figure 28). A portion of a concrete wall is exposed on the north side of the trail, roughly at the same elevation of the trail surface, and the top of the stream bank slope.

### Cross Section F

The original rebar marker for cross-section F was relocated. However, as-built survey data for the cross section was not available and no survey was conducted at the location in 2005.

Therefore, the cross-section location survey establishes baseline conditions (Figure 29). The new post marker is located along the trail, 62 feet past Cross Section E. The post is located at the toe of a steep slope, before the trail bends sharply to the south (Figure 30). Herbaceous vegetation surrounding the post marker includes poison oak (*Toxicodendron diversilobum*). A bay tree (1-foot dbh) is growing on the slope, approximately 20 feet above the post marker. A rock weir is located approximately 4-feet downstream of the cross section alignment. The bank between the trail and stream is vegetated with dense willows (*Salix* spp.). Several mature oak trees occur on the upper slopes of the opposite (northern) side of the stream.

### Cross Section G

The as-built survey location for cross-section G could not be determined and a marker for the 2005 cross-section G was not found. Therefore, the 2006 survey establishes baseline conditions (Figure 31). Cross-section G is located around the bend of the trail, 101 feet from Cross Section F. The post marker is located on a moderately steep slope, densely vegetated with native shrub and herbaceous species (Figure 32). A tall (8-foot) wild rose bush (*Rosa* sp.) occurs between the trail and the post marker. We adjusted the elevation at G based on a fixed benchmark (the manhole cover near cross-section H), due to apparent error in vertical elevation calculated from a turning point survey measurement.

### Cross Section H

We established a new location for cross-section H. E&L did not survey cross-section H in 2005 and we did not locate the original rebar marker. However, the 2006 survey elevations align with the 2001 as-built elevations, suggesting that the new location is very close to the original (Figure 33). It is uncertain whether the differences in surface elevations are due to true changes in channel morphology or differences in survey point measurements along the cross-section. If the measured elevations are accurate, it appears that there has been widening of the channel bed and bank relative to the 2001. However, there was no evidence of active erosion observed in the field to explain the differences in bank slope elevations.

Cross Section H occurs 126 feet along the trail past Cross Section G. A sewer manhole (56-000-65) is located on the side of the trail, 19 feet (on-center) past the post marker for Cross Section H (Figure 34). The post marker is approximately 4-feet from trail edge, on a slope densely vegetated with blackberry (*Rubus* sp.) and other shrub species.

### Cross Section I

We located the original rebar marker for cross-section I and marked it with a green post. The post is located 159 feet along the trail past Cross Section H. Cross-section survey data from 2001 is in alignment with the current survey (See Figures 35 and 37 for profiles and current conditions). Since 2001, there appears to be a widening and deepening of the stream channel. The survey also indicates that a secondary channel has formed along the left bank. Erosion on both channel banks may have lowered surface elevations since the 2001 survey, although there were no observations made in the field to confirm the presence of active erosion on the bank slopes.

The post occurs on a moderately steep slope, densely vegetated with herbaceous and shrub species (Figure 36). No distinctive trees occur in the immediate vicinity of the post, although a multi-trunk bay tree is located on the trail bank, approximately 40-feet away in the upstream direction. At the time of the 2006 survey, a large bay tree had fallen in the stream channel, across the cross-section alignment (Figure 37).

#### Cross Section J

We relocated the cross-section J rebar marker. The current survey was in alignment with the 2001 as-built and 2005 surveys (Figures 38 and 41). There was a substantial decrease in bed elevation since 2001. Between 2001 and 2005 the thalweg elevation decreased by approximately 0.2 feet. From 2005 to 2006, there was a decrease in thalweg elevation of approximately 0.7 feet. There also appears to have been an increase in elevation on the left bank, likely due to differences in point survey locations. Similarly, different point location measurements of previous surveys may explain differences in shape of the right stream bank.

We installed a new post marker for cross section J, located 50 feet past Cross Section I, approximately 10 feet past the multi-trunk bay tree (1-foot average dbh). The post marker is located on a moderate slope covered by English ivy (*Hedera helix*) (Figure 39). A rock weir is located approximately 5 feet downstream of the Cross Section J alignment (Figure 40).

#### Cross Section K

We relocated the rebar marker, but there was no as-built survey conducted at cross-section K. The cross-section location was in alignment with the 2005 survey (Figures 42 – 44). There does not appear to have been a significant change in bed elevation since 2005, although there are

notable differences in the slope of the lower stream banks. It is impossible to determine if these differences are real or due to shifts point elevation locations.

The cross section marker is located 41 feet along the trail past Cross Section J (in the upstream direction). The post marker is located on a slope covered by English ivy (Figure 43). The stream channel at the cross-section location is densely vegetated with willow trees and a rock weir occurs approximately 5 feet downstream of the cross-section alignment (Figure 44).

## **DISCUSSION**

Overall, it appears that the creek channel morphology has not changed significantly and that the project is performing as designed. Minor channel alterations that were observed are consistent with the goals of the restoration project. Based on a limited number of comparisons of cross-sections surveys, there is evidence that scouring along the channel has decreased bed elevations in some areas up to 0.7 feet. The significant drop in bed elevation at cross-section J after 2005 relative to the decrease between 2001 and 2005 may be attributed the intense rainfall events that characterized the 2005-06 winter. There also appears to be a widening of the channel bed along portions of creek. In some instances, it was difficult to determine whether apparent changes in channel morphology were real or due to differences in survey location and resolution.

The cross-section surveys conducted as part of the study establish baseline conditions for future monitoring at the site and provide initial evidence that the restoration project has successfully stabilized the channel. However, additional steps are needed to perform a comprehensive assessment of long-term bank and channel stability. It is important that cross-section markers be placed on the opposite stream bank to ensure that surveys are conducted along the same alignment. This would correct for potential discrepancies in survey results due to differences in the cross section trajectory relative to the channel. In addition, a long profile survey is needed to

evaluate the stability of the channel across the entire restoration reach and to determine where the cross-sections are located along the stream profile. As noted in E&L (2005), the long profile survey should start at the debris rack upstream of cross-section K and extend downstream to end of the restoration reach. The rock weirs are a key component of the project design objective to maintain channel stability. Therefore, additional, more detailed surveys of channel elevations upstream and downstream of the weirs would be useful.

The new cross-section marker system that we have established is an improvement to previous monitoring strategies at the site. First, the aluminum posts we installed are larger and more conspicuous than the original rebar markers and 2005 flagging pins placed at the site. In general, approximately 8 inches of the post is above the surface, making it unlikely that sediment from hill slope erosion will cover it. Should the markers become concealed, by soils or vegetation, our detailed documentation of the marker locations should allow for future recovery. Due to the close proximity to the trail, there is a chance that people may remove them. Again, our documentation of the markers should allow for accurate replacement at their original locations.

After establishing the new cross-section locations, we discovered that creek conditions at some of the cross-sections were not well suited or accessible for surveys (Figure 45). Dense vegetation along some transects may have led to measurement error of horizontal distances and elevations. . In general, the right stream bank was difficult to survey due to steep slopes and dense vegetation. In some cases, we were unable to obtain accurate surface elevations along the cross sections due to impenetrable vegetation. Given that the cross-sections are now permanently established, we recommend bringing a machete to clear overgrown vegetation along the cross section alignment during future surveys at the site.

Inconsistent monitoring methods limit our ability to evaluate the effectiveness of restoration techniques. Although cross-section locations were established in the pre-project phase, a more comprehensive monitoring plan established before construction could improve post-project monitoring conditions. Ideally, a pre-construction design would include clear guidelines and methods for evaluating the ongoing success of the restoration project. If future monitoring at the site is taken into account at an early phase in project conception, permanent markers could be integrated in the design itself at appropriate locations. Markers could be installed within rock boulders along trails and clearly marked for future monitoring. Such design elements would improve the efficiency and effectiveness of future monitoring efforts, and provide an educational opportunity for visitors to the park to learn more about the restoration project.

## **CONCLUSION**

Overall, the restoration project at Sausal Creek appears to be achieving its objective to stabilize the stream channel and banks. A comprehensive assessment of the project performance will require continued monitoring at established cross section locations in addition to a long-profile survey of the restoration reach. In assessing the work of previous post-project appraisals, we found it difficult to compare cross-section survey data from 2001 (WRI) and 2005 (E&L) with our current data because survey markers could not be relocated. In order to make future monitoring more consistent and efficient, we installed new cross-section post markers at well-documented locations and have established what we hope will be a durable monitoring system at the Sausal Creek Restoration Project site.

## ***ACKNOWLEDGEMENTS***

Thanks to Shannan Anderson and Jen Natali for their invaluable assistance in the field, Dave Shaw for equipment and Drew Goetting for background information and support.

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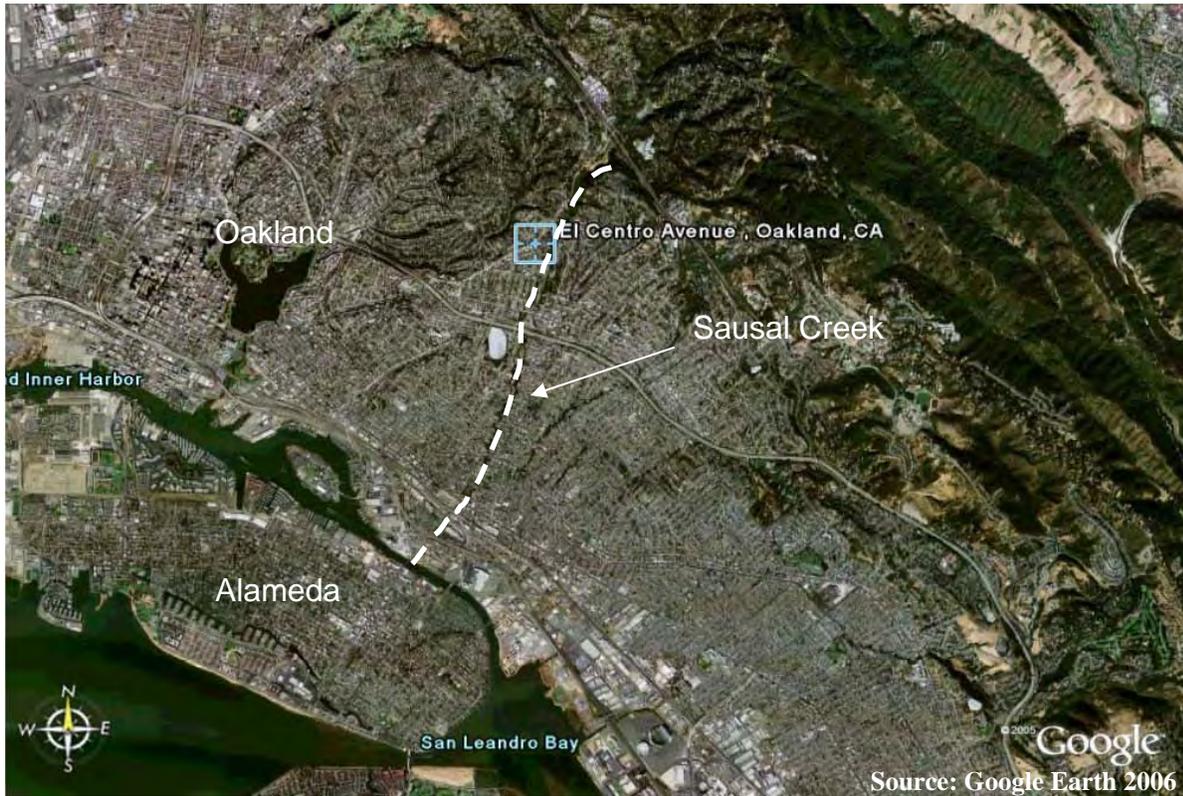
**Table 1 Past Survey Results**

DATE	STUDY
<p><b>May 2000</b></p>	<p>Wolf Mason Associates, “Sausal Creek Restoration in Dimond Park, Oakland, Alameda County, California”</p>
	<p><i>Purpose:</i> Evaluate site conditions and develop specific restoration recommendations associated with Sausal Creek at Dimond Canyon.</p>
	<p><i>Findings/Conclusions:</i> Key restoration objectives include:</p> <ul style="list-style-type: none"> <li>• Remove degraded concrete structures within creek</li> <li>• Restore hydrologic function for safe storm-water conveyance, sediment transport (dynamic equilibrium) and improved water quality</li> <li>• Restore stable channel profile and meander sequence</li> <li>• Re-establish stable channel and banks</li> <li>• Restore native regional riparian vegetation</li> <li>• Enhance and restore habitat for terrestrial and aquatic species</li> <li>• Provide long-term erosion control</li> <li>• Incorporate appropriate recreational amenities</li> </ul>
<p><b>Fall 2001</b></p>	<p>As-built survey of Sausal Creek Restoration Project, conducted by Drew Goetting under contract with Waterways Restoration Institute</p>
	<p><i>Purpose:</i> Survey cross-section and long profile of Sausal Creek Restoration Project</p>
	<p><i>Findings/Conclusions:</i> None reported. Survey data available in Grantham and Tollefson 2006 project data file (LA 222) and from Drew Goetting (Restoration Design Group)</p>
<p><b>Fall 2005</b></p>	<p>Eagon, Elizabeth and John Largent, “Post-Project Appraisal of the Sausal Creek Restoration Project, Oakland, California”</p>
	<p><i>Purpose:</i> Assess the degree to which project has met stated design objectives</p>
	<p><i>Findings/Conclusions:</i> Restoration project generally successful at meeting objectives Effective stabilization of channel bed and banks Successful native plant restoration Unknown change in water quality Unknown change in habitat quality for terrestrial and aquatic species Persistent problems with invasive plant species and minor bank and hill slope erosion Notable improvement in site access and recreation use value</p>
<p><b>Other</b></p>	<p>See Chanse &amp; Hernnon (2003) “Along Sausal Creek: an assessment of vegetation, habitat and morphology of an adopted urban creek” for a discussion of revegetation planting and monitoring at the site.</p>

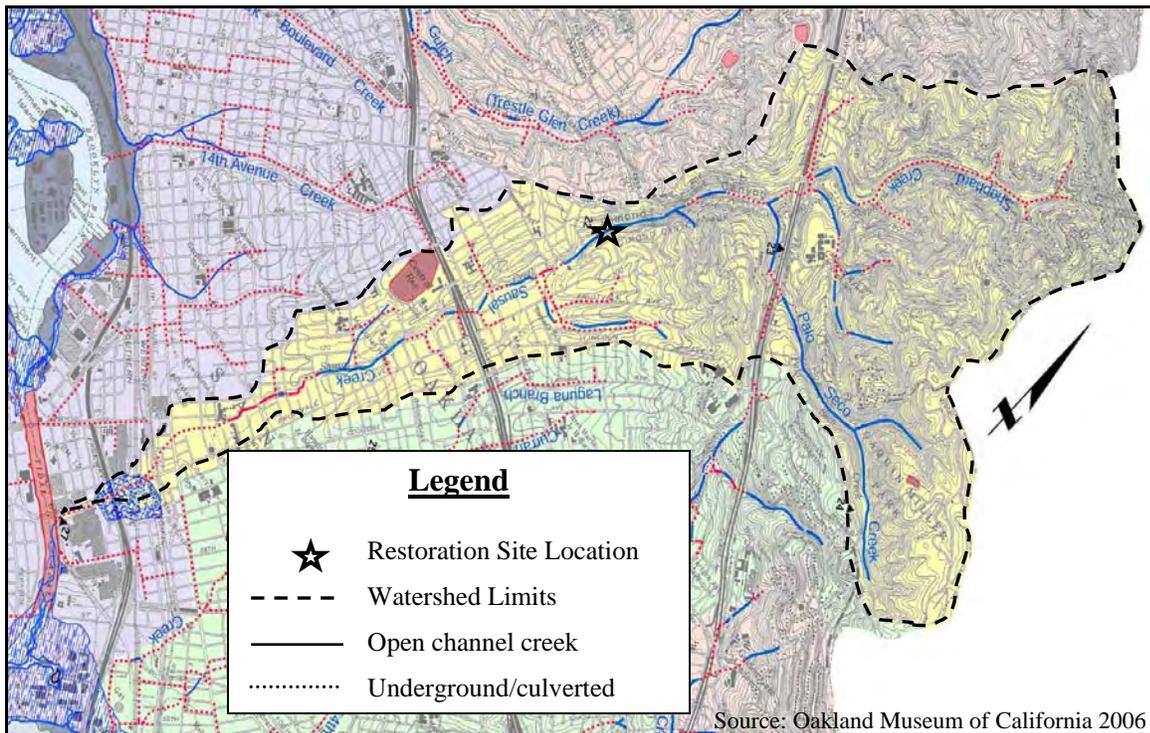
**Table 2 Summary of Cross-Section Survey Data**

<b>Cross Section</b>	<b>Distance from Northern Edge of El Centro Avenue</b>	<b>2001</b>	<b>2005</b>	<b>2006</b>
A	546'	N	U	S
B	572'	U	U	S
C	651'	S	U	S
D	762'	U	U	S
E	962'	U	U	S
F	1022'	N	N	S
G	1123'	U	N	S
H	1249'	S	N	S
I	1408'	S	U	S
J	1458'	S	S	S
K	1499'	N	S	S
S = Surveyed N = Not surveyed U = Surveyed at unreferenced location				

**Figure 1. Regional Location Map**



**Figure 2. Sausal Creek Watershed**



**Figure 3. Post-Project, Current Conditions of Sausal Creek**



Steep, vegetated banks and cobble streambed within typical channel section of upper reach of Sausal Creek.  
Photo: Kate Tollefson (KT), 4/26/06

**Figure 4. Post-Project, Current Conditions of Sausal Creek**



Dense riparian vegetation and shaded streambed within typical channel section of upper Sausal Creek.  
Photo: KT, 4/20/06



**Figure 6. Pre-Project Conditions at Sausal Creek Restoration Site**



Channel bank erosion at failing concrete check dam before project construction, looking in downstream direction. Photo: Drew Goetting (WRI), 2000

**Figure 7. Pre-Project Conditions at Sausal Creek Restoration Site**



Failing concrete check dam before project construction, looking in upstream direction. Photo: Drew Goetting (WRI), 2000

**Figure 8. Post-Project Rock Weir**



Typical rock weir installed as part of restoration project. Photo: Ted Grantham (TG), 4/20/06

**Figure 9. Post-Project Rock Weir Close-Up**



Close-up of typical rock weir within restoration reach. Photo: TG, 4/20/06

**Figure 10. Sample Cross-Section Marker**



Sample three-foot aluminum post at cross-section location. Photo: TG 4/20/06

**Figure 11. Sample Marker Location**



Example of cross-section post marker, approximately 6 feet from trail edge on slope opposite of stream channel. Photo: TG, 4/20/06

Figure 12. Cross Section A Survey

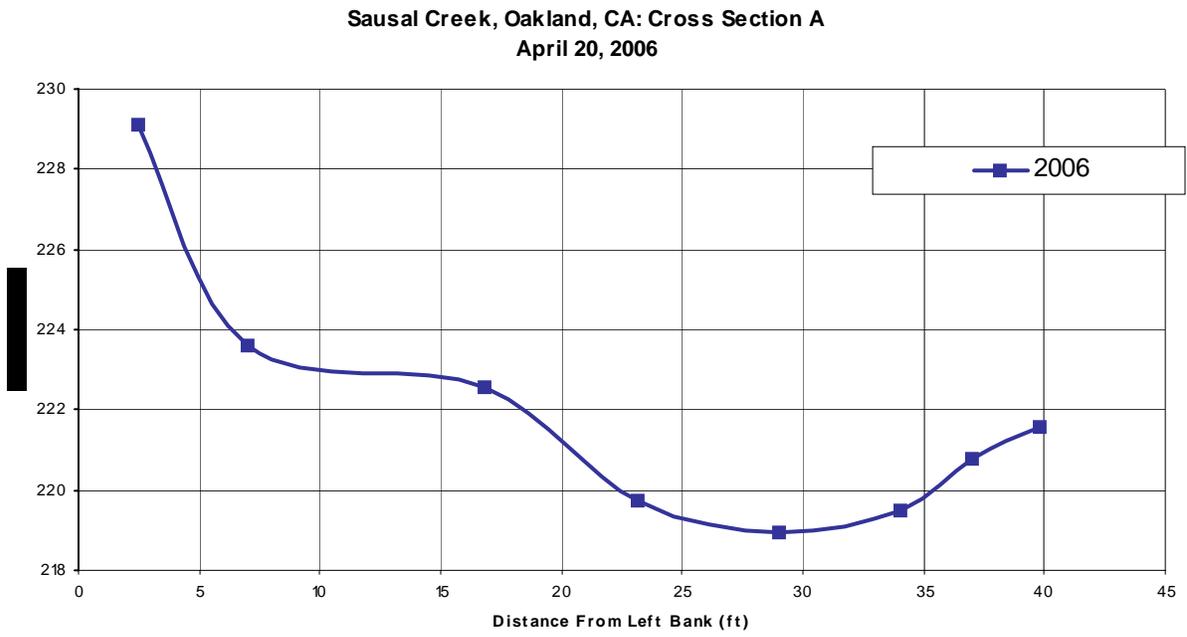


Figure 13. Cross Section A Marker



Photo: TG, 4/12/06

**Figure 14. Cross Section A Channel Conditions**



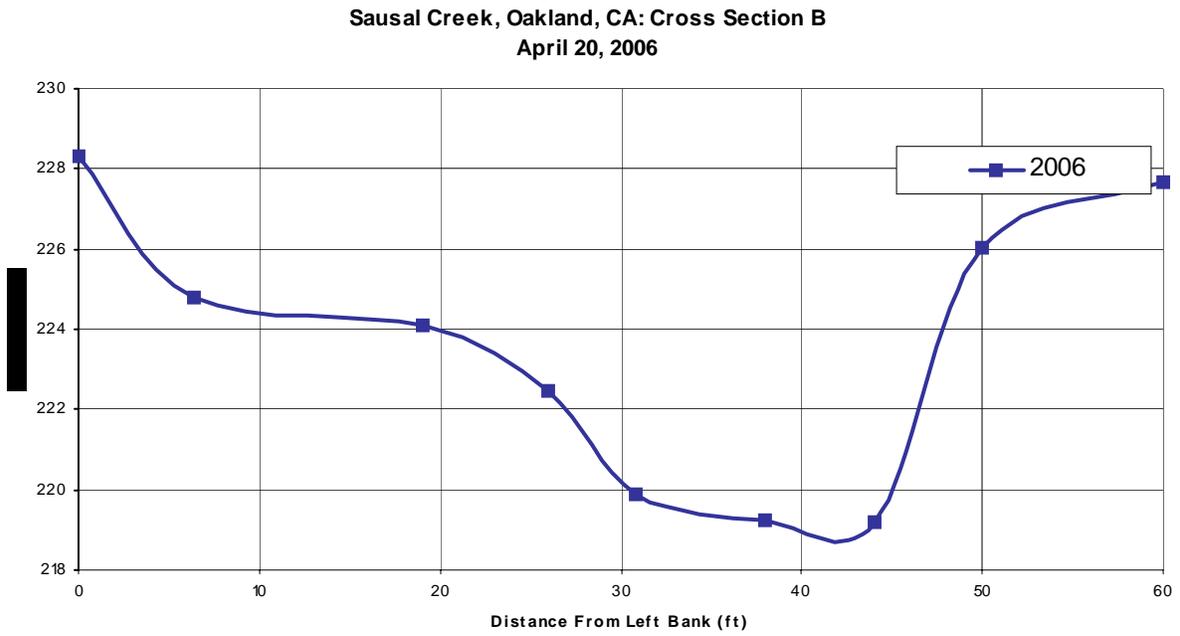
Channel survey at cross-section A, facing downstream at lower portion of restoration reach. Photo: TG, 4/20/06

**Figure 15. Cross Section A Marker**



Cross-section A marker at rock outcrop adjacent to trail. Letter "A" painted in orange on rock is visible below post marker. Photo: TG, 4/20/06

**Figure 16. Cross Section B Survey**

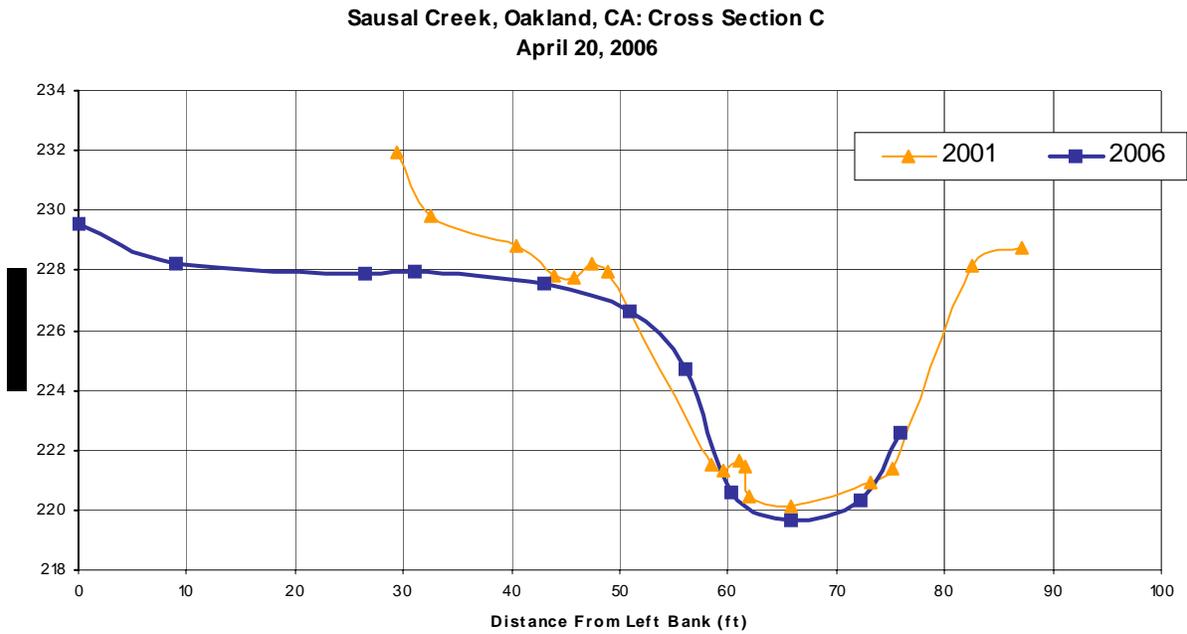


**Figure 17. Cross Section B Marker**



Photo: TG, 4/12/06

Figure 18. Cross Section C Survey



Evidence of minor channel incision between 2001 and 2006. Change in slope on upper left bank is likely due to grading after implementation and as-built survey of restoration project.

Figure 19. Cross Section C Marker



Cross-section C marker located behind log, at downstream end of wide terrace along trail.  
Photo: KT, 4/12/06

**Figure 20. Manhole near Cross Section C**



Manhole cover (56-000-63) partially buried by mud along cross-section C used as benchmark survey point.  
Photo facing south: TG, 4/12/06

**Figure 21. Manhole Near Cross Section C**



Photo facing north: TG, 4/12/06

Figure 22. Cross Section D Survey

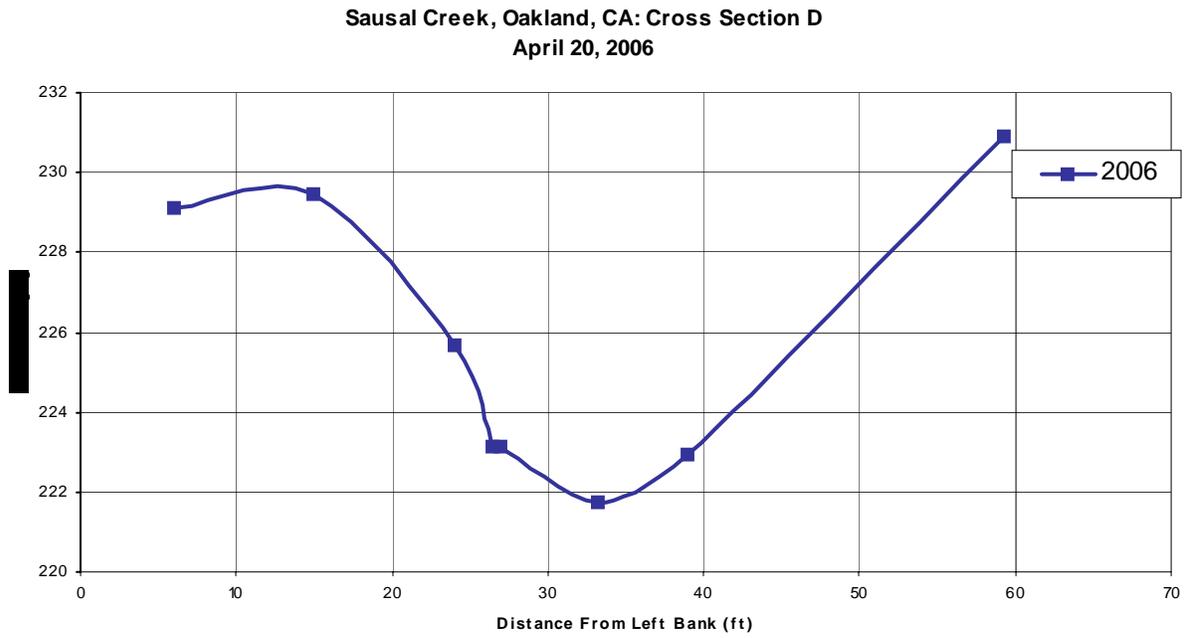


Figure 23. Cross Section D Marker



Cross-section D marker upslope of buckeye tree. Photo facing upstream direction: TG, 4/12/06

**Figure 24. Cross Section D Channel Conditions**



Stream channel at cross-section D. Photo facing downstream: KT, 4/20/06

Figure 25. Cross Section E Survey

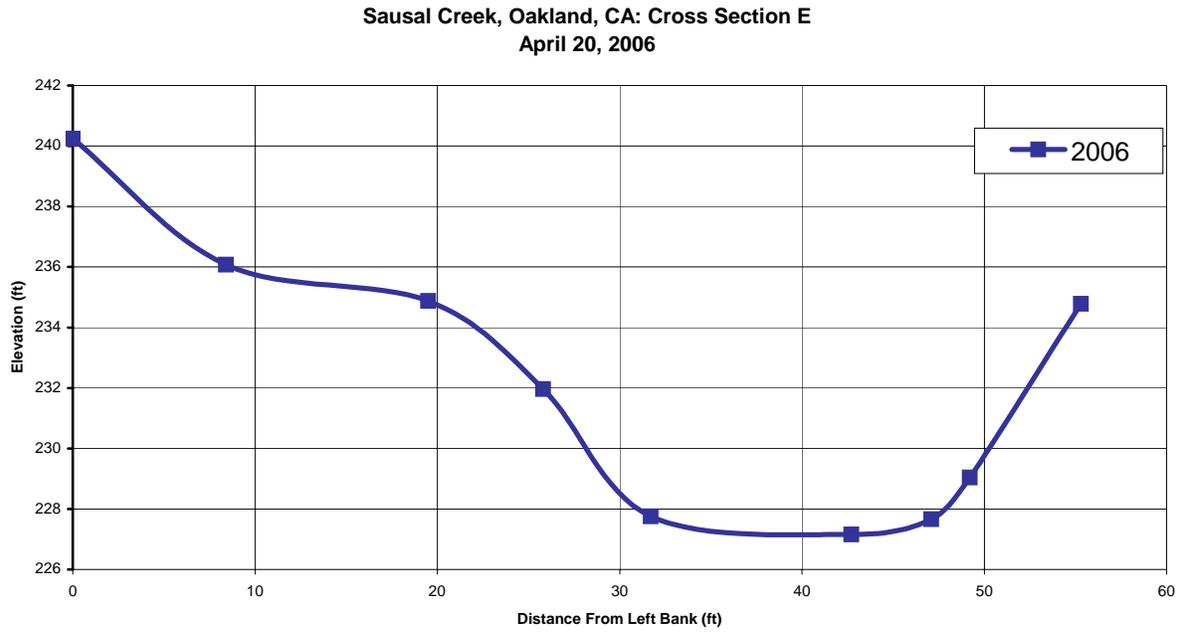


Figure 26. Cross Section E Marker



Cross-section E marker below buckeye tree. Photo: TG, 4/12/06

**Figure 27. Weir near Cross Section E**



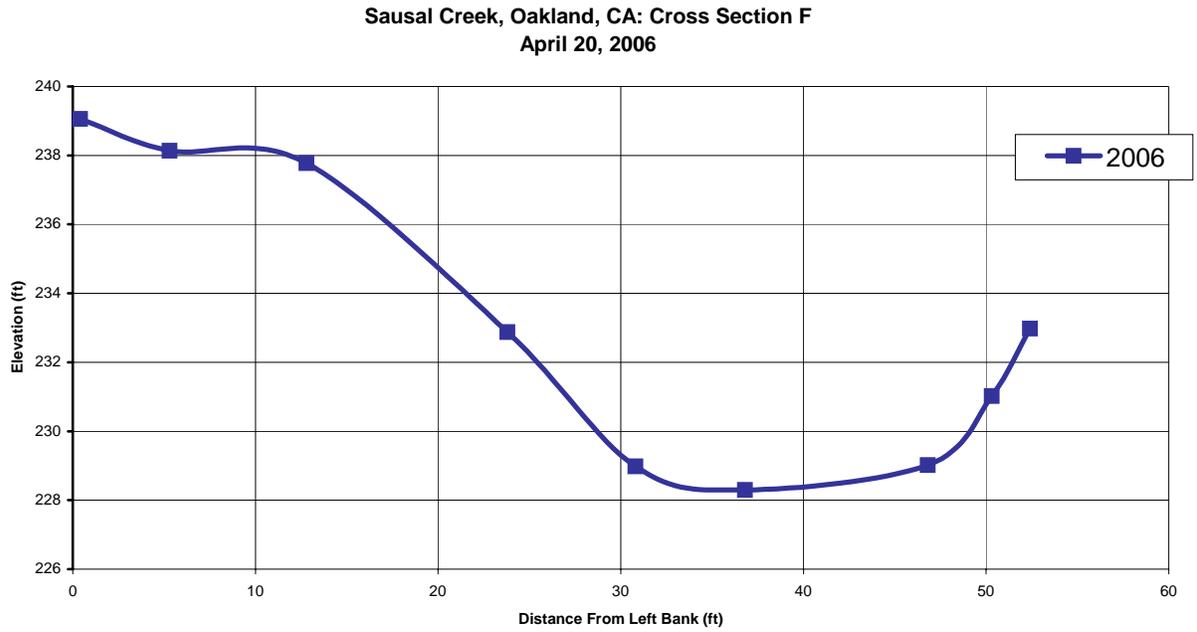
Rock weir near cross-section E installed as part of restoration project. Photo: TG, 4/12/06

**Figure 28. Overhanging Bay on North Bank near Cross Section E**



Photo: TG, 4/12/06

**Figure 29. Cross Section F Survey**

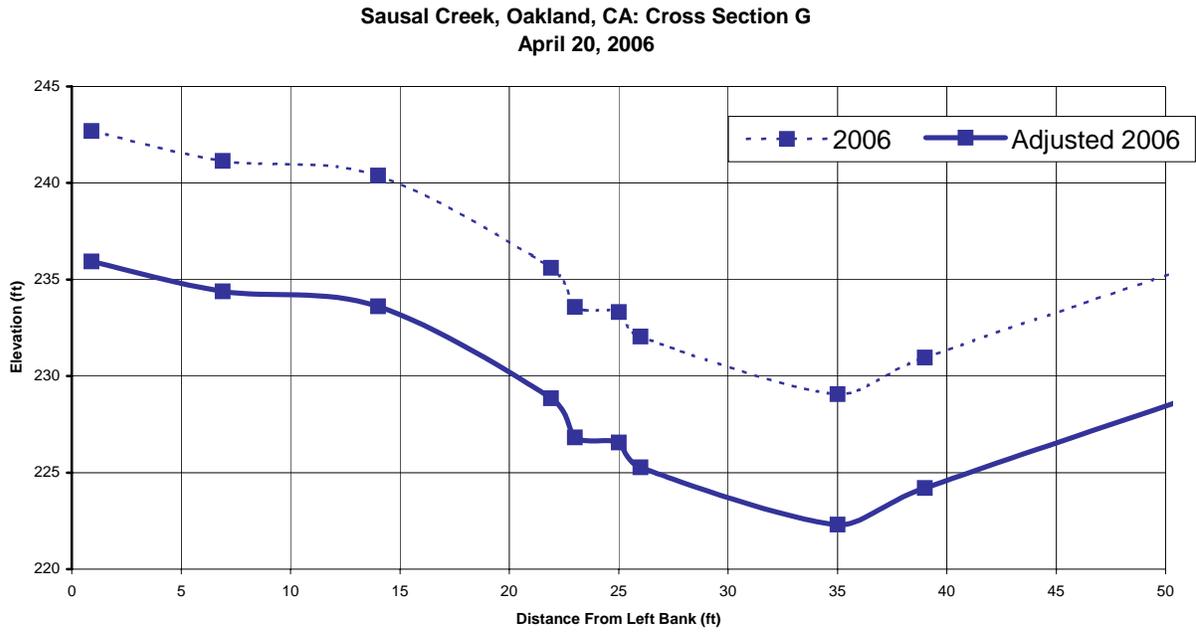


**Figure 30. Cross Section F Marker**



Marker for cross section F, facing upstream direction. Photo: TG, 4/20/06

Figure 31. Cross Section G Survey



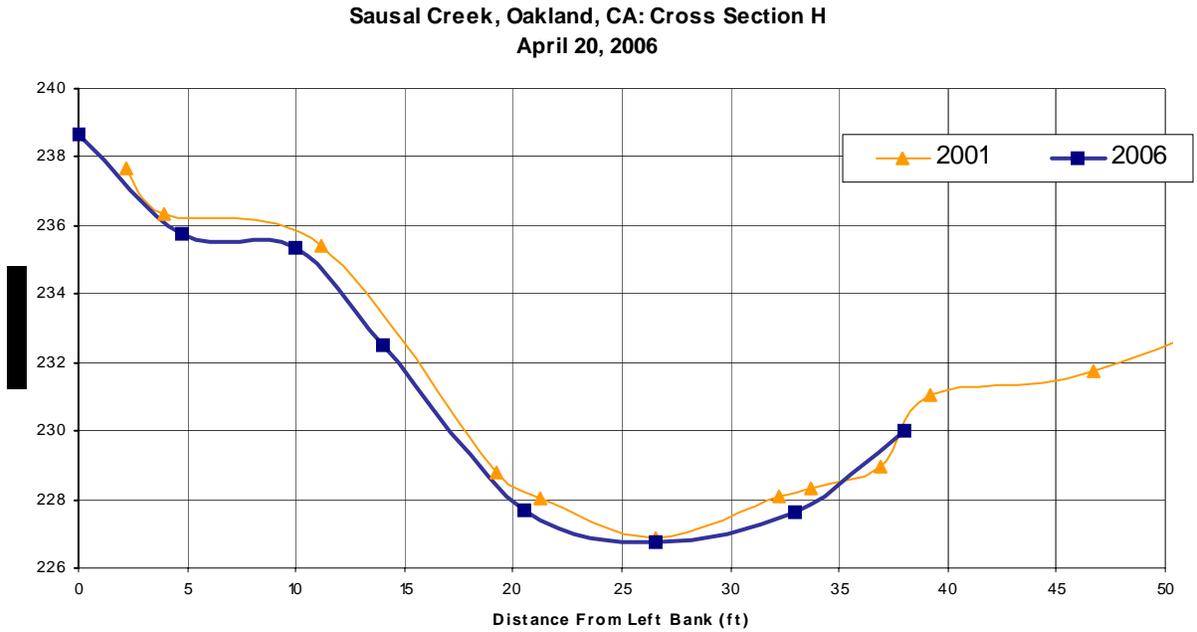
Cross-section G with adjusted elevation (solid line) to account for survey error.

Figure 32. Cross Section G Marker



Photo: KT, 4/12/06

Figure 33. Cross Section H Survey



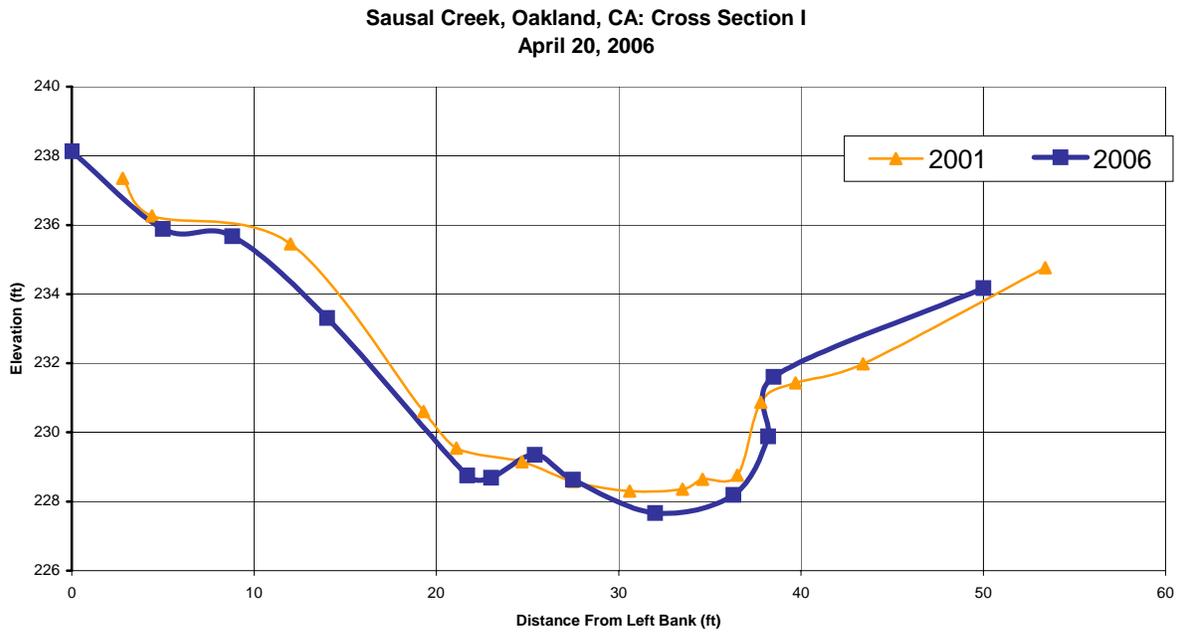
Uncertain whether difference in channel and left slope elevations are due to true changes in channel morphology along cross section or to differences in survey point measurements.

Figure 34. Cross Section H Marker



Cross-section H marker in circle on right and manhole (56-000-65) in circle on left. Photo: KT, 4/12/06

Figure 35. Cross Section I Survey



Stream channel has slightly deepened and widened since 2001 and a secondary channel has formed along the left bank of the streambed.

Figure 36. Cross Section I Marker



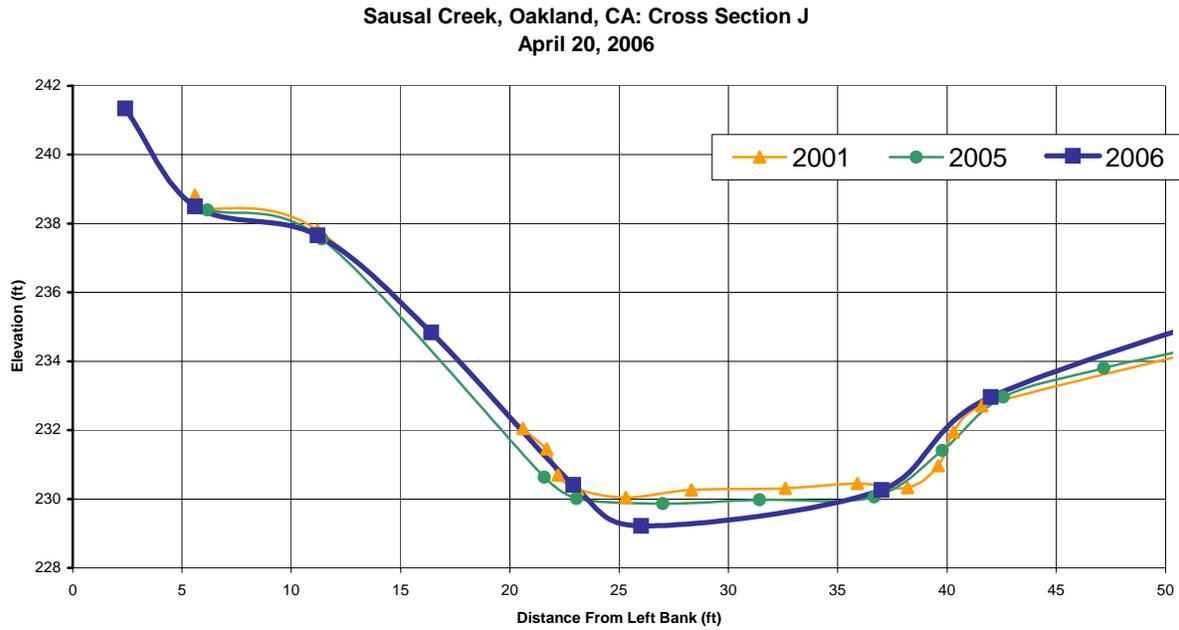
Post marker for cross-section I, looking in downstream direction along trail. Photo: TG, 4/12/06.

**Figure 37. Cross Section I Channel Conditions**



Fallen bay tree within stream channel across cross-section I alignment. Photo: KT, 4/20/06

Figure 38. Cross Section J Survey



The streambed elevation was relatively stable between 2001 and 2005, but decreased by approximately 0.7 feet at thalweg between fall of 2005 at April 2006 survey.

Figure 39. Cross Section J Marker



Photo: TG, 4/12/06

**Figure 40. Weir near Cross Section J**



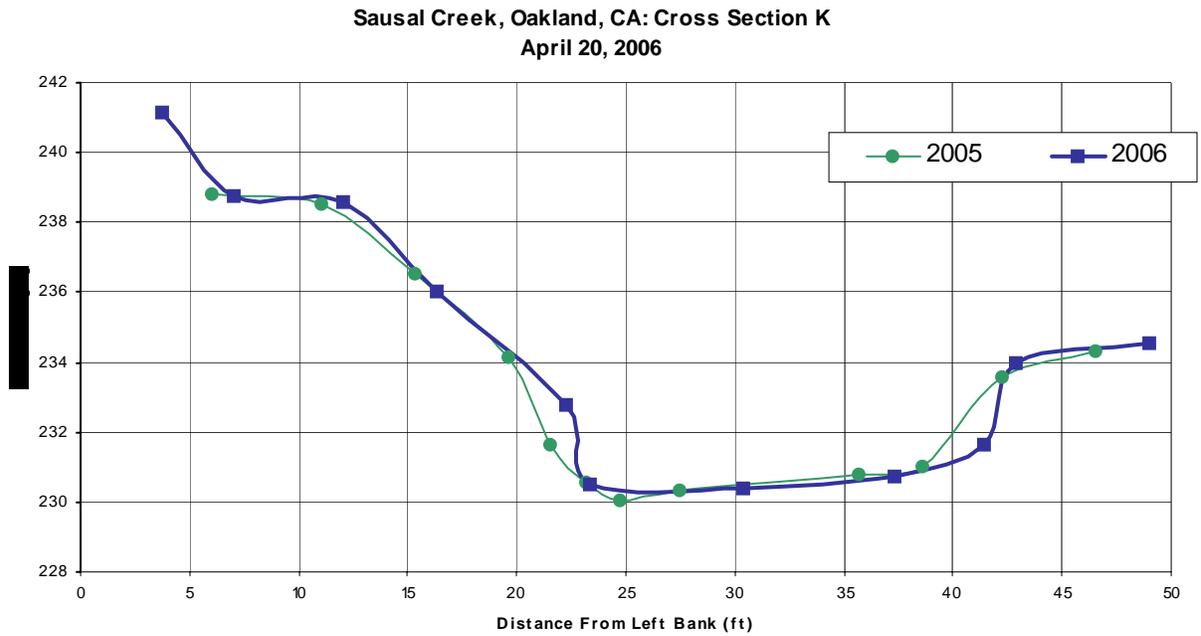
Photo: TG, 4/12/06

**Figure 41. Cross Section J Channel Conditions**



Photo: TG, 4/12/06

**Figure 42. Cross Section K Survey**



No apparent change in bed elevation since 2005 survey. Differences in lower stream channels are likely due to differences in locations of point elevation measurements.

**Figure 43. Cross Section K Marker**



Photo: TG, 4/12/06

**Figure 44. Cross Section K Channel Conditions**



Dense riparian vegetation and rock weir downstream of cross-section K alignment.  
Photo: KT, 4/20/06

**Figure 45. Example of Surveyor at Inaccessible Survey Location**



Surveyor location shown within circle. Photo: TG, 4/20/06

## **Appendix**

Attached: 2006 Survey Data for Cross Sections A - K